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Eco-certification protocols as mechanisms to foster sustainable environmental practices in telecoupled systems

ABSTRACT: The international trade of forestry and agricultural commodities leads distant regions across the globe to become connected through flows of products, information and capital. To deal with the sustainability and socioeconomic challenges of these interconnections, the ‘telecoupling’ conceptual framework has emerged. The telecoupling framework takes a coupled human-natural system approach to understand connections between different systems, classifying them as ‘sending’, ‘receiving’ and ‘spillover’ systems. This paper uses the telecoupling framework to investigate how distant systems are connected through flows of eco-certified forestry products and demonstrates how these connections drive environmental law compliance at the rural property level. We identify rural properties with eucalyptus plantations in Paraíba Valley, São Paulo State, Brazil as a sending system, and trace the outgoing flows of cellulose pulp to receiving systems. China and the European Union are the receiving systems, having been the major importers over the last ten years. Using a multitemporal and spatial approach, we found that between 1995 and 2005 rural properties containing eucalyptus plantations with FSC certification had higher rates of native forest cover regeneration than properties without FSC certification. Native forest conservation and regrowth in rural properties in Paraíba Valley is an effect of the telecoupled system based on the international demand of eco-certified cellulose pulp from elsewhere. Additionally, we find that the telecoupled system also results in impacts on surrounding areas in the Atlantic forest landscapes, which we identify as an adjacent spillover system.

Key words: Public environmental policies; voluntary agreements; telecoupling; agri-commodity supply chains; spillover system.

1. Introduction

The effects of ecologically unsustainable supply chains on consumption behavior pose a risk to forestry and agri-food markets, leading industries to find ways of preventing unsustainability practices across the supply chain (Hamilton and Zilberman, 2006). For example, organizations have emerged to set protocols and standards for sustainable production chains that aim to connect consumers with producers through reliable mechanisms such as certification labels (e.g. the Forest Stewardship Council, FSC; Kill, 2016; Piketty and Drigo, 2018). To explain changes in production towards sustainable practices, eco-friendly products, and trusted brands, the scientific literature in economics, ecology, and environmental sciences have developed studies in consumption behavior and markets (Waroux and Lambin, 2013; Ricci et al., 2018; Roheim et al., 2018; Weitzman and Bailey, 2018). These studies highlight the importance of individuals or groups in setting sustainable standards as a requirement to purchase goods and services. However, most recently Lambin et al. (2018) observed that demand for sustainable products is still tiny compared to overall demand.

In Brazil, certifications such as the Rainforest Alliance Certified™ (RAC) developed by Sustainable Agriculture Network (SAN) has proven effective for conserving forests and their biodiversity, as well as suppressing usage of pesticides and fertilizers in coffee plantations (Lima et al., 2009). In Colombia, coffee plantations certified by the RAC have fostered increases in native forest cover and landscape habitat connectivity significantly greater than in farms of non-certified coffee production in the same region (Rueda et al., 2015). The success of these initiatives is currently a subject of intense debate among researchers, stakeholders, governmental authorities and consumers, given that the recent literature shows examples of positive (Newsom and Hewitt, 2005; Dias et al., 2015), minor or neutral (Rametsteiner and Simula, 2003; Nebel et al., 2005; Lima et al., 2009; Blackman et al., 2015), and mixed (e.g., positive social and economic outcomes but not on-the-ground environmental outcomes – Blackman et al., 2017) results. In addition, previous studies have highlighted the lack of rigorous empirical evaluations of eco-certifications as the FSC (Blackman et al., 2017; Romero et al., 2017) and discussed the difficulty and costs associated with conventional monitoring systems (e.g., studies of species composition, forest and bird community structure) as a reason for scarce studies about the environmental impacts of certifications (lough and Persoon, 2010). More often, meta-analysis approaches relying on Public Summary Reports or corrective action requests issued by third-party certification bodies are used to evaluate environmental but also social and economic outcomes of FSC certification (Newsom and Hewitt, 2005; Blackman et al., 2017;

Rafael et al., 2018). Fewer studies focus on empirical assessment, such as the study conducted by Dias et al. (2015) in which the authors used the Stream Visual Assessment Protocol method (screening-level assessment method based on visual inspection of the physical and biological characteristics of instream and riparian environments) to find that forest management units under FSC certification improved stream quality compared to non-certified areas.

Recently, the interdisciplinary 'Telecoupling' framework has been developed, conceptualizing distant coupled human and natural systems (CHANS) as connected by flows (e.g., agricultural commodities, information) from sending to receiving systems and potentially triggering different expected and unexpected effects, including cascading effects in sending or receiving systems or the emergence of spillover systems (Friis et al., 2016; Silva et al., 2017a; Liu et al., 2018; Dou et al., 2018). In a telecoupled world, environmental products such as timber, food and cellulose pulp are supplied over great distances through long supply chains that facilitate flows of materials, capitals, and information (Liu et al., 2013; Silva et al., 2017a; Dou et al., 2018). In telecoupled systems, the demand of a given CHANS (e.g., a country) lacking capacity or ability to meet their own demands by internal production is externalized to export-oriented countries (Kastner et al., 2015). The dynamic markets of international agribusiness supply chains have also displaced the environmental externalities of receiving countries (i.e., importers) to producing nations (i.e. the sending systems or the export-oriented countries; Liu et al., 2013). For example, the oil palm plantations in Southeast Asia that dominate international palm oil supply chains, have been widely recognized as a major driver of tropical deforestation since the 1990s (Castiblanco et al., 2013; Koh et al., 2011). Consequently, many stakeholders in the palm oil supply-chain have pledged to eliminate deforestation from their palm oil sourcing, resulting in a zero-deforestation agreement in 2015 (Austin et al., 2017). Another example is in studies of forest transitions, where Lambin and Meyfroidt (2010) have argued that economic globalization displaced deforestation from countries under forest transition to forest-rich regions (e.g., tropical regions) at the cost of exploitation of forest products in those regions providing sources of timber to international supply chains.

The increasingly telecoupled world brings many challenges for sustainable development and highlights the need to broaden the perspective from local CHANS to understand the linkages of distant CHANS. Previous studies have emphasized that incentives for the adoption of forest certification are more related to external/international market forces (Tuppura et al., 2016). Additionally, limited governance capacity in the forestry sector at the national level, as in Ecuador, limits the potential environmental benefits of certification (Ebeling and Yasué, 2009). The

telecoupling framework is a potentially useful tool to improve our understanding of international supply chains based on the exploitation of natural resources with potential environmental harm for sending systems (i.e., exporting countries) and the related certification initiatives that according to Tikina and Innes (2008) must be analyzed as part of international environmental regimes.

Here we use the framework to investigate how certification protocols may promote sustainable land use practices with positive forest conservation outcomes in telecoupled systems of the forestry supply chain.

2. Eco-certifications

Eco-certification protocols are mechanisms to foster the adoption of sustainable environmental practices in production systems while also respecting social and economic dimensions intrinsically affected by the system through providing trusted evidence about the supply chain (Lima et al., 2009; Kraxner et al., 2017; Godfray et al., 2018; Lambin and Thorlakson, 2018). The insertion of the environmental dimension into trade relations has driven the emergence of new management approaches improving the qualitative and quantitative efficiency of productive systems, and is mirrored by the increasing number of environmental certifications as a clear alignment of the production sectors towards the society's claims for sustainable products (Paiva et al., 2016; Misiune, 2018).

Lambin et al. (2018) has identified four categories of supply chain initiatives to cope with deforestation: (a) collective aspiration by stakeholder groups; (b) company pledges; (c) company codes of conduct; and (d) sectoral standards. These mechanisms represent the strategies and approaches that companies, groups and sectors develop to achieve their sustainability goals. For instance, sectoral standards seek to align requirements of sustainable practices between several stakeholders (group of companies) within a sector and may benefit companies/actors by enabling premium prices for certified products (Lambin et al., 2018). For example, the Round Table on Responsible Soy Association (RTRS) Standard for Responsible Soy Production offers premium prices for soybean producers who follow their standards guidelines; but essentially, sectoral standards may ensure market access as the case of the FSC (Lima et al., 2009; Kill, 2016). For companies that operate in international markets of forest supply (e.g., cellulose pulp and paper), the FSC certification is essential to ensure market access (Paiva et al., 2015; Kill, 2016).

Many countries and regions demand the FSC certification as guarantee to purchase forest-based products, as part of other initiatives to ban illegal commercialization of plant products (e.g., cellulose and timber) and wildlife. In 1991,

companies in England formed the Global Forest & Trade Network (GFTN) to foster the acquisition of forest products from well-managed forest, expanding during the 1990s for many countries in Europe, North America and Asia. This initiative was important to promote a new market of certified products. Meanwhile, in 1993 the FSC emerged in the international scenario of the sustainable forest management practices, becoming a trustworthy organization to issue certificates for forest-based products from sustainable managed areas, being considered a gold standard and credible benchmark by GFTN participants (Viana et al., 1996; Canal & River Trust, 2017).

Supply chain initiatives to achieve sustainable standards (i.e., non-state market-driven governance regimes, Lambin and Thorlakson, 2018) are usually voluntary agreements and guided by principles set by stakeholders representing the many links that compose a supply-chain or sector. The principles can be guided by private policy-initiatives, such as those observed in the “soy moratorium” and the “zero-deforestation” agreements that do not allow major agribusiness traders to purchase soybean and beef produced in deforested areas in the Brazilian Amazon after 2006 and 2009, respectively (Dou et al., 2018). Nonetheless, many certification protocols require compliance with public (e.g., local, national) environmental legislations. For example, the first principle of the FSC when certifying forestry management operations is to comply with public legislation, so is the first principle of the RTRS (Paiva et al., 2015).

Recent studies have argued that private initiatives and public policies can be complementary within integrated approaches, which would improve the efficacy in achieving their goals (Lambin et al., 2018; Johansson, 2018). Persson et al. (2014) argues that supply-side measures or national conservation policies alone, may not be effective in long-term. In fact, we find in the literature examples of certified firms with minor non-conformance with environmental, social and legal aspects required by the FSC standard in Brazil (Rafael et al., 2018; Piketty and Drigo, 2018) and Piketty and Drigo (2018) concluded that the companies with certification in Brazil do not comply with all FSC indicators evaluated by certification bodies and auditors. Thus, questions remain about whether certification protocols can promote compliance with legal norms and legislations and so benefiting native forest conservation and biodiversity. To investigate this question in international agribusiness supply chains, we use the telecoupling framework to integrate the socio-environmental causes and processes across demand-supply parties. We examine native forest cover dynamics using landscape ecological indicators within rural properties of eucalyptus plantation for cellulose pulp production in the Paraíba Valley (São Paulo State, Brazil), a region located in the Atlantic forest biome, and compared them with rural properties with no eucalyptus plantation in the same region. Sustainable environmental governance

initiatives in supply chains are key tools to promote sustainable development but understanding about their ability to deliver on what they promise is incomplete. Given the varying situation and contexts that challenge their successes, little is known about how and whether they achieve environmental benefits at the site level (Blackman, 2017). Our study contributes to assessing environmental outcomes of FSC certified areas by using remote sensing times series (i.e., land-use and land-cover maps) allied with landscape analysis, and by applying a new systems framework (i.e., telecoupling) to add new insights about international environmental governance.

3. Methods

3.1 The telecoupling framework

The telecoupling framework integrates both human and environmental dimensions, taking advantage of previous social science studies on globalization (i.e., socioeconomic interactions between human systems across distances) and atmospheric science studies on teleconnections (i.e., environmental interactions between natural systems across long distances; Liu et al., 2013; Liu et al., 2018), advancing those approaches to develop an integrative science on coupled human and natural systems across distances. The five major components of the telecoupling framework are: systems (distinguished as sending, receiving and spillover); flows (e.g., agricultural commodities); agents (e.g., governments); causes (e.g., demand for food); and effects (e.g., CO₂ emissions). Spillover systems affect or are affected by interactions among sending and receiving systems (Carlson et al., 2018; Liu et al., 2018).

The telecoupling approach has been used in a variety of studies on distantly connected systems, to reveal hidden relations and consequences that are often overlooked by other methods. A publication to review the first five years (2013–2018) of the studies using the telecoupling approach found 89 scientific publications related to the subject (Kapstar et al., 2019) and telecoupled systems governance is emerging as a key topic for future studies. By adopting the telecoupling framework, Gasparri and Waroux (2015) found that policy challenges in the cattle and soybean industries in South America need to be overcome by actor-centered approaches on research and conservation policies. For instance, Silva et al. (2017a) used the telecoupling framework to demonstrate the cascading effects of soybean production in Brazil on its agricultural system that led maize production to become concentrated in the second-crop season, which is very susceptible to extreme (e.g., El Niño) weather events or to high variability in precipitation. The telecoupling approach was also useful to trace

deforestation on the Brazilian Cerrado biome (i.e., Brazilian savanna) as a spillover effect of the soy moratorium and zero-deforestation agreements to reduce deforestation in Amazon (Dou et al., 2018).

There are various agents and systems involved in the cellulose pulp international trade and eco-certification. We use the telecoupling framework because it is a systematic and heuristic approach capable to capture the flows, effects and components of different systems. (Liu et al., 2014, Friis et al., 2016). By applying the telecoupling framework on cellulose pulp international trade (Figure 1), we can demonstrate the role of each system in achieving the expected and unexpected outcomes of eco-certifications, including the reduction of deforestation and increases in native forest cover areas and landscape connectivity, thus providing new insights to telecoupled systems governance and on spillover systems.

Figure 1. A conceptualization of the telecoupled system of the eco-certified cellulose pulp trade and how it may change through time.

By applying the telecoupling framework (Figure 1) we can conceptualize the flows of material (i.e., cellulose pulp), information (e.g., FSC certification, capital) and the decisions taken by agents in the receiving system to subsequently investigate empirical outcomes (i.e., spillover effects). We assume that the telecoupled system of

the eco-certified cellulose pulp trade connects all its participants. Therefore, signals of environmental depletion as a result of unsustainable forestry production systems (e.g., as deforestation, Figure 1 t_0) may increase concerns among consumers and markets in receiving systems leading them to set standards to drive purchases of more sustainable products from sourcing regions (Figure 1 t_1). The required standards will be transmitted to the sending system as signals through information flows, influencing decisions affecting land-use and land-cover dynamics at the rural property level. As a result, if those signals are connected with market access or other benefits such as premium prices (i.e., consumer markets willing to pay an extra-money for sustainable products), there will be a likelihood of success for the adoption of eco-certifications in places geographically displaced from consumer centers (i.e., sending systems, Figure 1 t_2). Positive outcomes observed in supply chain initiatives feedback to receiving systems, increasing trust in eco-certification systems and leading agents to improve standards, seek new adopters and to promote sustainable products in consumption markets (Figure 1 t_2).

The eucalyptus plantations represent the rural economic activity that connects producers and rural properties with the international market of cellulose pulp as suppliers of timber to the local cellulose pulp and paper company. In order to trade in international markets, the producers need the FSC certification that results (among other outcomes) from following environmental legislations. Compliance with environmental legislation is a precondition to obtain FSC certification in Brazil. Rural properties without eucalyptus plantations develop non-agricultural and agricultural activities that are related to local economic and social contexts (Silva et al., 2018) attached to local markets and which are less stringent with respect to the environmental sustainability of their supply chain. In contrast, the demands of sustainable supply chains drive local land use decisions in the sending system (through information flows facilitated by agents) towards achieving eco-certification standards.

As this study focuses on rural properties within the Atlantic forest biome in the Paraíba Valley, the increase in landscape connectivity (Figure 1 t_2) provided by the rural properties with eucalyptus production is considered a spillover effect because it extrapolates from the rural property level (i.e., Certification) and emerges as an environmental outcome at the landscape (i.e., the Atlantic forest landscapes of the Paraíba Valley as the spillover system). Hence, the Atlantic forest biome - which encompass 15% of the Brazilian territory in seventeen States, is a biodiversity hotspot (e.g., containing 35% of the Brazilian plant species), and is the most endangered biome of Brazil - becomes a spillover system.

3.2 Data and analysis

This study is conducted through a case analysis of a telecoupled system related to forestry in Brazil in response to international demand for cellulose pulp. To conduct the spatiotemporal analysis our study used land-use and land-cover (LULC) data from Silva et al. (2017b) for the years of 1985, 1995 and 2005, and from Ronquim et al. (2016) for the year of 2015. These data are for the classes of native forest cover and eucalyptus plantations encompassing the Paraíba Valley of São Paulo state (approximately 14,500 square kilometers), within the Atlantic forest biome (Silva et al., 2017b; Figure 2). Historic data about environmental variables prior to certification is a challenge to perform assessments of the certification capacity to improve environmental quality or conservation (Romero et al., 2017). Therefore, the present study aims to fill this gap by using land-cover maps from remote sensing to support assessments of native forest cover status and landscape ecological indicators within rural properties before and after the implementation of FSC certification.

Figure 2. Study region, the Paraíba Valley of São Paulo State.

Brazil is an important producer of commercial forest plantations and exporter of forest-based products (Correa, 2018). Since the 1960's the Paraíba Valley has grown eucalyptus trees in monocultural systems (Borgonovi et al., 1967; Silva et al., 2016) with the greatest rates of expansion of eucalyptus forest plantations observed since the 2000s (Silva et al., 2017b). The largest cellulose pulp and paper company that operates in the region has 100% of its eucalyptus plantations in the Valley certified by the FSC, and 90% of the company's production is destined for international markets in

thirty-eight countries (Conde et al., 2016). For instance, the total area of managed forest certified by the FSC reached around 200 million hectares in 2018, 49.4% in Europe, 34.6% in North America, 6.9% in South America and Caribbean, 4.3% in Asia, 3.5% in Africa and 1.3% in Oceania (FSC, 2018).

To examine the effects of certification protocols (i.e., FSC) on the native forest cover areas and for landscape ecological indicators, spatiotemporal analyses were performed within two categories of rural properties: (a) rural properties with eucalyptus plantations, and (b) rural properties without eucalyptus plantations. The rural property boundaries are available from the *Rural Environment Cadastre* (CAR, <http://www.car.gov.br/>), which also provides the Permanent Preservation Areas (APP, i.e., riparian vegetation) shapefile of every rural property. Trade data from the Brazilian Agricultural Foreign Trade database (AGROSTAT) were used to detect flows of cellulose pulp production from São Paulo State to international markets. This enabled us to establish the receiving systems and to determine the extent to which eucalyptus plantations of the Valley are linked with international demand. Ancillary data from fieldwork surveys conducted in the Paraíba Valley during 2013 with seventeen stakeholders (Silva et al., 2017c) and in 2014 with ninety rural properties (Silva et al., 2018) are also used to complement the discussion.

Accounting both properties' categories used in the analysis, the study covered around 877,542 ha or 60% of the Paraíba Valley. The region also has conservation areas for exclusive purpose of conservation, research and recreation, such as the category of State Parks and National Monuments that encompass around 7% of the Valley, and other 4% of built-up areas, and are not subject of this study. The land area in 2015 occupied by rural properties without eucalyptus plantations was 691,012ha compared to 186,530 ha for rural properties with eucalyptus plantation. The data from CAR is still incomplete and does not cover the entire rural private lands of the Paraíba Valley.

The Forest Code (FC) is a stringent policy instrument for forest conservation in Brazil (Bernasconi et al., 2016). The FC demands 20% of a rural property for Legal Reserve (LR) and the conservation of native vegetation within 30 meters of river banks and within a 50 meters circular buffer around springs, known as APP (Rother et al., 2018). These rules are applied to the Atlantic forest biome and may differ in other biomes of Brazil. The area of LR in a rural property is 20% of the property's area less the APP. Hence, for the purpose of the present study, the area of forest cover within the rural properties was calculated for the two groups (a and b) discounting forest cover areas within the APP. The remnants of forest cover were calculated as a percentage of the total area of each group of properties to evaluate the proportion of native forest

cover areas within private rural lands. We also evaluated the mean patch size and number of fragments for the two categories of rural properties in 1985 and 2015 for the classes of fragments >200 ha, 200-150 ha, 150-100 ha, 50-100 ha, 10-50 ha, and <10 ha. In addition, the Nearest Neighbor Ratio (i.e., spatial clustering pattern) was applied to evaluate the state of the forest cover areas in both types of rural properties in 2015.

The forest transition process in the Paraíba Valley is a phenomenon documented previously by Silva et al. (2016, 2017b) and attributed to a variety of driving forces such the socioeconomic changes of the region during the second half of the 20th century, economic variables as the farm credit, landscape features related to agricultural suitability (e.g., slope), and the proximity of forest remnants and eucalyptus plantations. The present study builds on previous work but uses the CAR data to trace forest cover dynamics and spatial distribution within rural properties to assess FC compliance levels, key to sustain forest transition. In this case, the study does not consider other control variables (e.g., topography) as previous studies have – instead considering only rural properties with and without eucalyptus plantations – because the focus is on the compliance with the FC, expected to be observed by the spatiotemporal dynamics of native forest cover. Therefore, the compliance with this regulation is more related to the capacity, will or needs of rural producers. All rural properties must comply with the FC, regardless of natural conditions or geographical location.

As the compliance with the FC is a precondition for rural properties to obtain FSC certification in Brazil, landowners must have legally declared the specific areas destined to be LR and APP. Those areas must be preserved and protected from the rest of the property, usually surrounded by fences and covered by native vegetation. Given these conditions, if a specific rural property wants to source timber for the pulp and paper company in the Paraíba Valley region, it must be in compliance with the FC to be certified (in this case, the non-compliance with the FC is not considered a major or minor non-conformance with the FSC standard – i.e., the compliance with the FC is precondition to obtain the FSC certification).

4. Results

4.1 The telecoupled system of eco-certified cellulose pulp trade

Applying the telecoupling framework, we defined the rural properties of eucalyptus production as the sending system, and countries that import cellulose pulp are receiving systems (Figure 1). The cellulose pulp exported from São Paulo State flows to international markets and highlights the major trading regions for the State's production. The European Union is the major trade partner from 2000 to 2017,

accounting for about 50% of the exported amount by the state. North America occupied the second position in 2000 with 35% but decreasing to only 1% in 2017. The export to Asia, mostly to China, increased from 13% to 30% in the same period. From 2015 to 2017, we find an increasing trend in the cellulose pulp imports from Central America and Caribbean, majorly represented by the Cayman Islands. This forest-based supply chain is highly dependent on the international market, with the rural properties with eucalyptus production in the Paraíba Valley (i.e., 13% of the State's timber supply for cellulose pulp production between 2013 and 2017; PVES/IBGE, 2017) as the sending system while countries in North America, Europe, Asia, and Central America and Caribbean, the receiving systems (Figure 3).

Figure 3. Flows of cellulose pulp from São Paulo State, Brazil, to the major regions of imports (Source: AGROSTAT, <http://indicadores.agricultura.gov.br/agrostat/index.htm>).

In this telecoupled system, flows are movements of cellulose pulp from the sending to the receiving systems and the information of certified forestry products in the same direction, while in the opposite direction comes the flows of money and information (e.g., demand of certified eco-friendly products, norms, rules). Agents include the third-party certification bodies (i.e., responsible for plantation surveys and reporting for certification approval), the FSC board and representatives, eucalyptus producers (e.g., companies, landowners), cellulose pulp and paper companies, market retailers of certified forest-based products, stakeholders involved in the public consultation during the FSC auditing (e.g., environmental organizations and labor Unions) and consumers.

4.2 Native forest cover dynamics at rural property and landscapes

Based on the LULC data and using the two categories of rural properties, we found higher rates of native forest cover associated with LR and APP within the properties with eucalyptus plantations (Figure 4). In addition, between 1985 and 2005 native forest cover increased 105% in rural properties with eucalyptus plantations but only 64% in rural properties without this land use system. This period highlights the creation of one of the largest cellulose pulp and paper company in the world, Fibria Celulose S.A. (formerly Votorantim Celulose e Papel, until 2009), which in the late 1990s began a plan for its internationalization. In the year 2000, the major groups of buyers of certified forest products (GFTN) started to act in Brazil pushing the demand of forest certification by the FSC. At that time, around fourteen countries were part of the GFTN such as United States, Germany, Spain, Canada, Belgium, Australia, Netherlands, Austria, Sweden, Switzerland, Finland, Denmark, Norway and England (Sif, 2007). These events pushed the rural properties with eucalyptus plantations towards the certification procedures. Between 2005 and 2007 the company received the FSC certification, which required previous years of preparation and adequacy to environmental legislations and other certification compliances (Sif, 2007). After 2005, analysis of the LULC data indicates no increases of native forest cover within the rural properties with eucalyptus, but 25% in the other rural properties.

Figure 4. Proportion of a) native forest cover area as Legal Reserve and b) Permanent Preservation Areas within rural properties of the Paraíba Valley of São Paulo State, Brazil.

426 According to Guidot et al. (2017), the deficit of native forest cover on the APP in
427 the Atlantic forest biome is 56% *versus* a 22% deficit of LR. Rother et al. (2018) also
428 found lower amounts of native vegetation within APP (around 68% deficit) in rural
429 properties (dedicated to sugarcane, coffee, orange, pasture and mixed uses) in the
430 Atlantic forest and with total forest cover below 20% of the rural property.

431 At the Valley landscapes (but with effects more broadly on the Atlantic forest
432 biome), a decrease in the number of forest patches from 11,948 in 1985 to 8,761 in
433 2015 was observed in the rural properties with eucalyptus plantation, while in the
434 properties without eucalyptus plantations forest fragments increased from 26,334 to
435 33,510 (Figure 5). Both categories of rural properties have increased the number of
436 fragments over 10 ha but with a different trend in the fragments below this class. For
437 the patch size class '<10ha', the number of forest fragments decreased by 31% (minus
438 3655 fragments) in rural properties with eucalyptus plantations, compared to a 23%
439 increase (plus 5976 fragments) within the properties without eucalyptus. For the same
440 patch size class, the mean patch size presented higher increases in the properties with
441 eucalyptus, about 85%, compared to 22% for the other rural property category.

442

443

444 Figure 5. Distribution of forest fragments in six classes of forest patch size (hectares)

445 for 1985 and 2015 within rural properties with and without eucalyptus plantations.

The observed data for patch size class '<10ha' reveals that in rural properties with eucalyptus plantations there is a trend of increasing the average size of these small forest fragments rather than the emergence of new small patches. This trend indicates a positive contribution from the rural properties with eucalyptus to the Valley's landscape structure, observed by the Nearest Neighbor Ratio of 0.379 in 2015 while 0.525 for the other category of rural properties. For this metric, values less than 1 indicates clustering and smaller values mean higher tendency of clustered spatial distribution. This result may indicate a trend towards a less fragmented forest landscape (e.g., higher connectivity among forest patches tend to be in clustered areas; Minor and Urban, 2007) in rural areas with eucalyptus, which may improve landscape connectivity at the landscape and enhance biodiversity conservation in the Atlantic forest biome (Silva et al., 2017d; Costa et al., 2017). The effects produced at the landscapes (i.e., beyond the limits of the certified rural properties to the neighboring areas) are considered spillover effects of the telecoupled system of the eco-certified cellulose pulp trade where we assume the Atlantic forest is the affected system (i.e., spillover system).

5. Discussion

5.1. Public and private policies on the conservation pathway

According to the local cellulose pulp and paper company's 2016 report, 100% of its commercial forest plantations to supply the Valley's industry are certified by the FSC (Conde et al., 2016). In this case, being certified by FSC means that the rural properties of the company must follow the Brazilian environmental legislations, including the FC. When a company is not in full compliance with all legal requirements but wants to be certified, the company can submit a plan to meet them (IMAFLOA, 2018). The plan will be analyzed by a certification body. If approved, the company can be certified with the commitment to implement the plan. Every rural property certified by the FSC is audited each year, and the commitments are monitored by the certification body in different time intervals depending on the level of the non-conformance, but in periods shorter than a year (e.g., erosion process caused by machines during forest management operations and damages to native forest remnants; IMAFLORA, 2018).

In case where areas allocated for LR and APP are not yet covered by native vegetation at the time of the certification audits, the landowner must provide an action plan explaining how the native forest will be recovered. This could be by allowing the area to undergo natural forest regeneration process (very likely in the study region; Silva et al. 2017b) or by a forest restoration project. If the landowner opts for the

natural regeneration process, within a year of the last audit the auditors can either judge the regeneration process is providing satisfactory results of forest regrowth or demand the landowner to immediately implement a forest restoration project. Here we argue that the use of remote sensing techniques by applying land-use and land-cover analysis in temporal time series is a very useful method to improve surveillance capacity (for auditors) to monitor native forest regrowth in LR and APP, sparing human resources and time spent in fieldwork inspections.

The eucalyptus production areas in the Valley are not solely property of the local company but belong to local landowners of rural properties. According to fieldwork conducted at the rural property level in 2014 (Silva et al., 2018), the rural properties willing to trade their eucalyptus production with the company must follow the same protocols of the company's own lands to ensure that the entire supply chain is following the same environmental standards demanded by the FSC requirements.

This scheme represents a powerful tool to reach sustainable practices in agri-commodity production systems if two conditions are satisfied. First, the demand side of the supply chain (e.g., retailers, final consumers) must seek sustainable products and be concerned about human-induced environmental changes, such as the global warming, biodiversity loss, deforestation and water contamination. Second, the certification protocols and public policies must synergistically complement each other.

As the Brazilian FC demands a LR and APP within the rural properties, this public policy fosters not only the ending of deforestation and the maintenance of patches of forest remnants, but in fact boosts environmental recovery throughout the creation of the LR and APP. This implies the ecological restoration of those areas by induced restoration practices or by native forest regeneration. According to the FC, even if you have not committed deforestation in your land (e.g., you purchased it already deforested), you must have appropriate areas of LR and APP, and consequently you must restore or at least abandon some areas for natural regeneration within the property. In this case, the FSC certification protocol, which demand compliance with the FC (i.e., a public policy imposed on the region), induce positive rates of native forest regrowth and better performance in conservation standards in the certified rural properties compared to non-certified ones, thus synergistically enhancing governmental efforts for conservation.

In addition, the need of a concerned consumer market is key to transform the supply chain as the production of a given agri-commodity is intrinsically connected with the environmental outcomes of its production and may lead consumers to react negatively to products that cause environmental depletion. The negative reactions of consumers feedback to the producers (Figure 1), who react to achieve better

management and strategies to their production systems and thus, ensure market access (Leonidou et al., 2013).

In São Paulo State, the environmental law enforcement is improved by society's voluntary participation through the State's Environmental System (Silva et al., 2017c). Societal engagement is vital because, as acknowledged by the Environmental Military Police of the State, there are insufficient police staffs to perform systematic surveillance actions through the entire State (Silva et al., 2017c). The lack of enforcement is a key cause of the low level of compliance with environmental legislation in Brazil (Bernasconi et al., 2016). In contexts of stringent legal rules (e.g. Forest Code), certifications are not expected to set higher standards of forest management and environmental outcomes but to contribute to better enforcement of the existing norms (Buliga and Nichiforel, 2019). Therefore, the rates of native forest cover within the rural properties of eucalyptus plantations compared to the properties without this plantation system highlights a reasonable level (best performance in conservation standards) of their compliance with environmental legislations, which in this case can be accounted to another important feature of the FSC protocol, the third-party certification, a mechanism that contributes to enforcement of the Forest Code.

Once the rural properties that produce eucalyptus to supply the cellulose pulp production require the FSC seal, the properties are subject to inspections for certified professionals, seeking to observe if the property follows the FSC rules. This third-party scheme ensure surveillance within the rural properties, systematically, ensuring a more effective compliance with environmental legislations in comparison to other rural properties that do not produce eucalyptus in the region and so are subject to only the public service of surveillance.

The disadvantages of being certified by the FSC are not only the financial costs of certification but also for some landowners the entrance of 'strangers' (i.e., the auditors) that are allowed to visit the property, including 'surprise' (i.e., without warning) audits. This is a complaint of landowners of certified properties in the study region. The advantages for individual landowners, is the opportunity of access to markets only allowed for FSC certified properties. For companies, such as the pulp and paper company of the Valley, which has many rural properties spread across the region, all of its properties must be in compliance with the FC, even if one or more properties are not used to produce eucalyptus to supply its industrial production of paper and cellulose pulp. Therefore, the market access provided by the FSC certification is a strong push for producers to be in compliance with the Forest Code.

5.2 Embracing conservation through protocols and distances: the telecouplings

The observed native forest regeneration within rural properties with eucalyptus production in the Paraíba Valley and their performance in relation to the FC compliance are considered expected effects of the decision of the cellulose pulp and paper company to access international markets. In order to achieve its aims, the company invested in FSC certification, which pushed rural properties with eucalyptus production to achieve the best standards of FC compliance and a surplus of native forest cover areas (i.e., above the 20% of LR), compared to other properties in the region. Based on the results of the present study, we found that the rural properties with eucalyptus plantation in the Paraíba Valley have higher levels of FC compliance compared to the findings of Rother et al. (2018) at the biome scale; We found a surplus of native forest cover areas beyond the LR requirements (no deficit) and around 40% deficit of APP, which is lower compared to the Valley's rural properties without eucalyptus production (70% deficit). Therefore, by trading cellulose pulp in international markets of certified products, effects on rural areas of production are expected as a result of compliance with local policies (e.g., Legal Reserve) demanded by certification protocols.

The forest governance system is a key element to tackle the challenge of biodiversity conservation and to sustain ecosystem services provision (Dragicevic, 2019; Zeb, 2019; Gonzalez-Redin et al., 2019). Johansson (2018) has argued that collaboration among stakeholders and public agencies aiming for sustainable management of the environment may potentially enhance effectiveness of policy implementation. This is what we have observed in our study where landowners of rural properties act as agents within the sending system of the broader telecoupled system of eco-certified cellulose pulp trade, engaging in FSC certification as a means to access the international market. Thus, demands for FSC-certified forest-based products in geographically displaced markets (predominantly in Europe, Figure 3) have produced information flows that lead landowners towards higher levels of compliance with the Forest Code, a practice (or level of compliance) not observed in other agricultural sectors in rural areas. Importantly, the effects of certification observed through our native forest cover analysis highlights the potential of the FSC to enhance biodiversity conservation, not by applying new rules of conservation but simply by reinforcing the government's role law enforcement.

Although there are positive aspects for native forest conservation brought by eucalyptus plantation in the Paraíba Valley, controversial effects on social and environmental aspects remain. Farinaci et al. (2013) demonstrated that eucalyptus plantations in the region have undermined cultural traditions and rural amenities, for example by increasing the traffic of trucks and heavy machinery for timber transportation across rural communities. In a meta-analysis study of FSC certification

across Brazil (analyzing Public Summary Reports from third-party certification bodies), Rafael et al. (2018) showed that the largest non-conformities to FSC certification were related to 'Community Relations and Worker's Rights', the 4th principle of FSC.

Brazil has around 5.7 million hectares of eucalyptus plantation across the country to provide timber for many purposes (e.g., timber, energy, civil construction). The eucalyptus of the Paraíba Valley is just a fraction in the enormous territory of planted forest for commercial interests. However, we have shown the impact of eucalyptus on the native forest landscapes of the Paraíba Valley is effective in increasing the level of law compliance, thereby ensuring higher rates of native forest cover within rural properties producing eucalyptus. Understanding the eucalyptus production type (e.g., for cellulose pulp, solid wood products, etc.) and flows (i.e., destinations in receiving systems) of the eucalyptus plantations across Brazil is critical for biodiversity conservation as industrial production (e.g., cellulose pulp and paper) has the potential to shape management practices in sourcing areas. In addition, the destination of the products also matters given the importance of the receiving system demanding goods from areas under sustainable management practices and in compliance with local policies. Recent trends towards the flexibilization of environmental laws together with the limited capacity of local plants to process Eucalyptus pulp, pose new challenges for the maintenance of positive environmental outcomes in local forestry production systems. Thus, the role of supply chain initiatives for sustainable governance systems may become even more relevant.

The telecoupling framework provided a powerful tool to trace the flows of cellulose pulp to understand the outcomes in the sending system. We have observed that the flows direction matters for the interactions among distant CHANS once in an interconnected planet, decisions being taking in one place can foster expected and unexpected changes in other places across distances.

6. Conclusions

The non-growth of native forest cover within the rural properties with eucalyptus plantations between 2005 and 2015 (with a deficit of 40% of native forest cover within APP in 2015) contrasting with the 25% of native forest growth in the Valley's rural properties without eucalyptus in the same period, highlights the need for more studies to understand the decisions at the rural property level toward forest conservation.

The interaction of the Forest Code with the Forest Stewardship Council certification through the forest-based telecoupled system of the eco-certified cellulose pulp trade has resulted in positive effects at the rural property level in Paraíba Valley, Brazil, as measured by observed forest cover rates in different types of rural properties,

with and without eucalyptus plantations. By applying the telecoupling framework we found that the Atlantic forest has benefited from FSC certification (that acts at the rural property level) through increases in landscape connectivity as an unexpected result emerging from the aggregation of individual contributions of each property with eucalyptus plantation.

This study exemplifies how private and government efforts are not mutually exclusive but complementary, by improving the enforcement of preexisting rules (e.g., Forest Code) not attained by state-based actions alone, and fostering the entrance of new certified producers (i.e., which will increase levels of law compliance) by the power of the market in dictating sustainable products as a condition for trade. Market access provided by supply chain agreements strongly incentivizes landowners and rural producers to seek higher standards of law compliance, especially the agreements with third-party oversight, a key factor to fill the governmental gap of systematic surveillance actions in specific country contexts as in Brazil.

Higher levels of law violation transmit signals of environmental depletion (e.g., deforestation, massive use of pesticides) widely through the supply chain. In this context, governance systems emerge in which greater participation of different stakeholders from society and private sectors (in sending and receiving systems) is fundamental to improve adherence of landowners and rural producers to environmentally sustainable practices. Key for the success of these governance systems is the availability of capital inputs to support certification bodies and audits, and sets of normative rules that push the producers to re-shape land use and production practices to tangible standards (and principles) for positive environmental (but also social) outcomes.

Our study also fills a gap in assessing environmental impacts at multiple scales: landscape and property. We used remote sensing time series as a comprehensive and accurate way to measure landscape metrics and forest cover dynamics both prior to certification and after its implementation. Furthermore, larger-scale studies are also necessary to evaluate the impacts of the FSC and other certification standards more broadly. We observed that eco-certification initiatives may spillover their effects beyond the geographic limits of the certified area. This result contributes to improving our knowledge about environmental effects of supply chain initiatives, key for shaping future international environmental governance systems in telecoupled systems.

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