

# FOREST FRAGMENTS DISTRIBUTION AS RELATED TO GEOMORPHOLOGICAL PARAMETERS

*Distribuição dos Fragmentos Florestais Relacionados aos Parâmetros  
Geomorfológicos*

**Renato Fontes Guimarães<sup>1</sup>**  
**Osmar Abílio de Carvalho Júnior<sup>1</sup>**  
**Adriana Andrade de Carvalho<sup>1</sup>**  
**Roberto Arnaldo Trancoso Gomes<sup>1</sup>**  
**Eder de Souza Martins<sup>2</sup>**  
**Ana Paula Ferreira de Carvalho<sup>3</sup>**

<sup>1</sup>**Universidade de Brasília – UNB**  
**Departamento de Geografia**  
Campus Darcy Ribeiro, Asa Norte, 70910-900, Brasília, D.F., Brasil  
Fax: 55 61 3272 1909  
renatofg@unb.br  
osmarjr@unb.br  
robertogomes@unb.br

<sup>2</sup>**Empresa Brasileira de Pesquisa Agropecuária – EMBRAPA Cerrados**  
Rodovia Brasília-Fortaleza, BR 020, km 18, Planaltina, DF, Brasil  
Fax: 55 61 33889879  
eder@cpac.embrapa.br

<sup>3</sup>**Universidade de Brasília – UNB**  
**Departamento de Ecologia**  
Campus Universitário Darcy Ribeiro – ICC Centro, 70910-900, Brasília, D.F., Brasil.  
anapaula.fcarvalho@gmail.com

## ABSTRACT

This work aims at developing a study about the forest fragments in the Ariranha basin in Santa Catarina state, Brazil, by observing the geomorphologic characteristics and environmental fragility in order to propose the reforestation among the fragments to generate ecological corridors. The methodology consisted of the following steps: natural forest fragments mapping using IKONOS image, metrics calculation of the fragments and comparison between a scenario with the actual fragmentation and a fictitious scenarios where preservation areas would be fully vegetated. The methodology allowed supplying subsidies for implementation of an ecological corridor project including priorities areas for conservation..

**Keywords:** Forest Fragments, Digital Elevation Model, Ecological Corridor, IKONOS.

## RESUMO

Este trabalho tem como objetivo desenvolver um estudo sobre os fragmentos florestais na bacia do rio Ariranha, em Santa Catarina, Brasil, observando as características geomorfológicas e a fragilidade ambiental, a fim de propor o reflorestamento entre os fragmentos para geração de corredores ecológicos. A metodologia consistiu das seguintes etapas: mapeamento de fragmentos florestais naturais utilizando imagem IKONOS, cálculo das métricas dos fragmentos e comparação entre um cenário com os fragmentos florestais existentes na bacia e um cenário fictício, em que as áreas de preservação estão completamente vegetadas. A metodologia permitiu fornecer subsídios para a implementação de um projeto de corredor ecológico, tendo como prioridade as áreas de conservação.

**Palavras chave:** Fragmentos Florestais, Modelo Digital de Elevação, Corredor Ecológico, IKONOS.

## 1. INTRODUCTION

Together with the scientific-technological revolution, the environmental crisis is responsible for the world wide trend for reordering, what is expressed in the search for a new pattern of sustainable development (BECKER & EGLER, 1997). These concerns resulted in a normalization of laws to the environment in order to minimize the interference caused by the antropic use of natural resources. However, these laws are not always obeyed by all (BRASIL, 1983). The desired outcomes are only obtained when the work for conservation of water and soil are not restricted to isolated actions in agricultural property. It has been noticed that, in order to achieve the balance between environmental preservation and production activities it is important to analyze the regional context and aim at the multiple, continuum and economical use of natural resources.

One of the most remarkable environmental problems presently is the landscape fragmentation by the antropic action. It has been more and more intense due to the way of production of modern societies, which alter ecosystems structure, composition and functioning and create a mosaic of fragments (DINIZ & FURLAN, 1998; HARRIS, 1984; SOUTHWORTH *et al.*, 2004; TURNER, 1989; VIANNA *et al.*, 1997). Anthropoc alteration has provoked the sixth major extinction event of the history of life on Earth, as well as caused great change in the abundance and distribution of organisms (OLLF & RITCHIE, 2002). Human activities has modified the biogeochemical cycles (SCHLESINGER, 1991) and increased or reduced organism mobility with the introduction of species in regions that would not be reached by natural dispersion. In addition, it has created barriers to dispersion by reducing the genetic exchange among populations of the same species (BROKAW, 1998; CHAPIN III, *et al.*, 1991; ELTON, 1958; HOBBS & HUENNEK, 1992; VOS & OPDAM, 1993). The habitat fragmentation process involves as much the loss of habitat as the changes in the habitat's standards (MCGARIGAL & MARKS, 1994).

Particularly to the trees, an increment in the mortality rate and the formation of clearings might occur, what will alter the forest dynamics (LAURENCE *et al.*, 1998). A quite predictable consequence is the reduction of biodiversity (ANDRÉN, 1994; OLLF & RITCHIE, 2002; TERBORGH, 1989; WHITCOMB *et al.*, 1981).

The Brazilian ecosystem, which has suffered the most effects of antropoc action since colonial times, was the Mata Atlântica (MITTERMEIER *et al.*, 1998). Due to the high value for the wood, the forest has been reduced to isolated spots in the landscape (BORGIO & SILVA, 2003). The Mata Atlântica's fragments, in the southern Brazil, present variable size and conservation state; besides that, few studies have been conducted about it. Therefore, the protection of species is highly associated to the habitat's preservation, what makes

essential the conservation, protection and management of forest fragments remaining from Mata Atlântica to the preservation of the biodiversity (ZIMMERMANN, 1999).

Vegetation fragments play the key role in spreading of species colonization for adjacent areas. This contributes to the maintenance of spatial heterogeneity and landscape stability, besides keeping climate conditions, nutrients cycling, degradation of pollutants and the recuperation of deforested areas (MARTINS *et al.*, 1998).

To analyze the fragmentation process it is used metrics or landscape indexes which express the relation between spatial patterns and ecological processes, such as: remain fragments quantity, composition and distribution; the distance between them; the degree of isolation among forest fragments; their size and shape (METZGER, 2003; ZAÚ, 1997). Such indexes associated to the study of environmental legislation might contribute to the better comprehension of vegetation fragments in the sense of verifying the possibility of these fragments remain in the landscape. Thus, this kind of analysis helps in the territorial management since it establishes criteria to create conservation areas.

The present work aims at developing a study about the forest fragments in the Ariranha river basin, in the Santa Catarina State, south of Brazil, by observing the geomorphologic characteristics of environmental fragility in order to propose the reforestation among the fragments for purposes of generating ecological corridors. This work does not focus on a target-species, but the composition and structure of the landscape.

## 2. STUDY AREA

The study area is the drainage basin of Ariranha river with 236.36 km<sup>2</sup> area, located in the west part of Santa Catarina state (Fig. 1), near the city of Chapecó. It is part of five municipalities: Seara, Xavantina, Arvoredo, Ipumirim and Paial. According to the Köeppen classification the climate of the basin is under tropical constantly humid (Cfa) and tempered constantly humid (Cfp). The local economy is based on agricultural activity related with swine production and its industrial by-products. In this integrated system the swine producers run their production according to the technological standards established by the agribusiness (EPAGRI, 2001).

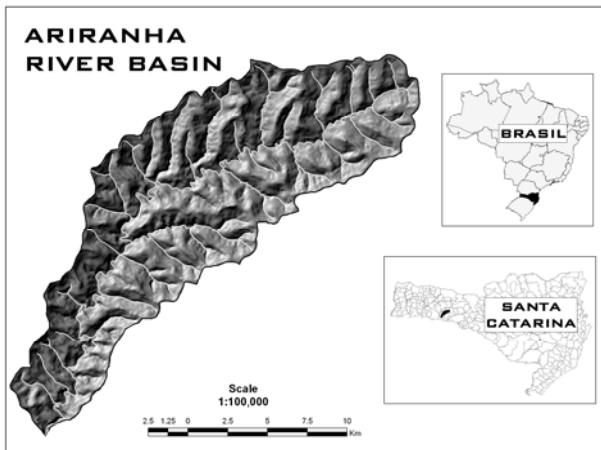


Fig. 1 - Location map of the Ariranha river basin.

This area is of forest planning interest due to the high population density where the main business is the swine production, which generates lots of pollutants. Therefore, it is necessary to establish a methodology to delimitate and quantify the areas of permanent preservation protected by federal legislation and their stage of conservancy. Besides that, it must be pointed new areas propitious for implementing reforestation and silviculture projects. The restitution of areas of law violation must be negotiated along with the community, taking into account the economical viability that will make possible the agriculturalists adherence and the harmony between financial and ecological gain.

### 3. GEOMORPHOLOGIC MAPPING

#### 3.1 Geologic framework

The relief evolution in the Ariranha river basin is closely correlated with the geologic characteristics. In the study area it is noticed the occurrence of rocks derived from acid and basic lava flows belonging to the Serra Geral Formation (ALMEIDA *et al.*, 1996). The volcanic rocks from this region belong to the group of continental tabular lava flows (plateau type) that cover extensive areas, such as Paraná (Brazil), Deccan (India) and Karroo (Africa) (TRUFFI & CLEMENTE, 2002).

The basic volcanism is the dominant in the Paraná basin, that is, 90% of the total (PICCIRILLO & MELFI, 1988). Firstly, the volcanic rocks from the Serra Geral Formation were described as being basalt toleitic of homogeneous composition (LEINZ, 1949; RUEGG & AMARAL, 1976). However, recent studies have showed that these basalt present significant chemical variations (ALMEIDA *et al.*, 1996).

The volcanism with intermediate composition to acid is formed by dacites, trackyidacites and rhyolites (MILNER *et al.*, 1992; NARDY *et al.*, 1986). The occurrence of these rocks is restricted to the residual tops and occupies around 150,000 km<sup>2</sup>, reaching locally 400m thickness (PICCIRILLO & MELFI, 1988). BELLINI *et al.* (1986) classified these acid rocks from Paraná basin in two big groups: Palmas type, concentrated in the southern part of Paraná basin, with

low contents of incompatible elements; and, Chapecó type, present in the northern and central part of the basin, comparatively richer in TiO<sub>2</sub>, P<sub>2</sub>O<sub>5</sub>, Zr, Ba and Sr. PEATE *et al.* (1992), subdivided the Palmas type in the subgroups Santa Maria and Caxias do Sul; and the Chapecó type in Guarapuava, Ourinhos and Sarusas, based on conventional and isotopic geochemistry.

The Ariranha's river basin volcanic pile is formed by toleitic basalt in the base and acid rocks on the top. The acid lava flows are classified as being of the Chapecó type, divided in the vesicular and phaneritic facies (BELLINI *et al.*, 1986). Those present the same characteristics described by UMANN *et al.* (2001) for the region of Cambará do Sul, RS, Brazil.

#### 3.2 Lineament

Several studies have been conducted in order to define the structural lineament of the Paraná basin, from relief analysis or drainage, remote sensing and geophysical data (ARTUR & SOARES, 2002; FERREIRA, 1982; RAPOSO, 1995; RICCOMINI, 1997; SOARES, 1992; ZALÁN *et al.*, 1990).

To the study area a visual interpretation of the structural lineament was made from the satellite images and the Digital Elevation Model (DEM) (Fig. 2). It was observed the presence of three conjoint pairs with preferential directions. These fracture systems condition the hydrologic organization and establish the basin's hierarchical pattern. One of the systems is associated to the 1st and 2nd drainage orders; while the other to the 3rd and 4th ones. The fractures condition water accumulation on the surface and the way of the superficial flow that gradually provokes the altering process and the vertical incision of the relief.

Ariranha river has its inferior part conditioned to a fracture direction N15°E while its superior part has, predominantly, a fracture N60°E. From a detail in the superior streambed of the river, abrupt direction variations with curvatures of low angle are noticed.

This way, the relief's evolving process connects fractures that induce the way of erosive and sedimentation processes and soil formation.

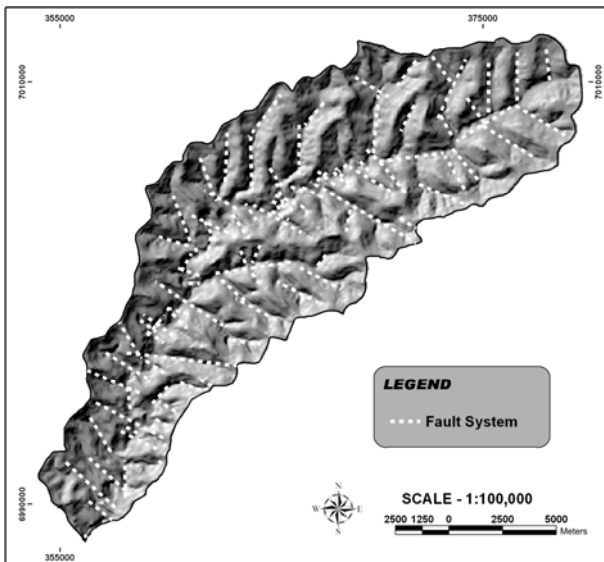


Fig. 2 - Fault system of Ariranha basin.

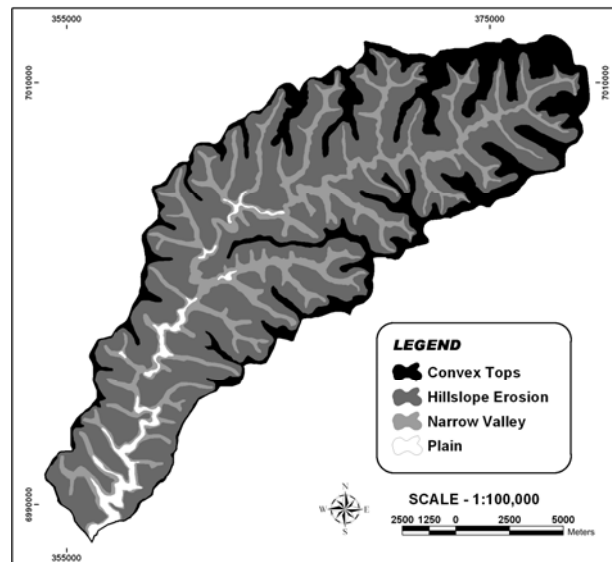


Fig. 3 - Ariranha river basin geomorphologic map.

### 3.3 Morphometrics

Morphometric parameters have been widely used to the characterization of hydrologic and geomorphologic processes (SCHIMIDT & DIKAU, 1999). However, it is difficult to establish an arrangement that describes all the complexity of the surfaces; and, for this reason, several methods have been developed for its description and analysis.

In this study the geomorphologic units were obtained from the DEM analysis that was generated by the interpolation of contour lines 1:50,000 by using TOPOGRID method and its derived slope and curvature charts. It could be distinguished four geomorphologic units: (a) top; (b) hillslope erosion; (c) narrow valley; and (d) plain.

The convex tops unit occurs in the higher altitudes of the basin, between 800 and 900 m, being formed by volcanic acid rocks. In the case of top acid rocks, the sub-parallel fracturing stratifies the landscape in scaled levels up to the contact with the basic basalt. On the top, the relief is flatter.

The hillslope erosion unit is characterized by the litologic change to basic basalt situated between the altitudes from 300 to 800 m, shaping multiconvex reliefs. The relief formed over basalt is the result of weathering over a material of physical and chemical isotropic characteristics. The main conditioner to the hillslope is the fracturing pattern that can be seen in the drainage direction of the basin in several levels of scale. Besides that, it is noticed the presence of soils of the argisols type, which are deep soils.

The unit of narrow valley is the result of the vertical evolution of the hydrologic erosion along the structural lineament, making the drainage surrounded by steep areas. While the plain areas present a flat background due to the action of Ariranha river, that became possible the backwards moving of the hillslope.

### 4. IDENTIFICATION OF FOREST FRAGMENTS FROM DIGITAL PROCESSING OF IKONOS IMAGES

IKONOS images of high spatial resolution present appropriate specifications to this work since they provide good detailing of the small properties and forest fragments, correspondent to the majority in the basin. The images obtained from the area correspond to 3 bands located in the superior, medium and inferior portions of the basin. Unfortunately, the band that covers the inferior part of the basin dates from 03/22/2000. The other two images from the superior part date from 05/13/2003.

The methodology adopted presents the following steps: (a) elaboration of the 3 buffer zone mosaic imaged by IKONOS sensor; (b) identification by spectral classification of forest remains; and, (c) adjustment by visual interpretation. Initially, it is elaborated the mosaic for the image sets of the same date. The images are tied together by tie points whose image coordinates are measured on multiple images with just 10% overlapping (Fig. 4).

Nevertheless, it has been noticed lateral distortions provoked by the topography in relation to the cartographic geometry (Fig. 5). As the distortions caused by the land can reach many meters, it is difficult to obtain the perfect liaison of the bands. Therefore, the use of these images without careful georectification might present significant discrepancies for detailed works (GRODECKI & DIAL, 2001). For this work purpose, those cartographic discrepancies could be minimized because of the bigger dimensions of the analysis targets, referring to forest fragments.

The block adjustment is even more damaged between the bands related to the low part of Ariranha river in relation to the others due to the 3 years time gap. In certain points where a significant change in land use occurred, it is observed a break in the images continuity.

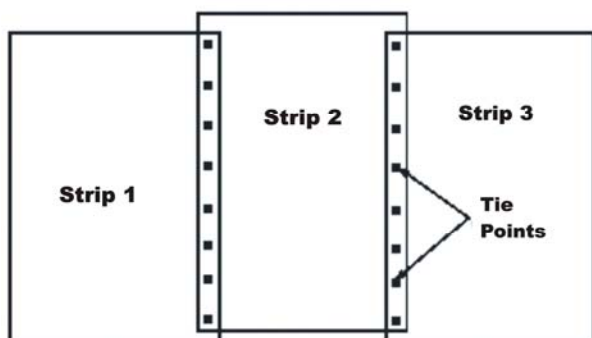


Fig. 4 - Block adjustment from tie points (GRODECKI & DIAL, 2001).

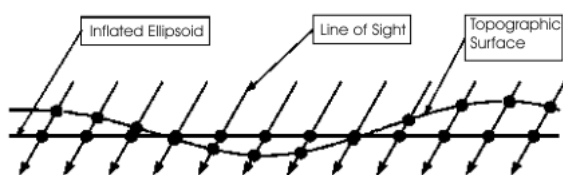


Fig. 5 - Strip adjustment from tie points (GRODECKI & DIAL, 2001).

In order to individualize forest remains a procedure that conjoins supervised classification to visual interpretation on screen was employed. The supervised classification was made by using the Maximum Likelihood method over images previously transformed by the Minimum Noise Fraction (MNF) method (GREEN *et al.*, 1988). The MNF transformation can be applied as a digital highlighting technique which points out the different targets that compose the scene. The sample selection was made over MNF images by considering forest areas and the different types of use such as areas with non-photosynthetic vegetation, bare soil, and agricultural areas in preparation. The shaded areas were also considered for classification due to their presence in different contexts; being, afterwards, visually classified. Because of the high variation of the vegetal canopy lightening, it has been observed that the employment of previous filtering by median permits a homogenization of the forest fragments.

After the automatics classification, a visual interpretation checking is made in order to adjust the limits, the shaded areas and the elimination of small classified polygons. **Fig. 6** shows a map of forest fragments. Also in visual form, it is searched to differentiate natural forest units from reforestation. Since different forest units are constituted by the same elements, that is, photosynthetic vegetation, the use of supervised classifiers is not effective to completely individualize these units. The distinction must be done by considering the textural characteristics of the vegetal canopy set by the shading pattern. The texture of

reforestation areas is more homogenous and its shading is defined in a linear pattern, while the natural areas are characterized by bigger tonal variations with isotropic characteristics. It has been observed that the small reforestation areas without a plantation pattern cannot be differed by visual interpretation being necessary data collection in the field.

## 5. DELIMITATION OF PROTECTED AREAS BY LAW

### 5.1 Delimitation of marginal buffer zone of rivers and areas surrounding springs, dams and lakes

The Brazilian Legislation on Waters (BRASIL, 1934) was one of the first federal laws to protect the environment. In the 60's, progress was also made with the Brazilian Legislation on Forests (BRASIL, 1965), Law of Wildlife Protection (BRASIL, 1967 a) and Brazilian Legislation on Mining (BRASIL, 1967 b).

Brazilian Legislation on Forests, put into effect by the Law 4771 (BRASIL, 1965), is a tool to discipline land occupation and protect forest functions. Its application aims at creating natural areas in all federal units. Its 2nd article, dedicated to the water sources, considers untouchable forests and other kinds of vegetation located along water flows, springs, areas surrounding lakes, lagoons and dams, tops of topographic elevations, hillslopes with slope great than 45 degrees, spit, and slope rupture higher than 1800 m.

This way, besides the benefits to the wild life, the vegetation maintenance in these areas contributes to lessen the erosive effects and soil lixiviation, what also promotes the regularization of the hydrologic flow and the reduction of water flow and alluvial deposits (COSTA *et al.*, 1996).

In the early 80's the Federal Law 6938 (BRASIL, 1981), which states the National Policy for Environment, incorporated and improved the states' regulation in effect. It was created the Sistema Nacional de Meio Ambiente (SISNAMA) – National Environmental System, composed by the Union, states and municipalities, where the states were attributed the bigger responsibility in the execution of regulations to protect the environment (MILARÉ, 1995; BRASIL, 1991).

Besides the difficulties these differences have brought to the formulation of an Environmental Policy at national level, the Conselho Nacional do Meio Ambiente (CONAMA) – National Council for Environment, the superior board of SISNAMA, has released important regulations on the environmental matter such as the requirement of elaboration of environmental impact reports (BRASIL, 1991). With the technical regulation issued by SISNAMA, it can be foreseen the beginning of an environmental policy which must integrate Union, states and municipalities in an effective governmental plan of action (MILARÉ, 1995).

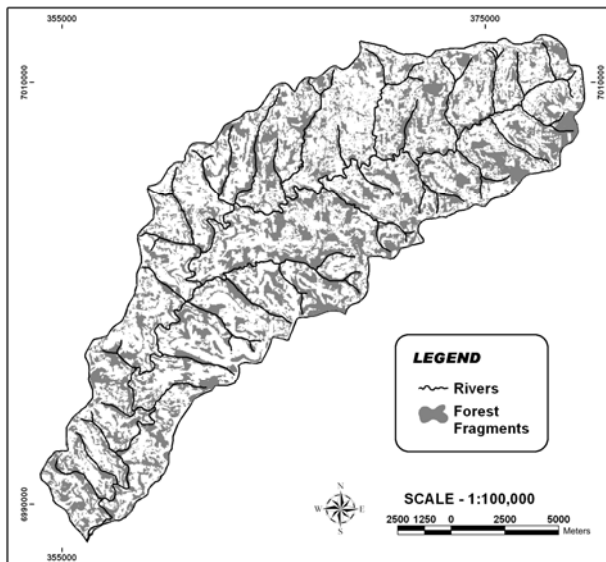


Fig. 6 - Ariranha river basin remains.

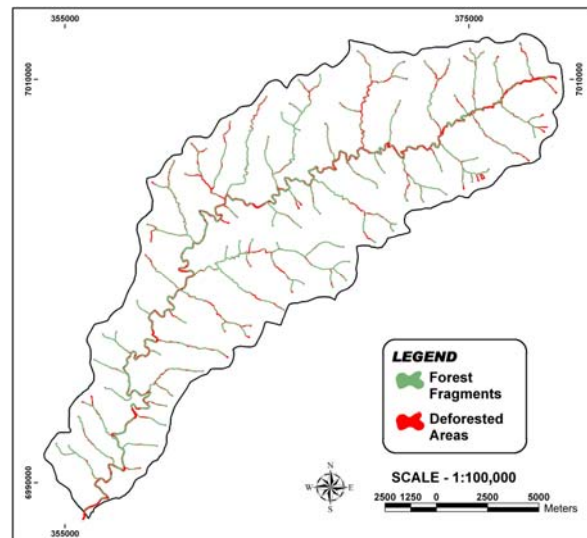


Fig. 7 - Maps of permanent preservation areas with vegetal coverage.

Besides the Brazilian Legislation on Forests 2nd Art. (BRASIL, 1965) has represented great progress to establish disciplined land occupation, its provisions lacked regulation on spring's protection areas, areas surrounding lakes, lagoons, natural or artificial water reservoirs, spits and slope rupture edges. In this sense, the most significant changes to federal laws are related to the Law 7803 (BRASIL, 1989) and CONAMA Resolution 004/85.

The preservation areas surrounding springs were regulated 24 years after the issue of Brazilian Legislation on Forests, by Law 7803, that stipulates to the springs, even the intermittent ones, for any topographic situation, a minimum range of 50m width. The minimum limit to the forest buffer zone and other forms of vegetation along the water courses, regulated in the original text of Brazilian Legislation on Forests, was augmented to the water courses wider than 100 m. In the 3rd article of the resolution, it was defined the criteria for forest preservation and other forms of vegetation located in the surrounds of lagoons, lakes or reservoirs and spits, provisioned in the Brazilian Legislation on Forests. According to this resolution, a band of 30m was stipulated to areas surrounding lakes, lagoons and water reservoirs, either natural or artificial, when those are situated in urban areas; of 50m and 100m to the water corps up to 20 ha and bigger situated in rural areas; and, of 100m to the power plant dams.

The delimitation of areas of environmental preservation around water corps was made in the vector form in the Geographic Information System environ. It was used the hydrologic digital net originated from the topographic map in the scale 1:50.000, updated by IKONOS images. To the whole extension of the river it was generalized a specific width. In order to improve calculus precision to the preservation area it would be necessary in loco measuring. The vectors referring to permanent preservation were confronted with the vegetal coverage. This crossing shows the places where forest coverage should exist and was taken (Fig. 7).

The estimate of permanent preservation areas of the marginal buffer zone is presented in Table 1. It is noticed that in the study area a high degradation in these protected areas occurs. The main reason for the diminishing of the vegetation in the river bank is the expanding agricultural areas by small farmers. In these locations the small farmers have better land for planting where flat areas associated to alluvial plains are situated.

## 5.2 Delimitation of slope and rupture edge area

The letter "g" of Brazilian Legislation on Forests 2nd Art. provisions permanent preservation areas on the slope rupture edges, but it does not establish criteria for its delimitation. Nevertheless, CONAMA Resolution 004/85 considers as ecological reserves the forests and any other vegetation forms situated in the slope rupture edges (places where such formations end in a abrupt cliff, with slope superior to 100% or 45°), in a band of minimum 100m wide. Afterwards, Law 7803 (Brasil, 1989) established as preservation areas the buffer zone 100m wide minimum, from the line of relief rupture in the slope rupture edges.

Considering the areas with slope up to 45°, it is noticed the delimitation of a small area considered to preservation (0.0133 km<sup>2</sup>) that is almost totally preserved (89%), which does not represent the environmental fragility of the region. This standard, considering the morphodynamics of the study area, does not cater for the needs of environmental conservation.

According to the agricultural potential studies for these lands, as described by RAMALHO *et al.* (1978) and OLIVEIRA & BERG (1985), the locations with heavy wavy relief, with declivities between 20% and 45% present agricultural use very restrict, due to the fact the erosion control is expensive and anti-economical. Even using appropriate management techniques, these areas present low productivity and high risk of erosion (LEPSCH *et al.*, 1991).



TABLE 1 – ESTIMATE OF THE VEGETATION REMAINS AREA IN THE ARIRANHA RIVER BASIN.

	BASIN (236,36 km <sup>2</sup> )		PERMANENT PRESERVATION AREAS (16,97 km <sup>2</sup> )	
	km <sup>2</sup>	%	km <sup>2</sup>	%
Native Forest	85,95	36,36	11,85	69,83
Secondary vegetation	2,72	1,15	0,07	0,41
Reforested	1,59	0,67	0,07	0,41
Forest remains (Total)	90,26	38,18	11,99	70,65

This way, for establishing the criteria of erosion susceptibility and environmental fragility the geomorphologic map of Ariranha river basin was used. Considering the class hillslope erosion it is possible to represent the areas of instability, which are considered for permanent preservation according to the Law 7803.

## 6. FOREST FRAGMENTATION ANALYSIS

To infer on the ecological processes through spatial conformation of environmental mosaics one must establish landscape indexes or metrics that permit quantify and describe spatial patterns (METZGER, 2003). Thus, fragmentation indicators permit understand how fragmented the study area is, and what is the viability for the fragments found to remain in the landscape, taking into account some characteristics such as, size, number, shape, edge and neighborhood.

Those ones can be subdivided in two types: (a) composition – it describes the presence and the quantity of fragments in the landscape, disregarding more accurate spatial references (such as location and shape); and, (b) configuration – it portrays the physical distribution (that expresses the relation between fragments like the nearest-neighbor metrics) and the spatial characteristics of fragments (metrics of “shape” and “core area”) (MCGARIGAL & MARKS, 1994).

To calculate the fragmentation metrics the program FRAGSTAS was used. It was considered the following metrics: (a) area metrics; (b) density metrics, size and variability; (c) edges metrics; (d) shape metrics; (e) core area metrics; and (f) “near neighbor” metrics (HAINES-YOUNG & CHOPPING, 1996). Table 2 summarizes the set of metrics that will be used. The metrics were calculated from forest fragments equal or bigger than 1000m<sup>2</sup> (0,1 ha) – in raster format. To determine the metrics in the fragstat for arcview it was necessary transform the vector data into raster.

The results for the fragment metrics were calculated from two different scenarios:

Scenario A – Considering all existent fragments, including the ones that compose the preservation areas.

Scenario B - Considering a fictitious scenario where preservation areas are totally vegetated (permanent preservation areas of rivers, slope rupture edges areas, and hillslope erosional area with slope greater than 35%) added to forest fragments outside permanent preservation area.

As follows, it will be analyzed the results obtained for both scenarios according to the values in Table 2.

### a) Area metrics (composition)

The study area has a significant volume of vegetated area (CA) of 9,024.29 ha, which represents around 38.1% of the total area (%LAND) (Scenario A). For Scenario B this area would reach 12,588.03 ha and 53.25% of the total area. The LPI index indicates that the greater participation of the biggest fragment, the lesser the fragmentation. This way, if the permanent preservation areas were preserved (Scenario B) the basin would be much lesser fragmented.

### b) Patch, density, patch size and variability metrics (configuration)

In this analysis we could see in the quantitative form, the decrease in fragmentation in the area from 3332 (Scenario A) to 2060 (Scenario B). And, consequently, increase of standard deviation and variation coefficient.

### c) Edge metrics (configuration)

Great part of the adverse effects of forest fragmentation over organisms is, direct or indirectly, related to the edge effect. In a forest, for instance, the edge effect results from differences of light and wind intensity, seed dispersion, among others, that can affect the vegetation structure (RANNEY *et al.*, 1981).

Considering that the area occupied by fragments (%LAND) are rather distinct for both scenarios, the metric “edges density” (ED), that standardizes the edge to a fixed unit area, demonstrates de decrease of fragmentation to Scenario B.

### d) Shape metrics (configuration)

There is a clear relation between the fragment shape or the set of fragments and the edge effect (MCGARIGAL & MARKS, 1994) that influences in several ecological processes, such as, for example, animal migration.

The metrics are determined from the relation perimeter and area, where MSI has value equals to 1 for a fragment with a simpler geometric shape (circle, to vector; square, to raster) and the numbers higher than these indicate bigger complexity in the fragment shape. Scenario B has less complex fragments, but, when this

calculation is made by giving proportional weight to the fragment (AWMSI), this scenario presents a bigger value because it has bigger fragments referring to permanent preservation areas.

The LSI, which determines the ratio of perimeter by area to the whole class, shows that the area of the fragment set for scenario A presents more complex shapes, being this way, more susceptible to the edge effect, characteristic traces for the fragmentation process (HARRIS, 1984).

e) Core area metrics (composition and configuration)

Core area metrics are related as much to the composition as to the landscape configuration. This is due to the fact that, besides aiming at the quantity of the core area existent (composition), the core area metrics (defined as the area inside a fragment which is from a certain distance of the edge band) are affected by the fragment shape and the “edge effect”.

In the analysis of both scenarios, the core area (total area of the class minus the edge band TCA) increased from 6,878.02 ha in scenario A to 10,375.07ha in scenario B. The number of core areas, NCA, can be bigger than the number of fragments, since, given its shape, there can be several core areas inside the same fragment. This metric, as well as the density, decreased significantly from scenario A to

scenario B.

The “total core area index” (TCAI) provides the percentage of the total fragments area that is composed by core areas. The more fragmented area, has the lower metrics value. This, once again, shows the smaller fragmentation of scenario B.

It was also calculated the measures for core tendency and dispersion for the core area measures. The first (which has as metrics the MCA1, CASD1 and CACV1) places the fragment as denominator. The MCA1 (medium core area 1), for example, reflects the medium size of the core area by fragment. Thus, a big and irregular fragment will be added its several core areas to the calculus of the mean. The second (which has as metrics the MCA, CASD and CACV) places as denominator its own core area. To these metrics there was a great increase of core areas for scenario B, what is favorable to the habitat’s improvement.

f) Nearest-neighbor metrics

Finally, two “closest neighbor metrics” were estimated. These metrics are related to the spatial distribution of fragments and, therefore, to the landscape configuration. They are important because the dynamics of plants and animals local population is influenced by other populations from the same or competitor species (Kareiva, 1990).



TABLE 2 - RESULTS ANALYSIS FROM FRAGSTAT.

Metrics	Abreivation	Scenario A	Scenario B
<b>a. Area metrics</b>			
Class área (ha)	CA	9.024,29	12.588,03
Total landscape área (ha)	TLA	23.636,0	23.636,0
Percent of Landscape (%)	%LAND	38,1	53,25
Largest patch index (%)	LPI	17,4	93,82
<b>b. Patch density, patch size and variability metrics</b>			
Number of patches (n)	NumP	3.332	2.060,00
Mean patch size (ha)	MPS	2,71	6,11
Patch size standart deviation (ha)	PSSD	33,24	260,13
Patch size coefficient of variation (%)	PSCoV	1.227,42	4.256,94
<b>c. Edge Metrics</b>			
Total edge length (in coverage units) of all	TE	3.094,040	3.156.500
Edge density (m/ha) of selected features (from TE)	ED	342,86	250,75
<b>d. Shape Metrics</b>			
Mean shape index	MSI	1,50	1,36
Area-weighted mean shape index	AWMSI	10,23	55,70
Landscape shape index calculated using TE (non-weighted edge length with background features excluded)	LSI	81,43	70,33
<b>e. Area metrics</b>			
Class área (ha)	CA	9.024,29	12.588,03
Total landscape área (ha)	TLA	23.636,0	23.636,0
Percent of Landscape (%)	%LAND	38,1	53,25
Largest patch index (%)	LPI	17,4	93,82
<b>f. Patch density, patch size and variability metrics</b>			
Number of patches (n)	NumP	3.332	2.060,00
Mean patch size (ha)	MPS	2,71	6,11
Patch size standart deviation (ha)	PSSD	33,24	260,13
Patch size coefficient of variation (%)	PSCoV	1.227,42	4.256,94

The first one is the “near neighbor mean” (MNN), given in meters. The second is the “mean proximity index” (MPI), which measures the isolation degree of the fragments: the smaller the value, the more isolated the fragments.

The distance between fragments present low values for both scenarios, however, for the MPI it is noticed a great improvement in scenario B, what shows that, in these conditions, there would be a huge decrease/diminishing in fragments isolation.

## 7. CONCLUSION

Through the analysis made by DEM and its

derived maps such as, slope and curvature, it was possible to elaborate a geomorphologic map that subsidized the identification of the most vulnerable areas for erosive processes.

The use of high resolution images permitted elaborating the forest fragment mapping in a semi-automatic way, with high precision. This mapping was essential for the stage of analysis of these fragments in the landscape, as well as to quantify the forest remains in permanent preservation areas.

This mapping made possible to conclude that the basin has had, for decades, intense agricultural activity, what provoked a diminution of forest resources, including in permanent preservation areas.

Besides that, nowadays, forest fragments do not have a good connectivity. They remain isolated without permitting the formation of ecological corridors.

The elaboration of a fictitious scenario where the preservation areas are totally vegetated (permanent preservation areas of rivers, slope rupture edges, and area of erosion surface with slope over 35%) added to the forest fragments outside permanent preservation areas permitted quantifying the significant improvement in connectivity, fragment isolation and the minimization of edge effects, if the present legislation was respected.

This way, the methodology provides not only the diagnosis but also presents a quantitative prospect for the planning actions that can be implemented in the sense of improving the environmental conditions of the basin.

## ACKNOWLEDGEMENTS

The authors are thankful to the financial support from: CNPq fellowship (Renato Fontes Guimarães, Osmar Abílio de Carvalho Júnior, Roberto Arnaldo Trancoso Gomes e Éder de Souza Martins), GESTAR project, coordinated by Ministério do Meio Ambiente – Ministry of Environment and FAO. They also thank Centro de Pesquisa para a Agricultura Familiar – Gerência Regional de Chapecó da EPAGI for the logistic support during the field work and Fundação de Empreendimentos Científicos e Tecnológicos (FINATEC).

## REFERENCES

- ALMEIDA, F. F. M., CARNEIRO, C. D. R., & MIZUSAKI, A. M. P. Correlação do magmatismo das bacias da margem continental Brasileira com o das áreas emersas adjacentes. **Revista Brasileira de Geociências**, v. 26, n. 3, p. 125-138. 1996.
- ANDRÉN, H. Effects of habitat fragmentation on birds and mammals in landscapes with different proportion of suitable habitat: a review. **Oikos**, v. 71, p. 355-366. 1994.
- ARTUR, P. C. & SOARES, P. C. Paleoestruturas e petróleo na bacia do Paraná, Brasil. **Revista Brasileira de Geociências**, v. 32, n. 4, p. 433-448. 2002.
- BECKER, B. K. & EGLER, C. A. G. **Detalhamento da metodologia para execução do zoneamento ecológico - econômico pelos estados da Amazônia Legal**. Brasília: Ministério do Meio Ambiente, dos Recursos Hídricos e da Amazônia Legal, Secretaria de Assuntos Estratégicos da Presidência da República. 1997.
- BELLIENI, G., COMIN-CHIARAMENTI, P., MARQUES, L. S., MARTINEZ, L. A., MELFI, A. J., NARDY, A. J. R., PAPTRECHAS, C., PICCIRILLO, E., ROISENBERG, A. & STOLFA, D. Petrogenetic aspects of acid and basaltic lavas from the Paraná plateau (Brazil): geological, mineralogical and petrochemical relationships. **Journal of Petrology**, v. 27, p. 915-944. 1986.
- BORGO, M. & SILVA, S. M. Epífitos Vasculares em Fragmentos de Floresta Ombrófila Mista, Curitiba, Paraná, Brasil. **Revista Brasileira de Botânica**, v. 26, n. 3, p. 391-401. 2003.
- BRASIL. Decreto 24.64, de 10 de julho de 1934, **Código de Águas**. 1934.
- BRASIL. Lei Federal 4.771, de 15 de setembro de 1965, **Código Florestal Brasileiro**. 1965.
- BRASIL. Lei Federal 5.197, de 3 de janeiro de 1967 **Proteção à Fauna**. 1967a.
- BRASIL. Decreto Lei 227, de 28 de fevereiro de 1967 **Código de Mineração**. 1967b.
- BRASIL. Lei Federal 6.938, de 31 de agosto de 1981 **Política Nacional do Meio Ambiente**. 1981.
- BRASIL. **Manejo e conservação do solo e da água; informações técnicas**. Ministério da Agricultura. Secretaria Nacional de Produção Agropecuária. Secretaria de Recursos Naturais. Coordenadoria de Conservação de Solo e Água. 1983.
- BRASIL. **Lei Federal 7.803**, de 18 de junho de 1989.
- BRASIL. **O Desafio do desenvolvimento sustentável - relatório do Brasil para a conferência das Nações Unidas sobre o meio ambiente e desenvolvimento**. Brasília: CIMA, 1991. 210 p.
- BROKAW, N. Fragments past, present and future. **Tree** v. 13, p. 382-383. 1998.
- CHAPIN III, F. S., ZAVALETA, E. S., EVINER, V. T., NAYLOR, R. L., VITOUSEK, P. M., REYNOLD, H. L., HOOPER, D. U., LAVOREL, S., SALA, O. E., HOBBIIE, S. E., MACK, M. C. & DIAZ, S. Consequences of changing biodiversity. **Nature**, v. 405, p. 234-242. 1991.
- COSTA, T. C. C., SOUZA, M. G. & BRITES, R. S. Delimitação e caracterização de áreas de preservação permanente, por meio de um Sistema de Informações Geográficas (SIG). In: VIII Simpósio Brasileiro de Sensoriamento Remoto, 1996. **Anais**. p. 121-127. 1996.
- DINIZ, A. & FURLAN, S. A. Relações entre as classificações fitogeográficas, fitossociologia, cartografia, escalas e modificações sócio-culturais no Parque Estadual de Campos de Jordão (SP). **Revista do Departamento de Geografia**, v. 12, p. 123-161. 1998.

- ELTON, C. S. **The ecology of invasion by animals and plants**. London: Methuen. 1958.
- EPAGRI. **Inventário das terras da sub-bacia hidrográfica Rio Ariranha**. Florianópolis: EPAGRI. 2001.
- FERREIRA, F. J. F. **Integração de dados aeromagnéticos e geológicos: configuração e evolução tectônica do Arco de Ponta Grossa**. 1982. 170 f. Dissertação (Mestrado) - Instituto de Geociências, Universidade de São Paulo, São Paulo. 1982.
- GREEN, A. A., BERMAN, M., SWITZER, P. & CRAIG, M. D. A transformation for ordering multispectral data in terms of images quality with implications for noise removal. **IEEE Transactions on Geoscience and Remote Sensing**, v. 26, n. 1, p. 65-74. 1988.
- GRODECKI, J. & DIAL, G. IKONOS geometric accuracy. In: Joint Workshop of ISPRS Working Groups I/2, I/5 and IV/7 on High Resolution Mapping from Space. 2001. **Proceedings**. University of Hannover, Hannover, Germany. 2001.
- HAINES-YOUNG, R. & CHOPPING, M. Quantifying landscape structure: a review of landscape indices and their application to forested landscapes. **Progress in Physical Geography**, v. 20, p. 418-445. 1996.
- HARRIS, L.D. **The fragmented forest: Island biogeography theory and the preservation of biotic diversity**. Chicago: University of Chicago Press. 1984. 230 p.
- HOBBS, R.J., HUENNEKE, L.F. Disturbance, diversity, and invasion: implications for conservation. **Conservation Biology**, v. 6, p. 324-337. 1992.
- KAREIVA, P. Population dynamics in spatially complex environments: theory and data. **Philosophical Transactions of the Royal Society**, v. 330, p. 175-190. 1990.
- LAURANCE, W. F., FERREIRA, L. V., RANKIN-DE-Merona, J. M. & LAURANCE, S. G. Rain forest fragmentation and the dynamics of Amazonian tree communities. **Ecology**, v. 79, p. 2032-2040. 1998.
- LEINZ, V. **Contribuição à geologia dos derrames basálticos do sul do Brasil**. 1949. 61 f. Tese (Doutorado) - Faculdade de Filosofia, Ciências e Letras, Universidade de São Paulo, São Paulo. 1949.
- LEPSCH, I. F. BELLINAZZI, J. R., BERTOLINI, D., ESPÍNDOLA, C. R. **Manual para levantamento utilitário do meio físico e classificação de terras no sistema de capacidade de uso**. Campinas: Sociedade Brasileira de Ciência do Solo. 1991. 175 p.
- MARTINS, A. K. E., NETO, A. S., MENEZES, I. C., BRITES, R. S., SOARES, V. P. Metodologia para a indicação de Corredores Ecológicos por meio de um Sistema de Informação Geográfica. In: IX Simpósio Brasileiro de Sensoriamento Remoto, 1998. **Anais**. p. 611-620. 1998.
- MCGARIGAL, K. & MARKS, B. J. **FRAGSTATS - Spatial Pattern Analysis Program for Quantifying Landscape Structure. Version 2.0**. Forest Science Department, Oregon State University, Corvallis, USA. 1994.
- METZGER J. P. Effects of slash-and-burn fallow periods on landscape structure. **Environmental Conservation**, v. 30 n. 4, p. 325-333. 2003.
- MILARÉ, E. Política Ambiental Brasileira. In: TAUK-TORNISIELO, S. M., GOBBI, N., FORESTI, C. & LIMA, S. T. (Org.). **Análise Ambiental: Estratégias e Ações**. São Paulo: T. A. Queiroz/Fundação Salim Farah Maluf, 1995. p. 15-18.
- MILNER, S. C., DUNCAN, A. R., EWART, A. Quartz latite rheoignimbrite flows of the Etendeka Formation, north-western Namibia. **Bulletin of Volcanology**, v. 54, p. 200-219. 1992.
- MITTERMEIER, R. A., MYERS, N., THOMSEN, J. B., FONSECA, G. A. B., OLIVIERI S. Biodiversity hotspots and major tropical wilderness areas: approaches to setting conservation priorities. **Conservation Biology**, v. 12, n. 3, p. 516-520. 1998.
- NARDY, A. J. R., MARQUES, L. S., RAPOSO, M. I. B. Aspectos petrológicos das rochas efusivas ácidas da Região Centro Sul do Estado do Paraná. **Revista Brasileira de Geociências**, v. 16, p. 43-57. 1986.
- OLIVEIRA, J. B., BERG, M. Aptidão agrícola das terras do Estado de São Paulo: Quadrícula de Araras: II. Memorial descritivo. **Boletim Técnico Instituto Agrônomo**, v. 102, p. 1-60. 1985.
- OLLF, H. & RITCHIE, M. E. Fragmented nature: consequences for biodiversity. **Landscape and Urban Planning**, v. 58, p. 83-92. 2002.
- PEATE, D. W., HAWKESWORTH, J. C., MANTOVANI, M. S. M. Chemical stratigraphy of the Paraná lavas (South America): classification of magma types and their spatial distribution. **Bulletin of Volcanology**, v. 55, p. 119-139. 1992.
- PICCIRILLO, E. M. & MELFI, A. J. **The mesozoic flood volcanism of the Paraná Basin: petrogenetic**

- and geophysical aspects.** São Paulo: Instituto Astronômico e Geofísico, 1988. 600 p.
- RAMALHO, A., PEREIRA, E. G., BEEK, K. J. **Sistemas de avaliação da aptidão agrícola das terras.** Brasília: EMBRAPA. 1978. 70 p.
- RANNEY, J. W., BRUNER, M. C., LEVENSON, J. B. The importance of edge in the structure and dynamics of forest islands. In: BURGESS, R. L. & SHARPE, D. M. (Org.). **Forest dynamics in man-dominated landscapes.** New York: Springer Verlag, 1981. p. 67-95.
- RAPOSO, M. I. B. Episódios intrusivos no arco de Ponta Grossa, determinados através de um estudo paleomagnético. **Revista Brasileira de Geociências**, v. 25, n. 1, p. 3-19. 1995.
- RICCOMINI, C. Arcabouço estrutural e aspectos do tectonismo gerador e deformador da Bacia Bauru no Estado de São Paulo. **Revista Brasileira de Geociências**, v. 27, n. 2, p. 153-162. 1997.
- RUEGG, N. R., AMARAL, G. Variação regional da composição química das rochas basálticas da Bacia do Paraná. **Boletim IG-USP** v. 7, p. 131-147. 1976.
- SCHIMIDT, R. & DIKAU, R. Extracting geomorphometric attributes and objects from digital elevation models – semantics, methods, future needs. In: DIKAU, R. & SAURER, H. (Org.). **GIS for earth surface systems.** Berlin-Stuttgart: Gebrüder Borntraeger, 1999. p. 153-173.
- SCHLESINGER, W. H. **Biogeochemistry: an analysis of global change.** San Diego, CA: Academic Press. 1991. 443 p.
- SOARES, P. C. *Tectônica sin-sedimentar cíclica na Bacia do Paraná - controles.* 1992. 148 f. Tese de Professor Titular - Universidade Federal do Paraná. Curitiba. 1992.
- SOUTHWORTH, J., MUNROE, D., NAGENDRA, H. and cover change and landscape fragmentation—comparing the utility of continuous and discrete analyses for a western Honduras region. **Agriculture, Ecosystems and Environment**, v. 101, p. 185-205. 2004.
- TERBORGH, J. **Where have all the birds gone?** New Jersey: Princeton University Press. 1989. 270 p.
- TRUFFI, S. A. & CLEMENTE, C. A. Alteração de plagioclásios dos riodacitos da Formação Serra Geral (JKsg) da região de Piraju – SP. **Scientia Agricola**, v. 59, n. 2, p. 383-388. 2002.
- TURNER, M. G. Landscape ecology: the effect of pattern on process. **Annual Review of Ecology and Systematics**, v. 20, p. 171-197. 1989.
- UMANN, L. V., DELIMA, E. F., SOMMER, C. A. & LIZ, J. D. Vulcanismo ácido da região de Cambará do Sul; RS: litoquímica e discussão sobre a origem dos depósitos. **Revista Brasileira de Geociências**, v. 31, n. 3, p. 357-364. 2001.
- VIANNA, V. M., TABANEZ, A. A. J & BATISTA, J. L. F. Dinâmica e restauração de fragmentos na floresta atlântica. In: LAURANCE, W. F. & BIERREGAARD, R. O. (Org.). **Tropical Forest Remnants Ecology, Management and Conservation of Fragmented Communities.** Chicago and London: University of Chicago Press. 1997. p. 351-365.
- VOS, C. C. & OPDAM, P. Patterns and processes in a landscape under stress: the study area. In: VOS, C.C. & OPDAM P. (Org.). **Landscape ecology of a stressed environment.** London: Chapman & Hall. 1993. p. 1-27.
- WHITCOMB, R. F., ROBBINS, C. F., LYNCH, J. F., WHITCOMB, B. L., KLIMKIEWICZ, M. K. & BYSTRAK, D. Effects of forest fragmentation on the avifauna of eastern deciduous forest. In: Burgess, R.L. & Sharpe D. (Org.). **Forest Island Dynamics in Man-Dominated Landscapes.** New York: Springer-Verlag. 1981. p. 125-205.
- ZALÁN, P. V., WOLFF, S., ASTOLFI, M. A. M., VIEIRA, I. S., CONCEIÇÃO, J. C. J., APPI, V. T., NETO, E. V. S., CERQUEIRA, J. R., MARQUES, A. The Paraná Basin. In: Leighton, M.W., Kolata, D.R., Oltz, D.F., Eidel, J.J. (Org.). **Interior Cratonic Basins.** Tulsa: AAPG, Memoir 51. 1990. p. 681-708.
- ZAUÍ, A. S. A ecologia de paisagem no planejamento territorial. **Floresta e Ambiente**, v. 4, p. 98-103. 1997.
- ZIMMERMANN, C. E. Avifauna de um Fragmento de Floresta Atlântica. **Revista de Estudos Ambientais**, v. 1, n. 3, p. 101-112. 1999.