Effects of roads, topography, and land use on forest cover dynamics in the Brazilian Atlantic Forest

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Effects of roads, topography, and land use on forest cover dynamics in the Brazilian Atlantic Forest

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ABSTRACT

Roads and topography can determine patterns of land use and distribution of forest cover, particularly in tropical regions. We evaluated how road density, land use, and topography affected forest fragmentation, deforestation and forest regrowth in a Brazilian Atlantic Forest region near the city of São Paulo. We mapped roads and land use/land cover for three years (1962, 1981 and 2000) from historical aerial photographs, and summarized the distribution of roads, land use/land cover and topography within a grid of 94 non-overlapping 100 ha squares. We used generalized least squares regression models for data analysis. Our models showed that forest fragmentation and deforestation depended on topography, land use and road density, whereas forest regrowth depended primarily on land use. However, the relationships between these variables and forest dynamics changed in the two studied periods; land use and slope were the strongest predictors from 1962 to 1981, and past (1962) road density and land use were the strongest predictors for the following period (1981–2000). Roads had the strongest relationship with deforestation and forest fragmentation when the expansions of agriculture and buildings were limited to already deforested areas, and when there was a rapid expansion of development, under influence of São Paulo city. Furthermore, the past (1962) road network was more important than the recent road network (1981) when explaining forest dynamics between 1981 and 2000, suggesting a long-term effect of roads. Roads are permanent scars on the landscape and
Introdução

Brazilian Atlantic Forest has a long land use history
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Past patterns of land use have an important role in cycles of deforestation, fragmentation, and reforestation
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Topography can also influence patterns of forest fragmentation and forest cover.

**Steep slopes** and poor soils → remain forested.
Brazilian Atlantic Forest has a long land use history. Past patterns of land use have an important role in cycles of deforestation, fragmentation, and reforestation. Topography can also influence patterns of forest fragmentation and forest cover. Steep slopes and poor soils remain forested.

Demand for agricultural products create new land use demands and influence rates of deforestation.
Introdução

Brazilian Atlantic Forest has a long land use history

Past patterns of land use have an important role in cycles of deforestation, fragmentation, and reforestation

Topography can also influence patterns of forest fragmentation and forest cover

Steep slopes and poor soils → remain forested

Demand for agricultural products create new land use demands and influence rates of deforestation

Rods → improve land access and allow new land uses
Objetivo

Evaluate the relationships of:

- Topography
- Land use
- Roads
- Forest fragmentation
- Deforestation
- Forest regrowth

Plateau of Ibiúna, a Pre-Cambrian formation situated 50 km from the city of São Paulo
Materiais e Métodos

Slope map were generated from topographic maps - IGC 1979

Topography
- Land use
- Roads

Forest fragmentation
- Deforestation
- Forest regrowth
Materiais e Métodos

Topography
Land use
Roads

Forest fragmentation
Deforestation
Forest regrowth

Slope map were generated from topographic maps - IGC 1979 agriculture, forest, buildings
Materiais e Métodos

Topography
Land use
Roads

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Uso ou cobertura?

Forest fragmentation
Deforestation
Forest regrowth
Materiais e Métodos

- Topography
- Land use
- Roads

Slope map were generated from topographic maps - IGC 1979
agriculture, forest, buildings
visual photo interpretation
(stereoscopic device)

- Forest fragmentation
- Deforestation
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Topography
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Forest fragmentation
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Forest dynamics


Forest fragmentation
Deforestation
Forest regrowth
Materiais e Métodos

Landscape modifications

Grid → 94 non-overlapping squares of 100ha
Materiais e Métodos

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Grid → 94 non-overlapping squares of 100ha

Each square and in each year: road distribution (road length/square area), land-use and land-cover proportions (class area/square area; agriculture, forest, and buildings), forest fragmentation (forest patch density, which was the number of forest patches in each square), slope variation (slope standard deviation to represent the relief variation), and distance from the city of São Paulo
Materiais e Métodos

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Desenvolvimento do Modelo

Forest fragmentation was transformed to a normal distribution using logarithm transformation
Desenvolvimento do Modelo

Forest fragmentation was transformed to a normal distribution using logarithm transformation

Não testou a normalidade:

Histograma

Skewness (simetria da distribuição)

Testes como K-S e S-W

Q-Q Plot
Desenvolvimento do Modelo

Forest fragmentation was transformed to a normal distribution using logarithm transformation

Não testou a normalidade:

Histograma

Skewness (simetria da distribuição)

Testes como K-S e S-W

Q-Q Plot

 Não apresentou metodologias semelhantes

Transformação dos dados pode comprometer a interpretabilidade
Desenvolvimento do Modelo

Forest fragmentation was transformed to a normal distribution using logarithm transformation.

Método dos mínimos quadrados generalizados – explorar as relações entre:
Desenvolvimento do Modelo

Forest fragmentation was transformed to a normal distribution using logarithm transformation.

Método dos mínimos quadrados generalizados – explorar as relações entre:

- Forest fragmentation
- Deforestation
- Forest regrowth
- road density
- agriculture cover
- buildings cover
- standard deviation of slope
- distance from the city of SP
Desenvolvimento do Modelo

Forest fragmentation was transformed to a normal distribution using logarithm transformation

Método dos mínimos quadrados generalizados¹ – explorar as relações entre:

- forest fragmentation
- deforestation
- road density
- forest regrowth
- agriculture cover
- standard deviation of slope
- distance from the city of SP

1. Generalized Least Squares (GLS)

O método GLS é aplicado quando a variância dos erros não é a mesma (heteroscedasticidade), ou quando há certa correlação entre os resíduos.

→ Fatores não foram analisados/justificados
## Modelos Similares – Explorar mudanças

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<tr>
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<th>Dependent variable</th>
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All variables with 60% or more of correlation were not included

A ausência de multicolinearidade\(^1\) é uma das premissas para estabelecer um modelo de regressão múltipla correto

---

1. variáveis independentes possuem relações lineares exatas ou aproximadamente exatas
All variables with 60% or more of correlation were not included

Visando simplificar as equações, foi selecionado uma abordagem de Backward elimination (equal chance of affecting forest variables) → todos os preditores são inclusos no modelos e de acordo com o p-valor são removidos

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Seleção de Modelos

*Bayesian information criterion* (BIC) – Critério de seleção de modelos dentro de um conjunto finito de modelos (introduz uma penalidade no número de parâmetros utilizados)
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*Bayesian information criterion* (BIC) – Critério de seleção de modelos dentro de um conjunto finito de modelos (introduz uma penalidade no número de parâmetros utilizados)

*ment was measured using Bayesian Information Criterion (BIC) values, which is more conservative than Akaike’s Information Criterion (AIC) (Burnham and Anderson, 2002). We calculated BIC*
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Raftery, 1995, for a pro-BIC account). A formal comparison in terms of performance between AIC and BIC is very difficult, particularly because AIC and BIC address different questions. Most simulations that show

Próximas etapas

Variables selection → examination of model residuals to validate the assumptions (normally distributed errors, constant variance, and independent observations)
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Ecological phenomena are NOT spatially and temporally independent
Próximas etapas

Variables selection → examination of model residuals to validate the assumptions (normally distributed errors, constant variance, and independent observations)

Ecological phenomena are NOT spatially and temporally independent

Tests → if spatial autocorrelation was detected additional models with the same variables and correlation structures were included
Atenuando o efeito da autocorrelação espacial

By including spatial autocorrelation structures in the final models, the aim was to nullify the effects of spatial autocorrelation on the significance of regression coefficients and reduce the chance of Type I errors (incorrect rejection of null hypotheses)
Atenuando o efeito da autocorrelação espacial

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Significance of the spatial correlation - ANOVA
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The presence of spatial autocorrelation in residuals can be used as a diagnostic tool indicating whether one or more processes are not included in the model or were not parameterized adequately.

Atenuando o efeito da autocorrelação espacial

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Significance of the spatial correlation - ANOVA

The presence of spatial autocorrelation in residuals can be used as a diagnostic tool indicating whether one or more processes are not included in the model or were not parameterized adequately.


regression models should be more robust
Resultados são pautados na mudança da cobertura entre os períodos: *Most deforestation was caused by agriculture*

Não há análise intermediária (19 anos não analisados)
The smaller the residual standard deviation, the closer is the fit to the data. When the Residual Standard Error (RSE) is exactly 0 then the model fits the data perfectly.
First Period: buildings and slope variation were the main factor affecting forest cover dynamics
Resultados

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<thead>
<tr>
<th>Time period</th>
<th>Dependent variable</th>
<th>Independent variables</th>
<th>BIC</th>
<th>Weight</th>
<th>Evidence</th>
<th>RSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1962–1981</td>
<td>Fragmentation</td>
<td>+Buildings62</td>
<td>126.89</td>
<td>0.926</td>
<td>1.0</td>
<td>0.433</td>
</tr>
<tr>
<td></td>
<td>Deforestation</td>
<td>+Slope</td>
<td>274.20</td>
<td>0.969</td>
<td>1.0</td>
<td>0.941</td>
</tr>
<tr>
<td></td>
<td>Regrowth</td>
<td>−Buildings62</td>
<td>142.62</td>
<td>0.996</td>
<td>1.0</td>
<td>0.472</td>
</tr>
<tr>
<td></td>
<td>Agriculture expansion</td>
<td>+Slope</td>
<td>198.35</td>
<td>0.995</td>
<td>1.0</td>
<td>0.623</td>
</tr>
<tr>
<td></td>
<td>Buildings expansion</td>
<td>+Agricult62</td>
<td>503.83</td>
<td>0.825</td>
<td>1.0</td>
<td>3.211</td>
</tr>
<tr>
<td></td>
<td>Road expansion</td>
<td>+Slope</td>
<td>238.04</td>
<td>0.990</td>
<td>1.0</td>
<td>0.773</td>
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<td>1981–2000</td>
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<td>86.47</td>
<td>0.965</td>
<td>1.0</td>
<td>0.343</td>
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<td>273.49</td>
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<tr>
<td></td>
<td>Regrowth</td>
<td>−Agricult62</td>
<td>233.81</td>
<td>0.548</td>
<td>1.0</td>
<td>0.740</td>
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<tr>
<td></td>
<td></td>
<td>+DistSP</td>
<td>234.74</td>
<td>0.344</td>
<td>1.6</td>
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<td></td>
<td>−DistSP</td>
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<td>Buildings expansion</td>
<td>−Forest62</td>
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<tr>
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<td></td>
<td>+Road62</td>
<td>290.84</td>
<td>0.313</td>
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<tr>
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<td>−DistSP</td>
<td>244.75</td>
<td>0.968</td>
<td>1.0</td>
<td>0.801</td>
</tr>
</tbody>
</table>

First Period: Buildings were positively related with fragmentation, and negatively related with forest regrowth.
Between 1981 and 2000, forest dynamics were strongly affected by 1962 road density

Não há resultados mais detalhados com base no RSE
Discussões

Paralelos com realidades internacionais ou de outras regiões do Brasil:
Discussões
Paralelos com realidades internacionais ou de outras regiões do Brasil: In regions where land use has occurred for centuries, for example Southeastern Brazil and Northern Wisconsin (USA), it is difficult to assign a direct causality. Nevertheless, remote areas in the North of Brazil could be used to evaluate the landscape changes caused by a new road.
Percepções Gerais

• Metodologias coerentes, embora pouco justificadas
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(Mac Nally, 1996). The HP method helps to identify the most influential predictor variables by capturing their independent and joint contribution to the goodness-of-fit of recruitment (Chevan and Sutherland, 1991, Mac Nally, 2000). In our analysis, the


Forest ecology and management, 262(8), 1608-1617.
Percepções Gerais

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• Ferramentas estatísticas não foram exploradas a fundo
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<td>Road expansion</td>
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Obrigada!