MAPPING LAND COVER IN THE PARAÍBA-DO-SUL VALLEY: FOREST AND REFORESTATION IN PARAIBUNA, SÃO LUIZ DO PARAITINGA AND SÃO JOSÉ DO BARREIRO

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ABSTRACT

Remote Sensing has proved to provide very useful tools to investigate land use/land cover and, in particular, changes in forest cover, a major topic of environmental change research. The present paper presents a Landsat-based estimate of the area of forest (primary and secondary) and commercial forest plantation in three *municípios* in the Paraíba-do-Sul Valley, State of São Paulo - Paraibuna, São Luiz do Paraitinga and São José do Barreiro – with varying degree of urbanization and industrialization, including paper and cellulose mills. A 2018 land cover map was produced for each *município*. The areas of forest (primary and secondary), reforestation and non-forest were estimated. Results show that forest cover 56% of the territory of the less urbanized and industrialized São José do Barreiro, and reforestation is incipient; in contrast, forests covered nearly a quarter and reforestation nearly a tenth of the territories of both Paraibuna and São Luiz do Paraitinga.

Keywords **—** Land use and land cover, forest transition, Paraíba-do-Sul Valley

1. INTRODUCTION

Forests are an important source of biodiversity and environmental services, providing forest and non-forest products, contributing to the regulation of the climate and the hidrological and the biogeochemical cycles, as well as the conservation of fauna and flora [1], making the study of forest destruction, degradation and recovery an important research topic.

Human activities such as agriculture, urban expansion and cattle breeding provide benefits to society such as increased food production and urban development, but they are accompanied by significant result in environmental impacts related to large-scale land use change and, in particular, to forest loss [2,3,4]. Because of the multiple scales of land use/forest cover changes, remote sensing and spatial analysis have offered important tools for the study of such processes [4].

While deforestation has remained an important land cover change process in Brazil [5,6], commercial forest plantations have significantly increased , in particular, with the expansion of Eucalyptus sp. for cellulose and paper production [7]. Eucalyptus plantations occupy 5.56 million hectares of the area planted forests in Brazil. Among the biggest Brazilian cellulose producers, the State of São Paulo ranks second with 17.6% [7]. Eucalyptus plantations can be considered as a form of forest transition [8,9,10].

Paraíba-do-Sul Valley is a region of ancient occupation, thus, there may be occurring a possibility of a forest transition. According to Mather [11], forest entanglement may occur in certain regions from a deforestation phase to a phase of increasing forest cover, which may occur in combination with other land-use change processes [12,13].

Remote sensing techniques are widely used for land use and land cover mapping, mainly for large areas. So, this paper aimed to analyze the land use/land cover at three *municípios* located in the state of São Paulo, it were selected three *municípios* in which we had evidence of different processes of changes in forest cover. It was utilized Landsat satellite data to estimate areas of forest (primary and secondary), reforestation and non-forest.

2. MATERIAL AND METHODS

2.1. Study Area

The study area is composed by the municípios of Paraibuna and São Luiz do Paraitinga,in the Paraibuna/Paraitinga micro-region, , and São José do Barreiro , in the Bananal micro-region with estimated populations of 18,180, 10,684 and 4,151 habitants in 2018 (Figure 1). They belong to the Vale do Paraíba Metropolitan Region, in the state of São Paulo [14], pertaining to Atlantic Forest biome.

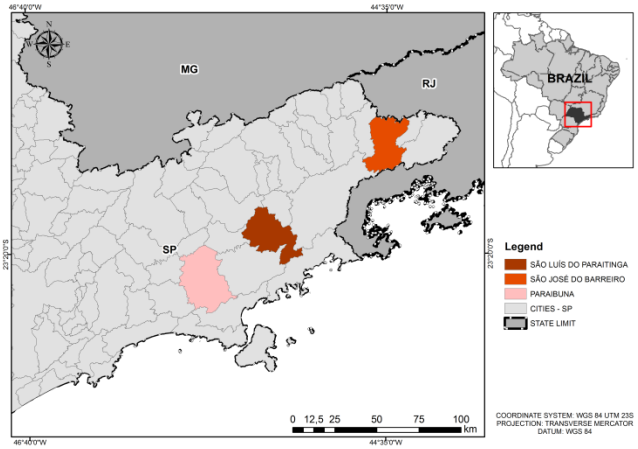

Figure 1. Localization Map.

2.2. Data acquisition

Satellite imagery used in the study included one Operational Land Imager (OLI) dated 23/August/2018, that was used for mapping present-day land cover, and a 1973-2013 Multispectral Scanner (MSS) and Thematic Mapper (TM) image time-series to support land cover classification. All data were downloaded from the Earth Explorer website (United States Geological Survey – USGS) in Universal Transverse Mercator projection [16].

Municipal boundaries were obtained from the Instituto Brasileiro de Geografia e Estatística - IBGE'S digital collection [17].

2.3. Land cover classification

A Maximum likelihood classification was performed and classification results were manually edited to produce a land-cover map distinguishing 3 classes: Forest (Primary and Secondary), Reforestation (commercial forest plantations) and Non-forest (all other, including pasture, exposed soil, agricultural crops, and urban areas).

2.4. Field data collect and classification validation

Between the 23rd and 30th of September 2018, we visited randomly 24 samples of 2x2 km and designed a sketch with the classes that we could identify visually in the field. Then, the sketches were vectorized in the software ArcGIS as shapefile in the output data. The fieldwork aided in the final edition of the map. We also visited an ICMBio office at São José do Barreiro, we asked some questions about National Park of Serra da Bocaina and area around.

To validate the classification was generated and analyzed a confusion matrix. In addition, the Kappa coefficient of agreement and the Accuracy Analysis were computed. As well were calculated errors of omission and commission by software Envi.

3. RESULTS

The land cover map of Paraibuna, São Luiz do Paraitinga and São José do Barreiro are presented in Figures 2, 3 and 4.

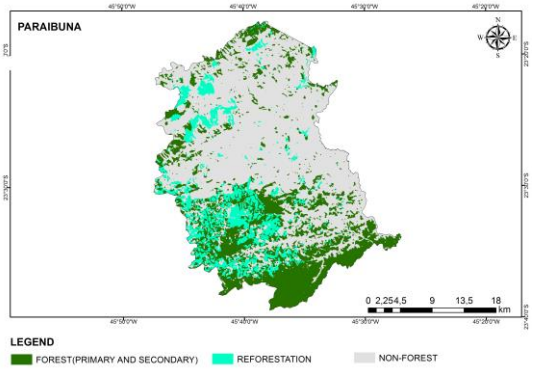

Figure 2. Land cover classification map of Paraibuna.

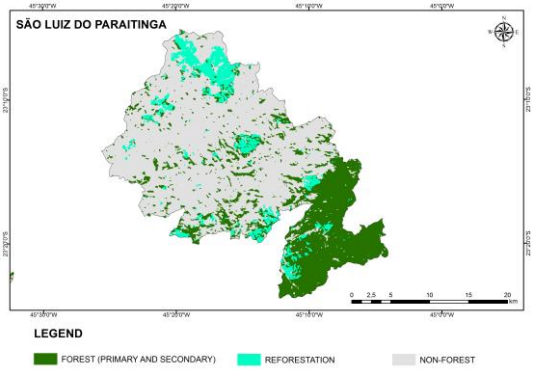

Figure 3. Land cover classification map of São Luiz do Paraitinga.

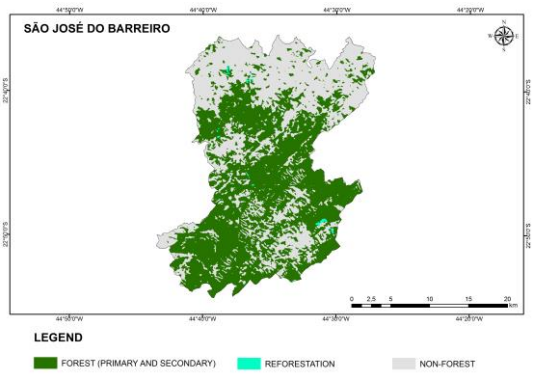

Figure 4. Land cover classification map of São José do Barreiro.

The areas occupied by each land cover class in each *município* are presented in Table 1.

	Paraibuna		São Luiz do Paraitinga		São José do Barreiro	
Class	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**
FPxS	21426.44	0.265	16863.67	0.273	31828.45	0.558
NF	49082.73	0.607	39390.57	0.639	25022.02	0.439
REF	10392.37	0.128	5429.06	0.088	175.00	0.003
TOTAL	80901.54	100.00	61683.30	100.00	57025.47	100.00

Table 1. Estimated area and fraction of the territory (%) occupied by primary and secondary forest (FPxS), non-forest (NF), and commercial forest plantations (REF – reforestation) in each *município*.

The Kappa coefficient of agreement was estimated as 0.91 (Table 2), indicating an almost perfect agreement between collected field data and classification results [18].

The Unclassified (UC class), considered in the confusion matrix, are all pixels with no data, in other words, equal to zero. It can be observed an Overall Accuracy as 99.89%. The diagonal cells present the accuracy of each class, while the off-diagonal cells show the percentage of classification error between classes.

		Reference (%)			
	Class	UC	FPxS	NF	REF
Classification	UC	**100.00**	0.01	0.01	0.00
	FPxS	0.00	**66.08**	0.17	28.41
	NF	0.00	27.92	**99.79**	29.04
	REF	0.00	5.98	0.03	**42.55**

Overall Accuracy: 99.89%; Kappa: 0.91

Table 2. Confusion Matrix. UC=Unclassified; FPxS=Forest(Primary and secondary); NF=Non-forest; and commercial forest plantations (REF=reforestation).

It can be noticed that among the three analyzed *municípios*, forest cover represent the largest fraction in São José do Barreiro, where it amounted to more than half of the *município* area, while in both Paraibuna and São Luiz do Paraitinga forest cover is estimated to represented nearly a fourth of the area.In contrast, commercial forest plantations was inexpressive in São José do Barreiro, representing nearly 10% of the area of the other two *municípios*.

The percentage rates of omission and commission errors are shown in table 3.

Class	Comission (Percent)	Omission (Percent)
UC	0.00	0.00
FPxS	16.42	33.92
NF	17.34	0.21
REF	24.17	57.45

Table 3. Omission and commission errors calculated.

4. DISCUSSION

Overall, the landscapes in the three *municípios* present some marked differences, that are reflected in the proportion and distribution of the forest and reforested areas. Paraibuna and São Luiz do Paraitinga are situated in the area near Serra do Mar, where predominates human activities, as pastures and reforestation in large scale.

Although Paraibuna has part of the territory in an area of environmental protection, including one of the largest reservoirs of water in the Paraiba-do-Sul Valley , and covers part of the Parque Estadual da Serra do Mar, we realize that few forest areas are being preserved, mainly within the APA Bacia do Rio Paraíba do Sul. As opposed to São José do Barreiro, Paraibuna and São Luiz do Paraitinga are nearest to the centers of consumption and show different degrees of urbanization and industrialization

São José do Barreiro presents a more forest cover compared to Paraibuna and São Luiz do Paraitinga. The município includes a large part of the Parque Nacional da Serra da Bocaina, presenting high altitudes up to 2000 m, characterized by altitude fields, what contribute to the extension of area of the forest cover. Also, it was possible to observe in the field small eucalyptus plantations that are not detected in images of medium spatial resolution such as Landsat, in addition there are pastures around the park area.

Some studies discuss the possibility of Forest Transition (FT) in the state of São Paulo [8,9,19]. The forest transition theory posits that forest loss in a region can decline and be accompanied by forest regeneration, resulting in a net increase in forest area and may occur in combination with other land use change processes [12,13]. During the first years of European colonization, native vegetation was constantly suppressed in São Paulo, beginning with the coast and advancing to the west, due to successive economic cycles, such as sugar cane and coffee [8]. São Luiz do Paraitinga presents more than 60% of its area as non-forest, followed by 27% of FPxS (16,863.67 ha). São Luiz do Paraitinga and Paraibuna are closer to the more urbanized (and their centers of consumption) and industrialized of the Valley (including cellulose mills) while São Jose do Barreiro is in a region farther away from the great center urban areas. São José do Barreiro includes a large part of its territory in the Park, which deserves further study.

Mather and Rudel [12,13] relate the questions of urbanization and industrialization with forest transition, in the case of the present study area forest transition seems to be more related not to regeneration but to reforestation.

Due to the colonization history of the state of São Paulo and the possibility of FT in it, a more extensive analysis is already running for the dissertation work, aiming at the identification of possible regeneration areas in the Paraíba do Sul Valley region. In relation to São José do Barreiro, it is suggested that it is possible that there is more secondary forest, which remains a question to be explored in future works.

5. CONCLUSIONS

The results suggest that, in the more urbanized and industrialized parts of the Valley, such as Paraibuna and São Luiz do Paraitinga, commercial reforestation can be an important process for forest transition. While in the less urbanized parts of the region, such as São José do Barreiro, deeper discrimination between primary and secondary forests may be necessary to investigate the hypothesis of a forest transition.

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