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

Applied Research

Final Synthesis Report

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Abbreviations

CCDRR	Climate change, and disaster-risk reduction
CLC	Corine Land Cover
EbA	Ecosystem based Adaptation
EC	European Commission
EAFRD	European Agricultural Fund for Rural Development
EFTA	European Free Trade Association
ERDF	European Regional Development Fund
ES	Ecosystem Services
ESM	Ecosystem Services Mapping
ESPON	European Territorial Observatory Network
EU	European Union
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
LU	Land Use
LC	Land Cover
N2K	Natura 2000 sites
NBS	Nature Based Solutions
NEP	Net Ecosystem Productivity
NUTS	Nomenclature of Territorial Units for Statistics
NWRM	Natural water retention measures
MS	Member State
OSM	Open Street Maps
PM	Physical Mapping
RecPot	Recreation Potential
RP	Relative Polliation
SEC	Soil Erosion Control
SES	Socio-Ecological System
WP	Water Purification
WR	Water Retention Index
WTP	Willingness to pay
UHI	Urban Heat Island

1. The Green Infrastructure concept, main benefits and impacts

Green Infrastructure (GI) and Ecosystem Services (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 in 2005. GRETA adopts the GI definition proposed by the European Commission (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: (i) connectivity, the idea of a network of geographical areas; (ii) the concept of multifunctionality, 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.

Proper delineation and implementation of GI requires an understanding of the potential benefits and impacts on the natural systems, but also on the socio-economic systems (SES). A causal loop diagram has been used to qualitatively describe the main elements and relations of SES that facilitate the implementation of GI. A combination of an extensive literature review and collaborative development with a range of stakeholders on the conceptual framework for GI implementation in Europe underpins the GRETA results.

The multifunctional character of GI elements provides a **range of benefits** by means of a variety of ES, which often appear in bundles, and can be mutually reinforcing under certain circumstances. The results of the literature 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 generally accepted within both scientific and policy-maker communities that the enhancement of GI has a positive link with biodiversity and ES, although there is little evidence on the specific mechanisms behind this relation. 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 only partial data is available. This positive link between GI on the one hand, and biodiversity and ES on the other hand, was a starting point for the GRETA spatial analysis. Simultaneous maximisation of all possible benefits to different GI policies is unlikely, thus trade-offs need to be strategically assessed.

GI is most prominently integrated into the following policy sectors: land use and spatial development planning; water management; agriculture, forestry, and fisheries; climate change mitigation and adaptation; environmental protection and biodiversity conservation; and rural development. GI is less prominent in the following policy sectors: finance, energy, health, and social services.

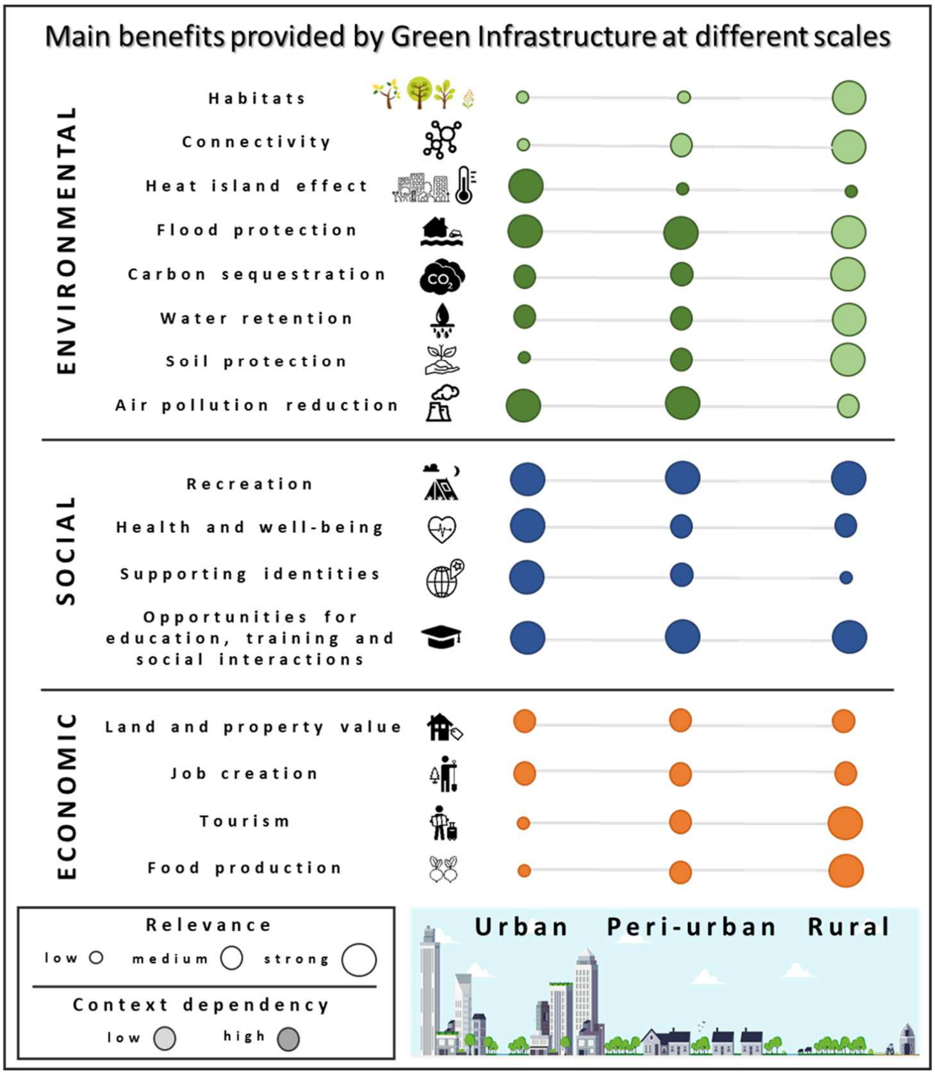


Table 1 Summary of main benefits provided by GI at different scales. Source: Prepared by the authors based on the combination of a literature review and expert knowledge.

In GRETA, a specific focus has been placed on the policy objectives related to biodiversity, climate change and disaster risk reduction, and water management. These three policies were selected 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 today, which is also linked to water management, and is critical for human survival and many economic activities. Preliminary findings from a policy analysis in 32 ESPON countries indicated that the selected policy frameworks are among those that include principles which are important for GI and that reinforce the policy priorities. From the perspective of functioning natural systems, these three policy areas are among those that most benefit from the operationalisation of the ES concept i.e. those that benefit most from adopting systematic and integrative strategies to include ES in their operational setting. Table 1 lists the benefits related to GI that have been stated by the studies GRETA reviewed.

The GRETA project also provides an overview of existing economic valuation studies on the benefits of GI in Europe. This overview identifies: (i) the variety of economic valuation methods that have been used; (ii) which ES (provided by GI) are being economically valued and how; and (iii) the average value associated with GI, accounting for characteristics such as size and location. The findings from a consultation with case study stakeholders determined that Cost-Benefit Analysis is currently not a widespread tool used in GI decision making, and when implemented, its implementation is heterogeneous and the benefits that are accounted for vary widely across the case studies. Most studies measure the monetary value of forests and parks, but other types of GI are still under researched. Across the studies, the finding have been that the general public: (i) seem to value GI more if the GI includes water elements and forests; (ii) have preferences for GI that provides, from highest to lowest preference, flood control, recreational services, and biodiversity support. These preferences, however, vary across the GRETA case studies.

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

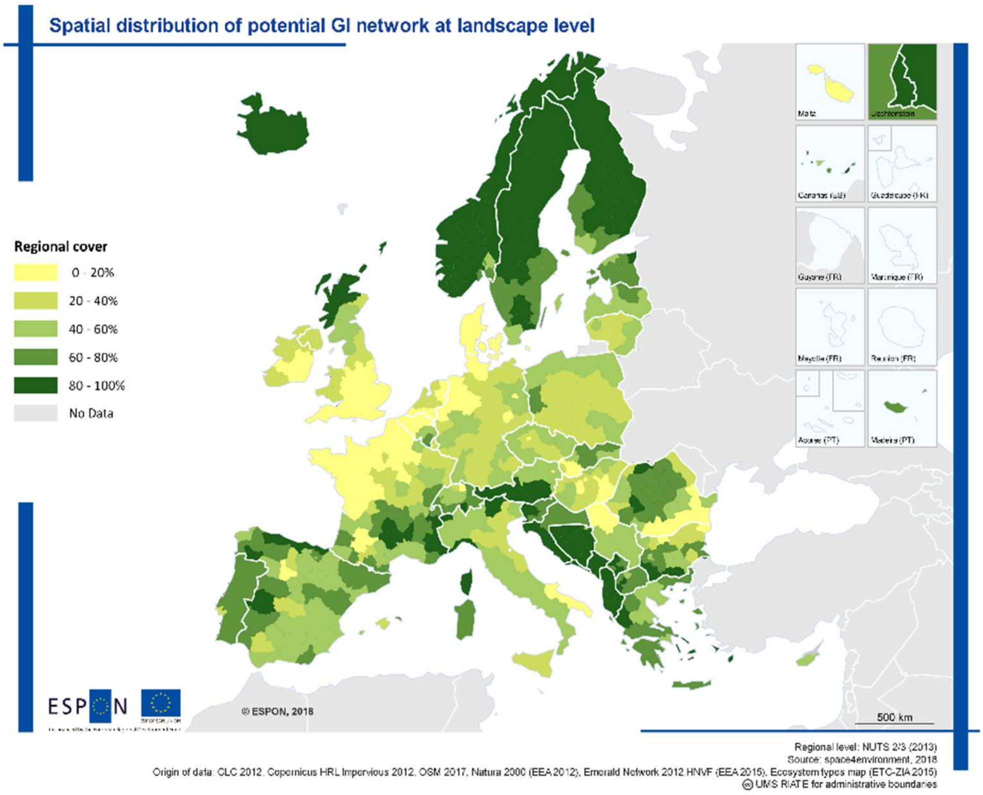
GRETA uses an innovative spatial analysis approach that combines: (i) a physical mapping of known areas of ecological value (hubs) (i.e. Natura 2000 and Emerald sites) and natural/semi-natural areas (links) (e.g. forests, grasslands, shrublands, farmland of inherent biodiversity value, and others, as mapped in standard European datasets such as CLC, Copernicus HRL impervious and High Natural Value Farmland); with (ii) an ES mapping to provide indicators which allow a standardised comparison to be made of a potential GI network across European regions at NUTS2/3 level and the ability of GI to deliver different policy objectives to be evaluated (i.e. biodiversity, climate change and disaster risk reduction, and water management). An understanding of the methodology applied and the data sets used in the analysis is important for the interpretation of the resulting maps.

The physical characteristics of potential GI in Europe

The spatial analysis of GI has resulted in an indication of a potential GI network at NUTS 2/3 level, in which two noticeable patterns can be clearly distinguished: (i) the very low percentage cover of potential GI in the regions of north-western France and Germany, south-eastern UK and Ireland, and Denmark; and (ii) the very high percentage cover of potential GI in the Nordic countries, the Balkan countries along the Adriatic Sea and the eastern Alpine region (Map 1).

This pattern is largely influenced by population density, infrastructure development, climatic and topographic conditions, as well as the distribution of utilised agricultural area in the EU territory – France has the largest agricultural area, followed by Spain, the UK and Germany.

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

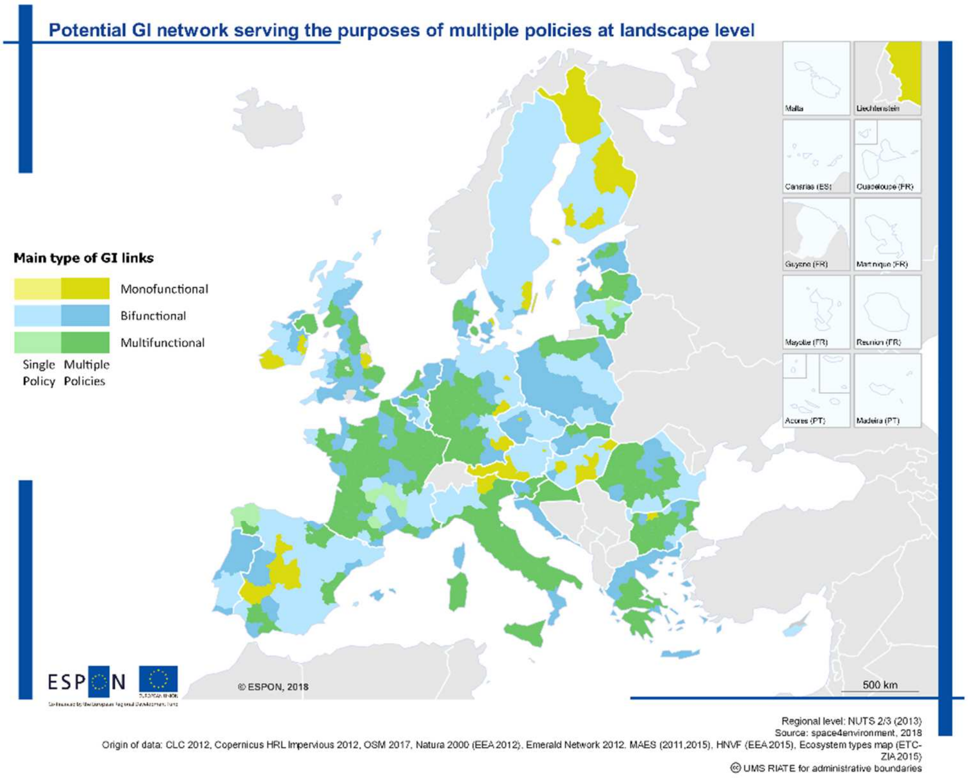


The functional performance of potential GI

Spatial analyses at NUTS 2/3 level were also used to investigate if the potential GI network is serving the purposes of multiple policy frameworks (biodiversity, water management, and climate change and disaster risk reduction) (Map 2).

ES and benefits provided by GI are unevenly distributed across Europe. The amount of services delivered simultaneously by GI and the number of policies benefiting from it are considerably higher in Central European regions, 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 change 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.

Map 2 Potential GI network serving the purposes of multiple policies at landscape level.

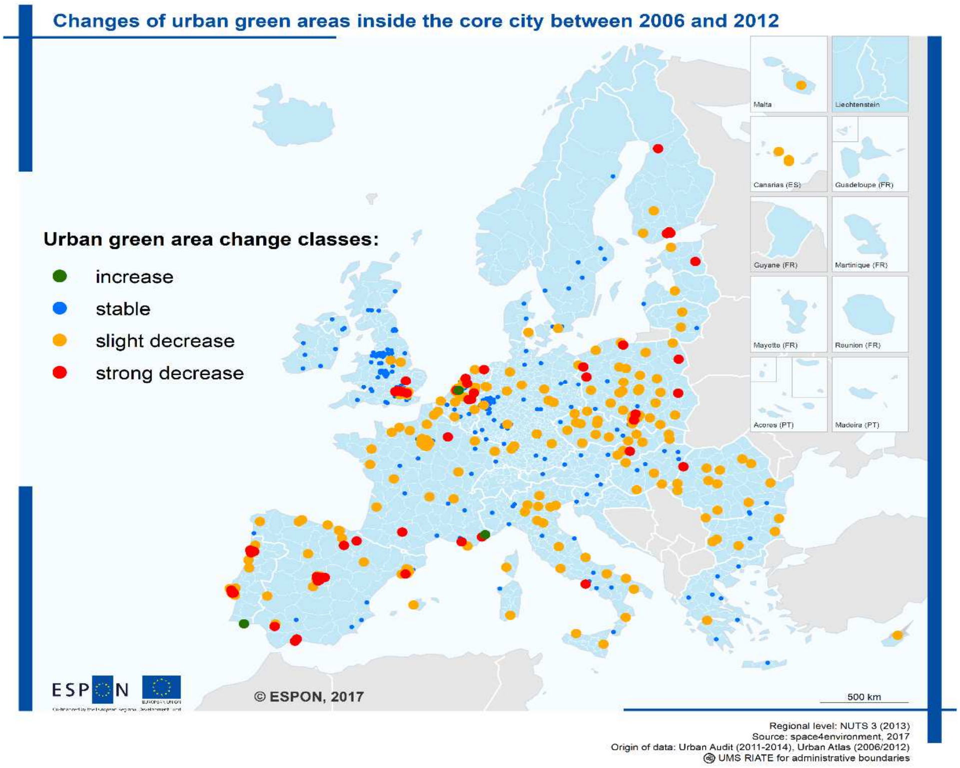


Differences in the type and amount of services provided by GI are due to both biophysical drivers (e.g. geology and climate) and land management practices, such as agriculture, forestry and urbanisation, which define the distribution and condition of natural ecosystems across Europe. Finally, the presence 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.

3. The geographic distribution of potential GI in European cities

At the urban level, GRETA provides an overview (only physical mapping) of urban GI based on green (and blue) urban areas for all core cities in Europe with an assessment of changes between 2006-2012. Changes in the share of green urban areas have been computed for around 500 cities, using the Urban Atlas layer for the two reference years. Map 3 illustrates the changes in the share of urban green spaces between 2006 and 2012. The 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 (larger than 2 %), respectively. Green dots show cities with an increase of more than 0.5 %.

Map 3 Changes in the share of urban green spaces between 2006 and 2012



As a general pattern, it can be observed that cities with stable or decreasing green spaces dominate the map. 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 strongest decrease in urban green spaces. On the other end of the spectrum, only three cities show an increase in urban green spaces, i.e. 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 economic development after these countries joined the EU (eastern Europe) or for touristic purposes (southern Europe). In any case, further research is required to investigate the reasons behind these patterns.

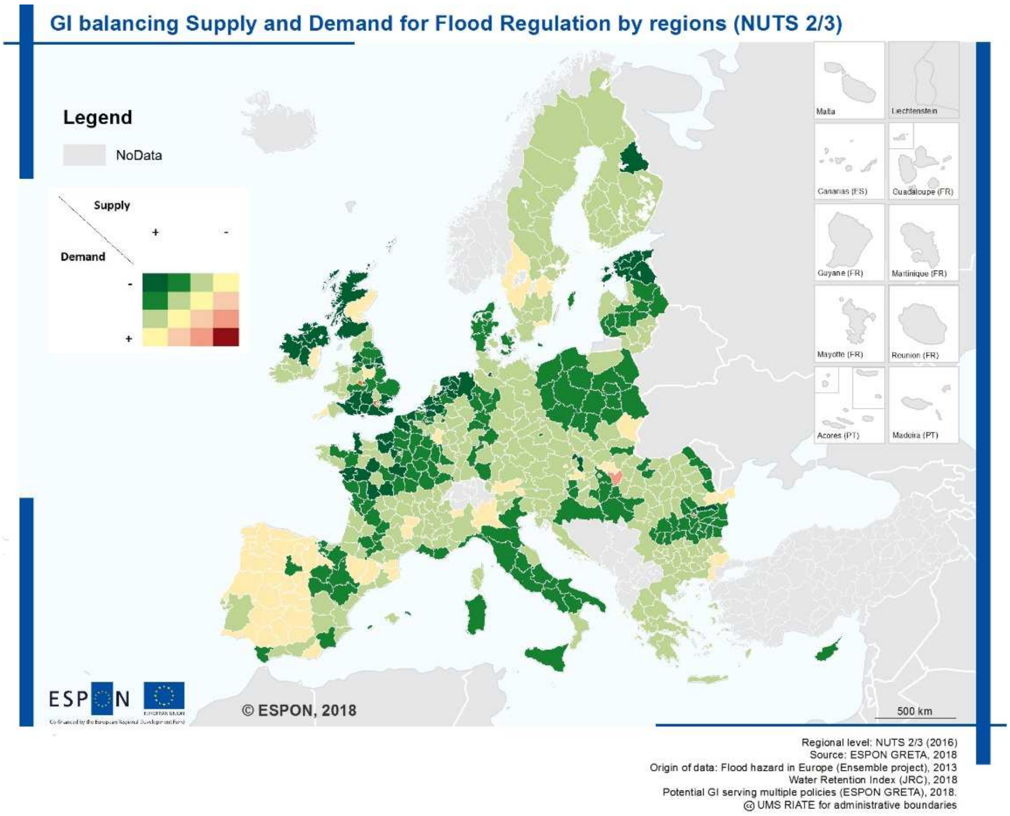
4. How do European regions fare in meeting the existing demand for regulating, provisioning and cultural services offered by GI

GRETA has explored the capacity of the GI network to meet the demand for ES where ES supply is defined as the capacity of ecosystems to provide ES, irrespective of whether they are used; ES demand can be defined as the amount of a service required or desired by society in a given location and time. This demand depends on several factors such as socio-economic conditions, cultural/behavioural norms, technological innovations, and availability of alternatives, among others.

Demand and supply have been combined for each of the selected ES, analysing supply and demand for flood regulation, for reducing soil erosion, for water purification, and for recreation.

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: i) This is a research area that is still under development; ii) there is need for a higher resolution of the data sources given the nature of the phenomena analysed; iii) the analysis of the balance between supply and demand is semiquantitative combining statistical and qualitive analysis; and iv) in some cases, more sophisticated modelling would be required to have an appropriate quantitative balance.

Map 4 Balancing Supply and Demand for Flood Regulation by regions (NUTS3)



Map 4 presents the balance between supply and demand quantified by the Water Retention Index, which assesses the capacity of the landscape to retain and regulate water passing through it. A positive balance is found mainly in the Northern part of Europe: some parts of Finland, Estonia, Northern Scotland, Northern Ireland, and some parts of France. The other regions that are still green could be considered as areas where the balance tends to be positive, which is dominant in Spain, Southern Ireland, and part of Scotland. These are areas where there is a need to reinforce GI with the objective of water retention. Finally, extreme deficit (low supply with high demand) is only found in Hungary.

GRETA has also assessed the degree of accessibility to GI as a key aspect in spatial linkage by determining the opportunity to move from the area where beneficiaries are located to areas where ES are produced, i.e. the GI network. Accessibility has been measured as the surface area of GI that could be reached by certain travel/walking time distances. Different travel distances have been analysed: 15’, 30’, 45’, and 60’. 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 (less than 5 km^2). Differences in accessible GI depend on several factors such as, for example: quantity of GI, its distribution (clustered or dispersed, etc.), and proximity to roads and trails. Therefore, having available GI (or percentage of GI in the peri-urban area) does not necessarily ensure it is accessible.

5. ES synergies and trade-offs in European regions

The multifunctional character of GI leads to multiple benefits and therefore synergies in the delivery of multiple policy objectives. There are inevitable trade-offs that must also be negotiated when selecting GI over other land-uses. The GRETA analysis presents the synergies and trade-offs related to the contribution that GI, and associated ES, make to multiple policy objectives, including: (i) biodiversity; (ii) water management; and (iii) climate change and disaster risk reduction. The GRETA project proposes a typology to characterise GI according to whether it contributes to multiple policy objectives (related to biodiversity, climate change, and water management), and how many ES it provides (see Map 4). An analysis of all possible pairwise combinations of ES allowed interactions to be identified. Some are positive and synergic (i.e. Italy, France, part of Germany, and Poland where most of the ES have a (strong) synergistic relationship), whereas others may lead to conflicts or trade-offs (i.e. Eastern European countries and Ireland). Synergies (green) and trade-offs (red) of ES have been analysed by policy domain. The lines connecting the ES indicate the type of association, by colour, while the width of the line indicates the strength of the association (Figure 1).

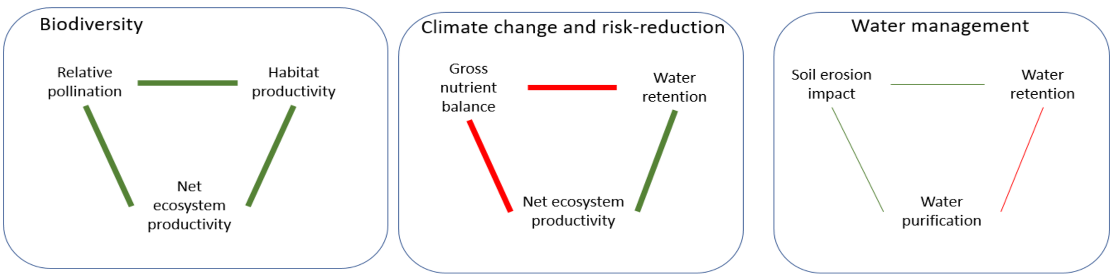


Figure 1 Synergies (green) and trade-offs (red) of ES analysed by policy domain

6. Policy and planning for GI

The GRETA project documents existing policy and planning support for GI in all 32 ESPON countries and highlights 25 transferable good practice examples which have a direct or indirect positive influence on green and blue infrastructure. These examples inform future GI policy, planning, implementation and management. All current European Union member states have adopted the Pan-European policy for Natura 2000 sites and have established Natura 2000 sites accordingly. All 32 ESPON member states[1] include GI in their existing policy regimes; however, only 11 of the 32 ESPON member states have specific GI policies at the national level. A Pan-European analysis of these suggests widespread integration of GI principles across policy

[1] https://www.espon.eu/links/member-states

areas beyond those related to biodiversity conservation; exceptions include finance, health and social services. It is broadly perceived that the responsibility for developing GI-related policy should be a shared duty between different levels of public administration and other actors; in practice, public administrations to take on most responsibility (compared to research entities, civil society organisations and businesses). The primary EU funding sources for GI implementation include: LIFE+ and Horizon 2020-project funds, the European Regional Development Fund (ERDF), and the European Agricultural Fund for Rural Development (EAFRD). Funding flows are from public-to-public, and from public-to-private actors and institutions; in some places private investment is in use.

7. Messages from the case study analysis

The GRETA project includes 12 multi-scale case studies representing different spatial, institutional, and jurisdictional settings. The case studies reveal that there is no one-size-fits-all solution, but rather a suite of approaches are provided which must be tailored to the context (goals, location, local climate/geology/geography, city/regional structure, governance, politics, knowledge, among others). Generally speaking, the case studies have adopted GI – to varying extents – as an intrinsic part of spatial and urban planning; some cases have a stand-alone GI strategic document, but it is often being mainstreamed into other sector policies. 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 well-being. The territorial challenges linked to GI implementation are shared by almost all cases and they include: transport, trade, boundary issues, demographic pressure, and climate-related risks (e.g. water management, flooding), agriculture, non-sustainable forest management, and forest drainage. The latter are particularly relevant to the case studies in northern countries. In some cases, significant efforts have been made with regards to the evaluation of ES and the delineation of GI, which constitute a strong baseline to informed 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 there is political commitment, and the planner is willing to incorporate GI as criteria in their planning process, there is still a need to have better knowledge, understanding and accessibility to the available data on ES, biodiversity and natural resources and how to harness this data to enhance the GI network (e.g. to use it for strategic decision making in spatial planning). Although generally positive, the relationship between GI, on the one hand, and biodiversity and ES, on the other hand, is dynamic. This indicates a need to monitor and examine GI over the long term in order to develop effective and adaptive management measures. Ecosystem based territorial planning for GI is recognised as a potential opportunity to utilise cross-border cooperation for GI implementation; in operational terms however, there are important challenges when different concepts of GI exist in different spatial planning jurisdictions.

8. Concluding remarks

Findings from the GRETA project highlight relevant key policy implications for supporting GI for territorial development in the European Union. Recommendations are provided at different national, regional and local governance levels. Due to the variety of planning systems in Europe, there is still ambiguity regarding at which planning levels it would be feasible for the GI concept to be used, and how to better benefit from its integrative capacity for supporting sustainable development.

Three Briefings have been developed based on GRETA results:
Briefing 1 Unpacking 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 available at https://www.espon.eu/green-infrastructure

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

- **Understand the demand for GI**. 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 demands and further research in this connection is needed, building on GRETA results. The GRETA research has also found practical planning examples where the GI supply and demand analysis are used 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 GI on the one hand, and biodiversity and ES on the other, is a starting point for the GRETA spatial analysis. Time series and change/trend analysis in this context of monitoring and data might be beneficial towards proactive and anticipatory planning.
- **Establish and assess the quality of GI.** 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.** Further research is needed to understand the social and geographical disparities of the trade-offs and synergies. This can be used to identify alternatives to minimise side effects.
- **Investigation into the role of the private sector**. There is a need to further highlight the importance of the private sector, NGOs, and private individuals in GI implementation. To further the integration of actors and institutions other 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 implementation failures.** The GRETA research indicates a need to further identify failures in 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.

Appendix

Issues regarding spatial coverage

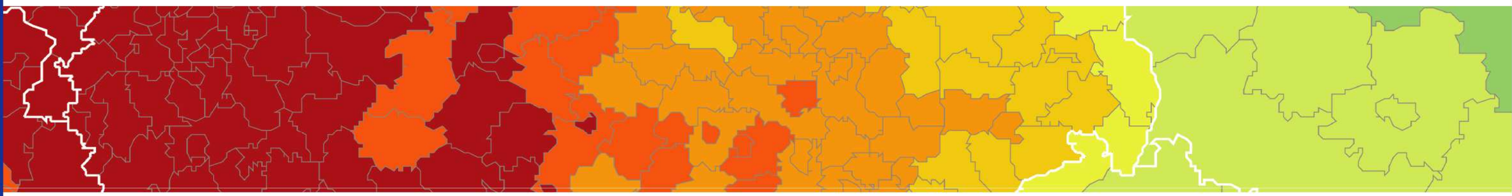
Physical Mapping

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 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.

Funcional 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).

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.



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