LAND COVER CHARACTERIZATION AND LANDSCAPE METRICS FOR *ÁGUA FRIA* WATERSHED (PALMAS – TOCANTINS)

Alexandre Marco da SILVA[1]
Cleber Ibraim SALIMON[1]

Abstract

Assuming that there are no landscape level studies in Palmas (Tocantins), this paper aims to survey some landscape metrics of forest formation in a 16,764.2 ha watershed (called Água Fria watershed). By using the land cover map of the study area, some landscape metrics were computed. According to the results, we observed that only 21.4% of the whole area had original land cover and there was a high frequency of small patches in the landscape whereas large patches were rare. From the remaining forest vegetation just 24.4% is not affected by the edge effect. On the other hand, the shape index presented a value that indicates that the patches tend to have, generally, a near circular shape. The high degree of fragmentation is attributed to fire action that is used randomly and in a high frequency, specially at the dry season.

Key-words: edge effect; native forest fragmentation; geographic information system; landscape metrics; Palmas (Tocantins).

Resumo

Caracterização da cobertura do solo e métricas da paisagem para a bacia hidrográfica do Ribeirão Água Fria (Palmas-Tocantins)

Considerando a não ocorrência de estudos sobre Ecologia da Paisagem na região de Palmas (Tocantins), este trabalho objetiva levantar o valor de algumas métricas da paisagem dos remanescentes florestais de uma microbacia hidrográfica (denominada microbacia do Ribeirão Água Fria), de 16764,2 ha. Utilizando-se do mapa de cobertura do solo da área de estudo algumas métricas foram estimadas. De acordo com os resultados, foi observado que apenas 21,4% da área total era coberta por vegetação nativa e uma alta freqüência de fragmentos de pequeno porte, enquanto que fragmentos de grande porte ocorreram com raridade. Da área total ainda com vegetação nativa, apenas 24,4% não estava afetada pelo efeito de borda. Por outro lado, o índice de forma apresentou valores que indicam que os fragmentos possuem uma tendência geral de possuírem um formato próximo ao circular. O alto nível de fragmentação é atribuído à ação do fogo que ocorria ocasionalmente mas numa freqüência alta, especialmente na estação seca.

Palavras-chave: efeito de borda; fragmentação de vegetação nativa; sistemas de informação geográfica; métricas da paisagem; Palmas (Tocantins).

[1] Laboratório de Ecologia Isotópica – CENA – USP. Av. Centenário, 303. Piracicaba-SP. CEP 13400-970. e-mail: amsilva@cena.usp.br

INTRODUCTION

Landscape refers to a mosaic of heterogeneous vegetation types, shapes and land use (METZGER, 1999). The holistic and transdisciplinary approach adopted by landscape ecology distinguishes it as unifying science, able to promote the integration and interrelationship of both natural and social aspects of the environment, and the understanding of interactions, leading to a global perception of the situation and comprehensive conclusions (METZGER et al., 1998).

Landscape ecology revealed itself to be an excellent tool for promoting the required integration towards practical applications (HOBBS, 1997), and this science, which had been restricted to the academic world, became more widespread since then, coming out of the research centers to practical life, especially at the regional planning scale (METZGER et al., 1998) and for restoration ecology purposes (HOBBS, 1997).

Landscape metrics quantify the pattern of the landscape within the designated landscape boundary only. Consequently, the interpretation of these metrics and their ecological significance requires an acute awareness of the landscape context and the openness of the landscape relative to the phenomenon under consideration (McGarigal et al. 2002).

The common usage of the term "landscape metrics" refers exclusively to indices developed for categorical map patterns (like land use map). Landscape metrics are algorithms that quantify specific spatial characteristics of patches, classes of patches, or entire landscape mosaics (MCGARIGAL et al. 2002). These landscape metrics are useful specially to quantify the structure of the landscape and the spatial relationship between distinctive patches (HOBBS, 1997).

The landscape ecology approach in Brazilian science started with biogeographers, around 1960, and remained to a few groups for 2-3 decades (METZGER et al. 1998). In São Paulo state, the fragmentation processes of the native vegetation in some watersheds have already been investigated. On this context, Toledo (2001) studied the relation between the vegetation fragmentation and the quality of the superficial water of two catchments located in Piracicaba (SP). Jorge; Garcia (1997) studied the fragmentation of the vegetation and its relation with the edge effect in a watershed located in Rio Claro and Piracicaba (SP).

In the Amazon region, where the deforestation rates have been significant (INPE, 2003), studies about fragmentation and landscape metrics have been done (KAPOS et al, 1997; PEREIRA et al., 2001).

Nevertheless, in the Tocantins state, located in southeastern Amazon there is no research related to landscape ecology yet. Its capital, Palmas, has presented high rates of human population increase; about 28% per year, between the 1994 and 1998, according to I.B.G.E. (2000) web site and urban areas have expanded greatly. This population increase leads to deforestation and habitat and biodiversity loss (DALE; PEARSON, 1997) and the local community has observed excessive burning activities and a diminution of the presence of the wildlife.

Considering the inexistence of information about landscape metrics for the Tocantins state, more specially for Palmas region, the goal of this paper was to survey and to evaluate some landscape metrics for Água Fria watershed, located in Palmas - Tocantins – Brazil. This type of study is important for future landscape management and planning for this urban area.

METHODOLOGY

Study area

This study was carried out at the Água Fria watershed. The Água Fria watershed is fully located in Palmas, the capital of the state of Tocantins, the newest state of Brazil. This watershed occupies about 9% of total municipal area. The geographical coordinates of watershed are: 48°16' - 48°23' west longitude and 10°03' - 10°20' south latitude (Figure 1).

This watershed has 16,764 hectares and its main river (Água Fria) is a 3rd order river that flows towards the Tocantins River. At west of the study area is the Tocantins River and at east there is the Lajeado's hill (SILVA, 1999). The main type of vegetation occurring in this watershed is the "Cerrado" (savanna), also occurring riparian forests along the streams of the watershed (RADAMBRASIL, 1981). The classification of the subcategories of this type of savanna followed Rizzini; Coimbra Filho (1988).

The edge of the watershed that is contiguous to the urban zone is constituted of plains and fluvial terraces (at west), where periodical floods can occur. This area, located at the shore of the Tocantins River, containing planes surfaces with smoothed dissections, has recently been inundated by a reservoir for electricity generation. Also there are areas where the relief presents planed tops above Pre-Cambrian lithology, among other geological basis. Also, steeped areas occur on Lajeado's hill (RADAMBRASIL, 1981).

Procedures

Land cover mapping

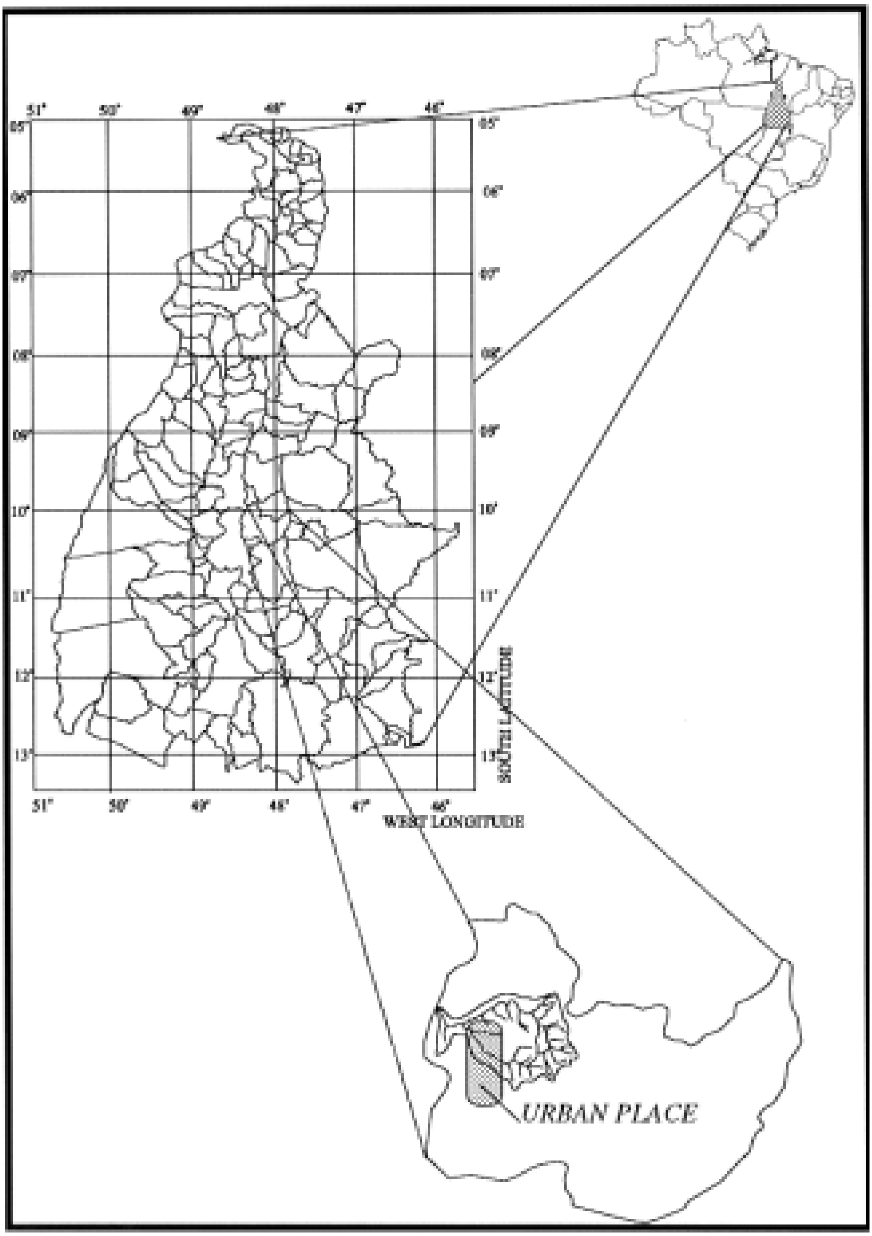
Land cover map was obtained from Silva (1999). This map was made from a color composition of a Landsat-5 thematic mapper image (TM3, TM4 and TM5 bands) of august / 1998 and it has eleven land cover classes. Using the "reclass" command of the Idrisi software (EASTMAN, 2001), the "forest vegetation" class was isolated from the other classes. With this new layer, we created a map containing only the vegetation remaining in the study area, shown on the figure 2.

Landscape metrics

The land cover map shown in figure 2 was used to compute the landscape metrics, by utilization of the Fragstats software (MCGARIGAL et al., 2002). The following metrics were computed: total forested area, number of patches, mean area, patch density, patch division index, fractal dimension. All of these metrics, as well as many others (equations, range of values, concepts, and other considerations), are totally explained and available on Fragstats' website (MCGARIGAL et al., 2002).

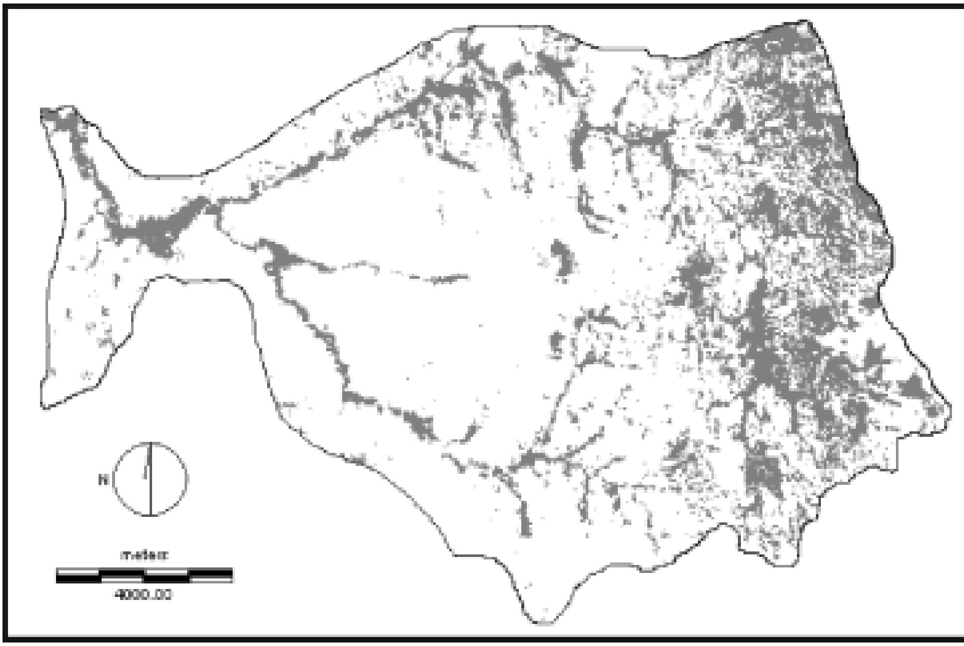
By using the "buffer" module in Idrisi, we calculated the proportion of the forested area that is affected by the edge effect and the proportion that is not (that is, the core area of the fragment). For this calculation we assumed a 30m edge effect. We chose this value because the pixel spatial resolution of the satellite image is 30m.

Figure 1 – Localization map showing the Tocantins state, the region of Palmas and the study area (Água Fria watershed), as well as the urban place of Palmas.



Source: Silva (1999).

Figure 2 – Map showing the native forest vegetation remaining along the study area



RESULTS AND DISCUSSION

Land cover map

Table 1 shows the area and percentage of each land cover type for the study area in 1998. It can be seen that the man-made alteration is high. Just 21.4% of the whole area is covered by native forest. According to Silva (1999 and 2001), these areas covered by forest are mainly riparian and/or steeped sites.

In spite of the fact that Palmas is a planned city, the environmentally correct land occupation has occurred just on the central area of the city. At the edge of the urban perimeter, the chaotic occupation and development are easily noticed. Silva (1999) noticed that vegetation burning on dry season is the human management that most directly affects land cover change.

The land cover map shows that land use in the watershed is not well defined. Only in two parts of the study area the land use is effectively defined: 1) on urban area, because there is the planning of urban development, and 2) on the high parts of the watershed, because there is the project of the “APA do Lajeado” (Area for Environmental Protection). However, in some parts of the APA’s region, we notice that the land cover management is incorrect and the land cover is already with drastic alteration (SILVA, 2001).

Table 1 – Land cover in Água Fria watershed in 1998

Land cover class	Area (ha)	Proportion (%)
Forest	3,595.397	21.447
Water bodies	27.325	0.163
Green urban gardens	96.729	0.577
Builds-up	56.663	0.338
Roads	60.183	0.359
Bare soil	196.811	1.174
Dirty field	3,937.887	23.490
Clean field	4,350.452	25.951
Bare rock	289.516	1.727
Burnt area	1,113.974	6.645
Sparse field	3,039.164	18.129
Total	16,764.191	100.000

Source: Silva (1999).

The classes "dirty field", "clean field" and "burnt area" occupy jointly 56.1% of the watershed and there is no agricultural land use. This fact shows that in spite of the removal of the pristine vegetation (mainly by the fire – personal observation), there were no clear intentions of use.

Landscape metrics

Table 2 shows landscape metrics for Água Fria watershed. The total area occupied by fragments was 3,595.4 hectares. The total number of patches was 2,279 and the density of patches was 9.0 patches km^{-2}. Jorge; Garcia (1997) found values of 0.7 and 1.1 patches km^{-2} in a watershed located in São Paulo state (Southeastern Brazil). This difference between the present paper's value and the Jorge; Garcia's shows that the native vegetation seems to be more impacted in São Paulo than in this study area. On the other hand, the areas cleared in São Paulo tend to be used more efficiently, since much of the area burnt in Palmas is abandoned afterwards.

The number of patches found on this study (2,279) is higher than that found by Toledo (2001) for the Cabras watershed (374) and for Piracicamirim watershed (572), probably because of the same reasons early commented about the area studied by Jorge; Garcia (1997).

The mean patch area was 11.056 hectares. The sum of the area of all patches smaller than the average value corresponds to 25.2% of total forested area. According to Valente (2001), for this size of patch, the majority of species of mammals become susceptible to extinction, because they require a minimum area of 100 hectares to live, while for birds the minimum area is near of 10 ha and for insects the minimum area is 1 ha. This result shows that only two patches have an appropriate area for the survival of mammals (Table 3).

Table 2 – Indicators of native vegetation fragmentation

Landscape metric	Values
Total area (ha)	3,595.397
Number of patches	2,279.000
Mean area (ha)	11.056
Shape index	1.170
Patch density (patches/100ha)	9.044
Patch division index	0.607
Fractal dimension	1.024

The shape index value was 1.170. This value is smaller than that found by Toledo (2001) for Cabras watershed (1.66) and for Piracicamirim watershed (1.71). According to Viana; Pinheiro (1998), when a patch has a shape value higher than 0.8, the patch can be considered near to circular shape and the edge effect tends to be smaller.

The patch division index was 0.6. According to McGarigal et al. (2002), division index tends to be zero when the landscape consists of a single patch. On the other hand, this index approaches to 1 when the focal patch type consists of single, small patch one cell in area. As the proportion of the landscape comprised of the focal patch type decreases and as those patches decrease in size, division index approaches 1.

Table 3 – Number of patches according to class of patch area

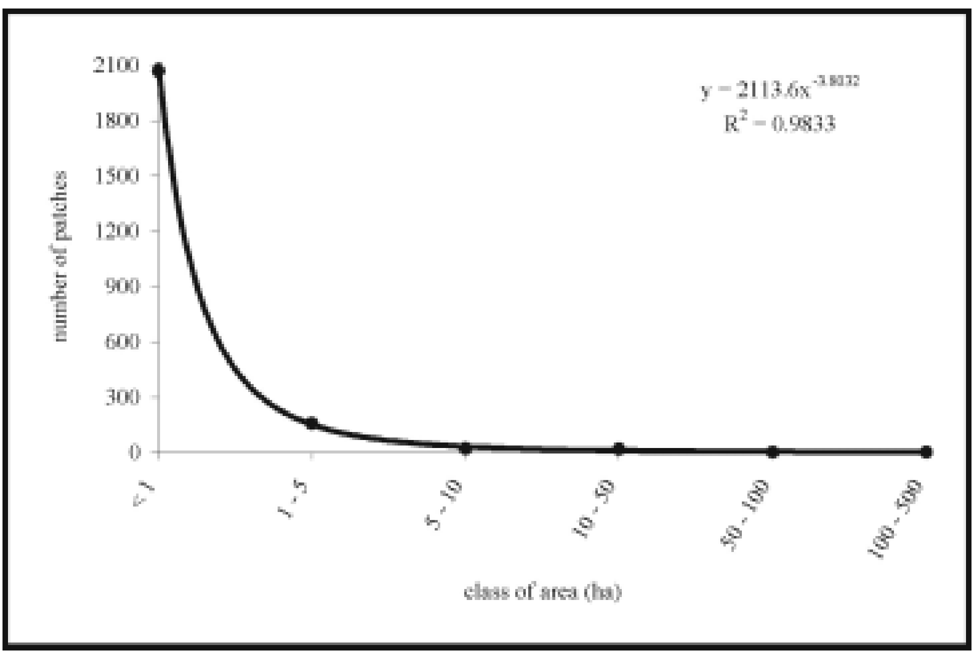
Class of patch area (ha)	Number of patches
<1	2070
1 – 5	159
5 – 10	23
10 – 50	20
50 – 100	4
100 – 500	2

Fractal dimension value was 1.02, a little smaller than those found by Jorge; Garcia (1997) (1.30 and 1.33). According to Metzger (2001), the fractal dimension is a system that keeps the same characteristics/properties through the different scales. For McGarigal et al. (2002), for simple Euclidean shapes (e.g., circles and rectangles), the relation between the length of the perimeter divided by the square of the area is approximately 1 (the dimension of a line). As the polygons become more complex, the perimeter becomes increasingly plane-filling and P ˜ A with D ? 2 (where P = perimeter; A = area and D = fractal dimension). According to this affirmation and by comparison, it can be concluded that the patches of this study area are less complex than the ones studied by Jorge; Garcia (1997), since our values are smaller.

Figure 3 shows the relationship between class of area and number of patches for the study area, and these numbers are exposed on table 3. It can be seen that the number of small patches is very high and this number decreases as the patch area increases. The relationship observed can be expressed by the equation cited on the figure 3.

We verified that the proportion of the forested area that is affected by the edge effect was 75.6% and just 24.4% is not under the edge effect (is located in a core area). These data suggest that the major part of the forests probably have already lost their original design, structure, dynamics and processes, although the actual edge effects (direct and/or indirect effects – biologic or abiotic) are not clearly evidenced, according to Murcia (1995).

Figure 3 –Relationship between class of area and number of patches for the study area



CONCLUSION

Based on these results, it can be concluded that:

- Just 21.4% of whole area has pristine forest vegetation.
- The study area does not have a defined pattern and purposes of land use. Since fire is the main “technique” used to clean soil surface, land cover shows a relatively high degree of alteration, because usually fire is recurrent before the native vegetation is fully regenerated, since fire frequency is high.
- There was a high frequency of small patches in the landscape whereas large patches were rare, which deeply affects the majority of wildlife species.
- Only 24.3% of the remaining forest vegetation is not affected by the edge effect.

REFERENCES

DALE, V. H.; PEARSON, S. M. Quantifying habitat fragmentation due to land use change in Amazonia. In: LAURANCE, W. F.; BIERREGAARD Jr., R. O. **Tropical Forest Remnants**: Ecology, Management, and Conservation of Fragmented Communities. Chicago: The University of Chicago Press, 1997, p. 400-409.

EASTMAN, J. R. **Idrisi32 - Release 2:** Tutorial. Worcester: Clark University, 2001, 224p.

HOBBS, R. Future Landscapes and the future of Landscape Ecology. **Landscape and Urban Planning**, Amsterdam, v.37, n.1, p.1 –9, 1997.

I.B.G.E. (Brazilian Institute for Geography and Statistic). **Website:** <www.ibge.com.br>, consulted in 2002.

JORGE, L. A. B.; GARCIA G. A study of habitat fragmentation in Southeastern Brazil using remote sensing and Geographic Information Systems (GIS). **Forest Ecology and Management**, v. 98, n. 1, p. 35 – 47, 1997.

KAPOS, V.; WANDELLI, E.; CAMARGO, J. L.; GANADE, G. Edge-related changes in environment and plant responses due to forest fragmentation in Central Amazonia, In: LAURANCE, W. F.; BIERREGAARD Jr., R. O. **Tropical Forest Remnants**: Ecology, Management, and Conservation of Fragmented Communities. Chicago: The University of Chicago Press, 1997, p. 33-44.

METZGER, J. P., Estrutura da Paisagem e Fragmentação: Análise Bibliográfica. **Anais da Academia Brasileira de Ciências**. Rio de Janeiro, v.71, 1999, p.445 – 463.

METZGER, J. P. O que é Ecologia de Paisagens? **Biotaneotropica**, Campinas, v. 1, n. 1/2, 2001, Website address: www.biotaneotropica.org.br (electronic journal).

METZGER, J. P.; PIVELLO, V.; JOLY C. A. Landscape Ecology Approach in the Conservation and Rehabilitation of Riparian Forest Areas in S.E. Brazil. <http://www.brocku.ca/epi/lebk/metzger.html>, 1998.

McGARIGAL, K., CUSHMAN, S. A., NEEL, M. C.; ENE, E., **FRAGSTATS:** Spatial Pattern Analysis Program for Categorical Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. 2002, <www.umass.edu/landeco/research/fragstats/fragstats.html>.

MURCIA, C., Edge effects in fragmented forests: implications for conservation. **Tree**, Amsterdam, v.10, p.58 – 62, 1995.

PEREIRA, J .L. G.; BATISTA, G. T.; THALÊS, M. C.; ROBERTS, D. A.; VENTURIERI, A. Métricas da Paisagem na caracterização da evolução da ocupação da Amazônia. **Geografia**, Rio Claro, v. 26, n.1, p. 59–90, 2001.

RADAMBRASIL, PROJETO, 1981. **Levantamento dos recursos naturais**. Volume SC 22 – Tocantins.

RIZZINI, D. T.; COIMBRA FILHO, A. F., 1988 **Ecossistemas Brasileiros**. Rio de Janeiro: Index, 1988, 200p.

SILVA, A. M. **Aplicações de técnicas de geoprocessamento no estudo das relações entre os processos erosivos e sedimentológicos de bacia hidrográfica**. Tese (Doutorado em Ciências da Engenharia Ambiental). Escola de Engenharia de São Carlos, São Carlos-USP. São Carlos–SP, 1999. 249p.

SILVA, A. M., Conflicts of the land cover / land use with relation to slope occurring on Água Fria watershed (Palmas, TO – Brazil). **Revista de Estudos Ambentais**, Blumenau, v. 3, n. 1, p. 111–119, 2001.

TOLEDO, A. M. **Evolução espaço-temporal da estrutura da paisagem e sua influência na composição química das águas superficiais dos ribeirões Piracicamirim e Cabras (SP). Piracicaba-SP-Brazil**. Dissertação (mestrado em Energia Nuclear). CENA-USP. Piracicaba-SP, 2001, 94 p.

VALENTE, R. de O. A., 2001. **Análise da estrutura da paisagem na bacia do Rio Corumbataí, SP**. Dissertação (mestrado em Ciências Florestais). Esalq-USP. Piracicaba-SP, 2001, 144p.

VIANA, V. M.; PINHEIRO, L. A. F. V. Conservação da biodiversidade em fragmentos florestais. **Série Técnica IPEF**, Piracicaba, v. 12, p. 25 – 42, 1998.

Recebido em junho de 2003
Aceito em julho de 2004