

## Spatial-functional pattern of ecotonal riparian landscapes on Meridional Plateau, Southern Brazil

Patrones espacio-funcionales de paisajes ribereños ecotonales en el Plató Meridional, en el sur de Brasil

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### SUMMARY

This study analyzes the Pitangui and Jotuba riparian zones in the Meridional Plateau, to create a landscape model of forest/field riparian ecotones. The areas were delineated from 2001 orthophotos (1:10,000), including all native vegetation in flooding limits of the lotic channels. The landscape units (UP) were represented by the Alluvial Ombrophilous Mixed Forest metacommunity (FOMA) including as phytocoenosis both the riparian woody forest (FR) and hydrophilous vegetation (VH). Landscape metrics and statistical treatment were used to characterize landscapes and patches. To evaluate the FR patches we presumed a 30 m edge. The Pitangui River (1,072 ha) has double the riparian area of Jotuba River (539 ha), although proportionally both were UPs equivalent (40 % of FR and 60 % of VH). Both rivers have a large number of small rounded patches and relatively few large areas that trend to more complex and irregular shapes as the area increases. Also smaller patches are more spatially heterogeneous than the larger ones, and more aggregated along the river channel. 60 % of FR area on both rivers is under an edge effect: Pitangui has 91 core areas linked by 69 corridors and the Jotuba River has 53 core areas with 47 corridors. In the riparian zones, VH areas occupy the flood plains showing higher variability in size and spatial distribution. This summarizes the natural fragmentation of the riparian vegetation of regional rivers in Southern Brazil.

*Key words:* landscape ecology, Campos Gerais, landscape metrics, natural fragmentation.

### RESUMEN

Este estudio analizó las zonas ribereñas de Pitangui y Jotuba en el Plató Meridional con el fin de crear un modelo de paisaje para ecotonos ribereños de bosques/pradera. Las zonas fueron delimitadas con ortofotos de 2001 (1:10.000), incluyendo toda vegetación nativa en los límites de inundaciones de los canales lóticos de los ríos Pitangui y Jotuba. Las unidades de paisaje (UP) estuvieron representadas por la meta comunidad de bosques mixtos aluviales ombrófilos (FOMA) con fitocenosis del bosque ribereño (FR) y vegetación hidrófila (VH). Se utilizaron métricas de paisaje y herramientas estadísticas para caracterizar los paisajes y los fragmentos. Para la evaluación de FR se asumió un borde de 30 metros. El río Pitangui (1.072 ha) presentó el doble de la zona ribereña que el río Jotuba (539 ha), aunque proporcionalmente ambos eran equivalentes UP (40 % de FR y 60 % de VH). Ambos ríos tienen gran número de pequeños fragmentos redondeados y relativamente pocas áreas grandes tendiendo a formas más complejas e irregulares al aumentar el área. Los fragmentos más pequeños fueron espacialmente más heterogéneos que los mayores y más agregados a lo largo del canal de río; 60 % del área de FR en ambos ríos está bajo el efecto de borde. Pitangui tiene 91 áreas centrales vinculadas por 69 corredores y el río Jotuba tiene 53 áreas centrales con 47 corredores. En las zonas ribereñas, las áreas de VH ocuparon las llanuras de inundación y mostraron la mayor variabilidad en tamaño y distribución espacial. Estos resultados resumen los patrones de fragmentación natural de la vegetación ribereña de los ríos regionales en el sur de Brasil.

*Palabras clave:* ecología de paisaje, Campos Gerais, métricas de paisaje, fragmentación natural.

### INTRODUCTION

The detection of patterns in the arrangement and structure of the mosaic helps to understand the functional movements and flows through the landscape (Forman 1995). Creating models start with patterns identification and, among the Brazilian landscapes, riparian zones are often the focus on conservation. For Turner (2005) and Landeiro and Magnusson (2011), one of the main methodological

problems in Landscape Ecology is the lack of replicated sites that share a pattern of spatial distribution, which provide a statistical basis of the properties and behavior of the patterns identified. This study analyzes the riparian zones in Pitangui and Jotuba rivers in the Meridional Plateau in Paraná State, in an attempt to build a landscape model in forest/field riparian ecotones by an internal data evaluation of its structural and functional integrity throughout connectivity.

METHODS

The study area was located in the Devonian Cuesta in Paraná State. This region is recognized by Probio (MMA 2002) as high and extremely high conservation importance. The river channels of Pitangui and Jotuba cross large floodplain areas. The riparian zones were delineated from orthophotos of 2001 (1:10,000), including native vegetation in flooding limits of the lotic channels (Attanasio *et al.* 2006, Arizpe *et al.* 2008). The anthropogenic areas were not considered in these riparian zones. The landscape units were represented by the alluvial ombrophilous mixed forest metacommunity (Veloso *et al.* 1991) including as phytocoenosis the riparian woody forest along the marginal deposits, and hydrophilous vegetation in the flooding surfaces.

This investigation was conducted at the landscape level, analyzing their composition gradient, number of patches, use diversity, aggregation, and structural connectivity. The patches were analyzed parametrically by media and standard deviation, including vegetation type, size of patches, shape, core area, and spatial disposition.

Riparian landscapes and patches were characterized by landscape metrics and statistical method, using the softwares FRAGSTATS v. 3.3 (McGarigal and Marks 1995) and PAST (Hammer 1999).

The riparian woody forest patches were classified in landscape elements (core areas, edges, bridges, branches and islets) using Morphologic Spatial Patterns Analysis (MPSA) method by software GUIDOS 1.3© Peter Vogt, EC-JRC (Vogt 2010) adopting a 30 m criteria as edge depth.

RESULTS

The Pitangui River had a 1,072 ha riparian area distributed in 95 riparian woody forest and hydrophilous vegetation patches, almost double that of the Jotuba riparian area, with 539 ha and 65 patches, although proportionally both were landscape units equivalent ( $P < 0.05$ ). In the Pitangui we found 34 fragments of riparian woody forest (41 % of the riparian zone) and 61 fragments of hydrophilous vegetation (59 %). In the Jotuba River, we delineated 19 fragments of riparian woody forest (40 %) and 46 fragments of hydrophilous vegetation (60 %).

Both rivers had a large number of small patches and relatively few large areas. The Spearman's correlation between area and shape index (AREA/SHAPE), and area and fractal dimension (AREA/FRACT), for riparian woody forest (Pitangui  $r_s = 0.85$  and  $0.80$ ; Jotuba  $r_s = 0.90$  and  $0.87$ ), and for hydrophilous vegetation (Pitangui  $r_s = 0.75$  and  $0.62$ ; Jotuba  $r_s = 0.78$  and  $0.61$ ), shows that trend to more complex and irregular shapes as the area increased.

There were 91 core areas (177 ha) in riparian woody forest of the Pitangui, linked by 69 bridges, 93 branches, and 19 islets (figure 1). In the riparian woody forest of Jotuba, there were 53 core areas (86.2 ha), 47 bridges, 296 branches, and 11 islets (figure 2). 40 % of the riparian woody forest area is under edge effect of both rivers.

In the riparian zones, riparian woody forest was along the active river channel while hydrophilous vegetation areas occupy the flood plains with high variability of size and spatial distribution. The longitudinal flows had higher importance for functional integrity of riparian forests, although lateral flows appeared to be more important for hy-

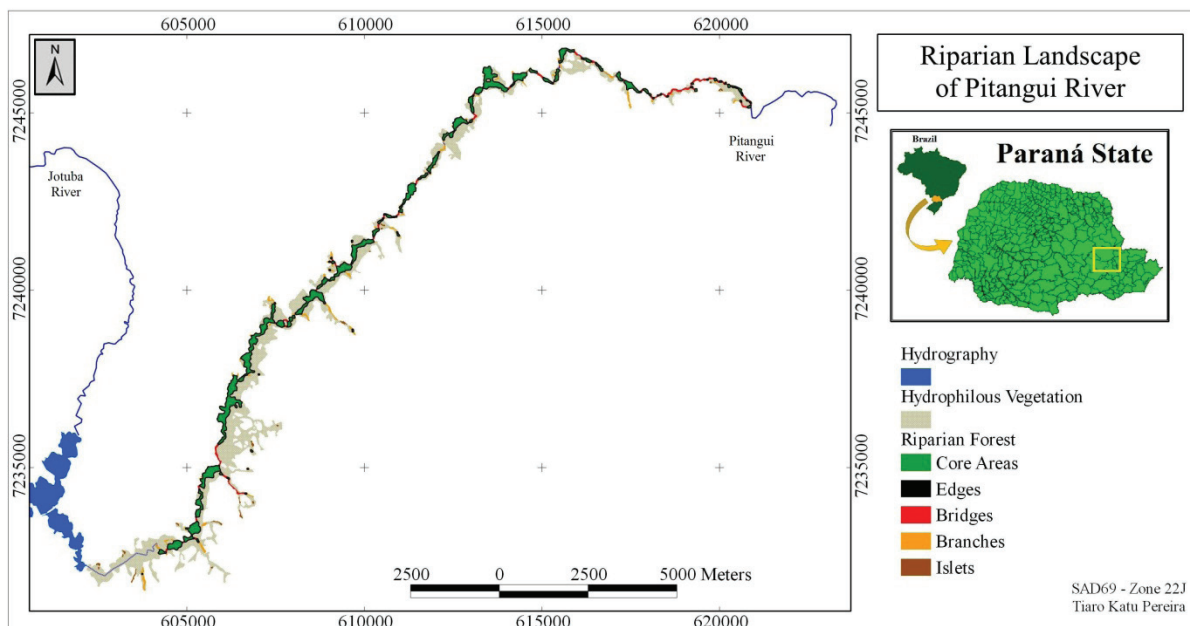
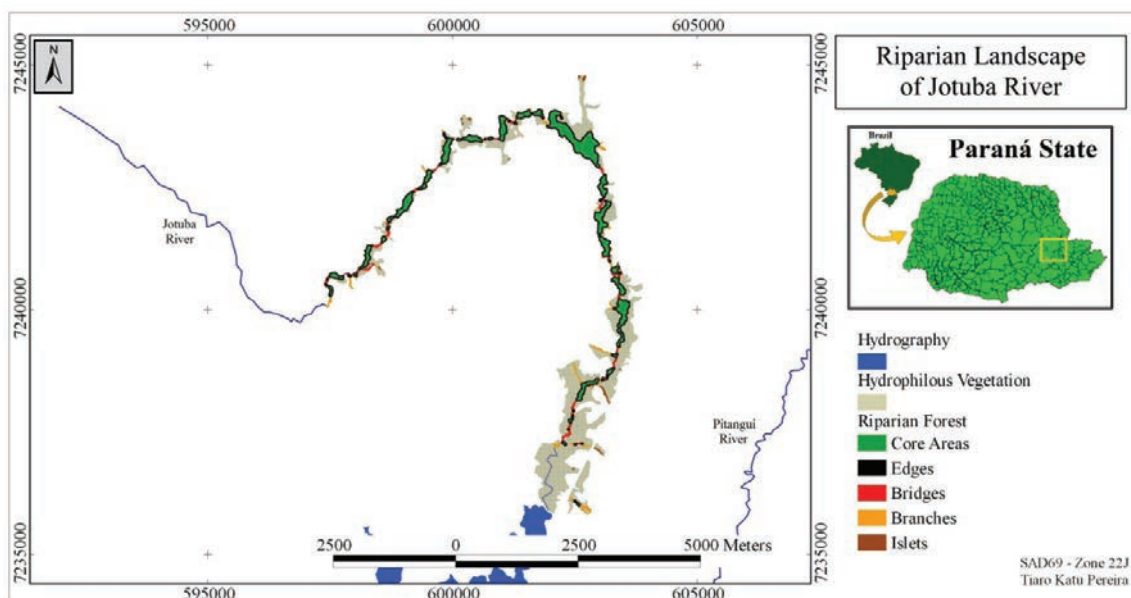


Figure 1. Landscape elements of Pitangui River, Paraná State, Southern Brazil.  
 Elementos del paisaje del río Pitangui, Estado de Paraná, sur de Brasil.



**Figure 2.** Landscape elements of Jotuba River, Paraná State, Southern Brazil.  
 Elementos del paisaje del río Jotuba, Estado de Paraná, sur de Brasil.

drophilous vegetation. Smaller patches are more spatially heterogeneous than the larger ones, and more aggregated along the river channels (tables 1 and 2).

#### DISCUSSION AND CONCLUSIONS

There are different patterns in the landscape related to relief, but the landscape elements are similar in both rivers ( $c^2 P < 0.0001$ ). In both, 60 percent of riparian areas is hy-

drophilous vegetation. The analysis pointed at the importance of including wetlands in riparian analysis in Pitangui and Jotuba rivers. The federal law protects only 30 meters of both sides no matter their declivity or flood extension, and is insufficient to protect all wetlands of those rivers (Attanasio *et al.* 2006).

The fragmentation processes, as shown by the spatial distribution of the evaluated areas, were mainly natural. Connectivity indices were low due to the linear riparian

**Table 1.** Connectivity indices of Pitangui River, Paraná State, Southern Brazil. Indices: size class (ha), NP: number of patches, PROX: proximity index, ENN: euclidean nearest-neighbor distance (m), SD: standard deviation.

Índices de conectividad del Rio Pitangui, Estado de Paraná, sur de Brasil. Índices: clases de tamaño (ha), NP: número de fragmentos, PROX: índice de proximidad, ENN: distancia euclidiana al vecino más cercano (m), SD: desviación estándar.

Class	Riparian forest					Hydrophilous vegetation				
	NP	PROX	SD	ENN	SD	NP	PROX	SD	ENN	SD
< 1.0	23	765.6	1,769.8	134.1	186.6	17	146.8	318.3	57.3	37.3
1.0-9,9	5	2,763.6	6,177.6	87.6	56.0	33	317.6	633.7	62.8	45.7
10.0-49,9	3	1,886.7	2,494.3	22.6	9.2	8	286.8	341.9	89.0	160.3
> 50.0	3	14,720.9	13,849.8	9.3	2.3	3	74.6	86.9	38.9	17.1

**Table 2.** Connectivity indices of Jotuba River, Paraná State, Southern Brazil.  
 Índices de conectividad del río Jotuba, Estado de Paraná, sur de Brasil.

Classes	Riparian forest					Hydrophilous vegetation				
	NP	PROX	SD	ENN	SD	NP	PROX	SD	ENN	SD
< 1.0	10	660.0	1,761.7	124.9	147.1	19	65.8	152.8	70.4	71.0
1.0-9.9	4	2,284.6	4,042.1	162.6	279.0	21	196.6	260.9	59.6	57.3
100-49.9	3	12,490.1	10,353.2	9.1	3.8	5	473.5	827.8	71.7	101.9
> 500	2	5,733.2	7,646.0	5.2	1.1	1	518.0	0.0	25.5	0.0

disposition of patches. The analysis revealed patterns of fragmentation and distribution of landscape elements, but to establish riparian landscape models for FOMA is important to extend the analysis to other rivers or segments (Turner 2005).

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