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USE OF GIS AND MULTITEMPORAL IMAGE DATABASE TO ASSES CORUMBATAÍ RIVER AREAS OF PERMANENT PRESERVATION.

AVALIAÇÃO DE ÁREAS DE PRESERVAÇÃO PERMANENTE DO RIO CORUMBATAÍ MEDIANTE USO DE SIG E BANCO DE IMAGENS AÉREAS MULTITEMPORAIS.

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ABSTRACT

This work used Geographical Information System (GIS) supplied of multitemporal (1940, before 1950, 1962, 1965, 1972, 1978, 1988, 1995, 2000, 2001, 2004, 2005, 2006, 2007 and 2009), high resolution scanning (1,200 dots per inch - dpi) and aerial image database aiming to assess the Corumbataí River Areas of Permanent Preservation (APP). Digital image from a pre-existing database and others acquired during the study, such as aerial photograph survey and satellite image in high resolution, were used in this work. The assessment results were validated at Santa Terezinha District and “Usina Parque do Corumbataí” Energy Museum, respectively situated at Piracicaba and Rio Claro cites, SP, Brazil. Photointerpretation method came out with opposed data regarding to stream-side vegetation coverage. The urban area expansion predominated, in ha and %, over stream-side vegetation at Santa Terezinha, otherwise at Energy Museum the stream-side vegetation expansion overcame other land uses. Thus, such valuation method allowed to relate and quantify types of land use occurred at APP with the environmental problems occurred at Corumbataí Basin. The use of these images intended to call attention of stakeholders and non-specialized people to the research results and to participate of discussion about sustainable territorial development.

Keywords: geoprocessing, stream-side vegetation, land use change.

RESUMO

Este trabalho utilizou Sistema de Informação Geográfica (SIG) e banco de imagens aéreas, multitemporais (1940, before 1950, 1962, 1965, 1972, 1978, 1988, 1995, 2000, 2001, 2004, 2005, 2006, 2007 and 2009) e de alta resolução (1.200 *dots per inch* - dpi), com o objetivo de avaliar Áreas de Preservação Permanente (APP) do Rio Corumbataí. A um banco digital de imagens pré-existente foram adicionadas novas imagens em alta resolução, oriundas de levantamento aerofotogramétrico e de satélite. Os resultados da análise foram validados no Distrito de Santa Terezinha e Museu da Energia "Usina Parque do Corumbataí", respectivamente localizados nos municípios de Piracicaba e Rio Claro, SP, Brasil. O uso de método fotointerpretativo revelou dados contrastantes em termos de cobertura de mata ciliar. Na APP de Santa Terezinha predominou a expansão da área urbana, em ha e %, sobre a área coberta com mata ciliar e no Museu da Energia, predominou a expansão da mata ciliar. Dessa forma este método permitiu relacionar e quantificar tipos de uso do solo ocorridos em APP com os problemas ambientais ocorridos na Bacia do Corumbataí. Foram então utilizadas imagens que visam atrair a atenção da faixa social "não-acadêmica" para debates de desenvolvimento territorial sustentável.

Palavras-chave: geoprocessamento, mata ciliar, mudança de uso do solo

INTRODUCTION

Areas of Permanent Preservation (APP) represent *"protected areas in terms of this law's 2nd e 3rd articles, covered or not with native vegetation, whose function is to preserve water resources"* (e.g. Brazilian Federal Law 4771/65).

The natural vegetation presence over APP plays an important part in water basins regarding to water store capacity, discharge regime balance, rivers margins stability and organic matter supplying to aquatic biota. Besides, these areas are fauna ways through and flora dispersions places which allow the formation of seed base and consequently initiate the natural vegetation recovery (Giordano & Riedel, 2008).

Such aspects show the importance of native forest at APP to conserve the ecosystem and population water supply, whereas Corumbataí River importance to furnish highly inhabited cities as Piracicaba (Palmieri & Carvalho, 2006).

Satellite images and aerial photographs, both in high resolution and temporal scale, processed in GIS attend on territorial recognition and allow to diagnose and predict disturbing factors for basins (Hodgson et al., 2003). Vertical and oblique photos are useful in such analysis (Tavares, 2006; Walstra et al., 2007).

Aerial photograph surveys are examples of vertical aerial photos and their main features are sidelap (30%) and overlap (60%) recovery between successive photos (Rosa, 2003). In some cases when the study area dimensions are beyond territorial recovery of a single photo it becomes necessary to create a mosaic of adjacent photos (Valta-Hulkkonen et al., 2004; Lange, 2008; Tuxen et al., 2008).

The aerial photograph and mosaic applying to territorial analysis regards to the use of techniques as fotointerpretation to analyze shapes and objects presented on the images (Tavares, 2006). Such technique demands user performs logical, deductive and inductive reasoning to identify, assess and arrange image features (Rosa, 2003).

The basin analysis by using multitemporal images showed to be efficient for natural resource projects. These images allow multidisciplinary professionals and non-academic people to join in the work to solve regional problems (Tress et al., 2009).

In such case, this work aims to evaluate a time series of aerial images with high resolution, by using GIS. The images were derived from a pre-existing digital database and new researches, during this work (Walter, 2004). Images recovering APP situated at Santa Terezinha District and “Usina Parque do Corumbataí” Energy Museum, respectively located in Piracicaba and Rio Claro, SP, were selected.

All materials and method used in this work acted as tools to analyze land use change at Corumbataí River APP (Apan et al., 2002). This analysis was based on different environmental conceptions of land use occurred in 1940, before 1950 (undefined data), 1962, 1965, 1972, 1978, 1988, 1995, 2000, 2001, 2004, 2005, 2006, 2007 and 2009.

MATERIAL AND METHODS

Study Area

The Corumbataí River Basin is situated in west-central São Paulo State, between the parallels 22º04'46"S and 22º41'28"S and the meridians 47º26'23"W and 7º56'15"W, corresponding to an area of 171,050 ha (Giordano & Riedel, 2008). The Corumbataí River APP was chosen as study focus due to Corumbataí River supplies with water important cities as Piracicaba and Rio Claro.

Work development and structuring

The work development was structured in the flow chart steps bellow (Figure 1).

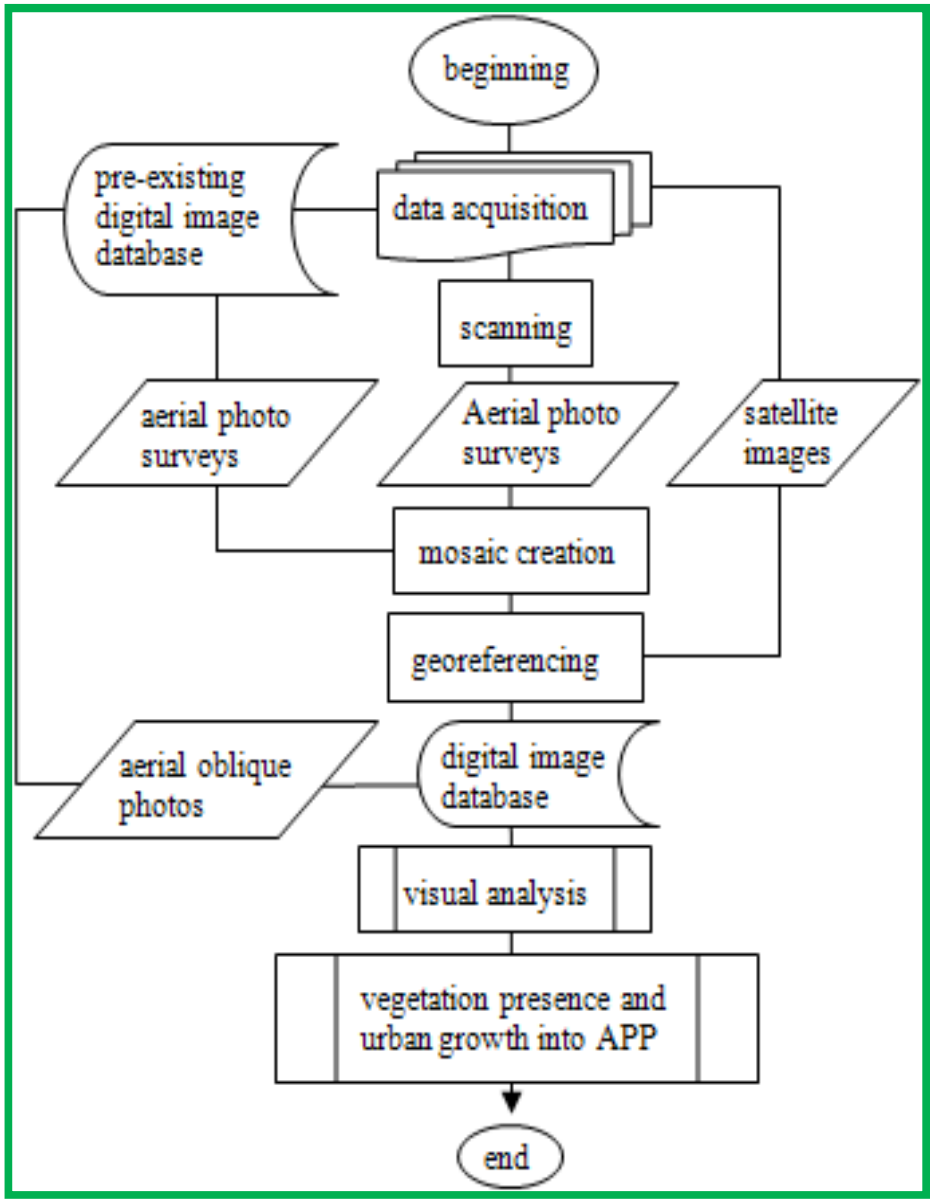

Figure 1: General flow chart with the work structuring steps.

The first step of this work was to acquire aerial images such as vertical and oblique aerial photographs, and also satellite images. Most of vertical aerial photographs and all of oblique ones, in high resolution (1,200 dpi), were obtained from a pre-existing digital database created by Tavares (2006). During the study the database was increased with new vertical aerial photos, and satellite images.

The image database allowed to recover several Corumbataí River APP's regions. The aerial photo surveys were organized in chronological order by survey year, scale, color (colour or B/W) and the Areas A1 and A2 selected for analysis (Table 1).

Table 1: Aerial photo surveys organization.

Year	Scale	(1) B/W	Colour	(2) A1	(3) A2
1940	1:20,000	X		X	
(*) 1950	1:20,000	X		X	
1962	1:25,000	X		X	X
1965	1:60,000	X		X	X
1972	1:25,000	X		X	X
1978	1:35,000	X		X	X
1988	1:40,000	X			X
1995	1:25,000	X		X	X
2000	1:25,000		X	X	X
2001	1:25,000		X	X	

(1) B/W: Black and White

(2) A1: Santa Terezinha District

(3) A2: “Usina Parque do Corumbataí” Energy Museum

(*) Undefined data – before 1950

Beyond aerial photo surveys this work also used oblique aerial photographs from 2004 and a controlled mosaic of aerial photo survey from 2002.

At last, the image database was supplied with high resolution satellite images available by the free version of GoogleEarth (2009) software. Those from years 2005 and 2007 recovered Area 1, from 2006 recovered Area 2, and from 2009 recovered both Areas 1

and 2. Satellite images were used to visualize the most recent objects or environmental events.

The pre-existing image database was useful to organize the aerial photo surveys, by creating photo indexes. Photo indexes provided great agility related to new aerial photos acquirement and mosaics creation. Mosaics were created into Adobe Photoshop software with support of photo indexes, in electronic spreadsheet format.

Based on the mosaic images the next step performed the georreferencing of each original photo (1,200 dpi) that recovered the study areas 1 and 2 using TerraSIG software. In some cases only one photo was enough to recover the study area and in others many adjacent images were accessed to visualize the whole study area.

The final steps were also performed into TerraSIG. Its GIS tools enabled to map the vegetation and the urban expansion and then make relations between such factors with their damage consequences over the river.

RESULTS AND DISCUSSION

Santa Terezinha District

The visual analysis of vertical aerial photos and satellite images indicated an urban expansion into Corumbataí River APP, located at Santa Terezinha District (Figure 2).

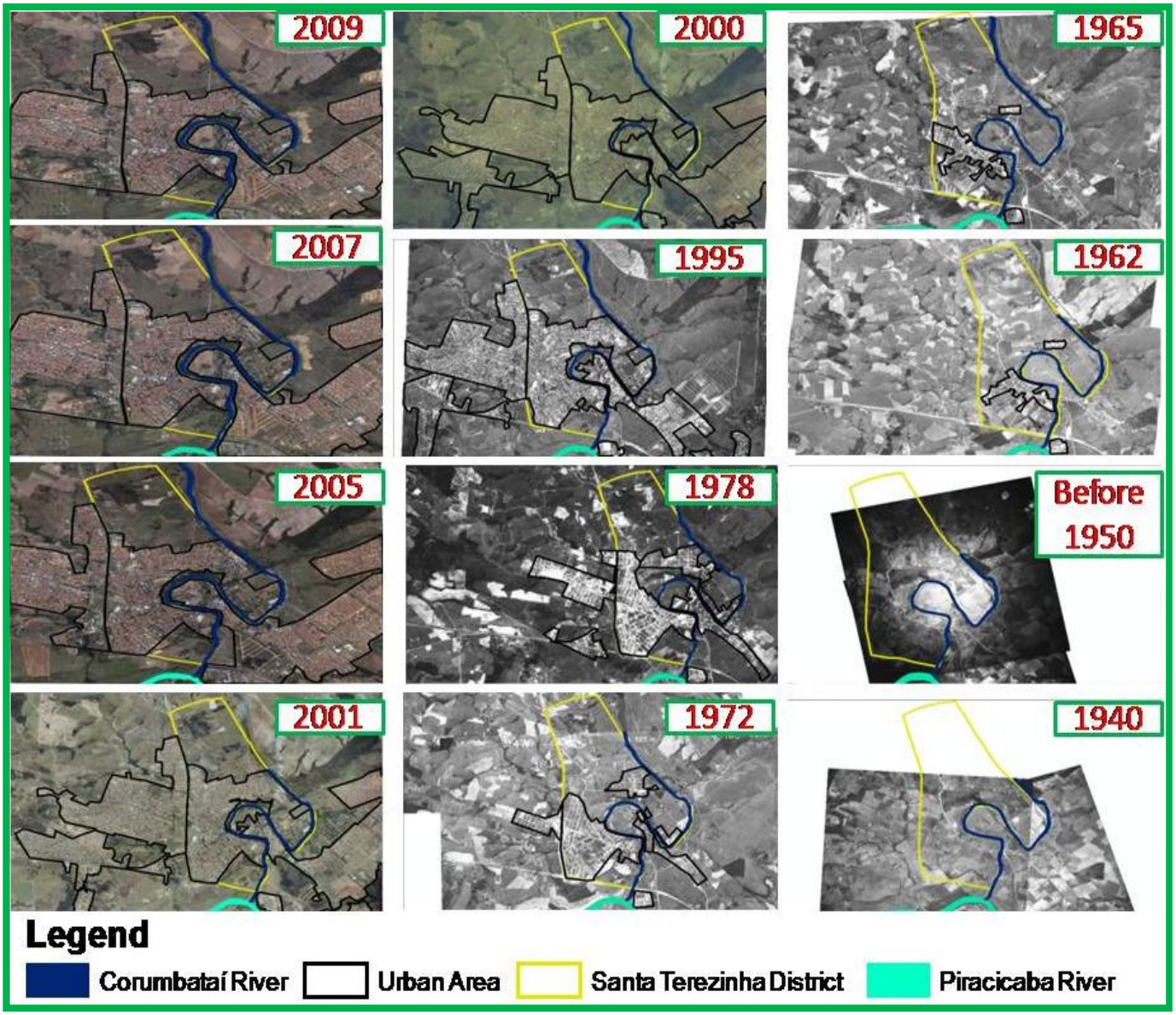

Figure 2: Urban expansion into Corumbataí River APP (1940 to 2009).

Between 1940 and before 1950 the images showed a predominance of land use by sugar cane at Piracicaba (Figure 3).

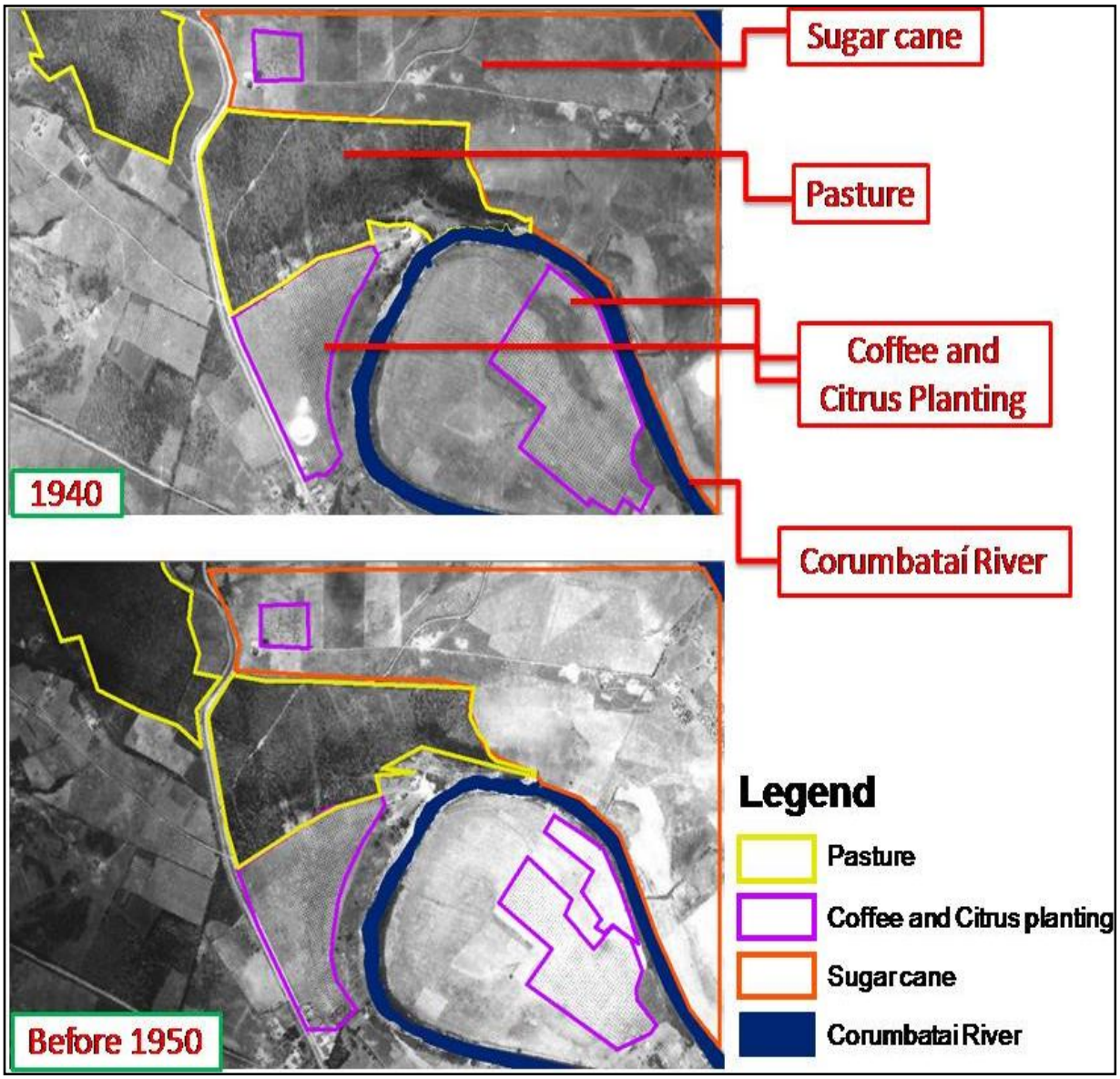

Figure 3: Santa Terezinha land use (1940 a 1950).

From 1962 to 2009, land occupation was characterized by urbanization. The highest indexes, 12.52 to 32.06% and 5.52 to 12.17% respectively at Santa Terezinha and into APP, occurred between 1965 and 1972.

The percentage values of urban expansion in the district became fixed, varying between 53.13 to 53.34% less than 1%, in 2000, and into APP they become fixed from 2001

(27.04 to 26.48%). Between 2007 and 2009, more than a half of district total area (53.19%) and more than a quarter of APP (26.48%) were occupied with urban area. The percentage values from 1962 till 2009 indicated an enlargement of 544.14% and 528.31% in the urban area and APP, respectively. From 1940 to 2009 showed a radical land use change in the district. In the 40 and 50 decades agricultural tillage was the main land use, and at 60 decade appear the first village occupying only 8.26% of total area and it is now the predominant land use (53.19%) (Table 2).

Table 2: Santa Terezinha urban expansion.

Year	(1) A1 (ha)	(2) %	(3) A2 (ha)	(4) %
1962	34.73	8.26	2.98	4.21
1965	52.67	12.52	3.91	5.52
1972	134.84	32.06	8.62	12.17
1978	169.48	40.29	16.39	23.14
1995	221.59	52.68	17.56	24.78
2000	223.49	53.13	19.01	26.83
2001	223.95	53.24	19.15	27.04
2005	224.37	53.34	18.90	26.68
2007	223.71	53.19	18.75	26.48
2009	223.71	53.19	18.75	26.48
1962-2009	-	544.14	-	528,31

Red: urban area decrease by comparing anterior periods. Green: increase.
(1) A1 – urban area at Santa Terezinha.
(2) Relation between urban area and Santa Terezinha total area (420,62ha).
(4) A2 – urban area into APP at Santa Terezinha.
(3) Relation between urban area located at APP and total APP (70,84ha) for Santa Terezinha.

Silting points vizualization at image 2004 were enabled due to the highest resolution of the images then great “zoom in” capacity (Figure 4).

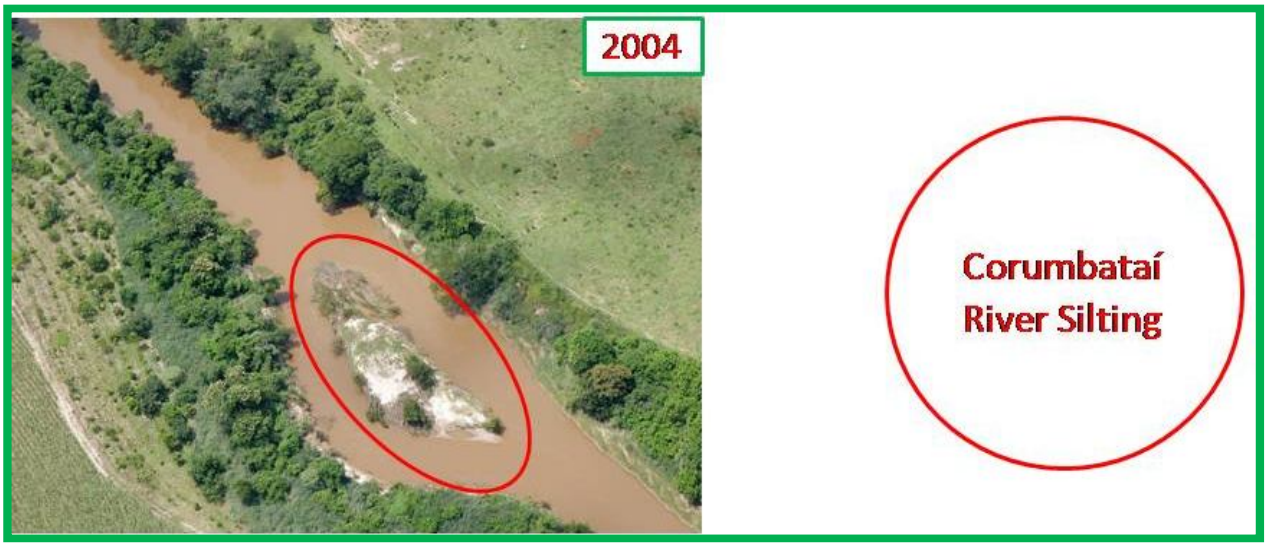

Figure 4: Corumbataí River silting points in several times.

The APP forest recovery visualized in 1940 indicated an increase when compared to 1962 followed by industries appearing.

Simultaneously to the urban expansion at Santa Terezinha and into APP the indexes of recovery vegetation also had a great increase (485.71 and 484.83%) between 1940 and 2009. Though, these data must take to account the fragmented conditions and the actual area value (32,77ha), lower than limit value (70,84ha) demanded by law, for vegetation recovery. It was still detected a lack of more than a half of vegetation area to be replaced into APP (Table 3).

Table 3: Vegetation recovery evolution into APP.

Year	(1) VRA (ha)	(2) %	(3) %
1940	5.61	1.33	7.91
(*)1950	8.83	2.1	12.46

1962	9.85	2.34	13.90
1965	9.18	2.18	12.97
1972	6.02	1.43	8.50
1978	10.02	2.38	14.15
1995	12.58	2.99	17.76
2000	12.34	2.93	17.42
2001	11.22	2.67	15.83
2005	17.81	4.23	25.15
2007	30.75	7.31	43.41
2009	32.77	7.79	46.26
1940 to 2009	-	485.71	484.83

Red: decrease of vegetation recovery area by comparing anterior periods. Green: increase.
(1) VRA – vegetation recovery area into APP at Santa Terezinha.
(2) Relation between vegetation recovery area into APP and Santa Terezinha total area (420.62ha).
(3) Relation between vegetation recovery area into APP and total APP (70.84ha) at Santa Terezinha.
(*) Undefined data – before 1950

"Usina Parque do Corumbataí" Energy Museum

Contrary to Santa Terezinha District over the "Usina Parque do Corumbataí" occurred a process of vegetation recovery into Corumbataí River APP (Figure 5).

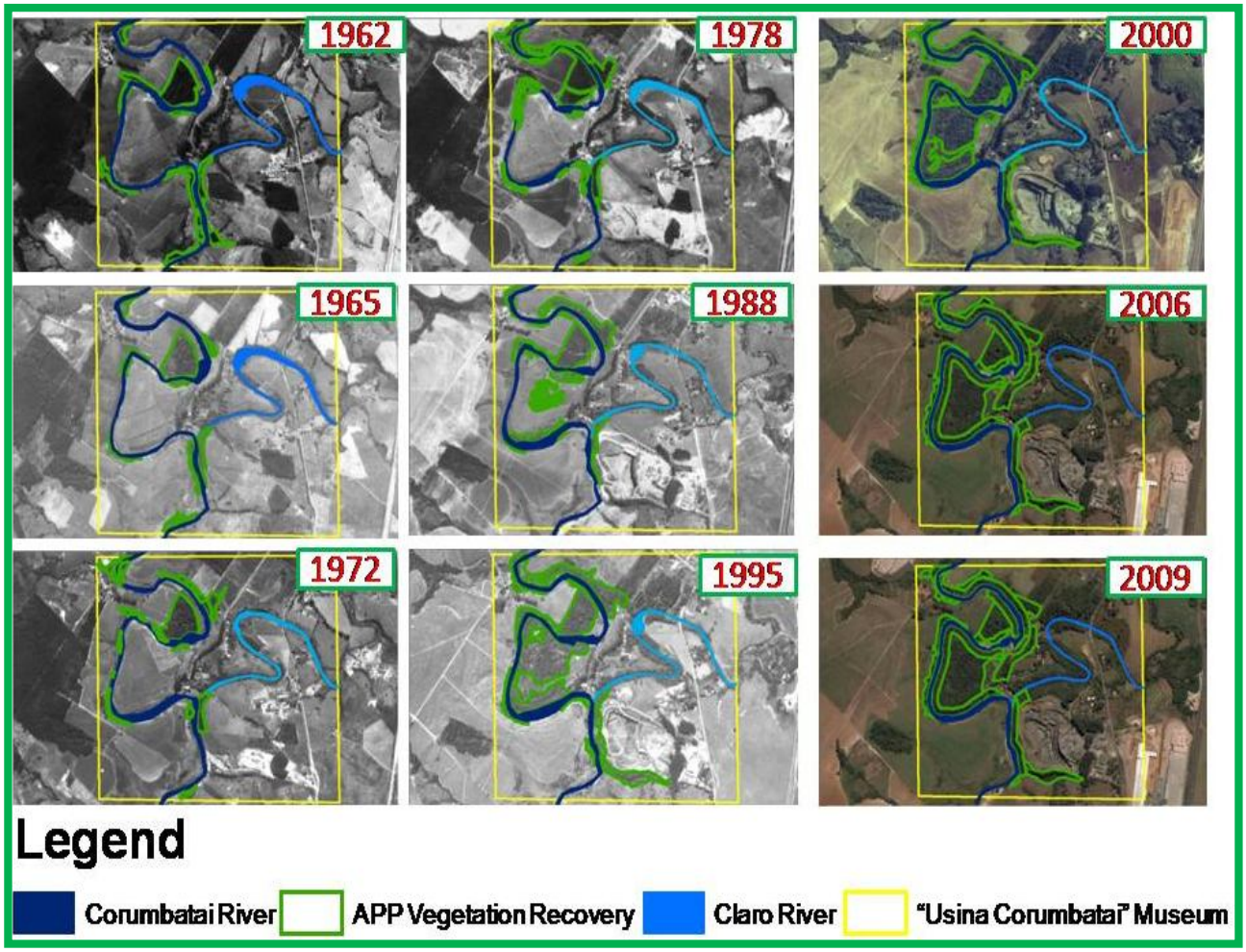

Figure 5: Vegetation recovery into Corumbataí River APP.

During 80 years activities as calcareous mining employs settled down surround Corumbataí River (Zuquette et al., 2009) (Figure 6).

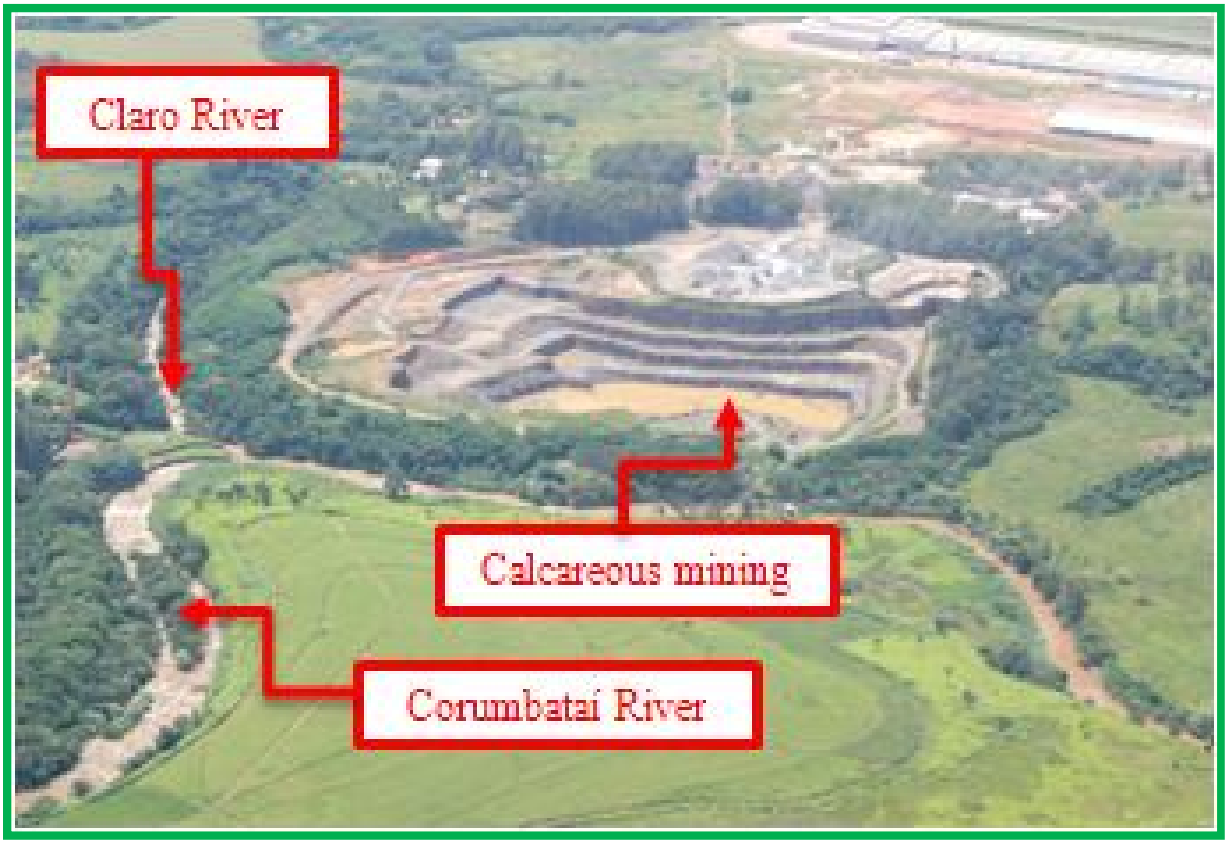

Figure 6: Aerial oblique photo showing a calcareous mining (2004).

The mapping and quantifying of forest expansion into APP found out a reduction from 12.51 to 9.73% between 1962 and 1965 whereas the comparison between 1988 and 1995 images indicated the highest increase of vegetation occurred in the 90 decade. This time there was an increase from 15.18 to 32.36% of forest area into APP what confirmed the efficiency of the reforesting projects started at 80 decade. Comparing the oldest image (1962) with the most actual (2009) it was observed an increase of 238.04% of forest into Corumbataí River APP (Table 4).

Table 4: Vegetation recovery evolution into APP.

Year	(1) VRA (ha)	(%) (2)
1962	12.51	29.23

1965	9.73	22.74
1972	10.46	24.44
1978	14.61	34.14
1988	15.18	35.47
1995	32.36	75.63
2000	35.43	82.80
2006	42.28	98.81
2009	42.28	98.81
1962 to 2009	__	238.04

Red: decrease of vegetation recovery into APP by comparing anterior periods. Green: increase.
(1) VRA – vegetation recovery area into APP at Energy Museum.
(2) Relation between vegetation recovery area into APP and total APP (42.79ha) at Energy Museum.

Map showing forest recovery and minimal area claimed for APP presented total forest absence in some locals and APP minimal area overcome in others (Figure 7).

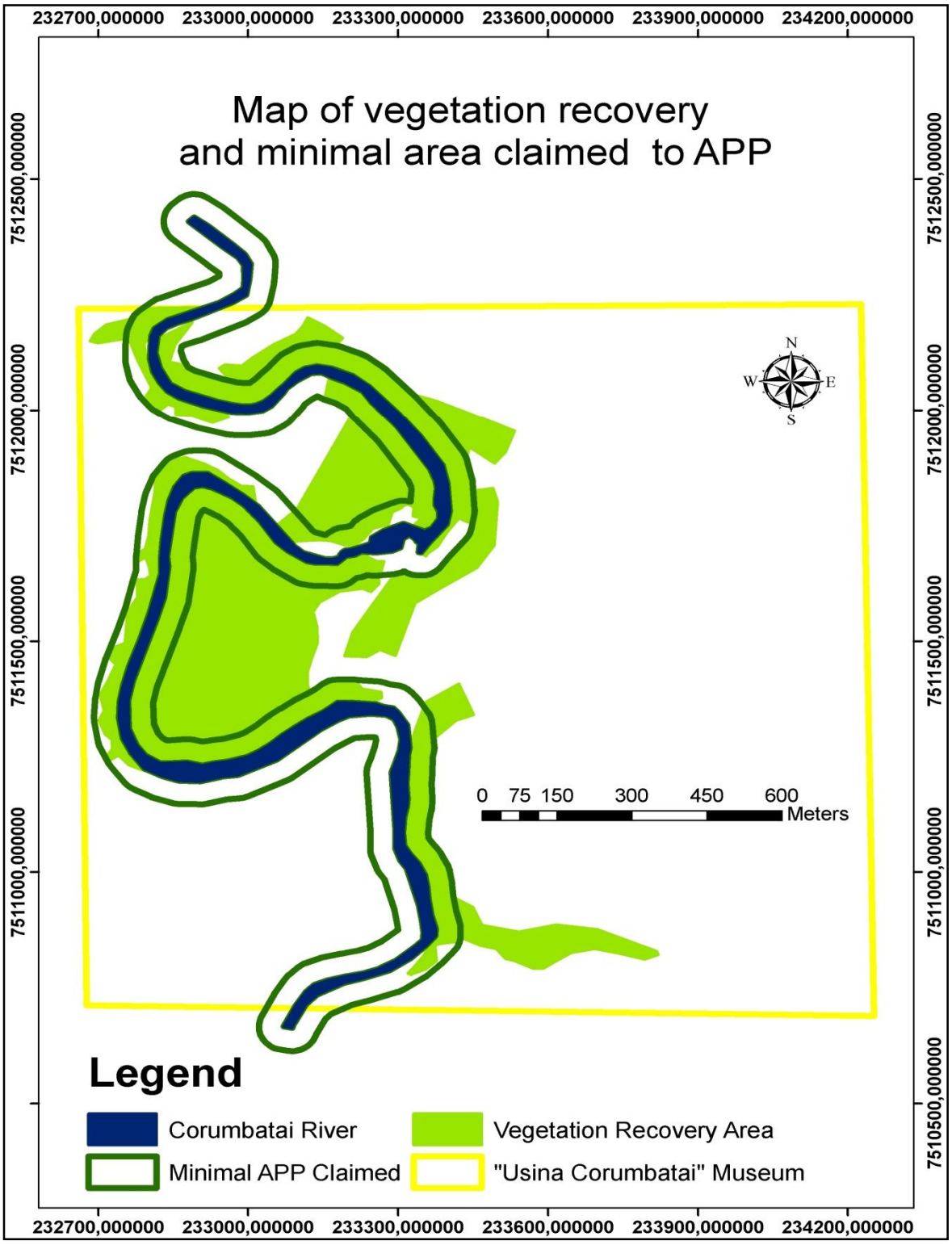

Figure 7: Map of vegetation area and minimal area claimed to APP.

CONCLUSION

The use of aerial photographs scanned in high resolution (1,200 dpi) and satellite images with high spatial resolution, from 1940, before 1950, 1962, 1965, 1972, 1978, 1988, 1995, 2000, 2001, 2004, 2005, 2006, 2007 and 2009, allowed to analyze Corumbataí River APP. Two different APP were evaluated in this work, one located at Santa Terezinha District and other at “Usina Parque do Corumbataí” Energy Museum.

Study areas presented opposite results for APP land use. There was a satisfactory forest recovery but not totally according to APP law claiming at “Usina Parque do Corumbataí” Energy Museum due to reforestation projects initiated at 80 decade. The against occurred at Santa Terezinha District which showed factors with degradation potential such as inexpressive forest recovery and urban expansion into APP, both directly related to the great difficult to implement projects of water resources sustainability already existent for the region.

A wide access to the digital image database organized in this work should make easier the inhabitants monitoring of landscape changes mentioning new interpretations and suggestions about region improvement. The consequence of wider non-academic people participation should be a debate enrichment about sustainable process of land use into APP and Basin in general way.

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