ESPON
EUROPEAN UNION
Co-financed by the European Regional Development Fund

Inspire policy making by territorial evidence

GRETA - "GReen infrastructure: Enhancing biodiversity and ecosysTem services for territoriAl development"

Applied Research

Final (main) Report

Version 08/08/2019

This applied research activity is conducted within the framework of the ESPON 2020 Cooperation Programme, partly financed by the European Regional Development Fund.

The ESPON EGTC is the Single Beneficiary of the ESPON 2020 Cooperation Programme. The Single Operation within the programme is implemented by the ESPON EGTC and co-financed by the European Regional Development Fund, the EU Member States and the Partner States, Iceland, Liechtenstein, Norway and Switzerland.

Authors
Hugo Carrao, Mirko Gregor, Manuel Loehnertz - space4environment (Luxembourg)
Jaume Fons, Raquel Ubach, Roger Milego, Anna Marín - UAB (Spain)
Elin Slätmo, Eeva Turunen, Kjell Nilsson - Nordregio (Sweden)
Katherine Irvine, Jessica Maxwell, Laure Kuhfuss, Scott Herrett, Michaela Roberts, Daniel Fisher - The James Hutton Institute (UK)
Gemma Garcia Blanco - TECNALIA (Spain)

Advisory Group
Project Support Team: Blanka Bartol (Slovenia), Kristine Kedo (Latvia), Julie Delcroix (EC, DG Research and Innovation), Josef Morkus (Czech Republic)
ESPON EGTC: Michaela Gensheimer (Senior Project Expert), Laurent Frideres (Head of Unit Evidence and Outreach), Akos Szabo (Financial Expert).

Acknowledgements
We would like to thank the Members of ESPON Contact Points and the Members of ESPON Monitoring Committee for their support in identifying questionnaire respondents particularly for the policy and governance analysis undertaken at national level and stakeholders at case study level.
We would like to thank the stakeholders in the case studies that generously collaborated with GRETA research and shared their insight into green infrastructure through the online consultations, phone interviews and meetings.

Information on ESPON and its projects can be found at www.espon.eu.

The most recent documents produced by finalised and ongoing ESPON projects can be viewed and downloaded from the web site.

This delivery only exists in electronic format.

Contact: info@espon.eu

ISBN 978-99959-55-36-6

GRETA - “GReen infrastructure: Enhancing biodiversity and ecosysTem services for territoriAl development”

Table of contents

List of Figures

List of Maps

List of Tables

Abbreviations

CBA	Cost-Benefit Analysis
CCDRR	Climate change, and disaster-risk reduction
CLC	Corine Land Cover
CF	Cohesion Funds
CLD	Causal Loop Diagrams
DCE	Discrete Choice Experiment
DRR	Disaster Risk Reduction
EAFRD	European Agricultural Fund for Rural Development
EbA	Ecosystem based Adaptation
EC	European Commission
EFTA	European Free Trade Association
EGTC	European Grouping for Territorial Cooperation
EIA	Environmental Impact Assessments
EMFF	European Maritime and Fisheries Funds
ERDF	European Regional Development Fund
ES	Ecosystem Services
ESF	European Structural Funds
ESM	Ecosystem Services Mapping
ESPON	European Territorial Observatory Network
EU	European Union
FOEN	Federal Office for the Environment (Switzerland)
FUA	Functional Urban Area
GI	Green Infrastructure
GNB	Gross Nutrient Balance
GUA	Green Urban Areas
HQi	Habitat Quality index
HRL	High Resolution Layer
HNV	High Natural Value
JRC	Joint Research Centre
LAU	Local Administrative Unit
LU	Land Use
LC	Land Cover
MAES	Mapping and Assessment of Ecosystems and their Services
MS	Member State
N2K	Natura 2000 sites
NBS	Nature Based Solutions
NEP	Net Ecosystem Productivity
NUTS	Nomenclature of Territorial Units for Statistics
NWRM	Natural water retention measures
OSM	Open Street Maps
PM	Physical Mapping
RecPot	Recreation Potential
RP	Relative Pollination
RUSLE	Revised Universal Soil Loss Equation
SDG	Sustainable Development Goals
SEA	Strategic Environmental Assessments
SEC	Soil Erosion Control
SES	Socio-Ecological System
WP	Water Purification
WR	Water Retention Index
WSL	Swiss Federal Institute for Forest, Snow and Landscape Research
WTP	Willingness to pay
UHI	Urban Heat Island

Glossary of terms[1]

Term	Description
Green Infrastructure (GI)	"strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings" (EC, 2013)
Potential GI	A network of natural and semi-natural areas that is related to the spatial patterns of ecosystem services supplied by existing ecosystems and their conditions, and not in terms of areas already bound by policy measures and secured by their obligations.
Strategically planned	GI planning aims to conserve, restore or create networks of green (and blue) areas in order to provide environmental, economic and/or social benefits for urban and rural societies (at several institutional levels). Simultaneous maximisation of all potential benefits from GI is however unlikely, thus trade-offs need to be strategically assessed. Therefore, GI networks are strategically planned in that decisions about conservation, protection, and restoration of ecosystems incorporate information on how potential geographical areas fit within a network to optimise its functioning and maximise its benefits, the connections, complementarities and contributions to different sectors. Integrating GI considerations into governance and planning processes allows all the relevant issues to be assessed and a considered comprehensive decision to be taken in order to secure as many benefits as possible. GI planning can make a significant contribution to regional development, climate change, disaster risk management, agriculture/forestry and the environment.
Network	GI relates to the identification and mapping of ecological networks. Two primary components of ecological networks are hubs and links (refer to Section 3.1). Hubs are areas of natural vegetation, other open space, or areas of known ecological value, and links are the corridors that connect the hubs to each other. A set of hubs

[1] in order as they appear in the text

	connected by links constitutes a network that can be used to inform conservation and other related land-use decisions.
Natural and semi-natural areas	Physical features that contribute to GI are diverse, specific to each location or place, and scale-dependent. Natural and semi-natural areas include elements such as: **Core areas:** e.g. local nature reserves, water protection areas, landscape protection areas, Natura 2000 sites, Emerald Network sites; **Natural and semi-natural connectivity features*:*** pastures, woodland, forest (not including intensive plantations), ponds, bogs, rivers and floodplains, wetlands, lagoons, beaches, hedgerows, small woodlands, ponds, wildlife strips, and riparian river vegetation (this list is conceptual and not all features were considered in the framework of this work – refer to Section 3.1 for further details on the features used).
Other environmental features	Other environmental features include elements such as: **Green urban and peri-urban areas:** street trees and avenues, city forests/woodlands, high-quality green public spaces and business parks/premises, green roofs and vertical gardens, allotments and orchards, storm ponds and sustainable urban drainage systems, and city reserves including Natura 2000 sites (this list is conceptual and not all features were considered in the framework of this work – refer to Section 3.1 for further details on the features used).
Ecosystem Services (ES)	The direct and indirect contributions of ecosystems to human well-being. Contributions can be of economic, social, cultural and/or ecological value. For example, a forest ecosystem might provide wood for forestry and/or for renewable energy, provide a recreational service, be part of a cultural landscape, regulate the supply of air, water and minerals, support biodiversity in the form of landscape cohesion and maintain ecosystem processes.
Other physical features	Other physical features include elements such as: Artificial connectivity features: e.g. eco-ducts, green bridges, animal tunnels (e.g. for amphibians), fish passes, road verges, ecological powerline corridor management.

Landscape scale	There is no single accepted definition of 'landscape scale'; rather, it is a term commonly used to refer to action that covers a large spatial scale, usually addressing a range of ecosystem and land uses (Ahern and Cole, 2012). In the GRETA framework, landscape scale refers to the spatial analyses performed outside the Functional Urban Areas. In the context of GRETA, landscape scale is also used as a synonym of the rural setting.
Functional Urban Areas (FUA)	The FUA can be explained as the core city (i.e. a local administrative unit in which most of the population lives in an urban centre of at least 50 000 inhabitants) plus its associated hinterland. The FUA is defined as "a territorial unit resulting from the organisation of social and economic relations within that. Its boundaries do not reflect geographical particularities or historical events. It is thus a functional sub-division of territories" (OECD, 2002, p. 11). It defines the travel-to-work catchment and gives an image of the actual role played by a city within and beyond the region in terms of functions (European Environment Agency, 2018).
Geographical area	An area of land that can be considered as a unit for the purposes of some geographical analyses.
Trade-offs	Trade-offs describe situations that involve losing one quality of something in return for gaining another. This happens when the use of one ecosystem service directly decreases the benefits supplied by another. Trade-off situations require choices or management decisions to be made.
Synergies	Synergies describe situations where the use of one ecosystem service directly increases the benefits supplied by another service (Turkelboom et al., 2015). These are win-win situations that involve the mutual improvement of both ecosystem services.
Bundles of ecosystem services	A bundle is a set of associated ecosystem services that are supplied by or demanded from a given ecosystem or area and which usually appear together repeatedly in time and/or space (modified from Raudsepp-Hearne et al., 2010).
Multifunctionality	Multifunctionality refers to intertwining or combining different functions and thus using limited space more effectively (Ahern 2012). Multiple functions should offer benefits for humans, for

	instance, in relation to human health or social cohesion, and likewise secure intact ecological systems (Tzoulas et al., 2007; Lafortezza et al., 2013). The concept of multifunctionality in GI planning means that multiple ecological, social, and also economic functions shall be explicitly considered instead of being a product of chance.
Connectivity	Connectivity can be defined as the degree to which the landscape facilitates the movement or dispersal of species and other ecological flows among habitat areas. The lack or loss of connectivity reduces the capability of organisms to move and can interfere with pollination, seed dispersal, wildlife migration and breeding. In the context of GI, hostile lands would be land uses with a low or null presence of GI elements (e.g. intensive agriculture, built urban areas, transport or grey infrastructure etc.), which constitute main obstacles to the inter-linking of high quality ‘green spaces’ of natural/semi-natural lands (Estreguil et al., 2016)

Executive summary

Green Infrastructure (GI) is considered a benefit for territorial development because they provide multiple functions on the same spatial area. The underlying principle of GI is that the same area of land can offer many environmental, social, cultural and economic benefits simultaneously, provided its ecosystems are in a healthy condition. Ecosystem services cover the benefits that can be derived from ecosystems, including, among others, the provision of food, materials, clean water, clean air, climate regulation, flood prevention, pollination and recreation.

The European Commission (EC) in 2013 defined GI as a *"strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services (ES). It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings."* This definition embraces three aspects that are important for effectively implementing GI into sectoral policies: (i) **connectivity**, i.e. the idea of a network of geographical areas; (ii) the concept of **multifunctionality**, i.e. the idea that the same geographical area can be used for several purposes/activities and, at the same time, supply multiple (ES); and (iii) the **links to spatial planning and management.**

GRETA adopted a mixed methods approach to investigate GI. GRETA focused on both the physical and functional dimensions of GI and the findings offer new knowledge, insight, and recommendations for implementing GI via multi-level governance mechanisms and cross-sector policy and planning.

Why is GI important for territorial development: positive and negative effects of GI and ES

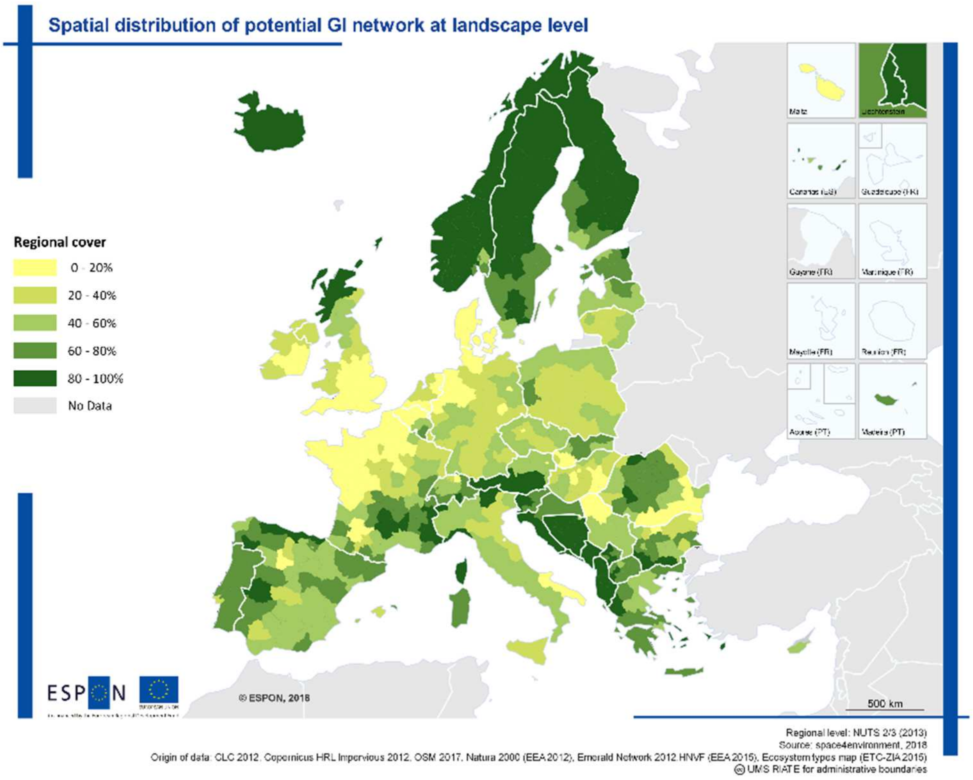
- **GI stands to improve quality of life** in many ways through its environmental, social and economic credentials, which are based on the multiple use of natural assets and in turn provide multiple benefits (often described as multifunctionality). By maintaining healthy ecosystems, reconnecting fragmented natural areas and restoring damaged habitats, GI offers an economically viable and sustainable infrastructure that delivers goods and services, and by which a multitude of policy objectives can be addressed. Examples include the role of ecosystems in regulating water flows (reducing the need for investment in flood defences), in sequestering carbon, in reducing heat island effect improving people´s health.
- Addressing multiple objectives and embodying a cross-sectoral nature positions GI as a useful tool to different EU and nationally driven policies and actions, including those in the fields of biodiversity, water, climate, agriculture and rural development, forestry, transport and energy, health and spatial planning.
- **Negative effects of GI include eco-(or green) gentrification, adverse effects on human health (allergies), higher costs to initiate and maintain GI, risk of invasion by alien species**. What can be done? Incorporate social justice principles when planning GI for equitable distribution of benefits; strategically plan where to encourage community gardens and find ways to 'shield' existing gardens from traffic. Invest in transport infrastructure to reduce pollutants from traffic, e.g. charging points for electric vehicles, bicycle lanes; use native species which are adapted to local conditions

which could reduce water use. Consider selecting plants that will be adapted to the future climate; adopt a 'learning-by-doing', based on scientific results and led by multi-disciplinary teams of practitioners and decision-makers.

- **Employing an ecosystem-based approach to examine the range of services provided by GI helps its benefits to be understood and compared to those of man-made investments.** Lack of understanding of multiple GI benefits makes it difficult to quantify the cost-benefit relation and discourages implementation. [See GRETA Briefing 1 for insight on benefits across spatial scales.]
- **Context matters**, so the quantification of benefits and challenges related to GI should be adapted to the type of GI, its spatial configuration, and other contextual specificities which could include, location, local climate, geology, geography, city or regional structure, governance goals, politics and local skills and knowledge. There is no one-size-fits-all solution, but rather a suite of approaches that must be tailored to the context. [See GRETA Briefing 1 for benefits one might find at different spatial scales.]

What does the geographical distribution of GI and ES look like in Europe?

- The spatial analysis of GI reveals that the potential GI network has a lower coverage for the regions in north-western France and Germany, south-eastern UK and Ireland, and Denmark. The coverage of potential GI is higher for Nordic countries (excl. Denmark), the Balkan countries along the Adriatic Sea and the eastern Alpine region. This pattern clearly reflects population density, infrastructure development, climatic and topographic conditions, as well as the distribution of utilised agricultural areas in the EU territory. See Map 1 below.
- In the framework of GRETA, three main policy domains relevant at EU level were selected to assess how well GI could support them: Biodiversity, Climate Change and Disaster Risk Reduction, and Water Management. With regards to multifunctionality, the amount of services delivered simultaneously by GI and the number of policies benefiting from it are considerably higher in Central European regions, as compared to North-eastern and South-western regions.
- Regions of multifunctional GI may represent opportunities for more sustainable management, by enhancing sustainable flows of a range of ES from ecosystems, while preserving their ecological value and biological diversity. Stable ES provision via GI may enhance stability and resilience of private sector initiatives (e.g. agriculture, nature-based tourism), and hence strengthen regional competitiveness.
- Planning for GI requires to consider the type of interaction between ES to take advantage of potential co-benefits (synergies) and avoid unwanted side-effects (trade-offs).
- Synergistic relations between ES are predominant in Italy, France, part of Germany, and Poland. In practical terms, the improvement of certain ES in these areas always has a multiplier effect on other ES, (increasing the provision of ES).



Map 1 Spatial distribution of potential GI network at landscape level.

- Trade-offs are predominant in Eastern countries, and those areas showing trade-offs with low ecosystem provision are scattered across Europe; being the dominant pattern in Ireland. In all these regions, management of GI requires a further understanding of these trade-offs and the need to identify alternatives to minimise side effects.

- GRETA has identified areas with a possible mismatch between the GI supply (e.g. capacity of the GI to provide certain ES) compared to the demand for GI (e.g. assessed by the needs of the population in the area) for flood regulation, reducing soil erosion, water purification and recreation. It could be said that water purification and recreation represent a challenge for many European regions.

Green infrastructure in urban areas

- Implementation of nature-based solutions by GI is particularly relevant in towns and cities where almost 70% of Europe's population live. Likewise, both the EU Urban Agenda as well as the global New Urban Agenda highlight the potential of GI in cities.

- Cities in eastern and southern Europe, the Netherlands and Finland need to focus on reversing the loss of green spaces between 2006-2012 to provide healthy living environments for their citizens.

- From a social perspective, the degree of accessibility to GI helps to monitor the effective and equitable distribution of derived benefits among citizens. Cities with higher accessibility are scattered throughout Europe, although tend to be dominant in Sweden, Finland, Baltic countries, the Czech Republic, Austria, Germany and Portugal. Conversely, cities in Ireland, Denmark and the UK are at the lower range of accessibility. Differences in accessible GI depend on several factors such as: the quantity of GI, its distribution (concentrated, patchy, dispersed, etc.), or the proximity to transport infrastructure. Therefore, having available GI (or percentage of GI in the peri-urban area) does not necessarily ensure it is accessible.

How can European cities, regions and national governments be supported in making full use of their GI and ES development potential?

Adopt a Green Infrastructure approach in planning. Spatial planning is considered an enabling discipline for territorial development, that articulates the deployment of other public policies affecting the spatial organization and governance of land – i.e. biodiversity, climate change, water management. The GRETA research has identified the Strategic Environmental Assessment (SEA)[2] as an example of a suitable policy tool for incorporating GI into strategies, plans and programs [see GRETA Briefing 2 on how to integrate GI into planning through the SEA process].

Identify existing assets and opportunities for Green Infrastructure. [See GRETA Briefing 3 for guidance on what methods might help with identification of existing assets and opportunities.]

Identify benefits and challenges of Green Infrastructure. GI networks need to be strategically planned in a way that conservation, protection and restoration of ecosystems are considered to harness the maximum benefits possible.

What do the GRETA Case Studies reveal?

Generally speaking, and to different extents, the case studies analysed by GRETA have adopted GI as an intrinsic part of spatial and urban planning (i.e. Basque Country)

Although ES are not always formally recognised, it seems that they are implicitly assessed in the GI approach, with a special emphasis on ecological connectivity, biodiversity, recreation, culture and wellbeing.

Main challenges for GI implementation are transport, boundary issues, demographic pressure, climate related risk, agriculture and non-sustainable forest management and forest drainage (i.e. Northern countries).

Lack of high-level guidelines on zoning and land use management in the planning instruments alongside political commitment and financial and economic investment constitute also key constraints for effective implementation of GI.

Identify Green Infrastructure "hot-spots". Planners and decision-makers should identify GI "hot spots" that either require increased safeguarding or restoration, informed by accurate and updated spatial data on potential GI networks. This should inform decisions on where to invest resources. [See GRETA Briefing 3 for methods.]

Integrate Green Infrastructure planning across policy areas. GI planning should be integrated across policy areas, including finance, energy, health and social services. This is key in order to reach wider territorial development goals. The European

Policy Integration in Practice:

In some Swedish regions the health and social service sector can prescribe 'green care' to rehabilitate people that have been outside job market for a long time. These jobs are on appointed farms, in forestry and in park management.

[2] Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014.

Commission's work on sustainable financing[3] provides an opportunity to integrate GI and finance for sustainable territorial development.

Facilitate cross-scale and cross-stage collaboration. Use GI development as a mechanism for further collaboration, awareness, capacity building, and knowledge exchange to build a common understanding between professionals operating at different implementation stages and scales. Such collaboration is especially important to adapt governance and management together with other territories that are not necessarily confined to traditional administrative borders, such as watersheds, biogeographical regions, or functional regions.

Combine private and public funding mechanisms for Green Infrastructure implementation. Key mechanisms that have been used to fund GI include Structural funds, Cohesion Funds and the European Agricultural Fund for Rural Development (EAFRD). Make GI a sustainable investment opportunity as part of the EU's integration of sustainability into financial policy framework.

Financing in Practice:
* Cyprus and Slovakia combine national environmental funds with European structural funds (i.e. ERDF, ESF, CF, EAFRD, EMFF).
* Belgium used the EAFRD for agro-environmental subsidies to enhance agricultural lands.
* Slovenia used Cohesion Funds for enhancing urban green areas.
* The European Fund for Strategic Investments have strict targets for climate-smart investments to ensure reaching the Paris agreement.

Adapt existing guidance on economic valuation methods to the specificities of green infrastructure. Guidance is needed on which methods are most suitable for benefits provided by GI, and how to apply the methods, developing especially guidance related to the inclusion of non-market benefits (environmental and social benefits). For example, the European Commission's guide to the use of cost-benefit analysis (CBA) for investment projects[4] could be "translated" or adapted for the use of CBA for green infrastructure.

Monitor progress and adapt to change. The relationships between GI, biodiversity, and ES are dynamic and must be monitored and examined over long time periods to develop effective and adaptive management measures.

GRETA Briefs.

Briefing 1. Unpacking Green Infrastructure- Focusing on the concept, benefits and side effects of the Green Infrastructure.

Briefing 2. Relating Green Infrastructure to the Strategic Environmental Assessment.

Briefing 3. Planning for Green Infrastructure: Methods to support practitioners and decision-making.

GRETA Briefs are available at https://www.espon.eu/green-infrastructure

[3] https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance_en
[4] https://ec.europa.eu/inea/sites/inea/files/cba_guide_cohesion_policy.pdf. See Annex III on valuation methods, p. 321.

1 Potential GI network as a tool to support multiple policy objectives

GI and ES have become hot topics in European policies over the past 10 to 15 years, starting with the definition of ES in the Millennium Ecosystem Assessment (MA, 2005). GRETA adopts the GI definition proposed by the EC in 2013 as a *"strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings."* This definition embraces three aspects that are important for effectively implementing GI into sectoral policies (Mubareka et al., 2013): (i) **Connectivity**, the idea of a network of geographical areas (Sections 3.1 and 3.2); (ii) the concept of **Multifunctionality** i.e. the idea that the same geographical area can be used for several purposes/activities and, at the same time, supply multiple ES[5] (Section 3.3); and (iii) the component of **Spatial Planning and Management** (Section 7.2., good practice examples in Annex IV-D, and at the case study level in Section 8 and Annex VI) – see also glossary of terms for detailed explanations of these concepts.

The understanding of a GI network as a spatial area specifically dedicated to providing multiple ES, in combination with accounting for the type of ES that are being provided, can help to identify potential policy beneficiaries and support their interest and participation in safeguarding or enhancing the provision of ES to achieve their goals. In the GRETA project, the comparison of GI across European regions and cities is based on the assessment of "**potential**" GI networks, in that **the mapped networks are related to the patterns of potential services supplied by existing ecosystems and their conditions**, and not in terms of identifying spatial areas already bound by policy measures and secured by their obligations. The proposed methodologies at different spatial scales provide standardised results that allow the capacity of land cover and use to be compared to elements in cities and regions to supply multiple ES that support the implementation of GI networks tailored to specific policy sectors.

Two sources of geographical datasets were used to map and assess the distribution of potential GI: (i) land use and land cover data; and (ii) ES. These two datasets were used to assess two of the previously mentioned key underlying principles of a GI network, as defined by the EC (2013) and similarly stressed by others (e.g. Mell 2017) – *connectivity* and *multifunctionality*.

Land use and land cover data are the foundation of a potential GI network assessment and mapping (Hoctor et al., 2000, Carr et al., 2002, Weber 2004, Weber et al., 2006) and are used to identify the two primary components of a GI network, i.e. 'hubs' and 'links' (Benedict and McMahon 2002), and to evaluate their connectivity. Data on ES is used to measure GI multifunctionality, which represents the ability of the GI elements (i.e. hubs and links) to simultaneously provide multiple benefits in the same spatial area (Mell, 2017). Annex I-A provides the list of datasets that were identified and collected for mapping potential GI elements and the related ES, at both the regional and city levels

[5] There is not a unique relationship between land use and ecosystem services.

in Europe. Supplementary datasets were collected to cover a larger number of ESPON Member States, to perform a time-series analysis of potential GI geographical distribution over the past 10 years at the city level, and to estimate additional benefits from the GI network (other than biodiversity related benefits).

For the GRETA project, eight ES indicators were selected to measure the ability of potential GI elements to provide multiple functions in the same spatial area. The selected indicators were collected from the list proposed in the framework of the Mapping and Assessment of Ecosystems and their Services (MAES), and published by Maes, Fabrega et al. (2015), which are: Gross Nutrient Balance (GNB), Habitat Quality index (HQi), Net Ecosystem Productivity (NEP), Relative Pollination (RP), Soil Erosion Control (SEC), Water Purification (WP), Water Retention Index (WRI) and Recreation Potential (RecPot). The selection was based on the capacity of each ES to support the achievement of some objectives defined in the context of the three selected policy frameworks (refer to subsection 1.4): Biodiversity, Climate Change and Disaster Risk Reduction, and Water Management. The description and rationale for including specific ES in the analysis of the functional performance of potential GI within each policy sector is presented in Annex I-B. Figure 1 shows the connections between the selected ES and the three policy frameworks. There are some ES that serve more than one policy (e.g. NEP and WRI); RecPot was included in the set of ES for this project as it is a transversal ES that adds to general human well-being. The synergies and trade-offs of ES within each policy domain are analysed in detail in section 7 of this report.

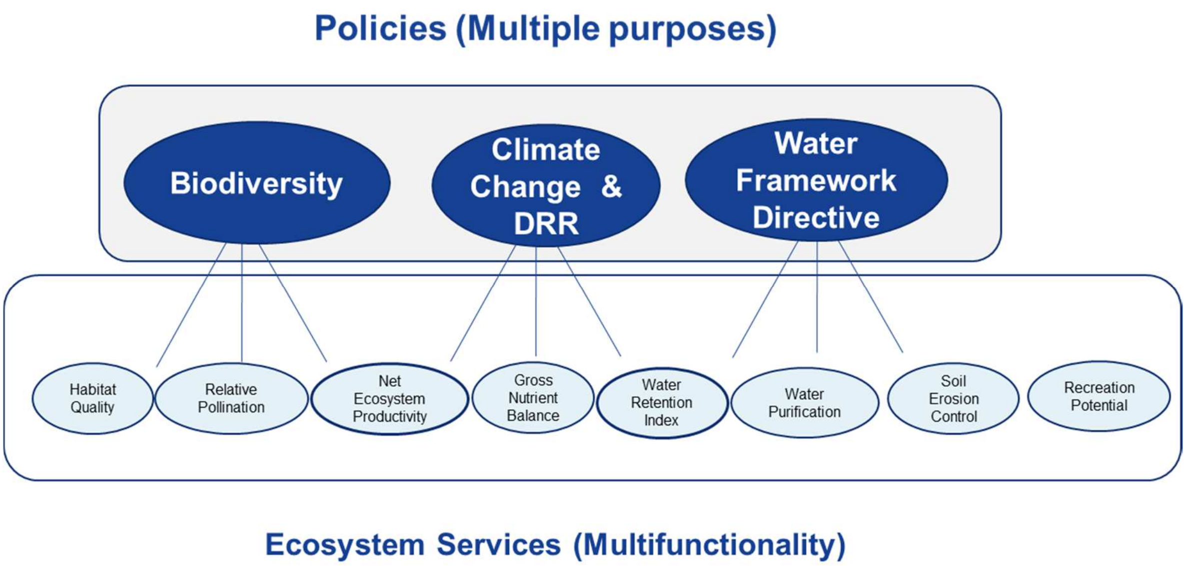


Figure 1 ES supporting the objectives of different policy frameworks (DRR = Disaster Risk Reduction)

The datasets used to analyse the geographical distribution of GI in European regions (NUTS 2/3) and cities are described in Annexes I-A and I-B. The data shortcomings and backup solutions are explained in Annex I-E. For example, the eight MAES ES indicators (Maes, Fabrega et al. 2015) used in this project only describe the potential supply side of ES and do not take into consideration the state or the condition of the ecosystems. Indeed, the European Environment Agency (EEA) is still preparing an assessment of ecosystem condition at European level, which should be published by the end of 2019 (Maes et al. 2018). Therefore, although the assessment of ecosystem condition at EU level will be a key element to understanding the link between ecosystem status and the provision of multiple ES, it is not yet considered in this project. Finally, the ES indicators are only based on data and models. To produce them, the authors (i.e. Maes, Fabrega et al. 2015) did not consult stakeholders who can often contribute valuable, expert-based knowledge at higher spatial scales.

2 The socio-ecological system for implementing GI

In this section we analyse the foundations for an integrated understanding of the social-ecological system (SES) that will inform better decisions (van den Belt and Blake, 2014). A transition towards nature-based solutions entails changes in manifold SES. These changes, however, involve complex processes that are characterised by multiple and interacting feedback, non-linear dynamics, and cause and effect relationships; these relations may not be evident in many instances.

Modelling methods provide a key tool to support decision makers in the conservation of ES. A model is a simplification of reality, a quantitative or qualitative description of key system components and of relationships between these components. When modelling is jointly developed with stakeholders, it is possible to identify potential conflicts (Angelstam et al., 2013). This co-creation process is also crucial to building a common understanding among all involved actors.

2.1 Main elements and relations of socio-ecological systems for GI in Europe

The **main elements and relations** of SES that facilitate the **implementation of GI** are now described Causal Loop Diagrams (CLDs) have been used to do so, which are qualitative models used to foster knowledge exchange and to highlight key aspects of dynamic systems. These diagrams are depicted through arrows representing cause–effect relationships between variables. A positive link "+" indicates that two variables change in the same direction (e.g. when variable A increases, variable B also increases). When two variables are directly connected with a negative link "-", this indicates that both variables change in the opposite direction (e.g. when variable A increases, variable B decreases). Therefore, CLDs may be used to develop dynamic hypotheses regarding the propagation of an impact within the system (Lopes and Videira, 2017).

The SES for implementing GI is defined here by 61 variables included in the CLD (see Annex II-A), which summarises the mental models of a range of stakeholders and describes the main variables and causal links. CLDs can also be used to identify the most critical pieces of the system and the interlinkages between them that influence each other through dynamic relations. On the one side, the social system receives benefits that improve the health and well-being of citizens and societal challenges can be determined. On the other side, certain territorial decisions are brought forward, which in turn impact on the state of ecosystems. Accordingly, the GRETA SES can be summarised by five groups of variables: ecosystem functioning, ecosystem services derived from GI, physical and psychological health and wellbeing, socio-economic aspects, and planning opportunities.

A first group focuses on **well-functioning ecosystems**, which refers to the combined effects of all processes (biological, geochemical, and physical) that sustain an ecosystem, considering the fluxes of energy and matter among its components. Maintaining the proper functioning of an ecosystem is important to ensure the long-term capacity of a region to supply **ES** which society benefits from. Social systems, on the left of the diagram in Figure 2, are characterised by the state of **health and human well-being** that will influence the societal challenges and push decision-making forward. Finally, the lower part of the diagram refers to the enabling factors described by these **socio-economic aspects** and the **planning opportunities** that will facilitate the implementation of GI. These groups are further described in the next sections.

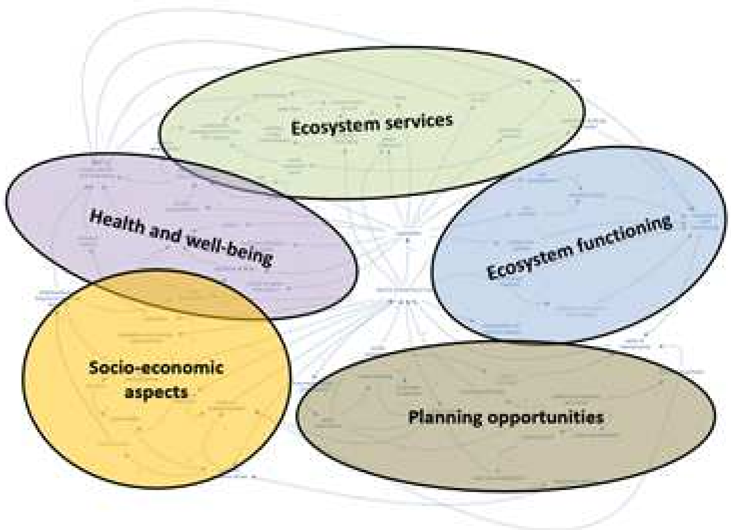


Figure 2 Synthesised Causal Loop Diagram for the GI socio-ecological system Source: Prepared by the authors based on the results from the literature review and consultation with stakeholders

2.2 Benefits and impacts

Proper delineation and implementation of GI requires an understanding of the potential impact (positive and negative) on the natural systems, but also on the socio-economic system. Since this is a relatively new topic, long term analyses (covering over 10-15 years) are not yet available. However, current knowledge already provides relevant principles to be considered when implementing GI to identify possible conflicts and to avoid unwanted side effects. This section provides an overview of the most recent literature on the impacts of GI and on economic valuation methods; this overview is complemented with a discussion on the implications from the policy perspective. A combination of the extensive literature review and the collaborative development of the conceptual framework for GI implementation in Europe with a range of stakeholders underpins the results explained in this section.

Positive and negative effects of GI need to be considered in relation to its spatial and temporal scale. As the introduction of the GI concept and its implementation in Europe is relatively recent (although some related practices were developed long ago), most studies include short to medium-term analyses. From the spatial perspective, it was found that **most studies analyse the impact of GI elements at the site or local level within urban areas.** For example, Bartesaghi Koc and colleagues (Bartesaghi Koc et al., 2018), found that nearly half of the studies (49% of studies from a literature review) on the cooling effects of GI were focused on the micro-scale (green walls, green roofs, trees as street canyons, courtyards or outdoor open spaces); circa 23% were applied at the local scale including green spaces and trees in neighbourhoods and urban districts, and only 23% focused on the meso-scale, covering larger areas such as cities and regions. These differences may be related to two main aspects: 1) the priority on "greening" urban areas to improve the health and well-being of the population, 2) the increased complexity of managing larger areas in terms of technical aspects, land ownership, or the need to coordinate between several administrations.

Given GRETA's focus, the aim was to discriminate between: (i) the urban and peri-urban level; and (ii) the landscape scale (considered here as the area outside the Functional Urban Areas (FUA) which may include rural and natural or semi-natural assets). There were, however, fewer landscape scale studies identified from scientific literature searches, making it evident that the terminology used at both scales is different, i.e. **the term "green infrastructure" is not often used for studies at the landscape level**.

Several studies have synthesised the positive effects from single GI elements such as green roofs (Francis and Jensen, 2017; Berardi et al., 2014; Williams et al., 2014), streetscape elements such as roadside vegetation (Säumel et al., 2015) or street trees (Salmond et al., 2016), urban gardens (Scott et al., 2018; A. Russo et al., 2017; Camps-Calvet et al., 2016; Lin et al., 2015), or urban forests (Kuehler et al., 2017; Pearlmutter et al., 2017). Others have focused on the benefits provided by GI from the perspective of a given topic such as biodiversity conservation (Schwarz et al., 2017), sustainable water management (Wade and McLean, 2014; Ellis, 2013), climate change (Bartesaghi Koc et al., 2018), low impact development (Eckart et al., 2017), public health (Bowen and Lynch, 2017; Coutts and Hahn, 2015; Tzoulas et al., 2007), cultural services (Hegetschweiler et al., 2017; O'Brien et al., 2017) or economic benefits (Wise et al., 2010). A general overview is provided here in an attempt to summarise evidence of the more relevant benefits provided by GI as a whole in a given territory (Scott et al., 2018; A. Russo et al., 2017; Camps-Calvet et al., 2016; Lin et al., 2015).

The multifunctional character of GI elements provides a **range of benefits** through a variety of ES, which often appear in bundles and are mutually reinforcing under certain circumstances. (Refer to Section 7 for a more detailed explanation of multifunctionality and ES interaction). Results of the review show that, although most of the studies are focused on a given topic (e.g. climate change, biodiversity conservation, health benefits) or on one type of GI asset (e.g. roadside vegetation, urban parks, green corridors), the implementation of GI often brings several different benefits. It is most likely for this reason that it is generally accepted (within both the scientific and the policy-maker communities) that enhancing **GI has a positive link with biodiversity and ES** (Schwarz et al., 2017), although there is little evidence on the specific mechanisms behind this relation. Table 1 provides an overview of some generalisations that arise from the literature which are discussed in further detail below. Moreover, the empirical evidence on the benefits of implementing GI would require specific monitoring over a certain period of time that is very often not carried out, or in the best cases, only partially addressed.

The role of GI **in biodiversity and species protection** is mainly underpinned by the provision of habitats for species and by ensuring connectivity among habitats. The capacity of GI to provide wildlife habitats in both urban and rural areas is well established (Landscape Institute, 2009). At the urban and peri-urban level, the development of green networks reduces isolation among habitat patches and favours species movement, improving the ecological value of connected urban green spaces (Wade and McLean, 2014). At the landscape scale, habitat connectivity plays a vital role in population viability by facilitating the dispersion, recolonisation and migration of species (Kong et al., 2010). While it is still widely accepted that diversity is a key indicator of ecosystem health (Rapport et al., 1995), species-rich habitats are considered more resilient than homogeneous ones and recent evidence (Schwarz et al., 2017) establishes that ecosystem functioning is more often determined by the distribution of species' trait values of that community than its taxonomic diversity (Díaz and Cabido, 2001; McGill et al., 2006). To date, however, most of the evidence for relationships between biodiversity and ES is based on taxonomic metrics (abundance/biomass, species composition or taxonomic diversity) rather than functional biodiversity metrics (mean trait values or functional diversity). In summary, more empirical research is needed on how species assemblages influence ecosystem functioning, stability and ES delivery (Alberti, 2015; Kowarik, 2011) which would inform how GI can be managed to enhance ecosystem health, particularly in urban areas.

The increase of vegetation cover in urban areas is one of the key methods for reducing the urban heat island effect; by increasing evapotranspiration and shading, and favouring ventilation, temperatures at the local level near vegetated areas can be significantly lowered. A study modelling the hypothetical increase of vegetation cover by 6.5% found that summer temperatures could be reduced by 3-5% (Sailor, 1998). At the landscape scale, greening favours **climate change adaptation** by strengthening carbon sequestration and the resilience of ecosystems. Besides acting as carbon sinks, well-designed and properly managed GI assets may encourage sustainable forms of transport.

Additionally, vegetation in cities and towns can reduce energy use for heating and cooling buildings by shading in summer and providing shelter in winter. GI approaches for climate change mitigation include planning areas for ground source heating, hydroelectric power, biomass and wind power.

GI is crucial for the water cycle as it facilitates infiltration and storage of water in soils and releases water into the air through evapotranspiration. Most **water management** examples relate to the implementation of sustainable urban drainage systems in new developments which manage water quality and quantity by mainly attenuating surface water run-off and favouring groundwater infiltration. Stormwater retention techniques include ponds, wetlands, green roofs, and rainwater harvesting systems, while infiltration elements comprise swales, trenches, sand filters, and porous pavements. For instance, increasing tree cover in residential green areas may reduce run-off by 5.7% in highest rainfall scenarios (Gill et al., 2007).

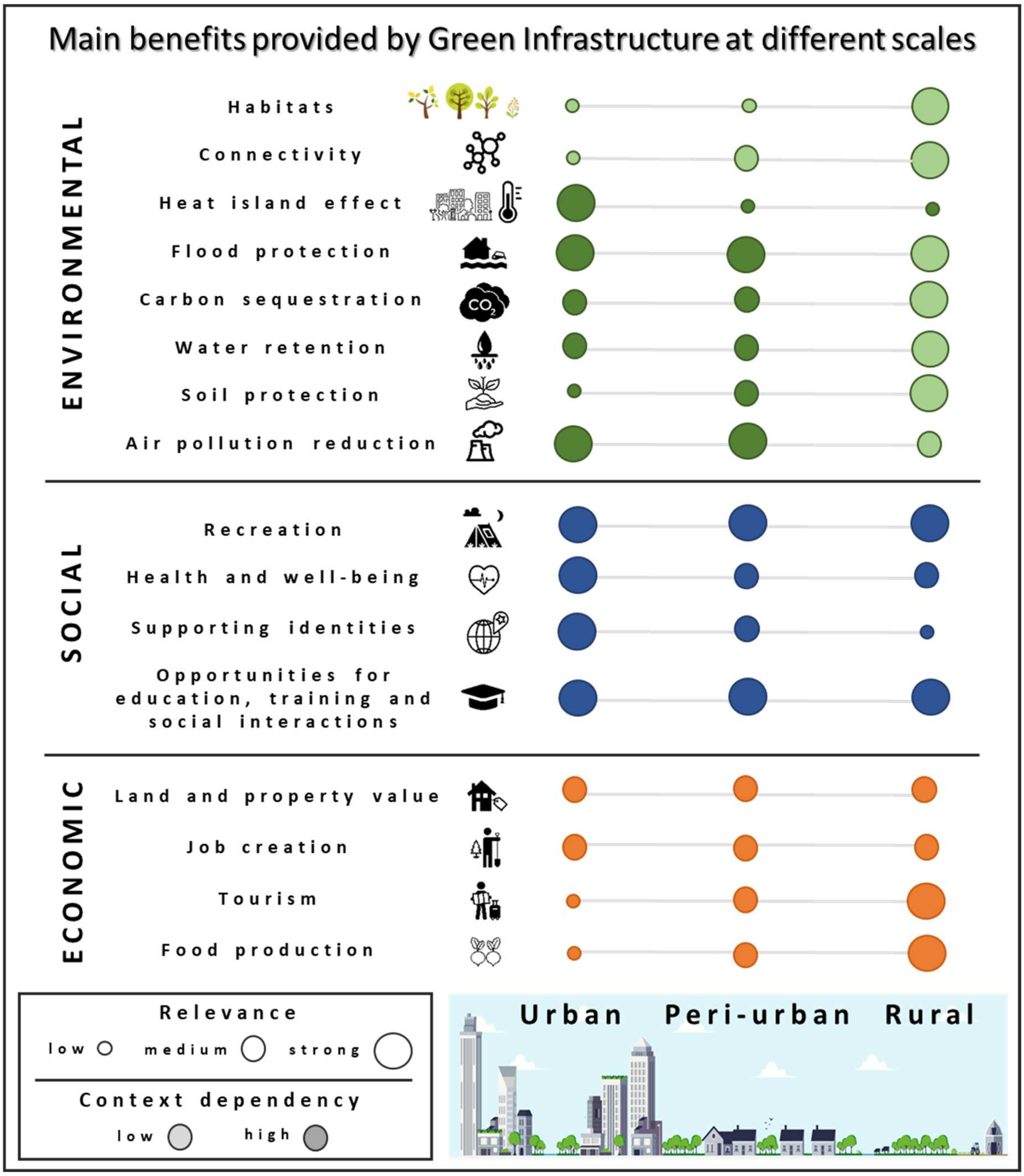


Table 1 Summary of main benefits provided by Green Infrastructure at different scales. Source: Prepared by the authors based on the combination of a literature review and expert knowledge.

Vegetation is an important ally in the fight to **reduce pollution** as it has the capacity to capture both gaseous and particulate airborne pollutants (Beckett et al., 1998). Gases are removed from the air via uptake by leaf stomata, absorption through leaf surfaces, and adsorption to plant surfaces; particulate matter removal occurs through deposition on leaves and other plant surfaces. Several modelling approaches estimate an annual removal of Particulate Matter (PM) 10 of between 852 and 2121 tonnes in Greater London (Tallis et al., 2011). GI not only addresses air pollution, as it may also improve water quality by reducing concentrations of heavy metals and bacteria and can complementary achieve noise abatement.

Edible GI elements (e.g. allotments, community gardens and orchards, edible roofs and walls, peri-urban forests (Russo et al, 2017)) provide an opportunity to promote urban agriculture and local **food production**. An important co-benefit of these assets is the sense of community and emotional bond to local culture and space that can occur. Contemporary green space planning is also creating new opportunities to integrate productive practises traditionally linked to rural contexts such as farming, horticulture, and bee-keeping.

A review of European studies on the relation between urban GI characteristics and society demands (Hegetschweiler et al., 2017) identified that benefits related with health (30%) and well-being (15%), including perceived restorativeness (20%) and self-reported mood (10%), were the most common compared with other socio-economic benefits. **GI has great potential to improve physical and mental health and to reduce the negative impacts of extreme events**. More accessible green areas (closer and higher quantity) increase the likelihood to undertake regular physical activity (Mytton et al., 2012), which can reduce heart disease, respiratory infections, or asthma (Janssen and Rosu, 2015; McMorris et al., 2015). There is strong evidence on the association between experiencing natural environments and reduced self-reported stress, as well as physiological stress, supported by the stress reduction theory (Ulrich, 2002). Additionally, vulnerable citizens will particularly benefit from reduced temperatures provided by GI during periods of intense heat (Bowen and Lynch, 2017).

GI may have a positive **economic impact** on land and property markets, creating settings for investment and promoting wider regeneration (Landscape Institute, 2009). Studies conducted in the UK and the USA found that properties with similar characteristics but close to parks have prices that are on average 8% higher than houses further away (Dunse et al., 2007; Northwest Regional Development Agency (NWDA), 2008). Moreover, several studies, report reduced energy use (Wise et al. 2010; Charlesworth et al. 2012; Mekala et al. 2015; Pochee & Johnston 2017) and other savings such as potable water use and the prevention of treatment costs from grey infrastructure.

Distinctive GI elements may favour community engagement and relate them to landscape and cultural heritage, fostering a local sense of place (Landscape Institute, 2009). It is also generally accepted that GI provides a range of opportunities for education, training and to facilitate social interactions that reinforce **culture and a sense of community**.

The ability to identify and value these benefits is crucial to appreciate GI's full potential. There are, however, drawbacks that should be properly acknowledged prior to implementing GI. While the literature on these **negative impacts** is more recent (thus limited), some general aspects can be highlighted. Most cited are those related to social aspects such as eco-gentrification and the increase in inequalities, the risk of vandalism in parks and open spaces, disagreement on stakeholders' priorities, fear of natural spaces, increased sources of allergies, and high levels of heavy metals and other pollutants in agricultural products from community gardens.

Eco- (or green) gentrification occurs when wealthy residents move into historically disadvantaged neighbourhoods after a new green area is promoted or developed. Rents and property values usually increase, forcing the displacement of long-term residents who cannot afford to stay. Moreover, the character of neighbourhoods and community changes through the loss of local distinctiveness and cultural heritage. To avoid such drawbacks and to ensure GI benefits are distributed equitably (particularly including vulnerable communities), urban greening needs to be planned by considering social justice principles.

Adverse effects on human health from the consumption of food produced in urban sites, via the uptake and accumulation of trace metals in plant tissues, differs according to crop type, species, and plant parts (Säumel et al., 2012; Warming et al., 2015). There are significant differences in trace metal concentrations depending on local traffic, crop species, planting style and building structures, but not depending on vegetable type (Russo et al., 2017). While a higher traffic burden increases trace metal content in plant biomass, the presence of buildings and large vegetation masses which act as barriers between crops and roads, reduces pollutant content.

Economic disadvantages include higher costs to initiate and maintain GI, and higher costs to purchase or lease land and properties. The main issue is often a lack of understanding on the multiple benefits that GI provides, which makes it difficult to properly quantify the cost-benefit relation and discourages implementation at different stages (design, planning and construction) and the management process (long-term funding and maintenance). Putting a 'learning-by-doing' approach into practice, based on scientific results and led by multi-disciplinary teams, has been identified as a key element to remove these barriers (Connop et al., 2016).

Among the ecological downsides are the risk of invasion by alien species, water pollution from fertilisers and other chemical inputs, and higher levels of water consumption. Urban green spaces have contributed to the introduction of alien species, especially plants (Galera and Sudnik-Wójcikowska, 2011) but it is also true for other taxa. Depending on conditions, these species may spread and colonise new areas, becoming invasive. When GI is fully integrated in a network of green areas, GI may act as a dispersal highway for these invasive species.

In summary, **the quantification of benefits provided by GI directly depends on the type of assets, their spatial arrangement, methodological aspects, and other specific context aspects**. Therefore, there is not a single one-size-fits-all-solution, but rather a suite of approaches that must be tailored depending on the context (goals, location, local climate, city/regional structure, among others). Finally, the relationships between GI, biodiversity and ES are dynamic and need to be monitored and examined over longer time periods in order for effective and adequate adaptive management measures to be proposed (Schwarz et al., 2017).

2.3 Attributing monetary values to the benefits of GI

This section analyses the evaluation of GI benefits by using economic valuation methods. Recreational benefits as well as biodiversity or water quality benefits arising from the existence of GI can be quantified in terms of number of visitors, number of species, or reduced nitrates for example, but these measures are not easily comparable to the costs of implementing or managing GI. Translating these physical measures into monetary terms is a way to express all benefits in the same units of measurement and facilitate their comparison, which is particularly useful when carrying out a CBA. However, not all benefits have a market price. It is therefore necessary to use alternative valuation methods to assign a monetary value to these benefits for which no markets exist. Within GRETA, the use and possible use of these methods for decision making by practitioners was analysed and a summary (meta-analysis) was provided on the monetary values assigned to GI benefits in academic publications in Europe.

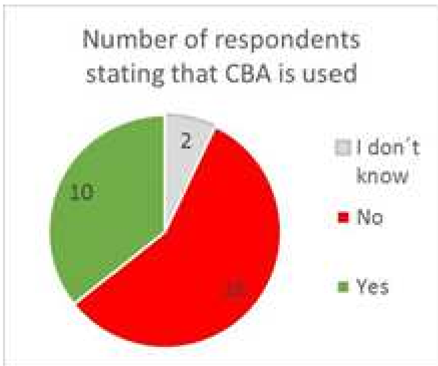
The main valuation methods considered include: replacement costs, avoided cost, hedonic pricing, travel costs, contingent valuation, discrete choice experiments (or choice modelling) and benefit transfer (refer to Annex III-A for descriptions).

The work on economic methods for valuing demand for GI is based on two complementary activities. Firstly, consultations with policy/decision makers and technical experts in the GRETA project case studies identified to what extent these methods and the values they provide are being used or are potentially useful for decision making. This consultation helped identify the barriers (e.g. skills, knowledge of methods, costs) to the use of various economic methods in GI decision making. Secondly, a meta-analysis of existing publications on the economic benefits of GI in Europe provided an overview of valuation methods currently used and the progress made in valuing demand for GI (refer to Annex III-B). The analysis focuses on identifying the range of monetary values that individuals attribute to GI and the characteristics of GI which make them more or less valuable to the general public.

2.3.1 Current practices for the inclusion of GI benefits in decision making and scope for further use of monetary valuation methods

This section draws on 28 responses to an online consultation of policy/decision makers and technical experts in 11 of the 12 GRETA case studies (only the Alpine Region was not represented, see Table 20 in Annex III-C). The survey was completed by 20 technical experts, 6 policy/decision makers, 1 researcher and 1 person who is both a technical expert and a policy/decision maker. Further information on the consultation process is included in Annex III-C of this Final report.

Current practices in the use of Cost-Benefit Analysis for GI decision making



CBA is used as a tool in the decision-making process when deciding on the best ways to manage or invest in GI by 10 of the 28 respondents (

Figure 3), over 5 different case study areas (Alba Iulia Municipality in Romania, Central Scotland Green Network, Greater Copenhagen, Randstad and Southern Estonia / Northern Latvia).

Figure 3. Current use of CBA

CBAs are primarily used prior to implementing GI as an ex ante evaluation (8 out of these 10 responses) rather than ex post, as a way to evaluate the results achieved (2 out of the 10 responses). The 10 respondents who report using CBA were asked which benefits were accounted for in the CBA. The benefit that is most commonly accounted for is recreation (7/10) but the effect of GI on flood mitigation and climate change mitigation or adaptation to climate change is also widely accounted for in CBAs (6/10). Health benefits are accounted for in half of the cases, while biodiversity and water quality improvements are more scarcely considered (4/10). Finally, some CBAs included travel time savings for cycling commuters, crime reduction, increased property (housing) prices and the preservation of historic monuments as additional benefits provided by GI. On average, 3 to 4 of these benefits were included simultaneously in the CBA, although some CBAs were only able to include 1 type of benefit while others included up to 6 different benefits. All CBAs mostly drew on non-monetary and monetary data regarding the socio-economic benefits of GI and some (5) also used ecological data.

The methods currently used to infer monetary values to the benefits of GI are hedonic pricing (which measures the effect of GI on property prices), contingent valuations, costs avoided due to GI, and the replacement costs to provide equivalent benefits in the absence of GI. The use of the travel cost method or discrete choice experiments is not as common. However, while most respondents were aware of the existence of economic valuation methods to provide monetary values to the benefits of GI, only 13 have used one of these methods, and 14 do not use them (see Table 21 Annex III-C). Only 1 respondent was not aware of the existence of these methods. The next section considers the limited use of such methods and identifies ways to further develop their use if they are judged to be potentially useful for GI decision-making processes about GI.

In conclusion, the main message is that CBA is currently not a widespread tool used in GI decision making within the GRETA case studies, and when implemented, its implementation and the benefits that are accounted for vary widely across the case studies. CBA is mostly seen as a planning tool rather than an evaluation tool, and there is room for economic valuation methods to be used further in order to better inform decision making.

Assessing the potential of economic valuation methods for GI decision making

The first striking result on the potential of economic valuation methods for GI decision making is that a vast majority of respondents (25 out of 28) would find the use of these methods helpful to better inform GI planning and decision-making processes. However, several respondents highlight the fact that these methods, including CBA, are only one of the many pieces of information that need to be taken into account in the decision-making process. This section firstly considers how these methods are currently used in decision making, then assesses what prevents their use, and finally determines the type of support that could be provided to make it easier to include monetary valuations of the benefits of GI in decision making.

The consultation indicates that the need for economic valuation methods has emerged in the context of a growing importance of GI in the decision-making process and increasing concerns for climate change. Respondents who currently use these methods consider that they provide additional information with a different perspective that helps build a case, guide decisions, and better design GI at the local and national scale. For example, results provided by economic valuation methods have been used in the implementation of city Development Strategies, in investment and budget decisions, and in promoting the city to the general public or local stakeholders. Being able to provide a quantitative monetary value to the benefits provided by GI is seen as a strength of such methods, as they help to build a stronger case to which policy makers, politicians and the general public are particularly receptive. It helps consider GI as a form of investment in a city or in a landscape and helps understand the potential for economic benefits. The use of these methods has also provided a way to better understand the importance of GI at the local level and the multiple benefits they provide. Important factors mentioned by several respondents are the availability of data that enabled the use of such methods in their case study area, and the existing links to researchers or members of staff able to implement these methods.

The use of these methods has associated challenges and limitations. Moral concerns are raised regarding putting monetary values on environmental, cultural or health benefits, and respondents highlight the need to consider this monetary value as just one of many pieces of evidence and not as the only decision-making criterion. This is also justified by the current methodological limitations that do not allow all types of benefits to be measured and account for (e.g. health) through economic valuation methods, something which is perceived as a challenge by several users of these methods. The use of these methods is also hindered by the lack of time and funding available for such additional analyses that require primary data collection.

These constraints echo those noted by the 14 respondents who, despite being aware that such methods to contribute to GI decision-making processes exist, do not currently use them: availability of reliable data, the lack of skills and time, and concerns about the reliability of the method are mentioned as hindering factors (refer to Table 22 in Annex III-C). An additional important constraint that is mentioned by respondents who do not currently use these methods is the lack of flexibility of existing planning protocols, policies and timeline imperatives for GI decision-making processes in their institutional context, or the lack of a framework or institutional support to undertake these analyses.

Finally, the current limited use of CBA as a decision-making tool could also be explained by the relatively recent appearance of GI on the political agenda. Many respondents state that they have not had the need or the opportunity to provide a monetary value to the benefits provided by GI as their importance was generally already recognised politically. With GI being only recently integrated into planning for their own case study area, several respondents mention that they are still at a stage where they need to focus attention on measuring the ecological benefits before trying to value these in monetary terms and integrate them into planning. However, projects are emerging where the use of these methods is being considered, for example in Scotland and Estonia.

Finally, 15 of the 28 respondents call for support in the form of access to data from valuation studies implemented for other GI, while 10 would welcome training in economic valuation methods to increase their ability to include these methods and CBA as part of their toolbox for GI decision making and planning.

To conclude this section, key messages are:

- The heterogeneity in the use and implementation of CBA suggests a need for a framework / guidance on how valuation methods can be implemented, and their results integrated to account for environmental effects of GI in CBA[6];
- There is general interest in the use of economic valuation methods in GI planning;
- Economic valuation methods can provide strong and convincing indicators for decision making and planning;
- These methods need to be considered as one of many criteria for decision making as they also have associated limitations; and
- Their use could be facilitated through training and increased data availability.

In connection with this last point, the following section examines the availability of relevant data on the monetary values of GI benefits provided in the literature through a meta-analysis.

2.3.2 The monetary value of GI benefits in Europe: a meta-analysis

This section draws on a meta-analysis of 33 papers. Unlike previous meta-analyses (e.g. Brander and Koetse 2011; Bockarjova and Botzen 2017) which also include non-EU monetary valuation studies, the meta-analysis carried out by GRETA is exclusively based on European data. This provides monetary values associated with GI in similar contexts which could be invaluable for benefit transfer considerations, i.e. transferring monetary values from one context to another. It also illustrates the monetary values given to GIs and explores the reasons behind differences in these monetary values.

As detailed in Annex III-B, two separate meta-analyses were implemented to analyse values separately that were produced using methods with different theoretical backgrounds that are not comparable. Hedonic pricing literature and stated preferences literature were analysed separately. The papers using other approaches were too few and too heterogeneous for a meta-analysis. The results from these 2 meta-analyses will now be discussed. Further details on the meta-analysis method are provided in Annex III-B, including all the tables.

The effect of GI on property prices – a meta-analysis in Europe

This section is based on results from 13 papers providing a total of 78 observations measuring the impact of GI on property prices, in 9 different countries (see Tables 2 and 4 in Annex III-B). The most frequently studied types of GI are: urban parks (with 34 observations) and urban forests (16 observations). Some papers (12) look at the effect of all urban green areas in general, confounded with no distinction between different types of GIs (Table 5 in Annex III-B). Because of the nature of the method, which requires large datasets of property prices, most observations are located in urban areas. As hedonic pricing analyses are implemented in a heterogeneous way (see Table 3 in Annex

[6] This point will be further developed in the policy guidelines section (section 10).

III-B), all different measures of impact were transformed into the average percentage variation, of property prices in the study area when distance increases by 100 metres[7].

The average impact of GI on property prices is a decrease in property prices of 0.88% (standard deviation of 12%) when the distance of the property to the studied GI (nearest GI when all green areas are analysed together) increases by 100 metres. Property prices are therefore relatively higher when located closer to GI. However, given the high level of heterogeneity in the application of the methodology in the original studies, this aggregated number is to be taken with particular caution.

In order to measure the effect of alternative GI characteristics on property prices, a regression analysis was carried out, controlling for country and study design effects. Unfortunately, this regression does not capture any general trend. Different types of GI (urban parks, urban forests, GI around lakes and watercourses, or the presence of playgrounds) do not influence property prices in significantly different ways and neither do different population densities in the NUTS2 region. One interesting result however is that when GI includes a water element (river, lake, or water structures in urban parks), their effect on property prices seems to be higher, with a larger positive effect of being located closer to a GI[8].

Stated preferences and willingness to pay for GI in Europe – a meta-analysis

This section is based on results from 20 academic papers providing a total of 203 observations of average willingness to pay (WTP) for the creation, maintenance or enhancement of GI in 10 different European countries (see Annex III-B). This meta-analysis covers a range of urban, peri-urban and rural GI, and different types of GI, again with studies predominately focussing on parks and forests (see Annex III-B). Regression analysis was used to better understand the which characteristics of GI might influence WTP. It was found that forests provide higher well-being increases than other types of GI, as individuals' WTP for this type of GI is the highest in the meta-analysis. Other types of GI (park, lakes or rivers, or GI for landscape biodiversity in rural area) provide benefits of comparable magnitude across types, but all lower than benefits provided by forests.

Regarding the type of ES provided by GI, the analysis indicates that GI is valued differently depending on the ES it aims to provide. GI that provides flood control is given the highest monetary value on average, but the standard deviation also indicates the largest variation across study areas. Indeed, in some instances flood control is highly valued (in monetary terms) while in others it is not. GI that provides recreational services is given the second highest value in the meta-analysis, and GI supporting biodiversity comes third in terms of average monetary value. Finally, GI providing other

---

[7] Other papers (3) use the average percentage variation of property prices, in the study area, when GI cover increases in the neighbouring area to measure the impact of GI on property prices but these could not be used in the meta-analysis.

[8] This result is based on the separate analysis of the 52 observations from papers that measured the effect of GI in an homogeneous way - through the percentage decrease in property prices when distance to the GI increases in metres (see Table 3 in Annex III-B)

ecosystem services (e.g. water quality) or that do not target specific ecosystem services[9] is in last place.

Similar to what was found in the meta-analysis on hedonic pricing literature, the population density in the NUTS2 region is not relevant in explaining the differences in the monetary values that individuals give to GI; individuals living in highly populated regions do not seem to be willing to pay more for GI than those living in less populated areas.

To conclude on these meta-analyses, it was found that the valuation studies implemented in Europe, despite using similar methods, are implemented in a very heterogeneous way, which makes meta-analysis work challenging. This is an obstacle to the use of the benefit transfer approaches in future studies. Most studies measure the monetary value of forests and parks, leaving other types of GI under researched. The main results are: (i) the general public seem to value GI that include water elements and forests more highly; and (ii) from highest to lowest, preferences are for flood control (but with high variations across studies), recreational services and finally biodiversity support.

2.4 The enabling factors for implementing GI

The causal loop diagram introduced in Section 2.1 (see Figure 2) acknowledges the enabling factors as those described by socio-economic aspects and planning opportunities, which frame a systemic understanding of GI within the social and ecological landscape system. Referring to the socio-economic aspects, GRETA socio-ecological system illustrates how GI may increase the local distinctiveness and create new jobs, which in turn, improves local wealth. However, some drawbacks can appear such as increased land and property values, gentrification, and the displacement of historical residents. Here, three factors are crucial for the implementation of GI; one is the cost of implementation, the second is the cost of maintenance, and the third is the availability of financial incentives.

Planning opportunities is the theme that groups all factors that will facilitate the GI implementation. This theme is related to social awareness, political commitment and strategic and common vision required to enable strategic planning. There is a leverage point here derived by urban densification, which encourages urban growth, increasing land use competition and reducing the placement options.

Social awareness and **political commitment and vision** can be highlighted from among the enabling factors that have a higher impact on the socio-ecological system and, therefore, provide more information on where to act (Lopes and Videira, 2016). Social awareness is a key factor for people to value the benefits from ES and the importance to maintain and preserve multifunctional landscapes. Political commitment at all scales (EU, national, regional and local) is crucial to leading the change towards more sustainable territorial development that produces a reliable transition. A strong commitment and a clear vision should ensure that policy objectives will not be substantially modified with a potential change in government after elections. To do so, the different forces need to

[9] In some instances, the objectives of the GI were not presented to respondents in terms of what benefits or what specific ES would be provided.

join together to build a long-term vision for the sustainable development of regions that goes beyond a 4-year political mandate. In addition, attention should be paid to the potential **displacement of long-term historical residents** as a result of an eco-gentrification process. All these key factors can be used as indicators to monitor the performance of management actions. Furthermore, the **cost of implementation** can be highlighted among the variables that are greater influenced by the socio-ecological system. That is, these variables are more impacted by changes occurring in the system, therefore they are good indicators to monitor change. The challenge is now to propose indicators to monitor progress that are easy to quantify.

A total of 22 feedback loops appear in the system that describe the implementation of GI. When two or more variables are connected in a closed cycle, this provides a feedback loop, which can be classified as Reinforcing (R) when it propagates the initial change in one of the variables, or Balancing (B) if the loop counteracts the initial impact. The shorter loops (where a smaller number of variables are involved) the faster the effect is propagated.

Here, the focus is on describing and analysing the implications of these shorter loops that relate to the key enabling factors. The first loop is a reinforcing one that is defined by the creation of new jobs, which in turn reduces the costs of implementation as more professionals are available that know how to put GI approaches into practice, and with less costs there is an increase in the number of GI elements finally implemented as costs in this case do not represent a burden. Another reinforcing loop is described by the knowledge base, an increase in information, which raises social awareness and pushes political commitment towards further engagement in strategic planning, that in turn favours the implementation of GI initiatives, and finally results in a richer knowledge base.

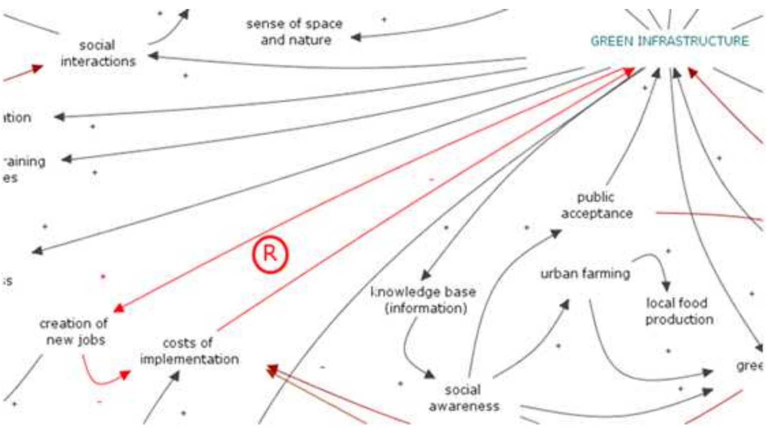


Figure 4. Creation of new jobs and impact on GI implementation costs.

On the other hand, a balancing loop illustrates how an increase in GI leads to an increase in land and property values, which in turn increases the costs of implementation as the acquisition of new land to develop GI projects is more expensive. Consequently, the deployment of GI elements is reduced. Finally, a longer balancing loop is depicted by the increase of land and property values, which drive an eco-gentrification process that forces the displacement of less favoured long-term residents. This, in some cases, reduces the local distinctiveness of the neighbourhood or region, which also disincentivises tourism, reducing local wealth opportunities, which finally brings about a decrease in land and property values.

2.5 The main policies, conflicts and hurdles of GI implementation

Simultaneous maximisation of all possible benefits to different GI policies is unlikely, thus trade-offs need to be strategically assessed. Table 2 provides an overview of different EU policy domains and where benefits or conflicts may arise.

In order to monitor the positive impacts of GI on conservation policies, “well-functioning ecosystem” could be used as an indicator, as proposed in the GRETA socio-ecological system for GI implementation (refer to Annex II-A). Having healthy functioning ecosystems is crucial to sustaining biodiversity, to ensuring the resilience of ecosystems, and finally to delivering ES. Ecosystem functions will be primarily affected by the amount of available habitat for species and for correct nutrient cycling, factors which will have a more or less continuous impact on the system. The removal of pollutants from water and the connectivity between habitats will also have an important impact that will increase over time. On the other hand, the dispersal of invasive alien species and the quantity of pollutants in the air will decrease ecosystem well-functioning, and these should therefore be priority areas for actions. In the framework of GRETA, three main policy domains that are relevant at the EU level were selected: Biodiversity, Climate Change and Disaster Risk Reduction, and Water Management.

EU environmental and policy area	Possible conflicts
Climate change	No conflicts in general. Carbon sequestration measures can affect biodiversity.
Biodiversity	No conflicts in general.
Water	No conflict in general.
Energy	Securing energy supply (by building gas pipelines, gridlines, new power plants) can damage habitat connectivity and decrease areas of GI. Solid biomass can contribute to the area of woodland and other natural ecosystems but also decrease biodiversity in those places.
Transport	Ensuring connectivity. Implementation of large transport networks.
Agriculture/Forestry	Improving agricultural productivity. Potential conflict with agricultural intensification and intense forestry management.
Cohesion	Improving network infrastructure.

Table 2 Overview of different EU policy domains and where benefits or conflicts may arise

The selection of the three policies was done according to multiple criteria:

- From the policy perspective, the conservation and enhancement of natural capital is one of the priorities of the 7th Environmental Action Programme. Moreover, climate change is one of the greatest challenges faced at present which is also linked to water management, as it is critical for human well-being and many economic activities.
- Findings from responses to a questionnaire performed across 32 ESPON countries (refer to Section 8 and Annex IV) indicated that the selected policy frameworks are among those that include principles important for GI and reinforce the policy priorities.
- From the perspective of how natural systems function, Schleyer et al. (2015) recognised that these three policy areas are among those that most benefit from operationalising the concept of ES, i.e. that most benefit from the adoption of systematic and integrative strategies to include ES in their operational setting.

It should be noted that within the climate change domain, the proposed approach undertaken in the GRETA project accounts for current conditions (capacity to provide different ES), i.e. how climate change will impact GI delineated today in the future is not considered. This is out of the scope of the project and requires local information and knowledge to be integrated.

The terms “regulatory frameworks” and “policies” are used interchangeably in this report, as both are encompassing concepts to denote different policy measures applied at EU and member state (MS) level, such as directives, communications, and strategies. The results from the geographical overview of GI and ES described in Section 3 of this report will help to understand in which European regions the objectives of these policy frameworks can be attained; this can be done through a common potential GI network assessed at landscape level, where the objectives are maximised for all policies and where the current conditions of potential GI elements are insufficient to support them.

3 The geographic distribution of the potential GI in European regions (NUTS2/3)

3.1 How potential GI in Europe was mapped

The GRETA project uses a novel methodological approach to map the geographical distribution of potential GI networks and assess their capacity to deliver ES contributing to the implementation of objectives defined in the three policy sectors introduced in Section 1. The approach is based on the combination of a Physical Mapping (PM) framework (also commonly referred to as ‘top-down’ framework), which was proposed by EC (2010) and applied by authors including Estreguil et al. (2014), with an Ecosystem Service Mapping (ESM) framework for GI (also commonly referred to as a ‘bottom-up’ framework), which was envisaged by authors including the EEA (2014), Maes, Barbosa et al. (2015) and de la Fuente et al. (2018).

Issues regarding spatial coverage: **Physical Mapping**

The Natura 2000 (N2K) network stems from the Birds and Habitats Directives and, accordingly, only the EU-28 MS have designated these areas. To mitigate the limited geographical coverage of GI ‘hubs’, the sites of the Emerald Network[10] officially designated for Switzerland and six West Balkan countries (i.e. Macedonia, Montenegro, Serbia, Albania, Bosnia and Herzegovina, and Kosovo) were included. It was decided not to include protected areas designated at the national level in order to avoid biasing the distribution of GI across Europe due to differences in the national policies designating such sites.

***Issues regarding spatial coverage*: Functional Mapping**

ES maps from Maes, Fabrega et al. (2015) act as a EU reference for measuring Target 2 in the Biodiversity Strategy 2020 (EC, 2011). Therefore, the geographical extent of the Maes, Fabrega et al.’s (2015) assessment is also the EU-28 countries. Given that most of these ES maps are derived through modelling approaches (Maes, Fabrega et al., 2015), maps of the same ES that are produced by different institutions may have large biases and are recommended not to be used together (Schulp et al 2014). Therefore, to avoid dissimilarities in the final results that are due to different input data characteristics, it was decided to perform a multifunctionality analysis of GI network only for EU-28 countries. Moreover, this provides consistency to the results and avoids mismatches with the outcomes from other EU level projects that base their analysis on the standard ES maps of Maes, Fabrega et al. (2015).

Figure 5 illustrates the input datasets and the combination of the 2-step methodological approach to potential GI assessment at the landscape level, i.e. outside the Functional Urban Areas (FUA, refer to glossary of terms for a definition). The example case illustrated in Figure 5 focuses on GI addressing climate change challenges and is split into three major panels that relate to the proposed methodological steps (Figure 5.A and B), and the integration of their results into a final map describing the capacity of the GI network to support a specific policy framework (Figure 5.C). The maps in the figure are snapshots from the original input datasets and from map outputs of the spatial analyses used to perform the PM (Figure 5. A) and the ESM (Figure 5.B), as well as from the integration of these two intermediary outcomes to derive a final potential GI network (Figure 5.C). Further details on input datasets are provided in Annex I-A and I-B, and the methodology is fully described in Annex I-C.

The PM framework (Figure 5.A) uses the Natura2000 (N2K) and the officially designated Emerald network sites as the potential GI ‘hubs’ that need to be connected with the wider landscape; all natural and semi-natural areas connected along the wider landscape can be used as potential GI network connectors, i.e. ‘links’, provided that they bridge together two or more ‘hubs’. Figure 5 illustrates the connectivity concept between ‘hubs’ and ‘links’ that establishes the final physical structure of a

---

[10] The Emerald Network is an ecological network made up of Areas of Special Conservation Interest. Its implementation was launched by the Council of Europe as part of its work under the Bern Convention, with the adoption of Recommendation No. 16 (1989) of the Standing Committee to the Bern Convention.The European Union, as such, is also a Contracting Party to the Bern Convention. In order to fulfil its obligations arising from the Convention, particularly in respect of habitat protection, it produced the Habitats Directive in 1992, and subsequently set up the Natura 2000 network. The Natura 2000 sites are therefore considered as the contribution from the EU member States to the Emerald Network.

potential GI network at landscape level, i.e. outside the FUA. In this diagrammed example, ‘Hub 1’ and ‘Hub 2’, connected by ‘Link 2’, are conceptually part of the final potential GI network, whereas ‘Link 1’ and ‘Link 3’, as well as ‘Hub 3’ would not be included in the network. See Annex I-C for the criteria used for selecting landscape elements to be included as part of the potential GI network at the landscape level.

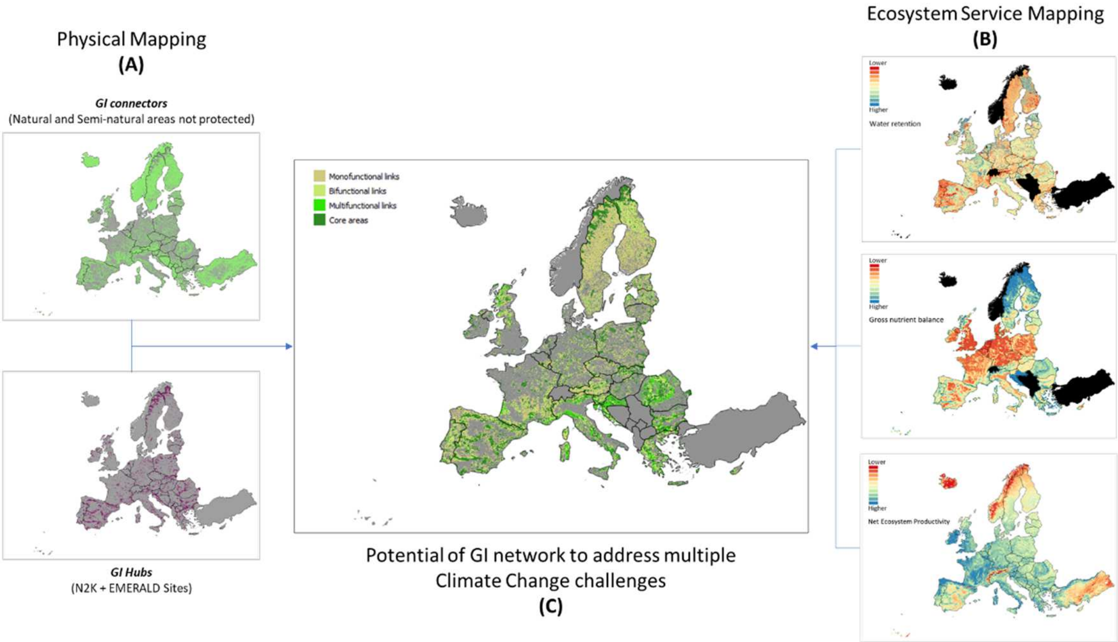


Figure 5 Illustration of the framework used to map potential GI at the landscape level addressing multiple climate change challenges. No data values are represented by grey and black colours in the maps.

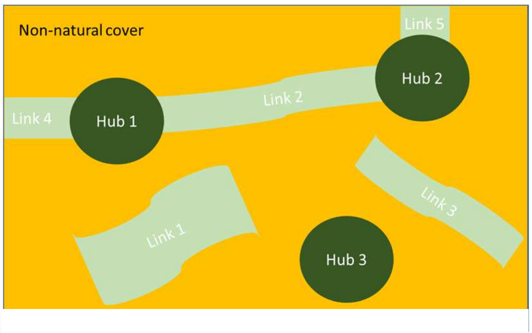


Figure 6 Illustration of connected ‘hubs’ and ‘links’ in the wider landscape.

The ESM framework (Figure 5.B) aims to evaluate the ability of the natural and semi-natural ecosystems to provide multiple benefits that support the implementation of one or several objectives defined by a specific policy framework. The potential GI benefits are relative and estimated at each geographical area by counting the number of ES that perform above the median of the combined EU-28 countries. In Figure 5.B, the ES specifically address the potential of GI to support multiple climate change challenges at the EU level (specifically flood protection, mitigation of nitrogenous gases emissions, and carbon sequestration). The framework can also be applied to other policy objectives (i.e. biodiversity and water management) that could be addressed through the selection and analysis of other ES indicators. As illustrated with the example in Figure 5.C, the overlapping ES indicators will result in the following categorisations:

- monofunctional – the potential GI in a specific place will outstand for one single ES. The capability to provide a specific ES is a continuum from the minimum (or no provision at all), to its maximum. Being monofunctional implies that there is only on ES that could be provided near to its maximum, and the capability to provide another ES is low. In practical terms requires to identify if it is possible to enhance other ES by different management options;

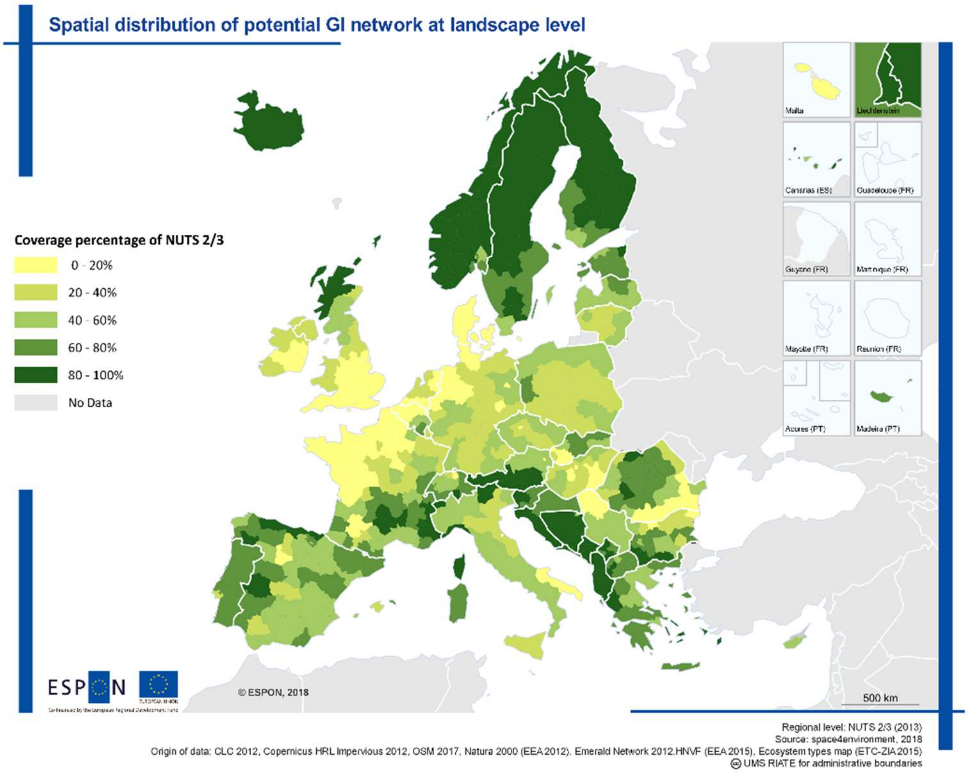
- bifunctional – the potential GI in a specific place can have a high performance providing two ES. There are lower capabilities to provide the other ESs analysed.;
- multifunctional – this is the optimum situation since the potential GI in a specific place has the highest capabilities to provide different ES (three or more);
- core area –potential network ‘Hub’. Landscape elements not considered in the PM are excluded from the potential GI network, whereas the ‘links’ and ‘hubs’ included are characterised according to categories defined during the ESM framework.

The resulting categories identify the geographical regions where potential GI at the landscape level is likely to support the objectives of one or multiple policy frameworks. The functional categories refer to the number of policies that are served by the GI network and the number of ES that are above the European median in each geographical region (see Subsection 3.3 for full details on the classification). To provide an overview of the geographical distribution of potential GI in European regions, a set of nine statistical indicators were derived at NUTS 2/3 level. Summary indicators of potential GI characteristics are mainly derived from the sum or majority of the landscape level GI maps produced at a higher spatial resolution, i.e. pixel level at 100x100m (see Annex I-C for illustrations of full resolution GI maps). The proposed indicators of physical and functional GI characteristics are described in the maps presented in subsections 3.2 and 3.3 (Maps 1-9); their analyses aim to provide insight into a relevant policy question, which is used as a heading for the discussion on the results.

3.2 The physical characteristics of potential GI in Europe

Where is potential GI?

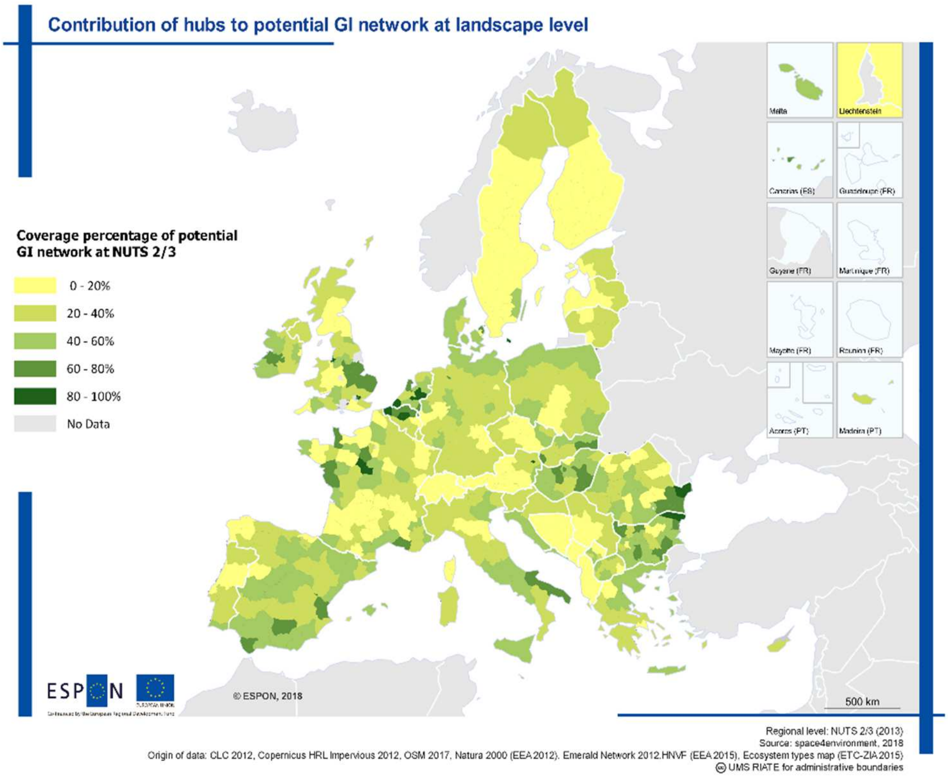
The indicator presented in Map 1 depicts the spatial distribution of the potential GI network across European NUTS 2/3 regions. It is computed as the share of the total GI network within each NUTS 2/3. Potential GI is lower for the regions in north-western France and Germany, south-eastern UK and Ireland, and Denmark. The coverage of potential GI is higher for Nordic countries, the Balkan countries along the Adriatic Sea and the eastern Alpine region. This pattern clearly reflects the population density, infrastructure development, climatic and topographic conditions, as well as the distribution of utilised agricultural areas in the EU territory.



Map 1. Spatial distribution of potential GI network at the landscape level.

What is the contribution of protected areas to potential GI?

Contribution of protected areas to potential GI = percentage of protected areas classified as GI in the GRETA context



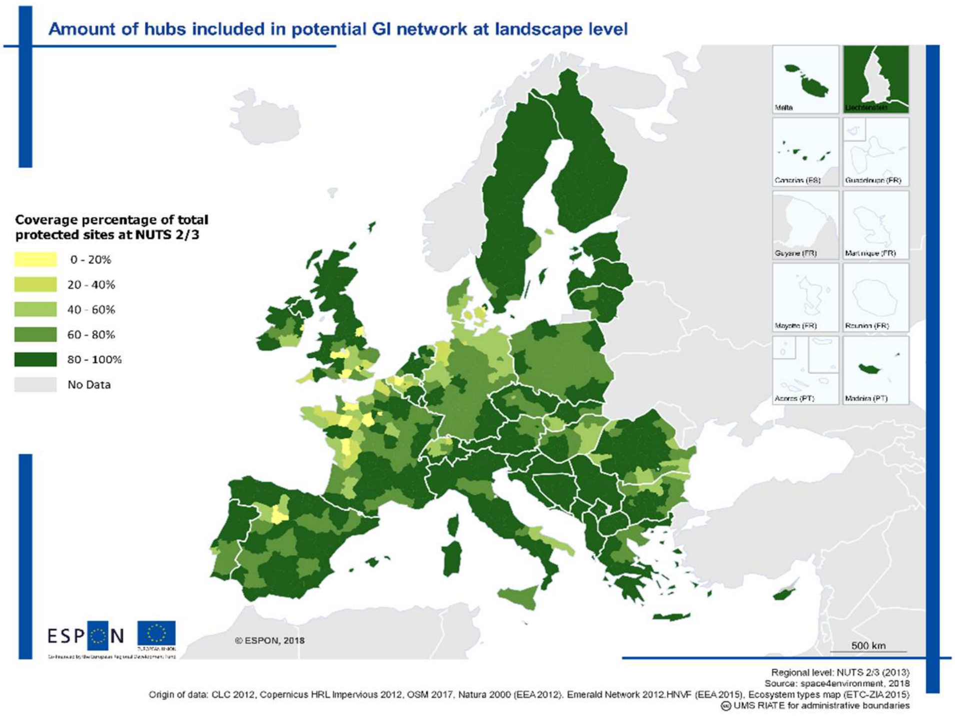
Map 2 Contribution of protected 'hubs' to the total area of potential GI network at landscape level.

Map 2 presents an indicator that is computed as the share of the potential GI network covered by protected areas (i.e. European Protected sites, namely N2K and Emerald sites) in each NUTS 2/3 region. On average, the proportion of protected areas in the potential GI network is below 40% for the majority of NUTS 2/3 across the EU. The Nordic countries, the Balkan countries along the Adriatic Sea, and the eastern Alpine region are among those with the lowest contribution of protected 'hubs' to the total area of potential GI. This outcome mainly reflects the differences in the number and extension of protected sites between N2K and Emerald networks, which is lower for the later. Moreover, it is also perceptible that non-protected natural and semi-natural areas have a larger contribution to the total GI network across Europe than the protected areas.

Where is potential GI not connecting protected areas?

Potential GI not connecting protected areas = Percentage of total protected areas that are not classified as GI.

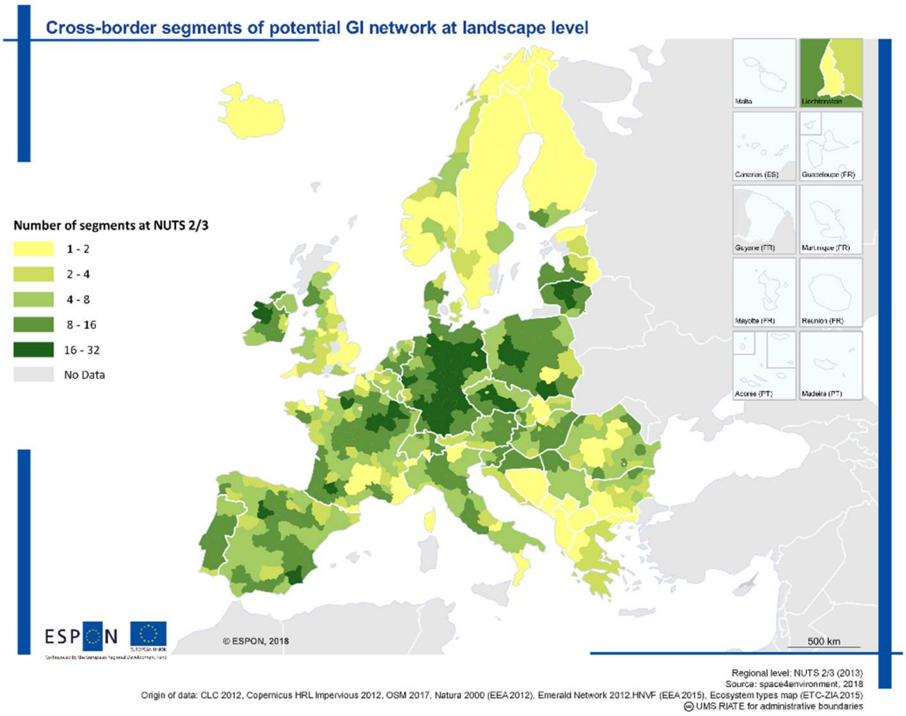
The indicator presented in Map 3 is computed as the share of protected areas that were mapped as part of the potential GI network within each NUTS 2/3 region. On average, more than 60% of protected areas are connected by a potential GI network at the regional level. Exceptions to this general pattern occur mainly in north-western France and south-eastern UK. Fragmentation of natural areas by urbanisation and agricultural expansion are the main factors obstructing protected areas from being connected in these regions.



Map 3 Total amount of hubs (i.e. European Protected sites) connected in potential GI network at landscape level.

Where is landscape fragmentation an issue to potential GI?

Landscape fragmentation = Number of disconnected cross-border GI elements.



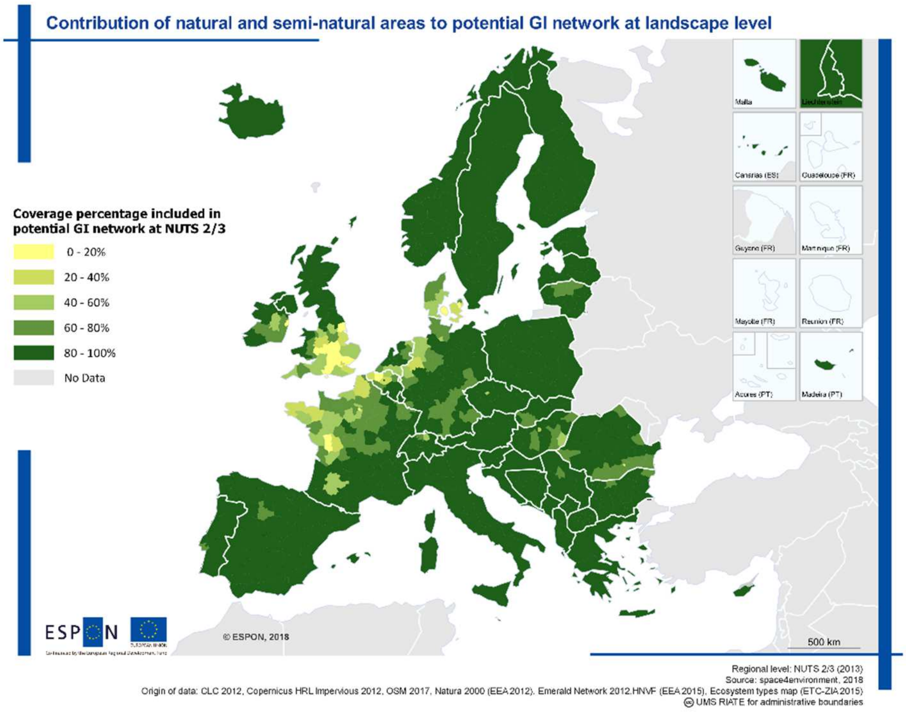
Map 4 Cross-border segments of potential GI network at landscape level.

The indicator in Map 4 shows the number of elements within the potential GI network that cross the borders of NUTS 2/3 regions. It is computed for each region as the sum of disconnected GI elements that cross its border. The presence of singular and continuous network elements is perceptible in the West Balkan countries along the Adriatic Sea as well as in Nordic countries. On the other hand, Central European countries, and mainly Germany, have the NUTS 2/3 regions with the highest number of cross-border GI segments. This is mainly due to high levels of industrialisation, and the lack of major topographical obstacles against the construction of transportation infrastructure explains this high level of landscape fragmentation.

How many natural and semi-natural areas can be used as potential GI?

Natural and semi-natural areas used as potential GI = percentage of natural and semi-natural areas classified as GI.

Map 5 presents an indicator that is computed as the share of natural and semi-natural areas used as potential GI ‘links’ in each NUTS 2/3. On average, and with the exception of north-western France and Germany, south-eastern UK and Ireland, and Denmark, more than 80% of natural and semi-natural areas in EU regions are serving as ‘links’ between protected sites.

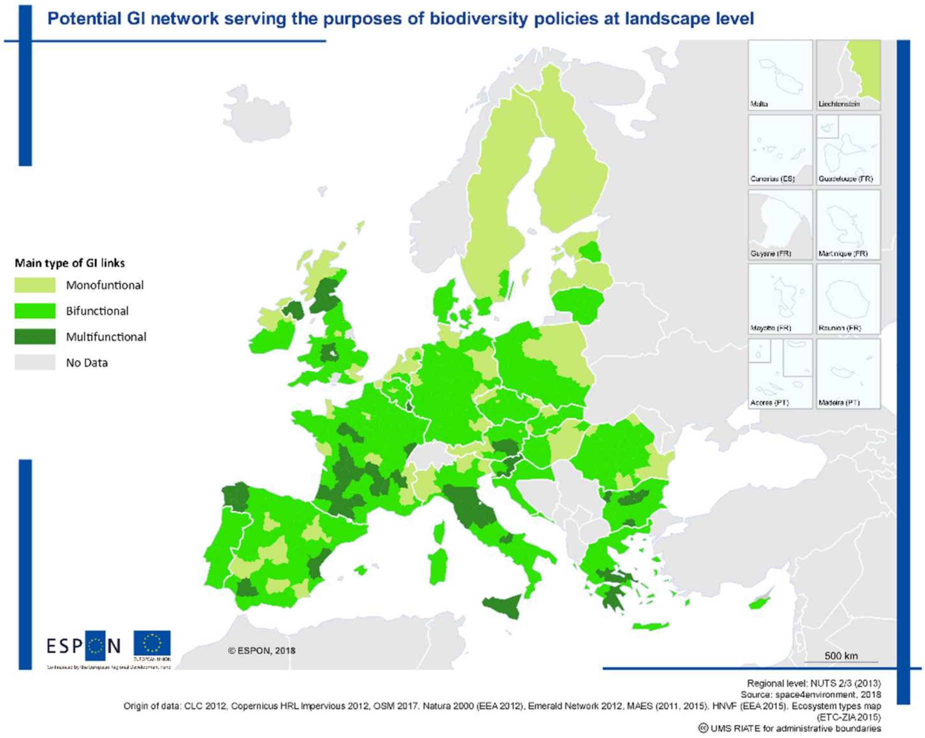


Map 5 Percentage of natural and semi-natural areas used as potential GI 'links' at landscape level.

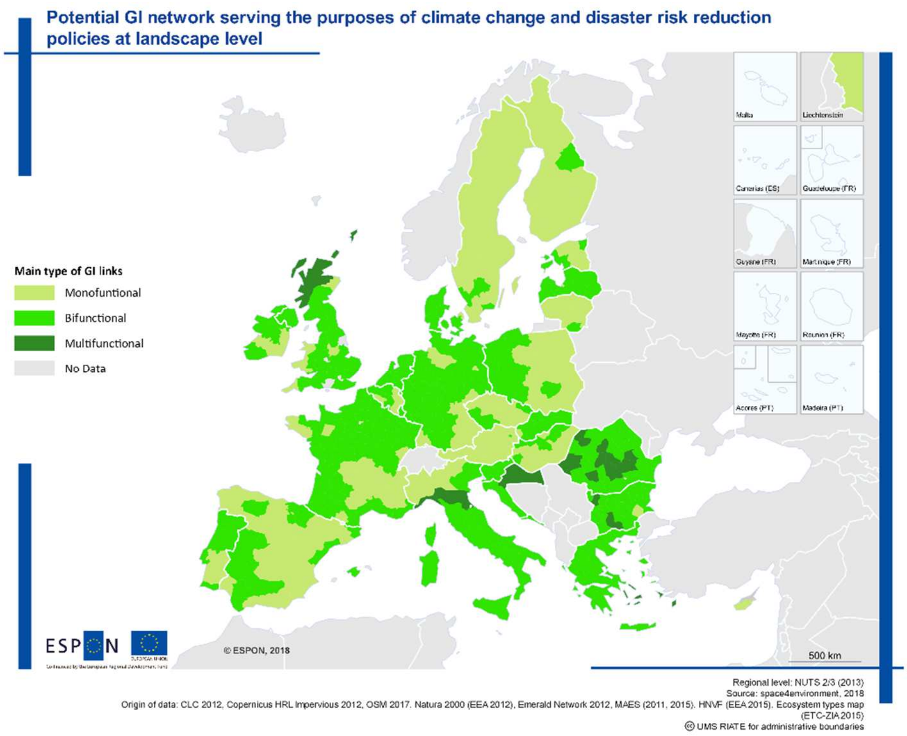
3.3 The functional performance of potential GI

Maps 6 to 9 summarise the functional performance of potential GI at the landscape level for individual policy frameworks (i.e. Biodiversity, Climate Change and Disaster Risk Reduction (CC&DRR), and Water Management), as well as for three policies considered simultaneously. As these maps were originally produced at 1ha spatial resolution (see full methodological description in Annex I-C), the indicator values at NUTS 2/3 level result from a regional aggregation using the statistical mode, i.e. the most commonly occurring value in the respective NUTS 2/3 region.

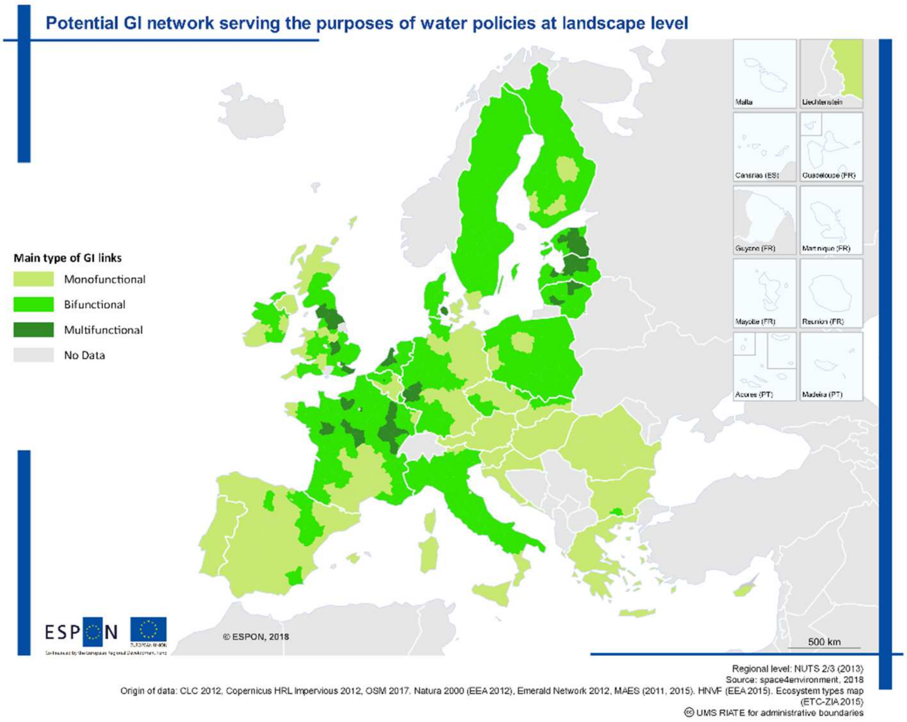
Based on the joint analysis of Maps 6, 7 and 8, it is possible to highlight the spatial differences in the multifunctional patterns of potential GI for the different policies. The first remark is that regions characterised by multifunctional links are few and scattered across European regions for all policy frameworks. This result is mainly due to the fact that ES differ across ecosystem types and these vary across the European regions, thus limiting the number of areas supplying all ES together. As GI multifunctionality depends on the capacity of the ecosystems to provide different ES and the types of ES that are of interest for the purpose of implementing a specific policy, then the potential GI in the same geographical area can be different for different objectives. This is the case for example in the Seville region in Spain. Potential GI is multifunctional regarding biodiversity but is bifunctional and monofunctional regarding CC&DRR and water management policies, respectively.



Map 6 Potential GI network serving the purposes of biodiversity policies at landscape level.



Map 7 Potential GI network serving the purposes of CC&DRR policies at landscape level.



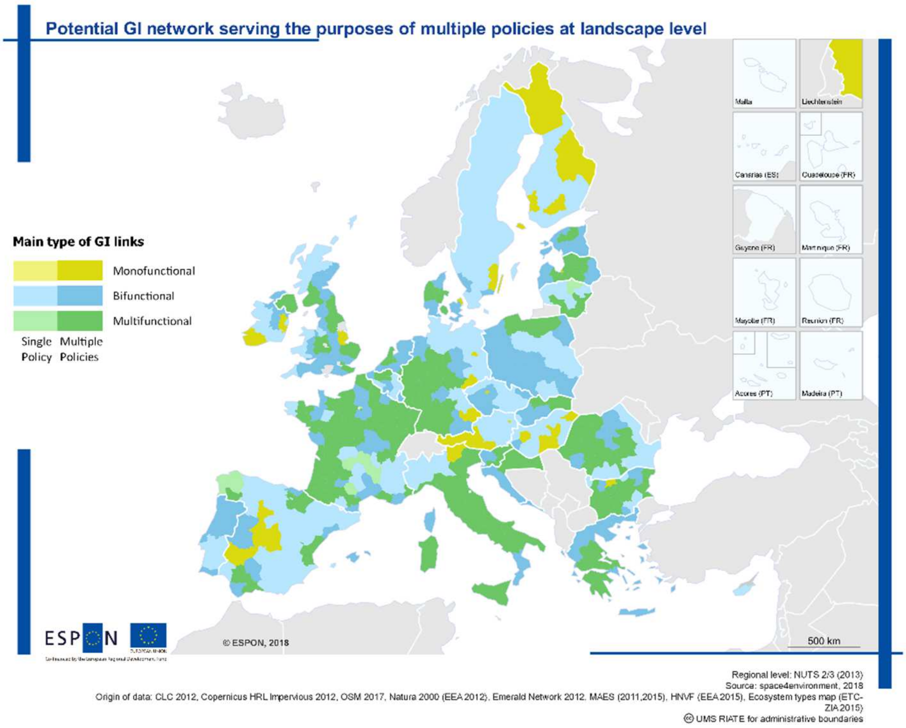
Map 8 Potential GI network serving the purposes of water policies at landscape level.

The type of relationship between pairs of ES detailed in Section 7 complements the understanding of these results. For example, if synergies are predominant (i.e. improving one ES also benefits another ES), then the region would be bi- or multifunctional. On the other hand, when trade-offs are present then GI would tend to be monofunctional. Although it is not possible to do an individual analysis for each EU region, Sicily can be considered as a specific example. The potential GI is dominated by protected areas (i.e. 'hubs'), as compared to the surface constituted by natural and semi-natural 'links'. With regards to the 'links', the network is multifunctional from the biodiversity perspective (Map 6), bifunctional for CC&DRR (Map 7) and monofunctional from the water management perspective (Map 8). Although it provides good conditions for biodiversity maintenance, for CC&DRR the water retention index is low and thus reduces the capacity for floods and droughts to be avoided, and for water management the capacity of ecosystems to purify water and for nutrient retention is also low on average. Thus, from a planning perspective, it would be sensible to improve soil conditions and restore its capacity in order to supply better ES.

Map 9 shows the summary indicator of the potential GI serving the purposes of multiple policy frameworks. The amount of services delivered simultaneously by GI and the number of policies benefiting from it are considerably higher in Central European regions, as compared to North-eastern and South-western regions. ES provided by GI in most Italian regions, central Germany and northern France are serving multiple objectives for biodiversity, climate, and water policies (dark green regions). To a similar extent, only a few regions in Romania, Bulgaria and Greece display GI with comparable characteristics. This information reveals potential opportunities for increasing cross-sectoral cooperation between those sectors and stakeholders to work together to achieve their respective objectives.

In contrast, the GI for Alpine, Boreal and Eastern Continental regions, as well as most of the Iberian Peninsula is providing bundles of two ES that mainly benefit a single policy (light blue regions). For example, regions in Northern Spain are mostly covered by forests that address climate change through carbon storage and protection against soil erosion. Regions in Nordic countries, where open water and wetlands predominate, are evidently important providers of water regulating services. A few exceptions to this pattern occur only in the North of Portugal and Western Poland regions (dark blue regions), where bifunctional bundles serve the aims of two or more policies. Differences in the type and amount of services provided by GI are due to both biophysical drivers (e.g. geology and climate) and land management practices, such as agriculture, forestry and urbanisation, which define the distribution and condition of natural ecosystems across Europe.

Finally, the presence of European regions characterised by monofunctional GI serving multiple policies (dark yellow regions) is more scattered, less prominent and displayed only in the Eastern Alps, Central Spain and Northern Finland. Although there is only a single ES performing well above the European median for these regions, it is evident that it benefits the implementation of objectives for different policies. For example, in the Lapland region, ecosystems are characterised by having a high-water retention capacity and can support objectives of both climate and water policies.



Map 9 Potential GI network serving the purposes of multiple policies (biodiversity, CC&DRR, water) at landscape level.

4 The geographic distribution of potential GI in European cities

4.1 Assessment of urban GI

The assessment of urban GI includes all available green and blue areas (i.e. whatever is 'green' – and 'blue' in this case - will be part of the urban GI network; refer to GI definition in Glossary of Terms and Annex I-F). The most relevant land cover/land use (LC/LU) data set for this analysis in cities and their immediate hinterland (peri-urban space) is the Urban Atlas layer provided by the European Copernicus programme. The Urban Atlas spatial data complement the city statistics collected by Eurostat in the framework of the Urban Audit programme. In the Urban Audit, cities are represented at three spatial levels (EC and UN-Habitat, 2016):

- The ***core city*** is a local administrative unit (LAU) in which the majority of the population lives in an urban centre of at least 50,000 inhabitants.
- The ***Functional Urban Area (FUA)*** adds the commuting zone to the city.
- The ***Greater city*** approximates the urban centre when this stretches far beyond the administrative city boundaries.

The Urban Atlas maps the FUAs of almost 700 cities or city agglomerations across Europe (list of FUAs and core cities are included in Annex I). The core city is, for the most part, a subset of the FUA in which it is located. To reflect the green (and blue) urban areas, all Urban Atlas classes that represent green and blue urban areas are aggregated into one class of "green urban areas (GUA)" and their proportion in relation to the total area of the reference units is calculated.

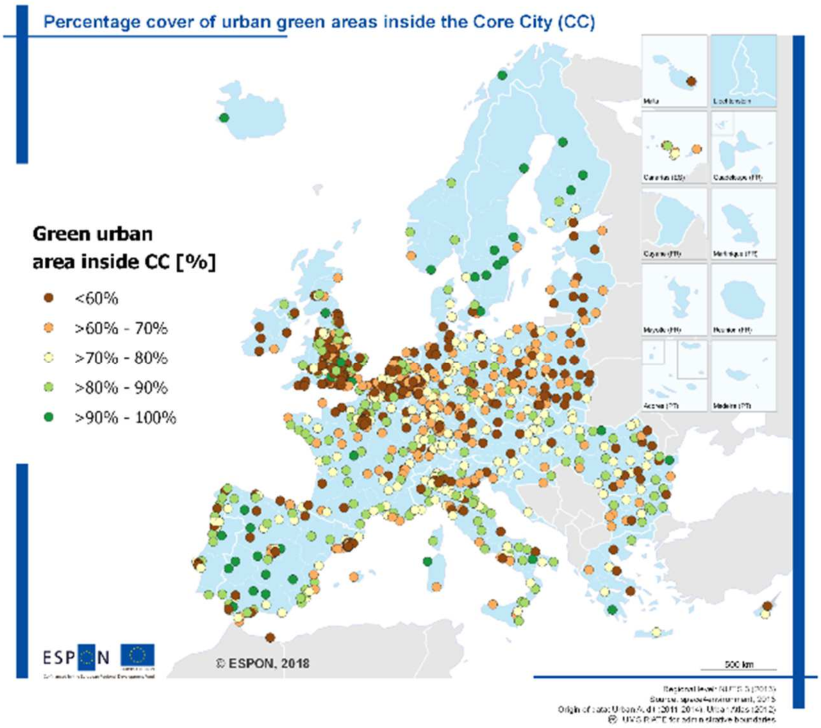
Hence, to provide an overview on the status of urban GI, the following parameters and indicators were calculated and mapped:

- Share of GUA within (i) the core city (representing the city level); (ii) the entire FUA (representing the entire reference unit); and (iii) the FUA without the core city (representing the peri-urban space alone; all values in [%]); and
- Ratio of GUA juxtaposing the share of GUA inside the core city and the share of GUA inside the entire FUA (unitless ratio).

***Issues regarding spatial coverage*:** At the city level, the Urban Atlas is the main source of information for the indicators informing about GI. The Urban Atlas is a EU product that in its first version in 2006 mapped cities in the EU-27 territory. In the newest Urban Atlas (reference year 2012), EU-28 and the four European Free Trade Association (EFTA) countries Iceland, Norway, Switzerland and Liechtenstein, i.e. the entire ESPON space, are covered. Consequently, 32 countries can be analysed for the reference year 2012 whereas cities from 27 (EU-27) will be assessed regarding changes.

Map 10 shows the share of green (and blue) urban areas for all core cities in Europe. It becomes clear that many European cities (including their commuting zones) are relatively green, many possessing more than 80 % green areas (the mean being 84.8 % and the median being 88.3 %; see descriptive statistics of all indicators in Table 4). Considering the maps of the share of GUA in the FUAs and the FUAs without their respective core cities, it becomes obvious (as expected) that the share of green spaces increases when moving away from the core city, i.e. the more built-up city parts, to the FUA (still including the core city) and finally to the peri-urban space alone (see Annex I-D, Map 2). For the peri-urban area, the mean and median are both greater than 90 % with almost 550 cities having a share of GUA above 80 %. It needs to be considered, however, that for more than 100 cities the FUA is identical to the core city, so this map contains less cities than the previous two maps.

In terms of distribution of values, there is a concentration of core cities with lower values in a corridor from the UK, over the Benelux countries, Germany, and the north-eastern part of Europe (Poland and the Baltic countries). Other clusters of low values are visible in northern Italy and Romania. The highest values are recorded in Spain and the Scandinavian countries. Analysing the distribution of values inside the FUAs and the FUAs without core cities (see Annex I-D, Maps 1 and 2), the only clusters of regions in which values below 70 % are visible are located in the UK (the large majority of cities with the lowest values are located in the UK), a stretch from western Germany into the Netherlands, and the Baltic countries.

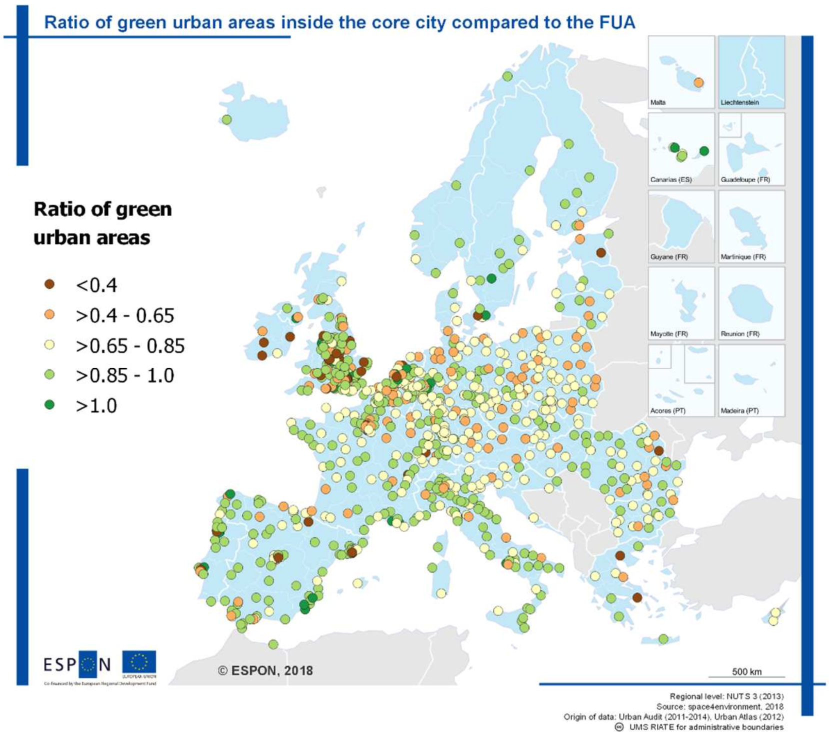


Map 10 Share of green urban areas inside the core city

Indicator	Max [%]	Min [%]	Mean [%]	Median [%]
Share of GUA (FUA)	99.3 (Tromsø, NO)	19.1 (Luton, UK)	84.8	88.3
Share of GUA (core city)	98.9 (Tromsø, NO)	1.6 (City of London, UK)	64.1	66.9
Share of GUA (FUA without core city)	99.4 (Reykjavík, IS; Tromsø, NO)	41.8 (Dordrecht, NL)	90.1	91.8

Table 3 Descriptive statistics of the 3 urban indicators

In addition to the share of green (and blue) urban areas, the ratio between the share of GUA inside the core city and the share of GUA inside the FUAs has been calculated (see Map 11) to enable the importance of the urban hinterland for providing green spaces to be analysed. A value of 1.0 would mean that both core city and FUA have the same share of GUA, values below 1.0 indicate a dominance of the peri-urban, and values above 1.0 mean that there are more green spaces in the core city than the peri-urban space. The mean value of 0.77 together with the minimum of 0.02 (London City), a maximum of 1.27 (St. Helens, UK) and with only around 30 cities that have values above 1.0 clearly point towards the rather unsurprising fact that European cities in general have more green spaces in their surroundings than inside of them. For around 100 cities, core city values equal the FUA values, so there is no difference between the them. The cities with values over 1 are distributed across several European countries, but most of them come from the UK or Spain.

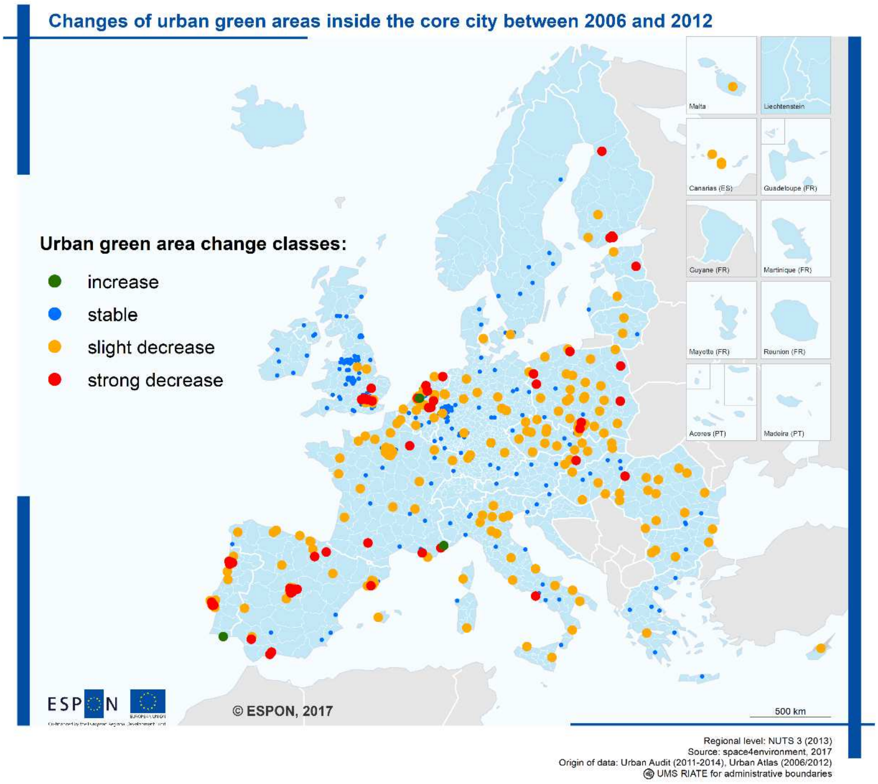


Map 11 Ratio between GUA inside the core city and the FUA

4.2 Changes in urban GI over time: analysis of the time period 2006-2012

The limitations regarding available data on land use and ES represent a huge constraint to providing information on the change/development of GI and ES at the landscape level over the past years (particularly concerning functional GI). While it would be possible to calculate changes in the physical GI structure, the ES data are only available for one reference year. Hence, this would only reflect one part of the picture and as a consequence provide incomplete information.

However, on the urban level, a physical mapping of GI is available and can be used to compute changes in the share of GUAs. The Urban Atlas layer that serves as the basis of the map has been produced for the two reference years 2006 and 2012 for around 500 cities. Map 12 illustrates the changes in the share of urban green spaces between 2006 and 2012. Blue dots represent core cities in which the share remained rather stable (i.e. a change of less than 0.5 % in a positive or negative direction). Orange and red dots indicate cities that experienced a decline in green spaces of more than 0.5 %, subdivided into slight decrease (0.5 to 2 %) and strong decrease (over 2 %), while green dots show cities with an increase of more than 0.5 %.



Map 12 Changes of urban green areas inside the core city between 2006 and 2012

As a general pattern, it can be observed that cities with stable or decreasing green spaces dominate the map, confirmed by a mean value of -0.83 % points. While a stable situation is more prevailing in central and north-western Europe (in particular Belgium, Germany and the UK, but also in the Alpine countries), a large proportion of decreasing green spaces can be observed in eastern and southern European countries, as well as in the Netherlands and Finland. Pamplona (-7.8 %) and Getafe (-7.6 %) from Spain are the two cities with the greatest decrease in urban green spaces, followed by Communauté d'agglomération de Sophia Antipolis in France (also -7.6 %). Only three cities show an increase in urban green spaces: Faro (Portugal, 3.3 %), Nice (France, 2.3 %) and Capelle aan den Ijssel (the Netherlands, 0.7 %). In eastern and southern European countries, the most likely reason for a decline in urban green areas are urbanisation processes due to the economic development after the countries joined the EU (eastern Europe) or for touristic purposes (southern Europe).

The urban case studies of the GRETA project will be used to illustrate some of the results. Alba Iulia in Romania shows a slight decrease in urban GI which could be linked to the increasing pressure on the Mureș river floodplain in which conflicts arise between urban infrastructure and agricultural use. This situation also limits the capacity of the area to support water-related policies, such as flood prevention or erosion control. Proper planning of the highly urbanised and agriculturally used floodplain would also allow the natural areas in the west and east of the city to be connected. The city of Hämeenlinna and its surrounding region in Finland has extensive GI coverage, whereby the urbanised axis formed by Tampere-Hämeenlinna-Riihimäki threatens to disconnect the GI. Hämeenlinna does not appear in the Urban Atlas data, but the closest Finnish cities Tampere and Helsinki, both show decreasing urban GI trends (Helsinki more so than Tampere). Multilevel governance has been put in place in Hämeenlinna to counteract the danger of disconnecting GI patches, the National Urban Park being one example. The last urban case study, Valencia in Spain, shows a stable share of urban GI, although the city faces the challenge to ensure that GI is connected between urban, peri-urban and rural landscapes, which is threatened by the intensively used coastal plains that could possibly isolate the GI patches located in the hillier hinterland. Integrating the blue areas might help to create a strong connection between the various protected areas (i.e. hubs) in the city surroundings.

Another striking example is Lisbon and its metropolitan area. Lisbon is not one of the GRETA case studies, but it is a city that has understood that there are significant benefits to improving and restoring GI elements within the confines of the metropolitan area. The trend between 2006 and 2012 is slightly negative, that is, urban GI has decreased. However, the city council has, together with partners, embarked on a programme defining a strategy for biodiversity in Lisbon for 2010-2020. This strategy was put in practice by a Local Action Plan that defines clear actions and approaches to reach the goals (Maes et al. 2016). In addition, Lisbon took part in the City Biodiversity Index[11], the MAES urban pilot (Maes et al. 2016) (together with Cascais and Oeiras which are located in the Lisbon metropolitan area) and acted as a city lab during the EnRoute project[12] (Maes et al. 2019). Although more recent data is not available from the Urban Atlas, one can assume that the share of urban GI might already have increased as a result of focussed and well-conceived spatial planning and local decision-making. Finally, the city was rewarded for its efforts by being selected as the European Green Capital for the year 2020[13].

It is important to mention however, that these assessments are purely based on European-wide spatial data that do not take into account single or small-scale local measures, such as green roofs, walls or green strips along roads. The reason for this is that these European datasets are based on remote sensing data with a specific spatial resolution (2.5 m pixel size in this case) Hence, smaller objects, in particular vertically oriented ones, cannot be mapped by the product. Therefore, only larger changes from green into non-green or vice versa are included in the maps, e.g. conversion from agricultural surface into residential or re-greening of old industrial sites by converting them into urban parks or recreational zones. Consequently, it is very difficult, if not impossible, to assess the effects of GI policies within urban areas today. In addition, the analysis of changes in the peri-urban space is aggravated by the fact that the delineation of the Urban Audit / Urban Atlas cities is purely administrative, and there is no guarantee that all relevant peri-urban surfaces are included. In that regard, the EEA[14]'s Urban Green Infrastructure web map viewer offers information on peri-urban GI and hotspots (i.e. touching points between green and built-up spaces) in a 50 km radius around the centre point of the core city. For decision-making purposes, the hotspot indicator is particularly relevant as it gives an indication of where action might be required or would be of highest value in

[11] https://www.cbd.int/subnational/partners-and-initiatives/city-biodiversity-index
[12] https://ec.europa.eu/jrc/en/publication/enhancing-resilience-urban-ecosystems-through-green-infrastructure-enroute.
[13] http://ec.europa.eu/environment/europeangreencapital/winning-cities/2020-lisbon/
[14] https://eea.maps.arcgis.com/apps/MapSeries/index.html?appid=42bf8cc04ebd49908534efde04c4eec8%20&embed=true

order to protect green spaces from disappearing and to preserve the health and well-being of citizens. Further research could attempt to analyse the location of such hotspots in GI hubs or links on the landscape level, and therefore provide further insight for spatial planners.

5 How do European regions fare in meeting the existing demand for regulating, provisioning and cultural services offered by GI

In this section GRETA explores the capacity of the GI network to meet the demand for ES.

In this study, GRETA has followed on from Burkhard and Maes (2017) where **ES supply** is defined as the capacity of ecosystems to provide ES, irrespective of whether they are used. **ES flow** refers to the actual level of use in a specific area and time. This includes a dynamic temporal dimension which is therefore not being assessed in this work. Complementarily, **demand for ES** can be defined as the amount of a service required or desired by society (Villamagna et al., 2013) in a given location and time. This demand is directly influenced by a number of factors from the socio-ecological system through complex relationships (refer to GRETA SES in Section 1 for further details). ES demand depends on several factors such as socio-economic conditions, cultural/behavioural norms, technological innovations, and availability of alternatives, among others.

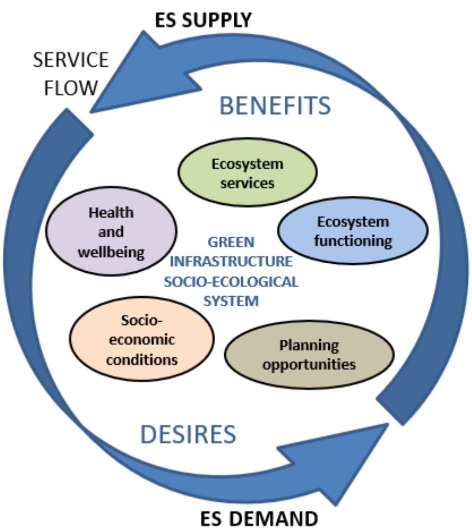


Figure 7 Conceptual framework linking GRETA GI SES and ES supply, flow and demand

The ES demand is also driven by individual needs, beneficiaries' awareness, and opportunity cost (Schröter et al., 2014). However, though demand indicates the desire of people to actively benefit from a service, other external factors (such as restricted accessibility and limited time for resource availability) may prevent people from receiving them (Wolff et al., 2015). Therefore, the following conceptual framework that links the main components of a GI SES with ES supply and demand (Figure 7).

ES supply directly depends on the ecosystem functioning that provides benefits through several ES that may be used through ES flow. On the other hand, ES demand is directly influenced by health and well-being factors and socio-economic conditions that will be translated into desires. Different approaches have been used in the operationalisation of ES demand, which mainly depend on the type of service and the related mechanisms to obtain benefits. These will be addressed by existing planning opportunities.

	ES Supply – benefits provided	ES Demand – specific definitions	Approaches to quantify Demand
Regulating services	Benefits are provided by maintaining desirable environmental conditions	Amount of regulation needed to meet target conditions	Reduction of risk
Cultural services	Benefits are provided by experiencing the natural environment	Desired total use (if rival service) or individual use (if non-rival service)	Preference and values / direct use
Provisioning services	Benefits are derived from consumption of final goods	Amount of goods obtained per unit of space and time or per capita	Direct use / Consumption

Table 4 Relation between benefits provided by ES supply and the corresponding ES demand definitions and operationalisation approaches. Adapted from: Villamagna et al., 2013 and Wolff et al., 2015.

Demand for **regulating services** can be defined as the amount of environmental conditions that ensure the provision of a desired regulation level. A risk reduction approach is usually applied to quantify demands for these services. Vulnerability to potential changes in regulating services may provide valuable insight into society's needs capturing main linkages from the SES.

Demand for **cultural services** has been mostly assessed by preferences and values for attributes of certain landscapes, ecosystems or heritage sites (Wolff et al., 2015). Preferences may be either quantified through stated preferences that relate to the desired level of services, or through revealed preferences (a proxy for the actual use of the service). Demand for cultural services has also been assessed by the direct use of a specific ecosystem, e.g. for recreation. This can be quantified by total visitor days per year or the number of fishing/hunting licenses, the presence of tourists, or by accounting for the accessibility or proximity to recreational areas.

Demand for **provisioning services** has been quantified based on direct use and consumption of final goods (Burkhard et al., 2012; Kroll et al., 2012; Boithias et al., 2014). It is worth noting that there usually a spatial mismatch between the area where the service is provided and the area where the service is consumed (Wolff et al., 2015), which is especially true for provisioning services. For this reason, inter-regional linkages have to be considered in order to properly identify faraway dependencies and assess the magnitude of potential impacts (Schröter et al., 2018).

Following the proposed conceptual framework, demand and supply have been combined for each of the selected ES. The focus of this approach was to highlight those areas where there is a high demand and a low supply, i.e. those areas where GI is unable to cover the ES demand. It should be noted that these results are of a more exploratory nature in the whole GRETA project considering the following limitations:

- This is a research area that is still under development;
- There is need for a higher resolution of the data sources given the nature of the phenomena analysed;
- The balance between supply and demand is semiquantitative; and

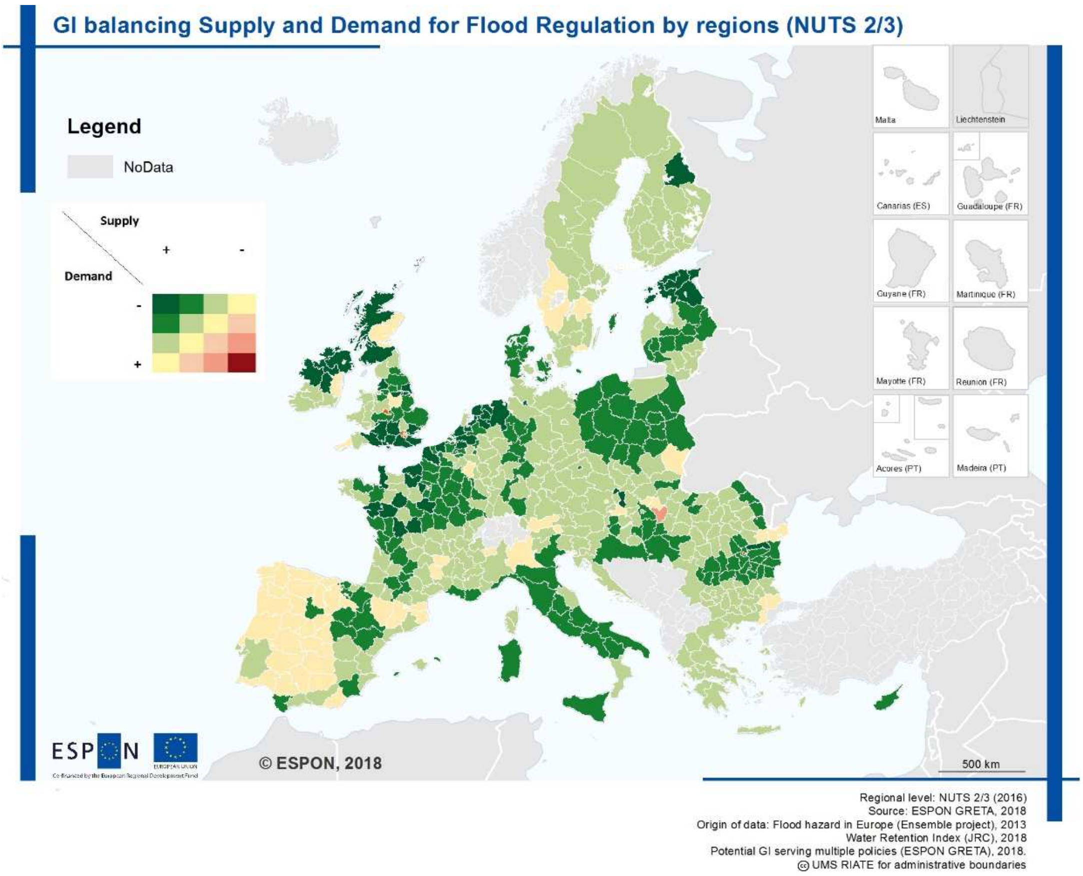
- In some cases, more sophisticated modelling would be required to have an appropriate quantitative balance.

Therefore, these results should be seen as an illustration on how this demand and balance could be approached.

Analysis of supply and demand for Flood Regulation

The demand for flood regulation has been quantified based on the potential flood hazard (Rojas et al., 2012). Exposure is described by the projected potential flood risk for the period 2011-2044 that results after applying the LISFLOOD model from the ENSEMBLES project. On the other hand, benefits are provided by the water storage capacity of land to regulate floods. The supply for flood regulation is quantified by the Water Retention Index, which assesses the capacity of the landscape to retain and regulate water passing through. This index is dimensionless and considers the role of interception by vegetation, the water-holding capacity of the soil, and the relative capacity of both the soil and the bedrock to allow water to percolate. The influence of soil sealing and slope gradient are also considered.

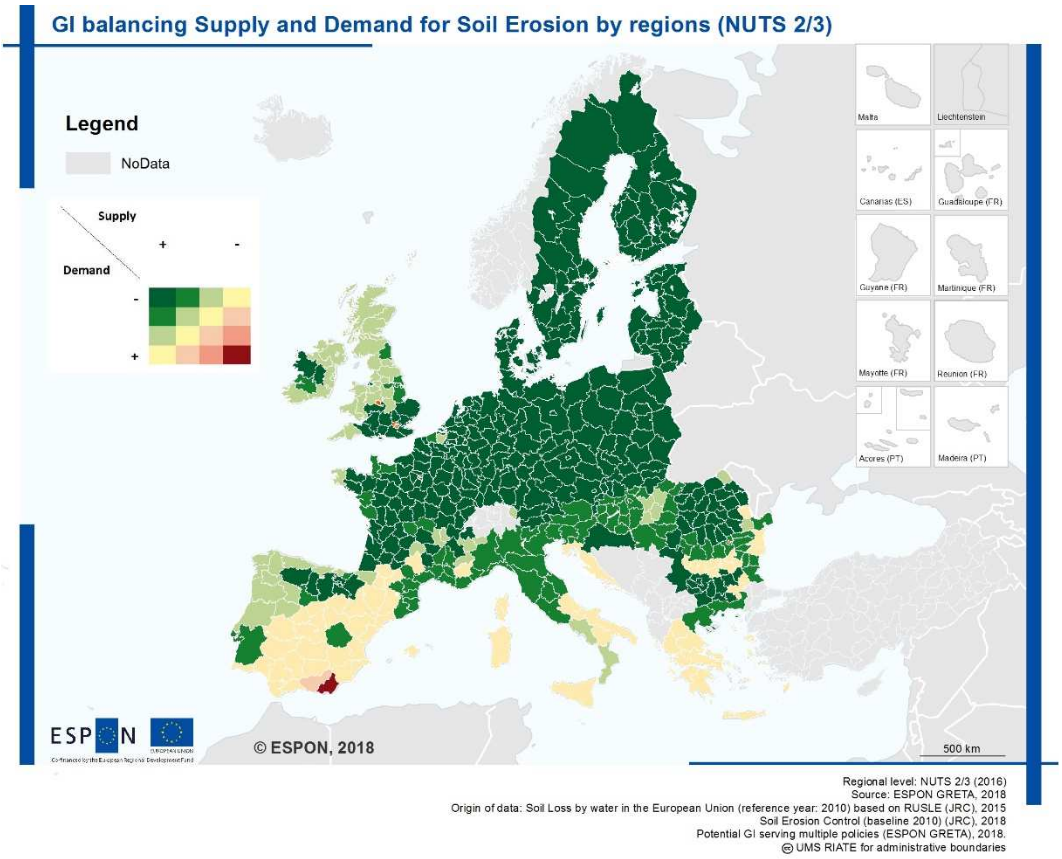
Map 13 presents a semi-quantitative balance between supply and demand. Dark green areas are those with maximum capacity of supply and where demand is very low –in this case the risk of flooding is assessed at the European scale. These conditions are met in few areas, mainly on the Northern part of Europe: some parts of Finland, Estonia, Northern Scotland, Northern Ireland, and some parts of France. The other regions in pale green could be considered as areas where the balance tends to be positive, in the sense that the supply is slightly higher than the demand. However, since the results are aggregated at regional level (NUTS2/3), it is most likely that some areas within the region will not be balanced and demand will not be fully covered. Therefore, these regions should be considered with caution. The yellow areas in the map represent balanced areas that are dominant in Spain, Southern Ireland, and part of Scotland. Even if these regions are considered as "balanced", the term should be considered more as a warning since the degree of equilibrium could not be measured more precisely. In practical terms it would mean that improving or reinforcing GI with the aim of improving water retention would have a substantial benefit. Finally, extreme deficit (low supply with high demand) is only found in Hungary.



Map 13 Balancing Supply and Demand for Flood Regulation by regions (NUTS2/3)

Analysis of supply and demand for Reducing Soil Erosion

The demand to reduce soil erosion by water has been assessed as it is one of the major threats to soils in the EU (Panagos et al., 2015), producing a negative impact on several ES, particularly to the ones related to crop production, drinking water and carbon stocks. Soil erosion by water is mainly affected by precipitation, soil type, topography, land use, and land management. Exposure is described by the soil loss rate (t ha^{-1} yr^{-1}) as estimated by the modified version of the Revised Universal Soil Loss Equation (RUSLE) model. Benefits are provided by the capacity of vegetation to control or reduce erosion rates. The supply is quantified by the Soil Erosion Control dataset (by the Joint Research Centre, JRC) which describes the capacity of ecosystems to prevent soil erosion. A clear geographic north-south pattern can be observed in the resulting Map 14, with the Mediterranean area being the one that is more exposed to soil erosion and with a greater need for soil erosion control service supply.

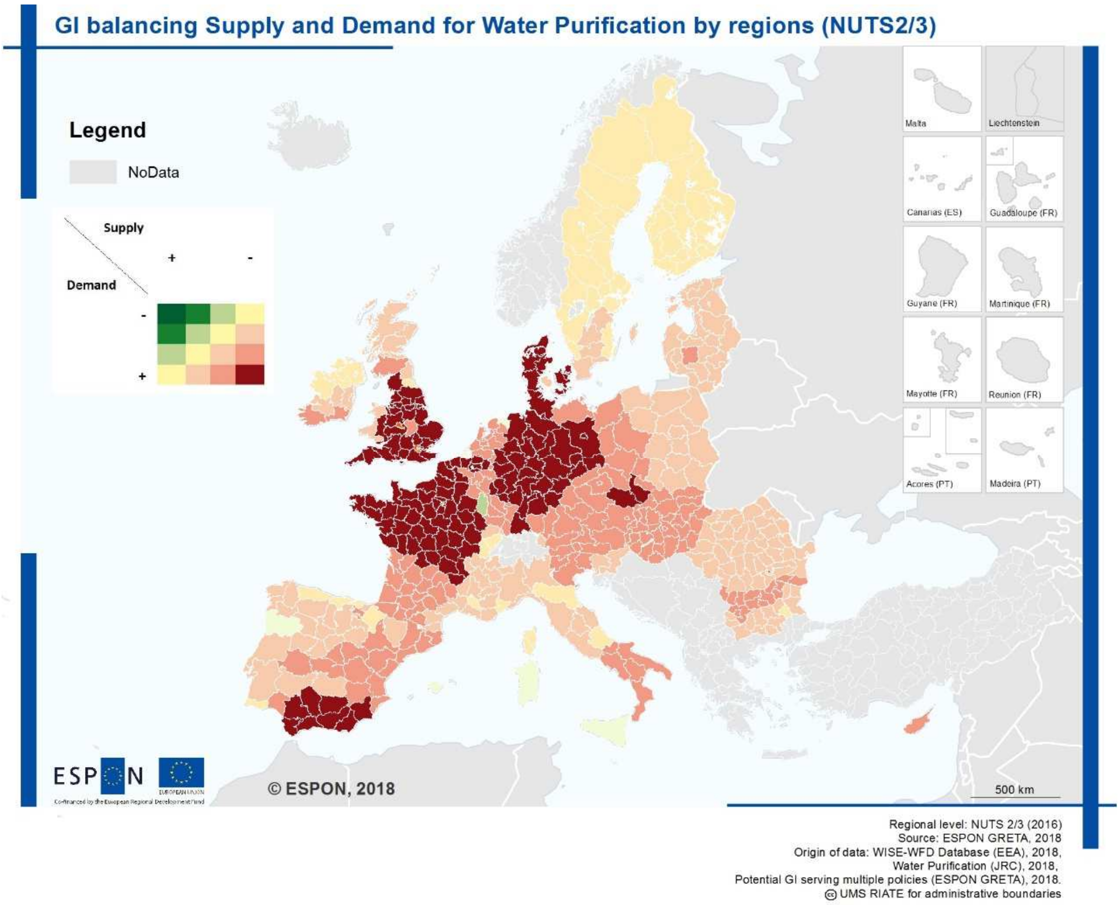


Map 14 Balancing Supply and Demand for Soil Erosion by regions (NUTS2/3)

Analysis of supply and demand for Water Purification

The demand for water purification has been quantified based on the level of pollutants emitted to freshwater ecosystems by polluting sectors, primarily agriculture and waste water treatment discharges from industry and households. Exposure is described by the mean annual concentration of nitrates in water (tonnes per year) captured in monitoring stations and aggregated by rivers (the WISE-WFD database). The supply is quantified by the Water Purification dataset (JRC) that assesses the in-stream retention efficiency of ecosystems to dilute or degrade nutrients.

The resulting Map 15 shows that water pollution is still a big challenge in Europe as confirmed by most recent assessments (EEA, 2018). With few exceptions in Italy, substantial increases in the provision of water purification are still required according to the current conditions.

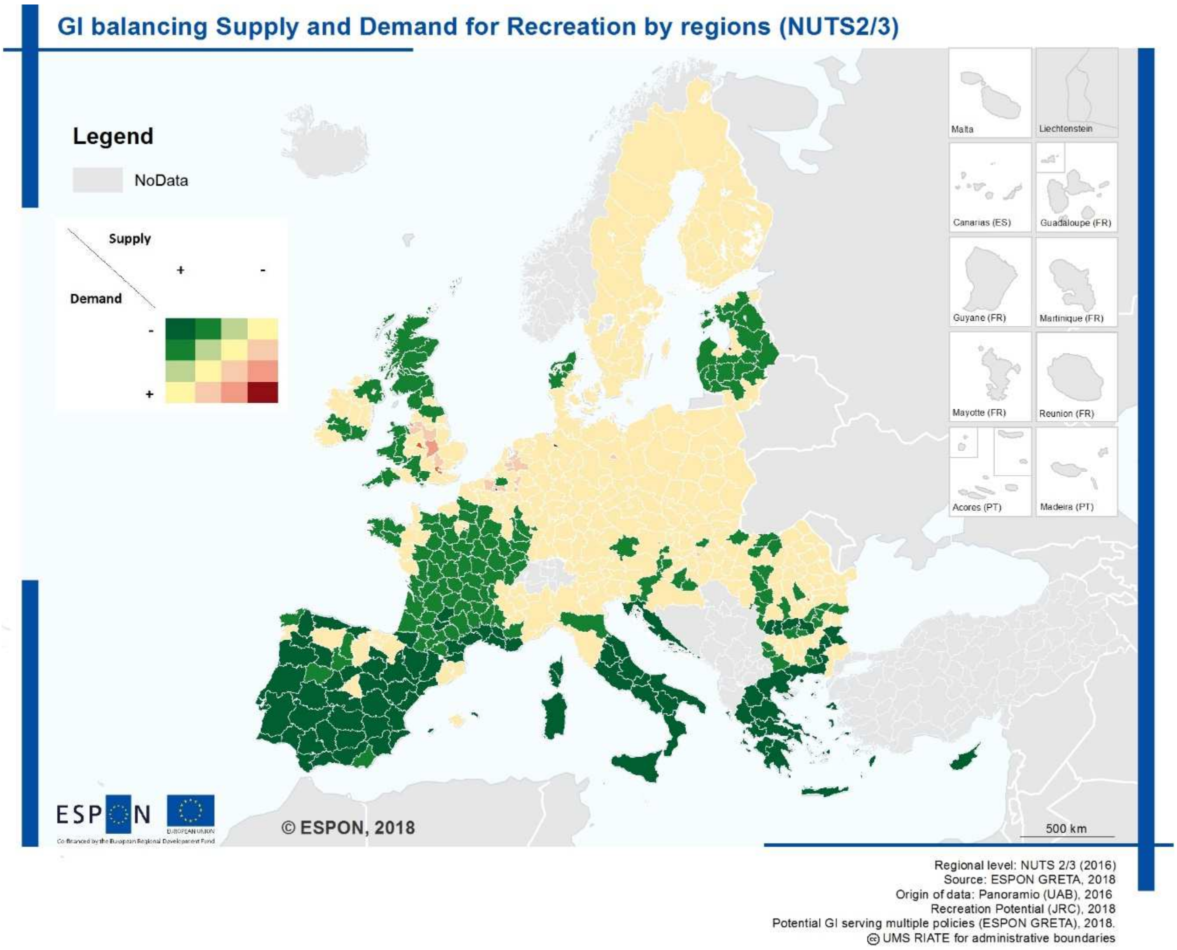


Map 15 Balancing Supply and Demand for Water Purification by regions (NUTS2/3)

Analysis of supply and demand for Recreation

Demand for recreation has been described by means of a proxy for visitation. Recreation and tourism are important elements for national and local economies, which also contribute to other intangible benefits (Wood et al., 2013). Recreation directly depends on environmental attributes such as species richness (Loureiro et al., 2012), diversity of habitats (Neuvonen et al., 2010), and climate (Loomis and Richardson, 2006). The usability of crowd-sourced information by means of location photographs has already been shown to be a reliable proxy for visitation rates to recreational sites (Wood et al., 2013). Location photographs in Panoramio have been used as a proxy for landscape attractiveness for visitors. Demand is quantified by the number of pictures per square km. On the other hand, supply is described by the Recreation Potential dataset (JRC) which quantifies the potential for outdoor recreation for citizens.

The resulting Map 16 shows a clear deficit of recreational service (low supply along with high demand) in the region defined as the “Blue Banana”, which is also known as the Manchester-Milan axis. It shows a discontinuous corridor spreading from the north of Wales, passing by Greater London, jumping to the Paris metropolitan area and the Benelux countries, following along south-western Germany, towards Northern Italy, and finishing in Barcelona. This shows a direct link with population density.



Map 16 Balancing Supply and Demand for Recreation by regions (NUTS2/3)

6 How do European regions fare in offering access to GI

With the majority of people living in cities, urban green spaces are the primary source of contact with nature. Access to ES provided by urban green spaces is increasingly perceived as an important factor for quality of life (Hegetschweiler et al., 2017). Moreover, the Sustainable Development Goals[15] (SDG) set a specific target for public space (SDG 11.7): “by 2030, provide universal access to safe, inclusive and accessible, green and public spaces, particularly for women and children, older persons and persons with disabilities”.

Accessibility can be defined as how easily a location can be reached from another location. Accessibility is a key aspect in spatial linkage and determines the opportunity to move from the area where beneficiaries are located to areas where ES are produced, i.e. the GI network.

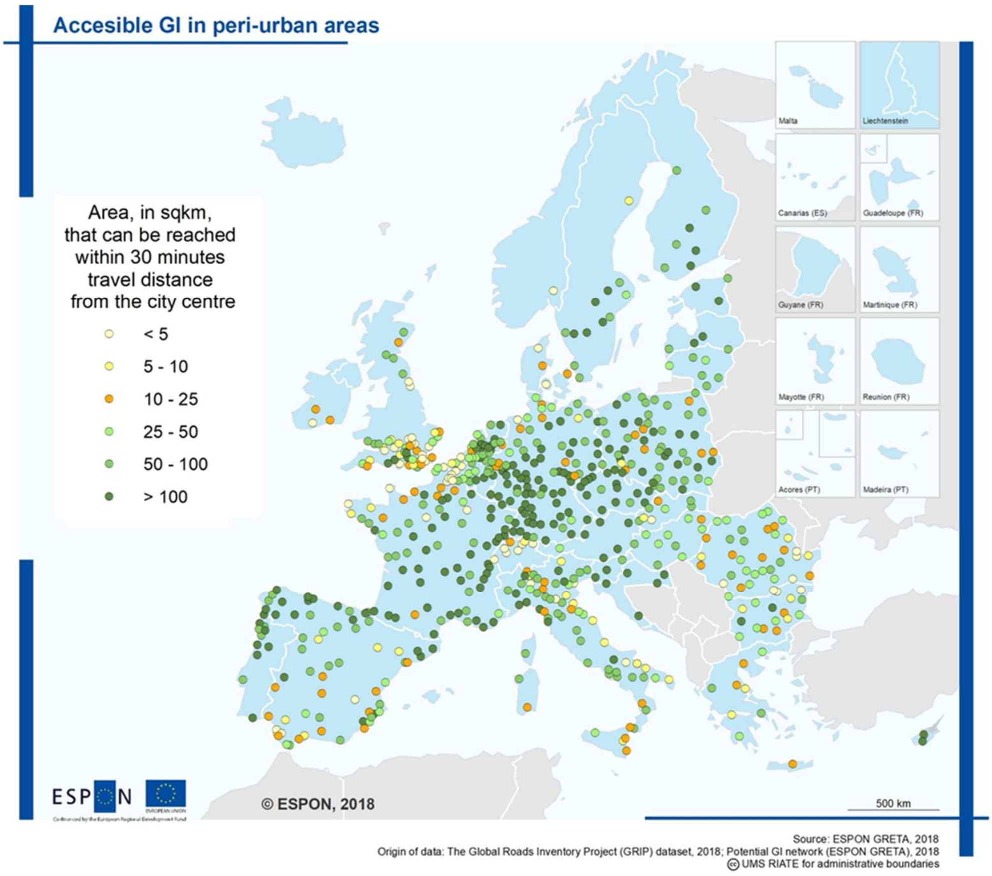
The accessibility analysis should be differentiated from the supply and demand assessment addressed in Sections 5 where the demand and supply analysis explored the needs (expressed by different approaches) of the population. Here, the accessibility analysis only assesses how well GI could be reached, independently of the number of people and their preferences.

[15] https://sustainabledevelopment.un.org/sdgs

Accessibility has been measured as the surface area of GI that could be reached by certain travel/walking time distance. Different travel distances have been considered depending on the specific location of the urban area: i) for the inner-city (Poelman, 2018) - a walking distance of 10 minutes; ii) for peri-urban- travel distances (by car) from the city centre to different targets of 15, 30, 45, and 60 minutes.

Poelman (2018) already provides an overview on accessibility inside the city. This analysis therefore focused on the peri-urban area and how well the inner-city is connected to the peri-urban area. Map 17 illustrates the substantial diversity in terms of accessibility to peri-urban areas, i.e. GI area that can be reached within 30 minutes travel distance from the city centre.

Cities with higher accessibility are scattered throughout Europe, although tend to be dominant in Sweden, Finland, Baltic countries, the Czech Republic, Austria, Germany and Portugal. On the other hand, cities in Ireland, Denmark, and UK are on the lower range of the accessibility scale (less than 5 km^2). Differences in accessible GI depend on several factors such as quantity of GI, its distribution (concentrated, patchy, dispersed, etc.), proximity to roads and trails, to name the most relevant ones. Therefore, available GI (or percentage of GI in the peri-urban area) does not in itself ensure its accessibility and accessibility depends on local conditions. This is corroborated since no influence of the city size on the accessible GI area has been observed.



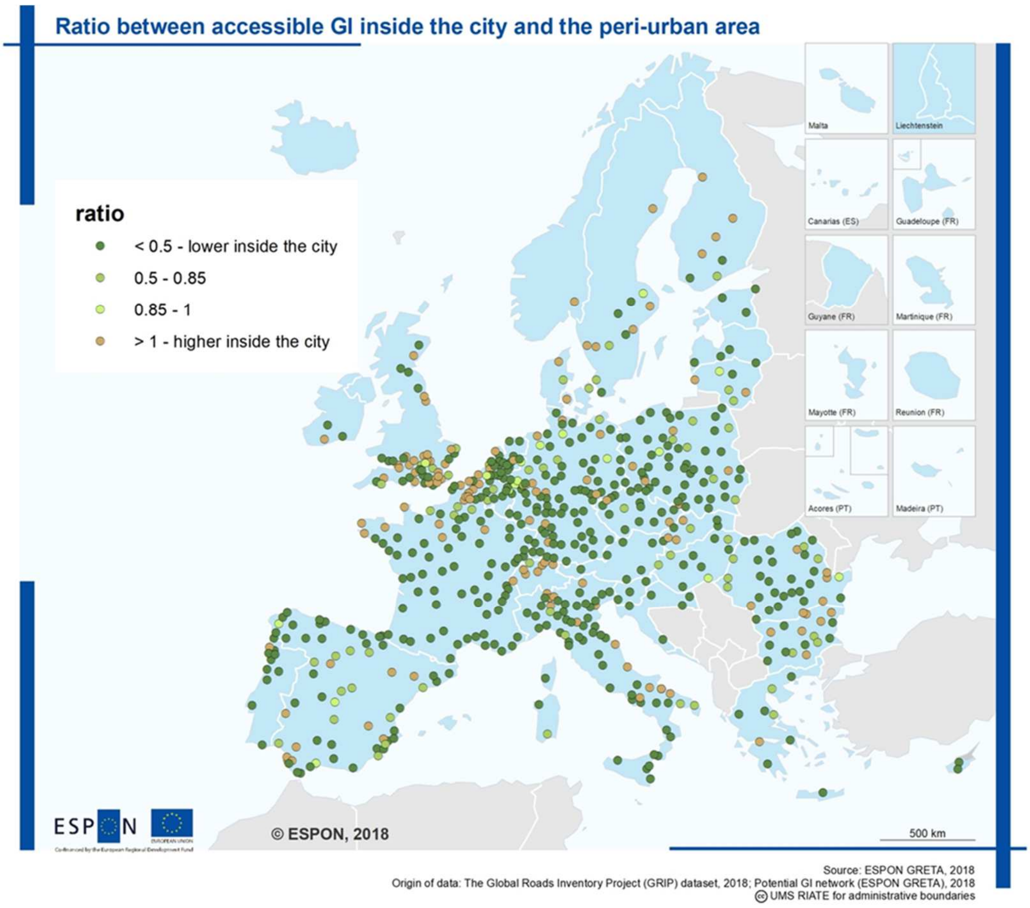
Map 17 Accessible GI in peri-urban areas. Area of GI, in km^2, that can be reached within 30 minutes travel distance from the city centre.

The ratio between accessible area within the city and the peri-urban area provides an indication of where it is balanced (ratio equals 1) or where either the inner city (ratio > 1) or the periphery predominates (ratio < 1). The analysis has been restricted to the peri-urban areas within 15 minutes travel distance in order to better identify where there is a continuum in the GI from the city centre to the periphery. Therefore, one would expect that those cities that have a break in the GI continuity would have a ratio above 1, in combination with lower accessibility in the inner city.

Not surprisingly, the most common situation in Europe is that the accessible GI area is greater in the peri-urban area compared with the accessible area in the inner city (see Map 18). This pattern is very similar to the one presented in Map 11, where the share between GI inside and outside the city has been compared. These cities are scattered across Europe.

Around 20% of cities have a ratio above 1, i.e. accessible area is greater inside the city. From this group, of special concern are those in Italy, Spain, UK, Belgium and Bulgaria, since the accessible area inside the city is quite low (Map 17). Therefore, these cities have certain limitations on the capacity to provide accessible GI both inside and on the first rings of the peri-urban area.

A different situation can be identified in Sweden and Finland, where cities with ratios above 1 have high accessibility both inside and outside the city.



Map 18 Ratio between accessible GI inside the city and the peri-urban area.

7 Where are the dominant patterns of interactions between ES in European regions

One of the characteristics of GI is its multifunctionality. The approach to multifunctionality in this study is based on the definition of certain policy priorities which, in turn, determine which ecosystem services need to be reinforced. A major challenge to promoting multifunctionality understanding is the interaction among ES. Usually, this is analysed by comparing how pairs of ES interact with one another (for example, the influence of ES1 on ES2, summarised in Figure 8 below).

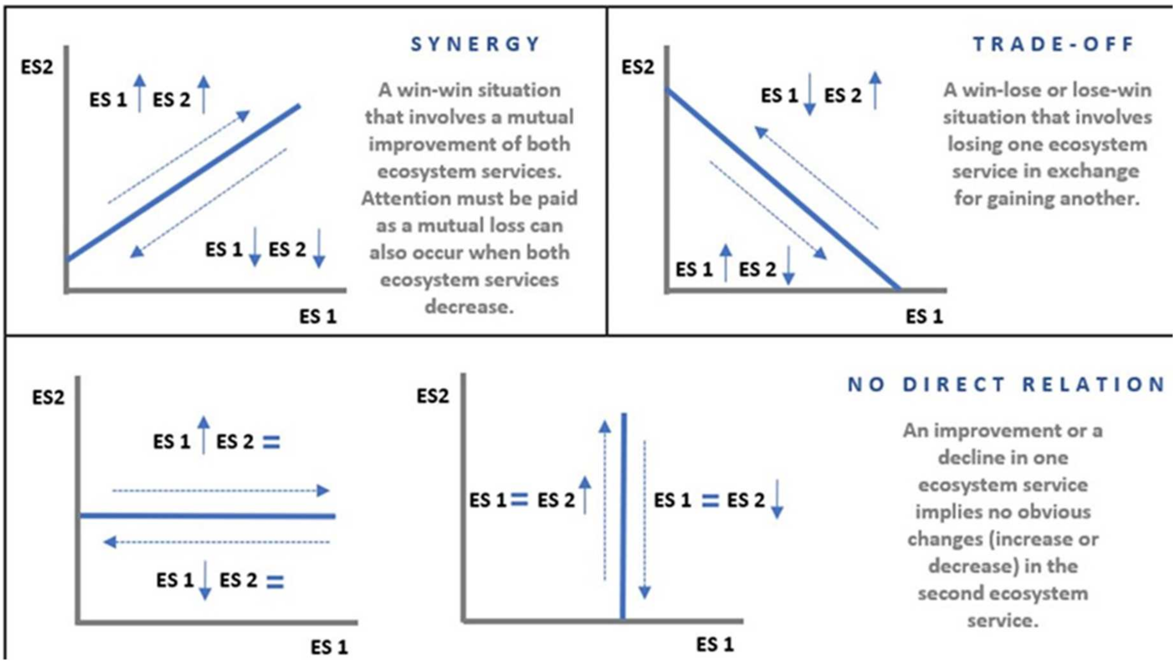


Figure 8 Comparing potential interactions between ES pairs

Synergies between ES happen when the elevation of on service causes an increase on another service. Trade-offs occur when the use of one ES directly decreases the benefits supplied by another. A change of ES use could be triggered by the demand and/or the supply side. A trade-off could take place in the same place or in a different area (e.g. impact of the management of a forest for wood production on local recreation and downstream water quality). In the case of no direct relationship, the use or enhancement of one ES has no impact on other ES.

Identification of synergies and trade-offs allows policy-makers to better understand the hidden consequences of preferring one ES over another. Synergistic interactions allow for simultaneous enhancement of more than one ES. As increasing the supply of one ecosystem service can enhance the supply of others (for example, forest restoration may lead to improvements in several cultural, provisioning, and regulating ES), the successful management of synergies is a key component of any spatial development strategy that aims to increase the supply of ES for the well-being of humans.

The relationship between an ES pair can differ across different scales and across different socio-ecological systems (Kremen, 2005; Hein et al., 2006; Bennett et al., 2009). An example of this is the “externality” of a decision on a certain service; a decision that seems to influence ES positively for a specific region might cause substantial trade-offs in areas nearby or faraway (Seppelt et al., 2011;

Rodríguez et al., 2006). If the effects of this decision are viewed at a larger scale, including all those negatively influenced areas, then the relationship between ES might be characterised as a trade-off. Cimon-Morin et al. (2013) showed in their review that the relationship between biodiversity and ES changes with scale and region. The relationship between carbon storage and habitat was, for example, described mainly as synergistic at the global scale, but at a finer regional scale, high biodiversity and high carbon storage might be disconnected, or even lead to a trade-off relationship. Furthermore, the relationship can change in different land systems[16]; a decision to increase a service can affect the other services differently in different land systems. For example, West et al. (2010) showed differences in a trade-off relationship between carbon sequestration and food provisioning among regions with different land systems.

Synergies and trade-offs at NUTS 2/3 level have been considered in this analysis in order to provide relevant information considering the resolution of the data, and to be meaningful for regional management. The analysis contemplated the three selected policy areas: biodiversity, climate change and disaster risk reduction (CC&DRR), and water management. There are already some attempts to provide pairwise comparison of ES at conceptual level (Kandziora et al., 2013). The approach described by Jopke et al. (2015) has been followed, which combines regression analysis with nonparametric statistics (due to the non-linear relations among some of the ES). ES data at NUTS level have been used to identify the type and strength of association among ES. A detailed description of the methodology is provided in Annex II. The findings for each policy area are briefly described here, followed by a visual illustration of these associations in Figure 9.

Stronger synergies were found between the three ES supporting biodiversity (see Figure 9.A), which is coherent with current knowledge (Liang et al., 2016). These results show that planning GI for biodiversity has the potential to have a multiplying factor by improving several ES at the same time.

In the CC&DRR domain (Figure 9.B) there are two trade-offs (i.e. a negative correlation for gross nutrient balance with water retention, and for gross nutrient balance with net ecosystem productivity), and one synergy (water retention with net ecosystem productivity). The trade-off between gross nutrient balance and water retention services should be considered in the European context, coming out from the combination of several mutually influencing processes: water retention, productivity, and nitrogen deposition pattern, which is an external factor. The higher net ecosystem productivity at higher emission levels (indicated by low values for ecosystem service) may reflect a fertilizer effect of nitrogen deposition. For the synergy between water retention and net ecosystem productivity, water retention is linked to a combination of soil properties that provide favourable conditions for ecosystem productivity. This combination of interactions, dominated by trade-offs, may explain the fact that most regions are monofunctional for CC&DRR as described in Section 3.3. Additionally, the analysis of ES linked to climate change shows the complexity when external factors, such as nitrogen deposition, interact. Therefore, good regional and local knowledge is required to overcome the issues

[16] Land systems constitute the terrestrial component of the Earth system and encompass all processes and activities related to the human use of land, including socioeconomic, technological and organisational investments and arrangements, as well as the benefits gained from land and the unintended social and ecological outcomes of societal activities (Verburg, 2015).

linked to gross nutrient balance. However, nitrogen deposition is a factor of uncertainty that could not be directly managed at regional and local level (mitigation measures could be taken).

For ES and water management (Figure 9.C), the type of relationship was found to be either a weak synergy or neutral (no influence). The findings are in line with the conceptual approach developed by Kandziora et al. (2013) where no trade-offs were found between regulating services, and the same neutral relationship between water purification and water retention was observed. Soil erosion control has a weak synergy with both water purification and water retention. Jopke et al. (2015) have also observed similar patterns analysing other regulating services across European regions.

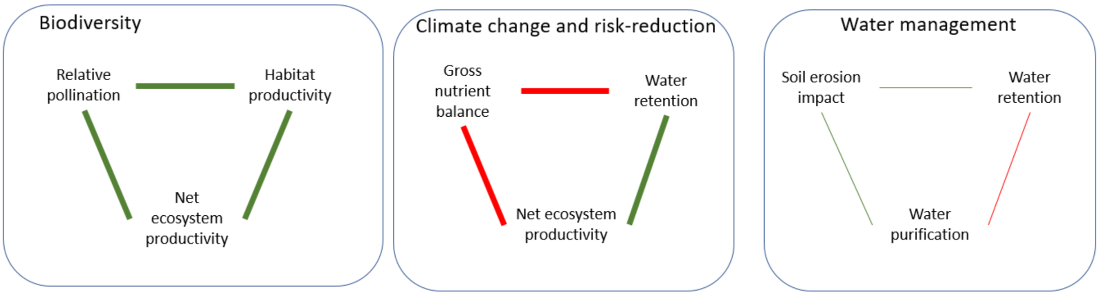


Figure 9 Synergies (green) and trade-offs (red) of ES analysed for three policy domains: A – biodiversity conservation; B – climate change and disaster risk reduction; C – water management. The lines connecting the ecosystem services indicate the type of association (by colour) and strength of the association (width of the line; thicker equals stronger association).

ES bundles - the role of recreation

The interactions amongst ES have been analysed according to policy objectives. The concept of bundles has been developed to refer to sets of ES that are linked to a given ecosystem and that usually appear together repeatedly. It should be noted that bundles could be analysed from two dimensions: spatial and temporal. Only the spatial dimension has been analysed in GRETA given the objectives of the project and data availability. However, the temporal dimension should be considered in the medium-long term, which takes into account the time needed to observe the changes of different ES due for instance to different managerial measures.

By analysing how the ES interact, two groups could be identified (Figure 10):

- Standalone ES, i.e. those that do not appear repeatedly together with any other ES in space, and also perform in a very unique way, different from the others.
  - Gross nutrient balance appears probably linked to the fact that nitrogen deposition (an external factor) has an important role.
  - Net ecosystem productivity. Although it has synergies with most of the ES (except gross nutrient balance), it does not appear always associated in space with another ES.
- ES that appear always linked to others (creating bundles of ES) and have a consistent type of relationship with another ES:
  - Habitat quality and water purification.
  - Regulating services and recreation potential (the largest group).

The type of relationship between these groups of ES is presented in Figure 10 (compare with definitions in Figure 8). Some of the patterns observed when the individual ES were analysed, appear here again:

- Nutrient balance has a trade-off relationship with most of the ES groups
- Net ecosystem productivity has a synergistic relationship with most of the ES
- Habitat quality and water purification are predominantly neutral (no relationship)
- The larger group (regulating services and recreation potential), have different type of relationship depending on which ES they are compared with.

The understanding of the mechanisms behind the ES bundles, and the type of relationships between them, would require a deeper analysis beyond the scope of this project. The identification of this kind of linkages is a first step needed to understand possible impacts of using/enhancing certain ES (either individual or a group). The next step, particularly at regional and local level, would require a better understanding of the causality and related mechanisms, which could allow taking appropriate management practices to avoid as much as possible trade-offs.

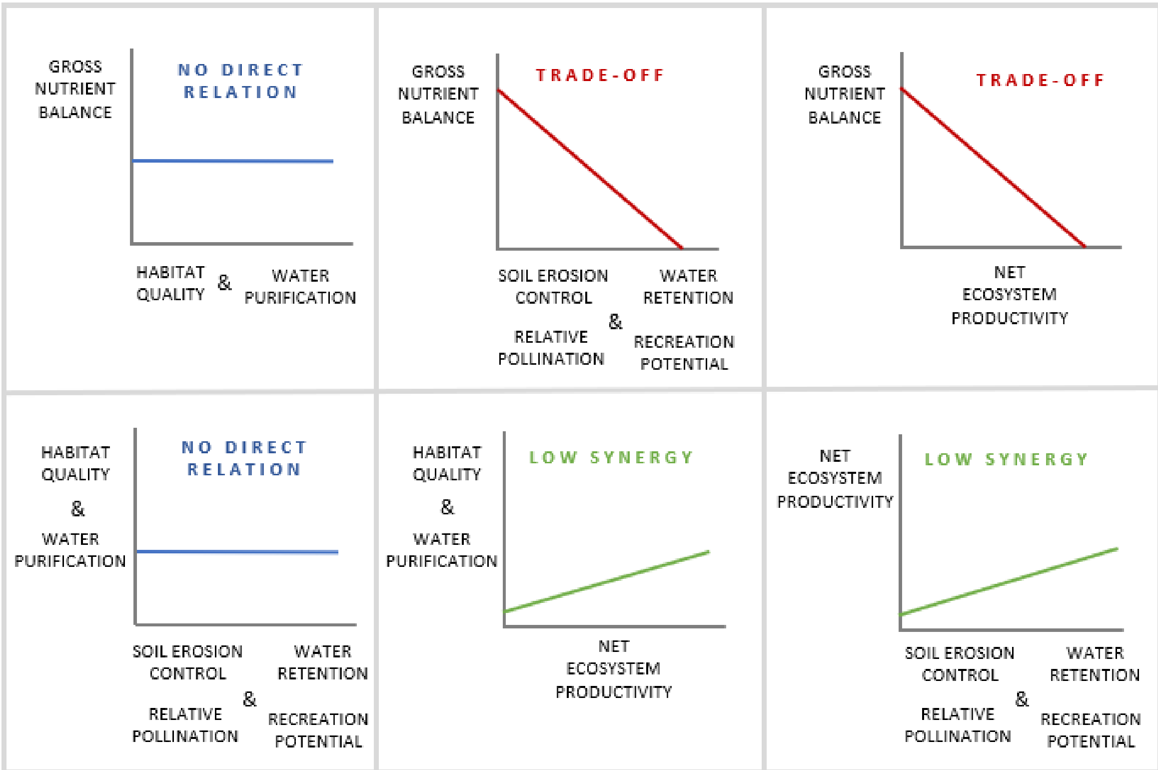
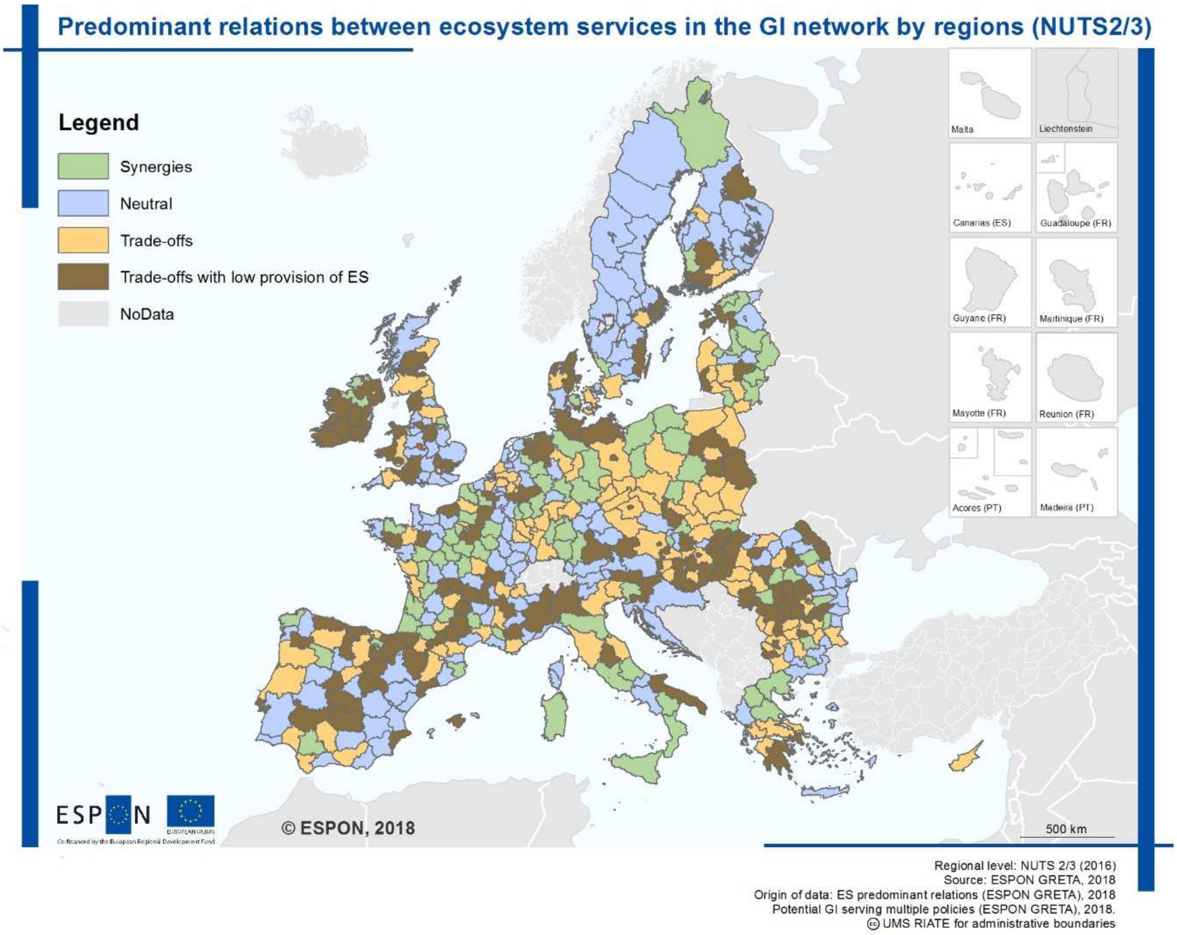


Figure 10 Standalone and bundles of ES.



Map 19 Predominant relationship between ES in the GI network by region. Type of relationship: Synergies; Neutral; Trade-offs; Trade-offs with low provision of services

Synergies and trade-offs at regional scale

Considering all the possible combinations of ES, the predominant type of relationship for each region has been identified. The resulting map (see Map 19) shows certain regional patterns:

Synergies. In these regions – in Italy, France, parts of Germany, and Poland – most of the ES have a (strong) synergistic relationship. There are, to a lesser extent, some trade-offs. In practical terms, the improvement of certain ES always has a multiplier effect on other ES (increasing the provision of ES). It means that the implementation of GI will be highly efficient since focussing on the improving of key ES will result in co-benefits, facilitating the accomplishment of several policy objectives.

Neutral. This is the larger group. Changes in one ES have no effect on another ES. These regions are scattered across Europe and can particularly be found in Spain, England, Finland and Sweden. In practical terms, it is likely that improving ES will not have unwanted side effects.

Trade-offs. There is a clear regional pattern, dominated by Eastern countries. In these cases, management of GI requires further understanding of these trade-offs and the need to identify alternatives to minimise side effects. The implementation of GI may be hampered by the fact that focussing in certain objectives may lead to the degradation of other ES, resulting in a general imbalance on the system.

Trade-offs with low ecosystem provision. These regions are scattered across Europe; they are the dominant pattern in Ireland. These regions would require special attention since the trade-offs are combined with low potential of provision of several ES.

8 Factors that can support European cities and regions in making full use of their GI and ecosystem services development potential

To assess if and how European countries implement the European GI strategy (2013), National Policy Factsheets have been created for each country in the ESPON space based on a desk study and questionnaire. These factsheets describe the national governance and policy contexts for GI in each ESPON country. Annex IV of this report details the methodology and includes each ESPON country's individual factsheet. A Pan-European analysis drawing together insight from the individual results is provided in this Section.

From these fact sheets and the 12 GRETA case studies, good practice examples have been identified to illustrate the diverse nature of GI design and implementation across ESPON countries. Design and implementation practices refer to the modern tools, policies and processes that are used to facilitate the enhancement of GI. The method and criteria for analysing these practice examples, as well as main results, are also described in Annex IV.

GRETA results imply that a more explicit approach to GI on national governance levels could facilitate the further implementation of the European Green Infrastructure Strategy. For countries without a national GI strategy, clearer top-down communication about the GI concept and its principles could facilitate the establishment of the multifunctional concept and also the implementation of the concept into the policy sectors where GI is not fully prevalent yet.

8.1 How do EU regions and cities look at the concept of GI and ES in policy processes?

Predominantly, the 47 respondents[17] across the 32 European countries that responded to the GRETA questionnaire on policy and planning, perceive GI as the physical expression of a network of connected non-built up environmental areas and/or ecosystems. Respondents from most countries include green areas, and the connectivity between them. Some acknowledge blue areas, e.g. bodies of water.

GI specific policies on national levels

Of the 32 countries surveyed, 11 countries have specific GI policies at a national scale. Exceptions include the UK and Belgium which have GI policies for respective country and region, but not on an overarching level. Refer to Annex IV-B, Table 23 for summarised results and the National Policy

[17] The respondents are primary advisors, experts or officials in public administration on national, regional or municipal levels (34 respondents). They are primarily working within fields of spatial planning or environmental resource management. For some of the countries, respondents from public administration did not provide answers and therefore the respondent(s) are academics (12 respondents) or private consultants (1 respondent). For some countries, both respondents within public administration and research have answered the survey.

Factsheets for country-specific information. All 28 EU member states have adopted the Pan-European policy for Natura 2000 (N2K), and established N2K areas accordingly. The implementation, monitoring and statutes of N2K areas vary between the countries. To follow-up and discuss common issues and solutions in and between member states, seminars are taking place in the different biogeographical regions in Europe every three years (EC, 2018).

Although most of the other countries have integrated GI into other policy sectors, a core recommendation is to develop an integrated national GI strategy to implement the European GI Strategy. Including GI into existing strategies, policies and legislation is in line with the EU GI strategy (EC, 2013, p.10), as it states that GI principles can be implemented by using existing policy and financial instruments. For implementation to take off, however, a core recommendation of the European GI Strategy is to develop GI specific policies on national levels.

Who is responsible for GI in Europe?

Two questions regarding the responsibility for GI were included in the questionnaire. Summarising the results for all 32 ESPON countries, the responsibility to develop GI policy is perceived as a main duty of public administrations. National authorities are perceived as having the main responsibility for developing GI policy and strategy in Europe (indicated by 19 countries) and for implementing the European and national GI strategies (indicated by 16 countries). It is optimistic to think that public administrations would take on the responsibility for implementing GI in their respective countries. This can, however, come with the risk of neglecting the other actors that are important for GI implementation to take place. These are for instance businesses, land owners, civil society organisations and researchers. Refer to Table 23 in Annex IV-B for summarised results for the 32 countries.

European funds for GI implementation

While all 7 EU funds included in the questionnaire were considered important to a certain degree, three were perceived as the most important for implementing GI. These include: LIFE+ and Horizon 2020-project funds; The European Regional Development Fund (ERDF), and The European Agricultural Fund for Rural Development (EAFRD). The funding flows both from public-to-public, and from public-to-private actors and institutions. To a certain degree, private investments, the so-called "Green Finance" is in use. Examples include: the five structural funds (e.g. ERDF, European Structural Funds (ESF), Cohesion Funds (CF), EAFRD, and European Maritime and Fisheries Funds (EMFF) which are used together with national environmental funds in Cyprus and Slovakia; the EAFRD are used for agro-environmental subsidies in Belgium and to improve environmental quality in N2K areas in Denmark; and CF is used for enhancing urban green areas in Slovenia. In addition, other funds are used, especially national funding and co-funding from different sources depending on the primary aim of the GI in question.

Integration of GI principles in policy sectors

One way to determine what GI consists of in practice is to establish an understanding of which policy sectors include principles that are important for GI. The questionnaire included 13 policy sectors;

Figure 11 summarises findings from these questionnaires across the 32 ESPON countries. The information in this figure is based on a survey. More detailed information on the policies for each country´s GI is available in Annex IV, the national policy fact sheets, and in the case study reports This regards for instance Malta.

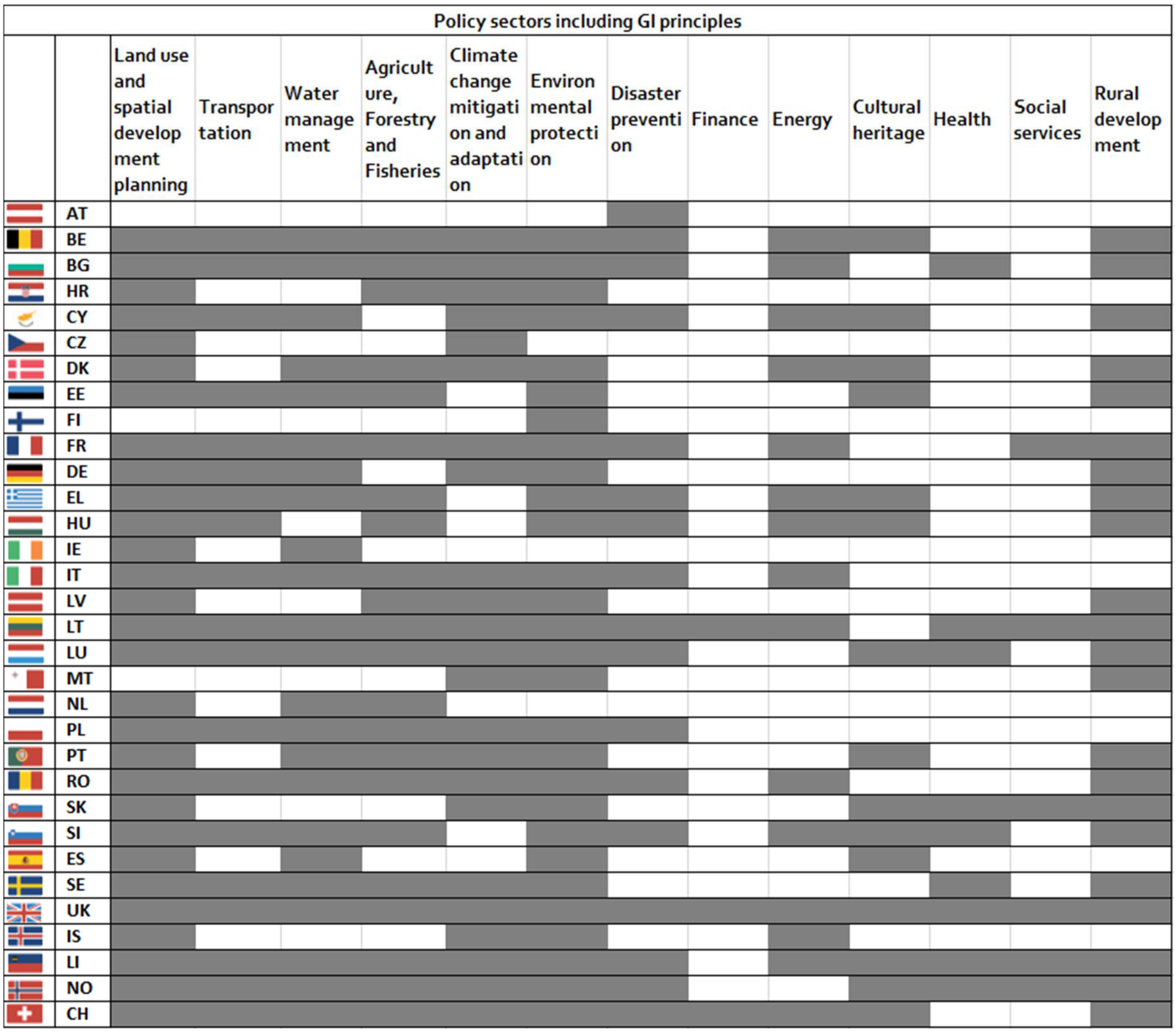


Figure 11 Green infrastructure (GI) in policy sectors in 32 ESPON countries. Grey cells indicate that GI is included in the policy ('yes'); white cells indicate not ('no').

Three overall observations can be made from the results. Firstly, it can be noted that there are more 'yes' than 'no' answers, even if the policy field does not explicitly address the exact term GI, green structure or green-blue infrastructure. Secondly, it can be noted that some policy sectors are more clearly including GI principles. For example, land use and spatial development planning; water management; agriculture, forestry and fisheries; climate change mitigation and adaptation; environmental protection; and rural development, are policy sectors that include principles of GI in Europe (e.g. have more than 20 'yes' answers to the questionnaire). This suggests that GI is perceived as broader than biodiversity protection, which is what the European GI Strategy from 2013 intended. Thirdly, the results indicate that GI principles are not prominent in some policy fields. Specifically, the Finance; Health; and Social Services policy sectors do not include GI principles in most of the ESPON countries). This result implies that work is required to further integrate GI principles into these policy areas to avoid conflicts of interest, both on an immaterial policy level and in order to fulfil the spatial expression of GI, e.g. to preserve and enhance non-built up areas, and their connectivity.

8.2 Georeferenced information on GI and its use in spatial planning:

One of the basic prerequisites for preserving and restoring networks of green and blue areas is to have geographical knowledge of the existing GI and its environmental qualities. Although GI potentially refers to non-built up lands also outside nature protection areas (e.g. see Map 1 in Subsection 3.2), the questionnaire asked if data on protected areas was available and in use in order to investigate whether geographical knowledge exists and is used in the ESPON countries. The respondents were therefore asked how often the information is used in decision-making processes for spatial planning on regional and local levels. According to the results, 30 countries always or often have available information about **where protected areas are located**. For 26 of the countries, respondents provided links to web portals where this information is available. The georeferenced information **on the environmental quality of the protected areas**, e.g. biodiversity rates, ES and/or other quality measures, is not to the same extent perceived as easily available on national levels throughout the ESPON space; 19 countries stated that this information is always or often easily available. In 18 countries, the information provided is always or often **used in decision-making processes for spatial planning on regional and local levels**.

These findings suggest that the location and size of the protected areas, in terms of coordinates, borders and hectares, are more easily included in decision-making processes than the qualities of these areas. Zoning of different land uses is one of the fundamental tools that is used in spatial planning. Continued mapping of land cover and land use patterns (e.g. protected areas, forests, agriculture, level of fragmentation, ecological networks) and the environmental quality of land and waters is an important action for GI implementation. The results also indicate that the available knowledge could be increasingly used as the basis for decisions in spatial planning on where to locate new housing, commercial areas, industries, roads, and waste disposals. This would enhance GI in Europe.

8.3 Existing governance challenges and opportunities

Table 5 lists the challenges and opportunities for GI governance most frequently mentioned by the 32 countries. Refer to the National Policy Factsheets for detailed descriptions (Annex IV-B).

Challenges	Opportunities
Lack of national policy	Strategic and practical work on GI is on its way
Lack of sector integration	National and regional policies in place for GI
Lack of collaboration between different institutional levels	Use GI as a communicative concept for territorial development
Lack of political willingness	Local initiatives in place, despite no national or regional policies
Lack of public awareness	

Table 5 Key challenges and opportunities identified across 32 ESPON countries with respect to GI governance

8.4 Good practice examples as inspiration for enhancing biodiversity and ES for territorial development

The GRETA analysis of policy and planning for GI and ES in Europe has identified that spatial planning tools used for including GI in territorial planning are diverse[18]. Official authorities note that good practice examples to implement GI are a wide range of tools, plans, programmes, nature parks, strategies, campaigns. as well as actor-networks and financing projects that monitor, establish and/or enhance the quality of the non-built up environment. In turn, both private actor initiatives and civil society organisation initiatives that are positive for GI are presented here. All the good practices below have a direct or indirect positive influence on green and blue infrastructure. The following list of 25 practice examples summarises some strategic and detailed good practices that could be transferable to other countries. This means that they could be scaled-up or scaled-out to other contexts. Detailed information on each good practice is provided in Annex IV-D.

Strategic good practices:

1. Creation of regional planning committees to show long-term political leadership for GI implementation (such as in the Reykjavik capital area, Iceland)
2. Implementing GI in urban spatial planning via four-step national criteria legitimised in planning legislation and driven via bottom-up approaches (such as in Hämeenlinna, Pori, Heinola, Hanko, Porvoo, Turku, Kotka, Forssa and Kuopio, Finland)
3. Establishing cross-border cooperation to make full use of the potentials that GI entails (such as the European Grouping for Territorial Cooperation (EGTC) Euroregion Nouvelle Aquitaine-Euskadi-Navarre, in France and Spain)
4. Implementing GI through a focus on recreation and health to ensure cross-border territorial planning (such as the cross-border Greater Copenhagen and Skåne committee, in Sweden and Denmark)
5. Developing regionally adapted methods to ensure integration of Ecosystem Services in spatial planning (such as the Trnava region, Slovakia)
6. Utilising green areas as a part of tourism-based development (such as the Alba Iulia Municipality, Romania)
7. Using extreme rainproof solutions in the design of houses, gardens, streets, and parks (such as the Waternet in the Netherlands)
8. Establishing long-term monitoring of biodiversity to develop current governance practices in a way that the physical network of green areas can be preserved, and the biodiversity quality maintained (such as the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) and the Federal Office for the Environment (FOEN), in Switzerland)
9. Setting strict targets for climate-smart investments to ensure the Paris agreement on climate change adaptation and mitigation is reached (such as the European Fund for Strategic Investments, in the EU)

[18] The good practice examples have been identified based on a questionnaire and work in GRETA´s 12 case studies. For method and criteria see Annex IV-C. For full information on good practices see Annex IV-D.

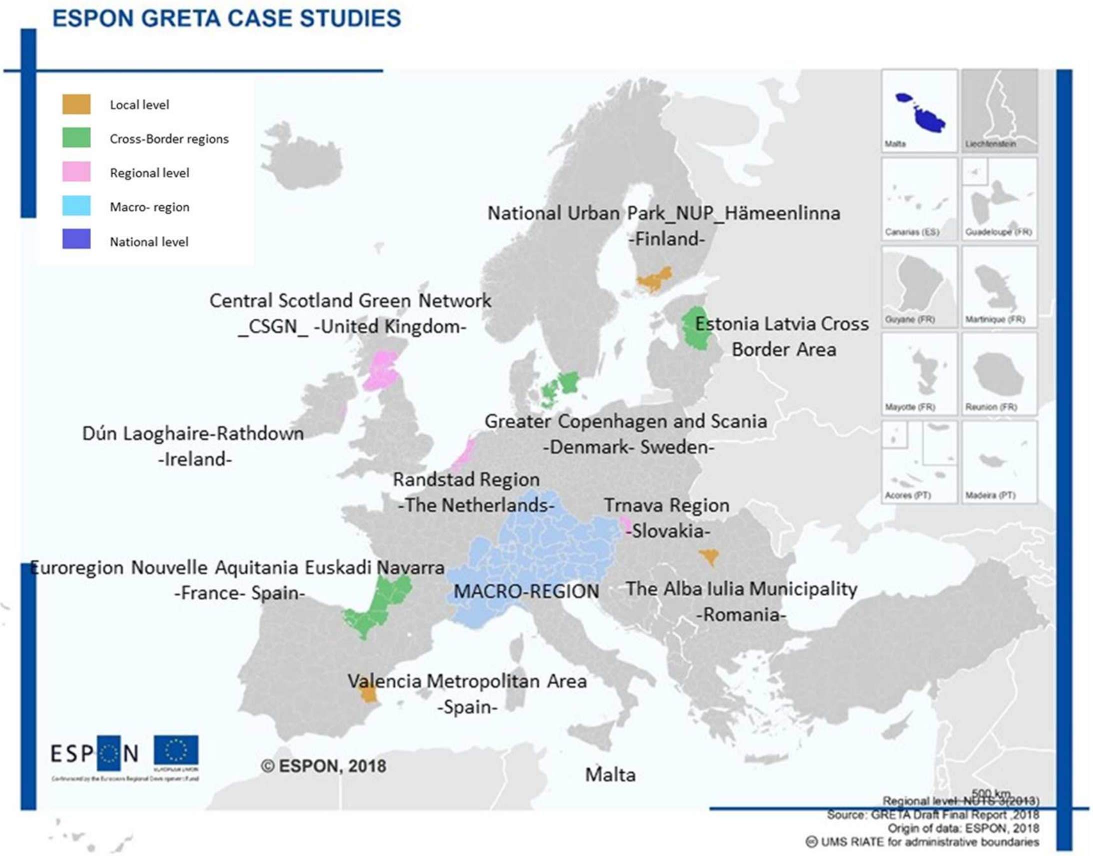
10. Integrating GI for flexible and long-term sustainable use of a purpose-built urban area (such as the London Olympics Park, in the UK)
11. Enhancing the quality and quantity of green space through Biodiversity plans with strict improvement targets (such as the city council of Lisbon, in Portugal)
12. Considering landscape connectivity as a critical target for management of the Natura 2000 network (such as the “Ecological corridor for habitats and species in Romania” project)
13. Using strong visionary leadership to implement GI in times of sustainable urban transformation (such as the public authority in Ljubljana, in Slovenia)
14. Reducing heat-related risks and adapting to climate change by implementing nature-based solutions (such as the Benicalap-Ciutat Fallera district in Valencia, Spain)

Detailed good practices:

15. Securing inhabitants’ access to outdoor recreational areas by setting targets for accessibility in spatial planning (such as the municipality of Oslo, Norway)
16. Regularly exchange of information on nature conservation across state borders and promoting green areas locally through a festival (such as in the cross-border region of North Livonia, Estonia and Latvia)
17. Restoring and enhancing high-quality wetland environments with financing from lottery grants (such as the Seven Lochs Wetland Park, Scotland)
18. Developing a freely available decision support software tool for biodiversity and ecologically based land use planning that includes economic analysis options (such as the ‘Zonation’, in Finland)
19. Decreasing the risk of flooding and polluting drinking water by compensating private property owners for investing in water management (such as in Copenhagen, Denmark)
20. Integrating a Green space factor as part of planning and building practices. For every surface that a developer wants to seal with buildings, asphalt or concrete, they will need to compensate this with something else that is green or blue (such as the local planning authority in Malmö, Sweden)
21. Increasing water availability in a cost-effective way through rainwater harvesting, storm water management and greywater reuse systems (such as the Alter Aqua Programme, in Malta)
22. Implementing green roof constructions adapted for Mediterranean environments (such as the University of Malta, Malta)
23. Restoring former golf courses and creating new multifunctional open spaces in close proximity to housing areas (such as the Honey park in Dún Laoghaire-Rathdown, Republic of Ireland)
24. Increasing the number of green roof and green wall constructions and reaching more sustainable rainwater management (such as the Bratislava Karlova Ves Municipality, Slovakia)
25. Protecting biodiversity by reconnecting fragmented habitats and decreasing barrier-effects for mammals and amphibians by implementing wildlife crossings (such as the Goois Natuurreservaat Foundation, in the Netherlands)

9 What do the GRETA case studies reveal?

GRETA is investigating 12 case studies that represent different spatial, institutional and governance settings and that range from urban centres to rural countryside. This section presents some of the findings of a series of three consultations that have been developed to gather relevant information on different aspects of GI spatial analysis, policies, planning and implementation that has served as input and inspiration for the policy recommendations (see Annex VI for details on consultations).



Map 20 ESPON GRETA case studies

In general, the case studies have adopted GI - to different extents - as an intrinsic part of spatial planning and urban planning. Some cases have developed stand-alone GI strategic documents (e.g. Dún Laoghaire-Rathdown council, Trnava Region, Valencia Metropolitan Area, Greater Copenhagen and Scania). In other cases, GI is being mainstreamed into other sector policies (e.g. the Basque Country and Alba Iulia). Although ES are not always formally recognised as such, it seems that they are implicitly assessed in the GI approach, with a special emphasis on ecological connectivity and biodiversity (e.g. Finland, Estonia-Latvia cross-border area, Trnava Region) but also on recreation, culture and well-being (e.g. Valencia Metropolitan Area and the Alba Iulia Municipality). GI is recognised as a cross-sectoral concept that necessarily implies more awareness raising and communication between the different spatial planning sectors for it to be operational.

Regardless of the spatial scale, the main territorial challenges linked to GI shared by most of the cases include transport/access, trade, border issues and demographic pressure (which are more obvious on the local scale), as well as climate related risks (e.g. water management, flooding) agriculture, non-sustainable forest management, and forest drainage, the latter being particularly relevant in northern countries.

In some cases (i.e. in the Basque Country, Valencia, Trnava, Estonia and Latvia), significant efforts have been made with regards to the ES evaluation and GI delineation, which constitutes a strong baseline to inform decision making and planning. However, the lack of high-level guidelines on zoning and land use management in the planning instruments is highlighted as one of the main challenges for effective GI implementation alongside political commitment and financial and economic investment. Even when the political commitment and planners' willingness to incorporate GI as criteria into their planning process exists, there is still a need for better knowledge, understanding and accessibility to the available data on ES, biodiversity, and natural resources, and on how to make use of this data to build up the GI network and use it for decision making and spatial planning (such as the Basque Country for example). In this sense, one of the most advanced cases is the Central Scotland Green Network, where there is a central governance mechanism/institute/organisation dedicated to GI. The relationships between GI, biodiversity, and ES are dynamic and need to be monitored and examined over long periods of time in order for effective and adaptive management measures to be developed.

The adoption of GI in private developments appears to be driven through stipulations and guidance within the local planning system, rather than through commercial incentives, such as hedonic valuations (Dún Laoghaire-Rathdown for example). The current EU-Directive for Environmental Impact Assessments (EIA) and Strategic Environmental Assessments (SEA) seems to be a viable tool for ensuring private actors consider ES and GI (as is the case with Greater Copenhagen and Scania) (see GRETA Policy Briefing 2).

The work on ecosystem-based territorial planning for GI is recognised as a potential issue to bringing about further cross-border cooperation (e.g. Alpine Region, Euroregion Aquitaine-Euskadi-Navarre, Greater Copenhagen and Scania), but in operational terms, there are yet important challenges when different concepts of GI exist in different spatial planning jurisdictions.

There is no one-size-fits-all solution, but rather a suite of approaches that must be tailored to the context (goals, location, local climate/geology/geography, city/regional structure, governance, politics, knowledge, among others). The GRETA methodological approach can be adapted to produce detailed input information for strategic planning purposes if local level data is available. Annex I-C provides a protocol for downscaling and applying the GRETA methodology to map a potential GI network serving multiple land uses for the land.

Full individual case study reports are incorporated in Annex VI. The case study reports analyse i) the potential GI network in each case study, as delineated by the GRETA project, analysing the identified synergies and trade-offs between the ES provided by the GI network and its potential for serving several policy objectives, and providing a relative analysis of the region with the general EU patterns; ii) How do the case studies fare in meeting the existing demand for regulating, provisioning and cultural services offered by the GI network, based on GRETA analysis of: flood protection, soil erosion, water quality and recreation.

10 Policy recommendations and Future Research related to GI for Territorial Development

This section seeks to provide applicable guidelines for policy and decision makers at multiple levels of governance to facilitate analyse of spatial assets to support planning and implementing of green infrastructure (GI) for territorial development in the European Union. The overall purpose is to offer clear information about the potential opportunities and challenges related to GI that can be used for promotion and development of GI in different geophysical and political contexts.

The recommendations consider specific elements as outlined in the Terms of Reference for GRETA which include: (i) analysis of local / regional context through identification of existing GI and exploring territorial assets for enhancing GI development; (ii) investment opportunities through spatial planning; (iii) possibilities for private sector involvement and access to finance; and (iv) potential governance mechanisms. The chapter also provides suggestions on further research on GI.

10.1 Policy Recommendations

In recognition that policies and practices differ across geographical scales, the recommendations are structured by governance level at which they could be considered. The guidelines in sub-section 10.1.1 are considered relevant across all levels of governance. The next three sub-sections (10.1.2 to 10.1.4) focus on recommendations that consider the particularities at the national, regional and local levels. The recommendations are drawn from the analysis and research evidence presented in this final GRETA report; internal discussions and feedback within the project team; the outcome of a one-day workshop in Barcelona with the GRETA advisory group (see Annex V), and reflections from the ESPON Monitoring Committee and the Project Support Team associated with the GRETA project. As applicable, we have linked to current European policy being revised[19], in review or for which an Action Plan is currently implemented.

10.1.1 General policy recommendations across levels

The GRETA project findings highlight key policy implications that are relevant for supporting GI for territorial development in the European Union. Due to the variety of planning systems in Europe, there is still ambiguity around the question on which planning level it is feasible to make use of the GI concept and how to maximize benefit from its integrative capacity for supporting sustainable development. The following recommendations can help decision-makers at any level of governance to plan and implement a connected and multifunctional GI network.

- **Adopt a Green Infrastructure approach in planning.** A GI approach looks for connections – between different elements of nature in the geophysical area, between nature and people's quality of life, across ecological and political boundaries, and across policy sectors. GI provides a range of benefits – environmental, social, economic – and can contribute to mitigating long term environmental challenges such as climate change and biodiversity loss. To enable this, we suggest proactive and strategic planning. The GRETA research has

[19] e.g. (1) the Water Framework Directive fitness check; (2) Cohesion Policy post 2020; (3) EC's current work on sustainable finance.

identified the Strategic Environmental Assessment (SEA)[20] as an example of a suitable policy tool for incorporating GI into strategies, plans and programs (see GRETA Briefing 2 on how one might integrate GI into planning through the SEA process). The additional recommendations here also highlight ways through which a GI approach to planning can be undertaken.

- **Identify existing assets and opportunities for Green Infrastructure.** What green and blue elements in the area already exist or could be restored, enhanced or created to be part of a GI network? Use existing available data to look spatially across the area for ways to connect these elements. Think creatively – are there rooftops or other structures that could have vegetation planted on them? Are there agricultural lands that could be enhanced by adding for example hedgerows thereby providing habitat for wildlife and contributing to management of water? [See GRETA Briefing 3 for guidance on what methods might help with identification of existing assets and opportunities.]
- **Identify benefits and challenges of Green Infrastructure.** Planners and decision-makers should identify and quantify the main benefits and challenges of implementing GI for strategic planning and development, regardless of the of scale of governance. This should be informed by the existing data, information and knowledge about the multiple benefits and challenges associated with GI. It is important to recognise the multiple benefits provided by GI. Using a 'learning-by-doing' approach, based on scientific results and led by multi-disciplinarian scientific teams can help identify these multiple benefits. One method to include GI benefits into decision making is via cost-benefit analysis. Use this insight to inform investment decisions in GI. [See GRETA Briefing 1 for insight on benefits across spatial scales.]
- **Take the context into account.** The quantification of benefits and challenges related to GI should be adapted to the type of GI, its spatial configuration, and other contextual specificities which could include goals, location, local climate, geology, geography, city or regional structure, governance, politics and local skills and knowledge. There is no one-size-fits-all solution, but rather a suite of approaches that must be tailored to the context. [See GRETA Briefing 1 for benefits one might find at different spatial scales.]
- **Identify Green Infrastructure "hot-spots".** Planners and decision-makers should identify GI "hot spots" that either require increased safeguarding or restoration, informed by accurate and updated spatial data on potential GI networks. This should inform decisions on where to invest resources. [See GRETA Briefing 3 for methods that can help identify hot spots.]

[20] Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014.

- **Integrate Green Infrastructure planning across policy areas.** GI planning should be integrated across policy areas, including finance, energy, health and social services. This is key to reach wider territorial development goals. The European Commission's work on sustainable financing[21] provides an opportunity to integrate GI and finance for sustainable territorial development.

> **Policy Integration in Practice**:
>
> In some Swedish regions the health and social service sector can prescribe 'green care' to rehabilitate people that have been outside job market for a long time. These jobs are on appointed farms, in forestry and in park management.

- **Facilitate cross-scale and cross-stage collaboration**. Use green infrastructure development as a mechanism for further collaboration, awareness, capacity building, and knowledge exchange to build a common understanding between professionals operating at different implementation stages and scales. Such collaboration is especially important to adapt governance and management together with other territories, i.e. river basin levels, functional regions, not necessarily within traditional administrative borders.

> **Financing in Practice**:
>
> * Cyprus and Slovakia combine national environmental funds with European structural funds (i.e. ERDF, ESF, CF, EAFRD, EMFF).
>
> * Belgium used the EAFRD for agro-environmental subsidies to enhance agricultural lands.
>
> * Denmark improved environmental quality of Natura 2000 areas using EARFD funding mechanism.
>
> * Slovenia used Cohesion Funds for enhancing urban green areas.
>
> * The European Fund for Strategic Investments have strict targets for climate-smart investments to ensure reaching the Paris agreement.

- **Combine private and public funding mechanisms for Green Infrastructure implementation**. Key mechanisms that have been used to fund GI include LIFE+, Horizon 2020-project funds, European Regional Development Fund (ERDF) and the European Agricultural Fund for Rural Development (EAFRD). Make GI a sustainable investment opportunity as part of the EU's integration of sustainability into financial policy framework which accounting for social, environmental and governance considerations.
- **Develop a repository for valuation data specific to green infrastructure.** Such a repository could provide comparative data and facilitate benefit transfer analysis[22]. Suggested data to include: detailed description of the green infrastructure under study (type, size, ecosystem services provided, facilities, location), socio-demographic characteristics of the population benefiting from the green infrastructure, and detailed description of the method used for valuation and on its implementation, e.g. date of study, specific benefits being valued.

---

[21] https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance_en

[22] Benefit transfer is a method that can be used to provide a monetary value to Ecosystem Services provided by GI of interest by "transferring" and adapting values found elsewhere to the GI of interest.

- **Adapt existing guidance on economic valuation methods to the specificities of green infrastructure**. Guidance is needed on which methods are most suitable for benefits provided by GIs, and how to apply the methods, developing especially guidance related to the inclusion of non-market benefits (environmental and social benefits). For example, the European Commission's guide to the use of cost-benefit analysis (CBA) for investment projects[23] could be "translated" or adapted for the use of CBA for green infrastructure.
- **Monitor progress and adapt to change**. The relationships between GI, biodiversity, and ecosystem services are dynamic and must be monitored and examined over long time periods to develop effective and adaptive management measures. Previous efforts in ecosystem services evaluation and GI delineation can be used as a strong baseline to inform decision-making on monitoring.

10.1.2 Policy recommendations at the national scale

It is broadly perceived that the responsibility for doing GI-related policy should be a shared duty between different levels of public administration and other actors. GRETA research indicates that public administration perceives themselves as the actors taking on the most responsibility (compared to research, civil society organisations and businesses). To ensure GI implementation, this responsibility must be further shared between public administration and other stakeholders.

- **Integrate GI across policy areas**. Including GI into existing strategies, policies and legislation is in line with the EU strategy on GI (EC, 2013, p.10), as it states that GI principles can be implemented by using the existing policy and financial instruments. The GRETA research suggests that in some ESPON member states GI principles are already integrated into some policies beyond those related to biodiversity conservation, for example flood management (to meet the Floods Directive[24]). However, the implementation into different policy sectors is highly varying between the different countries.
- **Develop national GI policies and action plans.** National GI policies and action plans could be created in each European country, in order to facilitate the implementation of the European Union's GI Strategy with consideration to the national contexts. GRETA research suggests that although all 32 ESPON member states[25] include GI in their existing policy regimes, only 11 of these have specific GI policies at the national level. The research results indicate that in those countries where the national level have established GI specific policies and action plans, the implementation of GI is more in progress.
- **Increase awareness about GI.** GRETA research suggests there is a need for increased awareness and communication between sectors in order to operationalise GI as a cross-sectoral concept. The analysis carried out for GRETA can be useful to inform the integration of GI principles into existing policies in countries that have low integration. This can be by cross-

[23] https://ec.europa.eu/inea/sites/inea/files/cba_guide_cohesion_policy.pdf. See Annex on valuation methods, p. 321.
[24] Flood Directive, 2007/60/EC
[25] https://www.espon.eu/links/member-states

national and cross-regional learning. [See GRETA Briefing 1 for an overview of benefits and challenges of GI.]

- ❖ **Ensure the availability of data.** Accurate and updated spatial data on potential GI networks should inform evidence-based decision-making on spatial planning and on where to invest resources. Continued mapping of data such as protected areas, forests, agriculture, level of fragmentation should be carried out.
- ❖ **Provide training on economic valuation methods and on spatial analysis methods.** To ensure the consideration of the economic value of ecosystem services provided by GI in the spatial planning and decision-making process, GRETA research suggests that more training would be provided on valuation methods (such as cost-benefit analysis) and geographical information systems.
- ❖ **Learn and be inspired from existing good practice.** Much can be learnt from existing examples of GI implementation. GRETA offers good practice examples to showcase projects that are developing innovative GI solutions, including diverse spatial planning tools, legislated planning systems, stakeholder networks and financing projects that design, implement and/or manage GI projects.

10.1.3 Policy recommendations at the regional scale

Regional scale integration of green infrastructure (GI) with its concomitant benefits and multifunctionality can help meet European Union directives, such as the Cohesion Policy, that seek to reduce disparities and strengthen its regions.[26]

- ❖ **Plan strategically**. Land-use planning should be carried out strategically, using the best data available. The maps produced through the GRETA project provide an overview of potential GI networks and the delivery of ecosystem services throughout the European Union, based upon the best current European Union level data and offer a standardised comparison among European Union regions.

Regional differences in the potential for green infrastructure:

GRETA research identified the following:

* Potential for GI is lower in north-western France and Germany, south-eastern UK, Ireland, and Denmark. This makes the maintenance of existing GI, the improvement of connectivity between protected areas and restoration of natural and semi-natural areas,particularly important in these areas.

* The Nordic countries, the Balkan countries along the Adriatic Sea and the eastern Alpine region display the highest potential for GI networks but have the lowest share of protected core areas. This calls for attention to the unprotected links in those regions.

- ❖ **Plan for GI implementation in adaptive cycles**. Consider three-year timescales for decision-making and focus on GI strategy based in regional and local assessments. In practice, such assessments can be done in the same way as the GRETA research; by using

[26] https://ec.europa.eu/regional_policy/en/2021_2027/

the existing georeferenced data on land cover and land use to depict the connectivity between green and blue areas and to enable representation of areas with 'connectivity opportunities'. To continuously update the georeferenced data layers, it is crucial to ensure that land use changes based on monitoring are incorporated. [See GRETA Briefing 3 for insight on methods used in the GRETA research project.]

- **Take into account the synergies and trade-offs between ecosystem services**. The multifunctional character of GI elements provides a range of benefits by means of a variety of ecosystem services. These ecosystem services often appear in bundles, and under certain circumstances, are mutually reinforcing (i.e. they are in synergy with each other) while in other cases they can affect each other negatively (i.e. there are trade-offs between ecosystem services). Such relationships are important to be aware of in order to prioritise on the basis of the best knowledge available. When designing GI policies, it is important to consider these trade-offs and synergies.

> **Regional patterns of relationships between ecosystem services**:
>
> GRETA research identified the following
>
> * In Italy, France, parts of Germany, and Poland, most of the ecosystem services analysed have strong synergistic relationships.
>
> * In Eastern countries there are trade-offs between ecosystem services provided.

10.1.4 Policy recommendations at the local scale

The city level analysis allows for the identification of gaps and untapped potential in GI networks. Few cities in Europe have seen an increase in GI. This represents a critical opportunity for more joined-up, cross sector planning, particularly in the face of the urgent need for climate change mitigation and adaptation action.

GRETA research has identified the following recommendations:

- **Plan strategically**. The quantification of the benefits and challenges of GI identified in this research should be used to inform strategic planning and development of European regions and cities. The GRETA spatial analysis methodology can be applied at local / city level to identify hot spots of potential GI for the delivery of ecosystem services that support different policy objectives. Financial incentives and funding opportunities should not be limited to the mere conservation of green area but aim at preserving certain ecosystem services such as improving ecological resilience or increasing public health outcomes.

> Cities in eastern and southern Europe, the Netherlands and Finland have experienced a strong loss of green spaces between 2006 and 2012. In the context of climate change mitigation and adaptation, these cities must focus on strategic, cross-sector planning to reverse these critical development trends and cater for their sustainable development.

- **Facilitate cooperation between actors.** There is no general rule as to who should lead the process of GI implementation. This largely depends on the existing policy or project targets, where the project is being developed and who is promoting it. Ideally, it should be a cooperative process, in which local authorities are the main stakeholders but communities of interest and communities of practice are vital if GI is to be scaled out. Interdisciplinary teams guided by professionals should ensure the integration of knowledge from different domains. A combination of bottom-up and top-down approaches is probably the best option for effective GI implementation processes at local scale.

- **Create a shared vision.** It is important for stakeholders involved in the implementation of GI to have a shared strategic vision. Both policy-makers and planners should agree on common goals, ensuring that the processes of planning, implementation and maintenance of GI are coordinated. Training may be needed to ensure that all stakeholders involved across different sectors have an adequate knowledge of the costs and benefits of implementing GI as well as in the processes of planning, implementation and maintenance of GI and on the functioning of ecosystems. The spatial analysis methodology presented in GRETA can provide the data needed to inform discussions and decision-making regarding the distribution of funding and subsidies for GI for territorial development.

10.2 Future research

The GRETA research has identified six areas that would need further research for successful GI implementation:

- **Understand the demand for GI**. It is important to understand the relationship between the supply of and demand for GI in European regions and cities, and further research in this connection is needed, building on GRETA results. The type of analysis presented in this research can help to inform the prioritisation of efforts to develop and invest in GI to meet current and future demand. The spatial analysis methodology presented in this research, which correlates the number of inhabitants in an area (demand) with access to green areas (supply), can be useful in identifying deficiencies in the availability of potential GI. The GRETA research has also found practice planning examples that illustrate the use of the supply and demand analysis of GI as an indicator for planners in the municipality of Oslo (Norway) and the municipality of Gothenburg (Sweden).
- **Continuous monitoring and sharing data.** The positive link between, on the one hand, GI and, on the other hand biodiversity and ES, is a starting point for the GRETA spatial analysis. To further the certainty of the empirical evidence on the benefits of implementing GI would require specific monitoring over a certain period of time. Time series and change/trend analysis in this context of monitoring and data would be beneficial.
- **Establish and assess the quality of GI.** For quantity of GI, the GRETA research indicates that much data is established on local, regional and national levels. GRETA research has found that improved indicators and metrics for assessing the quality of GI are needed. Such indicators can possibly be linked to the ongoing development of indicators for the 17 Sustainable Development Goals.
- **In-depth analysis on synergies and trade-offs in different European regions.** The GRETA methodology and findings allow for identification of areas to strengthen cooperation

for transboundary spatial planning. This is, for instance, the case for Eastern European countries, where GRETA research found indications on regional patterns of trade-offs. Further research is needed to understand the social and geographical disparities of the trade-offs and synergies. This to identify alternatives to minimize potential side effects of green infrastructure.

- **Investigation into the role of the private sector.** The GRETA research indicates the need to further highlight the importance of private sector, NGOs and private individuals in GI implementation. To further the integration of also other actors and institutions than public administration, the role of private actors (business owners, farmers and foresters, and urban land owners) in the implementation and management of GI needs further research attention.
- **Investigate failure of implementation.** The GRETA research indicates a need to further identify failure of implementing GI. Such failures could for instance be found in situations with low political support for GI, and where a holistic and spatial perspective of GI is lacking.

References

Alberti, M., 2015. Eco-evolutionary dynamics in an urbanizing planet. Trends Ecol. Evol. 30, 114–126. https://doi.org/10.1016/j.tree.2014.11.007

Ahern, K. and Cole, L. 2012. Landscape scale – towards an integrated approach. ECOS, 33, pp. 6-12.

Andreucci, M. B. 2013. Progressing green infrastructure in Europe. WIT Transactions on Ecology and the Environment, 179 Volume 1, 413-422. doi:10.2495/SC130351

Angelstam, P., Andersson, K., Annerstedt, M., Axelsson, R., Elbakidze, M., Garrido, P., … Stjernquist, I. 2013. Solving Problems in Social–Ecological Systems: Definition, Practice and Barriers of Transdisciplinary Research. AMBIO, 42(2), 254–265. https://doi.org/10.1007/s13280-012-0372-4

Baró, F., Bugter, R., Gómez-Baggethun, E., Hauck, J., Kopperoinen, L., Liquete, C., and Potschin, P. 2015. Green Infrastructure. In: Potschin, M. and K. Jax (eds): OpenNESS Ecosystem Service Reference Book. EC FP7 Grant Agreement no. 308428. Available via: www.openness-project.eu/library/reference-book

Bartesaghi Koc, C., Osmond, P., Peters, A., 2018. Evaluating the cooling effects of green infrastructure: A systematic review of methods, indicators and data sources. Sol. Energy 166, 486–508. https://doi.org/10.1016/j.solener.2018.03.008

Beckett, K.P., Freer-Smith, P.H., Taylor, G., 1998. Urban woodlands: their role in reducing the effects of particulate pollution. Environ. Pollut. 99, 347–360. https://doi.org/10.1016/S0269-7491(98)00016-5

Benedict, M.A. and McMahon, E.T. 2002. Green Infrastructure: Smart Conservation for the 21st Century Renewable Resources Journal, 20, 12-17.

Bennett, E. M., Peterson, G. D., & Gordon, L. J. (2009). Understanding relationships among multiple ecosystem services. Ecology Letters, 12(12), 1394–1404. https://doi.org/10.1111/j.1461-0248.2009.01387.x

Berardi, U., GhaffarianHoseini, A., GhaffarianHoseini, A., 2014. State-of-the-art analysis of the environmental benefits of green roofs. Appl. Energy 115, 411–428. https://doi.org/10.1016/j.apenergy.2013.10.047

Bockarjova, Marija. and Botzen, W. (2017) Review of Economic Valuation of Nature Based Solutions in Urban Areas. Report for the H2020 Naturvation project, grant agreement No. 730243. Deliverable 1.3 part III. 34p.

Boithias, L., Acuña, V., Vergoñós, L., Ziv, G., Marcé, R., Sabater, S., 2014. Assessment of the water supply:demand ratios in a Mediterranean basin under different global change scenarios and mitigation alternatives. Sci. Total Environ. 470–471, 567–577. https://doi.org/10.1016/j.scitotenv.2013.10.003

Bowen, K.J., Lynch, Y., 2017. The public health benefits of green infrastructure: the potential of economic framing for enhanced decision-making. Curr. Opin. Environ. Sustain., Sustainability challenges 25, 90–95. https://doi.org/10.1016/j.cosust.2017.08.003

Brander, L. M., & Koetse, M. J. 2011. The value of urban open space: Meta-analyses of contingent valuation and hedonic pricing results. Journal of Environmental Management, 92(10), 2763–2773. https://doi.org/10.1016/j.jenvman.2011.06.019

Brudermann, T., & Sangkakool, T. 2017. Green roofs in temperate climate cities in Europe – An analysis of key decision factors. Urban Forestry and Urban Greening, 21, 224-234. doi:10.1016/j.ufug.2016.12.008

Burkhard, B., Kroll, F., Nedkov, S., Müller, F., 2012. Mapping ecosystem service supply, demand and budgets. Ecol. Indic., Challenges of sustaining natural capital and ecosystem services 21, 17–29. https://doi.org/10.1016/j.ecolind.2011.06.019

Burkhard, B., Maes, J., 2017. Mapping Ecosystem Services. Adv. Books 1, e12837. https://doi.org/10.3897/ab.e12837

Byrnes, J., Lefcheck, J. S., Gamfeldt, L., Griffin, J. N., Isbell, F., & Hector, A. 2014. Multifunctionality does not imply that all functions are positively correlated. Proceedings of the National Academy of Sciences, 111, E5490–E5490.

Camps-Calvet, M., Langemeyer, J., Calvet-Mir, L., Gómez-Baggethun, E., 2016. Ecosystem services provided by urban gardens in Barcelona, Spain: Insights for policy and planning. Environ. Sci. Policy, Advancing urban environmental governance: Understanding theories, practices and processes shaping urban sustainability and resilience 62, 14–23. https://doi.org/10.1016/j.envsci.2016.01.007

Carr, M.H., Hoctor, T.D., Goodison, C., Zwick, P.D., Green, J., Hernandez, P., et al., 2002. Final Report: Southeastern Ecological Framework, http://www. geoplan.ufl.edu/epa/index.html—accessed 261009.

Charlesworth, Susanne M., and Colin A. Booth. 2012. 'The Benefits of Green Infrastructure in Towns and Cities'. In Solutions to Climate Change Challenges in the Built Environment, edited by Colin A. Booth, Felix N. Hammond, Jessica E. Lamond, and David G. Proverbs, 163–79. Oxford, UK: Wiley-Blackwell. https://doi.org/10.1002/9781444354539.ch14.

Cimon-Morin, J., M. Darveau, and M. Poulin, 2013, Fostering synergies between ecosystem services and biodiversity in conservation planning: A review, Biological Conservation 166: 144–154.144–154.

Connop, S., Vandergert, P., Eisenberg, B., Collier, M.J., Nash, C., Clough, J., Newport, D., 2016. Renaturing cities using a regionally-focused biodiversity-led multifunctional benefits approach to urban green infrastructure. Environmental Science & Policy 62, 99–111. https://doi.org/10.1016/j.envsci.2016.01.013

Coutts, C., Hahn, M., 2015. Green Infrastructure, Ecosystem Services, and Human Health. Int. J. Environ. Res. Public. Health 12, 9768–9798. https://doi.org/10.3390/ijerph120809768

de la Fuente, B, M. C. Mateo-Sánchez, G. Rodríguez, A. Gastón, R. P. de Ayala, D. Colomina-Pérez, M. Melero, S. Saura. 2018. Natura 2000 sites, public forests and riparian corridors: The connectivity backbone of forest green infrastructure, Land Use Policy, 75, 2018, 429-441.

Díaz, S., Cabido, M., 2001. Vive la différence: plant functional diversity matters to ecosystem processes. Trends Ecol. Evol. 16, 646–655. https://doi.org/10.1016/S0169-5347(01)02283-2

Dunse, N., White, M., Dehring, C., Royal Institution of Chartered Surveyors, 2007. Urban parks, open space and residential property values. RICS, London.

EC. 2010. Towards a green infrastructure for Europe, Developing new concepts for integration of Natura 2000 network into a broader countryside, EC study ENV.B.2/SER/2007/0076. Available from: http://ec.europa.eu/environment/nature/ecosystems/docs/green_infrastructure_integration.pdf, accessed 06 November 2017.

EC. 2011. Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions 'Our life insurance, our natural capital: an EU biodiversity strategy to 2020' (COM(2011) 244 final, 3.5.2011) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0244:FIN:EN:PDF) accessed 25 August 2017.

EC. 2013. Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions 'Green infrastructure (GI) — Enhancing Europe's natural capital' (COM/2013/0249final) (http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52013DC0249) accessed 25 August 2017.

EC. 2013b The Economic benefits of the Natura 2000 Network Synthesis Report
http://ec.europa.eu/environment/nature/natura2000/financing/docs/ENV-12018_LR_Final1.pdf

EC and UN-Habitat (2016): The State of European Cities 2016. Cities leading the way to a better future. https://unhabitat.org/books/the-state-of-european-cities-2016-cities-leading-the-way-to-a-better-future

EC. 2018. The Natura 2000 Biogeographical Process
http://ec.europa.eu/environment/nature/natura2000/seminars_en.htm

Eckart, K., McPhee, Z., Bolisetti, T., 2017. Performance and implementation of low impact development – A review. Sci. Total Environ. 607–608, 413–432. https://doi.org/10.1016/j.scitotenv.2017.06.254

Ellis, J.B., 2013. Sustainable surface water management and green infrastructure in UK urban catchment planning. J. Environ. Plan. Manag. 56, 24–41. https://doi.org/10.1080/09640568.2011.648752

ENV.B.2/SER/2014/0012 Service Contract for "Supporting the Implementation of Green Infrastructure" Final Report http://ec.europa.eu/environment/nature/ecosystems/docs/green_infrastructures/GI%20Final%20Report.pdf, accessed 2018-05-25

European Environment Agency. 2011. Green infrastructure and territorial cohesion: the concept of green infrastructure and its integration into policies using monitoring systems. Publications Office of the European Union, Luxembourg.

European Environment Agency, 2014. Spatial analysis of green infrastructure in Europe, EEA Technical report No 2/2014, European Environment Agency (http://www.eea.europa.eu/publications/spatial-analysis-of-green-infrastructure) accessed 25 August 2017.

European Environment Agency, 2018. Similarities and diversity of European cities. A typology tool to support urban sustainability. ETC/ULS. Report | 03/2018. https://uls.eionet.europa.eu/Reports/ETC-ULS_report_CityTypology_final

Estreguil, C., et al. 2014. Connectivity of Natura 2000 forest sites in Europe. F1000 Posters 5, 485.

Estreguil, C. et al 2016 Enhancing Connectivity, Improving Green Infrastructure; EUR 28142 EN;doi:10.2788/170924

Francis, L.F.M., Jensen, M.B., 2017. Benefits of green roofs: A systematic review of the evidence for three ecosystem services. Urban For. Urban Green. 28, 167–176. https://doi.org/10.1016/j.ufug.2017.10.015

Fronczek-Wojciechowska, M., Kopacz, K., Padula, G., Wiśniewski, S., Wojnarowska, A., 2017. Proposal for a Method of Constructing Inclusive Urban Green Infrastructure. Eur. Spat. Res. Policy 24, 81–105. https://doi.org/10.1515/esrp-2017-0005

Galera H, Sudnik-Wójcikowska B. Central European botanic gardens as centres of dispersal of alien plants. Acta Societatis Botanicorum Poloniae. 2011;79(2):147-156. doi:10.5586/asbp.2010.020

Gallent, N., Shaw, D., 2007. Spatial planning, area action plans and the rural-urban fringe. J. Environ. Plan. Manag. 50, 617–638. https://doi.org/10.1080/09640560701475188

Garmendia, E., Apostolopoulou, E., Adams, W.M., Bormpoudakis, D., 2016. Biodiversity and Green Infrastructure in Europe: Boundary object or ecological trap? Land Use Policy 56, 315–319. https://doi.org/10.1016/j.landusepol.2016.04.003

Gill, S.E., Handley, J.F., Ennos, A.R., Pauleit, S., 2007. Adapting Cities for Climate Change: The Role of the Green Infrastructure [WWW Document]. https://doi.org/info:doi/10.2148/benv.33.1.115

Hegetschweiler, K.T., de Vries, S., Arnberger, A., Bell, S., Brennan, M., Siter, N., Olafsson, A.S., Voigt, A., Hunziker, M., 2017. Linking demand and supply factors in identifying cultural ecosystem services of urban green infrastructures: A review of European studies. Urban For. Urban Green. 21, 48–59. https://doi.org/10.1016/j.ufug.2016.11.002

Hein, L., van Koppen, K., de Groot, R.S., van Ierland, E.C., 2006. Spatial scales, stakeholders and the valuation of ecosystem services. Ecological Economics 57, 209–228. https://doi.org/10.1016/j.ecolecon.2005.04.005

Hoctor, T.S., Carr, M.H., Zwick, P.D., 2000. Identifying a linked reserve system using a regional landscape approach: the Florida ecological network. Conserv. Biol. 144, 984–1000

Liekens, I., Schaafsma, M., De Nocker, L., Broekx, S., Staes, J., Aertsens, J., & Brouwer, R. (2013). Developing a value function for nature development and land use policy in Flanders, Belgium. Land Use Policy, 30(1), 549–559. https://doi.org/10.1016/j.landusepol.2012.04.008

Janssen, I., Rosu, A., 2015. Undeveloped green space and free-time physical activity in 11 to 13-year-old children. Int. J. Behav. Nutr. Phys. Act. 12, 26. https://doi.org/10.1186/s12966-015-0187-3

Jayasooriya, V. M., Ng, A. W. M., Muthukumaran, S., & Perera, B. J. C. 2017. Green infrastructure practices for improvement of urban air quality. *Urban Forestry and Urban Greening, 21*, 34-47. doi:10.1016/j.ufug.2016.11.007

Jopke, C., Kreyling, J., Maes, J., & Koellner, T. 2015. Interactions among ecosystem services across Europe: Bagplots and cumulative correlation coefficients reveal synergies, trade-offs, and regional patterns. Ecological Indicators, 49, 46–52. https://doi.org/10.1016/j.ecolind.2014.09.037

Kandziora, M., Burkhard, B., and Muller, F. 2013. Interactions of ecosystem properties, ecosystem integrity and ecosystem service indicators - a theoretical matrix exercise. Ecol. Indicat. 28, 54–78.

Kong, F., Yin, H., Nakagoshi, N., Zong, Y., 2010. Urban green space network development for biodiversity conservation: Identification based on graph theory and gravity modeling. Landsc. Urban Plan. 95, 16–27. https://doi.org/10.1016/j.landurbplan.2009.11.001

Kowarik, I., 2011. Novel urban ecosystems, biodiversity, and conservation. Environ. Pollut. 159, 1974–1983. https://doi.org/10.1016/j.envpol.2011.02.022

Kremen, C., 2005. Managing ecosystem services: what do we need to know about their ecology? Ecology Letters 8, 468–479. https://doi.org/10.1111/j.1461-0248.2005.00751.x

Kroll, F., Müller, F., Haase, D., Fohrer, N., 2012. Rural-urban gradient analysis of ecosystem services supply and demand dynamics. Land Use Policy. https://doi.org/10.1016/j.landusepol.2011.07.008

Kuehler, E., Hathaway, J., Tirpak, A., 2017. Quantifying the benefits of urban forest systems as a component of the green infrastructure stormwater treatment network: Quantifying the Benefits of Urban Forest Systems as Green Infrastructure. Ecohydrology 10, e1813. https://doi.org/10.1002/eco.1813

Lafortezza, R., Davies, C., Sanesi, G., and Konijnendijk, C. 2013. Green Infrastructure as a tool to support spatial planning in European urban regions. iForest - Biogeosciences and Forestry, 6, 102–108.

Landscape Institute, 2009. Green infrastructure: connected and multifunctional landscapes — position document.

Liang, J., Crowther, T.W., Picard, N., et al., 2016. Positive biodiversity-productivity relationship predominant in global forests. Science 354, aaf8957. https://doi.org/10.1126/science.aaf8957

Lin, B.B., Philpott, S.M., Jha, S., 2015. The future of urban agriculture and biodiversity-ecosystem services: Challenges and next steps. Basic Appl. Ecol. 16, 189–201. https://doi.org/10.1016/j.baae.2015.01.005

Loomis, J.B., Richardson, R.B., 2006. An external validity test of intended behavior: Comparing revealed preference and intended visitation in response to climate change. J. Environ. Plan. Manag. 49, 621–630. https://doi.org/10.1080/09640560600747562

Lopes, R., & Videira, N. 2016. A Collaborative Approach for Scoping Ecosystem Services with Stakeholders: The Case of Arrábida Natural Park. Environmental Management, 58(2), 323–342. https://doi.org/10.1007/s00267-016-0711-5

Lopes, R., & Videira, N. 2017. Modelling feedback processes underpinning management of ecosystem services: The role of participatory systems mapping. Ecosystem Services, 28(Part A), 28–42. https://doi.org/10.1016/j.ecoser.2017.09.012

Loureiro, M.L., Macagno, G., Nunes, P.A.L.D., Tol, R., 2012. Assessing the impact of biodiversity on tourism flows: an econometric model for tourist behaviour with implications for conservation policy. J. Environ. Econ. Policy 1, 174–194. https://doi.org/10.1080/21606544.2012.692865MA. 2005.

MA, 2005. Ecosystems and human well-being: Synthesis, Millennium Ecosystem Assessment, Island Press, Washington, DC, USA (http://www.maweb.org/en/index.aspx) accessed 25 August 2017.

Maes, J., Paracchini, M. L., Zulian, G., Dunbar, M. B., & Alkemade, R. 2012. Synergies and trade-offs between ecosystem service supply, biodiversity, and habitat conservation status in Europe. Biological Conservation, 155, 1–12. https://doi.org/10.1016/j.biocon.2012.06.016.

Maes, J., Barbosa, A., Baranzelli, C., Zulian, G., Silva, F.B. e, Vandecasteele, I., Hiederer, R., Liquete, C., Paracchini, M.L., Mubareka, S., Jacobs-Crisioni, C., Castillo, C.P., Lavalle, C., 2015. More green infrastructure is required to maintain ecosystem services under current trends in land-use change in Europe. Landsc. Ecol. 30, 517–534. https://doi.org/10.1007/s10980-014-0083-2

Maes, J., Fabrega, Domenech N., Zulian, G., Barbonsa, A., Vizcaino, P., Ivits, E., Polce, C., Vandecasteele, I., Mari Rivero, I., Guerra, C., Perpina Castillo, C., Vallecillo, S., Baranzelli, C., Barranco, R., Batista e Silva, F., Jacobs-Crisoni, C., Trombetti, M., and Lavalle, C. 2015. Mapping and Assessment of Ecosystems and their Services: Trends in ecosystems and ecosystem services in the European Union between 2000 and 2010. Publications Office of the European Union, Luxemburg.

Maes, J., Teller, A., Erhard, M., Liquete, C., Braat, L., et al., 2013. Mapping and Assessment of Ecosystems and their Services. An Analytical Framework for Ecosystem Assessments under Action 5 of the EU Biodiversity Strategy to 2020. Discussion Paper. European Union, Luxembourg, 57 pp.

Maes, J., Teller, A., Erhard, M., Murphy, P., Paracchini, M.L., et al., 2014. Mapping and Assessment of Ecosystems and their Services. Indicators for Ecosystem Assessments under Action 5 of the EU Biodiversity Strategy to 2020. 2nd Report.European Union, Brussels, 80 pp.McGill, B., Enquist, B., Weiher, E., Westoby, M., 2006. Rebuilding community ecology from functional traits. Trends Ecol. Evol. 21, 178–185. https://doi.org/10.1016/j.tree.2006.02.002

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

Maes J, Teller A, Erhard M (2018) Shaping an EU wide ecosystem assessment. Scoping paper for an assessment of the state and trends of ecosystems and their services under Action 5 of the EU Biodiversity Strategy to 2020. 21 pp.

Maes J, Zulian G, Günther S, Thijssen M, Raynal J, Enhancing Resilience Of Urban Ecosystemsthrough Green Infrastructure. Final Report, EUR 29630 EN, Publications Office of the European Union,Luxembourg, 2019, ISBN 978-92-79-98984-1, doi:10.2760/602928, JRC115375.

McGill, B., Enquist, B., Weiher, E., Westoby, M., 2006. Rebuilding community ecology from functional traits. Trends Ecol. Evol. 21, 178–185. https://doi.org/10.1016/j.tree.2006.02.002

McMorris, O., Villeneuve, P.J., Su, J., Jerrett, M., 2015. Urban greenness and physical activity in a national survey of Canadians. Environ. Res. 137, 94–100. https://doi.org/10.1016/j.envres.2014.11.010

Mekala, G.D., R.N. Jones, and D.H. MacDonald. 2015. 'Valuing the Benefits of Creek Rehabilitation: Building a Business Case for Public Investments in Urban Green Infrastructure'. Environmental Management 55 (6): 1354–65. https://doi.org/10.1007/s00267-015-0471-7.

Mell, I. C., Henneberry, J., Hehl-Lange, S., & Keskin, B. 2013. Promoting urban greening: Valuing the development of green infrastructure investments in the urban core of Manchester, UK. Urban Forestry and Urban Greening, 12(3), 296-306. doi:10.1016/j.ufug.2013.04.006

Mell, I. C. 2017. Green infrastructure: reflections on past, present and future praxis. Landscape Research, 42, 135–145.

Mubareka, S., Estreguil, C., Baranzelli, C., Rocha Gomes, C., Lavalle, C. and Hofer, B. 2013. A land-use based modelling chain to assess the impacts of Natural Water Retention Measures on Europe's Green Infrastructure, Int. J. of Geogr. 27, 1740–1763.

Mytton, O.T., Townsend, N., Rutter, H., Foster, C., 2012. Green space and physical activity: An observational study using Health Survey for England data. Health Place 18, 1034–1041. https://doi.org/10.1016/j.healthplace.2012.06.003

Neuvonen, M., Pouta, E., Puustinen, J., Sievänen, T., 2010. Visits to national parks: Effects of park characteristics and spatial demand. J. Nat. Conserv. 18, 224–229. https://doi.org/10.1016/j.jnc.2009.10.003

Northwest Regional Development Agency (NWDA), 2008. The Economic Value of Green Infrastructure.

O'Brien, L., De Vreese, R., Kern, M., Sievänen, T., Stojanova, B., Atmiş, E., 2017. Cultural ecosystem benefits of urban and peri-urban green infrastructure across different European countries. Urban For. Urban Green. 24, 236–248. https://doi.org/10.1016/j.ufug.2017.03.002

OECD, 2002, Redefining Territories. The Functional Regions.http://www.urbanpro.co/wp-content/uploads/2017/04/Redefining-Territories-The-functional-regions.pdf

Panagos, P., Borrelli, P., Poesen, J., Ballabio, C., Lugato, E., Meusburger, K., Montanarella, L., Alewell, C., 2015. The new assessment of soil loss by water erosion in Europe. Environ. Sci. Policy 54, 438–447. https://doi.org/10.1016/j.envsci.2015.08.012

Paracchini, M. L.; Petersen, J.-E.; Hoogeveen, Y.; Bamps, C.; Burfield, I. and van Swaay, C. 2008. High Nature Value Farmland in Europe. An estimate of the distribution patterns on the basis of land cover and biodiversity data. JRC Scientific and Technical Reports. European Communities, Luxembourg.

Pearlmutter, D., Calfapietra, C., Samson, R., O'Brien, L., Ostoić, S.K., Sanesi, G., Amo, R.A. del, 2017. The Urban Forest: Cultivating Green Infrastructure for People and the Environment. Springer.

Piorr, A., PLUREL (Project) (Eds.). 2011. Peri-urbanisation in Europe: towards European policies to sustain urban-rural futures: synthesis report. Forest & Landscape, University of Copenhagen, Frederiksberg.

Pochee, H., and I. Johnston. 2017. 'Understanding Design Scales for a Range of Potential Green Infrastructure Benefits in a London Garden City'. Building Services Engineering Research and Technology 38 (6): 728–56. https://doi.org/10.1177/0143624417734526.

Poelman, H., 2018, A walk to the park? Assessing access to greeen areas in Europe's cities, Working Papers WP 01/2016, EC Regional and Urban Policy.

Rapport, D.J., Gaudet, C.L., Calow, P., 1995. Evaluating and Monitoring the Health of Large-Scale Ecosystems.

Raudsepp-Hearne, C., Peterson, G. D., & Bennett, E. M. 2010. Ecosystem service bundles for analyzing tradeoffs in diverse landscapes. Proceedings of the National Academy of Sciences, 107(11), 5242–5247. https://doi.org/10.1073/pnas.0907284107

Richardson, R.B., Loomis, J.B., 2005. Climate Change and Recreation Benefits in an Alpine National Park. J. Leis. Res. 37, 307–320. https://doi.org/10.1080/00222216.2005.11950055

Rodríguez, J., Beard, J., Bennett, E., Cumming, G., Cork, S., Agard, J., … Peterson, G. 2006. Trade-offs across Space, Time, and Ecosystem Services. Ecology and Society, 11(1). https://doi.org/10.5751/ES-01667-110128

Rojas, R., Feyen, L., Bianchi, A., Dosio, A., 2012. Assessment of future flood hazard in Europe using a large ensemble of bias-corrected regional climate simulations: FUTURE FLOOD HAZARD AND CLIMATE CHANGE. J. Geophys. Res. Atmospheres 117, n/a-n/a. https://doi.org/10.1029/2012JD017461

Russo, A., Escobedo, F.J., Cirella, G.T., Zerbe, S., 2017. Edible green infrastructure: An approach and review of provisioning ecosystem services and disservices in urban environments. Agric. Ecosyst. Environ. 242, 53–66. https://doi.org/10.1016/j.agee.2017.03.026

Sailor, D.J., 1998. Simulations of annual degree day impacts of urban vegetative augmentation. Atmos. Environ., Conference on the Benefits of the Urban Forest 32, 43–52. https://doi.org/10.1016/S1352-2310(97)00178-7

Salmond, J.A., Tadaki, M., Vardoulakis, S., Arbuthnott, K., Coutts, A., Demuzere, M., Dirks, K.N., Heaviside, C., Lim, S., Macintyre, H., McInnes, R.N., Wheeler, B.W., 2016. Health and climate related ecosystem services provided by street trees in the urban environment. Environ. Health 15, S36. https://doi.org/10.1186/s12940-016-0103-6

Säumel, I., Weber, F., Kowarik, I., 2015. Toward livable and healthy urban streets: Roadside vegetation provides ecosystem services where people live and move. Environ. Sci. Policy 62, 24–33. https://doi.org/10.1016/j.envsci.2015.11.012

Schleyer, C., I. M. Bouwma, E. Primmer, G. Bela, P. Berry, A. Smith, J. Hauck, K.J. Winkler, C. Deerenberg, J. Young, E. Carmen, P. Bezák, J. Ŝpulerová, Z. Barankova, H.-L. Kangas, E. Preda, A. Vadineanu, and C. Görg. 2015. Paper on the Policy Analysis. EU FP7 OpenNESS Project Deliverable 2.1, European Commission FP7.

Schröter, M., Barton, D.N., Remme, R.P., Hein, L., 2014. Accounting for capacity and flow of ecosystem services: A conceptual model and a case study for Telemark, Norway. Ecol. Indic. 36, 539–551. https://doi.org/10.1016/j.ecolind.2013.09.018

Schröter, M., Koellner, T., Alkemade, R., Arnhold, S., Bagstad, K.J., Erb, K.-H., Frank, K., Kastner, T., Kissinger, M., Liu, J., López-Hoffman, L., Maes, J., Marques, A., Martín-López, B., Meyer, C., Schulp, C.J.E., Thober, J., Wolff, S., Bonn, A., 2018. Interregional flows of ecosystem services: Concepts, typology and four cases. Ecosyst. Serv., Global Flows of Ecosystem Services 31, 231–241. https://doi.org/10.1016/j.ecoser.2018.02.003

Schulp, C. J. E., Burkhard, B., Maes, J., Vliet, J. V., & Verburg, P. H. 2014. Uncertainties in Ecosystem Service Maps: A Comparison on the European Scale. PLOS ONE, 9(10), e109643

Schwarz, N., Moretti, M., Bugalho, M.N., Davies, Z.G., Haase, D., Hack, J., Hof, A., Melero, Y., Pett, T.J., Knapp, S., 2017. Understanding biodiversity-ecosystem service relationships in urban areas: A comprehensive literature review. Ecosyst. Serv. 27, 161–171. https://doi.org/10.1016/j.ecoser.2017.08.014

Scott, A., Dean, A., Barry, V., Kotter, R., 2018. Places of urban disorder? Exposing the hidden nature and values of an English private urban allotment landscape. Landsc. Urban Plan. 169, 185–198. https://doi.org/10.1016/j.landurbplan.2017.09.004

Seppelt, R., Dormann, C.F., Eppink, F.V., Lautenbach, S., Schmidt, S., 2011. A quantitative review of ecosystem service studies: approaches, shortcomings and the road ahead. Journal of Applied Ecology 48, 630–636. https://doi.org/10.1111/j.1365-2664.2010.01952.x

Sikorska, D., Sikorski, P., & Hopkins, R. J. 2017. High biodiversity of green infrastructure does not contribute to recreational ecosystem services. Sustainability (Switzerland), 9(3). doi:10.3390/su9030334

Tallis, M., Taylor, G., Sinnett, D., Freer-Smith, P. 2011. Estimating the removal of atmospheric particulate pollution by the urban tree canopy of London, under current and future environments. Landsc. Urban Plan. 103, 129–138. https://doi.org/10.1016/j.landurbplan.2011.07.003

Turkelboom, F., Thoonen, M., Jacobs, S., García-Llorente, M., Martín-López, B., & Berry, P. 2016. Ecosystem services trade-offs and synergies. Unpublished. https://doi.org/10.13140/RG.2.1.4882.9529

Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemela, J., James, P. 2007. Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. Landsc. Urban Plan. 81, 167–178. https://doi.org/10.1016/j.landurbplan.2007.02.001

Ulrich, R.S. 2002. Health benefits of gardens in hospitals, in: Plants for People. Presented at the International Exhibition Floriade, Plant for People, Haarlemmermeer, the Netherlands.

van den Belt, M., & Blake, D. (2014). Ecosystem services in new Zealand agro-ecosystems: A literature review. Ecosystem Services, 9, 115–132. https://doi.org/10.1016/j.ecoser.2014.05.005

Verboom J, Snep RPH, Stouten J et al. 2014. Using Minimum Area Requirements (MAR) for assemblages of mammal and bird species in global biodiversity assessments. WOt-paper 33. Wageningen, Statutory Research Tasks Unit for Nature & the Environment, Wageningen University and Research Centre.

Verburg, P.H., Crossman, N., Ellis, E.C., Heinimann, A., Hostert, P., Mertz, O., Nagendra, H., Sikor, T., Erb, K.H., Golubiewski, N., Grau, R., Grove, M., Konaté, S., Meyfroidt, P., Parker, D.C., Chowdhury, R.R., Shibata, H., Thomson, A., Lin Zhen, Land system science and sustainable development of the earth system: A global land project perspective, Anthropocene, Volume 12, 2015, Pages 29-41, ISSN 2213-3054,Villamagna, A.M., Angermeier, P.L., Bennett, E.M., 2013. Capacity, pressure, demand, and flow: A conceptual framework for analyzing ecosystem service provision and delivery. Ecol. Complex. 15, 114–121. https://doi.org/10.1016/j.ecocom.2013.07.004

Wade, R., McLean, N. 2014. Multiple Benefits of Green Infrastructure, in: Booth, C.A., Charlesworth, S.M. (Eds.), Water Resources in the Built Environment. John Wiley & Sons, Ltd, Chichester, UK, pp. 319–335. https://doi.org/10.1002/9781118809167.ch24

Warming, M., Hansen, M. G., Holm, P. E., Magid, J., Hansen, T. H., & Trapp, S. 2015. Does intake of trace elements through urban gardening in Copenhagen pose a risk to human health? Environmental Pollution, 202, 17–23. https://doi.org/10.1016/j.envpol.2015.03.011

Weber, T., (2004) Landscape ecological assessment of the Chesapeake Bay watershed. Env Mon Ass 94:39-53.

Weber, T., Sloan, A., and Wolf, J. 2006. Maryland's green infrastructure assessment: development of a comprehensive approach to land conservation. Landsc. Urban Plan. 77, 94–110.

West, P.C., Gibbs, H.K., Monfreda, C., Wagner, J., Barford, C.C., Carpenter, S.R., Foley, J.A., 2010. Trading carbon for food: Global comparison of carbon stocks vs. crop yields on agricultural land. Proceedings of the National Academy of Sciences of the United States of America 107, 19645–19648. https://doi.org/10.1073/pnas.1011078107

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

Wickham, J.D., Riitters, K.H., Wade, T.G., and Vogt, P. 2010. A national assessment of green infrastructure and change for the conterminous United States using morphological image processing. Landsc. Urban Plan. 94, 186–195.

Williams, N.S.G., Lundholm, J., Scott MacIvor, J., 2014. FORUM: Do green roofs help urban biodiversity conservation? J. Appl. Ecol. 51, 1643–1649. https://doi.org/10.1111/1365-2664.12333

Wise, S., Braden, J., Ghalayini, D., Grant, J., Kloss, C., MacMullan, E., Morse, S., Montalto, F., Nees, D., Nowak, D., Peck, S., Shaikh, S., Yu, C. 2010. Integrating Valuation Methods to Recognize Green Infrastructure's Multiple Benefits. American Society of Civil Engineers, pp. 1123–1143. https://doi.org/10.1061/41099(367)98

Wolff, S., Schulp, C.J.E., Verburg, P.H., 2015. Mapping ecosystem services demand: A review of current research and future perspectives. Ecol. Indic. 55, 159–171. https://doi.org/10.1016/j.ecolind.2015.03.016

Wood, S.A., Guerry, A.D., Silver, J.M., Lacayo, M., 2013. Using social media to quantify nature-based tourism and recreation. Sci. Rep. 3. https://doi.org/10.1038/srep02976

Wright, H. 2011. Understanding green infrastructure: the development of a contested concept in England. Local Environment: The International Journal of Justice and Sustainability, 16, 1003–1019.

Zinko, U., Ersborg, J., Jansson, U., Pettersson, I., Thylén, A., & Vincentz, R. 2018. Grön infrastruktur i urbana miljöer. TemaNord 2018:518.

List of Annexes

Annex I: Green Infrastructure and Ecosystem Services Assessment in European Regions and Cities

Annex II: Ecological, social, cultural and economic benefits and demand for Green Infrastructure in Europe

Annex III Economic methods and financial mechanisms

Annex IV Governance, policy and planning contexts for GI implementation in Europe

Annex V Policy and practice guidelines

Annex VI Case Study reports

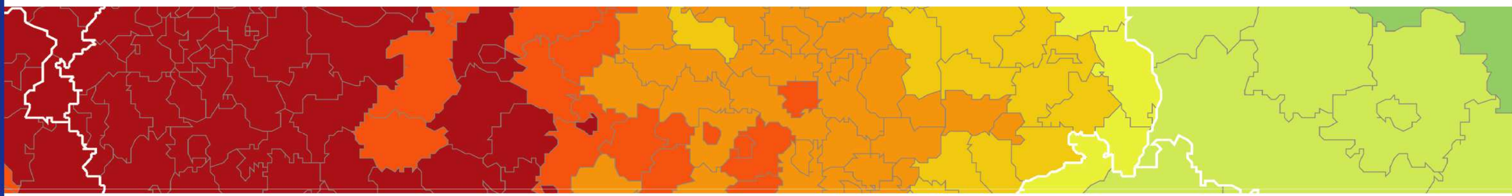
Additional Documents

Advisory Board Workshop Report

GRETA Briefing 1 Unpacking Green Infrastructure

GRETA Briefing 2 Relating Green Infrastructure to the Strategic Environmental Assessment

GRETA Briefing 3 Planning for Green Infrastructure: Methods to support practitioners and decision-making.



ESPON 2020 – More information

ESPON EGTC
4 rue Erasme, L-1468 Luxembourg - Grand Duchy of Luxembourg
Phone: +352 20 600 280
Email: **info@espon.eu**
www.espon.eu, **Twitter**, **LinkedIn**, **YouTube**

The ESPON EGTC is the Single Beneficiary of the ESPON 2020 Cooperation Programme. The Single Operation within the programme is implemented by the ESPON EGTC and co-financed by the European Regional Development Fund, the EU Member States and the Partner States, Iceland, Liechtenstein, Norway and Switzerland.