Relief influence on the spatial distribution of the Atlantic Forest cover on the Ibiúna Plateau, SP

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(With 1 figure)

Abstract

Several studies suggest that, on a large scale, relief conditions influence the Atlantic Forest cover. The aim of this work was to explore these relationships on a local scale, in Caucaia do Alto, on the Ibiúna Plateau. Within an area of about 78 km^2, the distribution of forest cover, divided into two successional stages, was associated with relief attribute data (slope, slope orientation and altitude). The mapping of the vegetation was based on the interpretation of stereoscopic pairs of aerial photographs, from April 2000, on a scale of 1:10,000, while the relief attributes were obtained by geoprocessing from digitalized topographic maps on a scale of 1:10,000. Statistical analyses, based on qui-square tests, revealed that there was a more extensive forest cover, irrespective of the successional stage, in steeper areas (>10 degrees) located at higher altitudes (>923 m), but no influence of the slope orientation. There was no sign of direct influence of relief on the forest cover through environmental gradients that might have contributed to the forest regeneration. Likewise, there was no evidence that these results could have been influenced by the distance from roads or urban areas or with respect to permanent preservation areas. Relief seems to influence the forest cover indirectly, since agricultural land use is preferably made in flatter and lower areas. These results suggest a general distribution pattern of the forest remnants, independent of the scale of study, on which relief indirectly has a strong influence, since it determines human occupation.

Keywords: relief, forest cover, Atlantic Forest, land use.

Influência do relevo na distribuição espacial da Mata Atlântica no Planalto de Ibiúna, SP

Resumo

Vários estudos sugerem que as condições do relevo influenciam, em larga escala, a cobertura da Mata Atlântica. Este trabalho teve por objetivo explorar estas relações em escala local, na região do Planalto de Ibiúna, denominada de Caucaia do Alto. Numa área de cerca de 78 km^2, procurou-se associar a cobertura florestal, dividida em dois estádios sucessionais, com atributos do relevo (declividade, orientação de vertente e altitude). O mapeamento da vegetação foi feito a partir da interpretação de pares estereoscópicos de fotografias aéreas de abril de 2000, na escala 1:10.000, enquanto os atributos do relevo foram gerados por geoprocessamento a partir de cartas topográficas digitalizadas, em escala 1:10.000. As análises estatísticas, baseadas em testes de qui-quadrado, revelam que há maior cobertura florestal, independentemente do estádio sucessional, em áreas mais íngremes (>10 graus) e situadas em altitudes mais elevadas (>923 m), porém não há influência da orientação de vertente. Não há indícios de influência direta do relevo sobre a cobertura florestal, através de gradientes ambientais que poderiam agir na regeneração florestal. Também não foram obtidas evidências de que estes resultados possam ser influenciados pelo distanciamento a estradas ou centros urbanos, ou ainda pelo respeito às áreas de preservação permanente. O relevo parece determinar o recobrimento florestal, principalmente por condicionar o uso agrícola dos solos, que se dá preferencialmente em áreas mais planas e baixas. Estes resultados sugerem um padrão geral de influência do relevo sobre a distribuição dos remanescentes florestais, independentemente da escala de estudo, onde o relevo atua indiretamente ao condicionar a ocupação humana.

Palavras-chave: relevo, cobertura florestal, Floresta Atlântica, uso da terra.

1. Introduction

In spite of the great diversity of approaches and analysis scales, several studies have shown that the richness and the composition of plant communities are influenced by relief characteristics such as slope orientation (Killingbeck and Wali, 1978), slope position (Oliveira Filho et al., 1994), altitude (Kappelle et al., 1995; Pendry and Proctor, 1996), and slope (Volpato, 1994). The heterogeneity of the topographic conditions can also affect the floristic composition (Swanson et al., 1988) as well as the richness and diversity of tree species (Everson and Boucher, 1998; Burnet et al., 1998). On the other hand, in the Atlantic Forest biome, there are still few studies on the influence of relief on forest spatial distribution, although, on a global scale, the correlation between relief and forest cover is widely recognized. Relief influence on the occurrence of semi-deciduous and dense rain forests, which form a large part of the Atlantic Forest sensu lato (Oliveira-Filho and Fontes, 2000), is due both to abiotic restrictions, which determine floristic and physiognomic regional differences, and to human occupation conditioning.

Relief has a close relationship with pedologic cover, since it determines the hydric dynamics and controls the incidence of solar radiation (Roy and Singh, 1994; Chen et al., 1997; Clark et al., 1998). Despite this interdependence, relief influence on the composition and structure of the vegetation is almost always clearer than that of soil attributes (Simonetti, 2001). In the "Serra do Mar" mountain region, this influence is even clearer when primary or less-disturbed forests are taken into consideration (Simonetti, 2001). Edaphic and topographic factors can influence not only more advanced successional stages, whose dominance of species can be related with specific soil characteristics such as water availability, but also early stages, because species at these stages are highly capable of occupying the most diverse types of terrains, such as areas of poor or shallow soil (Budowski, 1965).

Relief influence on the forest cover can also be indirect, since the dynamics of land use is conditioned by relief. Areas with high slope or poor soils increase the fragility of the system and decrease the possibility of anthropic use (Ranta et al., 1998; Resende et al., 2002). In view of these restrictions, the major part of the remaining covers of mountain semideciduous (Oliveira-Filho and Machado, 1993) and dense rain forests (Turner and Corlett, 1996) is situated in areas whose relief does not favor anthropic occupation, i.e. where the topography hinders access.

In the region of Ibiúna Plateau (SP), the Atlantic Forest still covers more than 30% of the landscape, essentially with forest fragments at distinct regeneration stages that range from initial to advanced. This percentage, in private properties, can be regarded as surprisingly high, considering that this region is predominantly agricultural and is close to the metropolitan area of São Paulo, one of the largest in the world. Other places in the interior of the State of São Paulo have less than 7% of cover. In order to try to understand why the forest cover in the region of Ibiúna Plateau is still so significant, an assumption was made that it would be associated with physical characteristics of the land, determined by relief. So, this study tested if the occurrence of different stages of forest succession can be explained by altitude, slope and slope orientation. These characteristics might influence the processes of forest regeneration and soil utilization for economic purposes (e.g. agriculture, forestry, exploitation for coal).

2. Study Region

The study region corresponds to about 7,800 ha located at the Crystalline Plateau of Ibiúna (Ponçano et al., 1981), Paranapiacaba Mountain Range, in the district of Caucaia do Alto, of the rural areas of the municipalities of Cotia and Ibiúna, in the State of São Paulo (23° 35' S, 23° 50' S and 46° 45' W, 47° 15' W, Figure 1). Ibiúna Plateau is part of the Atlantic Plateau, a highland region predominantly sustained by Pre-Cambrian crystalline rocks cut by Mesozoic-Tertiary alkaline and basic intrusive rocks, and in several zones re-covered by the sedimentary basins of São Paulo and Taubaté (Almeida, 1964). In the same region, Ponçano et al. (1981) detected different relief systems, such as mountain plateau with steep hillslopes, mountain with moderate to gentle hillslopes, and alluvial plains.

Hasui (1975) considers as the most important tectonic element in the region the group of sub-vertical faults (60° to 90°), the most significant being those at Taxaquara, Jundiuvira and Caucaia. In the light of current theoretical knowledge, these faults are actually ductile shear zones (Ramsay and Huber, 1983) occurring in large amounts in the Brazilian southeast. These huge structures are hundreds of kilometers long and their thickness can reach hundreds of meters.

The crystalline basement predominating in the Caucaia region is composed of rocks of a high metamorphic grade, such as the migmatites, and magmatic rocks, such as granite. According to the American Soil Taxonomy, the main soils in that region are: Alfisols, Ultisols, Oxisols and Inseptisols (Ross and Moroz, 1997). The occurrence of sesquioxide iron in the Caucaia region gives the soil a characteristic color of very well drained subtropical soils.

On the basis of meteorological data furnished by the Integrated Center of Agrometeorological Information (Centro Integrado de Informações Agrometeorológicas - CIIAGRO/IAC, São Paulo), the climate of Ibiúna was characterized as mild hot and humid, *Cfa* type (Köppen, 1948). On average, the maximum and the minimum temperatures are 27 and 11 °C, respectively. The average temperature in the hottest month is above 22 °C and the average precipitation in the driest month varies from 30 mm to 60 mm. The average annual precipitation is about 1,300-1,400 mm, with seasonal variations, April and August being the driest months with the lowest aver-

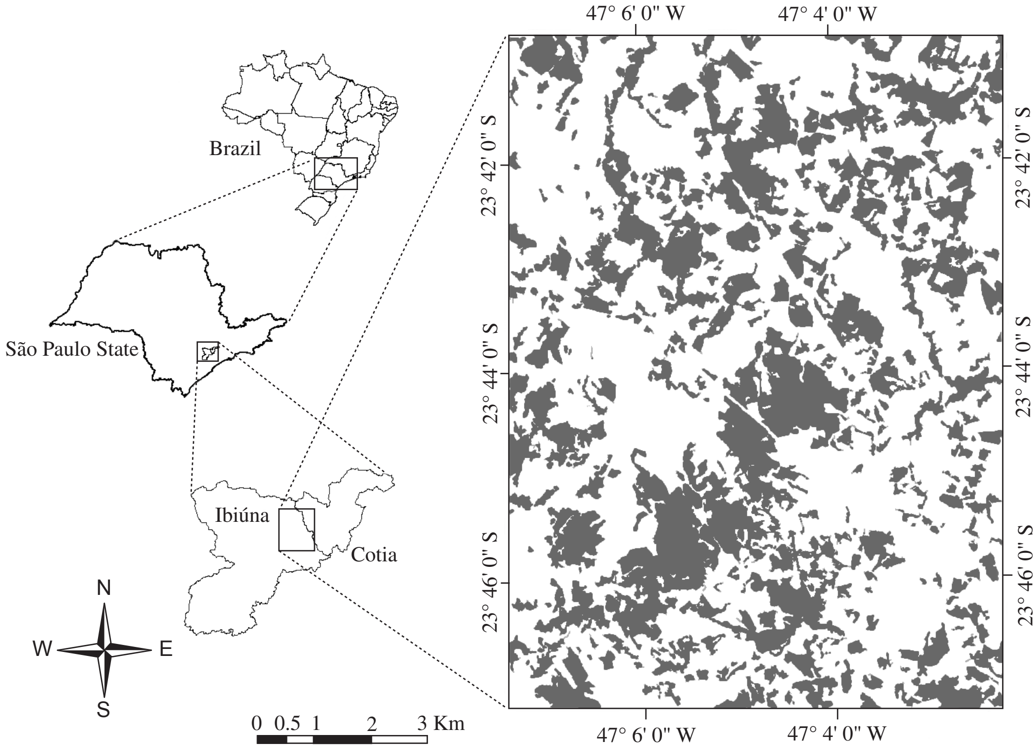

Figure 1. Map of forest cover (in grey) in the study area (Ibiúna Plateau, municipalities of Cotia and Ibiúna, SP).

age temperatures. The frequent occurrence of winds and mist characterizes the climate as relatively cold.

The original forest in the region has been classified as “dense montane forest” (Veloso et al., 1991) and can be considered as transitional between the coastal rain forest and the mesophyllous semidecidual forest of inland São Paulo State (Struffaldi-De-Vuono, 1985; Gomes, 1992; Aragaki and Mantovani, 1998). About 32% of the investigated landscape has forest cover, i.e. native vegetation at intermediate to advanced stages of succession (ca. 2,795 ha) defined by the Joint Resolution of SMA/IBAMA/SP-1 dated February 17, 1994. There is a prevalence of forests at an intermediate successional stage (18% of the landscape), which characterizes most of the forests investigated in this work. The most abundant tree species in these forests are *Guapira opposita, Clethra scabra, Casearia sylvestris, Myrcia multiflora, Matayba elaeagnoides, Rudgea jasminoides, Rapanea umbellata* and *Croton floribundus* (Bernacci et al., 2006).

The dynamics of deforestation and forest regeneration within the Caucaia region are strongly linked to the growth of the city of São Paulo, concerning both the supply of coal for power generation and the supply of agricultural products (Seabra, 1971). During the settlement of the village of Cotia in 1856, the Caucaia region essentially had small farmers. On the arrival of the Japanese immigrants, in the second half of the twentieth century, many subsistence crops were replaced by commercial activities, such as potato and tomato cultivation, fowl breeding and several other crops (fruits and vegetables), which accelerated the deforestation process. After the Second World War, the supply of coal to the city of São Paulo was substantially diminished, an opportunity for regeneration of vast forest areas thus being created (Teixeira, 2005). More recently, the easy access to the Caucaia region has led to an intense sub-urban expansion (e.g. division into lots, condominiums) as well as to the proliferation of leisure country houses, the deforestation rate increasing as a consequence.

3. Methods

3.1. Relief attributes

Relief attributes (altitude, inclination and orientation of the slopes) were based on 1:10,000 topographic maps (SEP 1979) and generated by geoprocessing. Initially, the contour lines, with an equidistance of 5 meters, were digitized on the computer screen, utilizing the Arcview GIS^{TM} software (*Environmental Systems Research Institute, Inc.*). After obtaining these data, maps of slope orientation (north, east, south, west), slope, and altitude were produced. Six regular classes were used to divide the maps of slope (classes of 5 grades: ≤5; 5.1 to 10; 10.1 to 15; 15.1 to 20; 20.1 to 25 and >25) and altitude (classes of 32 m: ≤891.89; 891.90 to 923.79; 923.80 to 955.69; 955.70 to 987.58; 987.59 to 1019.48; ≥1019.49).

3.2. Forest cover

Mapping of the successional stages of the vegetation was based on the interpretation of stereoscopic pairs of aerial photographs, from April 2000, on a scale of 1:10,000. Mirror stereoscopes (Leica, Wild ST4) and pocket stereoscopes (Opto-EB1) with magnifying glasses (2x) were utilized. The mapping was performed on a photographic mosaic and the polygons were digitized using the ArcView GIS™ software. Initially, four different successional stages, with predominance of arboreal features, were considered for the mapping of forest cover (Table 1). This classification was based on the definitions of secondary-succession stages from the Joint Resolution of SMA/IBAMA/SP-1 dated February 17, 1994, but with the limitation imposed by the aerial photographs, it essentially refers to the characteristics of the canopy (e.g. homogeneous/heterogeneous, open/closed, presence/absence of emerging trees). Once distinct formations or physiognomies can occur in very small areas, the classification of each polygon refers to the dominant pattern.

As a function of the restricted cover in the intermediate-advanced and advanced stages (Table 1, Figure 1), and of our low ability to distinguish, in the aerial photographs, these stages from the intermediate stage, these three classes were grouped. Thus, for the statistical analyses only two classes were taken into account: initial-intermediate and intermediate to advanced. The evaluation of the classification in the field was made based on visits to 65 places chosen at random within each successional category considered (25 points in areas at the initial-intermediate stage and 40 at more advanced stages). The final accuracy of the mapping was 88% (Table 2).

3.3. Hypotheses tests

The map with the two successional stages of vegetation considered here was laid on the maps of slope, slope orientation and altitude, and so the area and the percentage that each stage occupies in the different classes of the environmental maps could be determined. The expected area, considering a random distribution of the vegetation stages as a function of relief, should be equal to the total area of the stage in the landscape multiplied by the percentage of occupation of the class of relief considered. This percentage also corresponds to the expected percentage of cover of each stage in the class of relief, in case the distribution of the vegetation occurs independently of relief. To test the hypothesis of independence between the relief parameters and the successional stage of the vegetation, analysis of the qui-square (χ^2) (Zar, 1999) was utilized: $\chi^2 = \Sigma\, \Sigma\, (f_{ij} - \mathit{f}_{ij})^2/\mathit{f}_{ij.}$ The association between the variables of the table was evaluated, f_{ij} being the frequency observed for the intersection of line i with column j, and f_{ij} the frequency expected for this same intersection, considering a totally random distribution of the successional stages and of the relief classes.

4. Results

4.1.Slope

The slope values for the forest area in the Caucaia region were not very high (Table 3). There were practi-

Table 1. Cover of the different forest successional stages observed in the region of Caucaia do Alto (SP).

Class	Characteristics	Pattern in the aerial photograph	Area (ha)	%
Initial-Intermediate	Low arboreal vegetation and/or shrub-arboreal formation	Medium grain, heterogeneous pattern	746	9.55
Intermediate	Arboreal vegetation with rare emerging species	Average-to-coarse grain, pattern predominantly homogeneous	1.640	20.96
Intermediate-Advanced	Dense arboreal vegetation with occasional emerging species	Coarse grain, heterogeneous pattern	115	1.47
Advanced	Dense arboreal vegetation with common emerging species	Coarse grain, heterogeneous pattern	0.0006	0.05
Forest (total)	-	-	2501	32.03
Analyzed area	-	-	7822.30	

Table 2. Interpretation accuracy of forested areas in the aerial photographs of April 2000 (1/10.000, Ibiúna Plateau, SP; N = 65; Overall accuracy = 88%).

	Initial-intermediate stage	Intermediate to advanced stages	Total (photographs)	Accuracy (%)
Initial-intermediate stage	20	3	23	87
Intermediate to advanced stages	5	37	42	88
Total (field)	25	40	65	-
Accuracy (%)	80	93	-	-

cally no values above 25°, the classes lower than 20° prevailing (82.93% of the total area). The maximum slope is of 27.7°.

The presence of forest cover in the landscape of Caucaia do Alto was significantly related to the relief slope (Table 3). The forest cover observed is smaller than the one expected for the classes of lower slope (<10°) and larger than the one expected for the classes of higher slope (>10°). This tendency was particularly clear for the intermediate to advanced stages of succession, but it also repeats for the initial-intermediate stage of succession.

4.2. Slope orientation

The classes of south and west slope orientation were the most representative in the region, covering an area practically two times larger than the north and east faces (Table 4). There was no significant relationship between the presence of forest cover and the slope orientation (Table 4).

4.3. Altitude

The altitude modal values in the region vary from 890 to 924 m (Table 5), with a maximum amplitude of 192 m (860 to 1052 m). The highest areas, situated along the Caucaia faults, also corresponded to those with steeper slopes (for a group of 61 sampling points, Pearson correlation coefficient r = 0.376, P = 0.003; Silva, 2004).

Forest cover was significantly related to altitude (Table 5). There was less forest than expected in lower altitudes (<923.8 m) and more forest than expected in higher altitudes (≥923.8 m). This pattern was particularly significant for the intermediate to advanced stages.

5. Discussion

The results showed that, independently of the successional stage, forest cover was especially high in steeper areas (>10°) and/or at higher altitudes (>923 m), but there was no influence of the slope orientation. This spatial pattern may have been determined by two processes: i) forest regeneration, quite intense in the Caucaia region after the Second World War, could have been more rapid in higher terrain with steeper slope; and ii) the use of land for economic purposes is preferentially done in less declivous areas and at a lower altitude, leading to a more drastic reduction in forest cover in these situations.

5.1. Direct influence of relief on regeneration

The first explanatory hypothesis could be strongly based on natural processes of interaction between relief, soil and vegetation. These relationships might cause a

Table 3. Expected and observed percentages of forest succession stages as a function of the slope classes, and χ^2 test of independence between these two parameters.

Slope classes (grades)	Slope classes in the landscape (%) (expected percentages)	Percentage of vegetation per class of slope (observed percentages)		
		All stages	Initial-intermediate stage	Intermediate to advanced stages
0 to 5	28.10	14.11	19.72	12.83
5.1 to 10	32.08	21.63	21.52	21.75
10.1 to 15	22.42	30.03	30.83	30.05
15.1 to 20	9.98	18.19	16.46	18.58
20.1 to 25	4.29	9.21	6.74	9.65
>25.1	3.12	6.80	4.71	7.14
$\chi^2_{O,05,5}$	-	*29.69*	*15.55*	*33.50*
-	-	p < 0.001	p = 0.008	p < 0.001

Table 4. Expected and observed percentages of forest features as a function of slope orientation, and χ^2 test of independence between these two parameters.

Classes of slope orientation	Classes of slope orientation in the landscape (expected percentages)	Percentage of vegetation per class of slope orientation (observed percentages)		
		All stages	Initial-intermediate stage	Intermediate to advanced stages
Flat (<4 grades of slope)	22.34	14.66	21.24	13.28
North	14.00	14.47	14.77	14.58
East	13.57	14.15	18.97	13.45
South	26.48	27.22	20.63	28.45
West	23.60	29.49	24.38	30.26
$\chi^2_{O,05,4}$	-	4.17	3.56	5.73
-	-	p = 0.383	p = 0.468	p = 0.220

Table 5. Expected and observed percentages of forest features as a function of slope orientation and, χ^2 test of independence between these two parameters.

Classes of altitude (meters)	Classes of altitude in the landscape (%) (expected percentages)	Percentage of vegetation per class of altitude (observed percentages)		
		All stages	Initial-intermediate stage	Intermediate to advanced stages
≤892	25.26	8.47	17.94	6.23
892 to 924	40.94	24.50	34.48	22.24
924 to 956	21.79	31.31	25.67	32.94
956 to 988	7.67	21.88	9.87	24.00
988 to 1020	3.60	11.58	7.39	12.78
≥1020	0.71	2.23	4.62	1.80
$\chi^2_{0,05,\,5}$	-	69.19	29.98	88.45
-	-	p < 0.001	p < 0.001	p < 0.001

difference in the dynamics of secondary forest succession, permitting a more rapid regeneration of the forest under certain conditions. In the case of Caucaia, the regeneration could have been favored by steeper areas of higher altitudes.

The mechanisms of vegetation modification as a function of relief are still not well understood, because the environmental gradient is complex and includes many factors (Takyu et al., 2002). Taking into account the ecological processes, with the increase in altitude there is a decrease in temperature. As a consequence, the rates of organic matter decomposition are lower and the soils are poor in nitrogen and phosphorus (Tanner et al., 1998; Sanchez, 2001). The expected effects in the montane forests would be a decrease in the number of species and a reduction in the size of plants (Gentry, 1988; Sanchez, 2001; Wang et al., 2003). In principle the changes occurring with the increase in altitude, in particular a lower decomposition rate, should also reduce the rate of the regeneration process at higher altitudes, as compared with similar forests of the same age at lower altitudes (Kappelle et al., 1995; Pendry and Proctor, 1996; Sanchez, 2001). This, however, contradicts what was observed at Caucaia, where there were more forests at higher altitudes. The temperature factor, which is closely associated with differences in altitude, appears not to be having an effect on the landscape investigated, since the topographic amplitude is very small (192 m).

On the other hand, some of the highest areas of Caucaia are also the nearest to the Paranapiacaba Mountain Range (Serra de Paranapiacaba), where there is an extensive continuous forest that can be considered as a stable source of seeds for forest regeneration. Moreover, along with regeneration, a positive feed-back process should occur, since the larger the forest cover, the closer the sources of seeds. The combination of these two factors can favor the expansion of the forest cover at higher altitudes.

Surface inclination, together with latitude, time of the year and slope orientation promote a variation in the average insolation per area, which can be reflected in the structure and composition of the vegetation (Volpato, 1994; Turner and Corlett, 1996; Bertani et al., 2001; Pedroni, 2001; Takyu, 2002) and in the natural regeneration, as observed for secondary forests in the region of Viçosa, Minas Gerais (Volpato, 1994). In principle, steeper areas, situated on the northern slopes, would tend to receive more sun radiation, their regeneration thus being accelerated. The data on Caucaia showed an influence of slope, but not of slope orientation.

Nevertheless, an effective test of the hypotheses presented here, relating regeneration with altitude and slope, would demand historical data on forest cover that would allow one to date the forests and then to find out if the areas that started to regenerate simultaneously are developing at distinct rates. In spite of the strong evidence that the exploitation for coal was drastically reduced around 1950, which means that a significant part of the forest fragments might represent 50 years of regeneration, the analyses of the aerial photographs of 1962 (the oldest in the region) showed that the ages of the present forests are quite heterogeneous (Teixeira, 2005), a simplified analysis of the regeneration process not being possible. Furthermore, several other factors could have been influencing the regeneration, particularly the type of former soils and the proximity of sources of seeds (Thomlinson et al., 1996).

5.2. Human influence

The second explanatory hypothesis presupposes a fundamental role of man in the dynamics of the landscape, deforestation thus being the main controlling factor of distribution of the remaining forests. The first sign of the influence of the anthropic disturbance on the forest cover at Caucaia is the limited presence of vegetation at intermediate-advanced and advanced succession stages (<5% of the native vegetation in the region). Similar situations could be easily observed in areas of agricultural borders (Moran, 1994; Metzger, 2002), in landscapes intensively modified (Rao and Pant, 2001) or where the natural regeneration processes are controlled and avoided (Thomlinson et al., 1996). For instance, in the northeast of the State of Pernambuco, most fragments of the Atlantic Forest were located on the tops of small hills (50-100 m) surrounded by sugar cane fields at lower altitudes (Ranta et al., 1998), clearly indicating that the maintenance of fragments in these relief conditions was determined by land use.

If the hypothesis of the anthropic disturbance is correct, the most declivous areas in Caucaia, which also correspond to the highest areas, are of more difficult and costly use, either for farming or for other sorts of occupation. This has caused them to be more frequently abandoned for regeneration, although the declivities observed in Caucaia are not so high. The same pattern can be observed in other areas of the Atlantic Forest, as in the basin of Maquiné, State of Rio Grande do Sul, where the abandonment of the lands and further forest regeneration occurred preferably in more remote areas or in areas less appropriate for farming (Becker et al., 2004). In a similar way, in the semi-decidual montane forests of São José Mountain Range, Tiradentes (MG), the original cover was reduced to scattered fragments, most of them situated in areas whose topography makes their use difficult (Oliveira-Filho and Machado, 1993).

The same reasoning can be utilized to explain the absence of correlation between forest cover and slope orientation. This absence might be connected to the fact that slope orientation is not taken into consideration when choosing the areas to be deforested for agricultural ends. As there is no legal restriction concerning the protection of one or another slope direction, the farmers simply plant where the land is available.

Other alternative hypotheses can be suggested. The observed pattern of relationship might not be directly influenced by relief, but by the accessibility of the areas. Regions where the terrains are higher and rougher can also coincide with remote areas far away from roads or from urban areas and therefore more distant from possible sources of disturbance (Rao, 2001; Laurence, 2002; Santos and Tabarelli, 2002; Pereira, 2003). However, it is not possible to point out a direct effect of the proximity of anthropic areas (minor roads, asphalted roads, urban areas) on the occurrence of forests. The distances to these anthropic areas are similar in areas with or without forest cover, which indicates that the forest covers are similar, whether they are near or distant from the roads and urban areas (Table 6). This probably means that the access to the terrains and the outflow of the production are satisfactory, irrespective of the proximity of roads, so the largest forest cover in high and declivous areas is not related to a greater distance of such places from roads and urban areas.

One can also consider that the main factor conditioning the preferential distribution of the forests in higher and declivous areas is compliance with environmental legislation, in particular the Forest Code of 1965. This, however, does not seem to be the case of Caucaia, since there are no areas with more than 45° in slope, which would be included in the Areas of Permanent Preservation, and there is no tendency towards preservation of woods on top of hills (Diederichsen, 2003).

As these alternative hypotheses are not consistent to explain the present forest cover, the strongest probability is that the relief has influenced the choice of farming areas, thus determining the remaining forest cover. Small farmers also utilize declivous areas or areas with poor soils, owing to the unavailability of better soils, even though such areas are more costly, very fragile and less productive, mainly because of nutrient losses (Resende et al., 2002). The unavailability of better soils has occurred especially due to the division of inherited properties (Gomes, 1986). Some farmers from the north coast of the State of Paraná have conducted an undercover deforestation process as a strategy for maintaining the useful agricultural surface of the properties. The areas chosen are those of difficult access and consequently with a developed arboreal vegetation and no good conditions for planting (Neumann and Loch, 2002). At Caucaia, despite the fact that there is, under certain conditions, a secondary use of areas which are more declivous or not very appropriate for farming, there is a general tendency towards the preferential use of areas that facilitate exploration.

6. Conclusion and Implication

The relief attributes appear to be indirectly associated with the occurrence of forest cover when influencing human occupation. The greater the facility for current agricultural use, the smaller the extension of forest formations, irrespective of the successional stage. The result is an intense loss and forest fragmentation in less declivous areas, as also observed on a large scale for the whole Atlantic Forest region, where the largest fragments are

Table 6. Distances from dirt and asphalted roads and urban areas in places with or without the presence of forest at initial-intermediate to advanced stages.

	Places with forest		Places without forest	
	Average	**Standard deviation**	**Average**	**Standard deviation**
Asphalted road	1842.43	1251.50	1656.72	1263.91
Dirt road	354.41	261.42	267.46	239.52
Urban area	1173.52	669.31	1091.79	748.85

primarily within the areas of rough relief (Oliveira-Filho and Machado, 1993; Turner and Corlett, 1996; Ranta et al., 1998; Albuquerque, 1999; Gascon et al., 2000).

Although the pattern of a larger forest cover in areas of rougher relief is quite evident for the whole of the Atlantic Forest, the influence of relief has not yet been so evident on a local scale. At Caucaia, regardless of the small amplitude (192 m) and a slope no higher than 28°, relief has an evident influence, determining the agricultural occupation. As these forests in flatter terrains have species composition distinct from those of steeper areas (Silva et al. in press), strategies for conservation or restoration must try to compensate for their low representativeness in the Atlantic Forest landscapes.

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