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Research Paper

# Spatial alternatives for Green Infrastructure planning across the EU: An ecosystem service perspective

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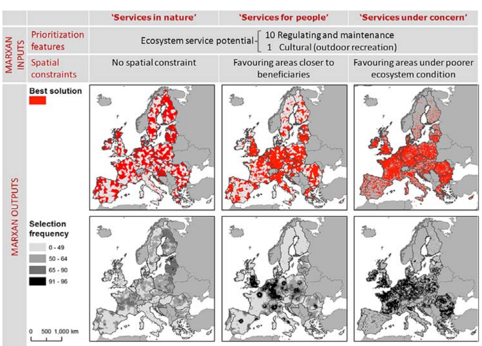
## GRAPHICAL ABSTRACT

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## ABSTRACT

Target 2 of the EU Biodiversity Strategy to 2020 aims at the deployment of Green Infrastructure (GI) and the restoration of at least 15% of degraded ecosystems. We assess different alternatives for the spatial planning of GI and ecosystem restoration across the European Union by using spatial conservation prioritization tools. We compared three different scenarios for the identification of priority areas in which the ecosystem service potential, beneficiaries (i.e. people) and ecosystem condition play different roles. As an example of GI restoration, we also assessed the cost-effectiveness of removal of invasive alien species in the areas prioritized under each scenario.

The comparative assessment of the spatial alternatives for GI shows synergies and conflicts. We found that GI could be efficiently established close to densely populated areas, since high multi-functionality is delivered in these locations (close to human settlements). However, restoration costs, such as the removal of invasive alien species, were higher in such areas given the influence of urban pressures. We also found that GI prioritized in areas under poor ecosystem condition would require a larger spatial extent of implementation, due to a lower ecosystem service potential per unit area.

Given the scarcity of resources for investment in GI and ecosystem restoration, win-win situations should be

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identified where GI designation can deliver several policy objectives simultaneously. The prioritization framework we have presented here could also be applied at the country or regional level to support local planning.

## 1. Introduction

The need for healthy ecosystems is becoming widely recognised, not just to halt the loss of biodiversity, but also to benefit from the many valuable services they provide to humans. An essential condition for healthy ecosystems is the maintenance of ecological integrity. Habitats throughout Europe are becoming increasingly fragmented and degraded due to an increase of pressures on the environment (Millennium Ecosystem Assessment, 2005). Given the scale of the challenge, more needs to be done at the European level for the benefit of people as well as nature. In this sense, Green Infrastructure (GI) planning is a policy tool that stands to improve human well-being through its environmental, social and economic values, based on the multi-functional use of ecosystems. GI designation is a key step towards the success of the EU 2020 Biodiversity Strategy. The Strategy's Target 2 (European Commission, 2011) requires that "*by 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15% of degraded ecosystems*". Ecosystem restoration has been shown to enhance not only biodiversity, but also ecosystem service potential (Barral, Rey Benayas, Meli, & Maceira, 2015; Benayas, Newton, Diaz, & Bullock, 2009). Therefore, setting priorities to restore and promote the designation of GI is essential at both the European Union and Member State level.

GI has been described 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" (European Commission, 2013). Different strategic plans could be adopted to identify priority areas for GI designation that would result in completely different spatial networks. At the EU level the European Environment Agency has proposed a methodology to identify multi-functional GI based on ecosystem services (ES); key habitats for target species; and connectivity (European Environment Agency, 2014; Liquete et al., 2015). In this approach, ES account for the natural contribution of ecosystems to generate services; usually termed 'ecosystem service potential' or 'capacity' (Syrbe, Schröter, Grunewald, Walz, & Burkhard, 2017). The socio-economic dimension, necessarily linked to the ecosystem service concept, is not considered in the identification of potential GI. This omission favours the prioritization of GI in areas with high ES potential, generally found in remote areas, where anthropogenic pressure is relatively low but also where beneficiaries of ES are therefore scarce. Moreover, if there is low demand for the service to generate benefit, only a small proportion of the ES potential will be effectively used. Ultimately, the actual flow of the service, which is a fraction of the ES potential, is steered by the demand for the service (Syrbe et al., 2017), and the spatial connection (e.g. proximity) between the service potential and demand (i.e. people). Therefore, in remote areas, benefits derived from nature would reach only a small proportion of the EU population, and the overall contribution of ES to human well-being would be limited.

Another example of GI prioritization at the EU level is the identification of key areas for GI designation based on the ES potential for a subset of services contributing to the mitigation of weather and climate change-related natural hazards, such as flood protection and mass stabilization (European Environment Agency, 2015a). This last example of GI integrates ES demand into spatial planning, taking into account the population and infrastructure requiring protection from weather and climate change impacts. Integration of socio-economic components into the GI prioritization would reinforce the link between ecosystems and socio-economic systems, resulting in a network with added value for society by increasing the provision of benefits and value of nature. In this sense, GI would also promote societal well-being by means of ecosystem services, which is also considered a key function of such a network (DG Environment, 2012).

The dependency of human well-being upon ecosystem services is widely acknowledged (Millennium Ecosystem Assessment, 2005; TEEB, 2012). Nevertheless, socio-economic systems are also key drivers of ecosystem change, exerting pressures either through the direct exploitation of ecosystem services or through the impacts caused by human activities in general (drivers of change arrow, Fig. 1). This may negatively affect ecosystem condition, compromising the long-term functioning of ecosystems and hence the benefits society can get from them. It will result in a negative effect on several components of human well-being in the long run (Millennium Ecosystem Assessment, 2005). Areas in poor ecosystem condition (i.e. degraded ecosystems) may hinder the long-term provision of multiple ecosystem services (Benayas et al., 2009; Frélichová & Fanta, 2015). Hence, in planning a multi-functional GI network capable of maintaining biodiversity and ensuring the delivery of ecosystem services, ecosystem condition should be taken into consideration.

In this context, the designation of GI closer to key socio-economic areas (i.e. cities) or those with poor ecosystem condition would require larger restoration efforts than in more intact (or remote) areas due to greater pressures and/or impacts. Restoration measures (e.g. replanting vegetation, rewetting), constitute an important investment (Tucker et al., 2013), but bring multiple benefits from the ecosystem services perspective (de Groot et al., 2013). Cost-effectiveness of ecosystem

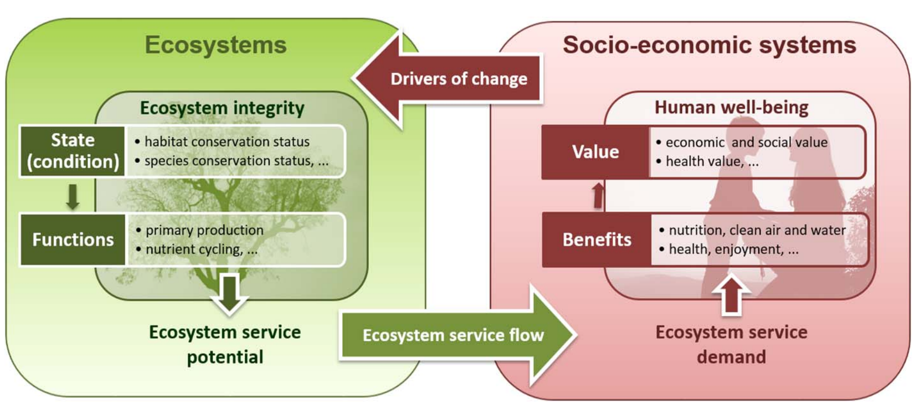


**Fig. 1.** Conceptual framework for EU wide ecosystem assessments linking socio-economic systems with ecosystems via ecosystem services and drivers of change, modified from Maes et al. (2013).