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Reconciling rural development and ecological restoration: Strategies and policy recommendations for the Brazilian Atlantic Forest

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ABSTRACT

Increased demand for both agricultural production and forest restoration may lead to increased competition for land in the next decades. Sustainably increasing cattle ranching productivity is a potential solution to reconcile different land uses, while also improving biodiversity conservation and the provision of ecosystem services. If not strategically implemented in integration with complementary policies, sustainable intensification can however result in negative environmental, economic and social effects. We analyzed the potential for sustainable intensification as a solution for a conflict between agricultural expansion and forest restoration in the Paraitinga Watershed at the Brazilian Atlantic Forest, a global biodiversity hotspot. In addition, we provide policy recommendations for sustainable development in the region, based on interviews with producers and local actors. We found that the Paraitinga Watershed has the potential to increase its cattle-ranching productivity and, as a result, relinquish spared land for other uses. This was true even in the most conservative intensification scenario considered (50% of the maximum potential productivity reached), in which 76,702 ha of pastures can be spared for other uses (46% of total pasture area). We found that restoration, apiculture and rural tourism are promising activities to promote sustainable development in the region, thus potentially increasing food production and mitigating competition for land. Our study shows that results from socioeconomic interviews and biophysical modelling of potential productivity increases offer robust insights into practical solutions on how to pursue sustainable development in one of the world's most threatened biodiversity hotspots.

1. Introduction

Between 2000 and 2012, tropical rainforests experienced the greatest forest loss, representing 32% of global forest cover loss (Hansen et al., 2013). Pressures on forests and other natural ecosystems are likely to continue due to increasing demand for agricultural products to support population growth and changing consumer demands (Smith et al., 2010; Wirsenius et al., 2010; Alexandratos and Bruinsma, 2012). There is also increasing interest in large-scale forest restoration initiatives to mitigate the loss

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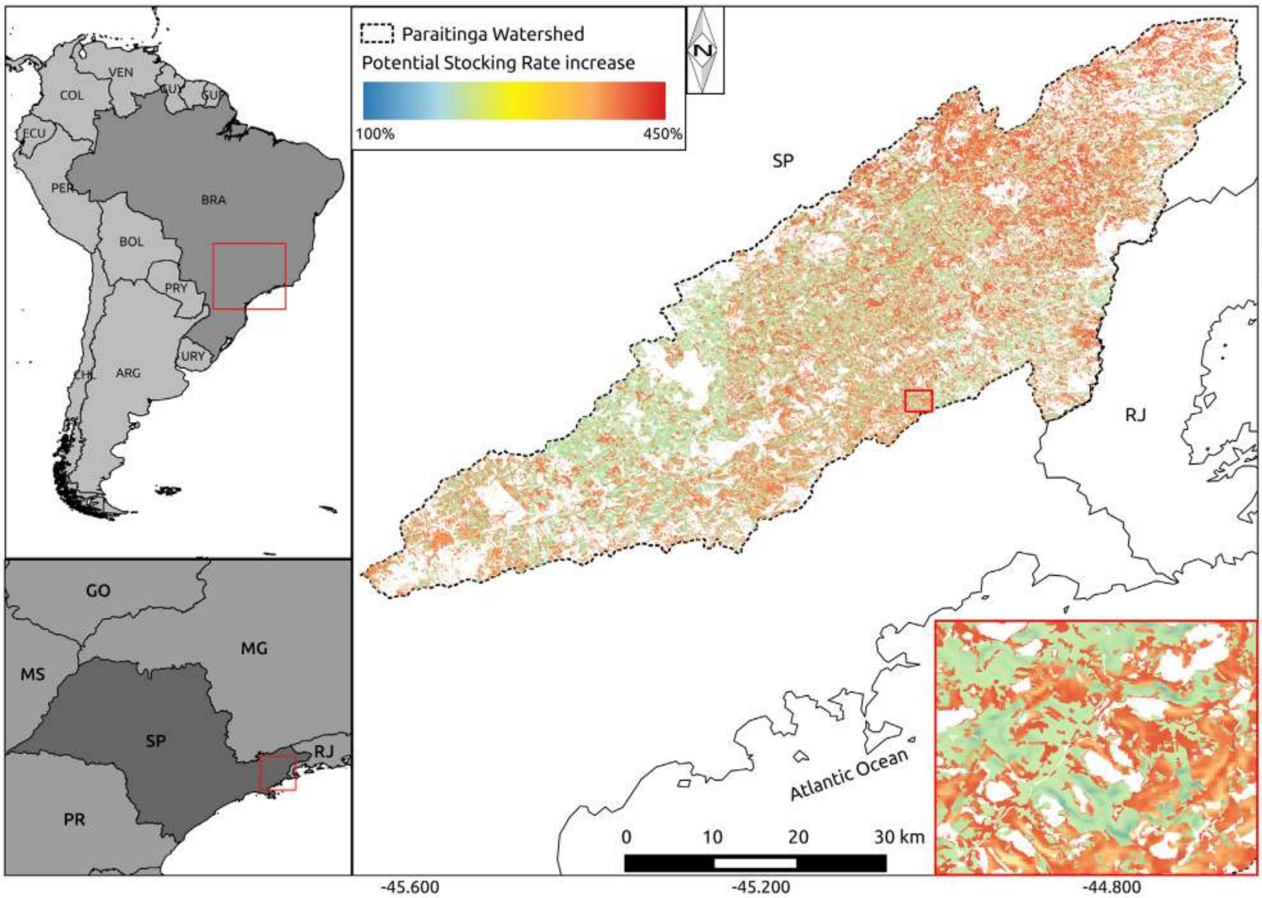

Fig. 1. Map showing the location of the Paraitinga Watershed in Brazil and São Paulo State. The colored areas are pastures with different potential stocking rates (%), and white areas represent other land uses.

of biodiversity and ecosystem services (Nazareno and Laurance, 2015). It is therefore likely that in upcoming years, an increased demand for both agricultural production and large-scale forest restoration will result in further competition for land (Smith et al., 2010), and debates will continue on how to diminish this competition (Latawiec et al., 2015).

Increasing cattle ranching productivity in a sustainable manner has been proposed as a potential solution to reconcile increasing demand for different land-uses, reduce competition for land, improve provision of ecosystem services and increase biodiversity conservation (Smith et al., 2010; Lambin and Meyfroid, 2011; Bustamante et al., 2012; Cohn et al., 2014; Latawiec et al., 2014a). Sustainable intensification was considered as moderate increases in agricultural productivity (increase in number of animals per hectare) in a system that maintains grass-feeding (most of the cattle-ranching systems in Brazil are extensive pasture-based grazing systems; Latawiec et al., 2014b). If not implemented correctly, sustainable intensification can however have negative environmental and socioeconomic effects. For example, rebound effect may follow where further deforestation occurs as more productive systems become more profitable (Lambin and Meyfroid, 2011). Indirect deforestation (Arima et al., 2011; Lambin and Meyfroid, 2011; Cohn et al., 2014), leakage (Strassburg et al., 2014a) and displacement of less capital-intensive smallholders (Bustamante et al., 2012) are other examples of unintended adverse effects. Delivering sustainable intensification without causing environmental and social adverse effects is a great challenge. Therefore, sustainable intensification should be developed and implemented concomitantly with complementary public policies and strategies.

In Brazil, agriculture and cattle ranching are among the main drivers of land-use change, with cattle ranching being the most important driver of deforestation (Nepstad et al., 2006; Gibbs et al., 2010; Cohn et al., 2011; Arima et al., 2011). Although the country is among the biggest beef producers worldwide (FAOSTAT, 2015), cattle ranching is based on an extensive system with low pasture efficiency (stocking rate is approximately 33% of the sustainable potential; Strassburg et al., 2014b). Furthermore, Brazilian landowners need to collectively restore approximately 21 million ha of native vegetation (Soares-Filho et al., 2014) in order to comply with the new Forest Code (National Law No. 12.651/2012). Approximately half of this restoration (12.5 million ha; Soares-Filho et al., 2014), will need to happen within the Atlantic Forest hotspot, the most affected by deforestation in Brazil (Lapola et al., 2014). Currently, only 12–16% of its original 150 million ha forest cover remains standing, with more than 80% of forest remnants now smaller than 50 ha (Ribeiro et al., 2009). It is a great challenge to integrate both large-scale restoration and increased agricultural production in the Brazilian Atlantic Forest (Latawiec et al., 2015).

The aim of this study is to propose strategies for land sparing based on modelling and interviews with local actors in the Paraitinga Watershed in the Brazilian Atlantic Forest. We first estimated the potential for sustainable intensification of cattle ranching, and estimated the amount of spared land that would be generated in three different sustainable intensification scenarios. We also performed interviews with producers and local actors in order to understand their perception of ecosystem services, and the potential of the region for diversification of agricultural activities. Our central hypothesis is that by increasing stocking rates within

Table 1
Local actors interviewed, presented as institutions and roles.

Interview	Institution	Role in Institution
1	APIS-tinga	President
2	Producers' Association – Mato Dentro	President/Funder
3	Council for Sustainable Rural Development – São Luis do Paraitinga	President
4	Rural Union – Areias	President
5	Nutrir – Socio-educative Association of small rural producers – Redenção da Serra	President
6	Association of Catuçaba	Employee
7	CATI – Cunha	Forestry Engineer
8	Banco do Brasil	Manager
9	Secretary of Environment and Agriculture – São Luis do Paraitinga	Secretary
10	Secretary of Environment and Agriculture – Silveiras	Secretary
11	Forestry Foundation – state of São Paulo	Manager
12	Water and Energy (DAEE) and Watershed committee	Director

sustainable levels, cattle production could be concentrated in areas with higher potential productivity while the remaining land could be spared for other uses, including large-scale forest restoration (e.g. Strassburg et al., 2014b). Our study combines socioeconomic research and an analysis of the biophysical potential for productivity increases, to offer robust insights into practical solutions on how to pursue sustainable development in one of the world's most threatened biodiversity hotspots (Myers et al., 2000).

2. Methods

2.1. Study site

The study was conducted in the Paraitinga Watershed (S 45.6535, W 23.4019; S 44.6435, W 22.7057), located in the northeast of the state of São Paulo, in the Atlantic Forest. The watershed comprises 268,010 ha, including parts of 12 counties of various sizes (Fig. 1), and occupies a strategic position in terms of water supply for São Paulo, Rio de Janeiro and Minas Gerais, three of the most densely populated states in Brazil. Between 2014 and 2015 these states faced a water supply crisis, reinforcing the importance of this watershed as an ecosystem service provider. The Paraitinga Watershed is occupied predominantly by pastures and forest remnants. Pasture areas represent approximately 61% of the total watershed, with 30% classified as pasture without signs of degradation, 21% as degraded and the remaining 10% showing signs of natural regeneration (hereafter non-degraded pasture, degraded pasture and abandoned pasture, respectively). Forested areas represent 27% of the watershed, including 21% mature forests and 6% secondary forests (Strassburg et al., 2014c).

2.2. Cattle ranching productivity modelling

In order to develop cattle ranching scenarios, we assessed current cattle productivity and calculated the potential sustainable carrying capacity of pastures in the region. We calculated the potential increase in productivity for different sustainable intensification scenarios (see below) and the amount of land that could be spared in each of the scenarios. We calculated current productivity based on stocking rates per county (IBGE, 2009). Thus, we used county level as our sampling unit, i.e. all pasture areas inside the same county had the same value of current stocking rate. We also calculated the average productivity in Animal Units (AU) per hectare, with 1 AU equivalent to 454 kg of live animal weight (FGTC, 1992). We incorporated the final values for pasture areas into an existing land-use map of the study region (Strassburg et al., 2014c).

In order to calculate the potential sustainable carrying capacity of pastures, we gathered spatial data for potential biomass growth (kg/ha) in all pasture areas from the FAO/IIASA Global Agro-Ecological Zones (GAEZ) project (FAO/IIASA, 2012). These data consider climatic information (e.g. temperature and rainfall), and terrain conditions (e.g. soil type, slope and elevation), but do not include seasonal changes. The sustainable carrying capacity (in AU/ha) was calculated based on 8 kg/day of ingested dry biomass per head, and 50% grazing efficiency (Equation (1)).

$$DDP = (SR \times I/GE)\cos S \quad (1)$$

where *DDP* is Daily Demand of Pasture (the total amount of feed needed per head of cattle); *SR* is Stocking Rate (AU/ha); *I* is Ingested feed (kg/AU/day), *GE* is Grazing Efficiency, and *S* is Slope. We assumed a value of 8 kg/AU/day for *I* according to Forage and Grazing Terminology Committee (FGTC, 1992), and 0.5 (i.e. 50%) for *GE*, which is considered realistic for advanced systems in Brazil (Barioni et al., 2007). Considering that most of the feed consumed by cattle comes from pastures (>95%), we calculated sustainable stocking rates assuming that pastures are the only source of cattle feed (Strassburg et al., 2014b).

We developed three scenarios considering intensification of cattle and calculated the total land sparing. The three simulated scenarios predict an increase of 50, 75 or 100% of the potential sustainable carrying capacity of pastures for the Paraitinga Watershed. For each scenario we calculated the total pasture area that could be spared for other land-uses, considering non-degraded pastures, degraded pastures and abandoned pastures, following the land-use classification from Strassburg et al. (2014c). No spatially explicit prioritization was developed for spared areas. We projected that the level of cattle production in the watershed will be constant over the next years due to its historical trends: production increased from approximately 11,000 head in 1985 to 13,000 in 2000, but then declined to 10,000 in 2012 (IBGE, 2009). We therefore considered cattle production to be maintained at current levels for all scenarios. All analyses were carried out in QGis 1.8.

2.3. Socioeconomic and policy aspects

Policy recommendations are based on the economic, social and environmental diagnosis of the region. First, we reviewed both peer-reviewed and gray literature from the study region. Second, based on the content analysis of these data we developed two questionnaires: one for the local agricultural producers and another for local actors. The number of producers selected was determined by the number of rural properties in each county inside the watershed, and a corresponding sample of properties for each county was set. One producer was interviewed per property. Interviewed producers were chosen randomly.

Other actors include technical extension assistants, representatives of local NGOs, governmental and research institutions, and producers' associations (Table 1). Actors were suggested either by the Environment Secretary of the State of São Paulo, by the Technical Assistance Institute (CATI) or by interviewed actors, in a snowball method. The first draft of both questionnaires was reviewed in consultation with different actors (e.g. Environment

Secretary of the State of São Paulo, local NGOs) in the Paraitinga Watershed.

Upon this consultation, it was decided that the best way to obtain the intended data was through the application of structured interviews with producers, aiming to obtain more quantitative data, and semi-structured interviews with other local actors. This structure allowed us to obtain qualitative data complementing the quantitative ones from producers' interviews. Once the questionnaires were ready, we performed a pilot study both with producers (N = 3) and with local actors (N = 2) in order to test the clarity of the questions and ensure that the information we required was successfully obtained. Upon preliminary analysis of these pilot study results, both questionnaires were slightly modified (some questions were clarified and others were added in order to allow data triangulation for cross verification).

We interviewed 175 producers in 7 different counties (Cunha, Lagoinha, Natividade da Serra, Paraibuna, Redenção da Serra, São Luis do Paraitinga and Silveiras) between February and April 2014, and 12 local actors during three field visits between January and June 2014. The questionnaire for producers included a variety of questions regarding their background (age, education level, years developing their main activity), activities performed and perception of ecosystem services. In this paper we specifically focus on six questions directed to the producers: i) Which activities do you perform in your property?; ii) Do you see the forest as an obstacle for your production?; iii) Do you think forests have positive effects on your property? If so, what are those positive effects?; iv) Would you perform an alternative activity if you would receive higher revenues?; v) Which activities would you like to perform?; vi) How do you conserve your property regarding environmental factors?

The questionnaire with other actors included background information (institutional profile, role in the institution), main economic activities developed in the region, producer's profile, profitability of economic agricultural activities developed in the region, market characteristics and potentialities, potentialities of the region and future trends of the market, producers' perception of ecosystem services, and description of the most important initiatives developed in the region related to sustainable development. The information obtained from these interviews was organized in a matrix and coded according to a pre-defined category (Organization Profile; Economic and Social Characteristics of the region; Market potentialities; Producers' Profile; Environmental characteristics, Interventions). We then counted the occurrences and carried the results forward to the analysis, along with results from the producers interview.

3. Results and discussion

3.1. Cattle ranching productivity and land-sparing potential

We found that the current stocking rate in the region varied between 0.8 and 1.4 AU/ha, whereas the potential sustainable stocking rate ranged from 2.5 to 3.79 AU/ha. This represents a potential increase of 111–420% of current rates (Fig. 1).

In the most conservative scenario (where 50% of the total sustainable carrying capacity is reached), the total pasture area spared reaches 76,702 ha (46% of total pasture area). This corresponds to 17% non-degraded pastures, 19% degraded pastures and 10% abandoned pastures (Table 2). In the intermediate scenario (75% of the total sustainable carrying capacity is reached), the total spared pasture area equals 105,095 ha (64%): 28% are non-degraded pastures, 24% are degraded and 12% are abandoned pastures. In the optimist scenario (100% of the total sustainable carrying capacity is reached), the total pasture area spared was found to be 119,292 ha (73%), where 33% are non-degraded pastures, 26% are degraded pastures and 13% are abandoned pastures (Table 2).

Table 2
Spared land in different pasture types in the Paraitinga Watershed under three intensification scenarios.

Spared land (hectares)			
Land Use	Scenario 50%	Scenario 75%	Scenario 100%
Pasture	28,427	45,592	54,174
Degraded Pasture	32,413	39,944	43,710
Abandoned Pasture	15,861	19,559	21,408
Total	76,702	105,096	119,293

Our analysis showed that it is possible to increase stocking rates within sustainable levels in areas with higher potential carrying capacity, which could in turn lead to land sparing for other uses, such as large-scale forest restoration. This corroborates previous studies that have shown that sustainable intensification can support high agricultural productivity and other land uses concomitantly (e.g. Bustamante et al., 2012). Strassburg et al. (2014b) demonstrated that the current carrying capacity of Brazilian pasturelands corresponds to only 32–34% of its potential productivity. Given the heterogeneity of the Paraitinga Watershed (Strassburg et al., 2014c), certain areas are characterized by higher differences between current and potential carrying capacity, and therefore may be less prone to competition for land (Lambin and Meyfroid, 2011). For instance, some areas have the potential to increase productivity by 420% (Fig. 1), while other areas are likely to have more competition for land because they already operate at higher levels of productivity or have lower stocking rate potential (Fig. 1).

3.2. Socioeconomic and policy aspects

Interviewed producers were representative of the rural population in the watershed as a whole in terms of farm size (most properties were smaller than 50 ha, in a region where small properties are considered of having up to around 150 ha) and primary activity developed (dairy and beef cattle) (IBGE 2009).

We found that activity diversification could be a key strategy to boost the implementation of sustainable intensification in the Paraitinga Watershed. This approach may help to avoid negative effects by integrating different, and possibly complementary, land-uses. Based on our interviews with local actors, we found that apiculture and rural tourism are theoretically interesting activities to be incentivized in the region considering their market and regional context (identified by six out of the 12 local actors interviewed). The price of honey can be more stable than of milk, and initiatives at the county level are currently incentivizing schools to buy local food from small producers for lunches in public schools, thus also creating demand for honey products (Lei no 11.947/2009). Once production is diversified, producers may reduce their financial risks through diminishing their dependence on a single market (e.g. milk or meat), and increase income and economic stability (Souza et al., 2014). Diversification of activities to increase producers' income has also been observed in other Atlantic Forest regions (Souza et al., 2014). Increased income from diversification could also compensate implementation costs, often required when shifting towards more intensive systems.

Currently, the major activities conducted by producer interviewees are dairy (81%) and beef ranching (20%), and only a few have other activities such as horticulture (8%). For instance, only one of the interviewees currently exploits rural tourism and only four practice apiculture (Fig. 2). According to local actors, the main obstacles for diversifying production are lack of capital to cover the initial investment and a weak supply chain. There is also the lack of necessary logistics for production, storage and transporta-

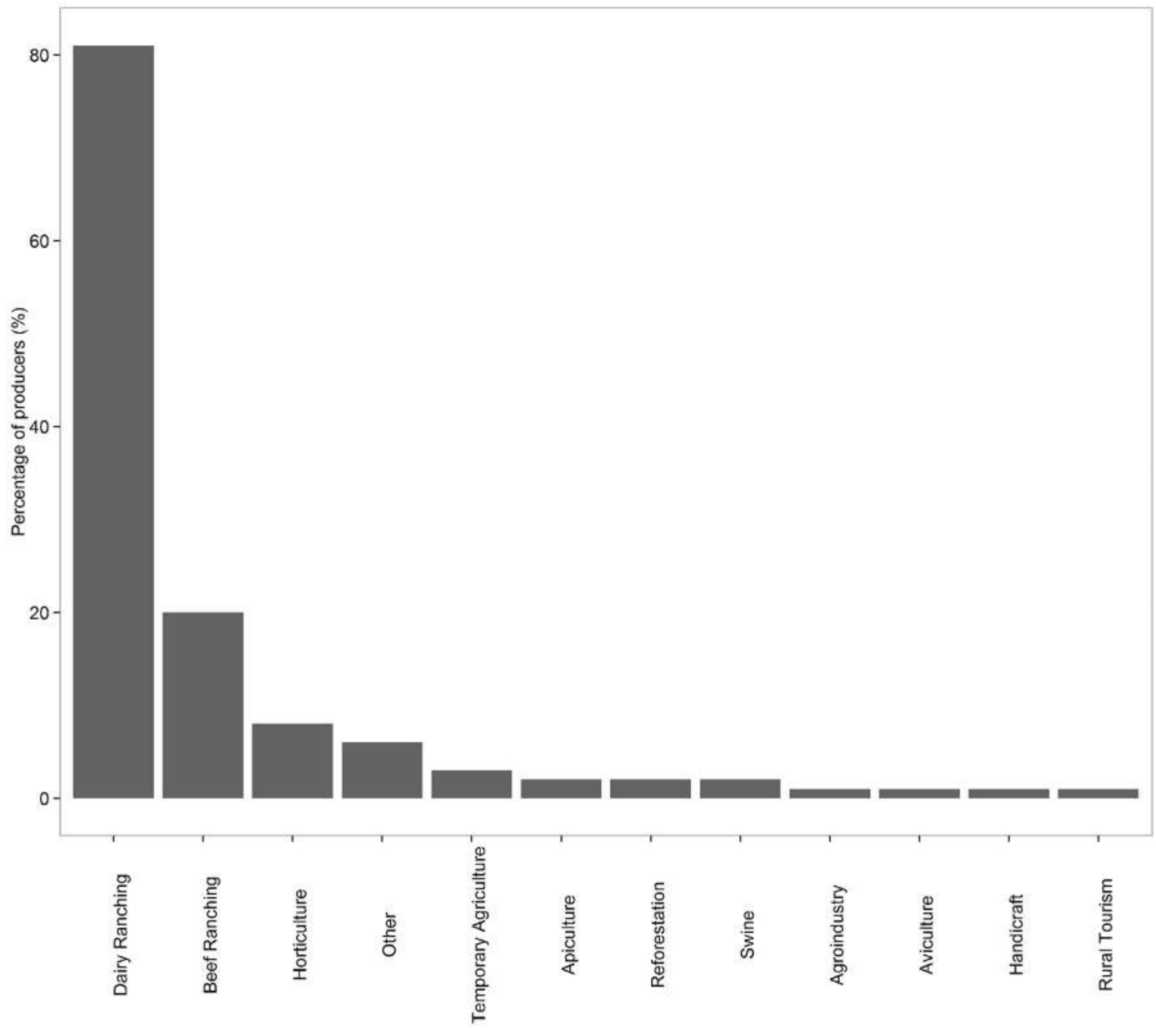

Fig. 2. Agricultural activities that are most frequently developed by interviewed producers in the Paraitinga Watershed.

tion processes, which gets even more difficult considering that the region is characterized by small rural properties (average size of 40 ha). Furthermore, producers showed little interest in changing their current activity: 72% of respondents (121 out of 167) claimed that they would not change their activity even if their income would increase. Therefore, although apiculture and rural tourism represent potential activities for the region, these are still in early stages of development, and improvements in local logistics, market and capacity building courses should be incremented. Disseminating information on the benefits of diversification and presenting successful case studies could provide motivation for producers to implement new and unknown activities. Logistics and the development of a market could then be further improved by the empowerment of local cooperatives. Finally, it is important that strategies and policies for sustainable development and territorial planning consider the cultural, biophysical and territorial contexts (Silva, 2014).

Forest restoration has a great potential for contributing to both biodiversity conservation and the provision of ecosystem services (Ditt et al., 2010). In the Paraitinga Watershed, restoration is likely to happen as the farmers must be compliant with requirements of the new Forest Code, and can be performed in a passive or an active way. Passive restoration can work particularly well for abandoned pastures (Holl and Aide, 2011), which cover 10% of the Paraitinga Watershed. In fact, these abandoned pastures are already in initial stages of natural regeneration and, in other Neotropical regions, vast areas have been restored passively following agricultural abandonment (Bowen et al., 2007; Chazdon, 2008). However, passive restoration in abandoned pastures does have some financial costs, e.g. establishing fences (Zahawi et al., 2014), and these costs can reach US$ 850 – 1200 per ha in the Atlantic Forest (Strassburg et al., 2014c).

Active restoration, although often complex and expensive (e.g. US$ 5000 per ha – see Brancalion et al., 2012), is an option that can be particularly relevant for degraded pastures, where restoration may be more difficult due to a history of intensive agricultural activities (Holl and Aide, 2011). Studies have also shown that the costs necessary to perform active restoration can be recovered, partially or completely, by the revenues obtained from the extraction of timber and non-timber products in reforested areas (Brancalion et al., 2012). Revenues can also be generated in 'silvopastoral' systems, which is another alternative becoming widely adopted and already reported to have positive environmental effects, such as high carbon sequestration (Ibrahim et al., 2010; McGroddy et al., 2015).

Restoration may be facilitated given producers' perception of forests, since 84% of interviewees do not perceive forests as a barrier to agricultural production, and 86% believe that forests have positive impacts on their property. These perceived benefits are mostly linked to water ecosystem services, such as water provision (claimed by 80% of the respondents). In addition, 98% of interviewed producers assured us that they protect water resources and forests by avoiding deforestation and fires and by fencing. Only three producers stated that they take no action toward the conservation of their property regarding the environment. The perception of the importance of the forests, restoration and landscape integrity, together with the need for compliance and the increasing incentives for sustainable practices (e.g. certification and Payment for Ecosystem Services – PES) are factors that are likely to motivate producers to implement forest restoration (Durigan et al., 2013). Although a positive perception of forests does not necessarily guarantee that restoration will be implemented, it may be a starting point for motivating producers to do so, and information on the benefits of restoration and silvopastoral systems should be further disseminated to landowners and local NGOs.

It is also a great challenge to successfully realize all the potential benefits of intensification. In order for intensification to be sustainable, it needs to be performed in a way that does not adversely affect the environment. Extensive cattle ranching in Brazil often leads to deforestation and soil degradation, and intensification beyond sustainable limits and overuse of agricultural chemical control may also lead to deterioration of the environment, as happened in other countries where agriculture is predominantly intensive e.g. some areas of Western Europe or United States (Latawiec et al., 2014b). In addition, rebound effect is always a risk when intensifying production and the Rural Environmental Registry may need to provide a mechanism to control for a potential spillover effect of more efficient cattle ranching.

In order for sustainable intensification to happen, a number of constraints will need to be considered and addressed. Bottlenecks for intensification include labour availability (De Souza Filho et al., 2011) and quality, technical assistance (Latawiec et al., 2014c), education and cultural resistance (Wagner and Rocha, 2007). The first step should be dissemination of knowledge on techniques and approaches to sustainable intensification as producers' engagement will underpin the willingness to adopt better land management. Financial incentives should be put in place to assist producers with the initial costs that are incurred.

Technical assistance is limited or very intermittent in the Paraitinga Watershed, which is particularly detrimental to small producers since they have little access to private assistance. In addition, most technicians are poorly qualified to assist the implementation of better land management practices. Improved technical assistance should also be provided to producers to facilitate their access to credit lines designed to increase productivity (Leite 2001; Strassburg et al., 2015), and to catalyze the implementation of restoration projects. Indeed, although credit access has increased 93% from 2002 to 2012 in the watershed, totaling approximately US$ 8 million in 2012, almost 50% of all credit lines' budgets were allocated in only two of the watershed counties (BACEN, 2004; BACEN, 2012). Finally, there is a lack of institutions available to provide technical assistance for ecological restoration in the state of São Paulo. The Forest Institute (IF) is in charge of developing research, whereas Technical Assistance Institute (CATI) provide technical assistance for agricultural production. Municipal and state government institutions should allocate more investments for increasing the number of technical assistants, who could be better trained by a partnership between these institutions, local NGOs and universities in the region, with the participation of producers. Research institutions have a very important role in providing information, whereas NGOs could help with its dissemination.

Incentive mechanisms, such as PES and certification, are available and can facilitate not only restoration initiatives, but also sustainable intensification, silvopastoral systems and the diversification of activities. Two thirds of PES programs in the Atlantic Forest involve restoration or reforestation actions (Guedes and Seehusen, 2011), although restoration costs can be high and in some cases PES programs are not sufficient to overcome these costs. The average payment for farmers is US$ 33–370/ha/year (Guedes and Seehusen 2011; Pagiola et al., 2013). Restoration and silvopastoral systems can also be subsidized by payments from carbon markets (Guedes and Seehusen 2011; McGroddy et al., 2015), and by generating income from non-timber forest products (NTFPs) (Alarcon et al., 2015). Furthermore, it has been shown that there might be substantial synergies between carbon storage and biodiversity conservation (Strassburg et al., 2010; Strassburg et al., 2012).

PES programs could also provide payments for the development of other activities, such as apiculture or rural tourism. For example, the *Water Conservation Program – Extrema* provide payments as cash, infrastructure, or machinery to encourage activities related to the protection of water resources in the Atlantic Forest (Pagiola et al., 2013). Schemes that include co-benefits are generally preferred as they increase local levels of human and productive capital, reducing the dependence on cash payment (Torres et al., 2013). Although lack of information on ecosystem services and high opportunity costs can be obstacles to the participation of producers in PES programs, it is believed that the legal requirement to comply with the new Forest Code may successfully incentivize producers to participate in PES programs (Alarcon et al., 2015). Finally, certification programs such as the Rainforest Alliance "Sustainable Agriculture Network", already developed in Brazil, could be further expanded to farms that have already spared areas for restoration, in addition to those required by the Forest Code.

PES and other initiatives (such as the Brazilian Low Carbon Agriculture program) may facilitate land-sparing and may be complemented by other strategies aiming to reduce deforestation (Cohn et al., 2014). These should integrate different activities, which must be mutually supportive and developed concomitantly and in coordination (Bustamante et al., 2012). For instance, the extractive use of forest products can complement income from intensification; apiculture and certified honey sale may facilitate restoration, whereas restored areas can catalyze rural tourism that in turn may increase certified product sales. Furthermore, it is important to overcome some of the obstacles that face the implementation of sustainable intensification, such as lack of labour, technical assistance, difficult access to credit and producers' lack of interest (Latawiec et al., 2014a).

When implementing policies aimed at land-sparing, local context should be taken into account to assure integration with state policies and other interventions (Silva, 2014). Finally, different actors from the private and public sector, as well as civil society, must participate in the initiatives aimed at land-sparing for restoration to maximize implementation efficiency (Bustamante et al., 2012).

4. Conclusions

Sustainable intensification has the potential to both increase food production and spare land for other uses, thus mitigating likely competition for land in the upcoming decades. Sustainable intensification needs, however, to be accompanied by public policies and other strategies, such as PES. Diversification of activities and forest restoration are potential strategies to be developed in spared lands, reducing economic and social risks for rural producers. Our study, by combining socioeconomic interviews and an analysis of biophysical potential for increasing productivity, offers a set of potential strategies that could contribute to formulating feasible environmental public policies. Although this study focused on a specific watershed, lessons learned may be expanded to other regions in the Atlantic Forest and other biomes in Brazil, as well as places worldwide, in order to diminish increasing competition for land in the future.

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