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Spatial patterns of the remaining Atlantic Forest and elements that make up the landscape of the Serra Do Mar
Paraiba do Sul River Valley: Micro-region of Paraibuna-Paraitinga

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Introduction

The landscape of the southeastern Brazilian suffered intense changes due to anthropogenic processes during the last 300 years, which reduced the natural forest area from 81% of the Atlantic Forest Biome to only 8%. Currently, the situation of this biome are broad areas that had its natural vegetation cover removed and have high forest fragmentation in almost whole its domain, which makes the Atlantic Forest remnants even more vulnerable to anthropogenic actions.

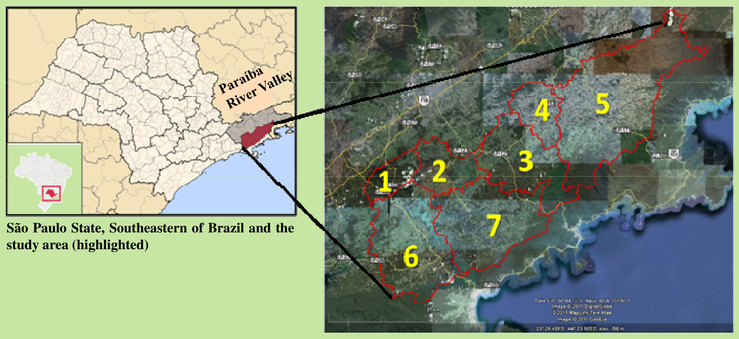
A region that represents these conditions of fragmentation is the Paraíba do Sul River Valley, which includes the cities located between the capitals São Paulo and Rio de Janeiro. In the lowland areas which follow the banks of the Paraiba do Sul River, the urbanization process, the economic cycles (especially the coffee cycle and livestock) and the industrialization were responsible, directly and indirectly, by the almost total extraction of coverage forest. On the other hand, in regions of higher altitudes and rugged relief, both in the Serra do Mar and in the Serra da Mantiqueira (the two mountain ranges that make up the valley), is observed a higher amount of remaining forest.

Considering the concepts of Landscape Ecology, in the Paraiba do Sul River Valley, the pastures areas are prevalent and can be considered the "matrix", while the remnants of Atlantic Forest can be considered as the "patches" scattered in the landscape. The forest coverage represent about 11% of the area of the Valley (in São Paulo State portion) and are composed mainly by isolated forest fragments of different sizes and with low connectivity among themselves.

It is still unclear what are the key factors that are related to the presence / absence of the remnants of the Atlantic Forest. Empirically, the spatial patterns that can be observed in the Paraíba do Sul River Valley only indicate relationships between land use and physical characteristics of the relief, so that the saw regions are more conserved, unlike flatter, which are more disturbed. The great variability of soil types, geomorphology, different conditions of access (roads) and a wide hydrographic network may have influenced the formation of different mosaics throughout the region. However, a priori, there is no clear indications of relationships between these factors and the spatial distribution of forest fragments.

Objective

Given the context described above, the objective of this study was to analyze physical and anthropogenic elements that may be conditioning factors on the presence / absence of forest remnants, and by means of a multivariate regression model, to explain its spatial distribution.



São Paulo State, Southeastern of Brazil and the study area (highlighted)

Figure 1) – Study area: Micro-region of Paraíbuna-Paraitinga. 1) Jambeiro, 2) Redenção da Serra, 3) São Luis do Paraitinga, 4) Lagoinha, 5) Cunha, 6) Paraibuna and 7) Natividade da Serra.

Study Area

The study area is the micro-region of Paraibuna-Paraitinga, which is situated between the axis linking the capitals São Paulo - Rio de Janeiro, and at the northwest is bordered to municipalities that are cut by the Highway Presidente Dutra (the most important road to Brazilian economy). The study area has about 4406 km2, of which only 14.5% (637 km2) is covered by native forest (Altantic Forest). For the plains (SW-NE central region), most of the forest fragments is less than 100ha and there are isolated in the landscape. However, fragments much larger and more continuous are found in the mountainous regions, that accounted 327km2, usually located within Conservation Units (CUs).

The main roads that cross the region are: Tamoios Highway, Oswaldo Cruz Route , and Paulo Virgínio Highway, linking the interior of the valley to the coast (Figure 2a). Another important feature of the region is the presence of the Paraibuna Rivem Dam (Southwest portion), which is responsible for controlling the flow of the Paraíba do Sul River. Elevations in this region can range from 500m in its central portion (in the areas closest to the main rivers, especially Paraibuna Dam) to 1700 on the high slopes that go toward the top of the Serra do Mar (Figure 2d). Close to the limits at Northwest are also found higher altitudes around 1300m, oriented NE-SW. This elevation of the relief, which has several springs tributaries of Paraitinga River is known locally as Serra do Quebra-Cangalha.

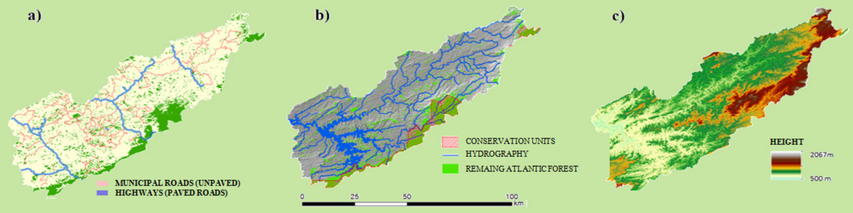


Figure 2) – Data base: a) rodas network; b) forest fragmentes, Conservation Units and h\idrography ; c) digital elevation model (provided by: Shuttle Radar Topography Mission).

Results

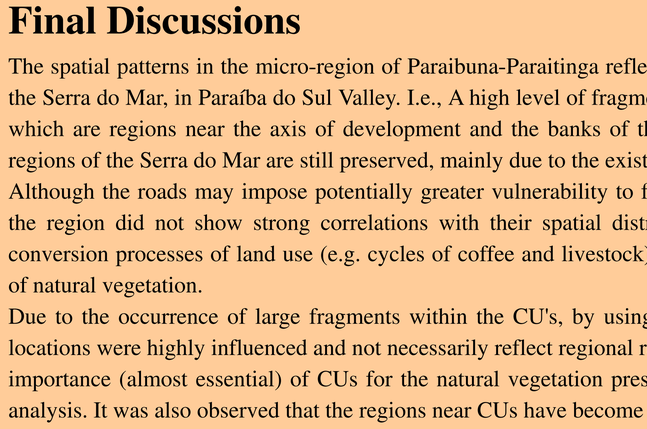


Figure 3 -Spatialization for the metrics generated by the plugin "Filling of Cells", provided by software Terraview: a) slope (in degrees), b) maximum slope (in degrees), c) average height (m), d) minimum distance of hydrographic network (m), e) minimum distance of paved roads (m), f) minimum distance of municipal roads - unpaved (m), g) presence of Conservation Units, h) aspect - the majority class, i) average of aspect.

Figure 4 - Total Percentage of Forest (TPF) for the cellular database generated with 500m x 500m cells.

Synthesis Methodology

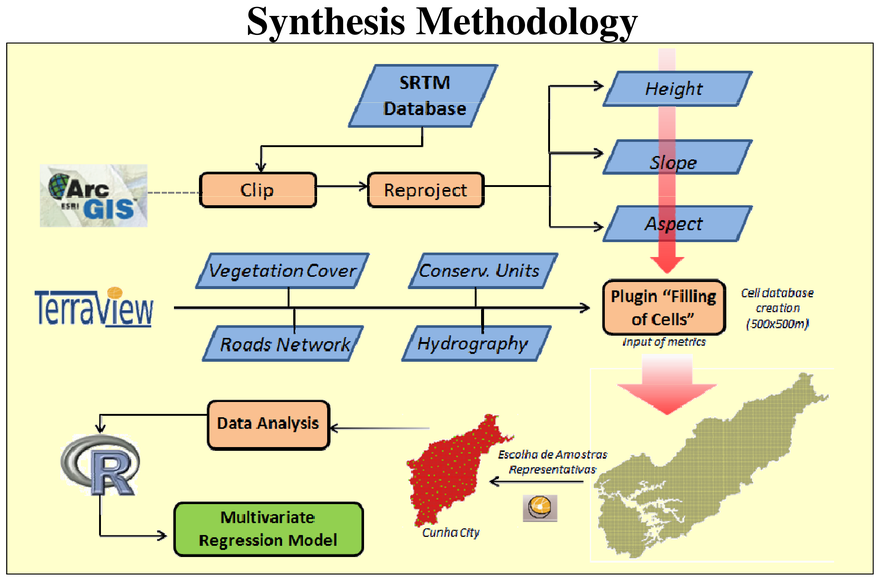
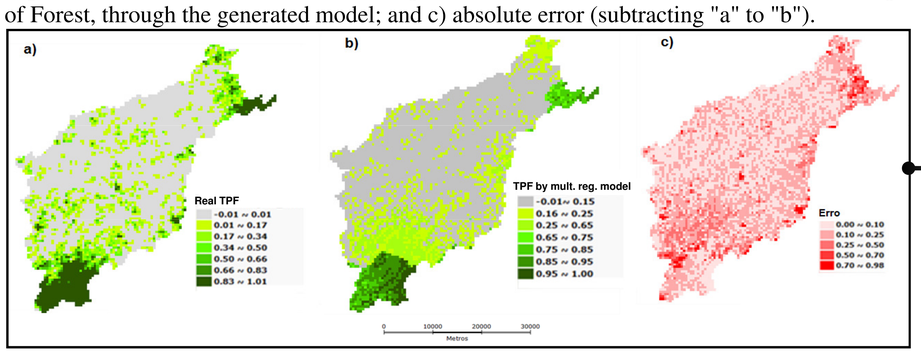


Figure 7 - Final Result: a) Total Percentage of Forest (Real) b) Prediction of Total Percentage of Forest, through the generated model; and c) absolute error (subtracting "a" to "b").



$$PTF = -0{,}054 + (0{,}6586 \times Vind_1) + (0{,}0256 \times Vind_2) + (0{,}000019 \times Vind_3)$$

For the spatial dependence between samples (cells) do not interfere with the linear regression analysis, a representative sample was selected randomly. This helps to minimize errors caused by crowded cells that have similar characteristics (clusters). Thus, for a universe with a total of 15,896 cells, we used Cunha City (5937 cells), where were chosen 130 random cells. The representativeness of these samples was evaluated by comparing the histograms of the total universe and this subset.

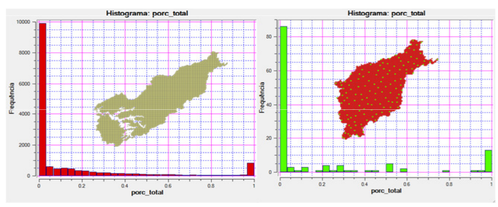


Figure 5 – TPF Histograms for: a) whole sutdy area e b) Cunha City.

Table 1 - Analysis of Correlation between Total Percentage of Forest and other variables.

Metrics (variables) used to filling of cells	Correlation with Total Percentage of Forest
Aspect (medium)	0,3556
Aspect (Major Class)	0,4671
Slope (medium)	-0,0192
Slope (maximum)	0,0004
Presence of Conserv. Units	0,8409
Distance of Hydrographic network	-0,0051
Height (medium)	0,1429
Distance of Municipal Roads	0,5421
Distance of Highways	0,1975

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Residuals:
     Min       1Q   Median       3Q      Max
-0.56479 -0.06552  0.00396  0.03147  0.63426

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)     -5.377e-02  2.775e-02  -1.937   0.0549 .
aspect_major_class 2.556e-02  5.627e-03   4.541 1.29e-05 ***
uc_presence      6.586e-01  4.901e-02  13.438  < 2e-16 ***
mun_road_distance 1.186e-05  4.557e-06   2.602   0.0104 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.1636 on 126 degrees of freedom
Multiple R-squared: 0.762,      Adjusted R-squared: 0.7563
F-statistic: 134.5 on 3 and 126 DF,  p-value: < 2.2e-16
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Figure 6 - Results of the regression analysis provided by R software for predicting the variable Total Percentage of Forest (TPF). The estimated values of β for each variable are in column "Estimate".

TPF = Dependent variable - Total Percentage of Forest
$Vind_1$ = *Presence of U.C. (high significance)*
$Vind_2$ = *Majority Class of Aspect (average significance)*
$Vind_3$ = *Distance of Municipal Roads (low significance)*

Final Discussions

The spatial patterns in the micro-region of Paraibuna-Paraitinga reflect a diversity of landscapes that is common on the slopes of the Serra do Mar, in Paraíba do Sul Valley. I.e., A high level of fragmentation of native vegetation is observed at lower elevations, which are regions near the axis of development and the banks of the Paraíba do Sul River. On the other hand, the headwater regions of the Serra do Mar are still preserved, mainly due to the existence of protected areas.

Although the roads may impose potentially greater vulnerability to forest fragments, the current situation of the native forest of the region did not show strong correlations with their spatial distribution. Indeed, the existence of roads is linked to other conversion processes of land use (e.g. cycles of coffee and livestock) that probably were the real responsible for the suppression of natural vegetation.

Due to the occurrence of large fragments within the CU's, by using data for the whole region (all cells), the results for other locations were highly influenced and not necessarily reflect regional realities. However, the model developed highlighted the great importance (almost essential) of CUs for the natural vegetation preservation, which had the highest statistic significance in the analysis. It was also observed that the regions near CUs have become more preserved.

Mathematically, it is difficult to develop a multivariate linear regression model that is capable to representing the local with no vegetation (TPF = 0), being necessary to include values close to represent this situation. As proposal, previously would be interesting to develop a regression model (logistic) for the variable "presence of forest", so that the model presented in this paper would apply only to the cells that had a high probability of having vegetation.

Empirically, the slope is a variable that could be related to the presence of forest fragments. For example, usually hilly areas are preserved due to restricted land use that it has (mostly slope > 25°). However, the resolution of SRTM data (90m) has not allowed the identification of these locations and the use of cells with 500x500m masked such information. Probably, this fact made the regression technique not consider the slope as a significant variable in the analysis step, not including it in the final model. On the other hand, the variable aspect showed patterns correlated with the spatial distribution of the forest remnants. By the used scale, the hillsides with SW-NE orientation are generally more continuous and extensive than the others. It is likely that this characteristic is the responsible for not induce the fragmentation process of native forest. Furthermore, a detailed analysis indicates that, when the hillsides are fairly continuous and extensive, they are also related with slopes steeper, which limits the land use and, consequently, favors conservation.