DEVELOPING A COMPREHENSIVE KNOWLEDGE BASE FOR ENHANCING GREEN INFRASTRUCTURE TO BENEFIT TERRITORIAL DEVELOPMENT IN DIFFERENT EUROPEAN REGIONS AND CITIES

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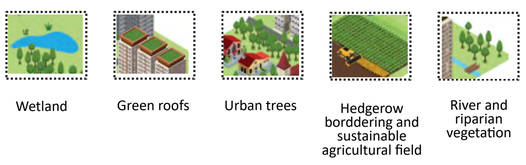
The **strategically planned network** of hubs and links, made of **green** & **blue** natural and semi-natural elements that is **multifuntional** and provides **multiple benefits**

What is green infrastructure?

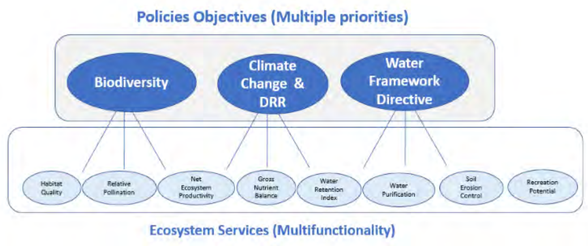


Green infrastructure includes natural elements (e.g. ecological corridors, stepping stones, riparian vegetation) and artificial features (e.g. fauna tunnels and fish passes) that enable structural and functional connectivity of species and habitats.

On land, green infrastructure is present in rural and urban settings.

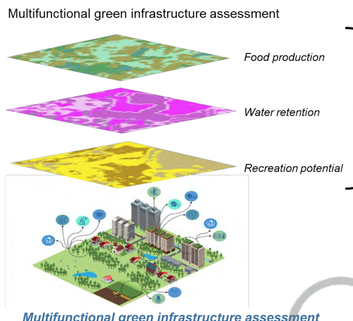
GRETA's innovative spatial analysis approach

The first step might be to establish the current state of green infrastructure: what are the elements of nature currently present in the geographic area? By identifying these elements and understanding their state and capacity to supply specific ecosystem services, one would then be able to identify the location of most suitable potential green infrastructure.



Physical green infrastructure assessment

Multifunctional green infrastructure assessment



Physical green infrastructure assessment

What does it do? – Maps the spatial distribution of the green infrastructure (i.e. land use and cover classes which fit the definition of green infrastructure, in this instance natural and semi-natural features).

How does it relate to other methods? – Provides base map for strategic planning and multifunctional green infrastructure assessment.

What questions could it answer? – Which land use and land cover classes could provide green infrastructure? Where are these located? Are they homogenously distributed?

What are the data needs? – Land use and land cover maps identifying natural and semi-natural areas. Maps of existing areas under environmental protection or that are providing natural ecosystems with exceptional services conditions (e.g. high nature value farmland).

What are the limitations? – Requires existence of high-resolution maps available at relevant scale; for example, at the EU level, this can be provided through the CORINE Land Cover Map.

Why this method over others? – Relative and scalable.

Multifunctional green infrastructure assessment

What does it do? – Assesses the performance of the physical green infrastructure in supplying multiple ecosystem services and, consequently, supporting multiple demands.

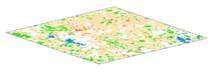
How does it relate to other methods? – Builds on physical map of green infrastructure to identify the ecosystem services supplied by the network. This feeds into the assessment of trade off and synergies.

What questions could it answer? – Where is ecosystem services provision highest within the network? Which areas of the green infrastructure provide the highest number of ecosystem services? Which demands can be supported by green infrastructure? Which areas need to be conserved and which ones need to be restored?

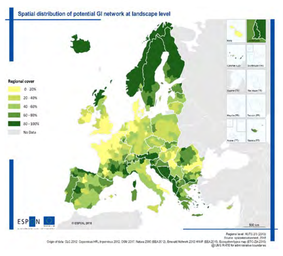
What are the data needs? – Maps of ecosystem services provision for the identified green infrastructure.

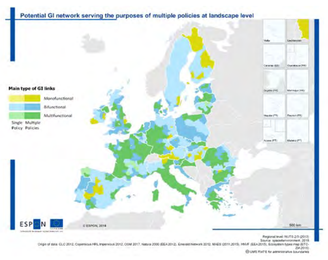
What are the limitations? – Many ecosystem services are not well mapped, and comparisons of ecosystem services provision means scaling to the resolution of the coarsest dataset. Data are normalised to a common range and unit for comparison, which may mean ecosystem services comparisons are lacking in context.

Why this method over others? – Relative and scalable.

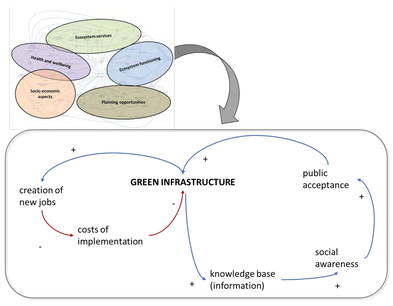


Map of green infrastructure multifunctionality





What are the enabling factors that favour the implementation of GI?



Example of factors that interact and influence the implementation of green infrastructure using a Causal Loop Diagram. The upper diagram represents all the possible interactions between different components, grouped by relevant domains (socio-economic, health, planning system, ecosystem services and ecosystem functioning). The lower diagram represents a subset of actors. Blue lines: positive impact; red line: negative impact. For example, planning of green infrastructure could create new jobs, which, in turn, could increase the cost of implementation resulting in an obstacle for further development.

Causal Loop Diagram

What does it do? – A Causal Loop Diagram is a conceptual tool that aids in visualizing how different elements, agents and actors related to GI are interrelated. This graphical representation helps to understand how institutions, public perception, regulations, funding, land prices, benefits of the GI, etc. mutually interact.

How does it relate to other methods? – This method comes as a complement to geographical mapping approaches by situating potential green infrastructures in their social and institutional setting. Mapped areas of potential green infrastructures might only fully develop in a functional network of green infrastructures if the right actors engage with the process and the right institutions (rules, legal frameworks and organisations) are developed and supported.

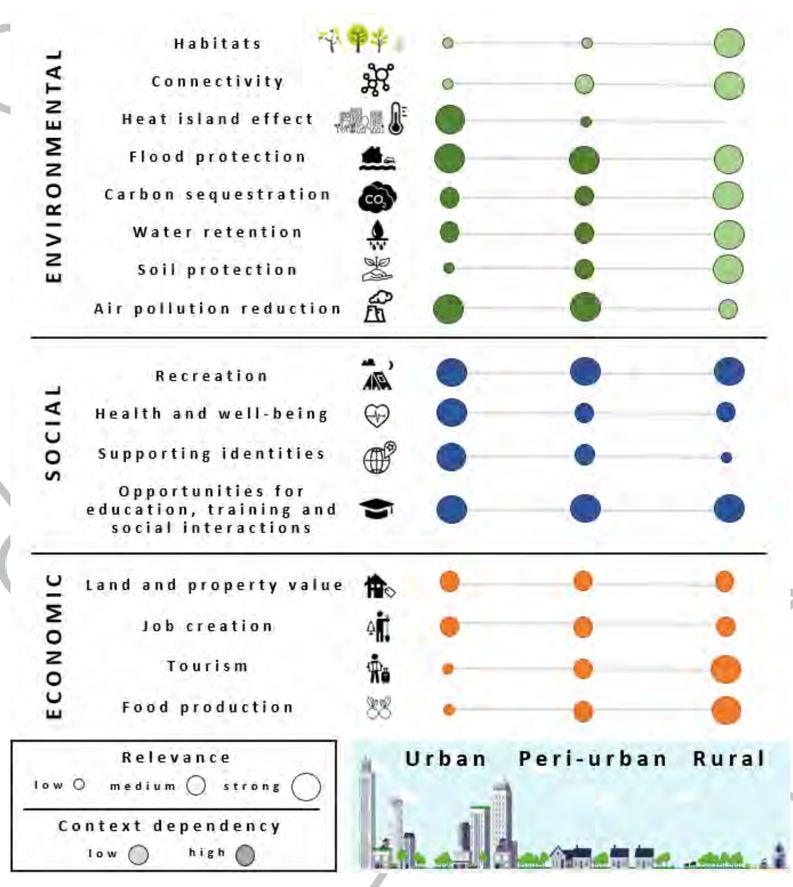
What questions could it answer? – Where are the current barriers in the creation of green infrastructures? Where to act, in the institutional framework, to facilitate the implementation of green infrastructure? What virtuous and vicious circles are likely to emerge with an intervention on green infrastructures?

What are the data needs? – The method relies on interviews with stakeholders, collecting information on ecosystem functioning, ecosystem services, health and wellbeing, socio-economic data and planning opportunities as well as the links (positive and negative) between these elements.

What are the limitations? – It is strongly dependent on the number of stakeholders involved in the interviews and their representativeness.

Why this method over others? – It derives semi-quantitative indicators from qualitative information

MAIN BENEFITS provided by GI at DIFFERENT SCALES



The multifunctional character of GI elements provides a **range of benefits** by means of a variety of Ecosystem Services (ES), which often appear in bundles, and under certain circumstances, are mutually reinforcing.

Are there side effects from GI?

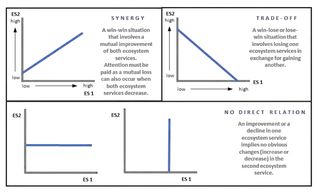
As with any development, green infrastructure has potential side effects that are important to be aware of, and as far as possible mitigate. Here it follows a list of common side effects, and how to avoid them.

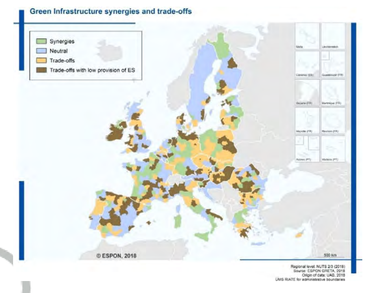
- **Eco- (or green) gentrification** – creating new or 'upgrading' existing green infrastructure can bring new residents to the area. This can be problematic if existing residents can no longer afford to live there. Sometimes the character of a neighbourhood and community changes through loss of local distinctiveness and cultural heritage.
  - **What can be Done**: incorporate social justice principles when planning green infrastructure for equitable distribution of benefits of green infrastructure.
- **Human health effects** – if the urban green infrastructure is used for food production, negative health effects can arise. 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. Differences in trace metal concentrations depends on local traffic, crop species, planting style and building structures, but not on vegetable type. While a higher traffic burden increases trace metal content in plant biomass, the presence of buildings and large masses of vegetation, acting as barriers between crops and roads, reduces pollutant content. Additional considerations include the possibility of increased sources of allergens.
  - **What can be Done**: 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.
- **Ecological downsides** – Among the ecological downsides are the risk of invasion by alien species, water pollution from fertilisers and other chemical inputs, or higher levels of water consumption. Urban green spaces have contributed to the introduction of alien species, especially plants, but this is also true for other taxa. Depending on conditions, these species may spread and colonise new areas, becoming invasive. When green infrastructure is fully integrated in a network of green areas, GI may act as a dispersal highway for these invasive species.
  - **What can be Done**: use native species which are adapted to local conditions, this could reduce water use. Consider selecting plants that will be adapted to the future climate.
- **Economic** – Economic disadvantages include higher costs to initiate and maintain green infrastructure and higher costs for purchasing or leasing land and properties. A challenge for informed decision making is the difficulty of properly quantifying the cost-benefit relation for benefits such as a 'sense of community', which are not easily translated into monetary terms. This can discourage implementation at different levels (design, planning and construction) and the management process (long-term funding and maintenance).

What and where are the trade-offs and synergies?

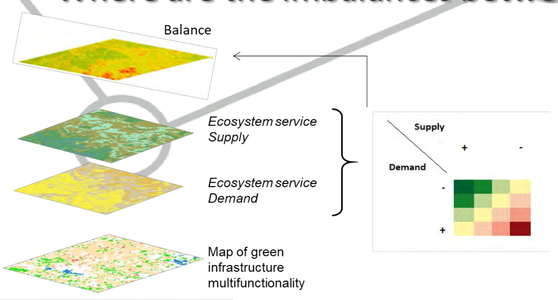
Considering all the possible combinations of ES, for each region we have identified which type of relationship is predominant. The resulting map shows certain regional patterns:

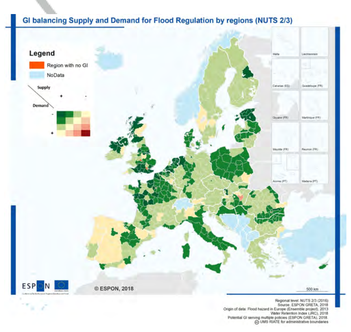
- **Synergies**. In these regions – in Italy, France, part of Germany, and Poland – most of the ES have a (strong) synergistic relationship. There are, to a lesser extent, some trade-offs. In practical terms, the improvement of certain ES has a multiplier effect on other ES, always (increasing the provision of ES).
- **Neutral**. This is the larger group. Changes in one ES does not also increase or decrease another ES. These regions are scattered across Europe. In particular 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 a further understanding of these trade-offs and the need to identify alternatives to minimise side effects.
- **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.





Where are the imbalances between supply and demand?





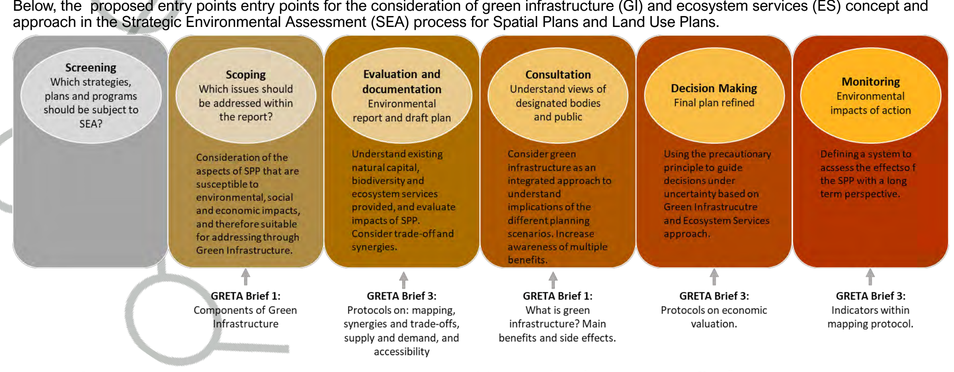
This mapping protocol assesses the balance between the demand and supply of ecosystem services by green infrastructure at a regional scale. It compares areas and looks for the extremes rather than computing complex calculations on ecosystems capacity. This simple framework is easily applicable to different ecosystem services.

GI in the context of Spatial Planning

The consideration of ecological processes to inform spatial planning is a pre-requisite for sustainable ecological, economic and societal development. The green infrastructure concept provides an integrative framework that supports comprehensive assessment of such ecological processes, their patterns and spatial distribution. This could greatly contribute to enhancing strategic thinking, positioning the ecological processes and their values/ benefits as a relevant planning criterion towards more resilient territorial development.

Spatial planning is an enabling discipline for territorial development, that articulates the deployment of other public policies affecting spatial organization and governance of and – i.e. biodiversity, climate change, water. Spatial planning is the umbrella under which the green infrastructure concept and approach could be operationalized.

Below, the proposed entry points entry points for the consideration of green infrastructure (GI) and ecosystem services (ES) concept and approach in the Strategic Environmental Assessment (SEA) process for Spatial Plans and Land Use Plans.



Summary findings

The GRETA findings highlight policy implications that are relevant for supporting GI for territorial development in the European Union. Although GI considerations are increasingly incorporated into European Union policies and strategic planning, the GRETA findings suggest that:

i. Although dependent upon local contexts and conditions, identifying and quantifying the benefits of GI leads to improved understanding of the environmental, social, and economic motivations for implementing GI.

ii. Accurate and updated spatial data on potential GI networks should be informing evidence-based decision making on where to invest resources, particularly for identifying GI 'hot spots' that either require increased safeguarding or restoration.

iii. GI is recognised as a cross-sectoral concept implies more awareness raising and communication between the different spatial planning sectors is needed to operationalise the concept. Policy integration must be encouraged and supported to maintain existing integration between policy areas and further embed GI in other relevant policy domains, including: finance, energy, health, and social services.

iv. There is a need for further collaboration, awareness, capacity building, and knowledge exchange to build a common understanding between professionals operating at different implementation stages and scales.

Knowledge gaps & future research

- Deeper understanding is needed on the relationship between the GI and biodiversity. Mid-long term monitoring of the (positive) impacts of implementation of GI would improve the understanding of underlying mechanisms.
- Improved indicators and metrics for assessing not only the quantity of GI but the quality of GI are needed.
- Better understanding of diverse ES and their interactions (developing a matrix of synergies and trade-offs).
- More in depth analysis of the GI network in FUAs.
- Further consideration of GI in the rural areas and reflections of the future consideration of GI in the context of the Common Agricultural Policy.
- Investigation into the role of the private sector in GI implementation and management at different scales (including land owners and managers in urban, peri-urban and rural areas).
- Guidance for the operationalisation of GI and ES approaches in spatial planning.

32 National Fact Sheets
25 Good Practise Examples
12 Multi-scale Case Studies
03 Policy Briefs

1 - Autonomous University of Barcelona, 2 - TECNALIA, 3 - Space4Environment, 4 - NordRegio, 5 - The James Hutton Institute

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