Green Infrastructure

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Conceptual approaches to Green Infrastructure

The concept of "Green Infrastructure" (GI) is gaining political momentum and has been rapidly introduced in both planning theory and policy, especially in US and Europe (see Lennon, 2014). Yet, it does not have a single widely recognised or accepted definition (Wright, 2011). The term has been adopted by various disciplines (e.g., land conservation, urban design and landscape architecture), sometimes with substantially different conceptual meanings (see EEA, 2011 for a thorough list of GI approaches). For example, the development of GI is a strategic approach to land conservation, addressing the ecological and social impacts of consumption and fragmentation of open land (Benedict and McMahon, 2006). In urban design, the concept is mainly approached as a planned network of living systems affecting the quality of life of urban population (Defra and Natural England, 2013). Although the lack of a clear and unequivocal definition can lead to confusion and misuse among academics and practitioners, and eventually to a generalization of the term to "anything green", Wright (2011) argues that a single precise meaning of GI is problematic because the concept is still evolving and has developed in response to different needs. GI could be hence framed as a "boundary concept", defined as "words that function as concepts in different disciplines or perspectives, refer to the same object, phenomenon, process, or quality of these, but carry (sometimes very) different meanings in those different disciplines or perspectives" (Mollinga, 2010:4). Still, there are at least two common underlying elements behind all GI approaches which can be identified (see also Mell, 2008); these are: 1) connectivity, and 2) multifunctionality. Connectivity comprises two components, structural and functional. The latter is the dynamic component expressing how landscapes allow various species to move and expand to new areas (Saura et al., 2014). Structural connectivity, equal to habitat continuity, is the static component measured by analysing landscape structure, independent of any attributes of organisms (EC, 2013b). Multifunctionality refers to multiple functions and benefits that the GI provides simultaneously on the same spatial area. For example, an area suitable for flood protection can serve for recreational needs, preservation of cultural heritage, natural pasture land for cattle and a habitat for wildlife (EC, 2012).

Considering the overall goals of the OpenNESS project and its variety of case studies, we think that it is important to have a clear idea about how the concept can be operationalised in practice, despite its inherent conceptual complexity and ambiguity. Hence, we suggest a comprehensive but flexible approach to GI, mainly based on the working definitions used in the European Commission (EC) communication "Green Infrastructure – Enhancing Europe's Natural Capital", commonly known as EU's Green Infrastructure Strategy (EC, 2013a). In the physical and functional sense, GI is defined there as a network of ecosystem structures with other environmental features which are 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, both in terrestrial and marine areas. Yet, the strategy also defines GI in two other ways: (1) as "a strategy to enhance natural capital" and (2) as "a successfully tested tool for providing ecological, economic and social benefits through natural solutions". As this approach does justice to the different aspects as well as to European policy intentions, we suggest to explicitly define GI in this three-tiered sense - as a physical entity, as a tool, as well as a strategic approach- within OpenNESS.

Scales at which GI can be addressed

According to, for instance, the EC (EC, 2013b), the physical building blocks of GI are present in rural and urban settings and, can vary from very small local elements like gardens and green roofs to trans-boundary features such as mountain ranges, and therefore, the EU's Green Infrastructure Strategy is rather broad and inclusive with respect to scales. For example, large building blocks are already covered in Natura 2000 network and the goal is "Improving the connectivity between sites in the Natura 2000 network and thus achieving the objectives of Article 10 of the Habitats Directive". This is explicitly mentioned as a contribution of GI in the strategy (EC, 2013a).

GI planning and implementation can be actually adapted to various scales (from site to supra-national levels) along the urban-rural gradient. For example, Allen (2014) attempts to frame GI planning across three spatial scales – named as site, regional, and landscape - with specific implementation strategies at each scale (see **Fig. 1**). Another GI framework consisting of five main interrelated blocks (ES; biodiversity; social and territorial cohesion; sustainable development; and human well-being) in time and space was presented by Lafortezza et al. (2013).

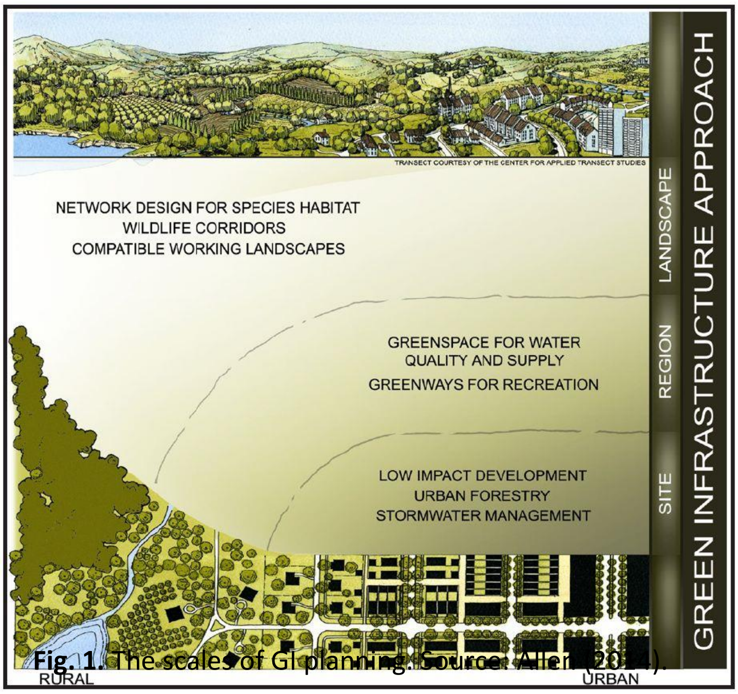

Fig. 1. The scales of GI planning. Source: Allen (2014).

Green Infrastructure and Ecosystem Services

The identification and assessment of GI functions and benefits is increasingly underpinned by the conceptual framework of ES (EC, 2012; EEA, 2011; 2014; Liquete et al., 2014; Maes et al., 2015; Kopperoinen et al., 2014). For example, Maes et al. (2015) quantifies how the land-use change caused by current socio-economic demand will affect the European GI network and, thus, the benefits people get from eight different ES. The report on GI and territorial cohesion (EEA, 2011) identifies eight groups of GI benefits and the report by Mazza et al. (2011) suggests a very similar classification based on ten categories. Both proposals can be merged as follows: (1) biodiversity/species protection and conservation benefits; (2) climate and climate changed related benefits; (3) water management; (4) food production and security; (5) recreation, health and well-being; (6) land and property values; (7) education, culture and communities; (8) investment and employment; and (9) natural resources. Tzoulas et al. (2007) also proposed a conceptual framework linking GI elements, ecosystem functions and services, ecosystem health (such as habitat diversity) and four aspects of human health (physical, psychological, socio-economic and community health).

Taking these multiple benefits into consideration, GI is often contrasted to 'grey' or built infrastructure. The EU, for example, argues that GI can be a cost-effective and environmentally friendly alternative, or so-called nature-based solution[1]. It can also be complementary to standard 'grey' solutions and, while the latter is normally designed as single-purpose, GI-based solutions can provide many benefits due to its multifunctionality. For example, an increasing number of studies call for GI-based approaches in disaster risk management like flood protection instead of traditional grey infrastructures such as levees or dikes (e.g., Costanza et al., 2006 after Hurricane Katrina's catastrophe occurred in 2005).

Identification and assessment of GI

According to the physical and functional conceptual approach mentioned above, GI is fundamentally a spatial concept. Therefore, spatially explicit assessment of ES is a central step towards the identification of GI networks and elements. The growing body of literature concerning methods for mapping ES (see Crossman et al., 2013 for a review) can hence provide useful methodological frameworks for identifying and assessing the multifunctional component of GI from a spatially explicit approach.

[1]Nature-based solution is still a developing concept, but some examples can be found here: http://ec.europa.eu/research/environment/index_en.cfm?pg=nature-based-solutions

As an example, the recent EEA report on spatial analysis of GI in Europe (EEA, 2014) presents a methodology based on two entry points: (1) the delivery of ES (multifunctionality), and (2) biodiversity conservation and functional connectivity (see **Fig. 2**). Point (1) leads to the identification of areas with high or moderate capacity to deliver various ES (in this example, a suite of eight ES). The performance in terms of services is related to the condition and functioning of the ecosystems. Point (2) leads to the identification of key species and dynamic habitat connectivity. It involves habitat suitability mapping for certain functional groups of interest (in this example, large mammals) and the differentiation between core habitats and migration corridors. The final integration of information requires the establishment of specific thresholds (between data classes) that should depend, not only on environmental knowledge, but also on policy and socio-economic priorities. The resulting landscape elements are then aggregated for a proposal of a GI network that identifies potential areas for conservation and for restoration[2].

The methodology covers the landscape level of GI, but it can be adjusted to different spatial scales. However it does have some limitations, e.g. an excessive number of key species or ES may cause technical infeasibility. Also, in order to support decision-making, it is highly recommended that users consider stakeholder involvement and feedback in the first steps of GI design (see EEA, 2014; Liquete et al., 2014 for more details). In addition, the end result of this method is either GI for conservation or restoration which neglects the fact that in the case of ES delivery, not all areas need to be of high biodiversity value.

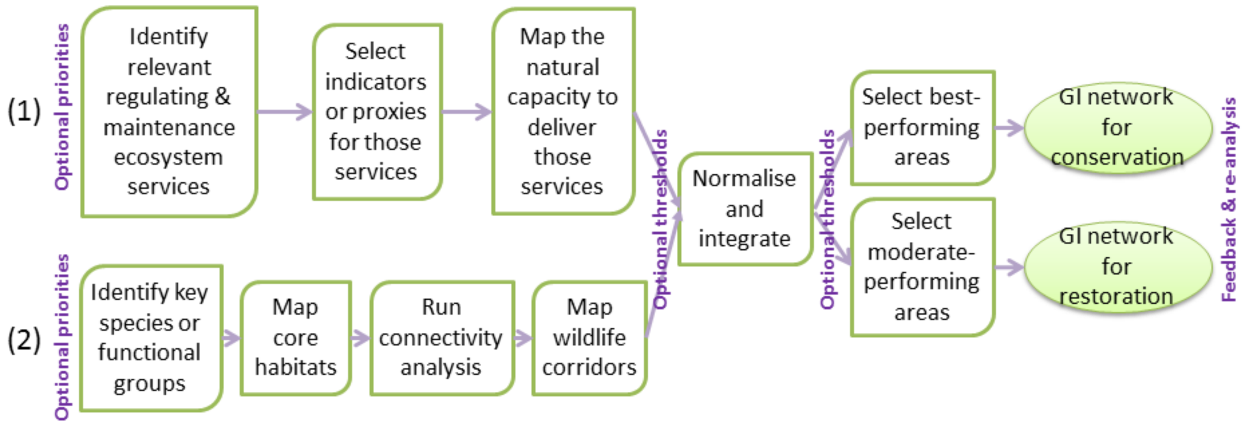

Fig. 2. Methodological workflow for the identification and mapping of GI networks. Modified from EEA (2014) and Liquete et al. (2014).

Integration of GI in policy sectors

One of the main goals of the EU's Green Infrastructure Strategy is the integration of related aims and objectives of the strategy into as many policy fields as possible. Policy fields that are particularly highlighted as suitable for this integration are: climate, water, nature conservation, particularly via the EU Biodiversity Strategy to 2020, regional policy, land and soil. Further, the strategy refers to national planning policies to ensure that they give "regional and local authorities clear guidance and direction on how to plan and manage GI" and to ensure that they "consider GI provision in local development planning and policy" (EC 2013a:10).

Other suggestions of integration are provided by the EEA (2011) report: (1) the Thematic Strategy on the Urban Environment recommends an integrated management of the urban ecosystems to avoid loss of habitats and biodiversity, (2) the Floods Directive requires flood risk management plans to consider maintenance and restoration of floodplains, (3) the CAP reform include instruments for protecting landscape elements and farm biodiversity, and (4) Cohesion policy already co-finances investment in GI.

[2] This responds to the goal of Target 2 of the EU Biodiversity Strategy ('by 2020, ecosystems and their services are maintained and enhanced by establishing Green Infrastructure and restoring at least 15% of degraded ecosystems') and to the specific work developed under Action 6 and the Restoration Prioritization Framework.

Open Problems/Issues to be discussed

1. What are the main criteria, methods and potential indicators to identify and assess GI at different spatial scales along the urban-rural gradient, both in terms of multifunctionality (e.g., diversity of ES provided) and connectivity? See EEA (2014) and Liquete et al. (2015)
2. How are the different "ES providing units or areas" linked to constitute a "green infrastructure"? And how and for which ES can connectivity between different GI elements contribute to enhancing ES and related benefits? See Mitchell et al. (2013).
3. To what extent and under which conditions can GI-based solutions be an alternative (for example in terms of cost-effectiveness) to "grey" infrastructure and in which cases they can only play a complementary role? Not specifically addressed in OpenNESS. Very much linked to the Nature-based solutions debate (see Kabisch et al., 2016; OpenNESS Synthesis paper on NBS, Potschin et al., 2016).
4. What are the actor constellations, institutional frameworks, including e.g. policies or property rights, socio-cultural and economic settings that can support or limit GI design and implementation? See Deliverable 2.1 (Policy analysis of key regulatory frameworks within Europe).
5. What are the possible interactions related to GI implementation in terms of potential synergies and conflicts between policy sectors? See Hauck et al. (2016).

Significance to OpenNESS and specific Work Packages[3]

GI can be considered a practical approach for the operationalization of NC and ES.

WP1 (Key challenges and conceptual frameworks): Integration of GI into the concepts and frameworks (Cascade Model) is necessary, especially concerning its multifunctional capacity. CICES (v4.3) classification explicitly mentions GI in the "Mediation of smell/noise/visual impacts" class: "Visual screening of transport corridors e.g. by trees; Green infrastructure to reduce noise and smells". OpenNESS should contribute knowledge on how multi-purpose 'green infrastructures' can be set-up based upon landscape ecology principles.

WP2 (Regulatory frameworks and drivers of change): GI related policy analysis can inform policy areas identified in OpenNESS to be directly relevant for ES operationalization, including regional development, climate change, disaster risk management, agriculture/forestry and the urban environment, among others. See Deliverable 2.1 (Policy analysis of key regulatory frameworks within Europe).

WP3 (Biophysical control of ecosystem services): OpenNESS will address spatially explicit models in relation to GI and their operationalization into land and natural resource management practices. See for example Maes et al. (2015) and Liquete et al. (2015).

WP4 (Valuation of the demand for ecosystem services): The integrated valuation of ES provided by GI is essential to demonstrate the importance of GI-based solutions in spatial planning and decision-making processes, especially in relation to the advantages of GI projects versus standard 'grey' solutions. A key question is whether non-economic valuation methods are better at dealing with this challenge. See Deliverable 4.2 (Framework for integration of valuation methods to assess ecosystem service policies).

WP5 (Place-based exploration of ES and NC concepts): Several of the OpenNESS case studies are based on a GI approach, for instance 'Case 14 - Planning with Green Infrastructure in five linked cases', 'Case 15 - Multipurpose wetland construction and landscape restoration in a peri-urban area: Case Gorla Maggiore in northern Italy', and most part of urban cases (Case 1: Sibbesborg; Case 4: Vitoria-Gasteiz; Case 27: Barcelona). These case studies represent an opportunity to test the feasibility and effectiveness of operationalising GI in real world situations and through policy branches. See WP5 deliverables (especially Deliverable·5.4).

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[3] For a brief description of the OpenNESS Work Packages see: http://openness-project.eu/about/work-packages

Relationship to four challenges[4]

Human well-being:	Sustainable Ecosystem Management:
Most documents on GI describe multiple ES with direct impacts in diverse human well-being components, including health, social relations, security and basic material needs (Mazza et al., 2011). For example, GI in cities can improve physical and mental health of urban population providing recreational opportunities within the urban fabric. Further, GI can mitigate the health impacts caused by the urban heat island (UHI) effect, especially during episodes of heatwaves.	The concept of GI and related analytical tools (e.g., mapping) can inform and enhance sustainable ecosystem management by encouraging a greater integration of environmental, economic and social dimensions and cross-sectoral cooperation in land use planning and management.
Governance:	**Competiveness:**
Governance is essential to ensure that GI becomes a standard part of spatial planning and territorial development that is fully integrated into the implementation of these and other cross-sectoral policies, for example, concerning territorial cohesion (EEA, 2011). Multi-scale governance approaches and participatory approaches are also necessary to overcome potential challenges of GI implementation. Likewise it is needed to ensure not only local but inter-regional, international connectivity.	GI can contribute to land and property values by increasing the attractiveness of places to live and work, and allowing cities to attract talented workforce. Investments in GI have substantial potential to strengthen regional and urban development, including job creation (EC, 2013a).

Recommendations for the OpenNESS consortium

For case studies looking into GI, we recommend testing the concept of GI into the Cascade Model. Thus GI functions or benefits should be identified as functions, services, benefits or values of the model. For instance, GI functions such as 'creating jobs' should be considered a benefit, 'raising property values' as a value and 'flood protection' or 'preventing soil erosion' as functions (capacities) or services (actual use). These case studies should also feedback on the CICES classifications linked to GI. The EC has recently instated a second Working Group on Green Infrastructure (see the must read website for reference). We recommend OpenNESS to closely track this group's progress and communicate with it as much as possible.

Suggested three 'Must Read' Papers:

European Environment Agency (EEA) (2011): *Green Infrastructure and Territorial Cohesion. The concept of green infrastructure and its integration into policies using monitoring systems*. EEA Technical report No 13/2011. Luxembourg: Publications Office of the European Union, 2011.

European Environmental Agency (EEA) (2014): *Spatial analysis of green infrastructure in Europe*. EEA Technical report No 2/2014. Luxembourg: Publications Office of the European Union, 2014.

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.

Must read website

http://ec.europa.eu/environment/nature/ecosystems/index_en.htm

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4 There are certainly more societal challenges; the reduced number presented here is due to the four major challenges mentioned in the work programme of FP7 to which OpenNESS responded.

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Liquete, C. et al. (2015): Mapping green infrastructure based on ecosystem services and ecological networks. A Pan-European case study. *Environmental Science & Policy* 54: 268–280. doi:10.1016/j.envsci.2015.07.009

Maes, J., et al. (2015): More green infrastructure is required to maintain ecosystem services under current trends in land-use change in Europe. *Landsc Ecol* 30(3): 517–534.

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Review editor: Kurt Jax (UFZ)

Suggested Citation: Baró, F., Bugter, R., Gómez-Baggethun, E., Hauck, J., Kopperoinen, L., Liquete, C., Potschin, M. (2016): 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

Acknowledgements: The following OpenNESS partners have contributed to the consultation: David N. Barton (NINA, Norway); Joachim Maes (IES-JRC, Italy); Raktima Mukhopadhyay (IBRAD, India); Pam Berry (UOXF-ECI, UK); Rolinde Demeyer (INBO, Belgium); Marina García-Llorente (UAM, Spain); Ben Delbaere (ECNC, the Netherlands); Ulrich Heink (UFZ, Germany); Angheluta Vadineanu, Jana Spulerova (UB-DSES, Romania); Conor Kretsch (UNOTT, UK);Bálint Czúcz, Ildiko Arany (MTA ÖK, Hungary).