Science of the Total Environment 651 (2019) 541–550

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Designing a network of green infrastructure to enhance the conservation value of protected areas and maintain ecosystem services

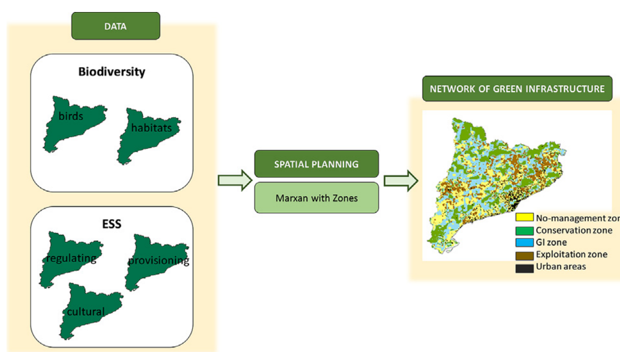
Mónica Lanzas [a,*], Virgilio Hermoso [a,g], Sergio de-Miguel [b], Gerard Bota [a], Lluis Brotons [c,d,e,f]

[a] Centre de Ciència i Tecnologia Forestal de Catalunya (CTFC), Ctra de St. Llorenç de Morunys km2, 25280 Solsona, Spain
[b] Departament de Producció Vegetal i Ciència Forestal, Universitat de Lleida-Agrotecnio Center (UdL-Agrotecnio), Av. Rovira Roure, 191, E-25198 Lleida, Spain
[c] InForest JRU (CTFC-CREAF), Ctra de St. Llorenç de Morunys km2, 25280 Solsona, Spain
[d] CREAF, Cerdanyola del Vallés, 08193, Spain
[e] CSIC, Cerdanyola del Vallés, 08193, Spain
[f] Catalan Ornithological Institute, Natural History Museum of Barcelona, Plaça Leonardo da Vinci 4-5, 08019 Barcelona, Catalonia, Spain
[g] Australian Rivers Institute, Griffith University, Nathan, Qld 4111, Australia

HIGHLIGHTS

- Managing biodiversity and ESS together is necessary to improve human well-being
- International policies support the design of GI networks and holistic planning
- We prioritized the allocation of management zones for ESS and biodiversity
- These zones would allow harmonizing conservation and development
- Our approach could inform decision-making and policy

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 23 July 2018
Received in revised form 12 September 2018
Accepted 12 September 2018
Available online 13 September 2018

Editor: D. Barcelo

Keywords:
Co-benefits
Connectivity
Marxan with zones
Multi-functionality
Systematic conservation planning
Trade-offs

ABSTRACT

There is a growing demand for holistic landscape planning to enhance sustainable use of ecosystem services (ESS) and maintenance of the biodiversity that supports them. In this context, the EU is developing policy to regulate the maintenance of ESS and enhance connectivity among protected areas (PAs). This is known as the network of Green Infrastructure (GI). However, there is not a working framework defined to plan the spatial design of such network of GI.

Here, we use the software Marxan with Zones, to prioritize the spatial distribution of different management zones that accommodate the needs of a network of GI. These zones included a conservation zone, mainly devoted to protecting biodiversity, a GI zone, that aimed at connecting PAs and maintaining regulating and cultural ESS; and a management zone devoted to exploiting provisioning ESS. We performed four planning scenarios that distribute the targets for ESS and biodiversity in different ways across management zones. We also conducted a sensitivity analysis by increasing ESS targets to explore trade-offs that may occur when managing together biodiversity and ESS. We use Catalonia (northeastern Spain) as a case study.

We found that the representation of ESS could be achieved for intermediate targets in all scenarios. There was, however, a threshold on these targets over which trade-offs appeared between maintaining regulating and cultural ESS and biodiversity versus getting access to provisioning ESS. These “thresholds values” were displaced towards higher ESS targets when we moved from more strict to more flexible planning scenarios (i.e., scenarios that allowed mixing representation of objectives for biodiversity and ESS within the same zone).

* Corresponding author at: Centre Tecnològic Forestal de Catalunya (CTFC), Ctra de St. Llorenç de Morunys km2, 25280 Solsona, Spain.
E-mail address: lanzas.monica@gmail.com (M. Lanzas).

https://doi.org/10.1016/j.scitotenv.2018.09.164

This methodological approach could help design a framework to integrate biodiversity and ESS management in holistic plans and decision making and, at the same time, meeting European mandates concerning the design of GI networks, or similar needs elsewhere.

1. Introduction

The degradation of ecosystems and habitats is a widespread process worldwide (Iii et al., 2000). Human impacts on ecosystems and biodiversity are cause of habitats loss and species extinctions (Didham et al., 2007). This is not only a problem concerning nature conservation but also for human wellbeing, given the dependence of humans on the services provided by ecosystems (Mavrommati et al., 2016; Bastian, 2013). The more degraded ecosystems become, the more difficult it is to cover the increasing human demand for the services that they provide (Carpenter et al., 2009; Tallis et al., 2008). These ecosystem services (ESS), represent all the products and services that human obtain from ecosystems (Egoh et al., 2007), directly benefiting people's wellbeing and contributing to economic development (Naidoo et al., 2008). However, according to recent assessment, up to 60% of world's ESS have been degraded (Maes et al., 2015).

Despite the increasing efforts devoted to conservation in the last decades, little impact has been observed and biodiversity and ESS continue to decline (Butchart et al., 2010; WWF, 2016) which claims for the need of more active ecosystem management, correct quantification and monitoring of ESS to preserve them and address societal needs (Tallis and Polasky, 2009). There is also urgent need for holistic landscape planning that integrates all these different objectives and values together (Martinez-Harms et al., 2015). The consideration of both ESS and biodiversity in decision-making can help create new opportunities for sustainable use of ecosystems and biodiversity conservation (Egoh et al., 2007; Schröter et al., 2014; Mitchell et al., 2015). Understanding the way ecosystems and human needs are related, offers the opportunity to develop new approaches in ecosystems management considering conservation and human needs as complementary (Balvanera et al., 2001). This new paradigm changes the way conservation has been conceptualized so far, shifting away from traditional conservation schemes, focused on strict conservation goals, towards a new vision that combines conservation and other social demands. This has been defined by Mace (2014) as the "nature and people" concept which considers dynamic and resilient interactions between human and ecosystems.

However, planning for both biodiversity and ESS together, poses a challenge as there are not only co-benefits to be addressed (e.g., Venter et al., 2009), but also trade-offs between conservation goals and granting access to particular ESS that might come at odds with the conservation of biodiversity and other ESS (e.g., Morán-Ordóñez et al., 2016). A conservation plan that seeks to enhance sustainability should ideally try to maximize co-benefits from ESS and biodiversity conservation goals (Chan et al., 2006) and, at the same time, to minimize trade-offs that could occur when managing together biodiversity and ESS. Therefore, specific planning strategies are necessary to manage all the factors that need to be included in holistic management plans to guarantee simultaneously the persistence of biodiversity and ESS as well as securing human well-being (Naidoo et al., 2008). This is especially the case of highly humanized landscapes like in Europe where there is high competition for space for different purposes (e.g., conservation vs. development). This approach of integrated planning is receiving increasing support from international policies. The EU is currently working on designing a network of green infrastructure (GI) strategically planned to conserve and reconnect fragmented natural areas and, at the same time, to foster the maintenance of a wide range of ESS and their associated socio-economic benefits (Benedict and Mcmahon, 2002; European Commission, 2016). This GI aims to achieve multi-functionality and smart conservation, with special focus on areas that connect protected areas such as Natura 2000 sites (Mubareka et al., 2013). In this way, including GI considerations in the planning and decision-making process can help maintaining ESS supply and biodiversity conservation goals, especially those threatened by land use changes, and to improve and restore soil and ecosystem functions (Liquete et al., 2015).

The aim of this study was to develop an operational GI planning framework to achieve biodiversity conservation and maintenance of ESS by using a systematic conservation planning approach. Our goal was to prioritize the spatial allocation of different management zones to maximize co-benefits between important areas for biodiversity and ESS that are compatible with conservation priorities. At the same time, we tried to minimize the trade-offs between ESS that are not compatible with conservation, always ensuring the access to provisioning ESS, using Catalonia region (NE Spain) as a case study area. We designed four planning scenarios to explore different landscape-level management options in the design of a GI network depending on how ESS are distributed between alternative management zones. We also performed a sensitivity analysis to illustrate thresholds over which trade-offs between ESS and biodiversity appear. To do so, we defined targets for every ES and biodiversity values, being targets the amount of each ES, or distribution of habitats and bird species that we wanted to be represented within our management zones.

2. Study area

The study focuses on Catalonia (NE Spain), which has a population of 7.5 million people and covers an area of 32,000 km^2. This region has wide diversity of habitats from coastal to alpine ecosystems structured in three main important geomorphological units: Coastal mountain range, Pyrenean mountain range and central depression. Catalonia mostly features a Mediterranean climate, although there are high temperature differences between the coastal areas (annual average temperature 16.5 °C) and the mountains with annual average of 9 °C (www.meteo.cat). The whole territory holds a rich biodiversity, with >3000 plant species and 763 animal species (Banc de Dades de Biodiversitat de Catalunya, 2016). In addition, over 29% of its territory has diverse conservation status under the Natura 2000 network, which is a coordinated network of protected areas along Europe comprising >27,000 sites and covering 18% of the EU (European Commission, 2018). This network is formed by 115 spaces declared of Community Interest and by 73 spaces declared Areas of Birds Special Protection.

Catalonia is covered by approximately two million hectares of forest area (Corine Land Cover, 2012), representing 61% of the total area of the region, as well as by large crop areas (35% of the total area), also hosting high biodiversity values (Corine Land Cover, 2012). A land use map is included in Appendix B for further information. These large forest and agricultural lands are socioeconomically relevant and also of major importance as habitats for many species (Observatori forestal Català, 2015), so its preservation is crucial for achieving biodiversity conservation goals and meeting socioeconomic needs and demands. The economic activities involving forestry and agriculture contribute to more than the 3% of total Catalan GDP. Furthermore, forest ecosystems have other contributions in terms of ESS such as climate regulation and mitigation, erosion control and hydrological regulation (Luque et al., 2017).