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Land use policy as a driver for climate change adaptation: A case in the domain of the Brazilian Atlantic forest

Camila Linhares Rezende[a,b,c,*], Joana Stingel Fraga[a,d], Juliana Cabral Sessa[a], Gustavo Vinagre Pinto de Souza[a], Eduardo Delgado Assad[e], Fabio Rubio Scarano[a,b]

[a] *Fundação Brasileira para o Desenvolvimento Sustentável, Rua Engenheiro Álvaro Niemeyer 76, São Conrado, CEP 22610-180, Rio de Janeiro, RJ, Brazil*
[b] *Universidade Federal do Rio de Janeiro, Departamento de Ecologia, Caixa Postal 68020, CEP 21941-970, Rio de Janeiro, RJ, Brazil*
[c] *Instituto Estadual do Ambiente, Diretoria de Biodiversidade e Áreas Protegidas, Av. Venezuela 110, 2° andar, Saúde, CEP 20081-312, Rio de Janeiro, Brazil*
[d] *Pontifícia Universidade Católica do Rio de Janeiro, Departamento de Geografia, Rua Marquês de São Vicente 225, sala 411-F, Gávea. CEP 22451-900, Rio de Janeiro, RJ, Brazil*
[e] *Embrapa Informática Agropecuária (CNPTIA), Av. Andre Tosello 209, Barão Geraldo, CEP 13083-886, Campinas, SP, Brazil*

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ABSTRACT

Brazil has a great potential for ecosystem-based adaptation to climate change and to disaster risk reduction, leveraged by the commitment of restoring 12 million hectares until 2030. This commitment is legally backed by the Native Vegetation Protection Law (NVPL), which defines the situations in which landowners must recover native vegetation in their land. In this paper, we discuss the role of land use compliance as a driver for adaptation in the Brazilian Atlantic forest domain based on the case of the State of Rio de Janeiro. We used high resolution satellite imagery (5 m pixel) to map the state's land use and land cover, delineate Areas of Permanent Preservation and calculate the environmental debt, i.e. the areas required for restoration in order to comply to the NVPL. We also related the distribution of the environmental debt to the socioeconomic conditions of the municipalities and examined potential funding sources for economic incentives to enhance feasibility of restoration in private lands. The state has 31% of native vegetation cover, and an environmental debt of 412,876 ha, correlated to Human Development Index ($R = -0.2952$, $p = 0.0043$) and vulnerability to poverty ($R = 0.3711$, $p = 0.0003$). The north-northwestern region hosts the hotspots both for environmental debt and vulnerability to poverty, therefore it should constitute a priority target for environmental and social policies. Compliance to this large environmental debt to abide to the regulatory policy NVPL will demand incentive mechanisms. Oil royalties are a potential funding source for programs of payment for ecosystem services, as 3% of those annual revenues could pay the restoration of 39% of the state's environmental debt per year over 20 years. Thus, policy mixes that combine existing regulatory and incentive mechanisms should ensure low-cost landscape restoration in tandem with new job opportunities in a restoration chain, and might represent a significant opportunity for the State of Rio de Janeiro.

1. Introduction

Recent anthropogenic emissions of greenhouse gases are the highest in history, with severe impacts in human and natural systems all across the globe. Climate change will amplify existing risks and create new ones, unevenly distributed, and generally greater for disadvantaged people (IPCC, 2014). Despite national commitments of reducing emissions, temperature will continue to rise, leading to the depletion of ecosystem services such as food and water provision (Rogelj et al., 2016). In this scenario, carbon mitigation will continue to be relevant, but alone will not suffice to halt or circumvent ongoing climate trends. Adaptation strategies are needed to increase resilience of vulnerable socio-ecological systems (Scarano, 2017).

Ecosystem-based adaptation to climate change (EbA) is the set of adaptation measures which take into account the role of ecosystem services (ES) in reducing the vulnerability of society to climate change (Magrin et al., 2014; Vignola et al., 2009). Within this approach, adapting requires a combination of policy instruments related to nature conservation and restoration with socioeconomic policies that foster livelihood diversification and, consequently, income generation and poverty reduction (Jones et al., 2012; Magrin et al., 2014; Scarano, 2017).

* Corresponding author at: Fundação Brasileira para o Desenvolvimento Sustentável, Rua Engenheiro Álvaro Niemeyer, 76, São Conrado, CEP 22610-180, Rio de Janeiro, RJ, Brazil.
E-mail address: clrezende@fbds.org.br (C.L. Rezende).

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Brazil has a great potential for EbA, leveraged by the commitment of restoring 12 million hectares until 2030, assumed in December 2016 by the national government in the Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC). Unlike many contributions announced by the UNFCCC parties, the one ratified by Brazil has national legal backing (Scarano, 2017). Brazil's Native Vegetation Protection Law − NVPL (Brasil, 2012) establishes the proportion of lands inside rural properties that must be maintained under protection and defines the situations in which landowners must recover native vegetation in their land (Brancalion et al., 2016). It establishes two main types of areas of restricted use: the Areas of Permanent Preservation (APP) and the Legal Reserve (LR). The APP comprises riparian areas, hilltops, slopes, high elevations and certain types of ecosystems; while the LR correspond to a proportion of the property (varying from 20 to 80% according to the biome where the property is inserted). In order to comply, landowners must restore all degraded areas inside riparian APP and LR, which constitutes the so-called "environmental debt" of a given property. The environmental debt of LR can also be settled outside its original property, through compensation and offset mechanisms such as environmental leaseholds or by purchasing areas with native vegetation in other properties (Brancalion et al., 2016).

Estimates are that for legal compliance rural landowners will need to restore 20 million hectares (Soares-Filho et al., 2014), which is nearly twice Brazil's commitment to the UNFCCC. Restoring those areas is essential to ensure water and food security in Brazil, once they provide key ecosystem services such as water flow regulation, soil fixation and pollination (Brancalion et al., 2016; Rey Benayas et al., 2009). At the same time, if well planned, landscape restoration has the potential to create jobs and improve livelihoods, enhancing society's resilience to climate change (Stanturf et al., 2015).

The main caveat is that restoration is costly. In the case of the Atlantic Forest biome, where most food production in Brazil takes place and also where the most capacity and tools are available (Scarano and Ceotto, 2015), conservative estimates point to an average cost of USD 5000 per hectare of forest restored by traditional techniques of direct planting (Brancalion et al., 2012b). The economic feasibility of restoration will require both public and private efforts in order to strengthen its economic chain, from the production of seedlings and inputs to the direct planting and management of degraded areas. Besides environmental benefits, this chain can enhance local economies, through the creation of new jobs and business opportunities (Silva et al., 2016).

In this paper we discuss the role of land use compliance as part of a subnational EbA strategy, by examining the case of the State of Rio de Janeiro, southeast Brazil. We analyze the distribution of the legal environmental debt in the state and discuss strategies to achieve compliance, considering both socioeconomic and environmental aspects. To perform this analysis we took the following steps: i) mapped the state's land use and land cover using high resolution satellite imagery (5 m pixel) and delineated riparian APP, based on the legislation; ii) calculated the environmental debt in APP of each municipality; iii) related the distribution of the environmental debt to the socioeconomic condition of the municipalities; and iv) examined potential funding sources for economic incentives to enhance feasibility of restoration in private lands.

2. Material and methods

2.1. Study area

The State of Rio de Janeiro (42°45′6"W; 22°25′39"S) comprises an area of 43,802 km^2 in Southeastern Brazil, an equivalent to the total area of the Netherlands or Switzerland, inserted in the Atlantic Forest biome, a biodiversity hotspot (Mittermeier et al., 2005) and one of the regions with the highest richness of terrestrial vertebrates in the world (Jenkins et al., 2013). The capital, Rio de Janeiro, is the fourth largest city in South America (United Nations, 2016), and together with its metropolitan region holds a total population of 12.3 million people, or 74% of the state's total population of 16.6 million people (IBGE, 2016)

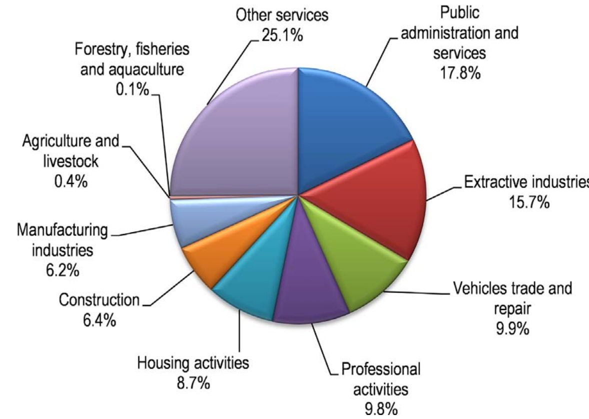

Fig. 1. State of Rio de Janeiro's gross domestic product (GDP) by gross value added (GVA). Data extracted from IBGE (2013a).

The economy of the State of Rio de Janeiro is strongly based in oil extraction. In 2015, the state produced 618 million barrels, which corresponded to 67% of Brazil's production (ANP, 2016) and 2% of global oil supply (IEA, 2016). It composes 16% of the state's gross domestic product, and moves a great part of the state's economy with its supply and processing chains (IBGE, 2013a). Rural activities such as agriculture, livestock and forestry compose less than 0.5% of the gross domestic product (Fig. 1).

Recently the state witnessed extreme climate events associated with the distribution of rainfall, which caused a series of casualties. Since 2012, a national-wide phenomena of a gradual and intense decrease in rainfall undermined significantly the water provision. This situation culminated in 2014, when, together with São Paulo, Rio de Janeiro faced a water supply collapse (Dobrovolski and Rattis, 2015; Marengo et al., 2015). In contrast, in 2011 and 2012 the region also faced major floods events, leaving more than 15,000 people homeless, businesses destroyed and plantations devastated (OECD, 2015). Recent studies indicate that water supply in Rio de Janeiro will be exhausted in 2030, when the metropolitan area of Rio de Janeiro will concentrate 95% of the state's water consumption due to a very uneven distribution of population and economic activity (COPPETEC, 2014). Avoidance of this scenario requires the development of adaptive mechanisms that enhance the state's resilience to extreme events.

2.2. Mapping

We mapped land use and land cover through supervised classification of RapidEye imagery (5 m resolution) of the year 2012, comprising the classes I) native forest formation; II) native non-forest formation; III) silviculture; IV) built areas; V) anthropic areas and VI) water. Total native vegetation cover is given by the sum of classes I and II, respectively forests (sensu IBGE, 2012) and all other native vegetation types (i.e high-altitude fields, inselbergs and sandy coastal plains − see Scarano (2009) for description of the vegetation types of the Atlantic forest biome). For a better understanding of the distribution of this class, we crossed the results of this mapping with the official databases of protected areas (MMA, 2017) in order to calculate the amount of native vegetation located inside protected areas.[1]

Regarding non-natural classes, silviculture comprises all tree monocultures, predominantly *Eucalyptus spp*. and *Pinus spp*. Built areas were extracted from Brazil's official continuous cartography (IBGE,

[1] Here we adopted the term protected areas as a synonym for conservation units, while APP and RL can be framed as Other Effective Conservation Measures (OECM).