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Socioeconomic changes and environmental policies as dimensions of regional land transitions in the Atlantic Forest, Brazil

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ABSTRACT

The industrialization of the Paraíba Valley, Brazil has been driven since the 1950s by an intense urbanization process, while municipalities located far from the valley's economic center stagnated. Despite the economic differences and unequal population distribution in the region, the municipalities share similar topographic characteristics with a predominance of hilly terrains. The depletion of the soils' productive capacity after numerous land use cycles without adequate management practices was a common cause of land use abandonment. This research analyzes land use/cover data, environmental policies, census-based data, and interviews with stakeholders, to understand the factors that account for a forest transition in the Paraíba Valley where gains in forest cover more than offset any remaining deforestation. Local conditions, such as topography, land use history, environmental policies, engagement of society in complying with legal regulations, commodity markets, and the action of enforcement agencies, represent dimensions which, combined, have boosted forest transitions.

1. Introduction

Land use shapes landscapes and causes direct and indirect impacts on the conservation of natural resources, with consequences for the quality and standards of living, and for the provision and maintenance of ecosystem services (Lambin et al., 2003; Foley et al., 2005; Wu et al., 2013). Several studies have defined empirical and theoretical relationships between demands for land and resources with population dynamics, economy and market globalization (Vanwey et al., 2005; Mora, 2014). Given the importance of forest ecosystems (Ango et al., 2014; Fenning, 2014) and the dynamic relationship of these ecosystems with the economic, cultural and social dimensions of land use, Forest Transition theory (FT) offers valuable insights into the process of deforestation and for the return of forest cover (Rudel et al., 2005). The FT theory uses a theoretical framework to understand the spatio-temporal phenomenon of forest resurgence (forest cover net gain) in areas long characterized by loss of forests.

The FT, as observed in many regions worldwide (Rudel et al., 2005; Lambin and Meyfroidt, 2010; Southworth et al., 2012), has been attributed to similar trajectories of land use, that occur even under different political, social, economic and environmental conditions (Lambin and Meyfroidt, 2010; Azevedo et al., 2014; Silva et al., 2016). The economic FT pathway assumes that forest regeneration is strongly related to economy, industry and urban development, influencing the process of rural depopulation and the consequent abandonment of the rural way of life, followed by positive forest growth rates on abandoned areas that had been occupied by agriculture (Rudel et al., 2005; Baptista, 2008). The scarcity FT pathway states that forest shortage can influence institutions at various levels to develop actions that favor forest recovery in order to restore ecosystem services and to supply timber and non-timber products (Rudel et al., 2005; Meyfroidt and Lambin, 2009).

A given forest's history has important implications in understanding forest ecology and the socioeconomic dimensions of human relationships with these ecosystems (Fairhead and Leach, 1995), both important in developing forest restoration strategies (Melo et al., 2013). Studies have highlighted secondary forests as important sources of ecosystem services, forest products for communities, and the urgent need to understand the proximate and underlying causes (biophysical and social) that affect their regeneration after agricultural land abandonment (Chazdon, 2012; Lira et al., 2012).

The Atlantic Forest has been undergoing losses for centuries and its remnants cover today around 13% of the area before Portuguese settlement of Brazil (Ribeiro et al., 2009). However, regional studies

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have revealed significant variations in the Atlantic Forest cover, as in the case of the Paraíba Valley with a +74% of relative net change between 1985 and 2011 (Silva et al., 2017). Empirical research on regional scale forest dynamics remain important to unravel the complexity of coupled human and natural systems (Jadin et al., 2013). In this article, we explore the context that has allowed a regional FT to occur, with the control of deforestation over mature forests and secondary successional areas; and how public policies, economic development, population dynamics, and environmental conditions induce FT processes in the Paraíba Valley, in the Atlantic Forest of southeastern Brazil.

2. Methods

The methodological approach for data acquisition began with structured and semi-structured interviews with stakeholders– agents with professional experience in environmental management, land use or policy enforcement in the study region. Census, land use and land cover, and topographic (slope) data were used in a Geographic Information System (GIS) to support the analysis of forest cover dynamics (for the purposes of this study, forest cover only represents native vegetation of the Atlantic Forest biome; planted forests represent the eucalyptus plantations, an exotic tree species in the Brazilian context). The interviews' content was used to provide empirical spatio-temporal context about the role of the socioeconomic changes, market globalization, public policies, and land use constraints to the FT in the Paraíba Valley.

2.1. Study region

The Paraíba Valley lies between two mountains, *Serra do Mar* with a maximum elevation of 1,877 m, and *Serra da Mantiqueira* with 2,791 m. This valley has an area of 55 thousand sq.km covering parts of the states of São Paulo, Minas Gerais and Rio de Janeiro, within the Brazilian Atlantic Forest biome. It can be divided in two distinct subregions: the Upper Paraíba Valley and the Middle Paraíba Valley (Fig. 1). The valley's portion in São Paulo State, of particular interest for this study, consists of 34 municipalities, and has an area of approximately 14,000 sq.km, more than two million inhabitants, and is an important industrial and economic hub. It encompasses the upper basin of the Paraíba do Sul river, responsible for the water supply to a population greater than 10 million inhabitants (Itani et al., 2011). The Paraíba Valley is the axis point linking two major metropolitan centers in Brazil (São Paulo and Rio de Janeiro), and for this reason, crossed by a complex of road and railway systems running parallel to the channel of the Paraíba do Sul river.

The Upper Valley consists of less developed, less industrialized municipalities, located farther from the main regional economic hub (President Dutra Highway) and did not benefit from the development policies issued by the Federal Government between the 1950s and the 1980s (e.g., *Target Plan*[1] in the 1950s, *II National Plan of Development*[2] between 1975 and 1979) and industrial decentralization of the São Paulo Metropolitan region in the 1970s. The industrial decentralization was a response of the State government due to the higher levels of urbanization, air pollution and traffic and transportations problems, which stimulated the development of the state's interior, such as the Paraíba Valley. The Middle Valley is made up mainly of industrial areas (e.g., textile, automotive, aeronautics, pulp and paper production), and concentrates around 90% of the region's population, jobs and capital (i.e., municipal revenue) with continuous urban areas connected by the President Dutra highway (Fig. 1).

2.2. Interviews

In 2012 and 2013, 17 interviews were conducted in the study region. The interviews were organized in structured and semi-structured questionnaires (4 questions and 12 questions, respectively). After a short introduction to contextualize the research and its aims, each interview took an average of 80 min for the completion of both questionnaires and was recorded in audio file. All interviews were applied by the same researcher.

The selection of stakeholders was based on Itani et al. (2011). From the information in this document, agents were identified to participate, with basis on their potential contribution to the research. Using the snowball sampling method (Atkinson and Flint, 2001), each interviewee named other stakeholders, which also were later contacted. Thus, the responding group was composed of three officials from municipal environmental agencies, a representative from the Department of Water and Energy of São Paulo State (DAEE) and former president of the Committee for the Integration of the Paraíba do Sul Watershed (CEIVAP), two employees from the Chico Mendes Institute for Biodiversity Conservation (ICMBio), a regional planning assistant from the Integral Technical Assistance Coordination of São Paulo State (CATI) region of Guaratinguetá, a director of CATI for the region of Pindamonhangaba, the technical director of the Ecological Corridors Association, two researchers from the Oikos Institute, two researchers from the National Institute for Space Research (INPE), a historian at the University of São Paulo (USP, Lorena campus), two farmers, one from Pindamonhangaba and another from the Cunha municipality, both resident in rural areas, and a Sergeant Major of the São Paulo State Environmental Military Police (EMP). The ages of this group ranged from 30 to 60 years old with an average of 15 years of professional experience in the study region.

2.3. Census, topography, and land use and land cover data

Land use and land cover data for a time series of 1962, 1985, 1995, 2005, and 2011 were retrieved from Borgonovi et al. (1967) and Silva et al. (2017). The slope was generated from the Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model (ASTER GDEM) with horizontal resolution of 1" (about 30 m). Census data were derived from the Brazilian Institute of Geography and Statistics (IBGE, http://www.ibge.gov.br/home/) and Foundation State System of Data Analysis (SEADE, http://www.seade.gov.br/). The dataset was analyzed at regional (Paraíba Valley) and subregional (Upper Valley and Middle Valley) scales, given the complexity and heterogeneity of the study area related to industrialization, urbanization, population dynamics and biophysical dimensions of the landscape.

3. Dimensions of forest transition

3.1. Socioeconomic changes and forest cover

The rural population of the Paraíba Valley in 2010 (132 thousand inhabitants or 5.81%) held 1.83% of the formal jobs available in the region against the 98.17% in the industry, commerce and services sectors. The rapid expansion of industry and services, since the 1950s, created an intense migration flow from the countryside to urban areas (Bordo, 2005) and from poorer municipalities to the major economic and industrial centers (Vieira and Santos, 2012). In the 1960s, the Paraíba Valley was considered one of the main industrial centers in Brazil (Vieira and Santos, 2012). At the regional scale, population censuses (IBGE, 2006, 2010) showed a sharp decrease in the rural population followed by urbanization between 1950 and 2010. However, this trend was not observed in all subregions (Fig. 2).

[1] The Target Plan was an industrialization and modernization program carried out under the presidency of Juscelino Kubitschek, in the form of an "ambitious set of sectorial objectives", which would give continuity to the process of import substitution that had been taking place in the previous two decades in Brazil.

[2] The II National Plan of Development (II PND) was a national economic plan to foster the production of basic supplies, food, capital and energy.