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REPORT

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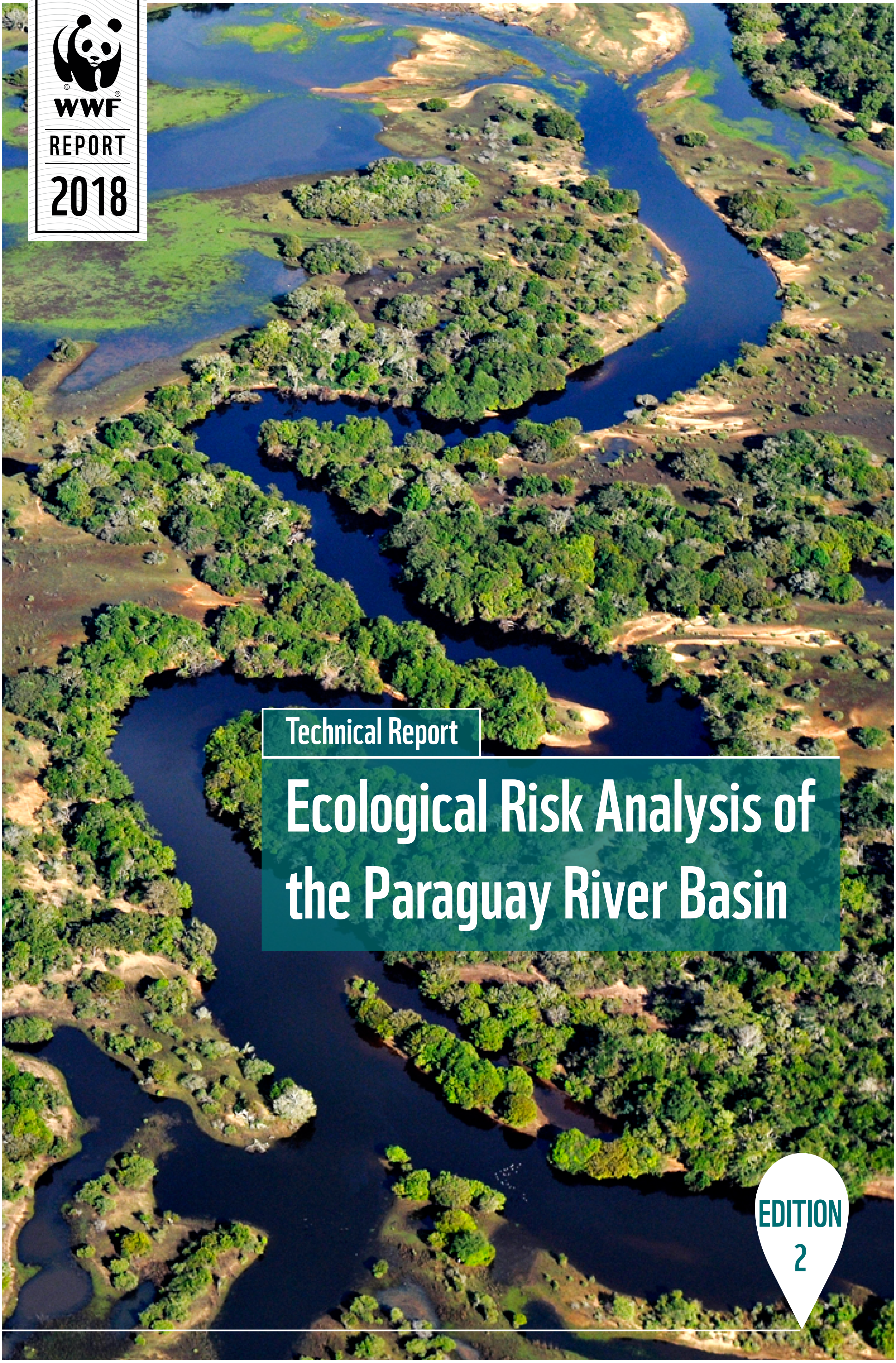

Technical Report

Ecological Risk Analysis of the Paraguay River Basin

EDITION 2

WWF-Brazil

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Sumário

Lista de figuras

1. INTRODUCTION

The Paraguay River Basin extends across Brazil, Bolivia, Paraguay and Argentina and is home to over 10 million people (IBGE, 2018; IGN, 2018, GeoBolivia, 2017; Gobierno Nacional de Paraguai, 2018) who depend on its ecosystem services and whose future is under threat as a result of climate change, water shortages and the absence of a socio-economic planning to promote sustainable development.

The Paraguay River Basin contains one of the planet's largest wetlands – the Pantanal (Fraser & Keddy, 2005). This immense floodplain covers an area the size of Holland, Belgium, Portugal and Switzerland combined and plays a fundamental part in the regulation of climate, rainfall, river flow, water quality and carbon capture, and in the high levels of primary production that sustain its widely biodiverse and complex food chains. The waters of the Pantanal originate from the rains falling on the neighbouring tableland areas that uniquely floods into the plains below. For this reason, an integrated and systemic vision of this drainage basin is required to protect the ecosystem services provided by this set of environments.

Although the Paraguay River Basin boasts a wealth of natural resources, these are under pressure from a range of threats that can be found throughout its entire territory. Thanks to tools such as the Ecological Risk Index, which is essential for the improved management of its natural resources, the identification, evaluation and mapping of these threats is now possible.

The Paraguay River Basin's Ecological Risk Index (ERI) was calculated for the first time in 2012 and has since been used in important conservations actions such as the Pantanal Headwaters Pact, this having ensured the recuperation of over 80 tributary springs along the Paraguay River to date.

The ERI methodology involves the geospatial analysis of threats identified across the entire drainage basin. Considering the probability and degree of severity of each threat for the range of different landscapes, it identifies areas in which the pressure on natural resources is most critical. This approach strengthens actions focused on mitigating and preventing impacts to the environment.

After fiver years of the first work to calculate ERI values, a need was identified to update this essential tool to support the water security and sustainable management of natural resources of this landscape. This task involved the participation of over 20 researchers and technicians from all of the four countries that share this ecoregion who work with natural resources in the Paraguay River Basin.

This exchange between landscape planning and management agents led to the compilation and validation of geospatial information and the evaluation of both the threats and the sensitivity of the region's different environmental territories.

This collaborative study between the countries that share the Paraguay River Basin presents priority areas for the management and conservation of natural resources, encouraging various social, governmental and economic actors to engage and take joint action in order to achieve the United Nations' 17 Sustainable Development Goals (SDGs) established in 2015.

By 2020, two-thirds of wildlife may be extinct

We are now approaching some key moments for the planet, and it is essential that immediate action be taken in order to preserve life and maintain social and economic relations as we know them. If global carbon emissions are not reduced by 2020, the effects of global warming, including the loss of biodiversity, rises in sea level and impacts on agricultural production, could be irreversible (Figueres, et al., 2017). In addition, two thirds of the world's wildlife could be extinct by 2020 (WWF, 2016). Highly-impactful joint action is urgently required, and this should be based on science and include the involvement of all sectors of society. Our hope is that this study will contribute to the construction of a better future for both people and the environment.

2. METHODS

The Ecological Risk Index (ERI) is a territorial planning tool focused on the integrity of natural resources in aquatic ecosystems. Based on the analysis of stressors, the ERI facilitates planning in the management, conservation and recuperation of threatened ecosystems, and by working with probabilities it can be used as a predictive tool for conservation planning.

Regions that are identified as having a high ecological risk are those whose natural resources have a high potential for degradation. One example is integrity analysis in relation to the threats associated with gas and oil pipelines. Areas with a high concentration of this type of infrastructure can present a higher Ecological Risk Index due to the higher probability of contamination of natural resources and the impact of this on the integrity of ecosystems.

Areas with a higher associated ecological risk should be a higher priority in the planning of actions for water and territorial management, and these should seek to create landscapes that are more sustainable and that have better water security.

2.1. The Ecological Risk Index

The Ecological Risk Index provides risk analysis for territorial planning with a focus on the conservation of water resources. This approach provides an understanding of the extent and intensity of human activity on the landscape and expresses the risk of water quality and environmental degradation associated with these activities (Mattson & Angermeier, 2006).

The calculation for the Ecological Risk Index evaluates threats based on their potential to cause damage to the integrity of water ecosystems, these being characterised by water regimes, physical habitats, water quality, energy sources and biotic interactions within the system (Mattson & Angermeier, 2006).

The methodology includes two elements in its risk calculation: the frequency and severity of stressors (threats). When the first version of this study was being designed, the group of specialists involved came to the consensus that an element of sensitivity could be used to better express the pressure exerted by each stressor on an ecosystem. This element of sensitivity is based on the principle that each ecosystem will react differently to the same stressor.

Therefore, the ERI was defined as the product of the frequency, severity and sensitivity of an ecosystem to a stressor:

$$ERI_i = F_i S_i Z_{i,j}$$

F: frequency of stressor i;
S: severity of stressor i;
Z: sensitivity of stressor i on ecosystem j;

This calculation allows the risk associated with each stressor to be identified, and the Composite Ecological Risk Index (C-ERI) provides an integrated vision of the risks that a river basin is exposed to. This is calculated from the sum of the risks of each of the stressors:

$$C - ERI_K = \sum_{i,k} IRE$$

Where:
I: identifier of the type of stressor;
K: identifier of the river basin or territory under analysis;

To evaluate sensitivity, categories were assigned relating to sensitivity in relation to each threat:

1: low sensitivity
2: medium sensitivity
3: high sensitivity

The severity was also split into categories:

1: low severity
2: medium severity
3: high severity

The frequency of the stressors was also analysed according to category:

0: no occurrence;
1: low occurrence;
2: medium occurrence;
3: high occurrence.

These categories were assigned after analysis of the distribution of stressors according to hydrological unit and the definition of frequency.

After calculation of the ERI and C-ERI, another set of categories was adopted to define high, medium and low ERI, the metodologie adopted was quantiles.

2.2. The steps involved in the study

This study involved a review of the literature and the construction of a database, followed by a workshop involving specialists from the countries where the river basin is located (on August 24-25, 2017), during which suggestions were incorporated and products were validated. As this is an update to a study performed in 2012, the previous scores for stressor severity and threat sensitivity were maintained. Indices were initially calculated through the completion of spreadsheets by the specialists involved, who assigned sensitivity scores to each of the elements studied in the landscape and the severity of each stressor in relation to the sensitivity.

Table 1 presents the stressors validated by specialists during the workshop held in 2017:

Table 1 - Stressors identified in the river basin.

STRESSOR	MEASURE OF FREQUENCY
Hydroelectric	Density of SHPs and HEPs in the hydrological unit (hydroelectric plants/km²)
Human population	Population density of the hydrological unit (inhabitants/km²)
Agriculture	% of agricultural land use in the hydrological unit (% area)
Cattle ranching	Herd size per hectare
Waterways	Length of waterways per hydrological unit (km/km²)
Roads	Length of roads per hydrological unit (km/km²)
Fire	Average no. of fire outbreaks between 2013 and 2016 (outbreaks/km²)
Urbanisation	% urban land use per hydrological unit (% area)

Other stressors were highlighted, including small and medium-sized dams, fishing activities without concern for fishing stocks (e.g., bait fishing) and degradation of the genetic heritage of invasive species. These threats are important in planning for the use and conservation of natural resources in the Paraguay River Basin. However, a lack of geospatial data meant they could not be included in the study.

The following landscape features were considered in terms of sensitivity:

- Climate;
- Land relief;
- Tributary systems and headwaters;
- Slopes;

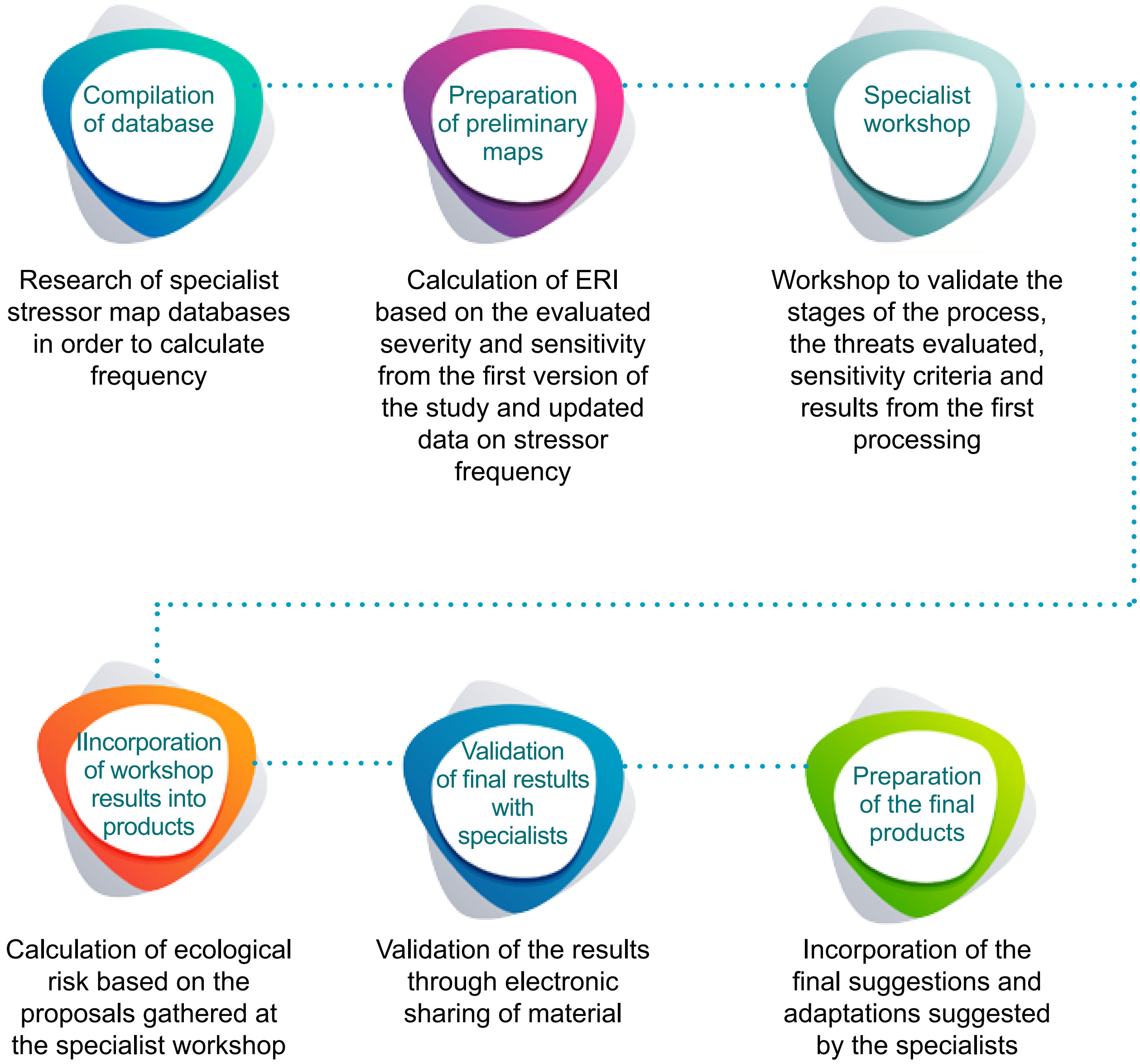

Figure 1 – Steps in the ERI process

Another important element used to get a better understanding of the ecological risk associated with the river basin was the identification of areas providing a high contribution of water. These areas, known as water towers, play an essential part in the hydrological dynamics of the region, mainly in the maintenance of the flood pulse in the Pantanal plain.

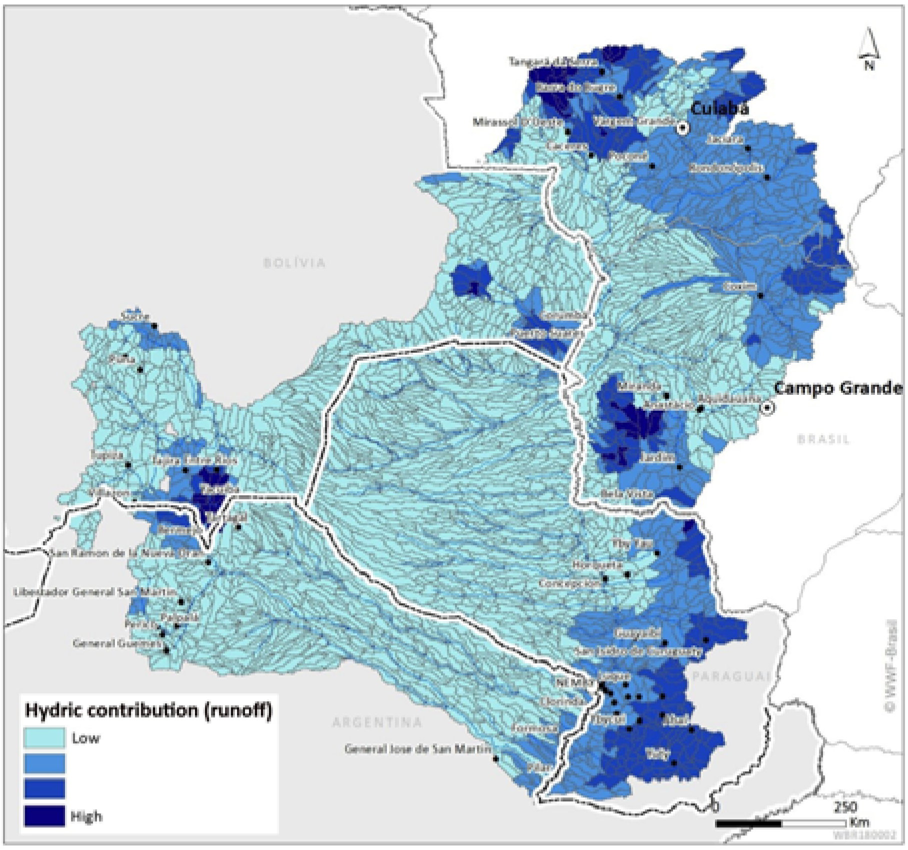

Figure 2 – Areas of high hydric contribution in the Paraguay River Basin

The areas in the northeast of the river basin identified as providing large contributions of water are those responsible for most of the flow into the Pantanal plains, guaranteeing the annual flooding dynamic in the ecosystems of the wet zones and river floodplains. Analysis shows the importance of a systemic approach focused on the hydrological system as a whole in order to promote the sustainable development of the Pantanal. The conservation of the Pantanal floodplain depends on the preservation of its principal "water sources", which correspond to these areas providing large contributions of water known as water towers.

3. RESULTS

Following the trends observed in the first version of the study, ecological risk is not distributed homogeneously across the whole of the river basin. There is a concentration of high ecological risk river basins in the tablelands of the Upper Paraguay River Basin overlapping most of the water towers. Even if this risk is concentrated over certain areas, its effects can propagate across the whole system and go on to affect areas of the floodplain as a result of the connectivity of these systems.

There is also a high ecological risk in the south-eastern areas covering parts of the Atlantic Forest, following the trend identified in the first version of this study. The same can be observed in the western regions in the Salta-Jujuy Development Zone, where impacts are primarily associated with high population densities and mining.

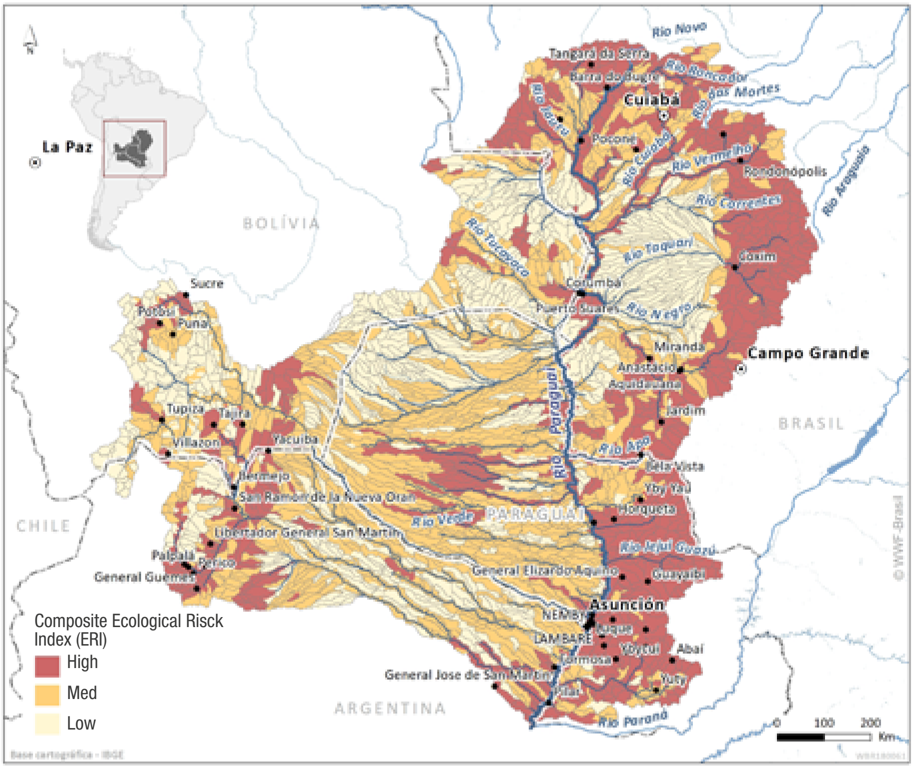

Figure 3 – Compound Ecological Risk Index for the Paraguay River Basin

An increase of approximately 5% in areas of high ecological risk was also observed, this corresponding to over 54,500 km². Twenty new high-risk river basins were identified, and these were distributed throughout the study area.

Strategic environmental assessments are key to a better understanding of the synergic environmental impacts on a water basin.

Stressors that have a big impact on the ecological risk of a river basin include agriculture and cattle raising, mining activities, urbanisation and dams (principally those used to generate electricity). All of these have a strong influence on water tower areas, and in many cases, these have a synergistic effect that is still not fully understood. Various river basins are under concomitant pressure from stressors such as inadequate practices adopted in agriculture, mining and dams, and these can cause cumulative impacts in aquatic ecosystems. However, in some cases, even when a range of stressors are acting on the same river basin, this synergistic effect cannot be observed. This is why it is important that strategic environmental evaluations are created, and integrated sustainable development and management plans are put together for this landscape.

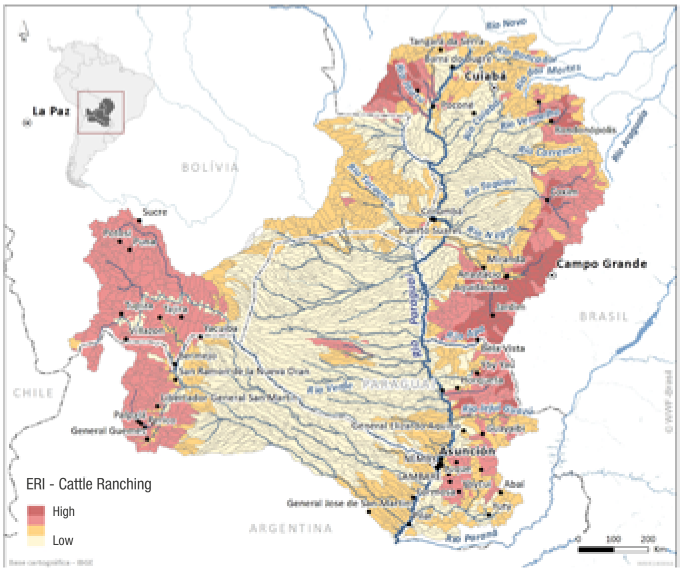

Figure 4 - Ecological Risk Index associated with cattle ranching.

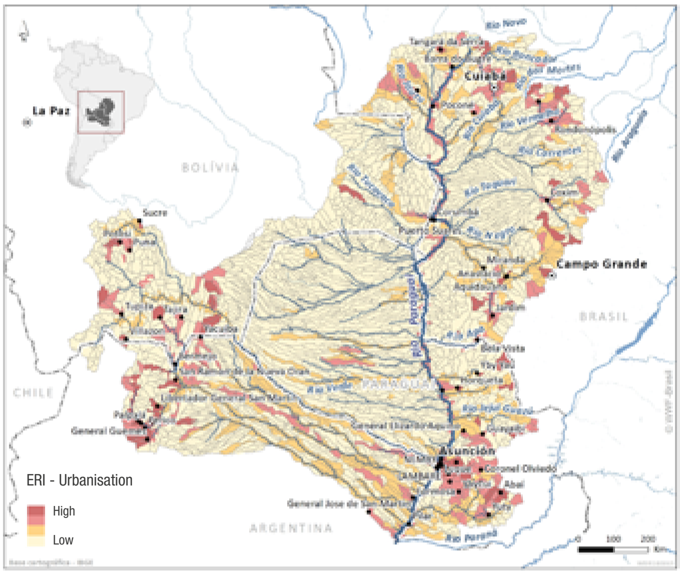

Figure 5 - Ecological Risk Index associated with urbanisation

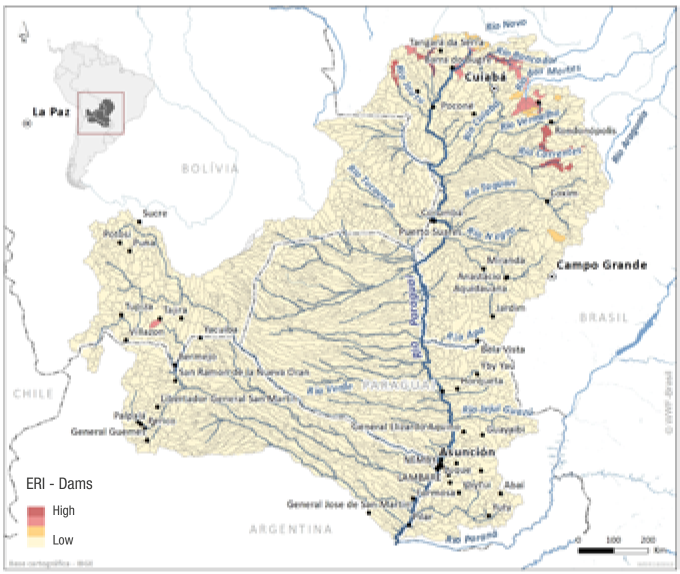

Figure 6 - Ecological Risk Index associated with dams

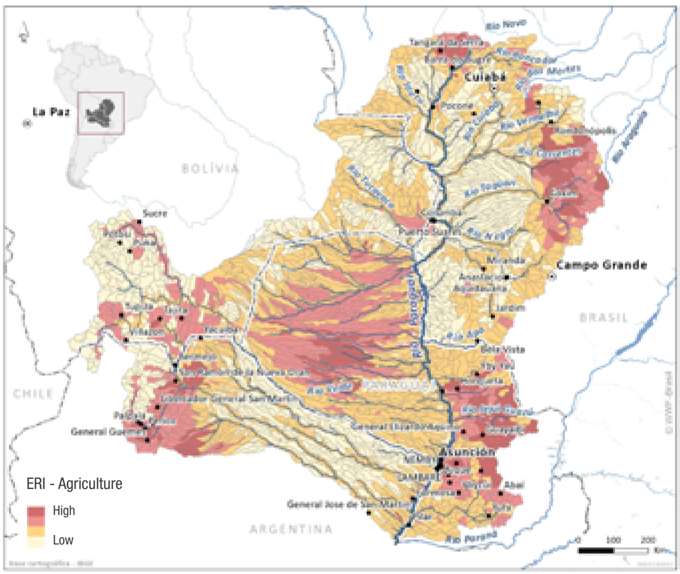

Figure 7 - Ecological Risk Index associated with agricultural activities.

The areas with the highest ecological risk were analysed in four regions: the Paraguay River Basin tableland, the Atlantic Forest area, the Salta--Jujuy Development Zone and the Porto Suarez and Tucavaca Valley.

3.1. Upper Paraguay River Basin Tableland

The Upper Paraguay River Basin tableland is almost completely within Brazilian territory, and 40% of this area is on high ecological risk. This is the main region in which the water towers that make the Pantanal a wetland are concentrated. Less than 1% of this area is protected in conservation sites and 55% has already suffered deforestation (WWF, 2016).

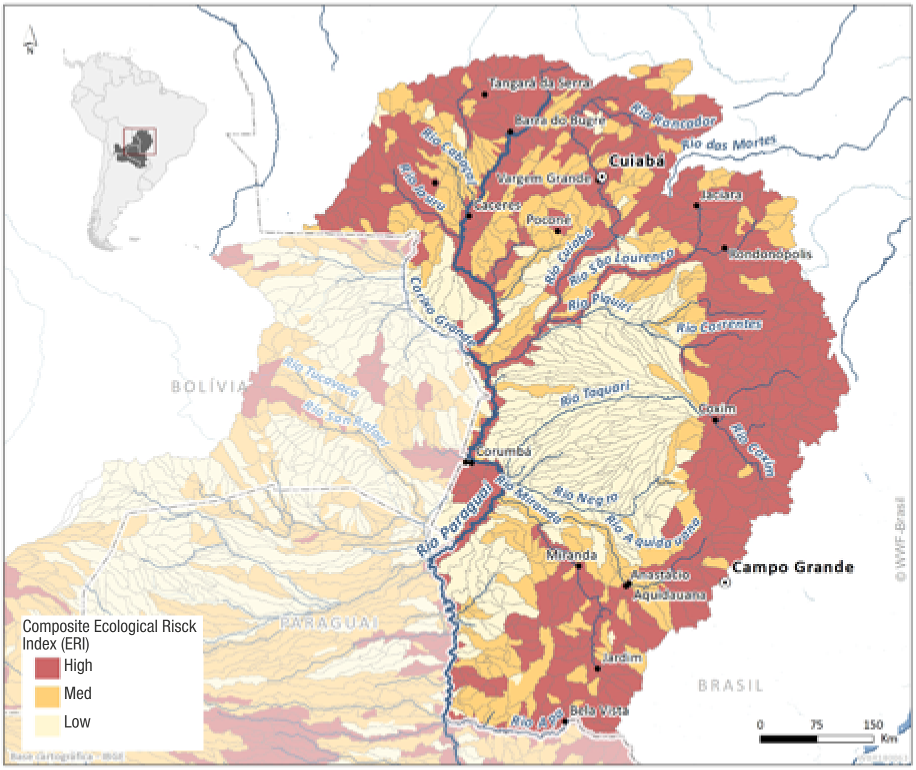

Figure 8 – High ecological risk areas in the tablelands of the Upper Paraguay River Basin

The main threats to this region are associated with hydroelectric dams, the inefficient use and degradation of agricultural areas and landscapes and the impacts of urbanisation. This has also been identified in the studies published by Alho & Sabino (2011).

In this region of the river basin, on average less than 15% of sewage is treated and the average rate of water loss along its distribution networks is 26% (SNIS, 2017). This inefficient management of water leads to waste water contamination of rivers and provokes water crises, particularly in regions such as Tangará da Serra in the state of Mato Grosso.


Adriano Gambarini/WWF-Brasill

The Cerrado biome in the Upper Paraguay River Basin tableland has suffered intensive conversion of vegetation into pastureland and crops. Very little of this agricultural expansion has taken place according to environmental safety criteria, which includes maintaining riparian forest and legal reserves. In the state of Mato Grosso alone there is currently an estimated deficit in legal reserves of 392,000 hectares (WWF, 2016).

The rate of agricultural expansion without the necessary environmental planning has led to impacts related not only to the loss of biodiversity, but also to increases in soil loss that go on to affect the flooding of the plains and alter the water regime of the Pantanal (Bergier, 2013)

Production in the region does not always follow best practice. Overgrazing is common in cattle raising areas, leading to the compacting of the soil and higher rates of surface runoff. It is fundamental that adequate livestock management techniques be adopted in order to avoid excessive herd sizes per hectare, and that techniques to reduce and control erosion are put into practice.

In addition, techniques such as terracing and no-till planting should be expanded in agricultural areas to reduce the silting-up of aquatic ecosystems.

There is a network of rural roads used to transport agricultural produce, which corresponds to 25% and 7% of Brazil's production in the states of Mato Grosso and Mato Grosso do Sul respectively (CONAB, 2017). These two states are also responsible for most of the country's beef production (IBGE, 2017). These roads rarely have the appropriate structure or maintenance and turn into canals that carry the sediment that silts up rivers, causing the quality and quantity of waters to deteriorate.

Another threat increasing the ecological risk of this region is the construction of hydroelectric dams. While the low slope degred of the Pantanal floodplain means it is not a suitable location for the installation of hydroelectric dams, there are another 101 interventions planned for the Upper Paraguay River Basin tableland, including Small Hydroelectric Plants (SHPs) and Power Generation Plants (ANEEL, 2018). Forty of these energy projects have already been constructed, damming up approximately 20 water courses. If all of the planned plants are constructed, over 45 tributaries of the Paraguay River will have their flows altered, creating unknown affects in the hydrological system and the aquatic biota depending on the connectivity of this for its ecological processes. The reproductive migration of fish that leave the plains and swim towards the headwaters (during the piracema) is one example of an ecological process under threat due to the presence of these dams.

The waterway can cause changes to the Pantanal's flood pulse, increasing the risk of contamination by fuels and other hazardous substances and causing severe damage to the margins of the drainage channels.

Although this study identifies areas with a higher risk associated with hydroelectric dams, it is important that further studies are developed to gain a better understanding of the synergistic effects of the construction of these structures on the ecosystem.

Industrial shipping proposals, such as the Paraguay River waterway, represent another threat to the Pantanal's hydric system. The intensification of dredging and the clearing of natural stone barriers need to be better understood within an integrated context, with the synergy of environmental impacts on the river basin being evaluated. Actions that are poorly planned in terms of the preservation of ecosystem services can cause changes to the Pantanal's flood pulse, increasing the risk of contamination by fuels and other hazardous substances and causing severe damage to the margins of drainage channels.

Road embankments that hinder natural flooding patterns are also stressors and have a cumulative effect that can interfere in the natural dynamics of the flood pulse.

This region has been the focus of various development plans. However, the installation of infrastructure in the river basin should be subject to the strategic and integrated evaluation of environmental impact through the participation of independent specialists and representatives from local communities.

The exotic species invasion on the river basin can cause loss of genetic heritage and future extinction of native species.

Another unmapped threat with a potentially high impact on the balance of the river basin's ecosystem is the fish farming of species that are exotic, hybrid or native to other river basins. This invasion of species that are not naturally occurring in the Paraguay River Basin is a significant threat. Once they are established, species such as Tilápia (*Tilapia spp*) or Tambaqui (*Colossoma macropomum* – native to the Amazon River Basin and introduced to the Paraguay River) can colonise a range of environments, spreading over various sub-basins and causing significant ecological imbalance, with the loss of genetic heritage and the future extinction of native species.

3.2. Atlantic Forest Area of the Paraguay River Basin

The Atlantic Forest area is to the southeast of the Paraguay River Basin in a transition zone containing areas of Humid Chaco, Atlantic Rainforest and Cerrado. This is also where Asuncion is located, which has a population of 2.1 million (Gobierno Nacional de Paraguay, 2018).

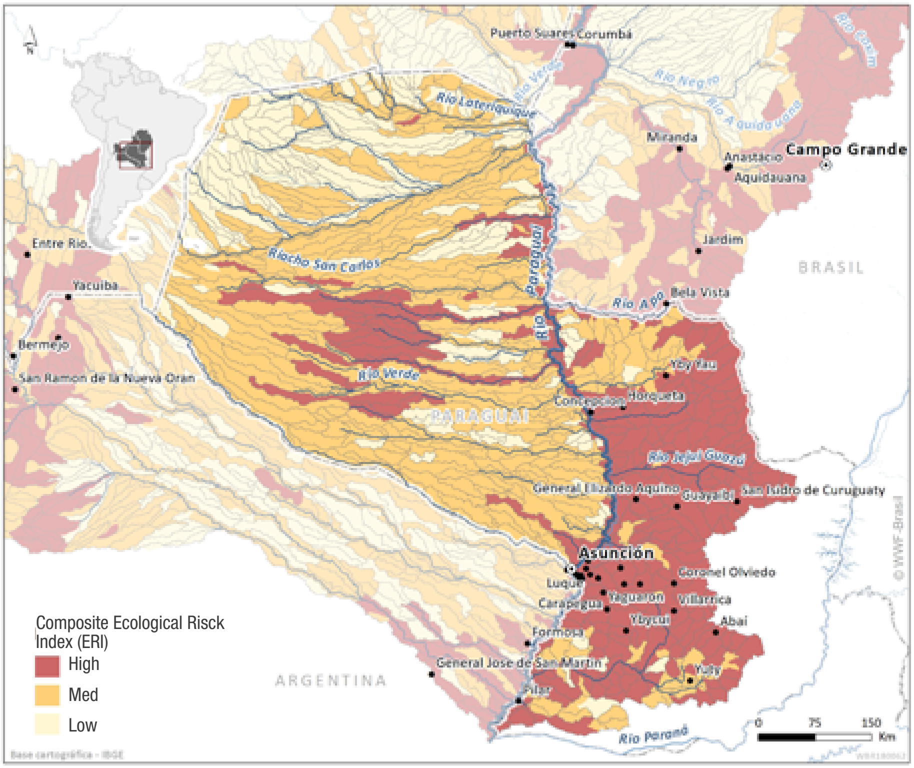

Figure 9 – Areas of high ecological risk in the Atlantic Forest area of the Paraguay River Basin

The region around Paraguay's capital is where the country's production infrastructure is concentrated, and is responsible for 70% of its GDP. It is also here that 30% of the population of Paraguay is located. The infrastructure associated with this level of development and population density brings environmental risk, which manifests through impacts relating to urban infrastructure, water transport (of mainly grain and ore) and road transport (Gobierno Nacional de Paraguay, 2018).

In the metropolitan region of Asuncion, the rate of sewage treatment is low at just 25%, directly impacting the Paraguay River (World Bank, 2012).

Grain production, mainly of soy, has been expanding in this region of Paraguay since the 1970s. Small rural properties have been acquired by large Brazilian, North American and European companies and farmers, establishing a new large-scale productive system. This dynamic brings with it the pressure of deforestation, associated with an increase in environmental risk factors including the indiscriminate use of pesticides.

3.3 . Salta – Jujuy Development Zone

The Salta-Jujuy Development Zone is located in the western area of the river basin on Bolivian and Argentinian territory. This region is the focus of various local integration projects, such as the Capricorn Hub by the South American Regional Infrastructure Integration Initiative (IIRSA).

IIRSA is a joint program between South American countries, the purpose of which is to improve infrastructure in transport, energy and telecommunications. Launched at the beginning of the 2000s, this has attracted investments mainly in road networks and hydroelectric projects.

This region is also part of the Bioceanic Corridor, a project that began in 2015 after the founding of a working group and the signing of the Asuncion Declaration by the presidents of Brazil, Argentina, Chile and Paraguay. The purpose of the corridor is to optimise logistics, with multimodal platforms and the shortening of the route to the Pacific Ocean in order to reduce freight costs to the Asian markets (Estado de Mato Grosso do Sul, 2018).

This region also stands out for its mining and oil and gas exploration activities. The infrastructure associated with these, such as dams for power generation and high road densities, also correspond to potential damage to aquatic ecosystems.

In San Salvador de Jujuy there are reports of contamination of watercourses by collapsed old oil wells and the detection of heavy metals in a variety of streams (Yapur, 2016).

This part of the river basin is also where the regions of high water contribution are located, such as the springs of the Bermejo and Pilcomayo rivers. The high relief and geomorphological characteristics of the region make it an area of high environmental sensitivity.

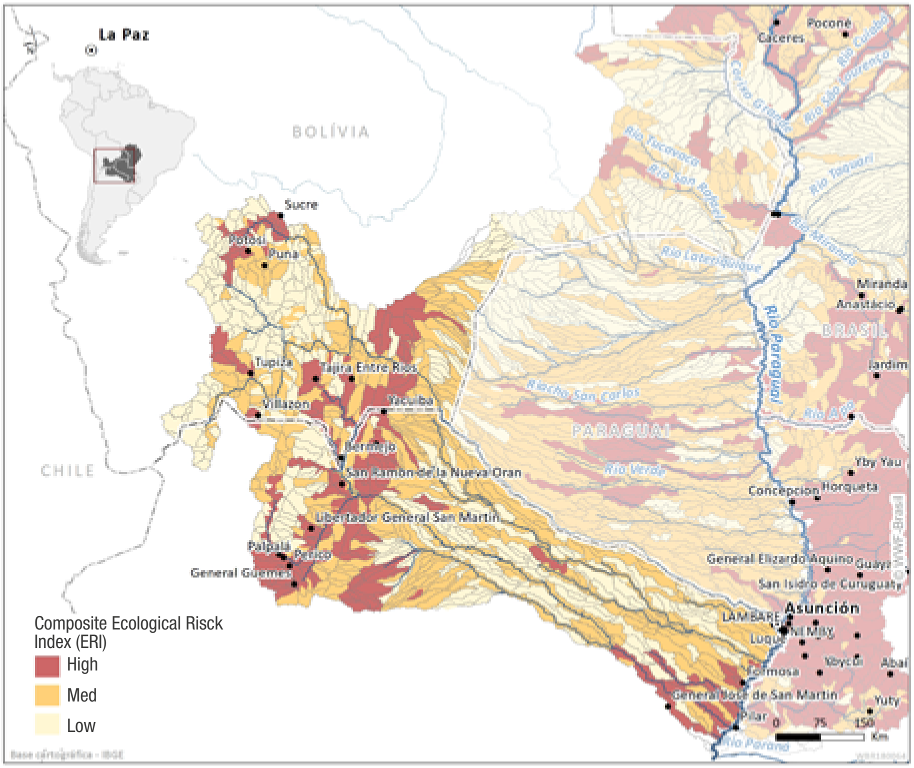

Figure 10 – High ecological risk areas in the Salta-Jujy Development Zone

3.4. Porto Suares and Tucavaca Valley

The Porto Suarez and Tucavaca River Valley region is an area of great biological and environmental diversity. There are fragments of forest formations, Chiquitano forest and Savanna formations. The high ecological risk of this region is associated with copper, gold and silver mining activities and the frequent occurrence of fires (that are related to agricultural practices and phyto-physiognomy).

Mining causes direct impacts to land and aquatic ecosystems, with the pressure of contamination and overuse of water resources.

There are also ecological risks related to the exploration of natural gas in the Chiquito forest area in the western part of the region, as well as the Gasbol pipeline (the Bolivia–Brazil gas pipeline) that transports natural gas to the state of Rio Grande do Sul in Brazil, which extends for 3,150 km. The Gasbol pipeline crosses areas of high sensitivity in the Bolivian and Mato Grosso do Sul parts of the Pantanal, and the continuous monitoring of the conditions of this pipeline is fundamental in ensuring the conservation of the landscapes through which it passes.

The Chiquitano forests have logging potential, and in the absence of policy to regulate their use, are the target of deforestation and unsustainable forest exploration.

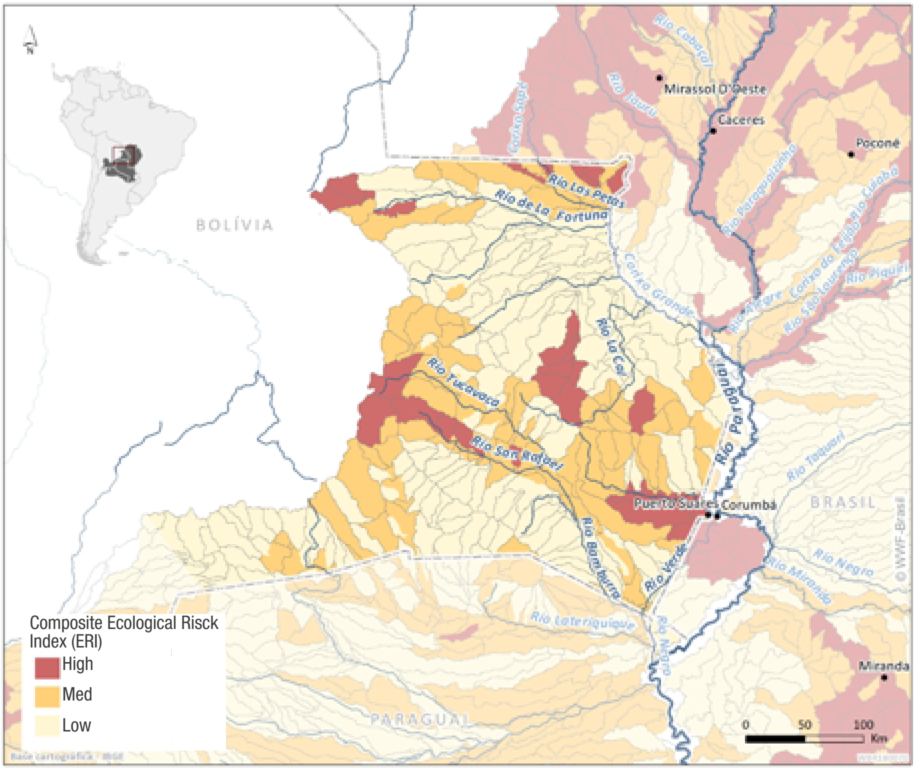

Figure 11 - High ecological risk areas in the Puerto Suarez and Tucavaca Valley

4. A Vision for the River Basin – DISCUSSIONS AND RECOMMENDATIONS

The Upper Paraguay River Basin is one of the main watersheds in the Americas, and is unique as it is also home to the Pantanal, one of the largest wetlands on the planet.

The conservation of the Pantanal is facing challenges in terms of territorial management, which demands an integrated vision of the region, the basic unit of which is the river basin as a whole that incorporates the floodplains and surrounding Cerrado areas in the tableland from which the waters that sustain the flood pulse originate.

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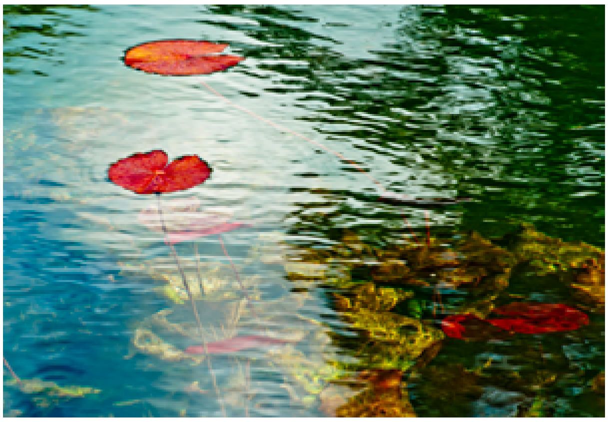
Despite the floodplain being one of the ecosystems with the highest percentage of vegetation in South America at around 80%, this high level of coverage of native vegetation does not guarantee its conservation. The main environmental factor in the Pantanal linked to its ecosystem services, heterogeneous landscapes, biodiversity, high biological productivity and its potential for cattle raising and tourism, is its flood pulse. The waters that guarantee its annual flooding originate from the water towers located outside the borders of the Pantanal in the tablelands of the Paraguay River Basin.

The conservation of the Pantanal depends on actions to protect these areas of high contribution, the water towers. Such actions, considering the main threats to the region (unsustainable agricultural models and the expansion of hydroelectric dams), are related to the identification of priority rivers to be maintained free from dams and the expansion of best agricultural practice through incentives to use integrated crop, livestock and forest models.

Projects such as the Pantanal Headwaters Pact are examples that should be expanded into other areas. This project, with the support of partners including HSBC and the WWF Network, has already promoted the recuperation of over 82 springs; the installation of approximately 40 environmentally friendly septic tank systems, benefitting over 240 people and generating a safe biofertilizer being used to increase fruit production; an incentive to construct three nurseries to grow seedlings of native species; over 160 kilometres of environmentally adapted rural roads; support from 25 local governments in the state of Mato Grosso for the implementation of conservation actions for the region's water resources; the introduction of four municipal laws to protect the environment; two municipalities benefitting from the National Water Agency (ANA) through the Water Producers Program to create Payments for Environmental Services (PES) – Tangará da Serra and Mirassol D'Oeste; hundreds of volunteers mobilised into action to clean rivers in the state of Mato Grosso, and over 5 million people reached through communication actions.

Areas downstream of the river basin, such as the Salta – Jujuy Development Zone and the Porto Suarez Tucavaca Valley, are areas of intense development in logistics and base industries. There are plans to build new roads, ports and railways and for significant oil and gas production. It is important that these projects are evaluated from an ecosystem service conservation perspective and that their methods of construction ensure the necessary environmental safeguards.

An area as vast as the Paraguay River Basin presents a great challenge in terms of territorial management. The heterogeneity of its landscapes, ecosystems, socio-economic profiles and governance guidelines amplify these challenges. However, a single joint management model for the territory with a focus on cross-border areas, such as the region denominated the Upper Paraguay River Basin, would enable the sustainable development of the region.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Natural resources, mainly water, tend to have a more significant economic value, and the setting of a cooperation agenda between the countries that share this river basin is urgently required. It is fundamental that territorial management regulations be standardised, as well as methods for how projects for more efficient management of water resources and wastewater treatment in urban areas can be developed.
The involvement of civil society is also essential in this process. The creation of and participation in river basin committees and the expansion and strengthening of this participative territorial water resource management model is fundamental to the success of local and regional action.

The WWF believes that this is the right moment for a pact to be created between all sectors of society and governments, dissolving the dichotomy between conservation and production. This is the only way that we can guarantee the future, not just for the next but also for the current generation, which is already facing the challenges associated with the deterioration of the environment. For this reason, we are working in this area and hope that this study will contribute to establishing and strengthening the links of this collective effort.

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