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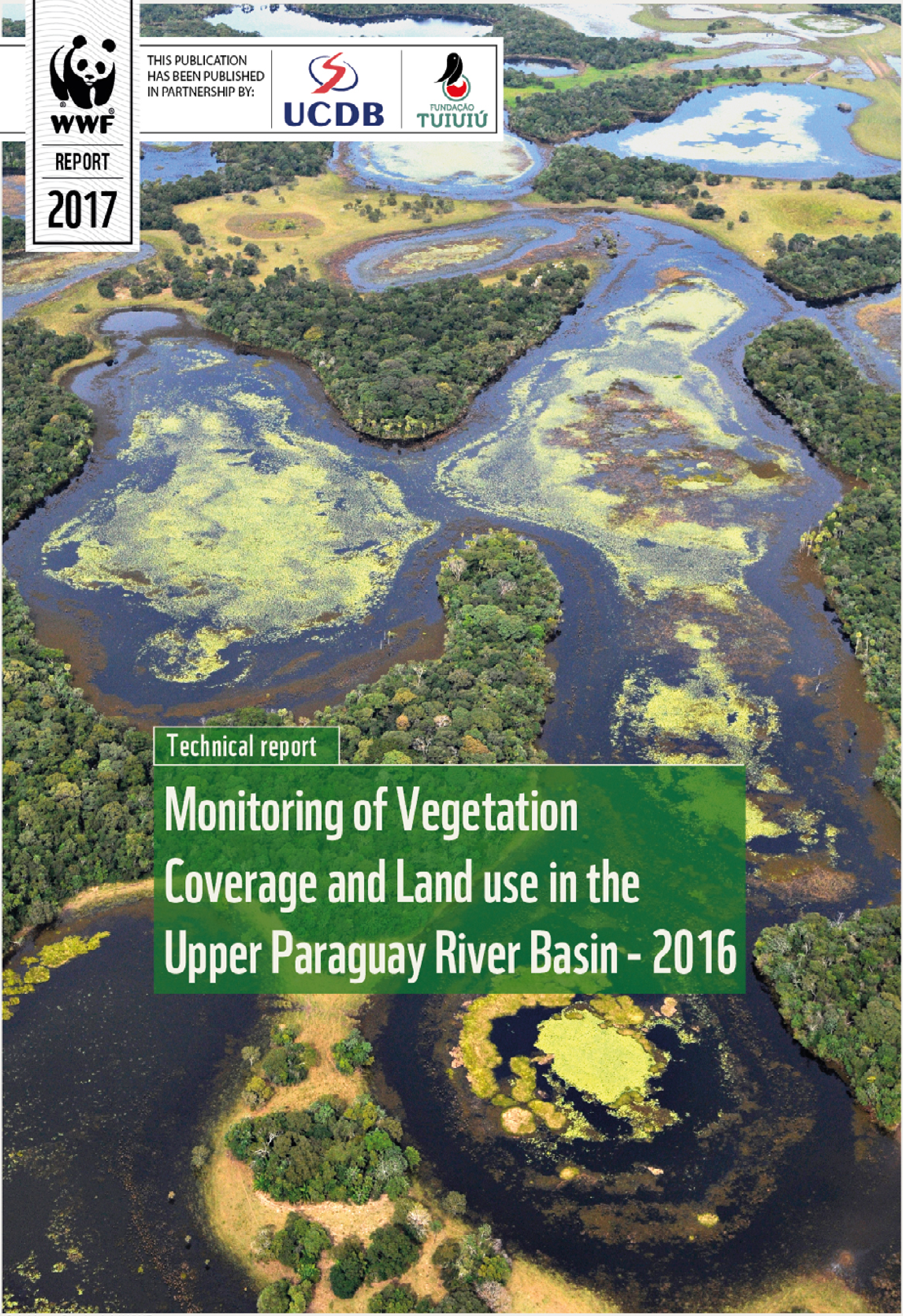

Technical report

Monitoring of Vegetation Coverage and Land use in the Upper Paraguay River Basin - 2016

THIS REPORT IS A PARTNERSHIP BETWEEN

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INTRODUCTION

The Paraguay river basin covers parts of Argentina, Bolivia, Brazil and Paraguay, and in Brazil it is located between the states of Mato Grosso and Mato Grosso do Sul. This part is therefore named the Upper Paraguay River Basin (UPRB) and it comprises three biomes: the Amazon, the Brazilian Cerrado and the Pantanal. *Figure 1* shows its location.

The UPRB is characterised by its division between higher tableland areas, where the Cerrado predominates, and lower floodplain areas. The dynamic between these areas is directly responsible for the environmental characteristics of the region, and as this is an interlinked system, environmental impacts propagate across various gradients. With a wide biodiversity and the provision of fundamental ecosystemic services, the river basin is still relatively uninhabited. However, the expansion of production models based on monocultures and the conversion of natural areas has provoked alterations to the region's vegetation coverage.

These alterations can be detected using geoprocessing and remote-sensing techniques. This technology has enabled breakthroughs in various areas of conservation science through automated data collection by satellite, allowing the monitoring and surveying of land resources on a large scale. Monitoring is used as a strategic tool, supporting decision-making processes for governmental and private-sector actions.

WWF-Brazil and its partnership organisations have been monitoring land use and coverage in the Brazilian Upper Paraguay River Basin since 2008. The observation of this dynamic enables the main threats to this ecosystem to be understood, and more importantly, more effective conservation strategies to be outlined.

Figure 1 - Location of the Upper Paraguay River Basin in Brazilian territory

Seeking the continued monitoring of the Upper Paraguay River Basin through an integrated perspective involving local actors and academia, this technical report presents the monitoring data for the 2016 dry season (April - September), jointly developed by the Dom Bosco Catholic University (UCDB), the Tuiuiú Foundation and WWF-Brazil.

In the final section, data from the mapping carried out by the WWF-Brazil team using satellite images from 2015 of the Paraguay River Basin in Argentina, Bolivia and Paraguay will be presented, enabling a global diagnosis of this environmental system independent of political borders.

Contents

1.METHODOLOGY

Methodology was adopted that would represent the vegetation coverage and land use of the region with a high degree of accuracy. Interpretation of satellite images and evaluation of natural areas was performed via the hybrid process, which involves unsupervised classification and the manual association and validation of categories.

The Landsat 8 is a satelite from United States of America for landcover monitoring. Is the 8th of a series of satelites, and the 7th of getting in orbit with success.

Landsat 8 OLI sensor satellite images present satisfactory spectral and geometric results, as the orthorectification of images dispenses with the need for georeferencing. It also enables the adoption of classification and post-classification procedures that have been consolidated in a range of publications. The low cloud coverage in the archives enabled a mosaic of the UPRB to be put together by connecting 28 images from the 2016 dry season.

Figure 2 presents a flow diagram of the methodology adopted for this study, enabling a better understanding of the procedure used.

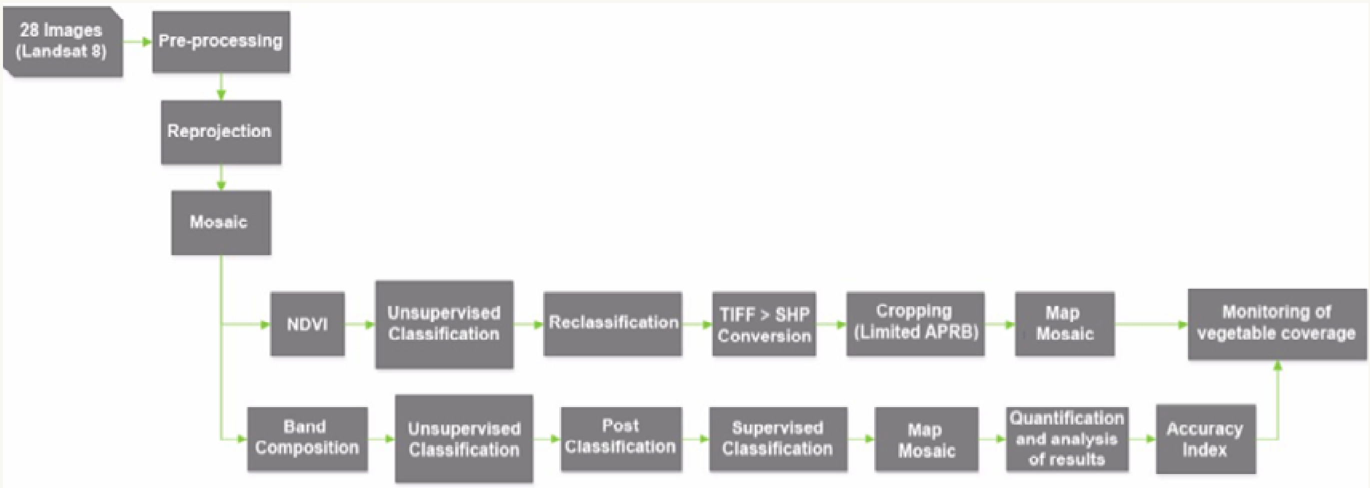

Figure 2 – Flow chart of the methodology used to monitor vegetation coverage and land use in the Upper Paraguay River Basin in 2016.

1.1. Image Acquisition

Images were used from a Landsat 8 satellite equipped with two sensors: Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS). These provide seasonal coverage of the earth's surface of different spatial resolutions: 30 metres for bands 1 to 7 and 9 (coastal aerosol, blue, green, red, near infrared - NIR, SWIR 1, SWIR 2 and cirrus); 15 metros for band 8 (panchromatic) and 100 metres for thermal bands (TIRS 1 and 2) (USGS).

Unlike images produced by the older Landsat satellites, those generated by Landsat 8 are already geometrically adjusted, and are already orthorectified when available for download. Therefore, they do not require georeferencing for data use, increasing agility and simplicity (DUARTE *et al.*, 2015).

Other factors that justify the use of these images involve the precision of the positioning and the concatenation of different scenes. The full coverage of Brazilian territory and the fact this is a free service are also significant factors to consider in large-scale analyses of the land (KALAF, 2013).

To create the mosaic of the Upper Paraguay River Basin (UPRB), 28 free-of-charge Landsat 8 images were selected from the United States Geological Survey (USGS). The criteria for the choice of images considered the minimal cloud coverage associated with the dry season (June to August) for the year 2016. From the total number of images acquired, 27 were taken in June and one was taken in August, and together they covered the entire Brazilian portion of the UPRB.

1.2. Pre-processing and Band Composition

After the selection of the images, 13 bands were downloaded. The Landsat 8 satellite images are aligned with true north and needed to be reprojected for the southern hemisphere. Once the images were correctly positioned, the bands (1 to 7) were stacked for each of the 28 images, and these were then put together to form the mosaic (*Figure 3* and *Figure 4*).

The false colour composite was used with bands 6/5/4 (R/G/B), as this provides a clear differentiation between water and vegetation. Band 6 (thermal infrared) has the sensitivity to detect certain phenomena related to thermal contrasts in water environments, enabling the water level of flooding in vegetation or exposed earth to be analysed (ROSA *et al.*, 2011).

Radiation reflected on the atmosphere has a determined distribution for each item found in nature. The way in which this is reflected, emitted and absorbed allows items to be differentiated from each other and provides information on shape, size and even some physical and chemical characteristics (MIRANDA *et al.*, 1996). The false colour composite (6/5/4 – R/G/B) enables easier differentiation given a range of reflectance responses.

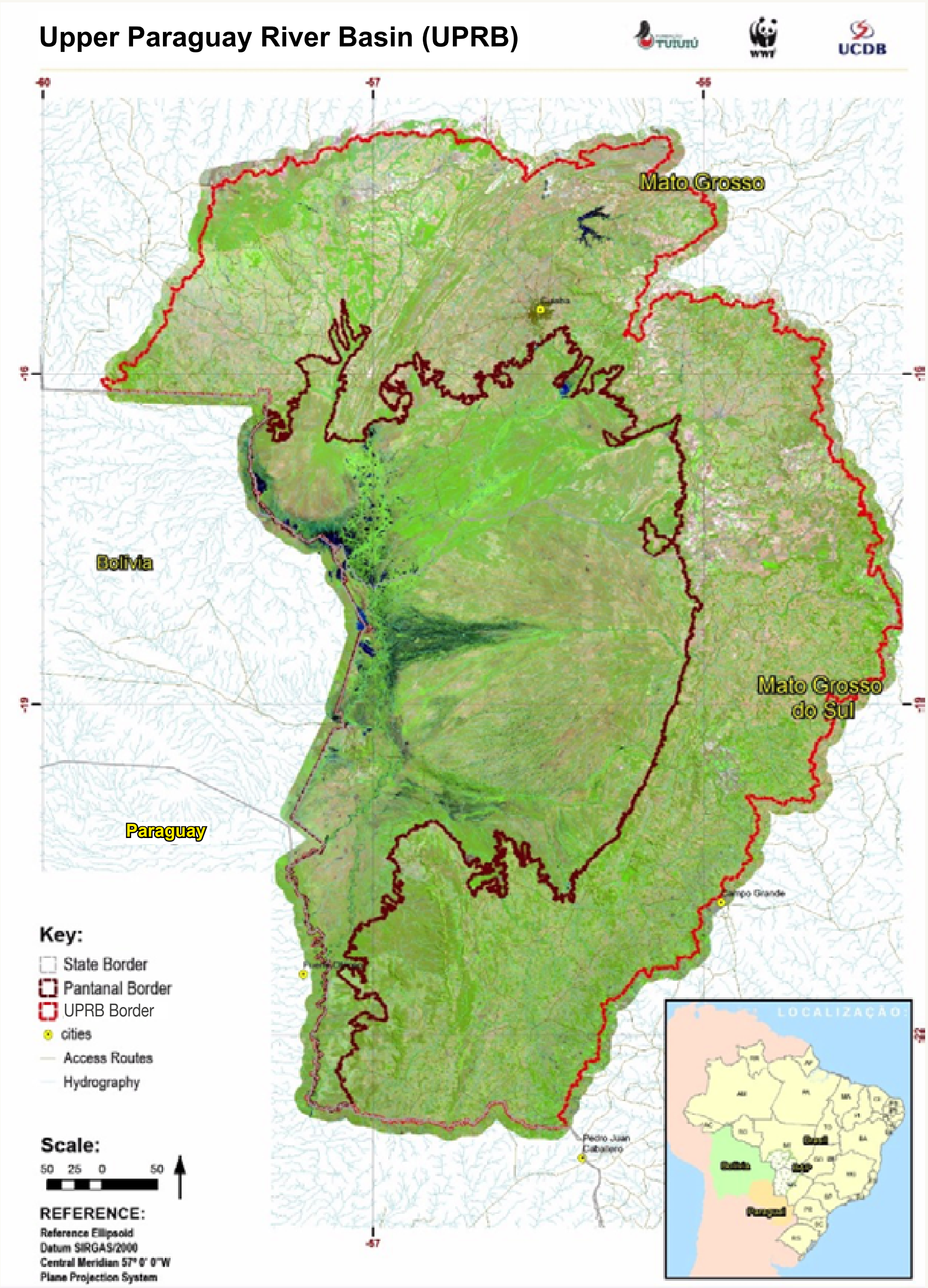

Figure 3 - Mosaic of "Landsat 8" false colour composite satellite images (R/G/B –6/5/4) of the Upper Paraguay River Basin, 2016

1.3. Normalised Difference Vegetation Index (NDVI)

A variety of vegetation indices have been developed to assist in the monitoring of vegetation coverage. Most of these indices are based on different interactions between the type of vegetation and its corresponding spectral signature in the zones relating to the red and infrared wavelengths (VICENS *et al.*, 1998).

The NDVI is related to vegetation density and is obtained through Equation 1 (EASTMAN, 1995):

$$NDVI = \frac{(NIR-R)}{(NIR+R)} \qquad (1)$$

Where:
NIR: reflectance values in the near-infrared region;
R: reflectance values in the red region.

This index varies from -1 to 1, and higher values are associated with greater vegetation coverage (VICENS *et al.*, 1998).

Classified images can be used to extract the minimum, maximum and average values and the standard deviation for each of the thematic classifications. For each interval, reclassification of the NDVI image provides a more refined thematic classification of vegetation coverage.

1.4. Classification and reclassification of NDVI

Initially, the NDVI was grouped into 10 intervals on an image-by-image basis, but divergences were observed between the current situation of the UPRB and the results obtained. It was then decided to classify using mosaics, grouping these together into 13, 6 and 9 scenes. This classification provided better results than the scene-by-scene approach (*Figure 4*).

After classification, the mosaics were reclassified into four categories. These reclassified mosaics were then cropped to fit the outer limits of the UPRB. The resulting NDVI image provided an overview of the whole area and the spatial distribution of uses within the UPRB, distinguishing between anthropic and natural uses.

It is important to note that the responses of water and land areas prepared for agriculture or with the presence of water were grouped together, leading to incorrect interpretation of the results. However, the behaviour of dense forests can be observed in relation to areas with no vegetation coverage. The NDVI is essential in prior classification analyses and in understanding spectral responses.

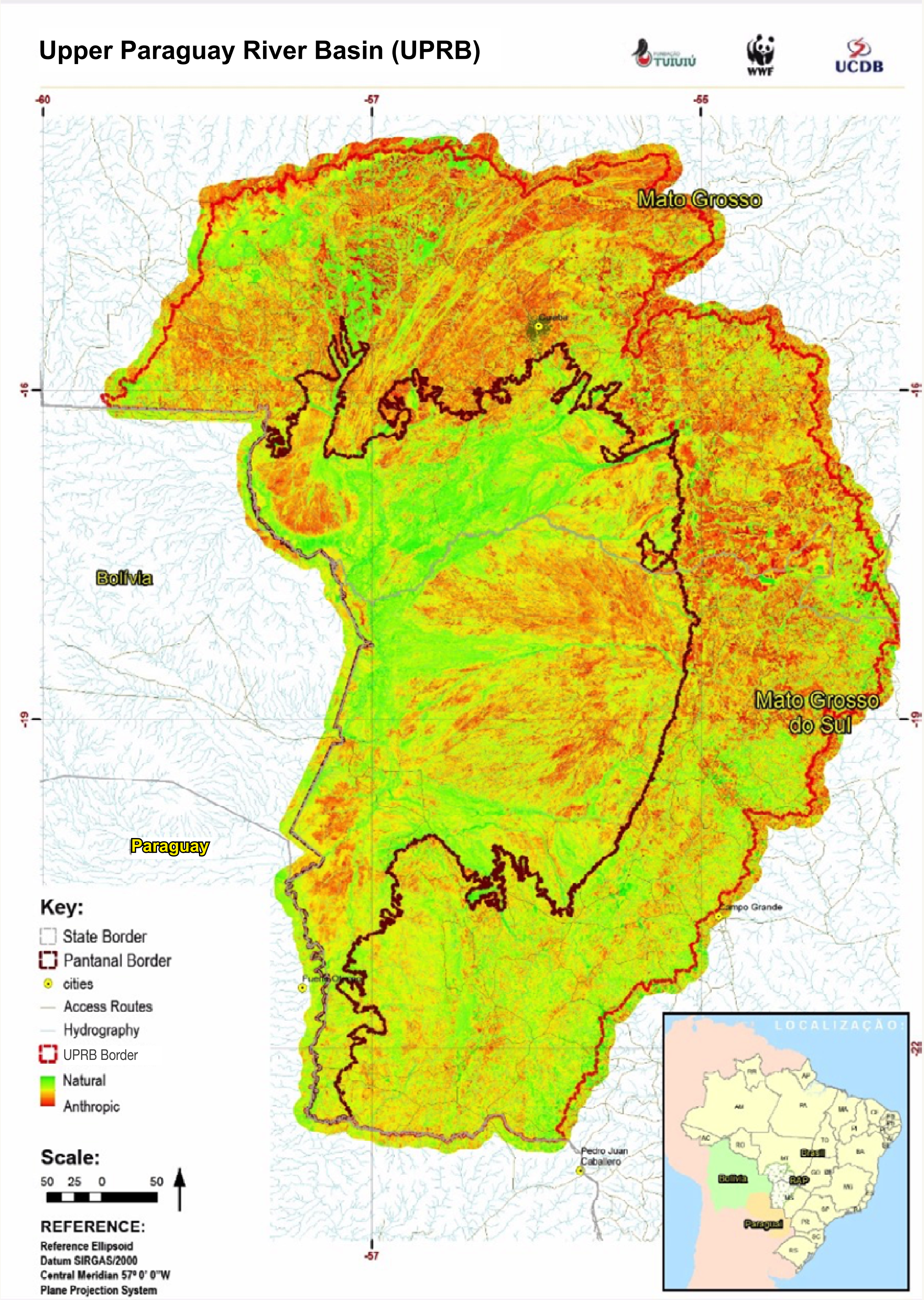

Figure 4 – Normalised Difference Vegetation Index

1.5. Unsupervised Classification

Unsupervised classification is carried out using clustering methods and is based on the principle that a computational algorithm is able to identify categories from a range of data (GONÇALVES, 2008). Tests were performed to define the different categories. Images were classified into 7, 10, 14, 20 and 50 categories, and the best results were observed for the processing into ten categories with a maximum of 20 interactions.

Filters were applied to equalise the results and eliminate noise from the process.

1.6. Post-classification

After classification, the map obtained presented noise and small segments. The mosaic was filtered using the nearest neighbourhood (3x3) method, in order to eliminate pixels with incoherent values or that were spread across the categories considered. The clump function was then applied to neighbours connected in fours to group together pixels with the same digital level.

The eliminate function was then applied to groups of at least four pixels to remove the smaller polygons, bringing together the larger ones (RAMOS-NETO *et al.*, 2004 *apud* MOREIRA, 2005). Finally, the images were cropped using a combination of a total of 153 topographic maps on a scale of 1:100.000 obtained from the IBGE (*Figure 5*).

This combination was subdivided in order to enable editing using a standard format in widespread use since the 1970s.

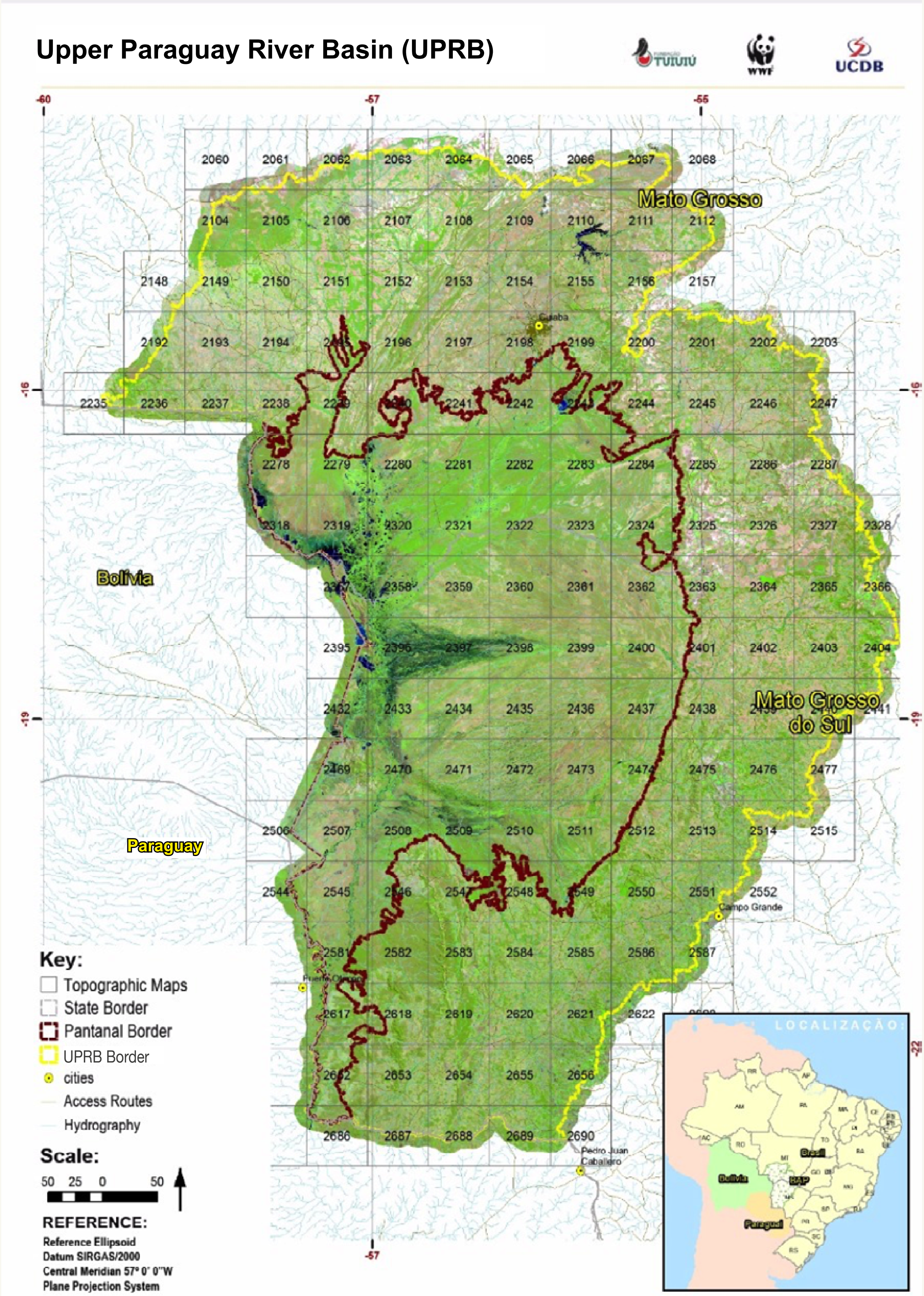

Figure 5 – Consolidation of topographic maps on a scale of 1:100,000.

1.7. Vectorial Editing

The vectorial editing of the 153 maps was carried out in two stages. The first consisted of associating 10 categories with anthropic and natural use. The second stage (validation) involved validation of on a map-by--map basis.

1.8. Regrouping of Vegetation Types

The original classification of plant physiognomy presented in the "Technical Manual on Brazilian Vegetation" (IBGE, 2012) presents 52 subclasses of natural vegetation. For the purposes of this study, the 52 subclasses were regrouped into 4 natural categories due to the similarity of their phytogeographic characteristics:

I) Forest Formations - FF;
II) Shrubland Savannah - SS;
III) River Influenced Vegetation - RIV;
IV) Natural Management Area - NMA.

1.8.1. Forest Formations (FFs)

This class comprises 23 plant typologies, including Deciduous Seasonal Forests, which can present alluvial formation and are located in floodplains and along rivers. Forest Formations have high trees and shrubs in their lower layer *(Figure 6)*.

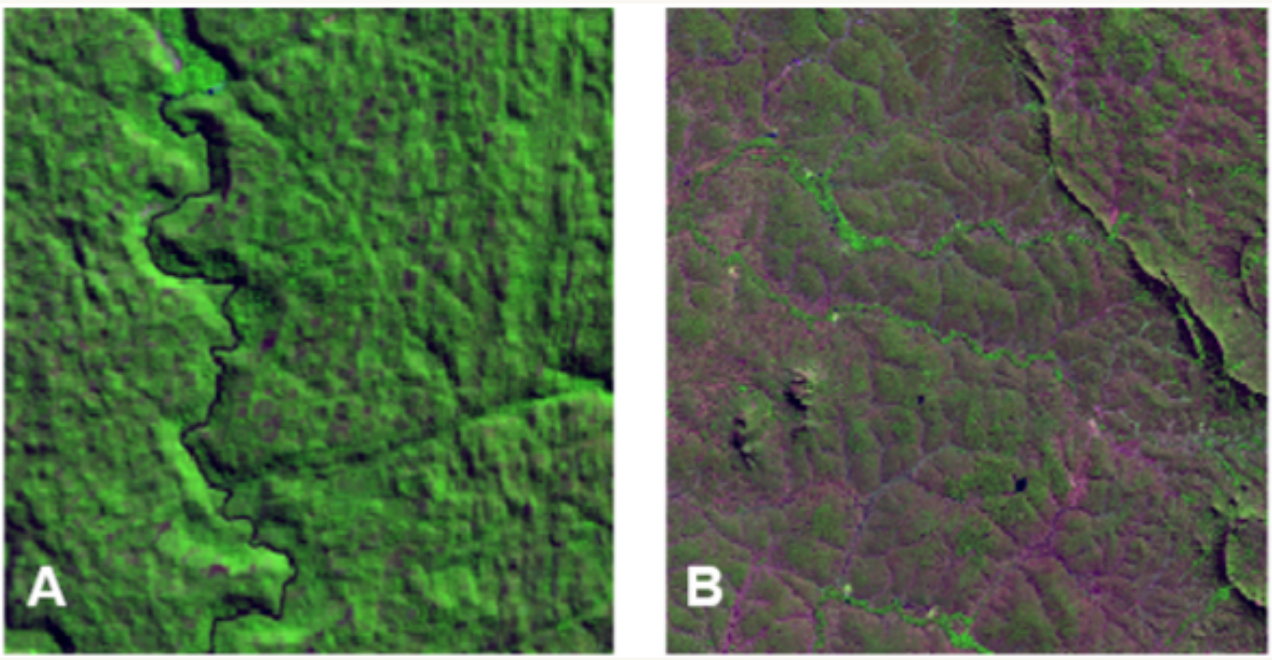

Figure 6 – Representations of Forest Formation categories. (A) Dense Forest Formation; (B) Sparse Forest Formation

Forest Formations also present densely arranged and smaller trees distributed more sparsely between widespread shrubland and herbaceous vegetation. *Table 1* provides the 23 types of plant physiognomy included in the Forest Formations group.

Table 1 – Plant physiognomy of Forest Formations

Ca	Deciduous Seasonal Alluvial Forest
Cb	Deciduous Seasonal Lowland Forest
Cs	Deciduous Seasonal Sub-Mountainous Forest
Fa	Semi-Deciduous Seasonal Alluvial Forest
Fb	Semi-Deciduous Seasonal Lowland Forest
Fs	Semi-Deciduous Seasonal Sub-Mountainous Forest
SN	Forested Savannah/Seasonal Forest
SNc(Sd+Fs)	Forested Savannah/Semi-Deciduous Seasonal Forest
SNc(Sd+Cs)	Forested Savannah/Deciduous Seasonal Forest (contact)
Sd	Forested Savannah
Sd+Cs	Forested Savannah/Deciduous Seasonal Forest
Sd+Fs	Forested Savannah/Semi-Deciduous Seasonal Forest
Sd+As	Forested Savannah/Wooded Savannah
Sd+Sg	Forested Savannah/Grassy Savannah
Sd+Spf	Forested Savannah/Savannah Preserve
SNt(SCt)	Savannah/Seasonal Deciduous Forest (transition)
SNt(SFt)	Savannah/Semi-Deciduous Seasonal Forest (transition)
As	Wooded Savannah
Sa+Sd	Wooded Savannah/Forested Savannah
Sa+Sg	Wooded Savannah/Grassy Savannah
Sa+Sp	Wooded Savannah/Savana Preserve
Saf	Wooded Savannah with Gallery Forest
Sas	Wooded Savannah without Gallery Forest

1.8.2. Shrubland Savannah (SS)

This class of vegetation presents sparsely spread tree species and predominantly shrubland, and normally occurs in areas with seasonal or permanent flooding (*Figure 7*).

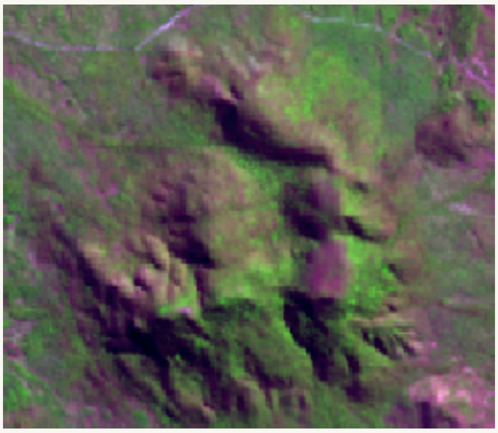

Figure 7 – Representation of Shrubland Savannah

The SS class incorporates 13 types of plant physiognomy, which are listed in *Table 2*.

Table 2 - Plant physiognomy of Shrubland Savannah

Sg	Grassy-Woodland Savannah
Sg+Sa	Grassy-Woodland Savannah/Wooded Savannah
Sg+Sd	Grassy-Woodland Savannah/Forested Savannah
Sgf	Grassy-Woodland Savannah with Gallery Forest
Sgs	Grassy-Woodland Savannah without Gallery Forest
Sp	Savannah Preserve
Sp+Sa	Savannah Preserve/Wooded Savannah
Sp+Sg	Savannah Preserve/Shrubland Savannah
Spf	Savannah Preserve with Gallery Forest
Spf+Sd	Savannah Preserve/Forested Savannah
Sps	Savannah Preserve without Gallery Forest
Vs	Secondary Vegetation
rsh	Refuge Area

1.8.3. River Influenced Vegetation (RIV)

This category is made up of woodland vegetation and pioneer formations (e.g., bogs, cambarazaland, paratudal formations and carandazal) located along water courses and in depressions that accumulate water (*Figure 8*).

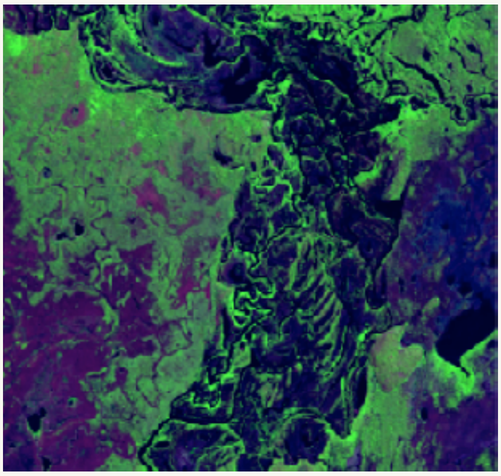

Figure 8 - Representation of River Influenced Vegetation.

Table 3 presents the 6 types of plant physiognomy included in the RIV class.

Table 3 – Plant physiognomy of River Influenced Vegetation

NPt(F+Pa)	Seasonal/Pioneer Forest (transition)
P	Pioneer Formations
Pa	Pioneer Formations with Influence from Rivers and/or Lakes
SP	Savannah/Pioneer
SPt(S+Pa)	Savana/Pioneer Formations (transition)
TPt(T+Pa)	Steppe Savannah/Pioneer Formations (transition)

1.8.4. Natural Management Areas (NMAs)

Cattle-ranching activities have existed for hundreds of years in the Pantanal, the floodplain area of the Upper Paraguay River Basin (UPRB), and the management of this is naturally incorporated into the biome and the landscape. Therefore, we considered areas predominantly comprising natural fields, which are often used for the development of these activities, to be Natural Management Areas.

In addition to spectral response, shape texture and rugosity, many essential elements are included in the images that can contribute to the identification of class. Previous maps were also considered as a guide to identifying NMAs (*Figure 9*).

Figure 9 - Representation of a Natural Management Area

1.8.5. Water Definition

The water class (*Figure 10*) was separate from the River Influenced Vegetation class. It includes the streams, channels, ebbs, bays and salt marshes present in the UPRB. It is also possible to observe regions of salt lakes with darker water in blue black and green tones.

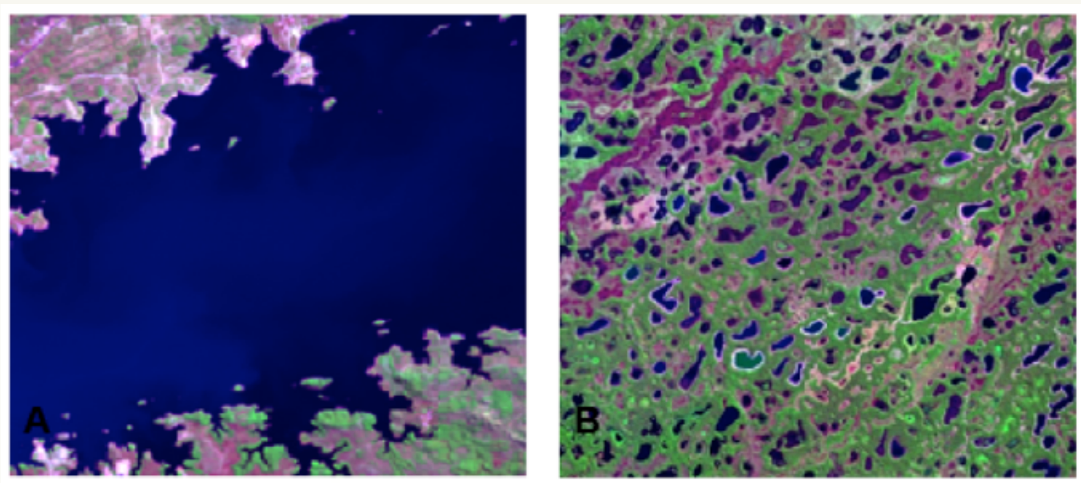

Figure 10 - Representation of water. (A) Water; (B) Salt lake.

1.8.6. Categories of Anthropic Use

The Anthropic Use class was identified using unsupervised classification, followed by a manual association of classes on a scale of 1:50.000. These were then subdivided into 6 groups, as presented in *Table 4*.

Table 4 – Classes of Anthropic Use

AC	Agriculture
PA	Pasture Areas
MI	Mining Influence
UI	Urban Influence
B	Burned Areas
R	Reforestation

Figure 11 presents representations of classes of Anthropic Use.

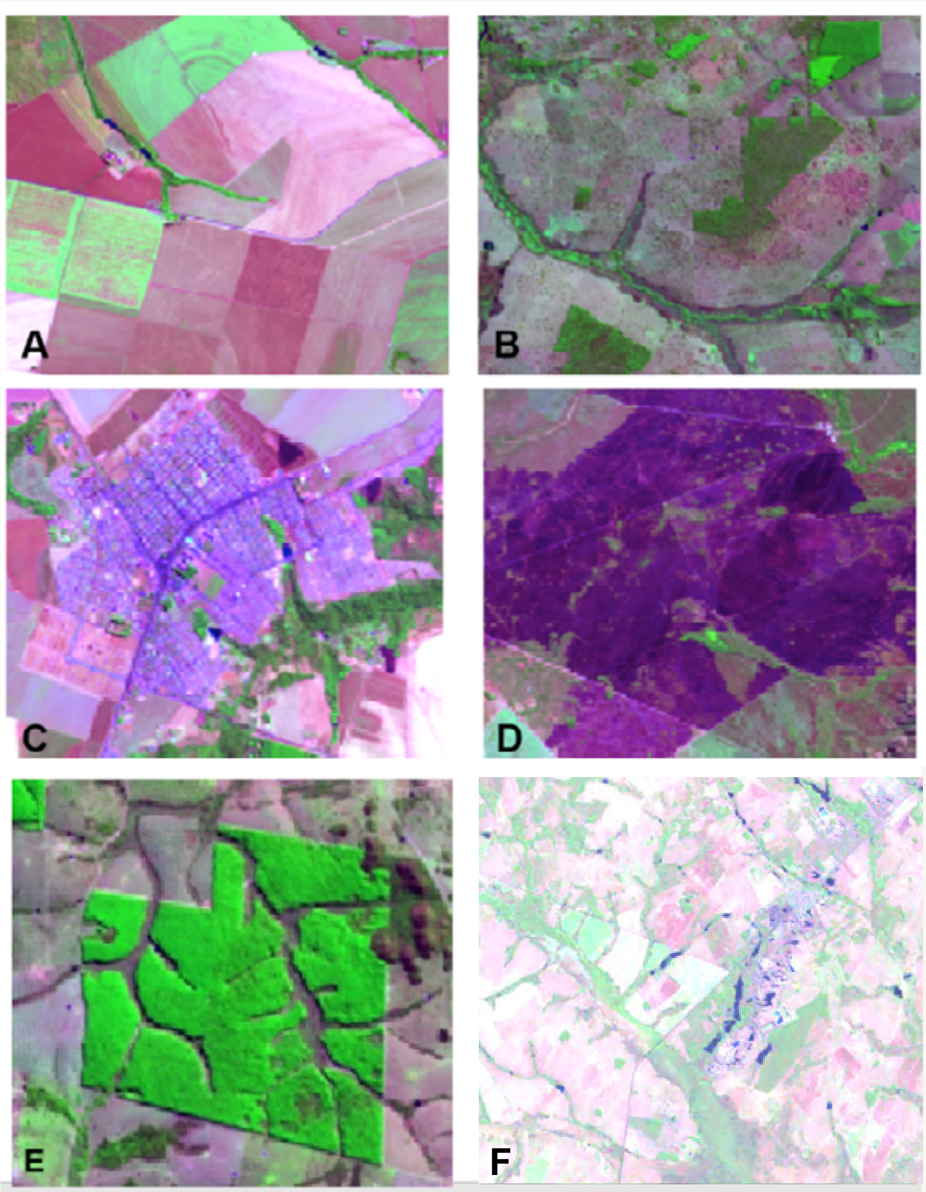

Figure 11 – Representation of Anthropic Use.
(A) AC = Agriculture; (B) PA = Pasture Area; (C) UI = Urban Influence;
(D) BA = Burned Area (E) R = Reforestation; (F) MI = Mining Influence

1.9. Map Mosaic

After supervised classification to define plant physiognomies and anthropic uses, the 153 maps were grouped together in order to quantify the results.

1.10. Analysis of the Deficit in Legal Reserves

Data was downloaded from the Environmental Registry of Rural Properties (CAR) on the SISCAR system for the state of Mato Grosso. As data on unregistered legal reserves often contains a lot of topological errors and is difficult to process, this data was converted into raster format (30-metre resolution). This raster was then transformed into vector format. A topological correction tool was then used on the resulting shapefile, which was then cropped according to the mapped land use for the UPRB tableland in the state of Mato Grosso.

2. Results

2.1. Quantification of Results

The Upper Paraguay River Basin (UPRB) covers an area of 361,848 km² within Brazilian territory and spans the states of Mato Grosso and Mato Grosso do Sul. This area includes two large physiographic regions: the tableland and the lowlands (*Table 5*). The demarcation of these is established by the National Water Agency (ANA) and comprises Water Resource Planning Units (UPH), which are studied subdivisions of river basins that share a range of homogeneous geomorphological, hydrographic and hydrological characteristics.

The tableland includes the Amazon and Cerrado biomes, and the Pantanal biome predominates in the lowlands. The entire Pantanal is located in the UPRB and covers an area of 140,534 km². The springs of the UPRB are located in the headlands surrounding the Pantanal, which cover an area of 221,314 km² (*Figure 12*).

Table 5 demonstrates how natural use classes are predominant in the lowland areas, while anthropic use areas are predominant in the tableland. This is the result of the land occupation models that have been developed in the river basin.

While the land occupation model based on extensive cattle-ranching was developed in the Pantanal lowlands – with the use of native pasture and a certain degree of management, preserving the original vegetation – in the tableland areas this original vegetation has been substituted with monocultures, such as soy and exotic pasture.

Table 5 – Quantification of natural and anthropic areas in the UPRB and tableland and lowland areas in the river basin

	TOTAL	WATER/OTHER		NATURAL		ANTHROPIC	
	(Km²)	(Km²)	%	(Km²)	%	(Km²)	%
UPRB	361.848	10.505	3,0	216.075	59,7	134.967	37,3
LOWLANDS	140.534	9.302	6,62	115.23	82,00	15.996	11,38
TABLELAND	221.314	1.574	0,71	100.789	45,54	118.951	53,75

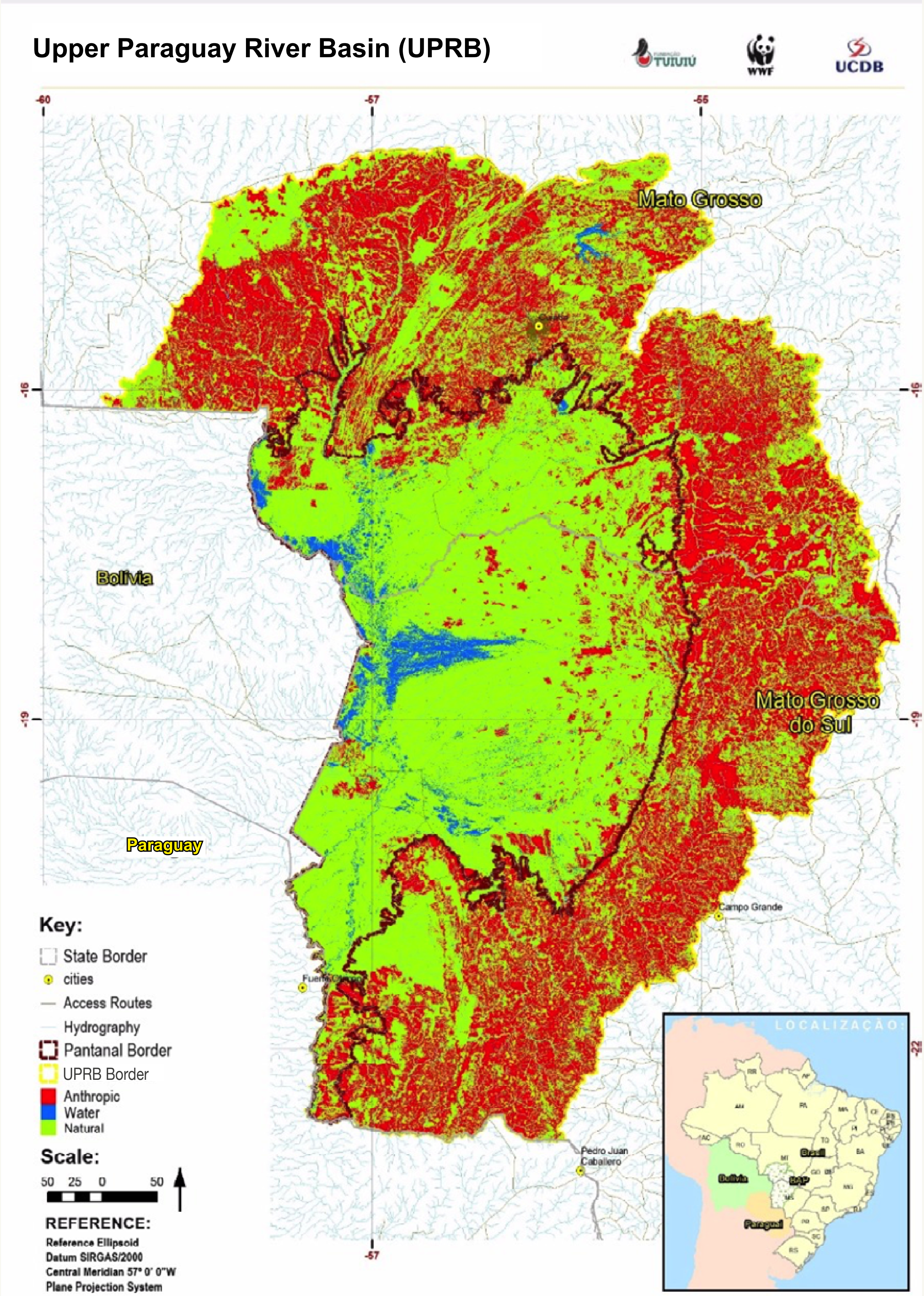

Figure 12 – Natural and anthropic areas of the UPRB, *2016*.

Based on the 153 maps used, a cropped mosaic of Landsat 8 images was produced from the classification and NDVI of each map. The following figures present close-ups of the maps for the tableland regions (north and south) and the lowland regions (north, central and south) showing the differences in vegetation coverage and land use. The black contour lines on the figures presenting the NDVI represent rural properies registered with the National Institute of Colonisation and Agrarian Reform (INCRA) that were included in the Land Registry Management System (SIGEF) database.

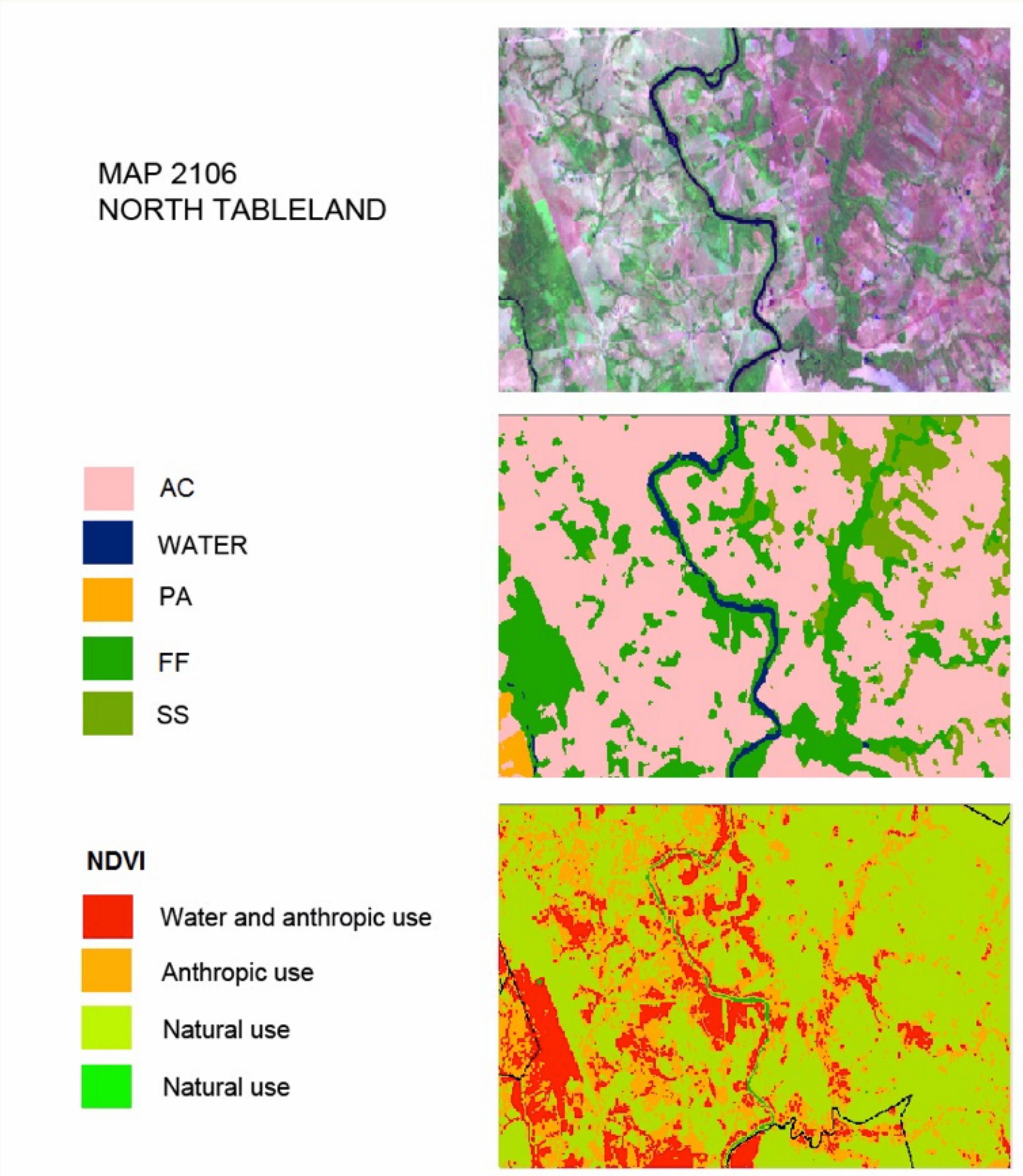

Figure 13 – Close-up of the north tableland region from map MIR 2106.

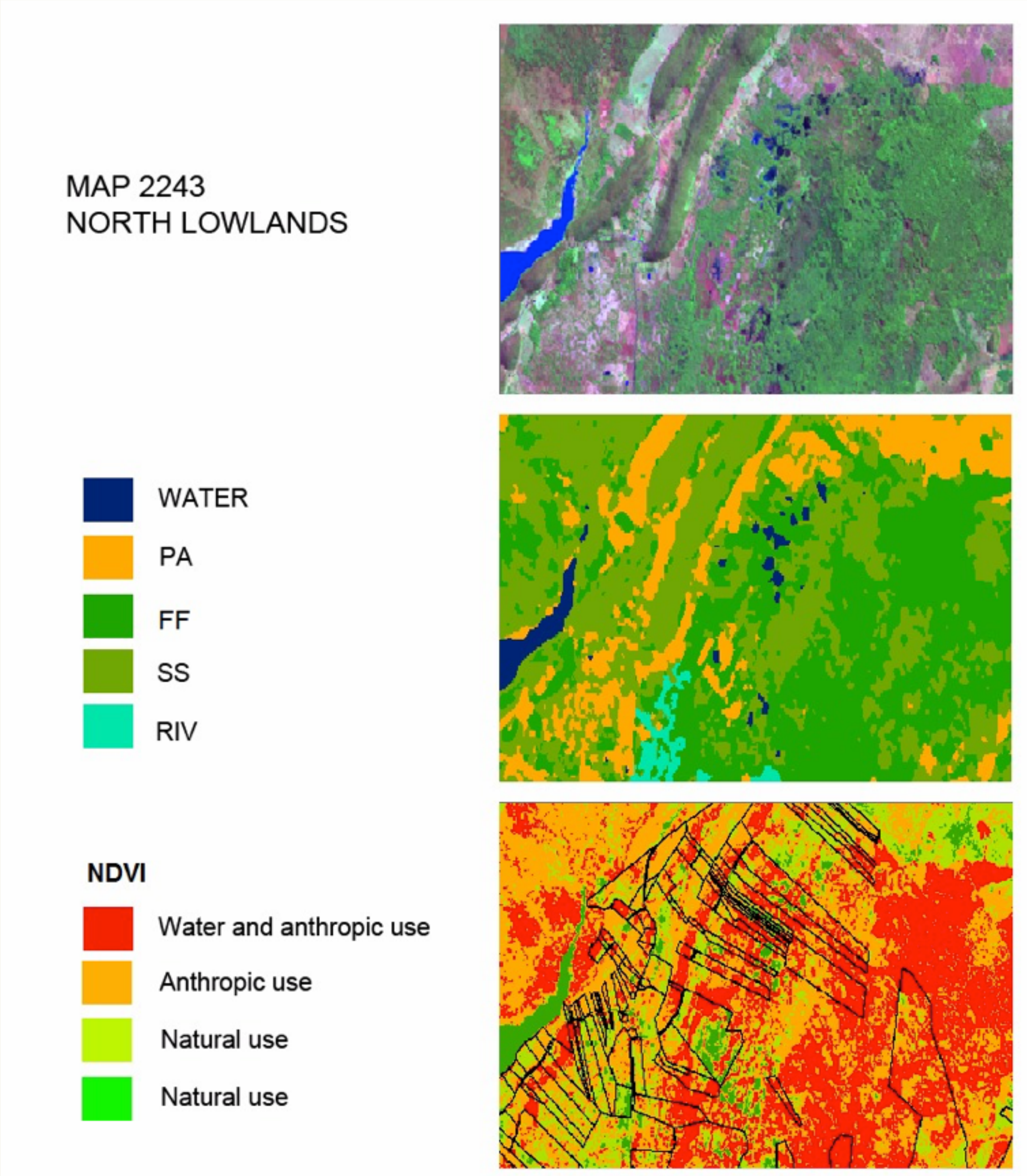

Figure 14 - Close-up of the north lowland region from map MIR 2243

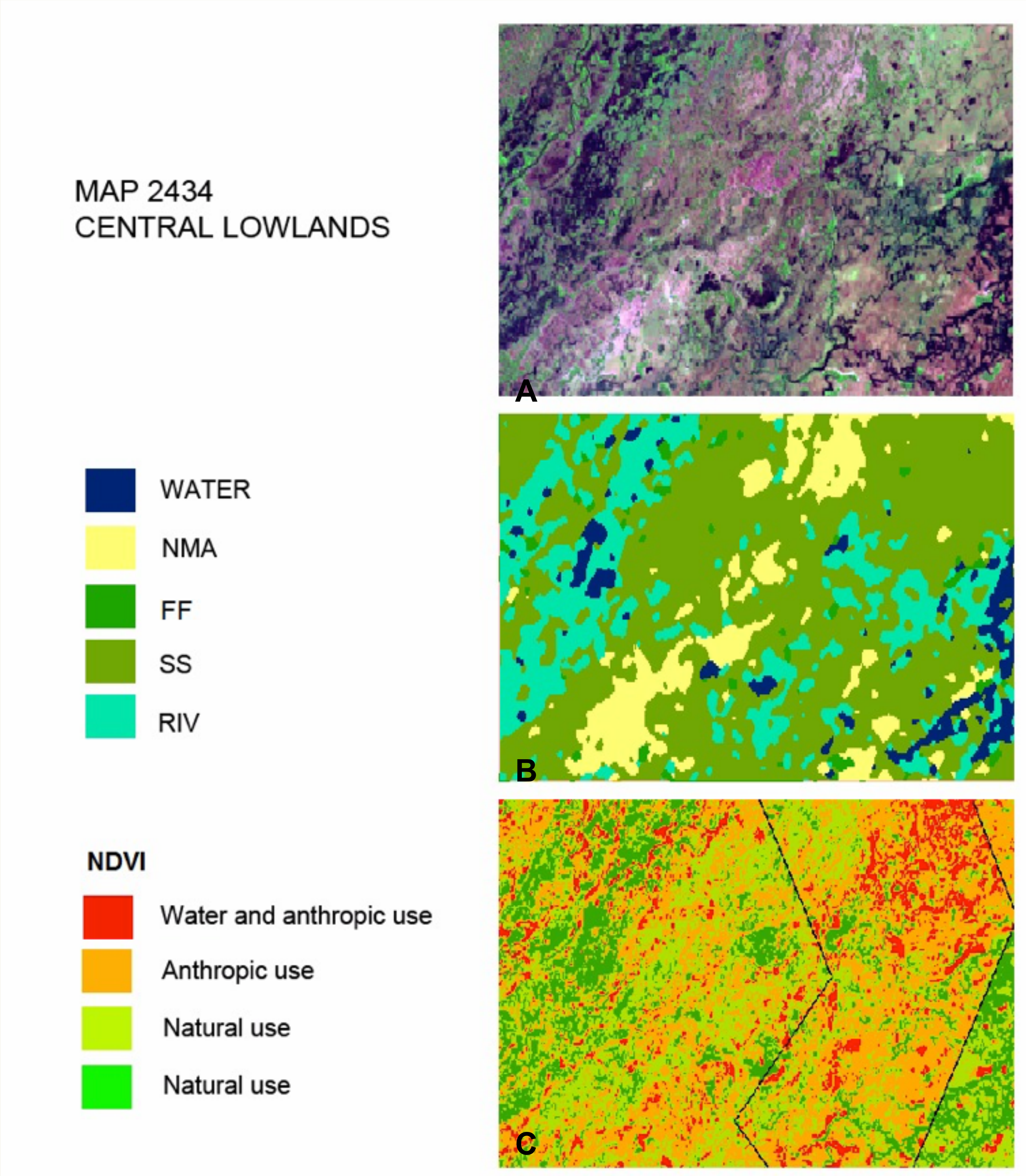

Figure 15 - Close-up of part of the centre lowland region from map MIR 2434.

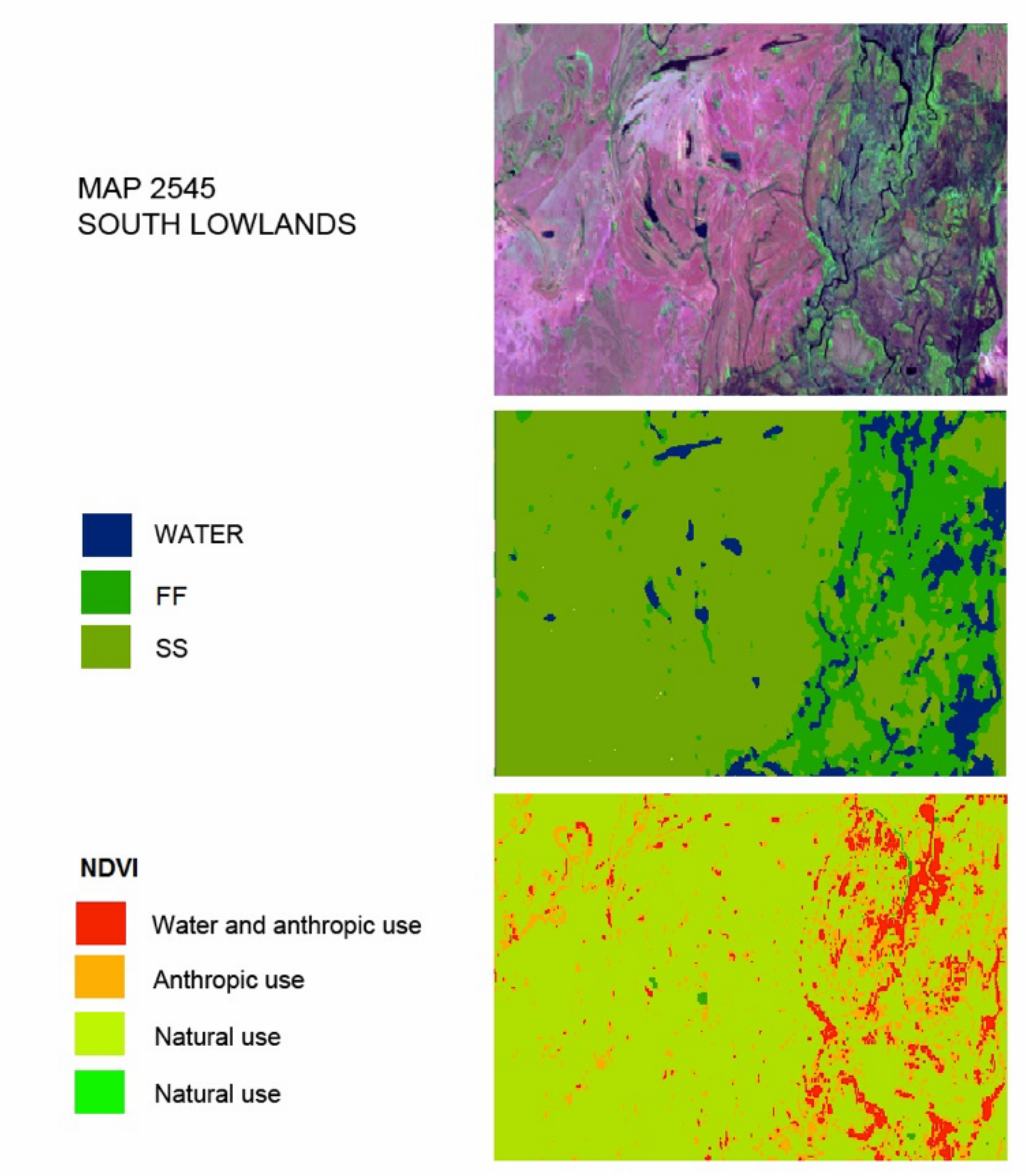

Figure 16 - Close-up of part of the south lowland region from map MIR 2545.

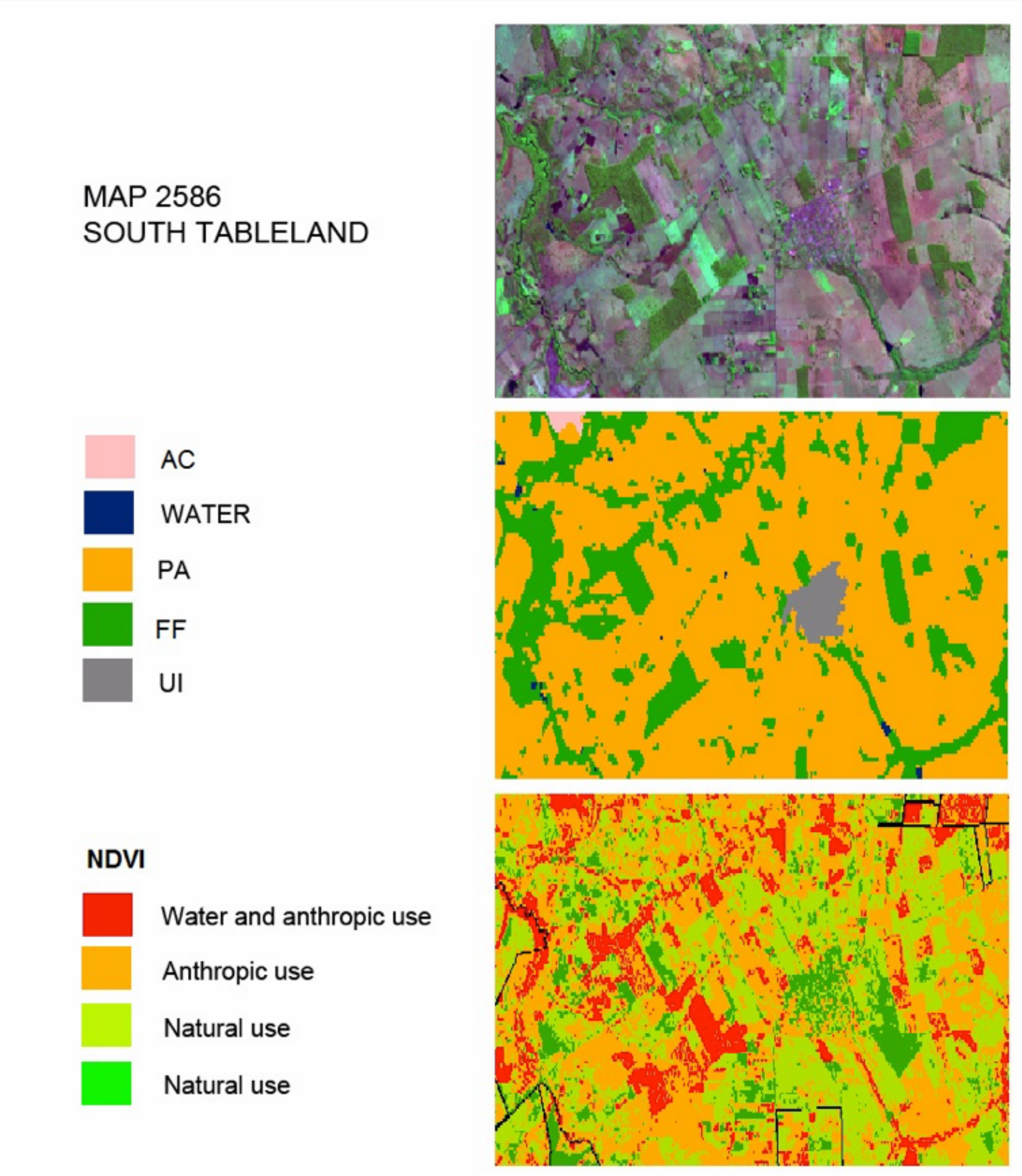

Figure 17 - Close-up of the south tableland region from map MIR 2586.

Agricultural areas are predominant in the north of the UPRB, in the Upper Paraguay and Upper Paraguay Superior river basins. These areas, which were also mapped as being associated with large water resource contributions by a WWF study published in 2012, certainly lack attention. These are regions where the dissemination of best practices relating to farming and the recuperation of degraded areas and springs should be included in public policy aimed at conservation and water security.

It can also be observed that agriculture is present on the borders of the Pantanal lowlands, and in some areas, on the floodplain itself. The fragility of this ecosystem and the need for frequent drainage work in order to enable the cultivation of the land means that the expansion of monocultures in these areas should be evaluated within an ecological and economic zoning context.

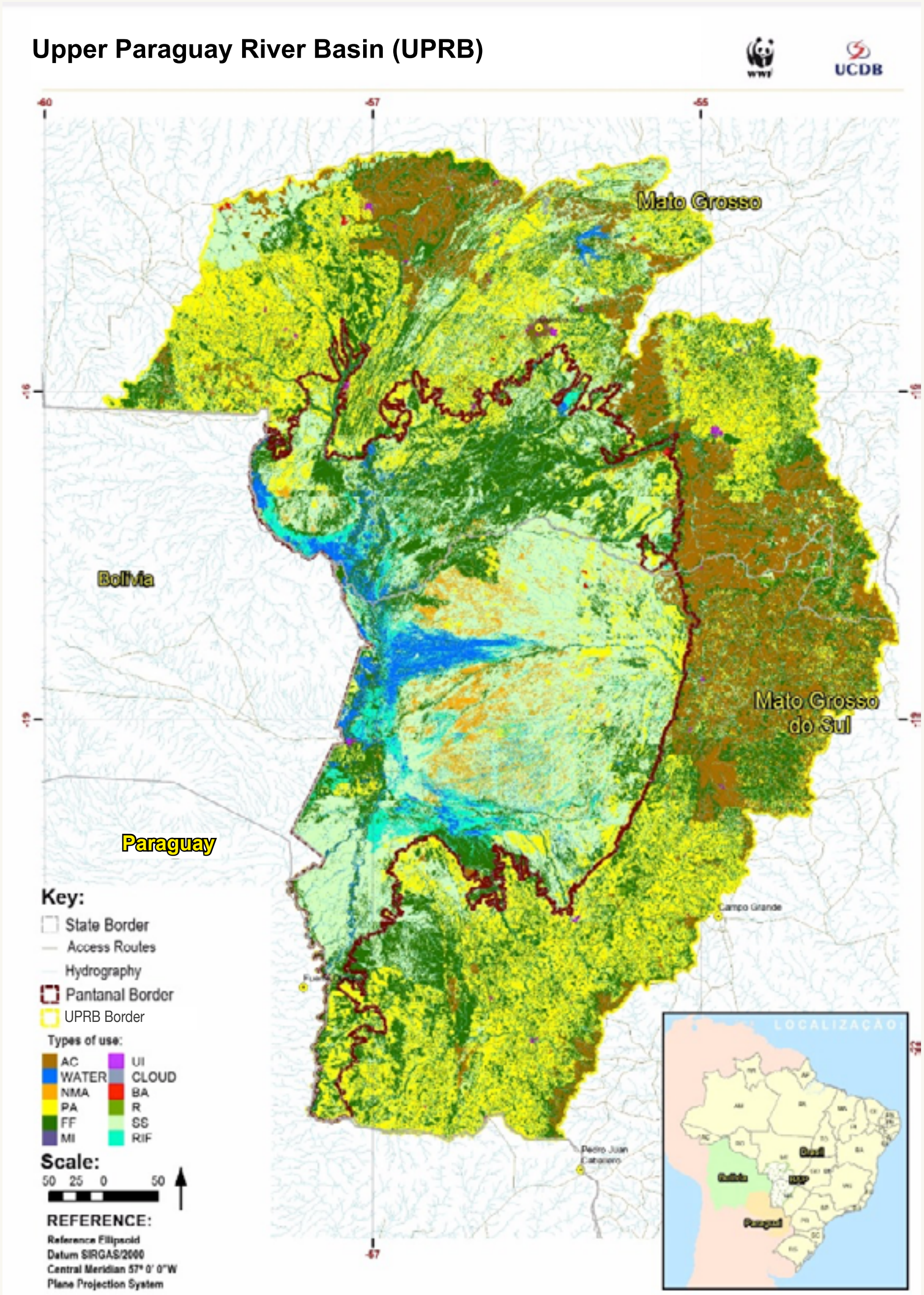

Figure 18 – Land use in the Upper Paraguay River Basin.

Table 6 presents the calculated area for the land use classes. It can be observed that Shrubland Savannahs and Forest Formations were the most commonly identified classes.

The areas identified as NMAs also represent a significant proportion of land use in the river basin, and this is relevant as they represent areas of intense and extensive cattle-ranching.

Of the anthropic uses, pasture areas were the most common in the UPRB, followed by agriculture, which demonstrates a tendency towards growth, mainly through pasture conversion.

Table 6 - Area in km² per class of land use and occupation

UPRB

NATURAL	km²	/ %	ANTHROPIC	km²	/ %	WATER/OTHER	km²	/ %
SS	86,985.29	24.04%	AC	44,329.09	12.25%			
RIV	8,407.18	2.32%	PA	89,217.09	24.66%	WATER	10,505.35	2.9%
NMA	7,468.13	2.06%	MI	106.21	0.03%	CLOUD	121.36	0.03%
FF	113,221.20	31.29%	UI	760.80	0.21%	BA	215.18	0.06%
			R	512.13	0.14%			
TOTAL	216,081.80	59.72%		134,925.30	37.29%		10,841.89	3.0%

TABLELAND

NATURAL	km²	/ %	ANTHROPIC	km²	/ %	WATER/OTHER	km²	/ %
SS	27,139.79	12.26%	AC	43,307.96	19.57%			
RIV	32.58	0.01%	PA	74,285.96	33.57%	WATER	1,297.14	0.58%
NMA	0.97	0.00%	MI	97.16	0.04%	CLOUD	121.36	0.05%
FF	73,647.70	33.28%	UI	726.29	0.33%	BA	151.83	0.07%
			R	509.92	0.23%			
TOTAL	100,821.05	45.53%		118,927.28	53.74%		1,566.33	1%

PANTANAL

NATURAL	km²	/ %	ANTHROPIC	km²	/ %	WATER/OTHER	km²	/ %
SS	59,845.50	42.58%	AC	1,021.13	0.73%			
RIV	8,374.60	5.96%	PA	14,931.13	10.62%	WATER	9,212.21	6.56%
NMA	7,467.16	5.31%	MI	9.05	0.01%	CLOUD	0.0000	0.00%
FF	39,573.49	28.16%	UI	34.52	0.02%	BA	63.35	0.05%
			R	2.21	0.00%			
TOTAL	115,260.74	82.02%		15,998.03	11.38%		9,275.56	6.60%

There are 94 municipalities in the UPRB, 59 of which belong to the state of Mato Grosso and 35 to the state of Mato Grosso do Sul. Note that of the 21 municipalities that have territories with over 50% of natural areas, 57% are in the lowlands and 43% are located in the tableland *(Table 7)*.

Table 7 – Natural areas and areas of anthropic use by municipality.

	MUNICIPALITY	UF	TOTAL AREA	NATURAL		ANTHROPIC		WATER	
			(km²)	(km²)	%	(km²)	%	(km²)	%
1	BARÃO DE MELGAÇO	MT	11171.15	10198.53	91.29%	748.67	6.70%	223.95	2.00%
2	CORUMBÁ	MS	64815.51	55426.79	85.51%	3905.37	6.03%	5483.35	8.46%
3	RESERVA CABAÇAL	MT	1336.80	1060.60	79.34%	275.78	20.63%	0.42	0.03%
4	POCONÉ	MT	17259.26	12770.84	73.99%	3737.36	21.65%	751.06	4.35%
5	AQUIDAUANA	MS	16973.98	12493.05	73.60%	3767.19	22.19%	713.74	4.20%
6	RIO VERDE DE MT	MS	8170.75	5699.40	69.75%	2428.41	29.72%	42.94	0.53%
7	LADÁRIO	MS	342.47	230.63	67.34%	70.76	20.66%	41.08	12.00%
8	SANTO ANTÔNIO DO LEVERGER	MT	12258.68	8143.74	66.43%	4020.87	32.80%	94.06	0.77%
9	MIRANDA	MS	5475.04	3607.92	65.90%	1808.26	33.03%	58.85	1.07%
10	PORTO MURTINHO	MS	17699.76	11602.06	65.55%	5983.13	33.80%	114.57	0.65%
11	NOSSA SENHORA DO LIVRAMENTO	MT	5073.17	3311.32	65.27%	1723.09	33.96%	38.76	0.76%
12	CÁCERES	MT	24317.51	15205.23	62.53%	7207.60	29.64%	1904.67	7.83%
13	ALTO PARAGUAI	MT	1844.89	1149.54	62.31%	692.57	37.54%	2.78	0.15%
14	PORTO ESTRELA	MT	2061.14	1228.44	59.60%	824.99	40.03%	7.71	0.37%
15	ROSÁRIO DO OESTE	MT	6627.03	3904.69	58.92%	2665.76	40.23%	32.69	0.49%
16	CHAPADA DOS GUIMARÃES	MT	6255.87	3581.12	57.24%	2347.82	37.53%	326.93	5.23%
17	RIO NEGRO	MS	1816.90	1020.02	56.14%	782.04	43.04%	14.85	0.82%
18	BODOQUENA	MS	2505.39	1384.38	55.26%	1112.49	44.40%	8.52	0.34%
19	NORTELÂNDIA	MT	1197.80	636.84	53.17%	556.60	46.47%	4.35	0.36%
20	CUIABÁ	MT	3493.79	1818.65	52.05%	1660.49	47.53%	14.64	0.42%
21	NOVA MARILÂNDIA	MT	1849.91	945.35	51.10%	903.39	48.83%	1.16	0.06%
22	VÁRZEA GRANDE	MT	1047.53	503.76	48.09%	638.44	60.95%	22.20	2.12%
23	LAMBARI D'OESTE	MT	1762.80	803.55	45.58%	954.64	54.15%	4.61	0.26%
24	ACORIZAL	MT	840.03	374.77	44.61%	459.76	54.73%	5.49	0.65%
25	BONITO	MS	4930.89	2176.73	44.14%	2740.89	55.59%	13.26	0.27%
26	ITIQUIRA	MT	8730.00	3760.70	43.08%	4939.73	56.58%	29.56	0.34%
27	PEDRA PETRA	MT	4122.93	1763.84	42.78%	2339.04	56.73%	20.05	0.49%
28	COXIM	MS	6413.79	2738.04	42.69%	3626.29	56.54%	49.45	0.77%
29	SALTO DO CÉU	MT	1751.48	714.82	40.81%	1036.62	59.19%	0.03	0.00%
30	NOVA OLÍMPIA	MT	1548.67	628.06	40.55%	916.44	59.18%	4.17	0.27%
31	RIO BRANCO	MT	562.60	226.32	40.23%	335.91	59.71%	0.38	0.07%
32	JANGADA	MT	1017.74	406.79	39.97%	607.13	59.65%	3.81	0.37%
33	SÃO PEDRO DA CIPA	MT	343.18	133.71	38.96%	208.84	60.86%	0.62	0.18%
34	ANASTÁCIO	MS	2948.00	1137.34	38.58%	1792.21	60.79%	18.45	0.63%
35	JUSCIMEIRA	MT	2207.14	837.18	37.93%	1352.88	61.30%	17.08	0.77%
36	SONORA	MS	4079.85	1543.53	37.83%	2525.05	61.89%	14.89	0.36%
37	CORGUINHO	MS	2639.74	976.27	36.98%	1661.33	62.94%	2.14	0.08%
38	SÃO GABRIEL DO OESTE	MS	3884.76	1433.89	36.91%	2435.16	62.68%	15.71	0.40%
39	BELA VISTA	MS	4880.43	1798.83	36.86%	3068.07	62.86%	13.53	0.28%
40	ALCINÓPOLIS	MS	4409.10	1610.19	36.52%	2777.22	62.99%	21.96	0.50%
41	NIOAQUE	MS	3921.94	1415.72	36.10%	2484.33	63.34%	21.89	0.56%
42	DOIS IRMÃOS DO BURITI	MS	2336.26	828.33	35.46%	1497.92	64.12%	10.01	0.43%
43	PEDRO GOMES	MS	3655.50	1269.09	34.72%	2376.08	65.00%	10.33	0.28%
44	CARACOL	MS	2931.66	1011.83	34.51%	1902.22	64.89%	17.60	0.60%
45	JARDIM	MS	2200.03	746.90	33.95%	1442.43	65.56%	10.70	0.49%
46	ARAPUTANGA	MT	1599.93	540.89	33.81%	1056.33	66.02%	2.71	0.17%
47	GUIA LOPES DA LAGUNA	MS	1209.96	392.24	32.42%	808.16	66.79%	9.56	0.79%
48	ROCHEDO	MS	1561.76	495.44	31.72%	1062.29	68.02%	4.03	0.26%
49	GLÓRIA D'OESTE	MT	853.58	267.58	31.35%	582.43	68.23%	3.57	0.42%
50	CAMPO VERDE	MT	1141.96	355.60	31.14%	786.24	68.85%	0.11	0.01%
51	TERENOS	MS	2809.75	872.97	31.07%	1928.55	68.64%	8.24	0.29%
52	ARENÁPOLIS	MT	416.46	125.51	30.14%	288.63	69.31%	2.31	0.55%
53	SANTO AFONSO	MT	1173.30	351.61	29.97%	820.34	69.92%	1.35	0.12%
54	MIRASSOL D'OESTE	MT	1075.90	320.98	29.83%	751.64	69.86%	3.28	0.31%
55	DENISE	MT	1306.14	380.82	29.16%	920.50	70.47%	4.81	0.37%
56	RONDONÓPOLIS	MT	4162.59	1203.08	28.90%	2927.56	70.33%	31.95	0.77%
57	JACIARA	MT	1644.73	459.75	27.95%	1181.27	71.82%	3.70	0.22%
58	CURVELÂNDIA	MT	359.55	96.46	26.83%	258.35	71.85%	4.74	1.32%
59	SÃO JOSÉ DOS QUATRO MARCOS	MT	1287.47	276.07	21.44%	1008.83	78.36%	2.57	0.20%
60	INDIAVAÍ	MT	603.25	119.32	19.78%	477.70	79.19%	6.23	1.03%
61	SÃO JOSÉ DO POVO	MT	444.45	86.95	19.56%	353.33	79.50%	4.17	0.94%
62	FIGUEIRÓPOLIS D'OESTE	MT	899.27	156.52	17.41%	736.28	81.88%	6.47	0.72%

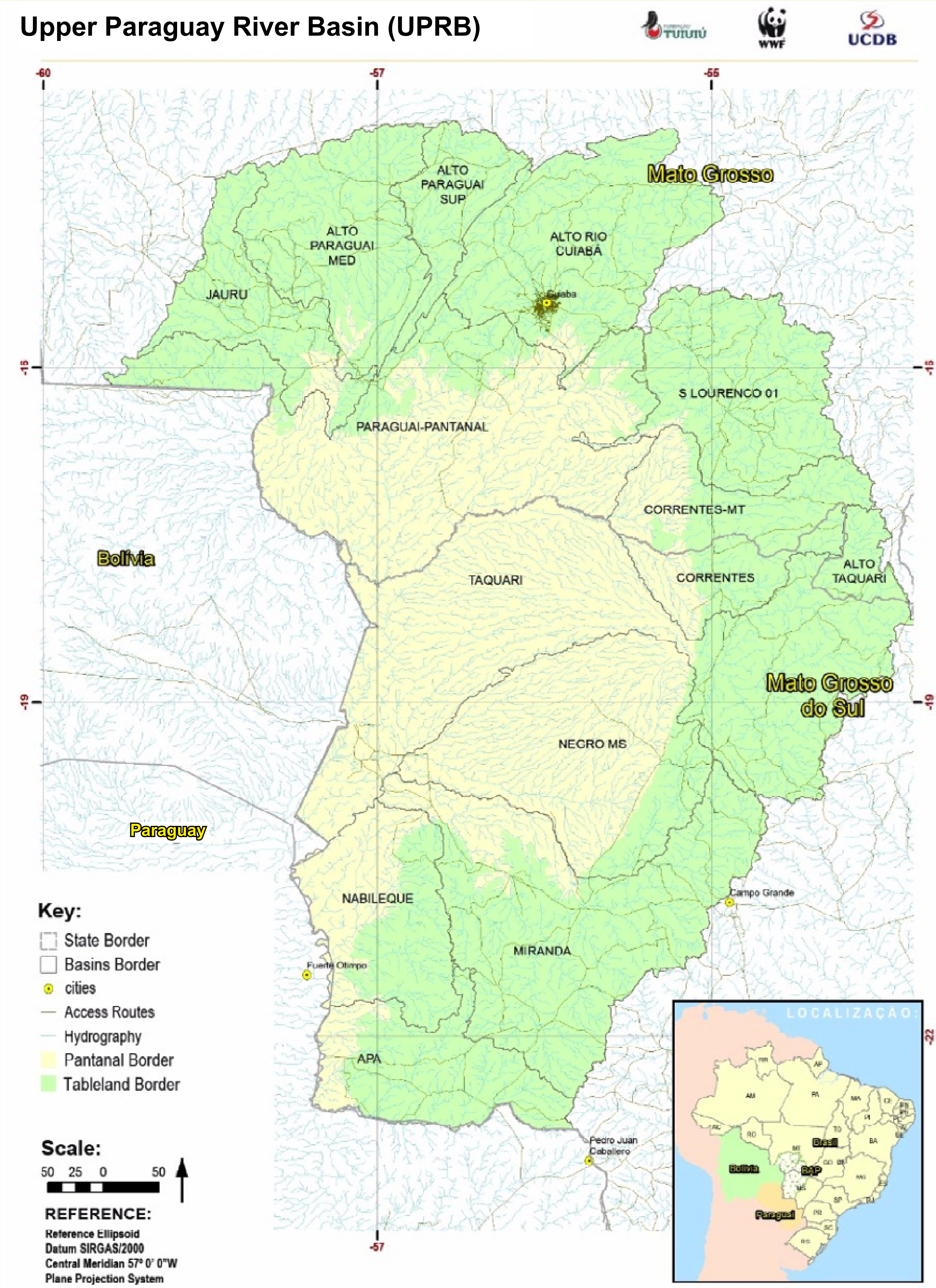

Figure 19 – The water basins of the UPRB

Table 8 presents the quantification of areas of natural use, anthropic use and water per river basin.

Table 8 - Percentage of natural and anthropic area per water basin.

BASIN	KM²	ANTHROPIC		NATURAL		WATER	
NEGRO-MS	35,72.99	4,349.98	12.4%	29,778.36	84.9%	944.66	2.7%
NABILEQUE	19,177.03	3,285.33	17.1%	15,470.29	80.7%	421.41	2.2%
PARAGUAI-PANTANAL	56,222.37	11,821.13	21.0%	41,572.70	73.9%	2,828.54	5.0%
TAQUARI	64,560.67	15,291.08	23.7%	44,715.95	69.3%	4,553.64	7.1%
ALTO RIO CUIABÁ	28,941.93	12,547.75	43.4%	15,860.69	54.8%	533.49	1.8%
ALTO PARAGUAI SUPERIOR	9,492.89	4,295.59	45.3%	5,173.54	54.5%	23.76	0.3%
ALTO TAQUARI	3,913.40	1,786.36	45.6%	2,093.46	53.5%	33.58	0.9%
CORRENTES-MT	13,903.50	6,858.10	49.3%	7,002.93	50.4%	42.47	0.3%
CORRENTES	8,753.35	4,389.10	50.1%	4,332.94	49.5%	31.31	0.4%
ALTO PARAGUAI MÉDIO	23,568.71	12,205.32	51.8%	11,233.80	47.7%	129.60	0.5%
MIRANDA	42,966.22	22,255.27	51.8%	20,006.73	46.6%	704.23	1.6%
APA	17,137.00	9,300.28	54.3%	7,723.83	45.1%	112.89	0.7%
ALTO SÃO LOURENÇO	23,738.50	1,3210.67	55.7%	10,395.30	43.8%	132.53	0.6%
JAURU	14,552.13	8,586.20	59.0%	5,844.34	40.2%	121.59	0.8%

2.2. Accuracy

Classification was validated through the application of the Kappa index, which measures the degree of agreement on a nominal scale assuming that the units, classes and reference points are independent (COHEN,1960). The intervals of characterisation accuracy are presented in *Table 9*.

Tabela 9 - Intervals of accuracy in relation to the situation on the ground

Kappa Value	Classification
<0,00	Very bad
0,00 – 0,20	Bad
0,20 – 0,40	Reasonable
0,40 – 0,60	Good
0,60 – 0,80	Very good
0,80 – 1,00	Excellent

Source: Landis and Koch (1977), adapted by Piroli (2010)

The accuracy of the classifications was verified in two ways: through the collection of samples from the entire area of the UPRB and the collection of samples map-by-map, using high resolution images as a reference.

In the first case, 100 samples were collected representing natural and anthropic classes, and the Kappa Index calculated presented a value of 0.8.

In the second case, the samples represent each class present in each topographical map, giving a total of 700 sample points collected (*Figure 21*), and the Kappa Index calculated presented a value of 0.7.

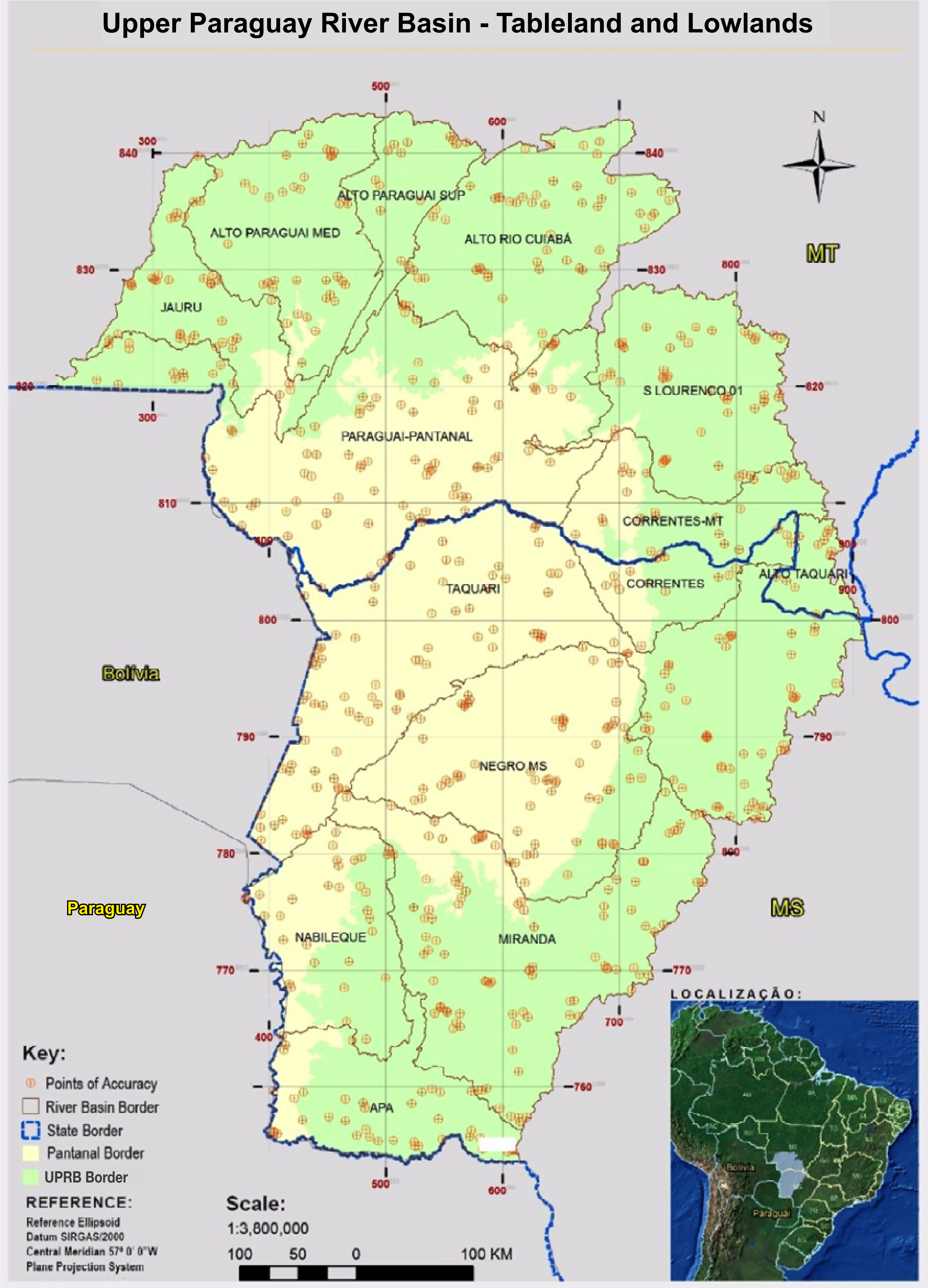

Figure 20 – Sample points in the UPRB area.

2.3. Deficit in Legal Reserves in the Pantanal Headwaters

Based on the data obtained from the CAR, it was possible to calculate the deficit in legal reserves for the Pantanal Headwaters region in the state of Mato Grosso.

A total of 392,145.71 hectares of legal reserves were identified with anthropic land use, which therefore represent environmental liabilities that need to be recovered.

Considering the average cost of forest restoration of US$3,130/ha for seedling planting (MMA, 2016), the cost to regenerate this entire area would be US$ 1,227,416,072.30.

The recuperation of this area represents a huge challenge in the integrated management of the UPRB. Agricultural expansion in the tablelands in many cases does not respect environmental legislation, causing impacts that also affect the floodplain.

The removal of natural vegetation causes an increase in surface runoff, and this accelerates erosive processes. The excessive deposition of sediments into the Pantanal floodplain affects flooding dynamics, causing permanent waterlogging in certain areas as well as social and economic impacts, such as the devaluing of property prices, the displacement of local populations and the development of cattle-ranching activities.

The regeneration of these areas is essential in order to maintain seasonal flooding patterns in the Pantanal and across the entire interconnected biodiversity.

3. THE PARAGUAI RIVER BASIN IN A CROSS-BORDER CONTEXT

The Paraguay River Basin extends through Argentina, Bolivia, Brazil and Paraguay. The division of this natural patrimony across different nations highlights the size of the challenge to establish responsible management that guarantees the preservation of ecosystemic services and the area's natural characteristics for future generations.

Data on land use and vegetation coverage are fundamental in the development of conservation and territorial planning activities, and are often difficult to find.

Based on the classification of Landsat 8 images from 2015, this paper presents a portrait of the parts of the river basin in Argentina, Bolivia and Paraguay.

The classification of land use was based on the selection and allocation of terms into different hierarchical levels, with a focus on the identification of natural and anthropic areas.

This mapping initiative is part of a tri-national activity model developed by WWF-Brazil in conjunction with WWF-Paraguay and WWF--Bolivia.

For Argentina, Bolivia and Paraguay, 76% of the river basin comprises natural land features, with a predominance of shrubland formations and rocky outcrops, particularly in its western areas.

Anthropic areas represent 23% of the river basin in this region and are mainly used for agricultural purposes. Just 0.7% of the surface is covered in water.

Regarding the river basin as a whole, including the territories in Argentina, Bolivia, Brazil and Paraguay, 70.8% of the land surface comprises natural areas, 27.7% is made up of anthropic areas and 1.5% is covered in water (*Figure 21*).

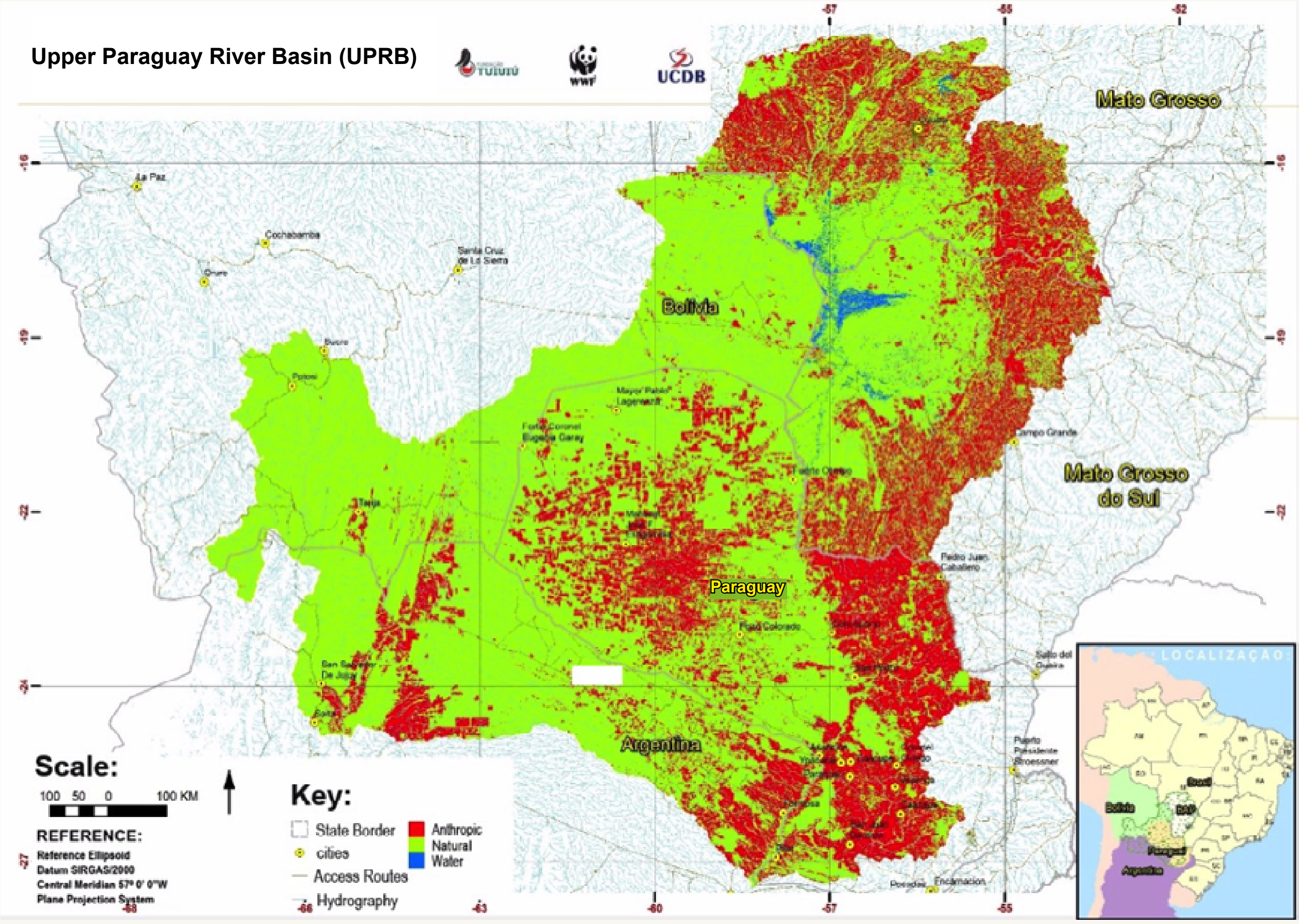

Figure 21 – Land use in the Paraguay River Basin in Argentina, Bolivia, Brazil and Paraguay Source: WWF-Brazil, 2015.

4. CONCLUSIONS AND NEXT STEPS

Vegetation coverage monitoring initiatives are essential in order to develop conservation and territorial planning activities. The dynamic of vegetation coverage is a strong indicator of anthropic activity, and the integrity of ecosystems and their continuous monitoring is of great importance. For this reason, it is fundamental that this initiative be continued.

The evaluation of soil coverage for the Upper Paraguay River Basin enables a better understanding of the dynamics of land use and the integrated evaluation of the Pantanal biome, which needs to be understood as an integrated system, including tableland and lowland areas.

Even though 58.7% of the UPRB is still preserved, just 45.5% of the tableland region comprises natural areas. The 82% of the lowland areas that is still covered in original vegetation is under pressure from the expansion of production models whereby natural pastures are substituted with their exotic alternatives.

Although the lowland areas are still fairly preserved, it is essential that actions relating to land conservation, the recuperation of degraded areas and sustainable farming be expanded, and mainly in tableland regions, which currently present a higher rate of landscape alteration due to anthropic activity.

The deficit in legal reserves in the Pantanal Headwaters region and the high cost of regenerating this area demonstrate the need to develop financial mechanisms that promote greener farming practices, including incentives and environmental safeguards.

The recuperation of this environmental liability must be used as an opportunity to create corridors of biodiversity and make the existence of fragmented landscapes environmentally feasible. The regeneration of these areas will positively contribute to the region's water security, agricultural productivity and biodiversity protection.

The percentage cover of natural areas in the Upper Paraguay River Basin is still considerable, and this natural system as a whole does not recognise geo-political boundaries. The biggest impacts have the potential to propagate across the entire length of the River Paraguay. Therefore, it is extremely important that joint initiatives be developed between the countries that share this environmental system, as studied in this paper.

It is hoped that these results will contribute to discussion and the organisation of the land, assisting the decision-making process by providing increased environmental feasibility.

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