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Is climate-smart conservation feasible in Europe? Spatial relations of protected areas, soil carbon, and land values

Kerstin Jantke [a,b,*], Jana Müller [a], Natalie Trapp [a], Benjamin Blanz [a]

[a] Research Unit Sustainability and Global Change, Universität Hamburg, Grindelberg 5, 20144, Hamburg, Germany
[b] Centre for a Sustainable University, Universität Hamburg, Mittelweg 177, 20148, Hamburg, Germany

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ABSTRACT

The expectations on protected areas to deliver not only biodiversity conservation but also to provide an array of different ecosystem services rise. Sequestration and storage of carbon are promising services that protected areas may provide. This study integrates spatially explicit data on terrestrial Natura 2000 sites, soil organic carbon, and agricultural land values to estimate the potential for climate-smart conservation planning in the European Union. The objectives of this study are to analyse spatial relations between protected areas soil carbon content, and land values on the European Union's land area as well as to locate and quantify the proportion of land with high carbon and low economic value within and outside protected areas. We apply a unique interdisciplinary framework with methods ranging from analyses based on geographical information systems, agricultural economics to statistics. Findings indicate that there is a significant overlap between Natura 2000 sites and regions with high carbon content across Europe. Statistical analyses show that carbon-rich regions have significantly lower land values than other areas. Our results suggest that biodiversity protection and mitigation of climate change through conservation of soil carbon could be simultaneously achieved in Europe's protected areas and beyond. We conclude that there is a notable potential for climate-smart conservation in Europe that needs further investigation.

1. Introduction

Biodiversity loss and climate change are major challenges of the 21st century (Cardinale et al., 2012; IPCC, 2014; Rockstrom et al., 2009). An important element of any strategy to conserve biodiversity and cornerstone of most national conservation policies is to set aside land of high ecological value as protected area (Margules and Pressey, 2000; Watson et al., 2014). Such areas can also contribute to mitigating climate change through natural carbon capture and sequestration (CCS) in ecosystems (Bonan, 2008; IPCC, 2014).

A challenge in global change research is to explore options to effectively link biodiversity conservation and mitigation of climate change. While pristine ecosystems such as primary forests and intact mires are generally both biologically diverse and carbon dense, degraded ecosystems suffer from biodiversity loss and often show a decreased or even reversed CCS capacity (Millennium Ecosystem Assessment, 2005; Moore et al., 2013; Wei et al., 2014).

Moreover, the issues of climate change and biodiversity are interlinked. Climate change is expected to negatively affect biodiversity as it implies, for example, large geographic displacements and widespread extinctions (Butchart et al., 2010; Dawson et al., 2011). Vice versa, a loss of biodiversity may accelerate climate change (e.g. through land use change). Deforestation or peatland drainage cause shifts in moisture and temperature as well as a release of stored carbon into the atmosphere (Betts et al., 2007; Joosten, 2010). This, however, means that protecting biodiversity can also help in mitigating climate change, e.g. when degraded ecosystems are restored and at best retain their potential as a carbon sink (Mitsch et al., 2013). While natural CCS in living plants and soils is likely to have a positive effect on biodiversity, other principal land-based approaches for reducing greenhouse gases, such as the replacement of fossil fuel with biomass fuel, may further accelerate biodiversity loss due to the intensification of production and increasing competition for agricultural land (Huston and Marland, 2003; Powell and Lenton, 2013; Schleupner and Schneider, 2010). As a consequence of the increasing land-based challenges,

* Corresponding author at: Research Unit Sustainability and Global Change, Universität Hamburg, Grindelberg 5, 20144, Hamburg, Germany.
E-mail addresses: kerstin.jantke@uni-hamburg.de (K. Jantke), frau.jana.mueller@gmail.com (J. Müller), natalie.trapp@uni-hamburg.de (N. Trapp), benjamin.blanz@uni-hamburg.de (B. Blanz).

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the focus of land use policies becomes broader to account for the variety of goods and services that people obtain from ecosystems (Millennium Ecosystem Assessment, 2005).

Consequently, the expectations on protected areas to deliver not only biodiversity conservation but also to provide an array of different ecosystem services rise (Stolton and Dudley, 2010; Watson et al., 2014). Natural CCS is especially seen as a promising service that protected areas may provide to mitigate climate change (Campbell et al., 2008; Ervin, 2011; Huston and Marland, 2003). Terrestrial ecosystems are estimated to store about 2050 gigatons of carbon (GtC) in their biomass and soil (0–100 cm depth) worldwide. Protected areas contain about 312 GtC or 15.2% of the global terrestrial carbon stock on 12.2% of the terrestrial area (Campbell et al., 2008).

Two types of economic values are relevant for exploring how to link biodiversity conservation and mitigation of climate change effectively: carbon values and land values. Ecological analyses, for example, include prices from carbon markets to estimate the monetary carbon values of ecosystems (Campbell et al., 2008; Strassburg et al., 2012; Ten Brink et al., 2011). Some studies use information on agricultural production to estimate the land opportunity costs for conservation of carbon and biodiversity to account for land values (Carswell et al., 2015; Jantz et al., 2014; Siikamaki and Newbold, 2012).

Regions with high biodiversity value, high carbon content as well as low economic land value would allow for a simultaneous and cost-effective management of biodiversity and climate change mitigation. However, most studies address either the relations between biodiversity and carbon or between biodiversity and land values, but the simultaneous linkage between them is often neglected.

Research on whether regions with high biodiversity value or protected areas contain more carbon than unprotected or less biodiversity rich sites gives a rather mixed picture. Strassburg et al. (2010) find that biodiversity is positively associated with biomass carbon in ecosystems globally, yet geographically variable. Miles and Kapos (2008) and Talbot (2010) suggest that biodiversity values and carbon values are distributed differently among tropical forests. Campbell et al. (2008) combine global data on carbon storage in vegetation and soil to estimate the amount of carbon stored within protected areas worldwide and find that protected areas capture a proportionately high amount of carbon. The spatial overlap of high biodiversity and high carbon areas with protected areas is shown in the Carbon and Biodiversity demonstration atlas (UNEP-WCMC, 2008) for several tropical countries. Zheng et al. (2013) as well as Soares-Filho et al. (2010) quantify the carbon benefits from protected areas for the United States and the Brazilian Amazon region, respectively. Recent studies find that combined carbon-biodiversity conservation strategies have substantial benefits over carbon-only or biodiversity-only strategies (Carswell et al., 2015; Siikamaki and Newbold, 2012; Thomas et al., 2013).

Little is known about spatial relations of protected areas and land values. Several studies claim that protected areas tend to be concentrated on land that, at least at the time of designation, was unproductive or too remote to be economically important (Joppa and Pfaff, 2009; Margules and Pressey, 2000; Pressey et al., 1996). However, data that underpin these findings are rarely given. Naidoo and Iwamura (2007) develop a spatially explicit global distribution map of agricultural land rents to address this gap. Their study shows a suboptimal allocation of conservation funds when neglecting land opportunity costs in conservation planning.

Despite the variety of studies, only few of them explicitly incorporate spatial relations between all three factors: carbon, biodiversity, and land value. To the best of our knowledge, previous studies restrict their analyses to individual regions with limited variability in climate, soil or land value. Anderson et al. (2009) find that high biodiversity coincides with high agricultural land value but low vegetation and soil carbon content in Britain. Moilanen et al. (2011) propose a method to balance alternative land uses including carbon storage, biodiversity conservation, agricultural value and urban development potential also using Britain as a case study. Jantz et al. (2014) conduct a multi-criteria analysis in the Brazilian Amazon to identify corridors with high biomass carbon, high biodiversity value and low opportunity costs.

The European Union (EU) is a pioneer in biodiversity conservation due to its efforts to implement the world's largest network of protected areas, Natura 2000 (European Environment Agency, 2012; Maiorano et al., 2015). The EU's 2020 Biodiversity Strategy includes, in addition to halting the loss of biodiversity, the urgent need to maintain and restore ecosystem services in its indicators and objectives (European Parliament, 2012). Europe is also widely perceived as a leader in climate change mitigation and adaptation (Creutzig et al., 2014; de las Heras, 2013). Accordingly, EU's climate strategy proposes storage of carbon in soils and forests as well as the preservation and restoration of carbon-intense ecosystems to mitigate climate change (European Commission, 2011). Though the potential trade-offs between biodiversity conservation and mitigation of climate change in Europe have received considerable research attention (e.g. (Meller et al., 2015; Pedroli et al., 2013; Schleupner and Schneider, 2010), possible synergies have rarely been addressed in research yet. Hence, the potential for climate-smart and cost-effective conservation in Europe is largely unknown. The closest antecedent to our study provide Ten Brink et al. (2011) who estimate that the carbon storage potential in the Natura 2000 network of protected areas in Europe is around 9.6 billion tonnes of carbon. Yet, their analysis is neither spatially explicit nor does it account for heterogeneous land values.

To address this gap, our study is the first to examine the potential for climate-smart conservation from biogeochemical, ecological, and economic perspectives on a continental scale. More specifically, the objectives of this study are

(1) to analyse spatial relations between protected areas, soil carbon content, and land values on EU's land area.
(2) to identify and quantify the proportion of land with high carbon and low economic value within and outside protected areas.

To address these questions we apply an interdisciplinary framework combining geographical information systems, agricultural economics and statistics. Although this study covers the EU, the methods are applicable to other regions of different spatial scales.

2. Materials and methods

2.1. Study area

The study area comprises the terrestrial parts of 26 out of the 28 member states of the EU covering a land area of about 4.3 million km^2. The states of Croatia and Cyprus as well as the EU overseas countries and territories (OCT) and outermost regions (OMR) are excluded due to data deficiencies.

The study area belongs to one of the world's most densely populated continents with about 500 million inhabitants. It contains parts of the Mediterranean biodiversity hotspot (Myers et al., 2000) as well as several priority ecoregions for global conservation (Olson and Dinerstein, 2002). Agriculture, as the dominant land use, accounts for 43% of the EU's land area and forestry covers 29.8% of the EU (Eurostat, 2015).