IMPACTS IN REGIONAL SOCIOECONOMIC STRUCTURE DUE TO FORESTRY IN PARAÍBA VALLEY – USING REMOTE SENSING

Impactos na estrutura socioeconômica regional devido a silvicultura no Vale do Paraíba – Usando Sensoriamento Remoto

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ABSTRACT

The growth of forestry, mainly eucalyptus, driven by the industry demand for pulp and paper, has significantly changed the landscape around the globe. The so-called agroforestry systems have the advantage of reducing pressure on native forests in different regions of the world. However, this practice can bring impacts to the environment, and contribute to the intensification of agrarian conflicts. The aim of this research is to expose the intrinsic relationship between the dynamic of the forestry expansion in the São Paulo area of the Paraíba Valley, one of the largest agro-producing regions in Brazil, and the regional socioeconomical structure. These results may support further studies in order to define the possibilities and limitations of this type of economic use. With the use of remote sensing techniques using Landsat satellite images, we measured the areas planted with eucalyptus in the study area (Paraíba Valley) between 1986 and 2010. This area was pioneer in this kind of forestry and still is one of the largest producers while still expanding. In the period studied, among positive and negative variations, the planted area increased from approximately 55,000 ha in 1986 to more than 60,000 ha in 2010. This change was driven by industrial demand, as shown by the IBGE data.

Keywords: Eucaliptus. Forestry. Sustainability. Land Use and Land Cover Change. Remote Sensing. GIS.

RESUMO

O crescimento da silvicultura, principalmente o eucalipto, direcionada pela demanda das indústrias de papel e celulose mudam a paisagem na Terra. Os chmados sistemas agroflorestais possuem a vantagem de reduzir a pressão nas florestas nativas nas diferentes regiões do mundo. Porém, esta prática tem impactos ao meio ambiente e contribui na intensificação de conflitos agrários. O objetivo deste trabalho é esclarecer a relação entre a dinâmica da expansão florestal em São Paulo, especificamente na região do Vale do Paraíba do Sul, um dos locais com grande produção no Brasil, e também a estrutura socioeconômica regional. Os resultados podem ajudar estudos futuros para definir as possibilidades e limitações deste tipo de uso da terra. Através da utilização de imagens do satélite Landsat da área de estudo (Vale do Paraíba do Sul) entre 1986 e 2010, foram classificadas as áreas plantadas de silvicultura. A área é pioneira neste tipo de silvicultura com grandes produções e continua se expandindo. No período estudado entre variações positivas e negativas, a área plantada aumentou de aproximadamente 55,000ha em 1986 paramais de 60,000 há em 2010. Este aumento foi devido principalmente pela demanda da indústria de papel e celulose, como apresentado por levantamento do IBGE.

Palavras-chave: Eucalipto. Silvicultura. Sustentabilidade. Mudança de Uso e Cobertura da Terra. Sensoriamento Remoto. SIG.

1 INTRODUCTION

Eucalyptus plantation is growing worldwide. According to Szulecka et al. (2014), in 2005 planted forests accounted for 7% of the global area of forest cover and occupied between 264-271 million hectares, that's because between the decades of 1990 and 2010 efforts to expand these plantations increased significantly. Due to this scenario, there were discussions throughout civil and academic environment involving the causes and consequences resulting from this expansion (Schirmer, 2006). The line of argument generally addresses the impacts to the natural environment, such as soil, water and biodiversity (Szulecka et al, 2014). However, this type of monoculture can also change the economic, social, cultural and power dynamics of the communities where they are implanted (Turnbull, 1999; Dean, 2004; Schirmer, 2006).

Eucalyptus is now one of the leading products in the agribusiness agenda. Its cultivation is also characterized by being mechanized and industrialized in a rational way. Eucalyptus are planted mainly in peripheral regions, with vast tracts of land and governments tax and regulatory incentives, which favors its expansion (Cubbage et al. 2010).

Eucalyptus plantation is used worldwide mainly for industrial purposes, such as generating energy through biomass, furniture manufacturing, oils and drugs. Its main purpose, however, is related to the demand of paper and pulp.

These demands are constantly linked to growth caused by economic development and population growth (Turnbull, 1999).

Over the time the forestry theme has undergone several transformations, and has been discussed both in social and academic environments. In the literature, there are several paradigms to address the issue. One of the main paradigms, named agroforestry, optimizes the combination of both types of crops, agricultural and forestry, in order to increasingly enhance this type of production. However, in the beginning of the1960s criticism on the subject began due to the advent of "externalities" inherent to the production process. Then there is the paradigm of "responsible forestry", which incorporates the concept of sustainability and the notion of growth with equity (Cubbage et al 2010; Szulecka et al 2014.). It is in this context that the need for studies that provide adequate management and zoning of forest crops appears.

Das et al (1996), used IRS LISS-II, Landsat 5 orbital images and GIS tools to analyze the changes in the forest cover in the Rajaji National Park, in the Indian State of Uttar Pradesh. This park has nomads living in it, which intensifies the degradation process. Among the results found during the study, the authors found an increase of the planted forest area between 1960 and 1993, including eucalyptus, among other exotic species in the park.

Calder et al (1997) studied the effects of eucalyptus plantations and other fast growing species and determined their impacts on water resources, erosion, soil nutrients and vegetation growth rates in places with different precipitation rates and soil depths in the Indian state of Karnataka. In this study, measurements were made based on meteorological data, plant physiology, soil water and interception of precipitation. The crossing of such data made it possible to answer important questions about eucalyptus plantation in areas of low rainfall in India. Thus, the authors determined that the use of water by these crops in water poor areas exceeds the replacement by precipitation.

Vanacker et al (2003), made a temporal analysis with aerial photographs over a period of 33 years (1962-1995) and evaluated the effects of changes in land use of central Ecuador. The motivation for this study was a major reform program of the use of existing land in the country alongside a strong population growth. Among the results was growth of the planted eucalyptus area, along with the decrease of native forest. However, the authors also concluded that this change, by prioritizing previously degraded areas, altered the water balance and soil erosion response positively.

Vihervaara et al (2011) used GIS analysis of results from satellite images to assess the possible impacts of fast-growing tree plantations, such as eucalyptus, on environmental services. This was done by integrating social evaluation systems to land-use changes in the central area of Uruguay.

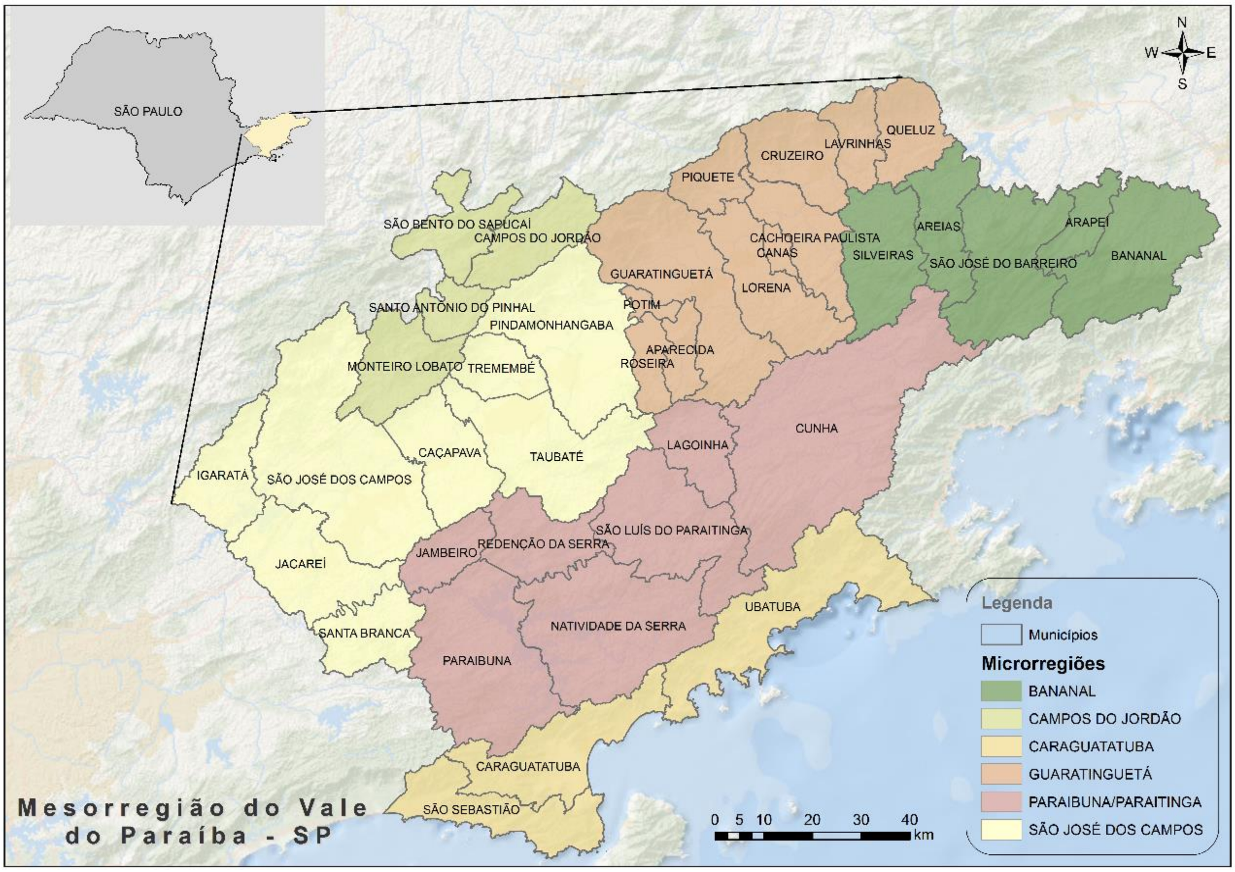
All of the studies used GIS and remote sensing data to obtain information that supports sustainable management of eucalyptus plantations for commercial purposes or even for reforestation. The demand for this kind of survey arose with the increase of the sustainable development paradigm for this type of culture. However, management is not always possible so impacts and conflicts rise in these areas. It is important to note that the use of remote sensing and GIS tools is useful not only for environmental sciences, but also in the study of social problems, as noted by Walker and Peters (2007). Studies about conflicts related to agroforestry systems around the world can also be found in Schirmer (2006) and Gerber (2010).

This article begins with the characterization of the study area, gives a socio-economical and historical context and introduces the region in the theme discussion. Then a description of the materials and methods used and finally the results are exposed along with the research and proposed discussions.

2 STUDY AREA

The São Paulo area of the Paraíba Valley (Figure 1) is defined as a social-economic Mesoregion bounded for administrative ends by SEADE (State System for Data Analysis Foundation). This area embraces the upper Paraíba River Basin and theNorthern coastline of São Paulo State.

Figure 1 – Mesoregion of the São Paulo Paraíba Valley



It is located between the two largest cities in Brazil: Rio de Janeiro and São Paulo, its main city is São José dos Campos. Its São Paulo half has two million inhabitants, according to IBGE (Brazilian Institute of Geography and Statistics, 2010). Its economy is highly diversified, with a significant industrial sector: automobiles, armaments industry, food and advanced technology. In the primary sector, we find mainly rice and forestry, besides an expressive dairy farming; the service sector is mainly represented by the religious tourism, along with business and a large number of universities. The Presidente Dutra Road is the main connection between the cities of the region, giving momentum to the economy.

The occupation of the region dates from the sixteenth century but was only intensified with the coffee plantations in the beginning of the nineteenth century. This period was one of great economical prosperity for the region. According to Ricci (2006), coffee plantation was certainly the progress factor for the region that grew and diversified the activities of its urban centers.

According to Júnior et al (2012) the first industrial-scale pulp plantations date back to 1965 due to fiscal incentives. Forestry found ideal conditions for its development in the Paraíba Valley, which made the concentration of this monoculture in the study area become one of the biggest in the country by the 1980 decade.

3 METHODOLOGY AND DATA

3.1 Image Collecting

Images were collected in the path/row (Landsat TM and ETM sensors 5 and 7 respectively): 218/76 on 1986, 1990, 1995, 2000, 2005 and 2010 and 219/76 in same years from the image catalog of the National Space Research Institute- INPE, available at: www.dgi.inpe.br/CDSR. The images were properly georeferenced and transformed to surface relectance for multitemporal studies purposes.

To set the study image area, the corresponding vector file that limits the administrative region of São Paulo Paraíba Valley was obtained from Continuous Base to the Millionth available at http://downloads.ibge.gov.br/downloads_geociencias.htm. For this project, the ground reference model system used is the SAD 69 and the projection is the UTM - Universal Transverse Mercator, a system of coordinates and projection of the Earth's surface using the metric system.

3.2 Socioeconomic Data

Socioeconomic data of the research on Vegetable Extraction and Forestry Production for the years 1990, 1995, 2000, 2005 and 2010 were obtained from the SIDRA system (IBGE System of Automatic Recovery - IBGE, 2010), corresponding to the quantities produced by each type of product in the forestry of the São Paulo Paraíba Valley to the respective years.

In addition, Municipal Agricultural Survey data, corresponding to Total Temporary Crop Areas in the Valley for the years 1990, 1995, 2000, 2005, 2010 were collected. Details for the Agricultural Censuses of 1995 and 2006, which correspond to the numbers of Properties and Permanent Crop Areas besides Forestry and Forest Exploration in the São Paulo Paraíba Valley in the respective years, were also collected.

The aim of the survey was to provide an economic basis to the research, which was later crossed with the information of use and land cover.

3.3 Vegetation Index - NDVI

Monitoring the Earth's vegetation cover involves several spectral vegetation indices, representing precise radiometric measurements of spatial and temporal variations of photosynthetic activity (Huete et al 1997; Shimabukuro et al., 1998). According to these authors, these indices are related to biophysical parameters of vegetation cover that influence the spectral response bands of remote sensors. In this work, we chose to use the Normalized Difference Vegetation Index (NDVI), which is the difference between the near infrared (NIR) and red (R) divided by the sum of the same bands, shown in equation 1 (Huete et al. 1997; Jensen, 2009).

$$NDVI = (IVP - V) \div (IVP + V) \quad (1)$$

Where: NIR = near infrared and R = Red

In this study, NIR corresponds to TM4 band and R corresponds to TM3 band, Landsat 5 and 7 from TM and ETM sensors. The NDVI is the most widely used vegetation index in the analysis of vegetation targets and evaluation of changes in the landscape. Its usefulness in satellite survey and land cover global monitoring has been widely demonstrated in the literature (Huete et al 1997; Ferreira and Huete, 2004; Barbosa et al 2006; Jiang et al 2006; Sá et al. 2010). The ratio of NDVI bands generates a normalized image in which the vigorous vegetation is highlighted because it reflects higher percentage of infrared, while the less vigorous reflects higher percentage of red (Novo, 2005).

In this research, the NDVI generated formed the basis for the generation of a theme mask that was used to slice into different targets the original images which were divided into three subgroups: Forest (forest, forestry, secondary forest), non-forest (water, exposed soil, urban, fires, rocky outcrops) and transition (areas of grass and pasture). The normalized image generated by pixels with NDVI has values ranging between -1 and 1. In this processing, values between -1 and about 0.2 approximately correspond to non-forest classes; values between 0 and 0.2 approximately correspond to the transition classes and amounts from about 0.55 up to NDVI peaks near 1 refer to the forest classes.

Subsequent ratings were performed on the compositions made with the slices corresponding to each band that were then assembled through mosaic, generating a single image. This method is designed to expedite the processing of the segmentation algorithm which was used subsequently, since this will not be worked on the entire image, but in its slices, and also speed up the visual interpretation process.

3.4 Unsupervised Classification

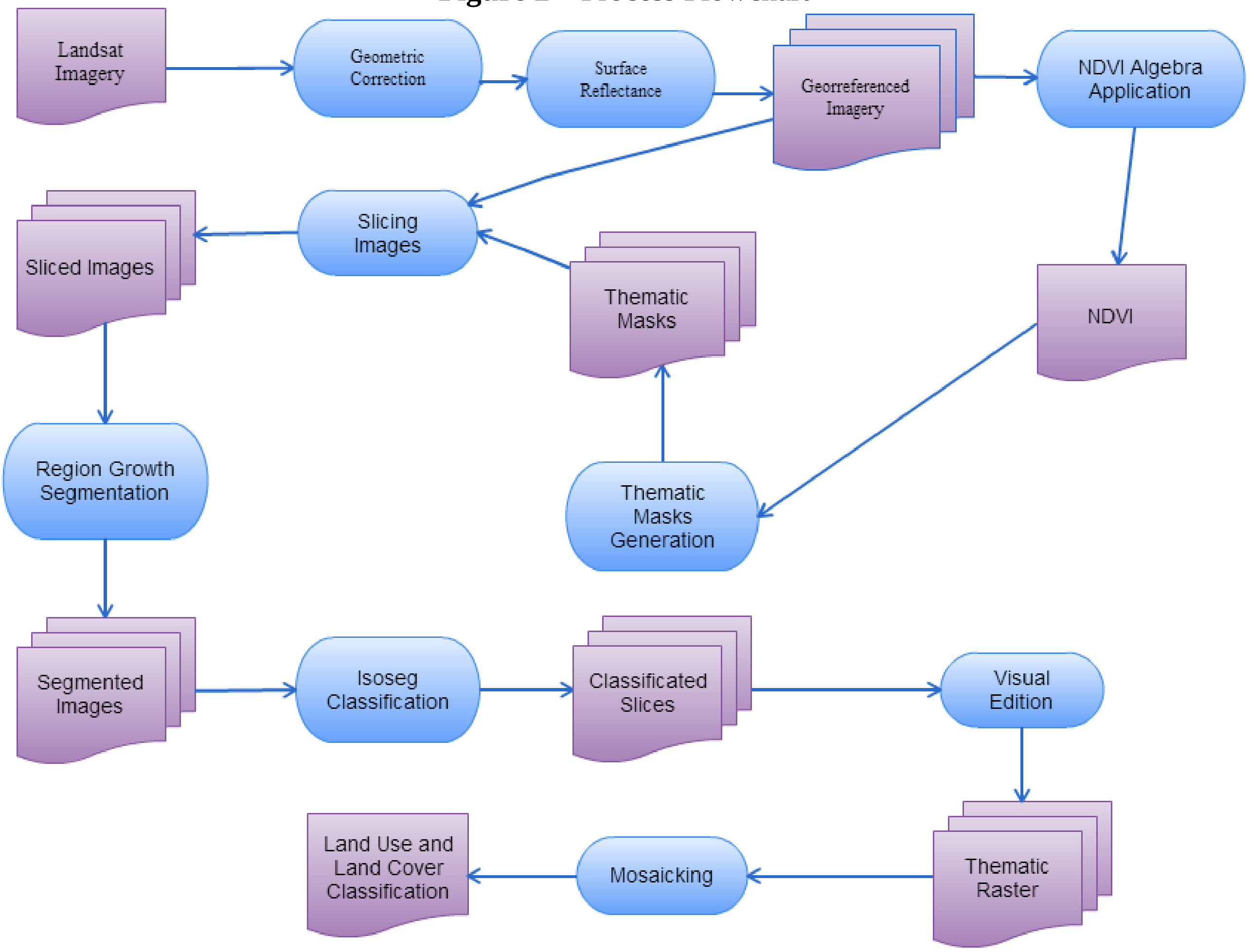
Unsupervised, classification involves pixel separation into natural arrangements based on similar spectral characteristics by means of a classification algorithm, and the assignment of informational classes to these arrangements by the analyst (Enderle and Weih Jr, 2005). This traditional type of classification is often used to generate thematic maps, including land cover maps (Xie et al. 2008). Each pixel group is called a cluster, and each cluster is therefore a spectral class. In this type of classification, the analyst does not provide classes to be worked, but only parameters such as minimum and maximum number of classes to be worked and the number of desired interactions. The generated classes usually do not coincide with the classes of interest, so they are properly classified later, characterizing an exploratory classification process which verifies what is statistically separable.

The process of segmentation by region growth has the advantage of quickly obtaining small scale mappings. Among its limitations is the subsequent need for visual rating by matrix editing and the need of the user's knowledge to select appropriate parameters to ensure the best quality of results (Shimabukuro et al 1998; Espindola et al., 2006). In this paper, this method was chosen because it presents better results than supervised classifiers.

According to Espindola et al. (2006), the segmentation algorithm based on region growth method defines areas using combinations of image bands. It allows the user to control the minimum size of the growth areas and the minimum difference between shades of gray to define boundary areas. This method shows a good potential for use in tasks such as preparation of land use maps because of the delineation areas, which provides a decrease in the volume of editing. The segmentation into developing regions is followed by unsupervised classification of its segments, for this work the automatic classifier called Isoseg was chosen.

The Isoseg is an unsupervised classifier consisting of an algorithm that uses the spectral and pixel spatial information. It then represents each spectral region by class, for example, urban area, forest, etc. This technique - clustering - groups pixels with close similarity. The distance between similarities is calculated by Mahalanobis distance (Mahalanobis, 1936), this process consists of three phases. The first is the definition of a threshold which is the Mahalanobis distance between the regions. The second stage, class detection, considers the statistical parameters of a region (mean and covariance matrix) and those of the larger area region. The unsupervised classification procedure was applied to each of the slices separated in the previous procedure. The results of this process were thematic maps containing random classes, which were then remapped according to the previously selected class. Then, the visual editing process described here which corrects flaws of the rating process was initiated. After completion of the editions, thematic maps are grouped by tile, to finally obtain the aimed result. The processes described in the preceding paragraphs are shown schematically in Figure 2.

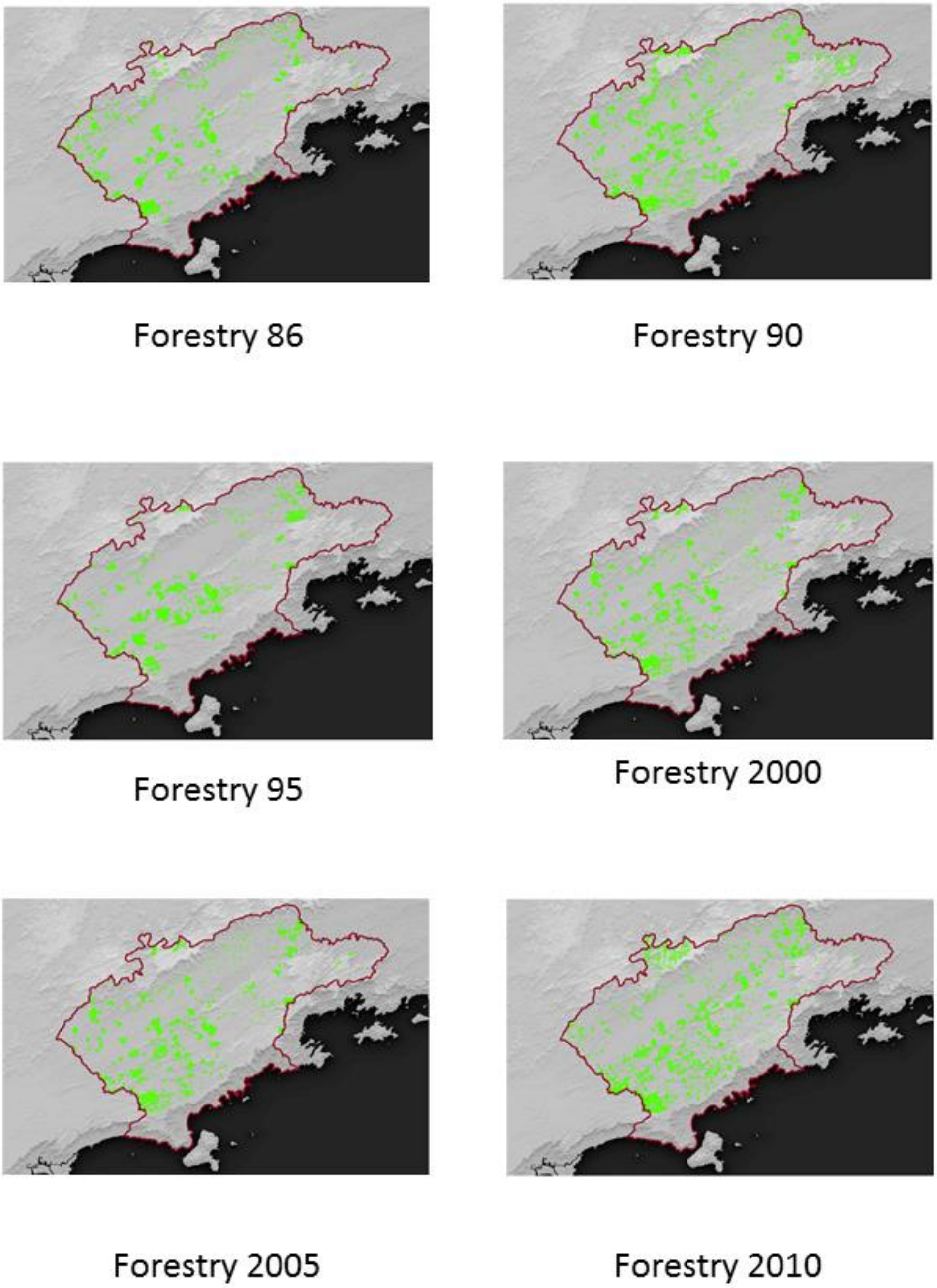
Figure 2 – Process Flowchart



4 RESULTS AND DISCUSSIONS

Figure 3 shows the resulting maps with the areas covered by forestry. The increase in the green areas over the period is noteworthy observing due to the fact that this growth occurred in a disorganized manner. The patches which were previously concentrated in large continuous areas now appear in small points distributed throughout the area. Another important aspect is the growth towards the Serra do Mar and Serra da Mantiqueira, in areas with Remaining Atlantic Rainforest.

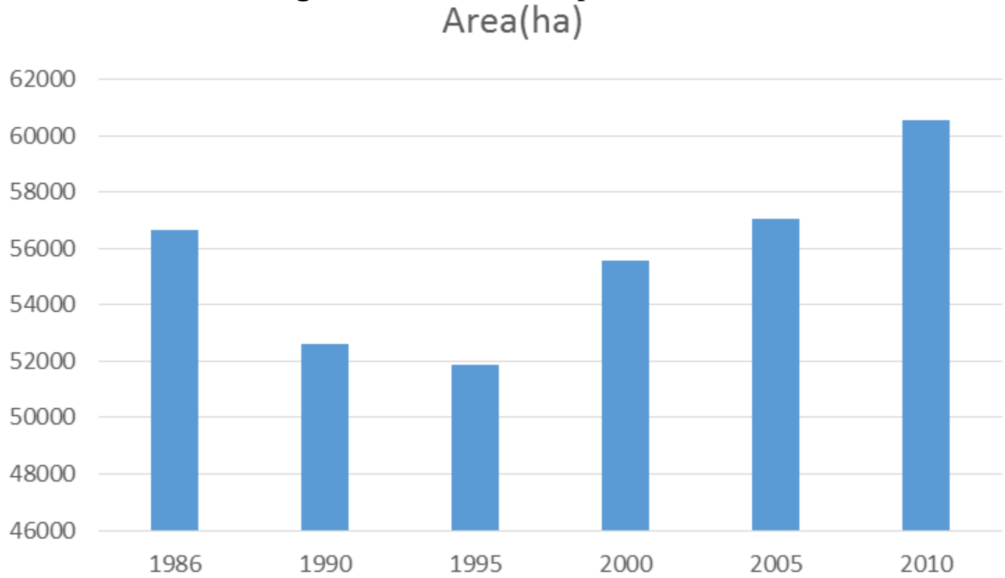
Figure 3 -- Mapped areas covered by forestry



The classification of 2010 was later validated in fieldwork with the acquisition of more than 600 points using a GPS unit (in random itinerary) (Figure 4); along with the landscape characterization of the points with previously produced maps. The field validation showed that the classification has an overall accuracy of 86%. The previous images were classified following the same procedure and compared to maps produced by official institutions (eg. IBGE); ratings always achieved over 80% accuracy.

However, successive and unsuccessful attempts at economic stabilization and inflation control during this period through economic plans, led to an inflation level in the range of 80% per year in 1990 (De Castro, 2005a). At the beginning of the Fernando Collor government with the implementation of the Economic Plan Collor I, Brazil was led to a strong economic contraction (-4.3%), mainly driven by the drop in industrial production (De Castro, 2005b). This scenario would be related to retraction of the areas covered by forestry, due to the decreased demand caused this crisis. These numbers, which came from Forestry Production and Extraction Research (PEVS) carried out by IBGE (2010), when compared to the total of Amount of Forestry Production presented in Table 1 confirm the unfavorable scenario for forestry production during the period explained by the fall in industrial demand. There is a considerable decrease in production of round wood (1,854, 778m³ to 1,219,289m³), used for industrial purposes. It is important to emphasize that the said research does not have data for the 1980 decade, as its historical series starts in 1990, so these data only indicate the backward trend.

Figure 4 – Variation of planted areas



In 1993 the economy would grow again, driven both by industrial as well as agricultural growth, starting a new cycle in the Brazilian economy, based on exports, due to the opening of the economy (De Castro, 2005b). This new scenario was marked by economic stabilization arising from the implementation of a plan of economic reform, called "Real Plan" which caused an increase in domestic demand (De Castro, 2005b). This situation reflected in the expansion of planted forestry areas as shown by the survey data. Between 1995 and 2000 the mapping registered percentage increase of 6.7% in these areas, demonstrating a strong expansion. Between 2000 and 2005, the planted area grew 3%. And between 2005 and 2010, the registered number was 6%, indicating further increase in the pace of industry growth. Data from IBGE (2010) in table 1 confirms this trend showing expansion of industry demand for raw material from early 2000s to the end of the decade. For the first period, this data shows increase in the quantity produced: 1,662,383m³ of logs for the year 2000. This indicates an increase in demand from 1995. In 2005, this quantity dropped down to 998,362m³, indicating contraction of industrial demand. This explains the decrease in the rate of expansion of planted areas, coinciding with the development at a slower pace mapped between 2000 and 2005. As for 2010 1,690,252m³ for roundwood were found, a recovery sign of demand that justifies expanding at a faster rate in the past five years.

Table 1 – Quantity Produced in Forestry

Years Type of forestry product	1990	1995	2000	2005	2010
Charcoal (Ton)	192	992	433	451	289
Timber (M^3)	390,443	43,481	80,605	90	40,607
Roundwood (M^3)	1,854,778	1,219,289	1,662,383	998,362	1,690,252

Source: Vegetation Extraction and Forestry Production – IBGE.

As demonstrated by temporal analysis made from the maps of land use and cover, areas intended for forestry increased during the period in question (1986-2010). This growth was accompanied by the decrease of the areas of temporary crops in the region, as demonstrated by Table 2. Note that the said time series starts in 1990, not containing therefore information about the 1980 decade. This suggests that areas used for other crops including related to food production, may have been relocated for eucalyptus plantation.

Table 2 – Total area of temporary crops on the São Paulo Valley of Paraíba

Year	1990	1995	2000	2005	2010
Area	58740	43965	34639	31680	26125

Source: Municipal Agricultural Production – IBGE.

In this context, researcher Eduardo Pires Castanho Filho from the Institute of Agricultural Economics (IEA) of São Paulo, in an interview to the newspaper Valor Econômico published 28/05/2012 (CASTANHO FILHO, 2012), states that the eucalyptus culture began to attract small and medium producers and says, "of the 800,000 hectares of eucalyptus plantations in São Paulo, 20% are already in the hands of 44,000 small and medium producers". Also, in the document Conservation Units Mosaic corridor of the Serra do Mar, Lino e Albuquerque (2007, p 37) states:

> After the coffee cycle, the plateau region, São Luiz do Paraitinga, Cunha, Sands, São José do Barreiro, Bananal, went through several economic cycles. Currently, they produce rice, potatoes, cassava, corn, beans, tomatoes, fruits, vegetables and even flowers, but the prevalence is dairy farming and agriculture, which are rapidly giving way to forestry, through the pine and eucalyptus reforestation.

Table 3 shows the number of properties and areas for temporary and permanent crops and forestry production, mentioned in the Agricultural Census available for the period studied, which correspond respectively to the years 1995 and 2006. According to IBGE (2010) the number of properties with permanent crops in the region grew from 531 in 1995 to 773 in 2006, their total areas increased from 19,584ha to 23,285ha in the respective years. This increase in agricultural establishments as well as the area devoted to permanent crops activity indicates a change in the agricultural structure of the region, which is based on smaller properties. The same source shows the growth in the number of forestry properties. They increased from only 27 in 1995 to 196 in 2006, their total area in hectares went from 75,447 to 90,691. These data indicate that the growth of eucalyptus culture occurred in a pulverized way, in smaller properties among the crops of other cultures, also based on small properties. That is also verified in the spread of forestry areas identified in table 3. The table related to temporary crops also suggest a decentralization of the sector, since the number of establishments of this economic activity group increased from 329 to 1267 while the size of their areas varied little, growing 74.679ha to 76.933ha during this period.

Table 3 – Number of establishments and área

	1995		2006	
Group of economic activity / Variable	**N.E(Un)***	**A.E (Ha)****	**N.E (Un)**	**A.E (Ha)**
Temporary crops	329	74679	1267	76933
Permanent crops	531	19584	773	23285
Forestry and logging	27	75447	196	90691

*Number of properties (Units); **Area of properties (Hectares)

Source: Agricultural Municipal and Agricultural Survey Census - IBGE.

5 CONCLUSIONS

As discussed, the variation in forestry is controlled by the fluctuations of the market, which determine the demand for roundwood, pulp and paper, among others. This change affects the whole productive structure of the region, both agricultural and industrial, due to the large extent of cultivated areas and strong presence of industries in this part of the region.

A better observation of these variations associated with its critical analysis can bring benefits to the regional planning by anticipating and finding solutions to possible impacts on the regional economy in the event of a drop in productivity in the sector.

As for the space issue, it is noteworthy that the region has potential for this type of culture, mainly due to the existence of large areas where vegetation cover has been removed for coffee cultivation in the past (Dean, 2004). There is also the need to monitor native vegetation removal replaced by eucalyptus forestry, as pointed out by Vanacker (2003) who mapped many areas of forestry on the hills, amid the Atlantic Forest remains. In Brazil as a whole, many areas originally covered by natural forests gave way to forest plantations for industrial purposes (Onofre et al. 2010). This can also lead to biodiversity problems, since monocultures are plantations of a single species (Putz et al. 2000).

But the most important issue to be examined here is social. Forestry is planted to suit various industrial demands such as: pulp and paper manufacturing, furniture manufacturing, electricity generation, etc. Therefore, this culture is often performed directly by large industrial groups and major transnational agribusiness. However, a new phenomenon has been observed, which is the conversion of small producting properties of various agricultural kinds into eucalyptus plantations. This is due to the fact that this kind of crop brings more income to the producer; some studies indicate that this conversion can induce decrease in conflicts (Schirmer, 2006). Nevertheless, other studies indicate that this scenario can cause significant impact beyond the environmental context, leading to socio-cultural and productive conflicts (Barney, 2004; Gerber, 2010). The main impact in this case is the decrease in food supply, since the decrease of crop areas directed to producing food was observed. Another possible impact that needs to be assessed is unemployment in the countryside. In this sense, it is clear that the eucalyptus plantation is required to national supply chain. But must be well planned because of the possible impacts it can cause, this is where the results obtained by this work can be helpful.

These results may provide concise bases to land use. Use of ratings and land cover along with the data obtained by the crossing of information can support possible management actions, such as: Environmental Zoning of eucalyptus growing in the area, as carried out by Francelino et al. (2012) in the city of Vassouras in Rio de Janeiro. Such zoning has been shown to be necessary as the demand of wood for the production of pulp and paper increased by pushing in turn the increased eucalyptus plantation. Zoning is a way to ensure that the management of Forestry is done correctly, reducing the risk of impacts of this type of production.

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Data de submissão: 28.01.2017
Data de aceite: 13.03.2018