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Integrating biodiversity, ecosystem services and socio-economic data to identify priority areas and landowners for conservation actions at the national scale

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ABSTRACT

Gaps in research exist for country-wide analyses to identify areas of particular importance for biodiversity and ecosystem services to help reach Aichi Target 11 in developing countries. Here we provide a spatial conservation prioritization approach that ranks landowners for maximizing the representation of biodiversity features and ecosystem services, while exploring the trade-offs with agricultural and commercial forestry production and land cost, using Uruguay as a case study. Specifically, we explored four policy scenarios, ranging from a business as usual scenario where only biodiversity and ecosystem services were included in the analysis to a potentially unsustainable scenario where expansion of alternative land uses and economic development would be given higher priority over biodiversity and ecosystem services. At the 17% land target proposed for conservation, the representation levels for biodiversity and ecosystem services were, on average, higher under the business as usual scenario. However, a small addition to the proposed target (from 17 to 20%) allowed to meet same representation levels for biodiversity and ecosystem services, while decreasing conflict with agricultural and commercial forestry production and opportunity costs to local landowners. Under the unsustainable scenario, a striking 41% addition to the conservation target (from 17 to 58%) was needed to meet same representation levels for threatened ecosystems and ecosystem services, which are crucial to sustain human well-being. Our results highlight that more realistic and potentially higher conservation targets, than politically set targets, can be achieved at the country level when sustainable development needs are also accounted for.

1. Introduction

Current declines of biodiversity and ecosystem services are unprecedented (Butchart et al., 2010). Local, national and international policies have been promoted and are being implemented to halt and reverse such declines. In 2010, 20 Aichi targets were adopted by the Convention of Biological Diversity to address this challenge (Convention on Biological Diversity, 2010). Aichi Target 11 promotes the expansion of the global protected area network to cover 17% of all terrestrial land by 2020. Individual countries have committed to conserve 3–50% of their land to help reach this target (Butchart et al., 2015). Decision makers need effective methods and scientifically sound information to identify "areas of particular importance for biodiversity and ecosystem services" through "ecologically representative systems of protected areas and other effective area-based conservation measures" (Convention on Biological Diversity, 2010). The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) promotes the use of scenarios to assess various policy interventions in order to inform Aichi Target 11 (IPBES, 2016). Meanwhile, the UN Sustainable Development Goal 15 (Life on land), which directly links to Aichi Target 11, promotes the integration of ecosystem and biodiversity values into national and local planning, development processes, and poverty reduction strategies (http://www.un.org/sustainabledevelopment/biodiversity/).

Spatial conservation prioritization is the sub-field of conservation planning that deals with the identification of priority areas for conservation action where limited resources should be allocated (Moilanen et al.,

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2009). Spatial conservation prioritization can be carried out at multiple scales, ranging from global to local (Butchart et al., 2015; Di Minin et al., 2016, 2013; Game et al., 2011; Montesino Pouzols et al., 2014; Smith et al., 2016; Soutullo et al., 2008; Venter et al., 2014). A recent global analysis found that expanding the global protected area network to 17% of all terrestrial land could potentially triple the coverage of all terrestrial vertebrate species if countries were to collaborate in the identification of new protected areas, as opposed to acting independently (Montesino Pouzols et al., 2014). At the same time, national analyses remain crucial, as countries are identified as the main actors in the implementation of the Aichi Targets (Convention on Biological Diversity, 2010). Furthermore, national to regional conservation planning assessments can include data that may not be readily available at continental extents, including detailed information about social, economic, and political factors affecting on-the-ground implementation (Knight et al., 2006). National to regional conservation planning assessments can also help identify priority areas that can fulfil and sustain the local demand for ecosystem services by their human beneficiaries (Cimon-Morin et al., 2013).

Conservation planning assessments published in scientific literature are mainly from Europe, North America, Oceania and South Africa (Kukkala and Moilanen, 2013; Kullberg and Moilanen, 2014). Currently, gaps in research exist for country-wide analyses at a fine resolution that encompass the full set of biological and socio-economic data needed to inform conservation decision-making in developing countries (Kukkala and Moilanen, 2013; Kullberg and Moilanen, 2014). This is worrying, as developing countries host some of the most threatened biodiversity (Butchart et al., 2015; Montesino Pouzols et al., 2014) and ecosystem services (Turner et al., 2007). Nation-wide conservation planning assessments are mostly missing from South America where there has mainly been a focus on regional scale conservation planning within countries (see e.g. Faleiro and Loyola, 2013; Faleiro et al., 2013; Tognelli et al., 2008). The lack of comprehensive, high-resolution, up-to-date spatial information about species, ecosystems, and ecosystem services is a major constraint to the development of conservation planning assessments in developing countries (Di Minin and Toivonen, 2015; Stephenson et al., 2016). In addition, conservation planning assessments often ignore the needs of society for human and economic development and food production (Lambin and Meyfroidt, 2011), failing to be implemented (Knight et al., 2006). Finally, national conservation planning assessments should be more directly linked to land use planning in order to promote stakeholders' engagement and enhance the implementation of conservation actions (Pierce et al., 2005).

To our knowledge, no previous country-wide conservation planning assessment to identify priority areas for the conservation of biodiversity and ecosystem services to help reach Aichi Target 11 was developed for a South American country. Here, we fill this gap and provide a spatial conservation prioritization approach for maximizing the representation of biodiversity features and ecosystem services, while exploring the trade-offs with agricultural and commercial forestry production and land cost, using Uruguay as a case study. Importantly, our approach can be used to identify the most important landowners to engage in the implementation of conservation actions at the national level. In Uruguay, national conservation authorities have independently identified key biodiversity features and ecosystem services that the country needs to conserve, and generated updated information on the spatial distributions of the same, with the aim of identifying priority areas for the expansion of Uruguay's presently very limited protected area network (< 1% of Uruguay is protected) to help reach Aichi target 11 (MVOTMA, 2015). The conservation authorities also aim to include the strategy for protected area expansion within a broader strategy for sustainable development following the UN Sustainable Development Goals, particularly #15 of which Aichi Target 11 is part of. In order to do so, we explored four policy scenarios to assess whether it was possible to decrease conflict between conservation and alternative land uses, as well as opportunity costs to local landowners.

2. Methods

2.1. Study area

Located in temperate South America (Fig. 1), most of Uruguay is a rolling plain that represents a transition from the Argentinian pampas to the hilly uplands of southern Brazil. Uruguay has a humid subtropical climate that is fairly uniform nationwide (MVOTMA, 2010). The whole country is part of the Uruguayan Savannah ecoregion, which is classified as a 'crisis' ecoregion because of its extensive habitat conversion and limited habitat protection (Hoekstra et al., 2005). This ecoregion constitutes one of the richest areas for grassland biodiversity in the world, including vegetation communities of great species diversity (~2000 species). Temperate grasslands, which are the most threatened biome at the global level with <0.6% of its extent protected (Noss, 2013), are the main ecosystem in Uruguay.

Historically, traditional cattle-ranching on native grasslands has been the main economic activity. Over the last 15 years a sustained increase in commercial forestry and agriculture has challenged meat as the main export product. With a population of <3.5 million people with <20 people per km^2 (http://www.ine.gub.uy/), Uruguay is among the top 5% countries in which the impacts of human development on biodiversity are expected to be the largest in the near future (Lee and Jetz, 2008).

2.2. Biodiversity features and datasets

The local conservation authorities identified 373 key biodiversity features for which reliable spatial distribution maps were also available (Suarez-Pirez and Soutullo, 2015) (Table 1 and Table S1 in Appendix A for a full list): i) 219 mammals, birds, amphibians, freshwater fish and plant species; ii) 92 threatened native ecosystems; iii) 6 ecosystem services; iv) 7 nationally recognized ecoregions; and v) 13 landscape units.

All species were threatened, either at the global or national level, or vulnerable to projected climate change in Uruguay (Soutullo et al., 2013, 2012b; Suarez-Pirez and Soutullo, 2015). Nationally threatened species have either a small population size or distribution in the country. Deductive models were used to model the distribution of all species (see e.g. Maiorano et al., 2006). Deductive distribution models use information about species-habitat associations based on literature reviews and expert knowledge (Brazeiro et al., 2012 and Supplementary Methods for more information). Deductive models were considered the most effective tool for modelling species distributions, as most priority species had well-understood relationships with accurately mapped habitat variables (Brazeiro et al., 2012).

Both ecoregions and landscape units delineate large homogeneous regions based on biophysical similarities. Yet, while ecoregions were delineated by integrating information on topography, soil types, land cover and species distributions (Brazeiro, 2015), landscape units were defined on the basis of the similarity of the landscape structure in terms of land cover and spatial patterns of the different landscape components (i.e., matrix, patches and corridors) (Evia and Gudynas, 2000). Threatened native ecosystems are those that currently cover <1% of Uruguay and are expected to further decline in size due to land-use change (Brazeiro et al., 2012). Threatened ecosystems represent smaller homogeneous units, which were mapped on the basis of land cover information derived from satellite imagery, soil types and topographic features and are mainly composed of native species.

For ecosystem services, we considered 6 provisioning and regulating services (Millennium Ecosystem Assessment 2005) that are relevant for rural activities, with benefits obtained in situ or in the vicinity of the ecosystems that produce them: (i) drinking water provision (continued access to water for consumption); (ii) genetic resources provision (maintenance of a high diversity of native organisms); (iii) climatic regulation (provision of conditions of temperature and humidity that are favourable for humans, cattle and most common local crops); (iv)