The potential of Tradable Development Rights (TDR) to improve effectiveness and reduce the costs of biodiversity conservation: study case in Sao Paulo, Brazil

Paula Bernasconi[1*]; Stefan Blumentrath[2]; David N. Barton[2]; Graciela M. Rusch[2]; Ademar R. Romeiro[1]
[1] Institute of Economics at the University of Campinas (UNICAMP), Brazil. [2] Norwegian Institute for Nature Research (NINA), Norway. *paulabernas@gmail.com

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 flexible mechanisms are being discussed. One of the options is the compensation of Forest Reserve requirements in another property, as a form of tradable development rights (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 potential effects of the TDR on the conservation outcome considering both the opportunity costs and the ecological gains and 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 – Headline of first order, font: 11, bold, space: 2 lines before, 1 line after

1.1 Context

The state of São Paulo is the most industrialized of Brazil, with a GDP of more than US$550 billion, with 40 million inhabitants (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).

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

However, in spite of the degradation, the remnants still contain 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 showing signals of recovery in line with the forest transition theory (Barreto et al., 2013; Farinaci; Batistella, 2012; Mather, 1992), but there is still the need for a more intensive and qualified restoration effort.

With the contribution of science, policymakers have considered two general objectives for conservation in 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 for 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 biodiversity and improve ecosystem services provision.

1.2 A brief review 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, which in the State of São Paulo (Atlantic Forest and Cerrado) corresponds to 20% of the property area. Since its first version, in 1934, the Forest Code and related instruments have plotted a historical path of many changes, including 84 revisions only between 1965 and 1998 (Hirakuri et al., 2003). Low enforcement has led to low compliance, with less than 10% of the farms claiming to have Forest Reserves (Oliveira & Bacha, 2003). The alterations in the law have repeatedly revised the amount of Forest Reserve required and also created the Permanent Protected Areas (APP). APPs guarantee the protection of fragile areas such as riparian areas, streams, slopes, hill tops, plateaus and mangroves, besides the area protected in Forest Reserves.

However, the low compliance doesn't mean that the Forest Code is not binding in any way nor imposes any costs on landowners; 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 could be in the order of US$3.2 billion, which means a reduction in 17.7% of the sector income. The estimated forest recovery costs required for compliance with the previous Forest Code requirements (APP and Forest Reserve) 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).

The complaints about the high compliance costs of the law motivated increasing demands from the rural sectors for relaxing the rules. In 2012 after many years of discussion in the National Congress and Senate, the president approved a new version of the Forest Code[1]. The new version reduced some strict rules that had raised expectations about higher enforcement and compliance.

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

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 using a surplus of Forest Reserve in another farm located in the same biome

The latest version of the Forest Code shows that a regulatory instrument is not enough to assure conservation, 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 and flexible incentives in addition to strict regulations (Lynch and Musser, 2001).

1.3 - Tradable development rights in a conservation policymix

According to Ring and 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.”

A complementary mix of policies could include positive incentives (subsidies, tax reliefs, fiscal transfers or payments) for providers of biodiversity conservation and ecosystem services, with negative incentives for harmful activities for biodiversity- and ecosystem service capacity (environmental taxes, necessity to hold a permit, obligation to buy offsets) (Schröter-Schlaack & Ring, 2011).

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 (prohibitively) high transaction costs (Schröter-Schlaack and Ring, 2011).

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

The "compensation of Forest Reserve" option for compliance allows the landowner which has less Forest Reserve than required by law 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). It could play an important role in this new phase of the biodiversity conservation in Sao Paulo and Brazil and complement the policymix by increasing its efficiency.

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 minimum requirement. TDRs take advantage of heterogeneities in the agricultural suitability and in the opportunity costs of conservation while ensuring the minimum Forest Reserve area requirement. Furthermore, 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 has 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 for the first time in 2000[2]. The current criteria for TDR are[3]:

1) A landowner can voluntarily forfeit, permanently or temporary, 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 offset future deforestation. It is only valid as a means of complying with the minimum requirement on land currently below the requirement (due to past deforestation).
3) The areas used for compensation must have equivalent extension and be part of the same Biome.
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 prior 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 for compliance, and the previous regulation of the TDR that required compensation both within the same biome and micro-watershed.

The potential of the TDR as a market-based instrument to contribute to 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),

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

some at the local level (Chomitz, 2004 and 2005) and some with theoretical approaches (Hercowitz, 2009; Bernardo, 2010; Barton et al., 2011).

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 the continental size of Brazil 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.

1.4 - Research Questions

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.

Questions remain regarding the potential results of TDR implementation:

- To what extent are compliance costs reduced with TDR, compared with compliance without TDR?
- What are the ecological results of an allocation of Forest Reserves based on only on minimisation of opportunity costs?
- Could the addition of an ecological criterion increase the cost-effectiveness of the instrument?

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 test 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.

Our related hypothesis is that, if constrained by a minimum set of ecological criteria, the allocation of forest reserve by this mechanism results in higher restored forest cover.

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

A corollary of the two hypotheses is that they trade-off in terms of cost-effectiveness. Assuming that heterogeneity of opportunity cost and biodiversity conservation features is positively correlated, cost minimization increases with market size, while ecological criteria for the equivalency of forest offset areas reduces market size.

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 deficits of Forest Reserve will have to be reforested on 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 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. Demand is composed of the deficits of Forest Reserves per farm in each biome while supply is determined by the surplus of Forest Reserve and by restoration in agriculture areas per farm 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 determined by the surplus of Forest Reserve and a restriction of restoration only in high restoration priority agriculture areas (Rodrigues et al., 2010) in each biome.

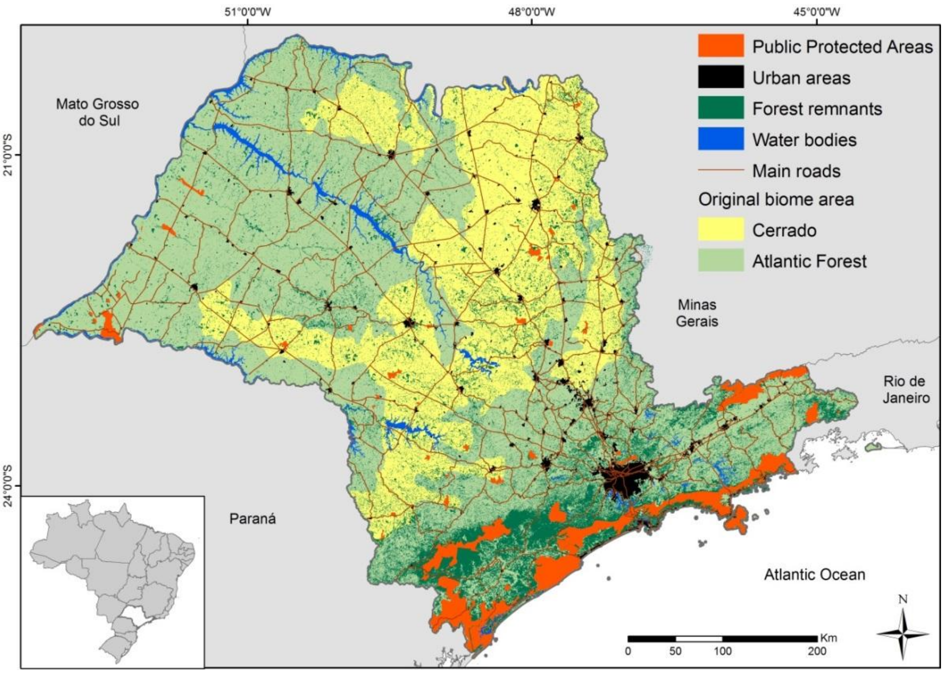


Fig. 1. State of Sao Paulo – public protected areas, urban areas, remnants, water, roads and biomes, source: elaborated with secondary data

2 - Methodology

2.1 - 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 for each 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.

We used Marxan with Zones software (Watts et al. 2009; Ball et al., 2009) to obtain an approximation of 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 an efficient market with no transaction costs and information similar to what we have available and,

b) has the functionality 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 an efficient market could allocate the required amount of Forest Reserve based on costs. We assumed that this is a more realistic situation than to simulate a market as if there existed 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. 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.

2.2 - Criterion of cost (opportunity cost)

To calculate the opportunity cost per hectare we used summary statistics on market price per hectare from the bare land value (BLV) database , compiled semi-annually as a proxy for the opportunity cost (IEA-APTA-CATI, 2012). In this database, for groups of municipalities (EDR) maximum, minimum and average land values are being reported for different categories of land use suitability. Here, the opportunity cost designation refers to market prices for agricultural land only and does not cover forest. In order to create an opportunity cost map for forest conservation from that database we applied the information there to existing map data.

In a first step, a map on administrative units and a map on the lands suitability for agriculture (Ministry of Agriculture, 1979) were combined in a way that the result matches the entities in the land price database. Within these spatial units maximum, minimum and average land prices were distributed spatially assuming their correlation with the accessibility of the land. In the lack of more detailed information distance to infrastructure (Roads, urban areas and buildings) was used as a proxy for accessibility. Here, a cost distance measure was applied, calculated with the r.cost module in GRASS GIS 6.4.2, because “cost distance” can take accessibility constraints of the landscape into account which can be defined in a friction map. In this case, friction of the landscape was defined as follows:

a) rivers were treated as “barriers” and

b) the friction of the terrain is defined as the squared slope in degree (the resolution of the grid cells).

For each combination of municipalities and suitability classes the 1st and 3rd quartile of cost distance to infrastructure was calculated. Then land prices were assigned proportionally as follows: the 25% of the area closest to infrastructure was assigned the max-value; the 25% of the area with the largest distance to infrastructure was assigned the min-value, and the remaining intermediate cost distance locations were assigned average land market prices.

This resulted in a map (Figure 2) with costs per hectare varying from R$1,2 thousand to R$50 thousand. The resulting cost layer is based on potential agricultural returns and does not account for any forestry values that may be realised on properties.

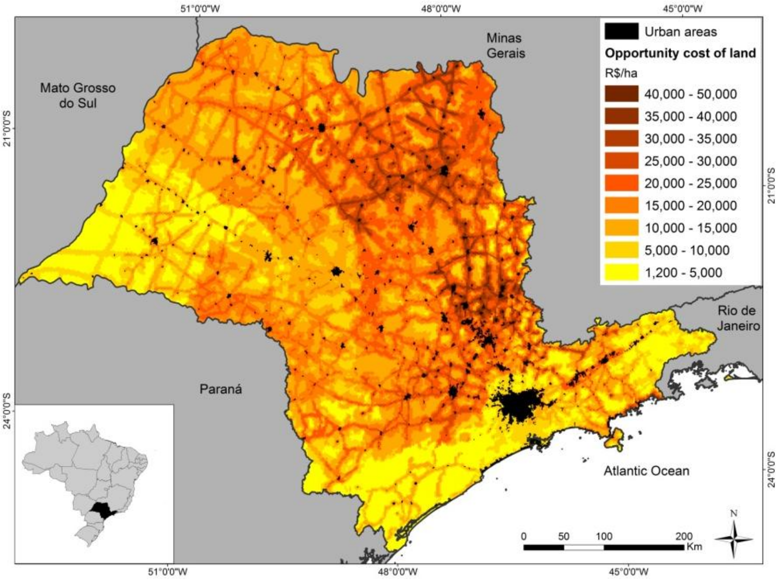


Fig. 2 - Distribution of Bare Land Values per hectare (BLV)/ Opportunity costs in São Paulo, Source: BLV- IEA, 2012, Elevation model (SRTM- GLCF), (IBGE), Urban areas (EMBRAPA)

2.3 - Criterion of biodiversity effectiveness (priority areas for restoration)

We used the map of Priority Areas for Restoration (Rodrigues et al. 2008) produced by BIOTA. This map, which has been the keystone of conservation planning in the state, 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, more than 15 laws and resolutions mention the recommendations made by the BIOTA/FAPESP Program (Joly et al., 2010).

The BIOTA map (Figure 3) 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.

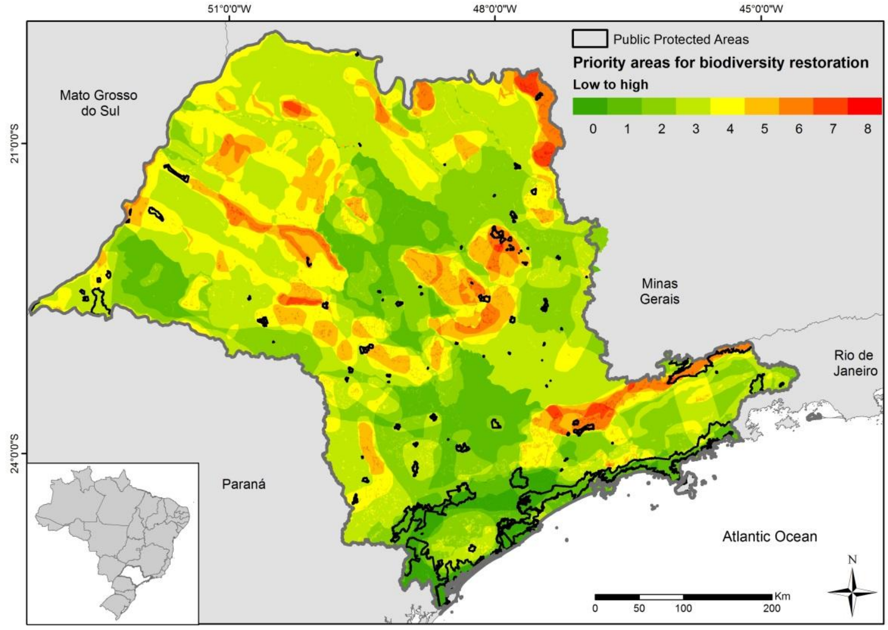


Fig. 1 - Priority areas for biodiversity restoration and existing network of state parks in Sao Paulo, source: Rodrigues et al. 2008

2.4 - Scenario 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.

1) Baseline (homogenous compliance): This scenario was performed using GIS software without Marxan. All area of deficits 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 deficits 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 deficit (calculated by planning unit) in each Biome to get the total net deficit of each Biome. Marxan was used to allocate the net deficit 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 deficit 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 deficits with the smallest costs. 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 deficit 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 we 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 at risk of deforestation.

The evaluation of the cost effectiveness of each scenario was carried out 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

3.1 - 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 “deficit” (Table 1).

Table 1. Area of deficit, surplus and net deficit per Biome in State of Sao Paulo, source: LUPA 2007-2008 (SAO PAULO, 2008)

Biomes	Forest Reserve (in thousand hectares)		
	Deficits	Surplus	Net deficits
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

This total deficit 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/deficits for Atlantic Forest of 1/2 and in Cerrado of 1/5.

3.2 - Scenario results

In all scenarios the total area of deficits (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 based on the Bare Land Value of the land. 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, source:LUPA 2007-2008 (SAO PAULO, 2008) and total costs (this study)

	New Forest Reserves			
	Compliance using	**Biome**	**Area (thousand ha)**	**Total Costs (million R$)**
Baseline scenario Only reforestation	Reforestation	Atlantic Forest	1,496	21,351
		Cerrado	801	15,701
	Total		**2,297**	**37,052**
Current policymix Trade within Biome	Surplus	Atlantic Forest	762	2,642
		Cerrado	166	1,121
	Reforestation	Atlantic Forest	734	5,137
		Cerrado	635	
	Total		**2,297**	**8,900**
Proposed policymix Trade within Biome & Top Priority Areas	Surplus	Atlantic Forest	762	2,642
		Cerrado	166	1,121
	Reforestation	Atlantic Forest	734	13,675
		Cerrado	635	
	Total		**2,297**	**17,438**

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

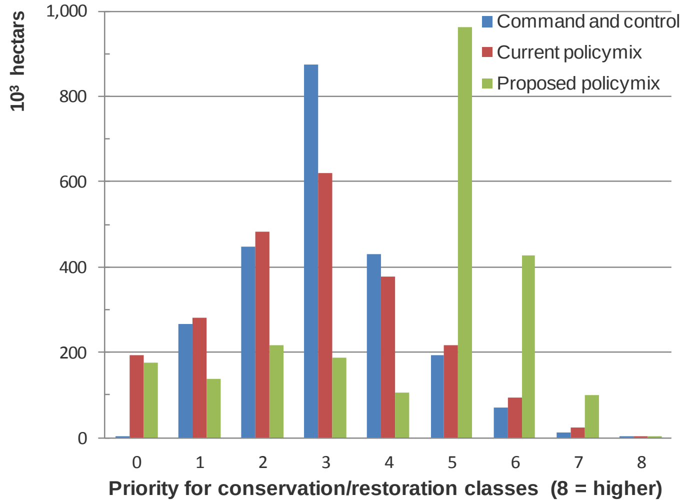
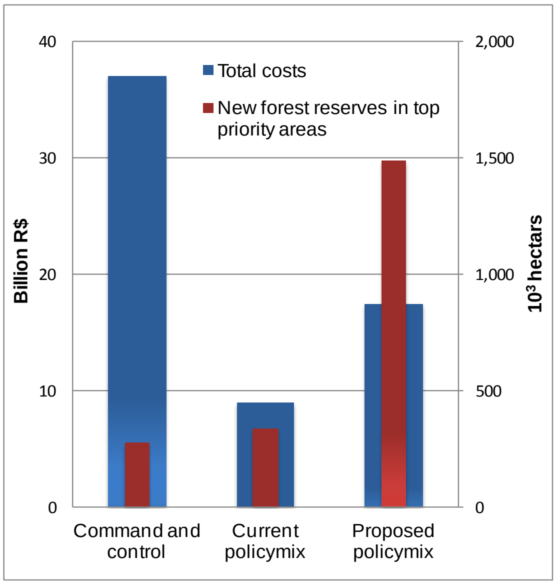


Fig.2. Area of new Forest Reserves by classes of priority for restoration, by scenario

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 reduction in costs of 76% and the proposed policymix, a reduction of 53% (Figure 5). 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%.



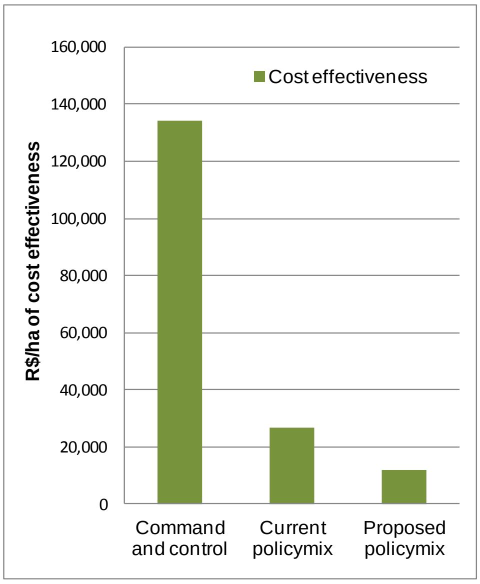


Fig. 5 and 6..Total costs, ecological effectiveness and cost effectiveness ratio, by scenario

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 6). The current policymix had an increase in the cost-effectiveness ratio of 165.2 thousand hectares/billion R$ and the proposed, 423.68, both compared with baseline scenario.

The costs mentioned for the second and third scenarios include the best allocation solution calculated by Marxan considering the smallest cost and the constraints selected. But we expect that a real market solution would be likely to be far away from the best optimal solution. For this reason 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 **Erro! Fonte de referência não encontrada.**7 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.

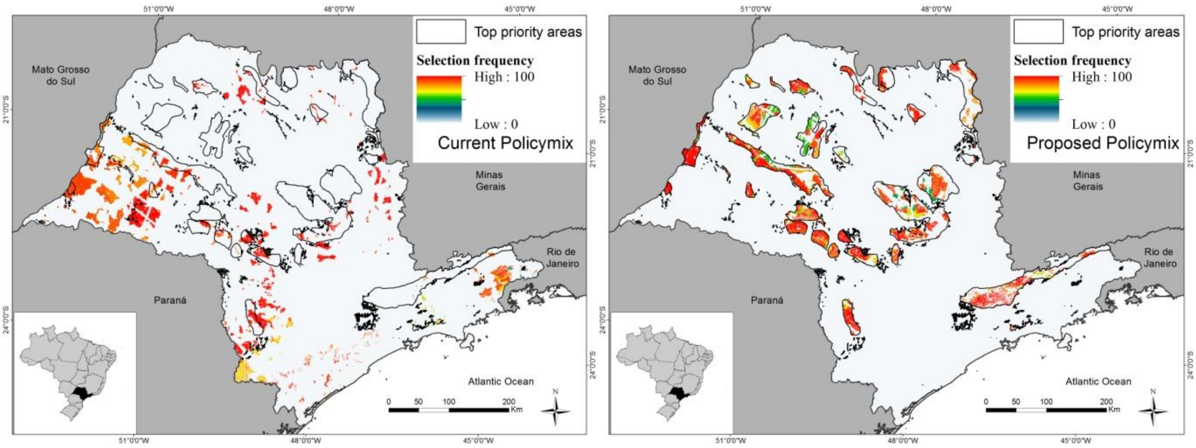


Fig. 7 - Selection frequency of current and proposed policymix scenarios, respectively.

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. The 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 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 by 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 was still 50% less costly than the baseline.

Besides having the largest cost and the least efficient result in targeting priority areas, the Baseline has the disadvantage of leaving 762 and 166 thousand hectares of remnants of Atlantic Forest and Cerrado, respectively, without protection by law. 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 cost 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 towards nature protection areas only on lands that are unprofitable for agricultural production.

In the scenarios where trade is assumed, the landowners with deficits 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 deficits and restoration is necessary to allow compliance. However, it is still not regulated by law, and there are some questions under discussion at State level such as:

-what will be the indicators (or how much time after the plantation) is needed for a reforestation area be considered "reforested" and valid for compensation?

-What will be the required reforestation technique (minimum number of species, proportion of native x exotic species)?

These questions make accurate opportunity costs estimation for this option very difficult because it depends on the methodology chosen. The history of degradation of the area could make the reforestation costs vary from US$760 to US$20 000 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).

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/ 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 a number of disadvantages 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) would reduce cost heterogeneity and the possibilities of arbitrage, including the margins necessary to sustain intermediaries necessary to make a trading scheme work . Our proposed scenario showed one possibility of constraint inclusion that can specifically target the priority areas without increasing costs. 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 the 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 private actors for the TDR will not be prohibitive. Nevertheless, public transaction costs in setting up the system may be large (Barton et al., 2011).

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. 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 - Conclusions

The results of our evaluation of the potential effect of the TDR in the State of Sao Paulo showed a clear potential of the TDR to both reduce compliance costs and improve ecological effectiveness of the Forest Reserve compliance compared this to a pure command-and-control approach.

The inclusion of the economic instrument allowing trades within the Biome reduced by 76% the compliance costs of the same amount of new Forest Reserves areas protected compared with the baseline. 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 was still 50% less costly than the baseline. The proposed scenario also showed 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.

This result indicates that higher priorities are also more expensive and a cost only constraint to Biomes has a potential to produce an outcome which does not fully reflect ecological priorities. The result also illustrates the importance of a policy mix that combines market and regulatory instruments, since market forces alone will tend towards nature protection areas only on lands that are unprofitable for agricultural production.

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References

Alston, L. J.; Mueller, B. 2007. Legal Reserve Requirements in Brazilian Forests: Path Dependent Evolution of De Facto Legislation. EconomiA, Selecta, Brasilia (DF), v.8, n.4, p.25-53.

Aronson, J.; et al. 2011. What Role Should Government Regulation Play in Ecological Restoration? Ongoing Debate in Sao Paulo State, Brazil. Restoration Ecology 19: 690–695.

Ball, I.R., H.P. Possingham, and M. Watts. 2009. Marxan and relatives: Software for spatial conservation prioritisation. Chapter 14: Pages 185-195 in Spatial conservation prioritisation: Quantitative methods and computational tools. Eds Moilanen, A., K.A. Wilson, and H.P. Possingham. Oxford University Press, Oxford, UK.

Barton, D. N., Lindhjem, H., Ring, I. and Santos, R., 2011. New Approaches and financial mechanisms for securing income for biodiversity conservation, In: Vatn, A., Barton, D. N., Lindhjem, H., Movik, S., Ring, I. and Santos, R. Can markets protect biodiversity? An evaluation of different financial mechanisms. Noragic Report No. 60.

Bernardo, K. T. Análise do êxito dos sistemas estaduais de gestão de reservas legais com foco no mecanismo de compensação. 2010. Master Dissertation presented to Univsersity of São Paulo, São Carlos-SP.

Bovarnick A.; Knight, C.; Stephenson, J. 2010. Habitat banking in Latin America and Caribbean: A Feasibility Assessment. Main Report. UNDP Working Paper.

Broughton, E., Pirard, R. 2011. What's in a name? Market-based Instruments for Biodiversity, Health and Environment Reports n°8, IFRI, Paris, 2011. Available at: http://www.ifri.org/index.php?page=detail-contribution&id=6640

Calmon, M.; Brancalion, P. H. S.; Paese, A.; Aronson, J.; Castro, P.; Silva, S. C.; Rodrigues, R. R. 2011. Emerging Threats and Opportunities for Large-Scale Ecological Restoration in the Atlantic Forest of Brazil. Restoration Ecology Vol. 19, No. 2, pp. 154–158.

Chomitz, K.M. 2004. "Transferable Development Rights and Forest Protection: An Exploratory Analysis". International Regional Science Review 27(3):348-373.

Chomitz, K.M.; Thomas, T. S.; Brandao, A. S. 2005. The economic and environmental impact of trade in forest reserve obligations a simulation analysis. RER, Rio de Janeiro, vol. 43, nº 04, p. 657-684.

Drechsler, A.; Wätzoldb, F. 2009. Applying tradable permits to biodiversity conservation: Effects of space-dependent conservation benefits and cost heterogeneity on habitat allocation. Ecological Economics, 68. 1083 – 1092.

EFTEC, IEEP, IUCN. 2010. The use of market-based instruments for biodiversity protection –The case of habitat banking – Technical Report. London.

Farinaci, J. S.; Batistella, M. 2012. Variation on native vegetation cover in São Paulo: an overview of current knowledge. Revista Árvore, Viçosa-MG, v.36, n.4, p.695-705.

Fearnside, P. M. 2000. Código Florestal: o perigo de abrir brechas. Ciência Hoje, v.28, n.163.

Hercowitz, M. 2009. O que eu faço com esse mato?: uma análise socioeconômica do mercado de compensações de Reserva Legal na Bacia do Xingu no Mato Grosso. São Paulo: ISA.

Hirakuri, S. R. 2003. Can Law Save the Forest? Lessons from Finland and Brazil. Center for International Forestry Research - CIFOR.

IBGE. Censo demográfico. 2010. Available at: http://www.censo2010.ibge.gov.br/

IEA-APTA-CATI. Bare Land Values (Valor da Terra Nua). Available at: http://ciagri.iea.sp.gov.br/nia1/precor.aspx?cod_tipo=1&cod_sis=8. Accessed in Dec2012.

IEA. 2008. Pagamento pelos serviços da reserve legal. Análises e Indicadores do Agronegócio. v.3, n.1, Janeiro-2008.

IEA. 2009. Reserva Legal em São Paulo obrigatoriedade, impactos e proposta de aprimoramento da legislação. Textos para Discussão, n.6.

Kronka, F.J.N.; et al. 2005. Inventário florestal da vegetação nativa do Estado de São Paulo. Secretaria do Meio Ambiente, Instituto Florestal, 200p.

Joly, C. A.; Rodrigues, R. R.; Metzger, J. P.; Haddad, C. F. B.; Verdade, L. M.; Oliveira, M. C.; Bolzani, V. S. 2010. Biodiversity Conservation Research, Training, and Policy in São Paulo. VOL 328, Science.

Laurance, W. F. 2009. Conserving the hottest of the hotspots. Biological Conservation 142. 1137.

Leite, C. C., M. H. Costa, B. S. Soares-Filho, and L. de Barros Viana Hissa (2012), Historical land use change and associated carbon emissions in Brazil from 1940 to 1995, Global Biogeochem. Cycles, 26, GB2011.

Leslie, H., M. Ruckelshaus, I. R. Ball, S. Andelman, and H. P. Possingham. 2003. Using siting algorithms in the design of marine reserve networks. Ecological Applications 13:S185–S198.

Lynch, L., Musser, W. N. 2001. A relative efficiency analysis of farmland preservation programs. Land Economics 77, 577-594.

Madsen, B.; Carroll, N.; Moore Brands, K. State of Biodiversity Markets Report: Offset and Compensation Programs Worldwide. 2010. Available at: http://www.ecosystemmarketplace.com/documents/acrobat/sbdmr.pdf

Metzger, J. P.; Rodrigues, R. R. Diretrizes para a Conservação e Restauração da Biodiversidade no Estado de São Paulo: Instituto de Botânica/Programa BIOTA/FAPESP, 2008.

Ministry of Agriculture - Brazil. Aptidão agrícola das terras do Estado de São Paulo (Estudos básicos para planejamento agrícola; Aptidão agrícola das terras). Brasília: BINAGRI, 1979. 114p.

Myers, N.; Mittermeier, R. A; Mittermeier, C. G.; da Fonseca, G. A; Kent, J. Biodiversity hotspots for conservation priorities. Nature, v. 403, n. 6772, p. 853-8, 2000.

Nalon, M. A.; Mattos, I. F. A.; Franco, G. A. D. C. 2008. Meio físico e Aspectos da Fragmentação da Vegetação. In: Diretrizes para a conservação e restauração da biodiversidade no estado de São Paulo. São Paulo: Instituto de Botânica/Programa BIOTA/FAPESP, 2008.

Oliveira, S. J. M., Bacha, C. J. C., 2003. Avaliação do cumprimento da reserva legal no Brasil. Revista de Economia e Agronegócio, Vol.1, Nº2.

Pompermayer. E. F. (2006). Compensação da Reserva Florestal Legal como instrumento de gestão integrada floresta–água: analise jurídica. 78 f. Dissertação (Mestrado) - Escola Superior de Agricultura Luiz de Queiroz,Universidade de São Paulo. Piracicaba, 2006.

Ranieri, V.E.L. (2004). Reservas legais: critérios para localização e aspectos de gestão. 149 f. Tese (Doutorado) – Escola de Engenharia de São Carlos, Universidade de São Paulo, São Carlos, 2004.

Ribeiro, M. C. et al. The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. Biological Conservation, v.142, n.6, p.1141-1153, 2009.

Ring, I., Schröter-Schlaack, C. (Eds.) 2011. Instrument Mixes for Biodiversity Policies. POLICYMIX Report No. 2/2011, available at http://www.policymix.nina.no

Rodrigues, E. R. et al. 2007. Avaliação econômica de sistemas agroflorestais implantados para recuperação de reserva legal no Pontal do Paranapanema, São Paulo. Rev. Árvore [online]. vol. 31, n.5 p. 941-948.

Rodrigues, R.R.; Lima, R.A.F.; Gandolfi, S.; Nave, A. G. 2009. "On the restoration of high diversity forests: 30 years of experience in the Brazilian Atlantic Forest", Biological Conservation, vol. 142, no. 6, pp. 1242-1251.

Rodrigues, R.R. et al. 2008. Diretrizes para conservação e restauração da biodiversidade no Estado de São Paulo. Governo do Estado de São Paulo, São Paulo, 238p.

Santos, R.; Clemente, P.; Antunes, P.; Schröter-Schlaack, C.; Ring, I. 2011. Offsets, habitat banking and tradable permits for biodiversity conservation, in: Ring, I., Schröter-Schlaack, C. (Eds.) (2011): Instrument Mixes for Biodiversity Policies. POLICYMIX Report No.2/2011.

SIFESP - Sistema de Informações Florestais do Estado de São Paulo. Disponível em: http://www.iflorestal.sp.gov.br/sifesp/. Acesso em: 26 de jul. 2010.

SAO PAULO. 2008. Secretaria de Agricultura e Abastecimento. Levantamento censitário de unidades de produção agrícola do Estado de São Paulo - LUPA 2007/2008. São Paulo: SAA/CATI/IEA, 2008. Available at: <http://www.cati.sp.gov.br/projetolupa>.

Schröter-Schlaack, C.; Ring, I., 2011. Towards a framework for assessing instruments in policy mixes for biodiversity and ecosystem governance, in: Ring, I., Schröter-Schlaack, C. (Eds.), Instrument Mixes for Biodiversity Policies. POLICYMIX Report No. 2/2011, pp. 175-208.

Sparovek, G.; Barreto, A.; Klug, I.; Papp, L.; Lino, J. 2011. A revisão do Código Florestal brasileiro. Novos Estudos, v. 89, p. 111-135.

Sparovek, G.; Berndes, G.; Barretto, A.; Klug, I. 2012. The revision of the Brazilian Forest Act: increased deforestation or a historic step towards balancing agricultural development and nature conservation? Environmental science & policy 16. 65–72.

Vatn, A.; Barton, D. N.; Lindhjem, H.; Movik, S.; Ring, I.; Santos, R.: Can markets protect biodiversity? An evaluation of different financial mechanisms. Noragric Report No. 60 (June 2011).

Watts, M. E.; et al. 2009. Marxan with Zones: software for optimal conservation based land- and sea-use zoning, Environmental Modelling & Software (2009), doi:10.1016/j.envsoft.2009.06.005