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Effects of budget constraints on conservation network design for biodiversity and ecosystem services

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ABSTRACT

Limited budgets and budget cuts hamper the development of effective biodiversity conservation networks. Optimizing the spatial configuration of conservation networks given such budget constraints remains challenging. Systematic conservation planning addresses this challenge. Systematic conservation planning can integrate both biodiversity and ecosystem services as conservation targets, and hence address the challenge to operationalize ecosystem services as an anthropocentric argument for conservation. We create two conservation scenarios to expand the current conservation network in the Dutch province of Limburg. One scenario focuses on biodiversity only and the other integrates biodiversity and ecosystem services. We varied conservation budgets in these scenarios and used the software Marxan to assess differences in the resulting network configurations. In addition, we tested the network's cost-effectiveness by allocating a conservation budget either in one or in multiple steps. We included twenty-nine biodiversity surrogates and five ecosystem services. The inclusion of ecosystem services to expand Limburg's conservation network only moderately changed prioritized areas, compared to only conserving biodiversity. Network expansion in a single time-step is more efficient in terms of compactness and cost-effectiveness than implementing it in multiple time-steps. Therefore, to cost-effectively plan conservation networks, the full budget should ideally be available before the plans are implemented. We show that including ecosystem services to cost-effectively expand conservation networks can simultaneously encourage biodiversity conservation and stimulate the protection of conservation-compatible ecosystem services.

1. Introduction

Creating protected areas is a much seen strategy for biodiversity conservation (Rands et al., 2010). For instance, throughout Europe a network of protected nature areas (Natura 2000 sites) has been established to conserve biodiversity as part of the European Union (EU) Biodiversity Strategy (European Commission, 2011). In addition, EU member states have made their own efforts to conserve and manage biodiversity. For example, the Netherlands has been developing the National Ecological Network since the 1990s to connect protected areas and to enhance the mobility of species (LNV, 1989). In recent years, severe governmental budget cuts have hampered the completion of this national ecological network (Buijs et al., 2014) and individual provinces must now arrange their own spatial conservation efforts.

Limited budgets often constrain current conservation efforts (Brooks et al., 2006; James et al., 1999). Optimizing the spatial configuration of the expansion of such conservation networks under constrained conservation budgets is challenging, in particular in face of other societal and economic interests in land use. Accounting for conservation costs, such as costs for acquiring land (opportunity costs), can improve the effectiveness of conservation planning (Naidoo et al., 2006). Systematic conservation planning is an approach to address this challenge. The approach systematically identifies surrogates for conservation features (biodiversity and ecosystem services), sets quantitative and operational targets, recognizes how these targets can be met by conservation areas and uses explicit, yet simple, methods to locate and design conservation areas (Margules et al., 2007; Margules and Pressey, 2000; Moilanen et al., 2009).

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Traditionally, conservation efforts, such as the creation of protected areas, have focused on biodiversity (Castro et al., 2015; Cimon-Morin et al., 2013). However, ecosystem services (ESs), which are defined as the contributions of ecosystems to human well-being (Haines-Young and Potschin, 2010), have been introduced as an additional argument for conservation (Armsworth et al., 2007; Chan et al., 2011; Schröter et al., 2014c). Increasing amounts of quantitative information are being gathered to spatially model ESs (Maes et al., 2012; Martínez-Harms and Balvanera, 2012; Nemec and Raudsepp-Hearne, 2013; Schägner et al., 2013). Spatial ES models are increasingly being used for ecosystem accounting, i.e. the systematic, spatially explicit monitoring of ES provision (Remme et al., 2015; Schröter et al., 2014a; Sumarga et al., 2015). However, appropriate policy purposes and applications of accounting still need to be further explored (Schröter et al., 2015). One such application could be systematic conservation planning. Biodiversity conservation networks could potentially both conserve and enhance the provision of specific ESs (Castro et al., 2015). Additionally, the inclusion of ESs in systematic conservation planning could well improve biodiversity conservation (Cimon-Morin et al., 2013), as important areas for ES conservation could provide additional areas to conserve biodiversity. However, including ESs in systematic conservation planning is a relatively recent, and yet underdeveloped research field (Chan et al., 2011; Schröter et al., 2014b) that requires further research, especially given the complex relationship between ES and biodiversity (Balvanera et al., 2014; Mace et al., 2012). For example, a distinction should be made between conservation-compatible ESs and ESs that are not compatible with biodiversity conservation (Chan et al., 2011). Conservation-compatible ESs can reasonably be used as an additional conservation argument as their inclusion creates potential synergies or at least no conflicts with biodiversity conservation. Generally, regulating and cultural services are conservation-compatible, while provisioning services are likely incompatible due to material extraction necessary to make use of the ES (Schröter and Remme, 2016).

We aim to assess the impact of limited conservation budgets on cost-effective spatial network conservation strategies for ESs and biodiversity. The conservation site selection software Marxan (Ball et al., 2009) offers an approach to integrate ESs and biodiversity targets as well as cost information in the context of systematic conservation planning, by implementing three main conservation principles: comprehensiveness (i.e. reaching multiple conservation targets), cost-effectiveness (i.e. cheaper solutions are preferred to costly solutions) and connectivity (i.e. a low edge-to-area ratio of a conservation area) (Wilson et al., 2010). Recent studies using Marxan have integrated ES and biodiversity targets to develop conservation networks. Likewise, the comparable reserve selection software Zonation has also been used to integrate ES and biodiversity targets (e.g. Durán et al., 2014; Snäll et al., 2016). Studies that used Marxan have included different types of cost data, ranging from restoration costs (Egoh et al., 2014) to opportunity costs for alternative land uses (Chan et al., 2011; Schröter et al., 2014b) and accumulated threats to ESs (Izquierdo and Clark, 2012). To date, direct costs of land acquisition have not been applied to develop conservation areas with Marxan. Land acquisition costs constitute an important cost factor in conservation planning (Naidoo et al., 2006). Including land acquisition costs in planning a biodiversity conservation network

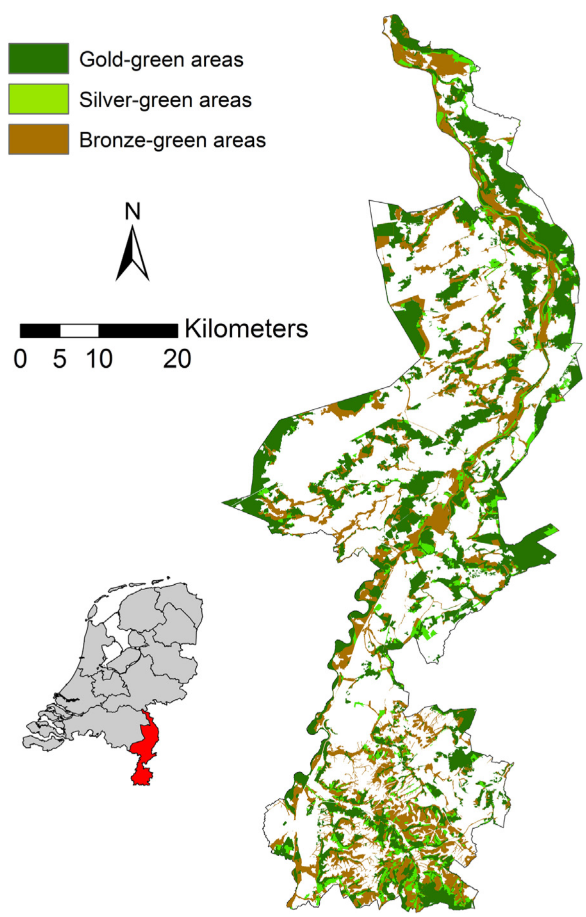

Fig. 1. Zonation of Limburg for a conservation network, with the gold-green (current conservation network), and silver-green and bronze-green areas (both possible network expansion areas). White represents areas that are not suitable for conservation. Derived from Provincie Limburg (2014). For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.