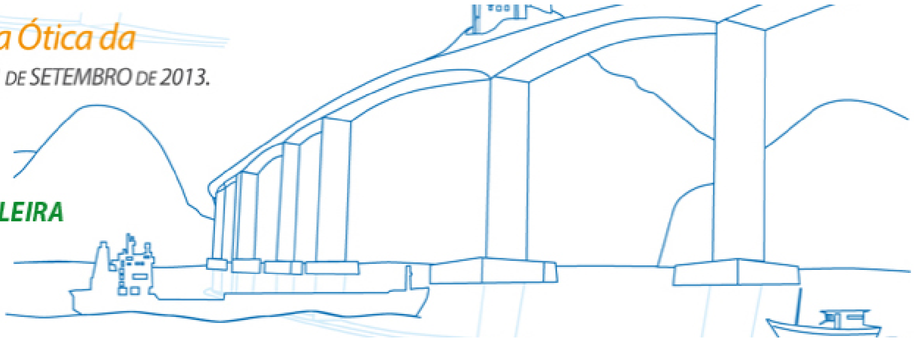
Inovação e Sustentabilidade sob a Ótica da Economia Ecológica. VITÓRIA/ES, 17 A 21 DE SETEMBRO DE 2013.
Hotel Vitória Grand Hall

X ENCONTRO DA SOCIEDADE BRASILEIRA DE ECONOMIA ECOLÓGICA



X ENCONTRO DA ECOECO
Setembro de 2013
Vitória - ES - Brasil

O PAPEL DA COMPENSAÇÃO DE RESERVA LEGAL ENTRE PROPRIEDADES NA CONSERVAÇÃO DA BIODIVERSIDADE NO ESTADO DE SP

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O papel da compensação de reserva legal entre propriedades na conservação da biodiversidade no estado de São Paulo

Resumo

A regulação direta por comando e controle sempre foi o mais importante tipo de política para conservação da biodiversidade no Brasil, principalmente através do Código Florestal. Um histórico complexo de seguidas alterações resultou em conflitos com o setor rural em relação aos custos de adequação ambiental e em um cenário de não cumprimento com a legislação. Após a última alteração do Código Florestal ocorrida em 2012 é esperado um aumento na pressão para o cumprimento da reserva legal, que é uma área que as propriedades rurais devem deixar para conservação. Visando reduzir os custos de adequação à reserva legal para os produtores rurais alguns mecanismos de flexibilidade estão sendo discutidos através de instrumentos econômicos. Um deles é a compensação de reserva legal em outra propriedade que é um tipo de mecanismo de negociação de direitos de desenvolvimento (TDR). Os produtores que desmataram mais que o permitido podem compensar seu déficit em outra propriedade que possua mais vegetação natural que o exigido. O objetivo desse estudo é avaliar os efeitos da compensação de reserva legal considerando tanto em relação ao impacto nos custos de oportunidade e nos ganhos de conservação, comparado a uma abordagem somente de comando e controle, por exemplo com a adequação das reservas legais dentro de cada propriedade. Usando o software de planejamento de conservação *Marxan with Zones* nós simulamos o efeito da inclusão da compensação nos moldes de mercado atuais da legislação e o efeito da inclusão de uma restrição ao mercado, tendo como cenário referência o comando e controle puro, e avaliamos a custo-efetividade de cada cenário. O estudo foi realizado no Estado de São Paulo, um dos que enfrenta grandes dificuldades de adequação à reserva legal. Os resultados mostram um claro potencial da compensação de reserva legal de tanto reduzir os custos de adequação como também de melhorar a efetividade das reservas legais, e a inclusão de um critério de restrição ao mercado se mostrou uma forma de melhorar ainda mais a custo-efetividade do mecanismo de compensação.

Palavras-chave: código florestal, compensação de reserva legal, instrumentos econômicos, políticas ambientais, São Paulo

Abstract

Until today, direct regulation has been the most important type of policy for biodiversity conservation in Brazil. This has resulted in conflicts with the rural sector about compliance costs and has led to limited effect on nature conservation. The main command-and-control (C&C) instrument for forest conservation is the Forest Code, which was newly amended in 2012. It requires that all private properties set aside parts of the property for conservation, called the Forest Reserve. In order to reduce the economic impact of the Forest Reserve on landowners some mechanisms of flexibility are being discussed. One of the options is the compensation of Forest Reserve in another property, which is a kind of tradable development right (TDR). The landowners who have deforested more than allowed by law can compensate their deficit in another farm which has more natural vegetation than required. In this paper we evaluated the effect of the TDR on the conservation outcome considering both the opportunity costs and the ecological gains compared this to a pure command-and-control (C&C) approach, i.e. compliance to the Forest Law on own property. Using the conservation planning software Marxan with Zones we simulated different scopes for the forest reserve market, and evaluated their cost-effectiveness. We focused our study in the state of São Paulo, the most industrialized and most populated in Brazil, which faces many ecological challenges. The simulations using Marxan showed a clear potential of the TDR to both reduce compliance costs and improve ecological effectiveness depending on different market restrictions on allocation of forest reserves.

1 Introduction

Context

The state of São Paulo is the most industrialized of Brazil, with a GDP of more than US$550 billion, with more than 40 million inhabitants living in 248 thousand km^2 (IBGE, 2010). Its location at the transition between the tropical and subtropical region, combined with a diverse topography, have created habitats to a vast biodiversity with many endemic species (Joly *et al.*, 2010). Both Biomes found in the State, Atlantic Forest and Cerrado, are recognized as world's biodiversity hotspots (Myers et al, 2000).

The economic status has pressed the natural systems transforming the landscape in extensive rural areas with many small fragments of forest remnants that accounts for 14% of original area of Atlantic Forest (Nalon et al., 2008) and 10% of Cerrado which has led to a large proportion of the vast biodiversity being threatened to extinction (Ribeiro et al 2009). Also, 75% of the remnant vegetation is located in private properties (Rodrigues and Bononi, 2008), highlighting the important role of this group in the conservation planning in Sao Paulo.

But, in spite of the degradation, the remnants still have significant samples of its original flora that hosts a diverse fauna, including jaguar and pumas as well as many other endangered species (Rodrigues et al., 2008). The deforestation dynamics in the state is now stabilized, and show signals of reversion tendency in line with the forest transition theory (Barretto *et al.*, 2013; Farinaci; Batistella, 2012; Mather, 1992) but there is still the need for a more intense and qualified restoration effort.

With the contribution of science, policymakers considered two main general objectives for the conservation in the Sao Paulo (Metzger and Rodrigues, 2008). The first is to preserve every small fragment due to the intense degradation process and to the importance of the fragments to the biodiversity conservation that granted them a high biological value. The second objective is to promote restoration because of the urgent need to reconnect the remnants and assure the existence of a minimum area of habitat to perpetuate the biodiversity and the ecosystem services provision.

Brief of conservation policy: from strict regulation to Tradable Development Rights

Until recently, most of the Brazilian conservation policies were focused on strict command-and-control regulation. The main instrument for private areas has been the Forest Code. It requires, amongst others, a Forest Reserve on every farm depending on the Biome, that in the State of São Paulo (Atlantic Forest and Cerrado) is 20% of the property area. Since its first version, in 1934, the Forest Code and related instruments has showed a historical path of many changes, 84 only between 1965 and 1998 (Hirakuri et al, 2003) with low enforcement which led to a scenario of and low compliance, less than 10% of the farms claimed to have Forest Reserves (Oliveira & Bacha, 2003). The alterations in the law have, in general, changed many times the amount of Forest Reserve required and also created the Permanent Protected Areas (APP), to guarantee the protection of fragile areas such as riparian areas, streams, slopes, hill tops, plateaus and mangroves, besides the area protected in Forest Reserves.

But, the low compliance doesn't mean that the Forest Code is absolutely not binding and imposes no costs on landowners since the efforts dedicated by landowners to sway changes in the legislation reflect the recognition that the legislation creates current and potential costs (Alston & Mueller, 2007).

According to IEA (2009), the reduction in the revenues from agriculture in Sao Paulo due to the total compliance with the law would be of US$3.2 billion, which means a reduction in 17.7% of the sector income. The estimated recovering costs were calculated in US$8.2 billion, totalling US$11.3 billion, which represents 65% of the total revenue from the agriculture sector in 2005 (IEA, 2009). Although many other countries have also restrictions on the use of private farms, the Forest Reserve is exceptional not only for the levels involved (up to 80% of a property in the Amazon) but also because the costs are to be borne solely by the landowner although the benefit has public good qualities (Alston & Mueller, 2007)

The complains about the high compliance costs of the law motivated an increasing demand for relieving the rules by the rural sectors. In 2012 after many years of discussion in the National Congress and Senate, the president approved a new version of the Forest Code[1] and the underlying rationales for the law revision, as summarized by Sparovek et al. (2012), were: (i) the illegitimate situation of landowners produced by a history of non-compliance; (ii) vulnerable and uncomfortable position of agriculture sector due to national and international awareness about environmental consequences of land use (iii) high costs of total compliance with the Forest Code; (iv) misconception from agriculture sector of a incompatibility between agriculture development and conservation in private areas and opinion that conservation should take place mainly on

[1]Federal Law 12.651/ 2012, with alterations by Federal Law 12.727/ 2012.

public land. The new version reduced some strict rules that, summed with the above mentioned arguments, have been changing the conservations scenario in Brazil to increasing expectations of higher enforcement and compliance.

The current Forest Code provides three compliance options for the landowners who are not compliant with the Forest Reserve:

1. Recover the Forest Reserve of its property by planting every three years, at least one tenth of the total area required for its completion, with native species.
2. Conduct natural regeneration of the Forest Reserve, but only when the viability is proved by a technical report and approved by the state environmental agency.
3. Compensate by a surplus of Forest Reserve in another farm located in the same biome

This context proves that the simple existence of a regulatory instrument is not enough to assure its implementation, especially in a country of continental size and with considerable law enforcement and implementation problems such as Brazil (Fearnside, 2000). In order to better address multiple objectives and conservation challenges in a context of private interests it is necessary to combine complementary instruments of incentives and flexibilization in addition of the regulations (Lynch & Musser, 2001).

This complementation could be through incentive based approach that aims to provide positive incentives (subsidies, tax reliefs, fiscal transfers or payments) for providers of biodiversity conservation and ecosystem services, or by burdening biodiversity-harmful activities and erosion of the capacity to provide ecosystem services (environmental taxes, necessity to hold a permit, obligation to buy offsets), establishing a policymix (Schröter-Schlaack & Ring, 2011).

According to Ring & Schröter-Schlaack (2011), “a policy mix is a combination of policy instruments which has evolved to influence the quantity and quality of biodiversity conservation and ecosystem service provision in public and private sectors.” The basic idea behind designing policy mixes is to overcome weaknesses of single instrument policies, such as low ecological effectiveness, high abatement costs (including opportunity and transaction costs) of environmental goal attainment, unjust distribution of environmental burdens or abatement costs among the affected stakeholders or high transaction costs (Schröter-Schlaack & Ring, 2011).

The third option for compliance is an economic instrument that could play an important role in this new phase of the biodiversity conservation in Sao Paulo and Brazil and complement the policymix increasing its efficiency. It is called “compensation of Forest Reserve”, and allows the landowner which has less Forest Reserve than required to compensate its deficit in another farm which has more forest than required. This kind of market-based mechanism is known as Tradable Development Rights (TDR).

According to Eftec (2010) “TDR programmes separate out the right to develop land from other rights such as use and lease. As the right to develop land is sold, that parcel of land becomes protected from development, often as a conservation easement. The parcel of land that the rights are transferred to is then allowed to develop, in some cases to a higher degree than normally would be allowed by standing planning permission."

The role of the TDR in the Forest Code is to reduce the compliance costs of the Forest Reserve on private properties and also to remunerate landowners who have natural vegetation on their farm above the Forest Reserve target. Thereby it is possible to address heterogeneities in the agricultural suitability and in the opportunity costs of conservation of the properties and at the same time to ensure the minimum Forest Reserve target required for conservation of biodiversity and of the capacity of ecosystem service provision. Also, it aims to protect at least part of the natural vegetation on private land that is presently not legally protected (Sparovek, 2012). This instrument also have the potential to reduce social inequalities by allow revenue transferences to regions that have low agriculture suitability and large forest areas.

The instrument is not a separate policy but rather an incentive-based instrument that was included inside the Forest Code during its historical process of development, and was established the first time in 2000[2]. The current criteria for TDR are[3]:

1) A landowner can voluntarily resign, permanently or temporary, to the right to exploit the surplus of native vegetation and offer such an area in excess to other landowners.
2) The trade is only allowed for compliance purposes. Thus, it is not a regular offset because the landowner cannot deforest and then offset, it is only valid for past deforestations.
3) The areas used for compensation must have equivalent extension and be part of the same Biome. Those areas should be located in the same State, but could be outside if they are designated priority areas for conservation or reforestation.
4) Recognizing the cases where there is lack of supply of Forest Reserve surplus area for compensation, the law allows that areas with degraded vegetation are used, but ties the acceptance of the compensation to the previous restoration of the area.

Although TDR has been present in the Brazilian policy mix for conservation for more than 10 years it still has a very low implementation all over the country. Some of the possible reasons for this could be the lack of demand due to the very low enforcement of the Forest Reserve requirements, and the previous regulation of the TDR that required compensation both within the same biome and micro-watershed. It restricted compensation as a market driven mechanism since the spatial constraints were possibly excessively restrictive in terms of opportunity cost differentials between buyer and seller. As pointed out by Sparovek (2012), there was usually a lack of surplus of natural land eligible for compensation within the watersheds where the deficits occur.

[2] Provisional Executive Order nº 1.956-50 / 2000.
[3] Federal Law 12.651/12, with alterations by Federal Law 12.727/ 2012

The potential of the TDR as a market-based instrument to contribute in a policy mix of biodiversity conservation has been recently assessed by many studies (Santos et al., 2011; Bovarnick et al. 2010a; Eftec et al. 2010). What regards the use of TDR in Brazil, some studies have focused on a national context (Madsen et al. 2010; Bovarnick et al. 2010b; Eftec et al., 2010, Sparovek, 2011), some at the local level (Chomitz, 2004 and 2005) and some with theoretical approaches (Hercowitz, 2009; Bernardo, 2010).

In the current version of the Forest Code, compensation can take place outside the state as long as it is within the same biome and in an area considered as a priority for conservation. Given that Brazil is divided into six large biomes, this means that farmers may compensate for Forest Reserve deficits by protecting natural land thousands of kilometres away from their farm. As a result, much of the compensation protection would likely become established in areas where the conversion pressure is low, and little would become established in regions experiencing agriculture expansion where compensation protection would more effectively contribute to nature protection (Sparovek, 2012).

But, the decision of allowing compensation out of the State area is political and should be taken by governments at the State level. In Sao Paulo, the government[4] has decided that all TDR should be traded within the State, to ensure a minimum area of Forest Reserve and reforestation within the State. The State law carries an extra recommendation about where to allocate the compensation areas: "areas that form corridors linking fragments of remaining native vegetation, APP, public protected areas and priority areas for biodiversity conservation indicated by the Ministry of Environment or by the Project BIOTA/FAPESP, 2008 should be chosen.

Research questions and objectives

In this context, some questions that remain about the potential results of TDR implementation are: In what extension are the compliance costs reduced with TDR, compared with the compliance without TDR? What are the ecological results of an allocation of Forest Reserves by market – economic criteria only? Could the addition of an ecological criterion increase the cost-effectiveness of the instrument – increasing more the ecological effectiveness than costs?

To answer these questions we simulate Forest Code compliance in three different scenarios of rules for Forest Reserve allocation, one baseline and two with TDR implementation, using the State of São Paulo as a case study. In particular we tested the hypothesis that the larger the spatial market for TDRs, the greater the opportunity cost differentials and the greater the economic arbitrage opportunities in a TDR market, which would result in smaller compliance costs.

[4] Helena Carrascosa, Coordinator of Biodiversity and Natural Resources at Environmental State Agency of Sao Paulo – personal communication, December, 2012.

Our related hypothesis is that, if constrained by a minimum set of ecological criteria, the allocation of forest reserve by this mechanism can also result in a better effectiveness of the efforts to restore forest cover. We hypothesized that since heterogeneity of the suitability for agriculture can be addressed, compliance costs for landowners and for the society can be reduced. And, at the same time, the definition of the market constraints focusing on restoration efforts in priority areas for biodiversity conservation has the potential to improve ecological restoration effectiveness.

All of our scenarios simulate the compliance with Forest Reserve in the State of Sao Paulo (20% of Forest Reserve in each farm) but have different configuration of policies and market restriction to define the allocation of the Forest Reserves:

- Scenario 1 – Baseline: This scenario simulates the compliance with Forest Reserve requirements based only in command-and-control (Forest Code) without any economic instrument of trades. It means that all area of debits of Forest Reserve will have to be reforested in each farm. This will serve as baseline to test the costs-effectiveness of the TDR.

- Scenario 2 - Current policymix: This scenario simulates the compliance of Forest Reserve considering the option of trade between farms – compensation of Forest Reserves - TDR. It reflects the current policymix, with the requirements of 20% of Forest Reserve creating the cap from command-and-control (Forest Reserve) and the economic instrument TDR allowing trades between farms, only constrained by the Biomes. The demand are the debits of Forest Reserves in each biome and the supply is composed by the surplus of Forest Reserve and by restoration in agriculture areas in each biome.

- Scenario 3 - Proposed policymix: The last scenario also simulates the compliance of Forest Reserve with trades, but with the inclusion of a criterion aiming to target the reforestation efforts in priority areas to increase the ecological effectiveness of the policies. In this case, the supply is composed by the surplus of Forest Reserve and by restoration in agriculture areas only in high priority areas for restoration (Rodrigues *et al.*, 2010) in each biome.

The area allocated in each simulation was called “new forest reserves”. With the results we calculated the total compliance costs of each scenario using the opportunity costs of the new forest reserves and we calculate the level of ecological effectiveness using the map of Priority Areas for Restoration (Joly *et al.*, 2010) as an indicator. We then compared the total costs and ecological effectiveness of the scenarios and discussed the cost-effectiveness of the different combination of policies and constraints.

As pointed by Drechsler & Wätzoldb (2009), tradable permits are certainly not a panacea for biodiversity conservation but they may improve current policies under specific ecological and socioeconomic circumstances. Our aim with this paper is assess whether the TDR of Forest Reserve in Sao Paulo have these specific ecological and socioeconomic circumstances that could make this instrument useful to complement the policy mix for conservation.

2 *Methodology*

Spatial distribution of deficit and surplus areas

We used a database from a state agricultural census, LUPA (SAO PAULO, 2008) with data about the area with forest in the Units of Agricultural Production (UPA), which is similar to farm units. We calculated the deficit and surplus of Forest Reserves by UPA, according to the reference value of 20% required by the Forest Code for the Atlantic Forest and Cerrado biomes. Due to confidentiality requirements, the more than 320 thousand UPAs were aggregated using a grid of hexagons of 500 hectare each, resulting in 50,600 planning units.

Landowners with rural properties below 4 fiscal modules which have less than 20% Forest Reserve do not need to buy credits or to do restoration to be compliant. However, all forest area in their property up to 20% cannot be deforested. In addition, all the forest area could be considered a “surplus”. So, they can also participate in the instrument, but only as sellers and not buyers. But we could not eliminate the UPAs with less than 4 fiscal modules from the sample because of the confidentiality issues. This way, the amount of debits and surplus calculated could be overestimated or underestimated.

We used Marxan with Zones software (Watts et al. 2009; Ball et al., 2009) to obtain close-to-optimal cost-effective allocations of the Forest Reserves using three different restrictions of the market. We chose Marxan because it:

a) finds solutions for allocating Forest Reserves at minimal costs, which represents the behaviour we expect of a market and,

b) has the unique ability to provide multiple near optimal solutions to meet conservation objectives (Leslie et al. 2003). This means the algorithm does not produce one single optimal solution but many different ways the market could allocate the required amount of Forest Reserve based on costs. We assumed that this is a more realistic situation than to simulate the market as if it was able to find the one optimal solution. Furthermore the multi-solution output of Marxan with Zones provides us with additional information about whether there are many equally cheap or good alternatives (flexibility) and therewith how likely it is that the market will end up with a solution similar to those simulated, both in terms of costs and conservation outcome.

Although optimization is one of the core functions of Marxan, where many different criteria could be optimized including economic and ecological features, in our scenarios we used Marxan to allocate a fixed amount of an ecological feature that corresponds to the target of Forest Reserve. So there is not really an optimization between one or more features in this case, only spatial allocation of the targeted feature in the available areas constrained by different criteria aiming to reduce the costs.

We used for scenario allocation Marxan with Zones v2.1 and the spatially explicitly analysis were performed using ArcGis (ArcView v9.2), Quantum GIS v1.7.3 and GRASS v6.4.2.

Criterion of cost (opportunity cost)

We used the Bare Land Values (BLV)[5] per hectare, a database collected semi-annually (IEA-APTA-CATI, 2012) as a proxy for the opportunity cost. In order to make the data spatially explicit we created a correspondence between the categories of land of IEA with the map of Suitability for Agriculture (Ministry of Agriculture, 1979), group of municipalities (EDR) and combined Maximum, Minimum and Average BLV based on "Cost distance" to Infrastructure (Roads, urban areas and buildings). Cost distance was calculated using the r.cost module in GRASS GIS 6.4.2 based on a map of "friction costs" where rivers were treated as "barriers" and the friction of the terrain is defined as 100 (the resolution of the grid cells). Thereby the area of an EDR/Suitability combination is subdivided like this: the 25% of the area closest to infrastructure got the max-value, the 25% of the area with the largest distance to infrastructure got the min-value, and the rest got the avg. It resulted in a map (Figure 1) with costs per hectare varying from R$1,2 thousand to R$50 thousand.

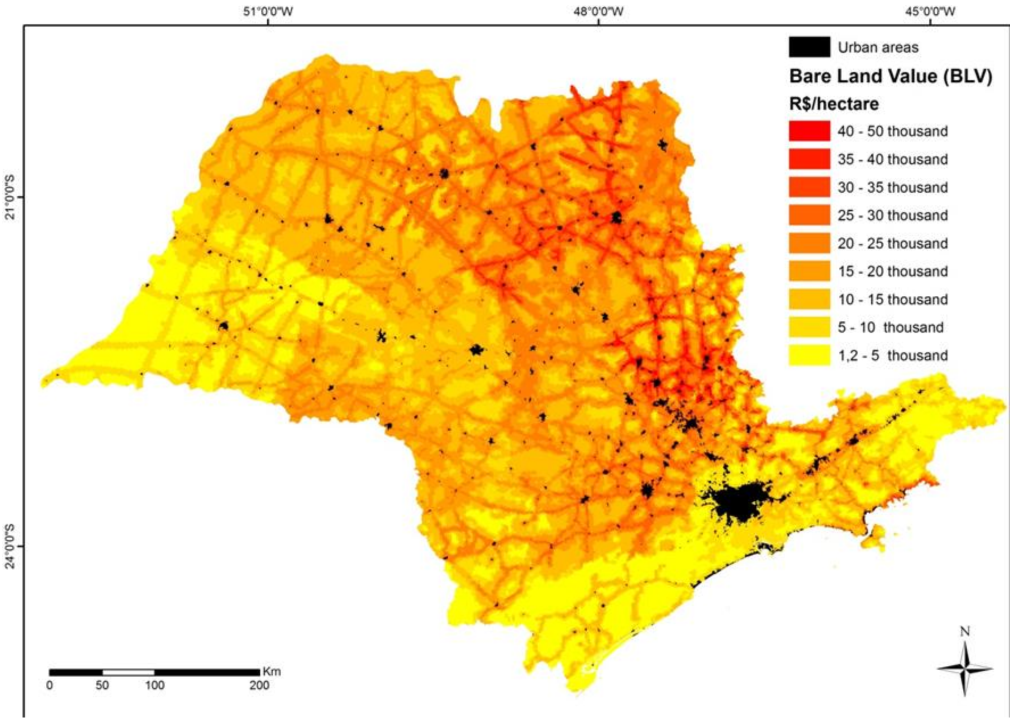

Figure 1 – Distribution of Bare Land Values per hectare (BLV)/ Opportunity costs in São Paulo

Source: BLV- IEA, 2012, Elevation model (SRTM- GLCF), (IBGE), Urban areas (EMBRAPA)

[5] The BLV reflects the market price of the land, collected by municipality of the State and is presented by groups of municipalities (EDR) and by different categories of land suitability. It is also provided the maximum, minimum and medium values for each category. For a better description of the methodology, in Portuguese, see: http://ciagri.iea.sp.gov.br/nia1/Precor_Sistema_Sobre.aspx?cod_sis=8

Criterion of biodiversity effectiveness (priority areas for restoration)

We used the map of Priority Areas for Restoration[6] (Rodrigues et al. 2008) produced by BIOTA, despite the existence of a more recent conservation priority map (Calmon et al. 2011). The BIOTA map compiles 20 years of data and experience in conservation in the State, and guides at the moment, the conservation priorities for practitioners and policy-makers. Up to now, 4 governmental decrees and 11 governmental resolutions mention the recommendations made by the BIOTA/FAPESP Program (Joly et al., 2010). The map (Figure 2) classifies the State of São Paulo in classes of priority for restoration ranging from 0 (low priority) to 8 (high priority). The amount of new forest reserves in the top priority classes, between 5 and 8, were used as our indicator for ecological gain.

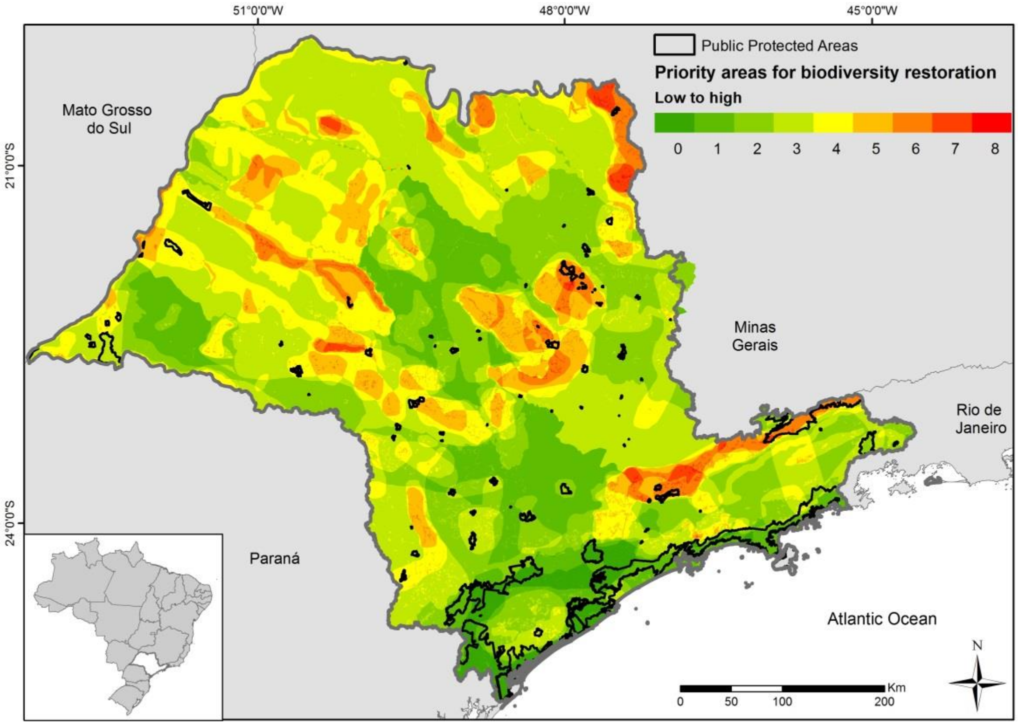

Figure 2 - Priority areas for biodiversity restoration and existing network of state parks in Sao Paulo Source: Rodrigues et al. 2008

Scenarios definition

In all scenarios we simulated compliance with the Forest Reserve, which means that every rural property has to reach the target of 20% of Forest Reserve. But each scenario had different options and constraints to achieve compliance.

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[6] Priority scores were based on the number of recommendations made by the team of experts in each taxonomic group recorded in the area (out of a possible seven: cryptogams, phanerogams, insects, amphibians, reptiles, birds and mammals) and the evaluation of one landscape ecology team. The higher the score, the larger the number of groups or species that inhabit the area that could benefit from restoration actions. Decisions were based particularly on the occurrence of ~3200 target species (e.g., rare, specialists, endemic, disturbance sensitive, and endangered species) and on some landscape structural features, such as fragment area and connectivity (Joly et al., 2010).

1) Baseline: This scenario was performed using regular GIS, no Marxan. All area of debits in the planning units was considered reforested and set as new forest reserves. It was then multiplied by the opportunity costs per hectare to get total cost of the scenario. Next, overlapped with the BIOTA map to check in which class of priority are located the new forest reserves. The surplus areas were not considered to reduce the debits in this scenario.

2) Current Policymix: We first considered all the area of surplus by planning unit in each of the two biomes as traded using TDR and used for compensation of Forest Reserve. This area was multiplied by the map of opportunity costs to get the costs for the conservation of Forest Reserve surplus. Then we deducted this surplus area from the total debit (calculated by planning unit) in each Biome to get the total net debit of each Biome. Marxan was used to allocate the net debit per biome (which will be the new forest reserves) using two zones: the first one is the area which will be selected for new forest reserves, and the second zone is the area not selected for forest reserves. The planning units available for new Forest Reserve allocation were set as the total area of the State of Sao Paulo excluding urban areas, water bodies, existing forest remnants and existing protected areas. Each planning unit had two attributes: total opportunity cost (calculated as the opportunity cost per hectare multiplied by the area of each planning unit) and type of biome (Atlantic Forest or Cerrado). We set a target for each biome corresponding to the area of net debit of Forest Reserve. Marxan then selected the cheapest planning units to reach the target in both biomes. We asked for 100 possible solutions of allocation of the debits with the smallest costs and we selected the best solution in Marxan which has the smallest cost. The total cost of this scenario includes the total cost of the best solution in Marxan for reforestation summed with the costs calculated for the surplus.

3) Proposed Policymix: We performed the same steps as in the previous scenario, but, besides the restriction of allocation within the Biome, Forest Reserves would be allocated only in areas of top Priority for Restoration (classes 5 to 8). To do that, all planning unit had an extra feature that corresponds to its priority class according to BIOTA map. Also, we removed from the planning units available for Forest Reserve allocation the ones with priority 0 to 4. The targets were defined as the net debit per biome in area and only planning units with the same biome and priority 5 to 8 contributed to the target.

In the baseline scenario was only used the reforestation and in the current and proposed policymix scenarios was used a combination of surplus (compensation by trade) and reforestation. The difference between the two scenarios with trade is the region where the new Forest Reserves were allocated. We refer to this as “new Forest Reserves”, because even if part of it is forest that already existed as surplus, it was not protected by the law and was a deforestation risk.

In the scenarios where trade is allowed, the landowners with debits have two options according to the Forest Code: to allocate the Forest Reserve in properties with surplus or allocate them in properties that are doing reforestation above the 20%. The second option is especially important in States such as Sao Paulo where the surplus area is smaller than the area of debits and restoration is necessary to allow compliance. However, it is still not regulated by law, and there are some issues under discussion in State level such as: what will be the indicators (or how much time after the plantation) is needed to a reforestation area be considered “reforestated” and valid for compensation? What will be the required reforestation technique (minimum number of species, proportion of native x exotic species)? These two doubts make the accountability of costs for this option very difficult because the methodology chosen and the history of degradation of the area could make the reforestation costs vary from US$760 to US$20 thousand per hectare (Rodrigues et al, 2009). Also, when we think about ecological importance, an area of remnant is frequently richer in biodiversity and in ecological functions than a new planted forest. Also, researchers argue that even strict requirements about methodology of plantation are clearly insufficient to verify whether a reforestation project would be successful, i.e. self-perpetuating, in the mid- or long term (Aronson et al., 2011).

So, in order to minimize error in opportunity cost evaluation of the reforestation option and to benefit the option of protection of remnants surplus areas which are not protected by law, in our simulation we will assume that the option of allocating the debits of Forest Reserve in an area of surplus of Forest Reserve will always be preferable over the option of allocating in an area of reforestation. So, our simulation models will first allocate all debits in the available surplus area and then allocate the rest of debits in potential areas of reforestation.

The evaluation of the cost effectiveness of each scenario was done comparing the total costs of the scenarios and the amount of the areas allocated for Forest Reserve according to the classes of priority for restoration.

3 Results

Demand and supply

Our results show that there is an amount of 13.3% of natural vegetation considering all the rural area (in LUPA census) in the State. It means that if all the rural area of the State was a single farm, it will have a deficit of 6.7% of forest reserve, which represents around 1.3 million hectares.

However, the distribution of the natural vegetation is very unequal within the state. Some areas are totally covered by natural vegetation while others have 100% of crop plantation. The analysis at the planning unit level shows that 17,096 units have an area of natural vegetation larger than the required by law, a total of 928 thousand hectares of “surplus”. On the other hand, 35,882 units have an area of natural vegetation smaller than required by law, with a total of 2.3 million hectares of “debits” (Table 1).

Table 1 – Area of debits, surplus and net debits per Biome in State of Sao Paulo

Biomes	Forest Reserve (in thousand hectares)		
	Debits	Surplus	Net debits
Atlantic Forest	1,496.0	762.1	733.9
Cerrado	801.0	166.2	634.8
Total - SP	2,297.0	928.3	1,368.7

Source: LUPA 2007-2008 (SAO PAULO, 2008)

This total debit of Forest Reserve is divided in 1.45 million hectares in the Atlantic Forest and 801 thousand hectares in the Cerrado. The surplus of Forest Reserve in the Atlantic Forest has a relation between surplus/debits for Atlantic Forest of 1/2 and in Cerrado of 1/5.

Scenarios results

In all scenarios the total area of debits (2.3 million hectares) was considered compliant with the addition of the same amount of area as “new Forest Reserves”. Baseline scenario without the trade was the most expensive one, with total costs of R$37 billion. Current policymix scenario, with the inclusion of trade possibility, resulted in considerably lower costs, R$8.9 billion. Proposed policymix, with constraints for top priority areas for conservation, had a cost of R$17.4 billion (

Table 2). These values do not represent the amount that the landowners will have to pay to be compliant (buying or renting credits). The value is only a proxy of the costs, as it was used the Bare Land Value of the land and the most important results is the relative values between them.

Table 2 - New Forest Reserves in area and costs, by scenario, type of compliance, and Biome

<table>
<tr><th rowspan="2"></th><th colspan="4">New Forest Reserves</th></tr>
<tr><th>Compliance using</th><th>Biome</th><th>Area (thousand ha)</th><th>Total Costs (million R$)</th></tr>
<tr><td rowspan="3">Baseline scenario Only reforestation</td><td rowspan="2">Reforestation</td><td>Atlantic Forest</td><td>1,496</td><td>21,351</td></tr>
<tr><td>Cerrado</td><td>801</td><td>15,701</td></tr>
<tr><td colspan="2">Total</td><td>2,297</td><td>37,052</td></tr>
<tr><td rowspan="5">Current policymix Trade within Biome</td><td rowspan="2">Surplus</td><td>Atlantic Forest</td><td>762</td><td>2,642</td></tr>
<tr><td>Cerrado</td><td>166</td><td>1,121</td></tr>
<tr><td rowspan="2">Reforestation</td><td>Atlantic Forest</td><td>734</td><td rowspan="2">5,137</td></tr>
<tr><td>Cerrado</td><td>635</td></tr>
<tr><td colspan="2">Total</td><td>2,297</td><td>8,900</td></tr>
<tr><td rowspan="4">Proposed policymix Trade within Biome & Top</td><td rowspan="2">Surplus</td><td>Atlantic Forest</td><td>762</td><td>2,642</td></tr>
<tr><td>Cerrado</td><td>166</td><td>1,121</td></tr>
<tr><td rowspan="2">Reforestation</td><td>Atlantic Forest</td><td>734</td><td rowspan="2">13,675</td></tr>
<tr><td>Cerrado</td><td>635</td></tr>
</table>

Priority Areas	**Total**	**2,297**	**17,438**

Source: LUPA 2007-2008 (SAO PAULO, 2008) and total costs (this study)

What regards the representation of the new Forest Reserves in the classes of priority, Baseline Scenario 1 had 38% of the new Forest Reserves concentrated in Priority 3, and 19% in Priorities 2 and 4 (Figure 3). Only 12% of the new Forest Reserves were allocated in the top priority classes (5-8).

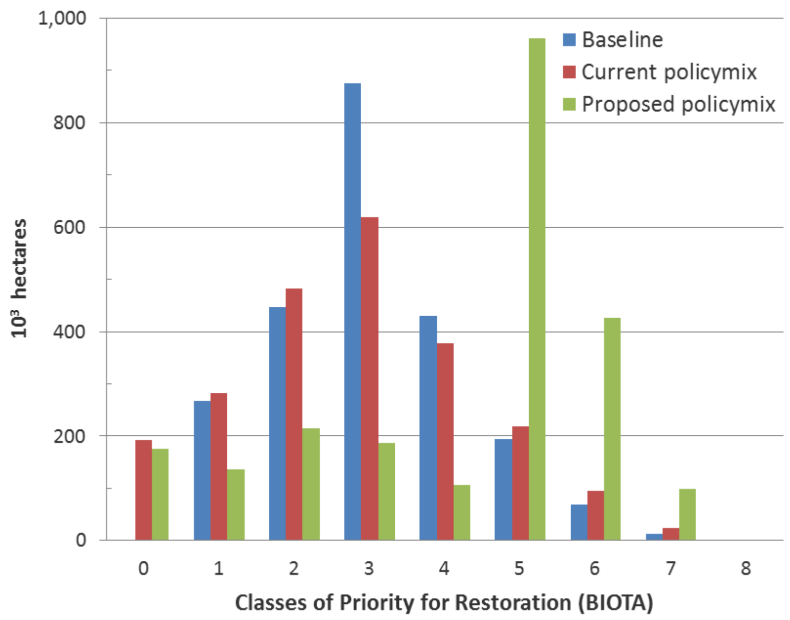

Figure 3 - Area of new Forest Reserves by classes of priority for restoration (BIOTA), by scenario

The Scenario 2 had a similar result of the amount of new Forest Reserves in top priority classes, 14%, but had a worse distribution in the other classes, increasing the amount of areas with priority class 0, from 0.1% to 9%. However, the Scenario 3 resulted in more than 64% of the new Forest Reserves in classes of top priority for restoration, 5 to 8.

When compared to the baseline scenario, the current policymix showed a marginal reduction in costs of 76% and the proposed policymix, a reduction of 53% (Figure 4). To incorporate the differences in priority between the top priority classes we weighted the area of new forest reserves selected under each priority class by its class (5 to 8), and called it ecological effectiveness. Regarding the ecological effectiveness compared to baseline, the current policymix scenario presented an increase in 23%, while the proposed policymix presented a very high increase in of 448%.

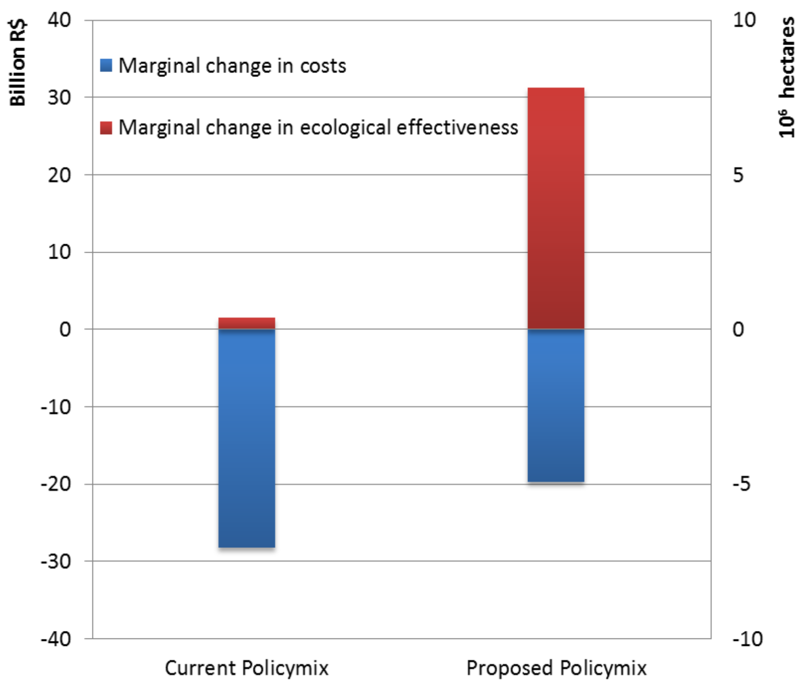

Figure 4- Comparison of marginal costs and marginal ecological effectiveness by Scenario

In order to calculate the cost-effectiveness of the scenarios we divided the ecological effectiveness (in hectares – weighted by class) by the costs of each scenario. Baseline scenario resulted in a cost-effectiveness of 39.3 thousand hectares/billion R$ (Figure 5). The current policymix had a marginal cost-effectiveness of 165.2 thousand hectares/billion R$ and the proposed, 423.68 thousand hectares/billion R$.

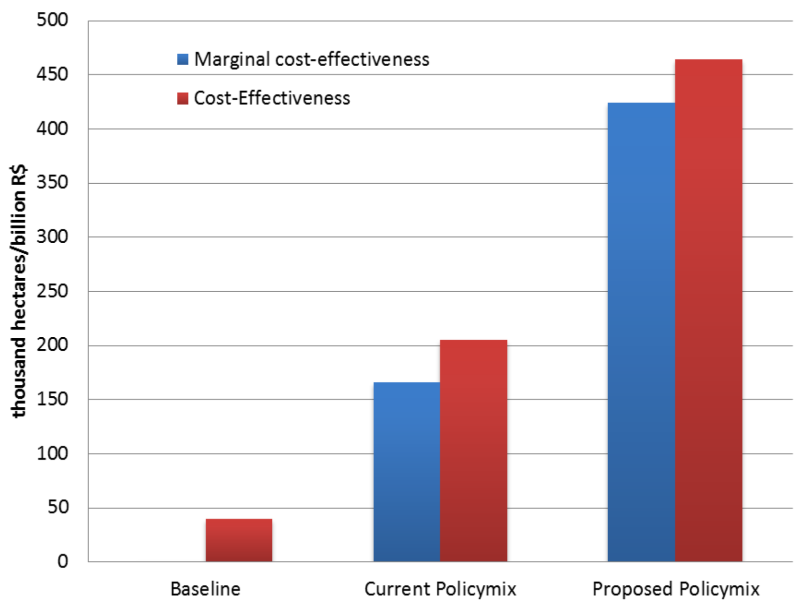

Figure 5- Cost-effectiveness and marginal cost-effectiveness in each scenario

The costs mentioned for the second and third scenarios include the best solution of allocation calculated by Marxan considering the smallest cost and the constraints selected. But we know that the real market solution is likely to be far away from the best optimal because of many reasons including the lack of information and transaction costs. So, it’s also interesting to analyse the frequency of selection of each area as a new Forest Reserve between the 100 possible solutions given by Marxan.

In the Figure 6 we see that the selection frequency in Scenario 2 is concentrated in very few areas and they are concentrated in the west part of SP, east part and some patches in the central area. On the other hand, Scenario 3 has selected areas in different regions which have few coincidence areas.

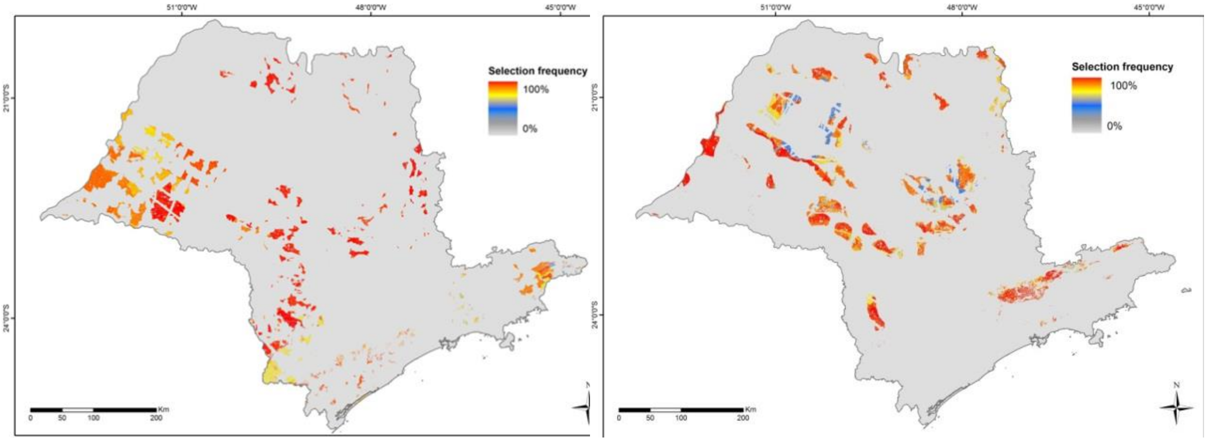

Figure 6 – Selection frequency for of current and proposed policymix scenarios, respectively.

We summarized these results with a “flexibility index”, defined as the number of selected planning units divided by the average of selection frequency (>0) of all planning units, in order to compare the availability of good alternatives. Current policymix scenario resulted in a flexibility index of 805.3, while proposed policymix scenario resulted in 872.7, concluding that the proposed policymix scenario has more available good alternatives comparably to current policymix scenario.

4 Discussion

The results showed a good cost-effectiveness of TDR instrument and a very high potential to both reduce the compliance costs and improve the ecological effectiveness of the Forest Reserve compliance. The inclusion of the economic instrument allowing trades within the Biome reduced 76% the compliance costs of the same amount of new Forest Reserves areas protected in Scenario 2 compared with the baseline (Scenario 1). Although the inclusion of a new constraint targeting the Priority Areas almost doubled the cost (+95%) compared with Scenario 2 of “free trade” constrained only by Biome, it still showed 50% less costly than the baseline.

Besides having the largest cost and the least efficient result in targeting priority areas, Baseline has the disadvantage of leaving 762 and 166 thousand hectares of remnants of Atlantic Forest and Cerrado, respectively, without protection by law, and under high deforestation risk. These areas usually are marginal lands, with very low opportunity cost and with conditions that have made them of limited interest to deforestation until now. But, they are still very important for biodiversity and for their ecological functions. Also, the reforestation of extensive areas for compliance in other regions could displace the demand for agriculture and these forested areas could suffer an increased pressure for deforestation.

The proposed inclusion of a constraint of the market within the BIOTA priority areas simulated in Scenario 3 has shown compared to the reference scenario of not TDR, substantially larger conservation gains relative to the increase in costs, which leads to considerable increase in ecological effectiveness and resulting in the most cost-effective option.
According to the selection frequency results the selected areas for new Forest Reserves have almost no overlap between scenarios 2 and 3. This result indicates that higher priorities are also more expensive and a market only constraint to Biomes has a potential to produce an outcome which does not fully reflect ecological priorities. This is not unexpected since areas of high conservation value are likely to coincide spatially with areas with high opportunity costs, where the pressure of human activities is highest, and consequently, where the most threatened nature occurs. The result also illustrates the importance of a policy mix that combines market and regulatory instruments, since market forces alone will tend to strengthen a skewed distribution of nature protection areas towards marginal (and hence low opportunity cost) lands for agricultural production.
The interesting issue in the design of this TDR is that when farmers with forest cover below the Forest Reserve target are required to purchase forest restoration or surplus, while farmers with surplus of legal reserve are allowed to deforest down to 20% without restoration requirements, the mechanism is no longer really TDR, but rather a biodiversity offset/habitat banking scheme with differentiated minimum reserve requirements. The instrument has become a hybrid due to political negotiation and historical deforestation trends (policy path-dependency of the instrument) discussed in the introduction.

Due to the current very low implementation of the TDR, it can be considered more as a potential instrument than as an existing one. Besides its potential of implementation highlighted in our results the constraints must be taken into account. They may be summarized into three main aspects. First, the alternatives between a wide scope and little regulated market on one hand, and a restricted and regulated trade scheme on the other, has to be considered carefully. As our study shows, the implementation of the economic instrument allowing the trades could reduce the costs without rendering a cost-effective result for conservation. But, too much restriction, as the previous version of Forest Code required (same Biome, same watershed) could discourage or even prevent the action of the market. Our proposed scenario showed one possibility of constraint inclusion that can specifically target the priority areas without increasing excessively the costs and likely without discouraging the market. Therefore, there is the need for studies that could simulate inclusion of other constraints which could target other priorities.

The simulation results we conducted in Sao Paulo may not be applied to all Brazilian States and biomes, with very different economic and ecological contexts. They should also be studied to provide subsidies to a better design of regulation for TDR in other States.

A second point is the institutional constraints that such instrument requires, and their associated cost-effectiveness. The federal government shall provide better general criteria to be applied at a national level as well as the States and its environmental agencies have to assume thel roles as organizers, regulators and monitoring agencies of the TDR. Some states have already developed local level systems of property data base management that has showed to be a key in subsidizing land-use and conservation planning, especially to ensure that the transaction costs for the TDR will not be prohibitive.

The third and maybe most important point is the creation of the demand. Market instruments like TDR require a demand stimulated by a regulation of a cap or minimum reserve requirements besides (Barton et al., 2011). The environmental protection of such a system lies in the cap (Vatn et al., 2011) so they are only feasible in contexts where direct regulation is in place and properly enforced. In the TDR case in Brazil this is an essential issue whereas this instrument has never been implemented yet due to the lack of demand, caused by lack of enforcement of the Forest Code. The last change in the Forest Code has brought about the expectation of an increased enforcement of the law and has led to increased interest in compliance. That makes more urgent the need for a better design of the implementation of the instrument.

These points highlight the importance of a policymix approach for design and implementation of cost-effective biodiversity conservation policies. In this approach, policymakers have a key role in combining different instruments to target the conservation objectives, and also assuring its economic viability. In our case study, we discussed a command-and-control legislation focusing on the conservation of a minimum area of habitat for each of the biomes in private lands, that has evolved towards the inclusion of an economic instrument (TDR) to address the aims of costs reduction to achieve higher level of compliance to the law. We simulated the inclusion of another market constraint to this economic instrument in our proposed scenario, which even if it has potentially low increments in costs, could be politically difficult to implement. One possible solution is to add to the current policymix one instrument that could address targeting the conservation priority areas without adding any new constraint, but incentives instead. For example, the State government could stimulate landowners to allocate the new Forest Reserves in priority areas offering to pay for the difference in costs that might exists. This could work as a kind of payment for ecosystem services (PES) scheme, because there will be an incentive proportional to the additional opportunity cost for changing behaviour (allocating the Forest Reserve in a top priority area instead of a less priority area). Alternative, the State could buy land in priority regions to create new public Protected Areas and sell the credits in the market, financing the creation of the protected areas and intervening in the allocation of the market.

Several possibilities for instrument combinations should be addressed by policymakers and studied by researchers to find the most cost-effective and feasible solutions to fit each region.

5 *Acknowledgments*

The authors would like to acknowledge funding from the POLICYMIX project (http://nina.policymix.no) funded by the European Commission, Directorate General for Research, within the 7th Framework Programme of RTD, Theme 2 – Biotechnology, Agriculture & Food (Grant no. 244065). P. Bernasconi also thanks CAPES for scholarship support received. We thank IEA staff, especially Mr. José Alberto Ângelo, for providing access and support with the LUPA database.

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