Land Use Policy 42 (2015) 329–339

Contents lists available at ScienceDirect

Land Use Policy

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

Carbon sequestration and riparian zones: Assessing the impacts of changing regulatory practices in Southern Brazil

Marilice C. Garrastazú[a], Sabina D. Mendonça[a], Teçá T. Horokoski[a], Denise J. Cardoso[a], Maria A.D. Rosot[a], Evelyn R. Nimmo[b], André E.B. Lacerda[a,*]

[a] Brazilian Agriculture Research Corporation—Embrapa Forestry. Estrada da Ribeira, km 111, Caixa Postal 319, Colombo 83411-000, PR, Brazil
[b] ER Nimmo Consulting, Ontario, Canada

ARTICLE INFO

Article history:
Received 1 April 2014
Received in revised form 21 July 2014
Accepted 2 August 2014

Keywords:
Carbon sequestration
InVEST
Ecosystem services
Riparian zones
Forest management
Agricultural incentives

ABSTRACT

Despite the consensus that riparian zones are important for the conservation of biological diversity and many other ecosystem services, there are no consistent regulations for how, or if, riparian areas should be used and the size of buffer zones required. Recently, controversial revisions to the Forest Code in Brazil have been implemented which include a reduction in the width of protected riparian buffer zones required along rivers. In order to model the impact of legislative changes on ecosystem services, we used the integrated valuation of environmental services and tradeoffs (InVEST) tool to assess a 30,000 ha watershed in southern Brazil and carbon sequestration as an indicator for ecosystem services. The results demonstrate that the adoption of improved agriculture practices, development of secondary forests and especially the conversion of land into more restrictive types of land-use has a significant and positive impact on the levels of carbon sequestered. On the other hand, the easing of riparian zone requirements shows an important potential loss in carbon sequestration. More importantly, reducing the size of the buffer zone might result in land-conversion into agriculture or pasture, impacting both carbon sequestration and other ecosystem services. However, the easing of restrictions on riparian areas under the revised Forest Code might be overshadowed by changes to Legal Forest Reserve provisions which could have a much greater impact on carbon sequestration. Despite the restrictions imposed by various pieces of legislation, the loss of ecosystem services due to a reduction in the protected riparian area, as well as possible land conversion due to changes in Legal Forest Reserves, are possible unless efforts involving narrowing the gap between research and policy, effective law enforcement, and implementing attractive payment for ecosystem services programs, are put in place. We believe that introducing incentives to farmers to maintain the protection of riparian areas by implementing agroforestry systems, such as erva-mate (*Ilex paraguariensis*), would be beneficial socioeconomically and ecologically and should be integrated into the Forest Code.

Introduction

Recent changes in the Brazilian Forest Code (Brasil, 2012) have prompted concerns about whether the relaxation of the required area of river embankment protection has important impacts on the ecosystem services provided by riparian forests. Changes to the Forest Code have significant implications for both the farming industry and environmental protection. While the agribusiness sector praised the legislative change, other sectors were less enthusiastic citing an increased risk of deforestation and deterioration of ecosystem services. As the reviewed Forest Code might substantially impact the land use trends across the country, sequestration/emission budget of GHG (greenhouse gases) could also be affected. Large-scale analyses of the potential changes to carbon stocks and sequestration have allowed for an overview of the expected trends at the national and biome level (e.g. Ipea, 2011; Soares-Filho et al., 2014). However, a fine scale examination that uses detailed information on the various factors that affect carbon sequestration is necessary. Both levels of spatial analysis are complementary: large-scale research helps inform general patterns

* Corresponding author. Tel.: +55 41 3675 3532.
E-mail addresses: marilice.garrastazu@embrapa.br (M.C. Garrastazú), dmsabina@hotmail.com (S.D. Mendonça), horokoski@gmail.com (T.T. Horokoski), denise.cardoso@embrapa.br (D.J. Cardoso), augusta.rosot@embrapa.br (M.A.D. Rosot), ernimmo@gmail.com (E.R. Nimmo), andre.biscaia@embrapa.br, abiscaia@uol.com.br (A.E.B. Lacerda).

http://dx.doi.org/10.1016/j.landusepol.2014.08.003
0264-8377/

suitable for national policy development, while small-scale studies are essential for defining standards and understanding the practicalities of implementing national and regional policies at the local level. In this context, we modeled the potential implications of the reviewed Forest Code using carbon sequestration as a key indicator in order to provide insight into the consequences of the new legislation at a local scale.

Capital is considered to be a stock of materials, generating a flow of services that can be used to transform materials and improve human welfare (Costanza et al., 1997, 2014). The capital stock found separately in forests, rivers, soil, the atmosphere, and together as an ecosystem, is known as natural capital. The combination of natural capital with manufactured and human capital produces ecosystem services (Costanza et al., 1997, 2014). According to Tallis et al. (2013), ecosystem services are the stream of vital benefits flowing from natural capital to people. Daily (1997) defined these services as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life." In other words, they are the variety of natural processes and products that provide or deliver goods and services to support human existence.

With the world-wide reduction of natural habitats, the benefits societies obtain from ecosystems are becoming increasingly at risk. With a reduction in the abundance of the services provided by ecosystems, or with diminishing quality, their scarcity can lead to incentives to trade services thus leading to the establishment of payment for ecosystem services (PES) programs (Alcamo et al., 2003; Wunder, 2005) and other initiatives aiming at reducing the negative impacts of human activities on ecosystem services. In this context, the ability to reduce carbon emissions and enhance carbon sequestration are key elements in controlling the large-scale impacts of human-induced processes, such as climate change, and their effects on other ecosystem services (IPCC, 2014). As such, carbon has been the focus of numerous strategies which include cap-and-trade schemes and carbon taxation. Despite recent economic volatility observed in the carbon market, a number of successful PES programs based on carbon have been established around the world (e.g. Zammit, 2013).

In 2009, Brazil established the National Policy on Climate Change (NPCC; Brasil, 2009) in alignment with the Kyoto Protocol. The NPCC aims at reducing emissions to between 36.1% and 38.9% by 2020 by improving and strengthening anthropogenic greenhouse gas sinks. One of the most prominent ways Brazilian policy-makers have envisioned attaining these goals is through reducing emissions especially from deforestation, land restoration and natural resource conservation, among others. However, recent changes to the Forest Code in 2012 reduced the area of riparian forests required on small-scale farms (defined as less than 4 times the minimum area used for property tax calculation) from 30 to 15 m (Brasil, 2012) and these riparian forests can be considered part of the mandatory forested area required on a rural property (Legal Forest Reserve).

The relaxation of the protected area required along river banks for small-scale farms could have significant impacts on the ability of riparian forests to provide the ecosystem services relied on both locally and nationally and it may have a significant impact on Brazil's ability to achieve its GHG reduction goals. Worldwide, the regulations regarding riparian forest protection varies significantly; Brazil's Forest Code is one of the most stringent in terms of land use and buffer size (McDermott et al., 2010). The protection of riparian zones is acknowledged as an essential aspect of protecting ecosystem services, from water quality and availability, to fostering fish spawning grounds, and conserving biodiversity, and most jurisdictions have some form of regulation restricting land-use activities in these regions. However, the regulations range from voluntary restrictions and best-practices management on private property in some US states, Portugal, and Finland, to the absolute prohibition of land-use up to 500 m around wide water courses in Brazil, or 500 m of limited management zones along rivers longer than 500 km in Russia. Questions remain, however, as to the best approach to define the types of activities allowed within riparian areas and the size of the buffer to be implemented. McDermott et al. (2010) note that the most appropriate approach is more 'results based' which considers all of the ecosystem services and biodiversity provided by the forest and prescribes restrictions based on the indicators of that particular context. However, this approach is challenging not only in terms of enforcement, but also in terms of gathering sufficient data to truly calculate and include all of the services provided by the watercourse and ecosystems in question.

Some reports have discussed the impacts the revised Forest Code could have in relation to changes in Brazilian sequestration/emission budget of GHG (greenhouse gases) (e.g. Observatório do Clima, 2010; Ipea, 2011; Soares-Filho et al., 2014). In these studies, the authors used very broad scale (national level) information to estimate changes in GHG budget considering different scenarios. The authors found important potential impacts where the GHG emissions could increase independently of the scenario. One report produced by the Observatório do Clima (2010) explicitly noted that those studies faced key constraints due to the large scale of the database: an issue we address in the present study.

A major challenge for identifying and implementing carbon sequestration strategies is effectively translating scientific evidence into public policy. One strategy is to model the consequences of different agriculture, forestry and livestock practices, natural areas conservation and landscape planning on carbon emissions. Direct comparisons between modeled scenarios can provide policy-makers with data that inform the decision-making process regarding public policies enabling effective communication of these policies and their rationales to gain public buy-in. Carbon sequestration, as both a regulatory policy and an economic opportunity, should be analysed at broad scales as well as at the regional and local scale. In this context, our study brings the discussion of environmental laws and their impacts on the use of natural resources/land management to the local level and assesses how the implementation of legislation can affect carbon sequestration opportunities as an indicator of ecosystem services.

We employed the InVEST modeling software to visually map and spatialize the potential outcomes of the recently reviewed Forest Code (FC) on carbon sequestration potential and discuss opportunities and constraints for the carbon market in Southern Brazil in light of the environmental legislation in Brazil. Our case study models the consequences of reducing riparian forests on small-scale farms in a region dominated by this type of farming. We also assess alternative agricultural and natural forest management practices to determine the impact their implementation could have on carbon sequestration.

Materials and methods

Study area

The case study area includes the upper east side of the Rio do Peixe river basin in the municipality of Caçador, Santa Catarina State, Southern Brazil. The study area is comprised of 33,913 ha located between the longitudes 50°48′ and 51°04′ West and latitudes 26°43′ and 26°57′ South (Fig. 1). The region varies in altitude between 800 and 1200 meters in a subtropical highland climate (Cfb), where frosts can occur during the winter months and, less frequently, light snowfall can occur in the highest areas; year mean precipitation is 1660 mm, without a dry season.