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Mapping green infrastructure based on ecosystem services and ecological networks: A Pan-European case study

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ABSTRACT

Identifying, promoting and preserving a strategically planned green infrastructure (GI) network can provide ecological, economic and social benefits. It has also become a priority for the planning and decision-making process in sectors such as conservation, (land) resource efficiency, agriculture, forestry or urban development.

In this paper we propose a methodology that can be used to identify and map GI elements at landscape level based on the notions of ecological connectivity, multi-functionality of ecosystems and maximisation of benefits both for humans and for natural conservation. Our approach implies, first, the quantification and mapping of the natural capacity to deliver ecosystem services and, secondly, the identification of core habitats and wildlife corridors for biota. All this information is integrated and finally classified in a two-level GI network. The methodology is replicable and flexible (it can be tailored to the objectives and priorities of the practitioners); and it can be used at different spatial scales for research, planning or policy implementation.

The method is applied in a continental scale analysis covering the EU-27 territory, taking into account the delivery of eight regulating and maintenance ecosystem services and the requirements of large mammals' populations. The best performing areas for ecosystem services and/or natural habitat provision cover 23% of Europe and are classified as the core GI network. Another 16% of the study area with relatively good ecological performance is classified as the subsidiary GI network. There are large differences in the coverage of the GI network among countries ranging from 73% of the territory in Estonia to 6% in Cyprus. A potential application of these results is the implementation of the EU Biodiversity Strategy, assuming that the core GI network might be crucial to maintain biodiversity and natural capital and, thus, should be conserved; while the subsidiary network could be restored to increase both the ecological and social resilience. This kind of GI analysis could be also included in the negotiations of the European Regional Development Funds or the Rural Development Programmes.

1. Introduction

Many aspects of human wellbeing and economic activities rely on ecosystem functions and processes. For instance, our food security is based on the existence and maintenance of fertile soil; we breathe the air that plants filter; our lives and properties are protected from flooding by soil infiltration, dune systems or riparian forests; and our mental and physical health may depend

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on the accessibility to green spaces (MA, 2005; Alcock et al., 2014). Furthermore, some nature-based technical solutions (e.g. green roofs, bio-infiltration rain gardens, vegetation in street canyons) have demonstrated in several cases to be more efficient, inexpensive, adaptable and long-lasting than the so-called "grey" or conventional infrastructure (e.g. Gill et al., 2007; Pugh et al., 2012; Ellis, 2013; Flynn and Traver, 2013; Raje et al., 2013).

The European Commission communication (2013) on green infrastructure (GI) sets the ground for a tool that aims to provide ecological, economic and social benefits through natural solutions, helping us to mobilise investments that sustain and enhance those benefits. This vision pursues the use of natural solutions (considered multi-functional and more sustainable economically and socially) in contrast with grey infrastructure (that typically only fulfils single functions such as drainage or transport). In the EC communication, GI is defined 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*. This definition includes three important aspects: the idea of a network of areas, the component of planning and management, and the concept of ecosystem services. In this sense, GI integrates the notions of ecological connectivity, conservation and multi-functionality of ecosystems (Mubareka et al., 2013).

In the European context, besides the abovementioned EC communication, the conservation and development of a GI is identified as one of the priorities in EU policies covering a broad range of sectors, like the EU Biodiversity Strategy to 2020,[1] the roadmap to a Resource Efficient Europe,[2] the Commission's proposals for the Cohesion Fund and the European Regional Development Fund,[3] the new Common Agricultural Policy[4] (note the change from direct payments towards the second pillar payment that can be a strong incentive for GI restoration and maintenance), the new EU Forest Strategy[5] (especially relevant since many GI elements might be forest-based), or the forthcoming communication on "land as a resource" in 2015 (which will highlight the importance of using land efficiently and as a finite resource). Within the Biodiversity Strategy, target 2 aims at maintaining and restoring ecosystems and their services by 2020, by establishing a GI and restoring at least 15% of degraded ecosystems. Action 6 is setting priorities to restore and promote the use of GI. The forthcoming land communication will focus on the value of land as a resource for crucial ecosystem services and on how to deal with synergies and trade-offs between multiple land functions. Systematically including GI considerations in the planning and decision-making process will help reduce the loss of ecosystem services associated with future land use changes (i.e. land take and land degradation) and help improve and restore soil and ecosystem functions.

To support the planning process, approaches for mapping GI are necessary. They should focus on two basic concepts. The first one is multi-functionality, ensured by quantifying and mapping a number of ecosystem services. Decision makers can then seek for areas providing multiple services. The second concept should build on connectivity analyses such as the analysis of ecological networks. Spatial delineation of GI elements has often been based on a re-classification of available land cover data combined with information on natural values of each cover class (e.g. Weber et al., 2006; Wickham et al., 2010; Mubareka et al., 2013). Recent studies have shown the relevance of including sector specific models and connectivity in the analysis of policy impacts over GI networks (Mubareka et al., 2013). In particular, these authors find particularly relevant to forecast the land claimed by the agricultural sector, population projections, forestry and industry.

The objective of this paper is to propose a feasible and replicable methodology to identify and prioritise GI elements, including the concepts of ecosystem services and ecological connectivity. This methodology can be used at different spatial scales for planning and policy implementation. The proposed approach is applied in a continental case study, covering the EU-27 territory, focusing on a landscape scale. In this case the results could be used for conservation policies since they are aligned with the EC communication and the Biodiversity Strategy. This paper is a further refinement of a study started by EEA/ETC-SIA (EEA, 2014).

2. The proposed methodology

2.1. Conceptual aspects: criteria to identify GI elements

As we anticipated in the introduction, this study is focused on the identification of GI elements at landscape level. Unlike in urban environments, in the open landscape not all green areas qualify as GI. It is not economically or technically feasible to cover the entire territory with natural ecosystems in order to secure their positive influence on natural processes on every spot. Hence, we consider as crucial criteria to identify GI elements (i) the multi-functionality linked to the provision of a variety of ecosystem services, and (ii) the connectivity associated to the protection of ecological networks.

The first criterion, ecosystem services, are the contributions of natural systems to human wellbeing. We propose that GI elements should be multi-functional zones in terms of services' delivery (EC, 2012). Moreover, we focus on the identification of GI elements for conservation purposes, in line with one of the aims of GI in the EC Communication (2013): *protecting and enhancing nature and natural processes* as a green alternative to grey infrastructure. We concentrate on the regulating and maintenance services (as defined in Table 4 of Haines-Young and Potschin, 2013), since most of the provisioning and cultural services are mainly driven by human inputs like energy (e.g. labour, fertilisers) or capital (e.g. touristic infrastructures), and do not necessarily enhance natural processes (see trade-off analysis and conclusions in Nelson et al., 2009; Maes et al., 2012). These concerns are further explained in section 5. For example, if we include food provision in the assessment and we highlight the areas with a maximum production (crop yield) we will probably spot intensive agriculture areas that are sustained more by human inputs, like fertilisers and mechanical means, than by nature, like soil organic matter. With the available knowledge and information, by concentrating on regulating and maintenance services, we can assume that an improvement on the resulting GI network will enhance the condition of the ecosystems and natural processes.

With these premises (protecting and enhancing nature and natural processes), we decide to focus on the natural capacity of landscapes to deliver services before taking into account the human demand. This natural capacity, also refer to as "ecosystem function" in the ecosystem services' cascade framework (or "pathway" in de Groot et al., 2010), depends on the biophysical

[1] COM (2011) 244 final, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0244&from=EN.
[2] COM (2011) 571 final, http://ec.europa.eu/environment/resource_efficiency/pdf/com2011_571.pdf.
[3] COM (2011) 612 final/2, http://www.espa.gr/elibrary/Cohesion_Fund_2014_2020.pdf; COM (2011) 614 final, http://www.esparama.lt/es_parama_pletra/failai/fm/failai/ES_paramos_ateitis/20111018_ERDF_proposal_en.pdf.
[4] COM (2010) 672 final, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0672:FIN:en:PDF; Regulations 1305/2013, 1306/2013, 1307/2013 and 1308/2013.
[5] COM (2013) 659 final, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2013:0659:FIN:en:PDF.