ENVIRONMENTAL QUALITY IN URBAN FORESTS IN CAMPINAS – SÃO PAULO STATE/BRAZIL

REGINA MARCIA LONGO, ALESSANDRA LEITE DA SILVA, SUELI DO CARMO BETTINE, ANTONIO CARLOS DEMANBORO, ADRIANO BRESSANE, FELIPE HASHIMOTO FENGLER & ADMILSON IRIO RIBERIO
Urban Infrastructure Systems, Pontifical Catholic University of Campinas, Brazil.

ABSTRACT
The process of ecosystem fragmentation causes three types of changes in the ecosystem: changes of abiotic, direct biotic and indirect biotic nature. Among these changes, some of them are the microclimatic alterations, edge effect, decrease of the gene flow and losses of biodiversity, among others. In this way, the present study aimed to evaluate the environmental quality of forest remnants in a highly urbanized area through environmental indicators and landscape metrics, such as total area, circularity index, shape of forest fragments, nuclear area, connectivity between them, use and occupation around and distance from the nearest neighbor. The indicators were evaluated according to the methodologies established in the literature and grouped into an index to determine the environmental quality of each forest remnant. The index consisted of the sum of the weighted values for each indicator, according to its classification. The results indicate that most forest remnants evaluated in the study area present medium environmental quality, which demonstrates the degree of edge effect to which they are submitted, and this emphasizes the need for appropriate management actions in these areas, in order to soften such external pressures and ensure long-term sustainability. In addition, it was also identified that the metrics related to the area are essentially important for the determination of the environmental quality of forest remnants.
Keywords: environmental indicators, forest remnants.

1 INTRODUCTION

Fragmentation refers to the process of transformation of the original forest matrix into isolated areas of remnant vegetation, commonly referred to as forest fragments [1]. Deforestation and fragmentation in addition to the reduction of natural habitat size lead to changes in the remaining habitat [2]. According to references [3] apud [2], changes caused by edge effects have three distinct natures: abiotic, direct biotic and indirect biotic.

Among the changes of an abiotic nature, microclimatic changes stand out [2]. According to references [4] apud [5], the forest microclimate is the one that characterizes the environment covered by treetops to the ground, presenting different meteorological characteristics. When subjected to increasing wind incidence, solar radiation and humidity reduction, from direct contact with the external environment, the peripheral areas of the fragments will undergo modifications and greater sun exposure, altering their microclimatic condition and may even cause changes in the macroclimatic patterns [1, 6, 7].

A study by Sampaio pointed out the existence of a microclimatic gradient in the edge–center direction, in which the edge effect is attenuated as it enters the forest, indicating, on average, that from 50 m from the edge of the fragment, the edge effect on the microclimate begins to be smoothed. It should be noted, however, that the neighborhood has significant influence on this aspect. In this way, the fragments whose environment has highly contrasting characteristics to the forest will present greater distances of penetration of this effect [5].

ISSN: 2398-2640 (paper format), ISSN: 2398-2659 (online), http://www.witpress.com/journals
DOI: 10.2495/EI-V2-N2-117-130

Regarding the direct biotic modifications, the most studied and cited modifications in the literature concern the changes in the distribution and abundance of the species [2]. Both the fragmentation phenomenon and the increase in the marginal area subject to the edge effects lead to the reduction of the area of the 'habitat of the interior' that is favorable to the species [8]; this leads to a decrease in populations since many species that require larger habitat areas will not survive in small fragments with low food availability, for example [7] and [9].

This is a factor that leads to the third type of change resulting from the fragmentation of the forest ecosystem: indirect biotic change, manifested mainly through changes in the interactions between organisms [2]. Due to the increased distance between forest fragments, the possibility of colonization of certain species and dispersal ability can be greatly altered [8]. Studies carried out by Bierregaard et al. [7] pointed out that vegetation ruptures of at least 80 m already imply strong isolation and barrier sufficiently large for some species of insects, mammals and some birds. Consequently, there is a change and elimination of the original ecological relationships between plant species, pollinators and dispersers [10].

However, what is worth mentioning is that the remaining vegetation areas exert a significant influence on the conditions of environmental and living quality of the environments and of populations living in urban spaces [11–13]. In this context, these areas play a fundamental role, promoting social, esthetic and ecological contributions to the mitigation of environmental impacts resulting from the urbanization process [14].

Among the functions performed by these areas, their significant contribution to the conservation of regional flora diversity and/or biodiversity support, acting as 'ecological trampolines', in the case of small fragments is the major one [6, 15, 16]. In addition, they contribute to the equilibrium of the humidity, promote attenuation of air pollution through the production of O_2 and reduction of carbon dioxide, promote the adsorption of pollutant particles and guarantee and, in this way, improve the air quality [11, 13, 14, 17]. They also influence the quality and quantity of water in the watershed, promote interception of rainwater, reduce the percentage of surface runoff, favor the control of erosive processes, contribute to flood control and also promote the protection of water catchment areas and water resources in general [13–15].

Studies [18] pointed out that not only the proportion of forested areas but also the spatial distribution of these areas is significantly important for maintaining the environmental quality of ecosystems. Therefore, promoting the correct management and recovery of forest fragments raise their potential as islands of biodiversity, increasing the gene flow and promoting the restoration of biodiversity in highly fragmented landscapes, such as urban landscapes [19, 20].

In this sense, the present study promoted an analysis of the environmental quality of vegetation fragments in a basin through landscape indicators and metrics together with the spatial analysis, in order to diagnose the remaining vegetation areas, identifying the priority areas for recommending actions of environmental management and recovery.

2 MATERIALS AND METHOD

The study area covered in the present work was the Anhumas River Basin in Campinas – State of São Paulo/Brazil, where: UTM Zona is 23 S, from 7,462,827 to 7,482,500 N and from 282,500 to 296,870 L. This covers an area of approximately 150 km², as shown in Fig. 1.

The watershed is located in a tropical climate region called Tropical Central Brazil [21], under the Atlantic Forest biome, with a small portion of Brazilian Cerrado area and soils predominantly classified as Latosols and Argilossos soils [22]. After the general characterization of the Anhumas River Basin by means of information on geographic location, biome,

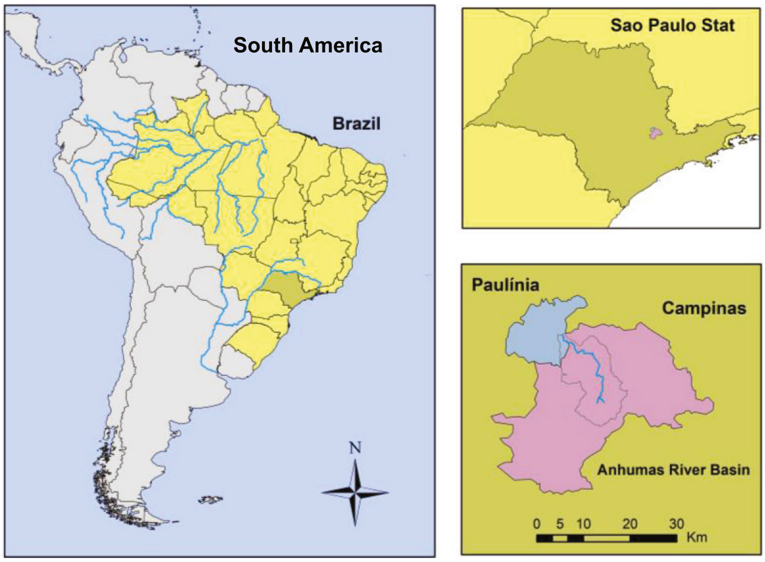


Figure 1: Geographic location of Anhumas River Basin.

pedology and land use and occupation (Fig. 2), the forest fragments were mapped and the landscape metrics were analyzed, as presented in Fig. 2.

Table 1 presents a brief description of the indicators used to calculate the environmental quality of forest fragments. These were calculated for the three regions of the basin: high, medium and low course of the basin.

Using these indicators, the Environmental Quality Index was calculated by summing the weighted values associated with the indicators, for each remnant and according to their classification (Table 2) and fragments [31].

The value obtained from this sum was normalized and classified according to Table 3 [31].

To analyze the data, a correlation matrix was also constructed in order to identify the most strongly correlated indicators. The correlation matrix presents the set of coefficients *r* that evaluate the correlation between the indicators, in pairs. The coefficient *r*, a dimensionless value that varies between −1 and 1, indicates negative (−1), positive (+1) or null (0) correlation between the two variables. However, because these extreme values are difficult to find, some considerations are taken to evaluate the degree of correlation between these variables, with values between 0.10 | and | 0.30 | indicating a low degree of correlation; between | 0.40 | and | 0.60 | indicating a moderate degree of correlation; and between | 0.70 | and | 1.00 | indicating a strong degree of correlation. Principal component analysis (PCA) was also performed to identify the indicators to be determined in the characterization of these fragments.

3 RESULTS AND DISCUSSION

Preliminary mapping of forest remnants in the Anhumas River Basin identified 128 fragments classified as forest and/or reforestation areas in the study area [32]. The high number of fragments in a relatively small area, such as this river basin, indicated an intense process of fragmentation of the landscape. It is worth remembering that, according to the definition of

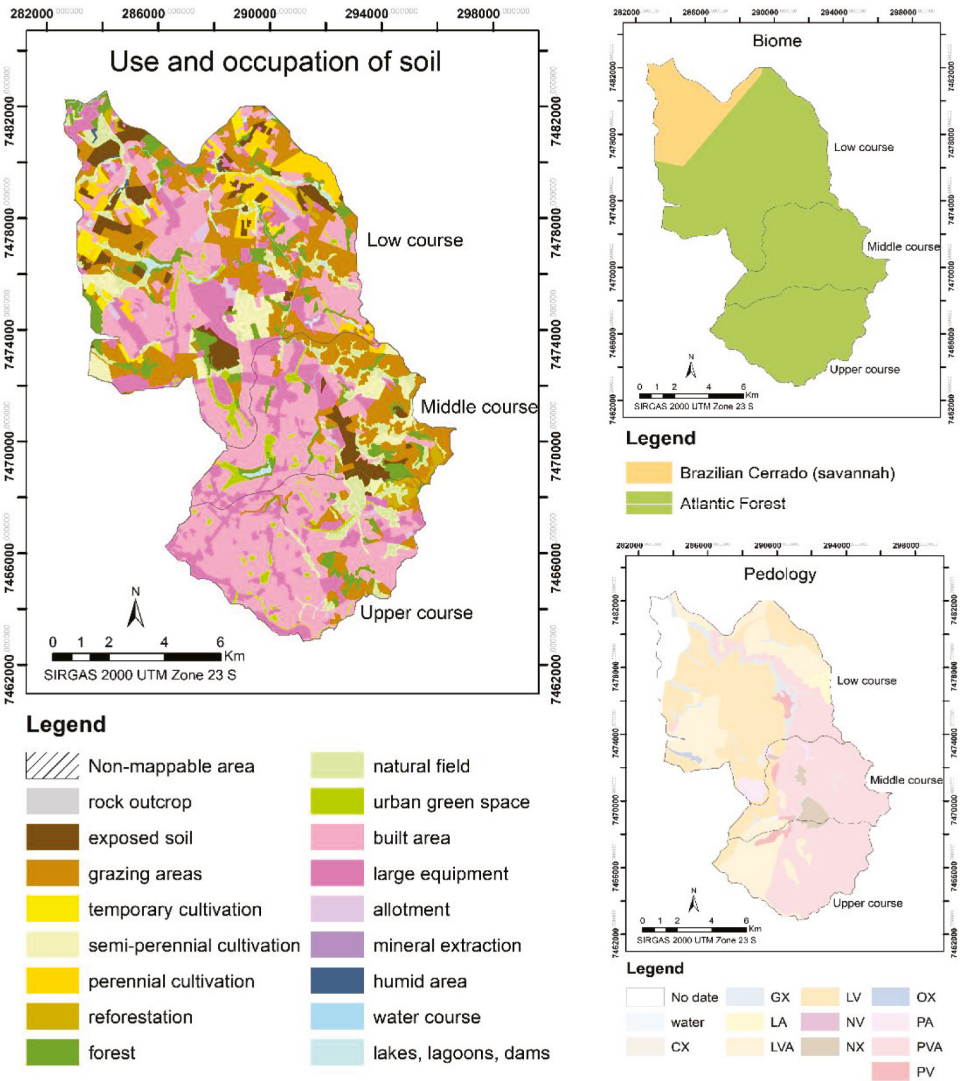


Figure 2: Biome, pedology and use and occupation of soil in Anhumas River Watershed.

the Brazilian Ministry of the Environment [2], fragmentation is precisely the phenomenon of division or fractionation of a previously continuous landscape or habitat. When fragmented and isolated, these areas present little resemblance to the original balanced habitat and begin to interact more effectively with the diverse environments in the environment. In this way, they become even more vulnerable to the edge effect, intensifying habitat alterations and increasingly characterizing that environment [5, 33].

Regarding the size, total area, of each fragment, it was verified that there is a great variation in each region of the watershed. Although there are fragments ranging from 0.36 ha of area (high course) to fragments with little more than 65.0 ha (low course), in all regions of the basin (high, medium and low course), there is a predominance of intermediate fragments,

Table 1: Indicators and landscape metrics.

Indicators and landscape metrics	Characteristics	Calculate
Total area	Parameters related to the diversity and richness of species in the remaining areas. Fragmented forest areas may become too small to house certain species that need more extensions to survive [1, 16, 23]	Area of each fragment (ha)
Circularity index	Used to identify the degree of proximity of the shape of the forest remnant with that of a circumference (circumference: the edge area is minimized in relation to the total area) [24, 25]	$CI = \frac{\left(2.\sqrt{\ \ .A}\right)}{L}$ CI = circularity index *A* = fragmentation area (m²) *L* = length of fragmentation (m)
Shape of forest fragments	The closer to 1 the index was, the more circular was the remainder; on the other hand, distant indices of 1 represent fragments of more elongated shape [26]	Classification through *circularity index in:* CI < 0.65: elongated 0.65–0.85: moderately elongated CI > 0.85: rounded
Nuclear area	Central area of the fragment when it is excluded the edge band, that is, the one more subject to the anthropic actions and other external actions [1, 27]	The value of this range of edge effect varies in the literature from 20 to 100 mValue adopted: 60 m
Connectivity	Presence or absence of intersections between two or more fragments [28 apud 29]	Evaluated through the generation, in GIS software, of buffers of 175 m from the edge of the remnants
Use and occupation around	Classification by [18]: **Class 0:** Unmodified **Class 1:** Minor modification **Class 2:** Medium modification **Class 3:** High modification **Class 4:** Very high modification	Evaluation of the surrounding areas (surrounding radius: 175 m) and classification according to the intensity of the natural landscape
Distance from the nearest neighbor	It is a metric related to the remnant isolation that indicates the Euclidean distance (in meters) from the center of a forest fragment to the center of its nearest neighbor. This metric helps to understand the connectivity of the landscape, since from a certain degree of isolation, the biological populations of the fragments begin to present losses in terms of biological flow [27, 30]	Evaluated, in GIS software, through the proximity tool 'near'

Table 2: Criteria for assessing indicators in forest fragments.

Area (ha)		Circularity index (CI)		Nuclear area* (%)		Connectivity		Use and occupation around	
<0.50	0	<0.65	3	<5	0	No	3	Class 4	1
0.50–1.00	1	0.65–0.85	7	05–20	2	Yes	10	Class 3	3
1.00–5.00	5	>0.85	10	20–40	4			Class 2	5
5.00–20.00	8			40–60	6			Class 1	8
>20.00	10			60–70	8			Class 0	10
				>70	10				

* Percentage in relation to the total area of the fragment.

Table 3: Criterion for classification of the environmental quality.

Score Qf	Environmental quality
0.00–0.20	Very low
0.20–0.40	Low
0.40–0.60	Mean
0.60–0.80	High
0.80–1.00	Very high

with area up to 10 ha, as shown in Fig. 3a. In this context [34], it also highlights that the fragments with an area of less than 1 ha present a high proportion between edge perimeter and area and are therefore most susceptible to external interference.

Although a small number of fragments were classified as ‘good’ or ‘suitable’ (i.e. with area greater than 5.00 and 20.00 ha, respectively, according to reference [29]), it was found that the sum of the areas covered and the total area covered by medium-sized fragments (between 1.00 and 5.00 ha) is high. Pirovani et al. [16] performed the same verification by observing that the relationship between the number of fragments and the area they occupy is inversely proportional; that is, although fragments of class of small size present larger number of spots, the greater representativeness of forest areas comes from larger fragments.

With respect to the circularity index, Fig. 3b shows the large amplitude between the maximum and minimum values of the indices found in each region of the basin. Despite this, it was evidenced that there are no fragments with extremely low indices; however, a few fragments were those with high indices and most present intermediate indices. It is worth remembering that the circularity index analyzes the similarity of the shape of the fragment to a circular shape that, given its regularity, guarantees greater distance from the edges in relation to the center; therefore, values closer to 1 indicate, a priori, greater protection to the nuclear areas of the fragments. Thus, more than 50% of the fragments in each region of the river basin can be classified as moderately elongated, according to reference [31] and presented in Fig. 3c.

It is also emphasized that the association between reduced area and irregular shape is one of the main causes for the decrease of the nuclear area in the forest fragments [8]. In this way, these are essential indicators for the management and monitoring of forest fragments, especially those under high pressure, such as urban remnants [31]. Sampaio [5] emphasizes that

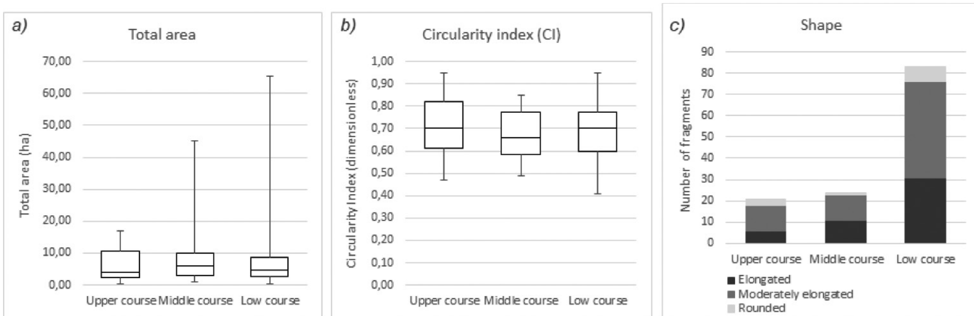
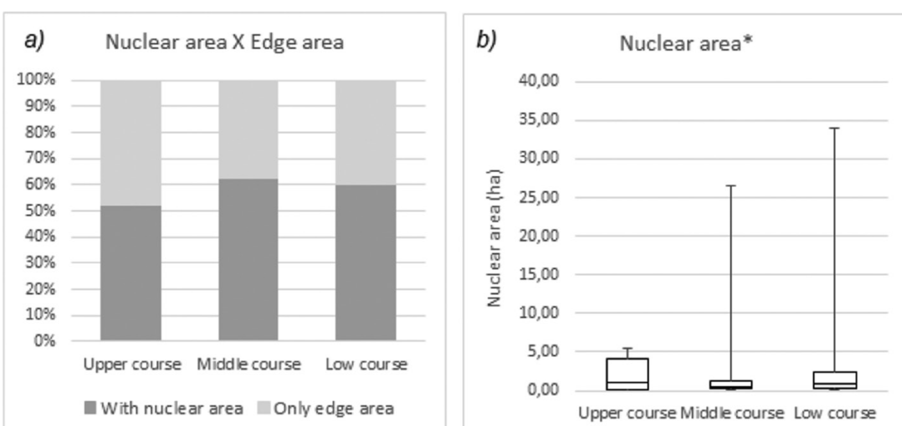


Figure 3: Results related to total area, circularity index and shape.

in cases where the proportion between the areas is affected by the edge effect, i.e. the edge/ interior area is high, the correct management of these fragments is indispensable, aiming, in particular, to soften the edge effect and enable the increase of the effective area of habitat for the species.

In this context, Fig. 4a shows the percentage of forest fragments that present nuclear area in detriment to those that do not present nuclear area (due to their reduced area and/or elongated shape) and consist entirely of border area, suffering from the edge effects. The results show that between 40% and 50% of the fragments have no nuclear area. In addition, among those with a nuclear area, in at least 75% of cases, this area does not exceed 5.00 ha (Fig. 4b). As identified by [27] in the Sepotubinha/MT – Brazil microbasin, the larger part of the fragments presents fairly irregular forms and their nuclear areas are restricted to very small portions inside the fragments.

Also considering the problem associated to edge effects, where it was identified that fragments of small area are most fragile, it is also recommended the adoption of actions that increase the size of these remnants in order to protect their biodiversity [10]. For this, the reforestation in the regions bordering the fragments is highlighted as a very efficient



** referring to the fragments that presented nuclear area*

Figure 4: Results for the nuclear area.

alternative [25]. According to the simulations carried out by Ranta et al.[8], the adoption of measures of reforestation in fragmented vegetation matrices allows for an increase in the forest area of up to 48%, and the increase of the interior areas of the fragments can reach up to 166%.

In this way, fragments with greater nuclear area will be essential for the composition of a landscape that seeks to maintain the integrity of its natural vegetation cover since the density of edges will be smaller and less susceptible to edge effects [35 apud 36, 37]. According to reference [20], reforestation is also very beneficial to the conservation of forest fragments since they avoid the risk of forest fires, especially, when using border plantations and agroforestry systems in the regions surrounding the remnants. The maintenance of well-conserved fireplaces is also a very effective measure since they work as fire protection curtains and colonization of invasive plants [1, 10].

Thus, ecological corridors function as essential interconnections for maintaining the flow of species in fragmented ecosystems, such as in the case of urban landscapes [38]. Its implementation consists of an important biodiversity conservation strategy, not only at the local level but also at the regional level, and it promotes the protection of natural resources, increased flow of dispersers of flora, seeds, and other animals and ensures the biological diversity through genetic exchange, both between plants and animals [10, 39]. For [38], the identification of reduction of vegetation cover and habitat fragmentation are sufficiently significant factors for the proposition of ecological corridors.

Studies also point out the importance of identifying the proximity between fragments and native vegetation areas, as this proximity would have a positive influence on the fragments, especially in terms of seed dispersal and favorable conditions of recovery [40]. In view of this, the evaluation of the distance between the fragments and their nearest neighbor made it possible to identify the degree of isolation between them. As shown in Fig. 5a, about 75% of the fragments in all regions of the study area show a distance from the nearest fragment up to 400 m. This distancing is even smaller in the region of the lower course.

These indices contribute to the fact that most of the fragments are classified as ‘with connectivity’ with other fragment(s) (Fig. 5b). This is because the animal trafficability is limited around 350 m distance, and it can be considered that until this distance there is still connectivity between the fragments [28 apud 29]. Thus, it was identified that in the upper,

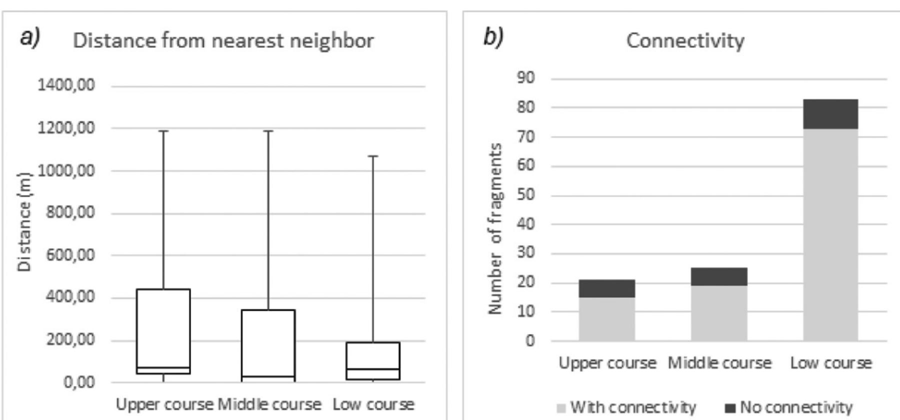


Figure 5: Resultados relativos à distância do vizinho mais próximo e conectividade.

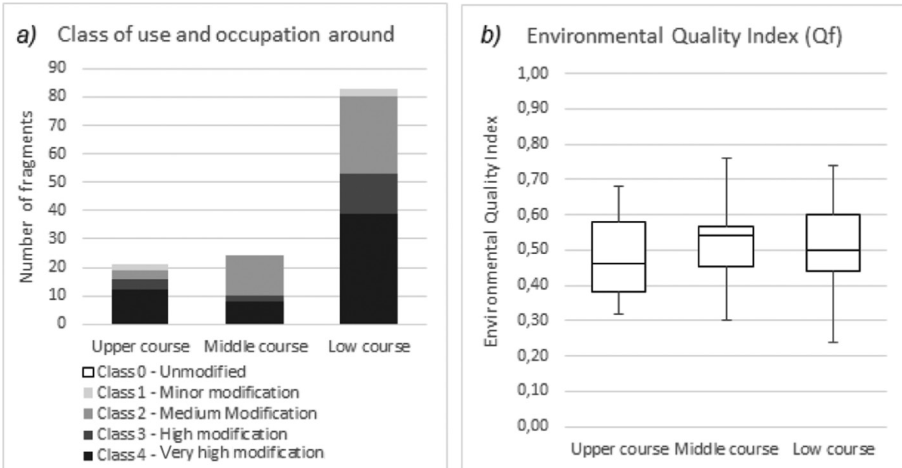


Figure 6: Resultados relativos ao uso e ocupação do solo e Environmental Quality Index.

middle and lower regions, respectively, 66.7%, 83.3% and 88.0% of the fragments present connectivity [31].

Other authors emphasize, however, that the reduction in the average isolation of the fragments does not necessarily represent an improvement in the landscape. This is because the smaller distance between them may occur not only due to the incorporation of forest area to the fragments but also due to the fragmentation of larger remnants that gave origin to several others of smaller size and closer to each other [27].

In addition, the identification of the degree of use and occupation of the soil around the fragments made it possible to evaluate the intensity with which the pressures of the external environment have been exerted on the remnants. It was identified that most of the forest fragments present are surrounded by areas of high and/or very high modifications (Fig. 6a). This classification includes deforested and/or degraded areas, streets, exposed soil, buildings, etc. Changes in land use and occupation, especially for uses of major modifications such as urbanization, can promote disturbances in forest ecosystems, as well as interfere with the intensity of fragmentation, the remaining vegetation cover and the size of the fragments [31].

In all the regions of the basin, no remnant was classified with very high or very low environmental quality [31]. There were predominant remnants with intermediate indices, with values between 0.40 and 0.60 [24] and, therefore, classified with moderate environmental quality. According to a study by Fengler et al. [24], remnants that received such classification refer to areas that ‘present a moderate degree of alteration of natural vegetation and whose resulting vegetation presents characteristics different from the originals due to the greater influence of built areas, road network and use of the soil’.

Figure 5b also shows that, despite very similar results between high, medium and low basin course, the region of the low course was the one that presented the greatest amplitude of results regarding the environmental quality of the remnants; this may be related to the fact that this region of the basin concentrates the largest number of remnants (83 fragments) distributed over a larger area that covers urban, periurban and rural areas. In this way, the existence of a considerable number of fragments with low indices, but also an important number of fragments with high indices, is identified. The remnants with high environmental quality indicate an area that despite its proximity to disturbing activities (urbanization and/or others) still maintains its physical and biological characteristics preserved, in contrast to areas with low environmental quality that, due to direct contact with disturbing sources, present significant degree of natural vegetation change [24].

Regarding the correlation between the data, it was identified that there is a strong correlation ($r > |\ 0.70\ |$) only among the indicators related to the area (Table 4).

In relation to PCA, three main components were identified which, together, describe 85.43% of the data variance (Fig. 7). The first (45.61%) refers to the total and nuclear area indicators, confirming the above conclusion that these are the most correlated indicators. The second component (24.54%) is more related to the classification of use and occupation of the soil in the surroundings and the distance of the nearest neighbor. Finally, the third (15.28%) describes both the circularity index and the distance between the nearest neighbor, indicating that there may be a relationship between these indicators.

Table 4: Matrix of correlation between indicator indices and evaluated.

	Area_ha	IC	QA	Near_ neigh	Nuc_ area_ha	Nuc_ area_%	Class
Area_ha	1.0000	−0.3452	0.4387	−0.0858	0.9613	0.8400	0.0494
IC	−0.3452	1.0000	0.1591	0.1074	−0.1743	−0.0655	−0.1900
QA	0.4387	0.1591	1.0000	−0.4935	0.4365	0.6237	−0.5236
Near_neigh	−0.0858	0.1074	−0.4935	1.0000	−0.0726	−0.0356	0.2423
Nuc_area_ha	0.9613	−0.1743	0.4365	−0.0726	1.0000	0.8208	0.0096
Nuc_area_%	0.8400	−0.0655	0.6237	−0.0356	0.8208	1.0000	−0.0082
Class	0.0494	−0.1900	−0.5236	0.2423	0.0096	−0.0082	1.0000

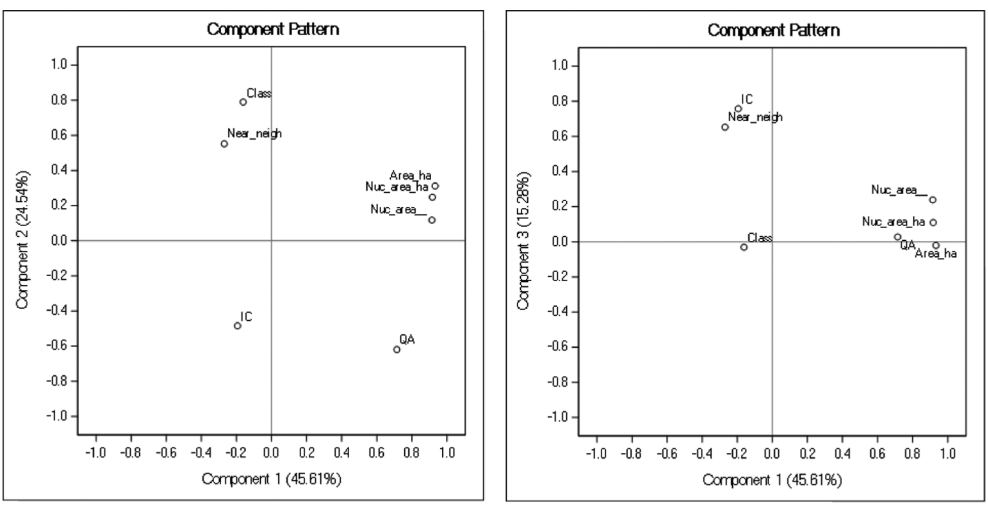


Figure 7: Principal component analysis results.

4 CONCLUSIONS

By analyzing these indicators, it was possible to classify the environmental quality of the forest fragments present in the study area and to verify that most of them present medium environmental quality; this demands management actions that aim to alleviate the external pressures suffered in these areas and guarantee their sustainability in the long term. Therefore, it is proposed that this information should be used as an instrument to support local managers in the recovery and management of forest remnants.

In addition, it was identified that there are correlations between indicators. The main one concerns area metrics, which are highly correlated. It is possible to affirm that, in general, the fragments with larger total area will also present a larger nuclear area which, together with a high circularity index, may indicate greater preservation of the interior of the fragment and, therefore, higher environmental quality.

ACKNOWLEDGMENTS

We thank the Foundation for Research Support the State of São Paulo (FAPESP) for the financial support for the execution of the research.

REFERENCES

[1] Calegari, L., Martins, S.V., Gleriani, J.M., Silva, E. & Busato, L.C., Análise da dinâmica de fragmentos florestais no município de Carandaí, MG, para fins de restauração florestal. *Revista Árvore*, **34(5)**, pp. 871–880, 2010 (in Portuguese). http://dx.doi.org/10.1590/S0100-67622010000500012.

[2] Ministério do Meio Ambiente (MMA), *Fragmentação de ecossistemas: Causas, feitos sobre a biodiversidade e recomendações de políticas públicas*, MMA: Brasília, 2003 (in Portuguese).

[3] Murcia, C., Edge effects in fragmented forests: implications for conservation. *Trends in Ecology & Evolution*, **10**, pp. 58–62, 1995 (in Portuguese). https://doi.org/10.1016/S0169-5347(00)88977-6.

[4] D'Arrochella, M.L.V., Araújo, R.S., Miranda, F.S.M. & Silva, W.M., Análise microclimática inter e intra fragmentos florestais na Área de Proteção Ambiental de Petrópolis – RJ. *Proceedinf of the XII Encontro de Geógrafos da América Latina*, 2009 (in Portuguese). available at http://observatoriogeograficoamericalatina.org.mx/egal12/Procesosambientales/Climatologia/19.pdf (accessed 20 May 2017).

[5] Sampaio, R.C.N., *Efeito de borda em um fragmento de floresta estacional semidecidual no interior do Estado de São Paulo*, Master's dissertation, Botucatu, 2011 (in Portuguese).

[6] Etto, T.L., Longo, R.M., Arruda, D.R. & Invenioni, R. Ecologia da paisagem de remanescentes florestais na bacia hidrográfica do Ribeirão das Pedras – Campinas –SP. *Revista Árvore* **37(6)**, pp. 1063–1071, 2013 (in Portuguese). http://dx.doi.org/10.1590/S0100-67622013000600008.

[7] Bierregaard, R.O., Lovejoy, T.E., Kapos, V., Santos, A.A. & Hutchings, R.W., The biological dynamics of tropical rainforest fragments: a prospective comparison of fragments and continuous forest. *BioScience*, **42(11)**, pp. 859–866, 1992 (in English). https://doi.org/10.2307/1312085.

[8] Ranta, P., Blom, T., Niemelã, J., Joensuu, E. & Siitonen, M. The fragmented Atlantic rain forest of Brazil: size, shape and distribution of forest fragments. *Biodiversity and Conservation*, **7**, pp. 84–403, 1998 (in English). https://doi.org/10.1023/A:1008885813543.

[9] Santos, A.L.C., Carvalho, C.M. & Carvalho, T.M., Importância de remanescentes florestais para conservação da biodiversidade: Estudo de caso na Mata Atlântica em Sergipe através de sensoriamento remoto. *Revista Geográfica Acadêmica*, **7(2)**, pp. 58–84, 2013 (in Portuguese). http://dx.doi.org/10.18227/1678-7226rga.v7i2.2992.

[10] Borges, L.F.R., Scolforo, J.R., Oliveira, A.D., Mello, J.M., Acerbi Junior, F.W. & Freitas, G.D., Inventário de fragmentos florestais nativos e propostas para seu manejo e o da paisagem. *CERNE*, **10(1)**, pp. 22–38, 2004 (in Portuguese). http://cerne.ufla.br/site/index.php/CERNE/article/view/357/300.

[11] Camargo, M., Soares, I.N., Hoffmann, C.A., Camargo, M.A.S., Masutti, G.C., Friedrich, L.F. & Uliana, R.S., A sustentabilidade urbana analisada através do estudo de implantação de corredores verdes em dois logradouros da cidade de Cruz Alta/RS. *Revista Gedecon*, **1(1)**, pp. 127–135, 2013 (in Portuguese). http://revistaeletronica.unicruz.edu.br/index.php/GEDECON.

[12] Londe, P.R. & Cezar, M.P.A., A influência das áreas verdes na qualidade de vida urbana. *Hygeia*, **10(18)**, pp. 264–272, 2014 (in Portuguese). http://www.seer.ufu.br/index.php/hygeia/article/view/26487.

[13] Bargos, D.C. & Matias, L.F., Áreas Verdes Urbanas: Um Estudo De Revisão e Proposta Conceitual. *Revista da Sociedade Brasileira de Arborização Urbana*, **6(3)**, pp. 172–188, 2011 (in Portuguese). http://dx.doi.org/10.5380/revsbau.v6i3.66481.

[14] Toledo, F.S. & Santos, D.G. Espaços Livres de Construção. *Revista da Sociedade Brasileira de Arborização Urbana*, **3(1)**, pp. 73–91, 2008 (in Portuguese). http://dx.doi.org/10.5380/revsbau.v3i1.66254.

[15] Franco, G.A.D.C., Souza, F.M., Ivanauskas, N.M., Mattos, I.F.A., Baitello, J.B., Aguiar, O.T., Catarucci, A.F.M. & Polisel, R.T., Importância dos remanescentes florestais de Embu (SP, Brasil) para a conservação da flora regional. *Biota Neotropica*, **7(3)**, pp. 145–161, 2007 (in Portuguese). http://dx.doi.org/10.1590/S1676-06032007000300017.

[16] Pirovani, D.B., Silva, A.G., Santos, A.R., Cecílio, R.A., Gleriani, J.M. & Martins, S.V., Análise espacial de fragmentos florestais na Bacia do Rio Itapemirim, ES. *Revista Árvore*, **38(2)**, pp. 271–281, 2014 (in Portuguese). http://dx.doi.org/10.1590/S0100-67622014000200007.

[17] Nucci, J.C., *Qualidade ambiental e adensamento urbano: um estudo de ecologia e planejamento da paisagem aplicado ao distrito de Santa Cecília (MSP)*, 2nd ed., O Autor: Curitiba, 2008 (in Portuguese).

[18] Chaves, H.M.L. & Santos, L.B., Ocupação do solo, fragmentação da paisagem e qualidade da água em uma pequena bacia hidrográfica. *Revista Brasileira de Engenharia Agrícola e Ambiental,* **13**, pp. 922–930, 2009 (in Portuguese). http://dx.doi.org/10.1590/S1415-43662009000700015.

[19] Zaú, A.S., Fragmentação Da Mata Atlântica: Aspectos Teóricos. *Floresta e Ambiente*, **5(1)**, pp. 160–170, 1998 (in Portuguese). http://s3.amazonaws.com/host-article-assets/floram/588e2257e710ab87018b4744/fulltext.pdf.

[20] Viana, V.M. & Pinheiro, L.A.F.V. Conservação da biodiversidade em fragmentos florestais. *Série Técnica IPEF*, **12(32)**, pp. 25–42, 1998 (in Portuguese). https://www.ipef.br/publicacoes/stecnica/nr32/cap03.pdf.

[21] Instituto Brasileiro de Geografia e Estatística (IBGE). Mapa de Clima do Brasil, available at ftp://geoftp.ibge.gov.br/informacoes_ambientais/climatologia/mapas/brasil/clima.pdf, 2002 (acessed 26 May 2017).

[22] Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA). *Aspectos Ecológicos*, available at http://www.cnpf.embrapa.br/pesquisa/efb/aspec.htm (accessed 28 May 2017).
[23] Dario, F.R., I*nfluência de corredor florestal entre fragmentos da mata atlântica utilizando-se a avifauna como indicador ecológico*, Master's dissertation, Piracicaba, 1999 (in Portuguese).
[24] Fengler, F.H., Moraes, J.F.L., Ribeiro, A.I., Peche Filho, A., Storino, M. & Medeiros, G.A. Qualidade ambiental dos fragmentos florestais na Bacia Hidrográfica do Rio Jundiaí-Mirim entre 1972 e 2013. *Revista Brasileira de Engenharia Agrícola e Ambiental*, **19(4)**, pp. 402–408, abr. 2015 (in Portuguese). http://dx.doi.org/10.1590/1807-1929/agriambi.v19n4p402-408.
[25] Neto, R.S., Bento, M.C., Menezes, S.J.M.C. & Almeida, F.S., Caracterização da Cobertura Florestal de Unidades de Conservação da Mata Atlântica. *Floresta e Ambiente*, **22(1)**, pp. 32–41, 2015 (in Portuguese). https://doi.org/10.1590/2179-8087.058013.
[26] Nascimento, H.E.M. & Laurance, W.F., Efeitos de área e de borda sobre a estrutura florestal em fragmentos de floresta de terra-firme após 13-17 anos de isolamento. *Acta Amazônica*, **36(2)**, pp. 183–192, 2006 (in Portuguese). http://dx.doi.org/10.1590/S0044-59672006000200008.
[27] Massoli, J.V., Statella, T. & Santos, V.S. Estimativa da fragmentação florestal na microbacia Sepotubinha, Nova Marilândia – MT, entre os anos de 1990 a 2014. *Caminhos de Geografia*, **17(60)**, pp. 48–60, 2016 (in Portuguese). https://doi.org/10.14393/RCG176004.
[28] Pires, J.S.R., Pires, A.M.Z.C.R. & Santos, J.E., Avaliação da integridade ecológica em bacias hidrográficas. *Faces da Polissemia da Paisagem: ecologia, planejamento e percepção*, eds. J.E. Santos, F. Cavalheiro, J.S.R. Pires, C. Henkeoliveira & A.M.Z.C.R. Pires, Rima: São Carlos, pp. 123–150, 2004 (in Portuguese).
[29] Freitas, E.P., *Análise integrada do mapa de uso e ocupação das terras da microbacia do Rio Jundiaí-Mirim para fins de gestão ambiental*. Master dissertation, Campinas, 2012 (in Portuguese).
[30] Lima, B.C., Francisco, C.N. & Bohrer, C.B.A., Deslizamentos e fragmentação florestal na região serrana do Estado do Rio de Janeiro. *Ciência Florestal*, **27(4)**, pp. 1283–1295, 2017 (in Portuguese). http://dx.doi.org/10.5902/1980509830321.
[31] Longo, R.M., Silva, A.L., Bettine, S., Demanboro, A.C., Bressane, A., Fengler, F.H. & Ribeiro, A.Í., Environmental indicators in forest fragments from urban watershed. *WIT Transactions on Ecology and the Environment*, Vol. 215, WIT Press: Seville, Spain, 2018, ISSN 174–3541. http://dx.doi.org/10.2495/EID180111.
[32] Silva, A.L. & Longo, R.M., Influence of urbanization on the original vegetation cover in urban river basin: case study in Campinas/SP. Brazil. *Proceedings of the Geophysical Research Abstracts*, Vol. 19, EGU2017-5368, 2017 (in English), available at https://meetingorganizer.copernicus.org/EGU2017/EGU2017-5368.pdf (accessed 25 May 2017).
[33] Oliveira, L.S.C., Marangon, L.C., Feliciano, A.L.P., Lima, A.S., Cardoso, M.S.O. & Santos, W.B., Edge effect in Atlantic forest remnants in the watershed of the river Tapacurá, Perbambuco. *CERNE*, **21**(**2**), pp. 169–174, 2015 (in Portuguese). http://dx.doi.org/10.1590/01047760201521021185.
[34] Silva, K.G., Santos, A.R., Silva, A.G., Peluzio, J.B.E., Fiedler, N.C. & Zanetti, S.S., Análise da dinâmica espaço-temporal dos fragmentos florestais da sub-bacia hidrográfica do Rio Alegre, ES. *CERNE*, **21(2)**, pp. 311–318, 2015 (in Portuguese). http://dx.doi.org/10.1590/01047760201521021562.

[35] Geneletti, D., Using spatial indicators and value functions to assess ecosystem fragmentation caused by linear infrastructures. *International Journal of Applied Eath Observation and Geoinformation*, **5**, pp. 1–15, 2004 (in English). https://doi.org/10.1016/j.jag.2003.08.004.

[36] Valente, R.O.A. *Definição de áreas prioritárias para conservação e preservação florestal por meio da abordagem multicriterial em ambiente SIG*. Doctorate thesis, Piracicaba, 2005 (in Portuguese).

[37] Silva, M.S.F. & Mello, R., Padrões espaciais de fragmentação florestal na FLONA do Ibura – Sergipe. *Revista Mercator*, **13(3)**, pp. 121–137, 2014 (in Portuguese). http://dx.doi.org/10.4215/RM2014.1303.0009.

[38] Rial, A.B. & Moreno, E.C. Corredores Ecológicos como Estrategia para la Conservación de los Ecossistemas Boscosos de la Reserva Florestal de Caparo, Venezuela. *Interciencia*, **40(4)**, pp. 275–281, 2015 (in Spanish). http://www.redalyc.org/articulo.oa?id=33935906007.

[39] Moretti, A.I.P., *Mapeamento de corredores ecológicos na APA Fernão Dias – MG a partir de técnicas de geoprocessamento e análise espacial*. Master's dissertation, Campinas, 2011 (in Portuguese).

[40] Freitas, E.P., Moares, J.F.L., Peche Filho, A. & Storino, M. Indicadores ambientais para áreas de preservação permanente. *Revista Brasileira de Engenharia Agrícola e Ambiental*, **17(4)**, pp. 443–449, 2013 (in Portuguese). http://dx.doi.org/10.1590/S1415-43662013000400013.