Ecological Risk Assessment for the Paraguay River Basin

Argentina, Bolivia, Brazil and Paraguay

January 2012

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1st Edition

Contents

Introduction

This publication provides the results of an ecological risk assessment for the Paraguay River Basin, which is the first step to establish regional vulnerability to climate change and serves as an input for the discussion on which risks could become more severe in the future.
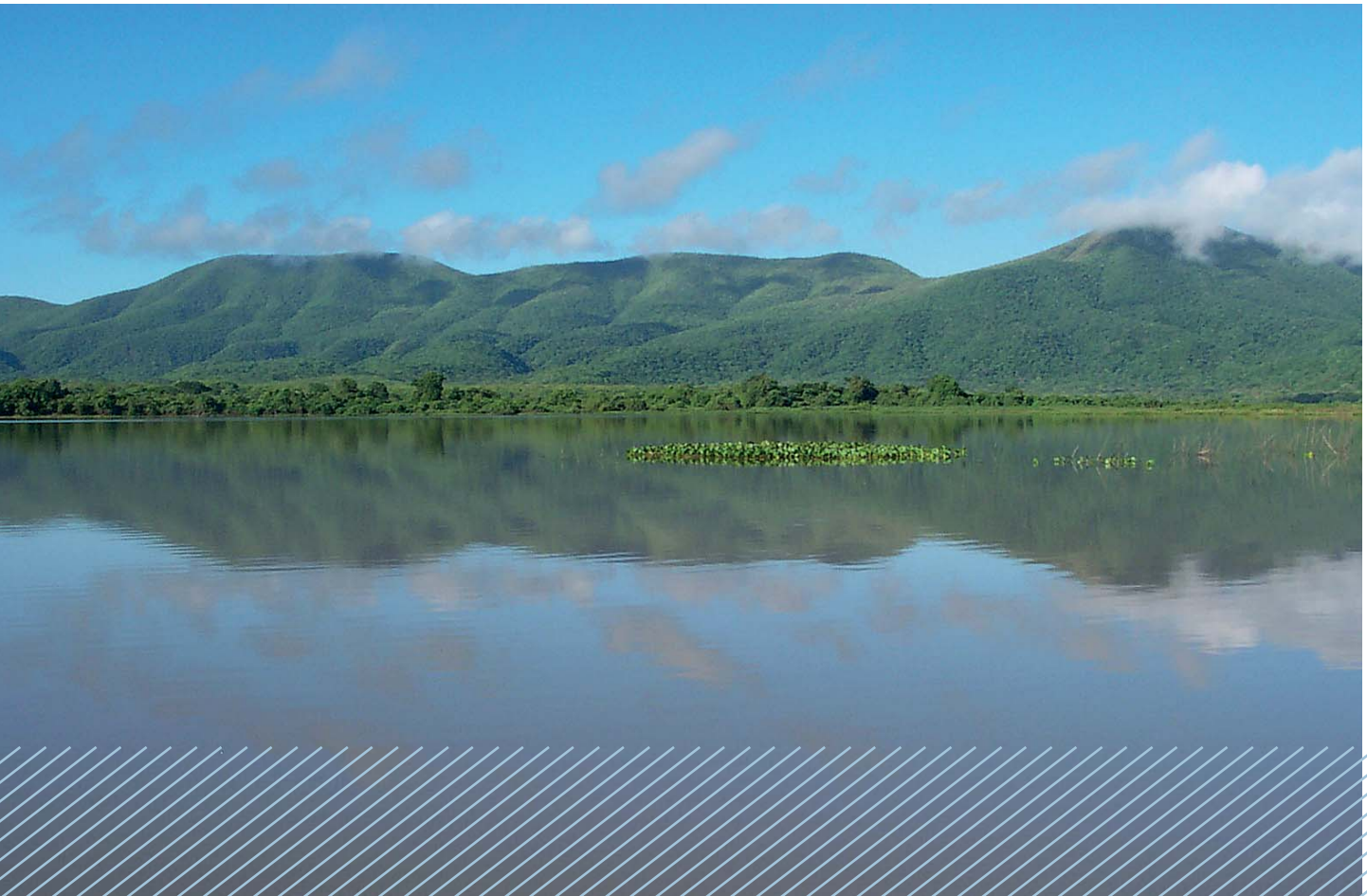
The ecological risk assessment adresses at the current non-climate stresses. In the vulnerability assessment, stresses related to the effects of global climate change are considered and assessed in terms of their synergistic interaction with current stresses.

The purpose of this study is to identify the status of the ecological components that ensure integrity of aquatic ecosystems in the basin. This assessment will inform the governments of the four countries that share the basin, as well as civil society organisations so that they can develop a climate change adaptation agenda for the Pantanal Wetlands and work on its implementation with a view to enhancing resilience[1] and minimizing the basin's vulnerability. The findings in this study could also support integrated, cross border management of water resources.

Despite its ecological and economic importance, the aquatic environments in the Paraguay River Basin are under constant threat of degradation, especially in the highlands and plateaus around the Pantanal, where the most important rivers that sustain the life in the floodplain originate in the Cerrado. Thus it is fundamentally important to learn how threats – whether individually or in conjunction with other threats – affect aquatic systems ecological integrity since climate change is certain to increase the intensity and frequency of floods or droughts, for instance.

This study is intended to enhance the understanding that the unique features of the Paraguay River Basin depend on the correlation between the highlands and the plain. Therefore, any actions that could have an impact on the hydrological systems in the highlands have impacts on the plain as a consequence. Any negative impacts on the highlands – where the headwater of rivers that flow into the plain are located – transfer problems from upstream to downstream in the basin.

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1   Resilience means the ability of an ecosystem to recover and restore its original conditions and functions after alterations in the environment, such as drought, flood, fire, or deforestation.

We must bear in mind that the Paraguay River Basin is home to the largest floodplain in the planet – the Pantanal – where the annual cycles of floods and droughts dictate the lives of thousands of species. The seasonal variation in water levels imposes natural limits on large scale human settlement in the area. The basin covers the extensive plains of Chaco and part of the Andes Mountain Range, and it is exposed to severe drought spells due to the prevailing arid climate.

Beef cattle production has been one of the most traditional economic activities in the Pantanal for over two centuries. However, yields are low if compared with the upper located in the Cerrado. This is because during the flood season the flooded pasture lands the cattle is forced to seek shelter on higher lands. As a result, cattle ranchers have no extensive pasture lands for a period of the year, which is a problem since large tracts of land are required for this business to be viable.

On the other hand, the receding and flooding cycle accounts for the ecological wealth of the region and for high value ecosystem services, such as fertilisation of fields. It also provides optimal conditions for the reproduction of fish

and other species, and with the help of aquatic plants, purifies the waters and attracts a myriad of waterfowl in search for food.

Every year, such natural wealth attracts nearly one million tourists who come to experience wildlife and to engage in sport fishing. A recent study by Moraes (2008) estimates that ecosystem services in the Pantanal amount to US$ 112 billion (approximately R$ 180 billion) annually. Therefore, it may make much

more sense to preserve a part of this region than fully convert it into livestock and crop areas, whose estimated annual earnings would total only US$ 414 million. This is particularly so due to the fact that ecosystem services benefit the wider society, while agricultural earnings only go to ranchers/growers and some of the people directly or indirectly involved in the business with the remainder of society only benefiting from the consumption of associated products.

Background

This report is part of the *Iniciativa Água e Clima* (Water and Climate Initiative), which is the result of a global partnership between the WWF Network and HSBC to support adaptation of river basins to climate change. Likewise, the *Aliança dos Grandes Rios* (Great Rivers Alliance) is the culmination of a partnership between The Nature Conservancy (TNC) and the Caterpillar Foundation, whose goal is to change management of major river basins around the world by developing a new sustainability model for those large aquatic systems.

To that end, WWF-Brazil and TNC have partnered in order to identify the environmental risks in the Paraguay River Basin using an approach developed by Mattson & Angermeier (2007). This method is based on a multi-criteria participatory approach that takes into consideration knowledge of the basin by local stakeholders – an ecological risk index is developed according to the severity of the impacts on ecosystems, their frequency in the basin and the basin's sensitivity to them.

This report is also part of the Synergy Project, which is managed by the Pantanal Research Centre (CPP) and is intended to develop climate change scenarios for the Pantanal until 2100. The CPP is a Mato Grosso based Civil Society Organization of Public Interest (OSCIP, in the Portuguese acronym) devoted to promoting the welfare of Pantanal dwellers and environmental sustainability in the region. With support from the National Council for Scientific and Technological Development (CNPq),

the Synergy Project has a network of integrated research and management for the Paraguay River Basin – the Synergy Network – which brings together over ten research institutions and approximately 40 researchers. The Network held international meetings involving Brazil, Bolivia, Argentina and Paraguay to establish six research topics and nine projects for implementation, including the ecological risk assessment for the Paraguay River Basin[2].

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Scope

From its source, in the area of Diamantino, Mato Grosso, Brazil, to its confluence with the Paraná River in Corrientes, Argentina, the Paraguay River extends for over 2,600 kilometres. The drainage area covers more than 1,135,000 square kilometres (sq km), which is equivalent to more than 800 combined Itaipu reservoirs, or 35 times the territory of Portugal; it covers parts of Bolivia, Brazil, Paraguay, and Argentina (Figure 1).

There are wide altitude variations across the basin – the highest areas lie on the western side, in the Andes, over 4,500 meters above sea level, while the lowest point is in the confluence with the Paraná River, 50 meters above sea level.
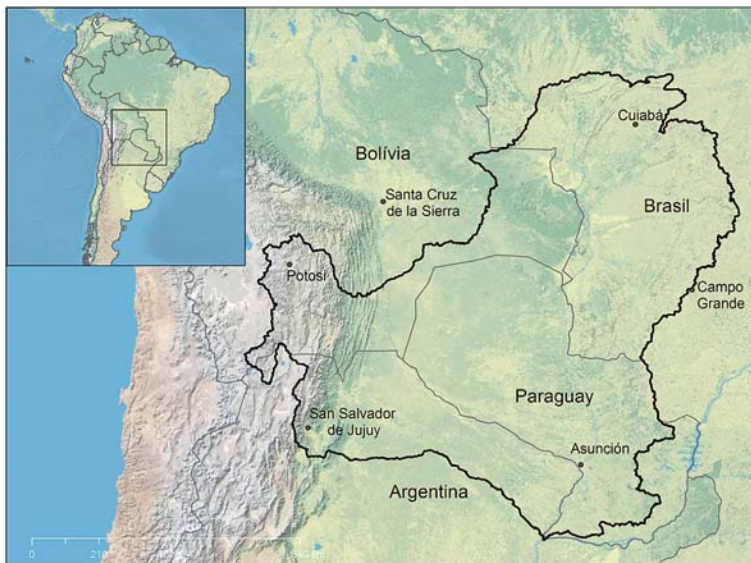
Figure 1. Location of the Paraguay River Basin in South America.

The climate in the basin varies significantly, and it becomes increasingly dry and seasonal east/west and north/south. The climate is tropical in the north and northeast, with abundant rains during the summer and drought spells lasting three to four months. In the southeast, the climate is predominantly subtropical with cold fronts in winter. The mid south and southeast areas have a dry climate with strong seasonality in rainfall patterns. As the topography rises along the eastern edge of the Andes, humidity falls and in the top portion the climate is primarily semi desert.

The main sources of water for the Paraguay River are the tributaries along its left bank, such as the Rivers Cuiabá, São Lourenço, Taquari, and Miranda. Their headwaters are located in the adjacent highlands and all of them drain into the Pantanal Wetlands. On the right bank, the main tributaries are the Rivers Pilcomayo and Bermejo, both with their headwaters in the Andean region.

Between 2006 and 2008, the WWF Network and TNC led a collaboration with several other research organizations to develop a global map that identified 426 aquatic ecoregions[3] (Abell, R. et al. 2008), 50 of which in South America. This research filled a gap of information on the distribution patterns of aquatic biodiversity on the planet, which is much larger than terrestrial biodiversity. In 2006, a chapter on the management of biodiversity in aquatic ecoregions was added to Brazil's National Water Resources Plan. Two major aquatic ecoregions are represented in the Paraguay River Basin – Chaco and Paraguay (Figure 2).
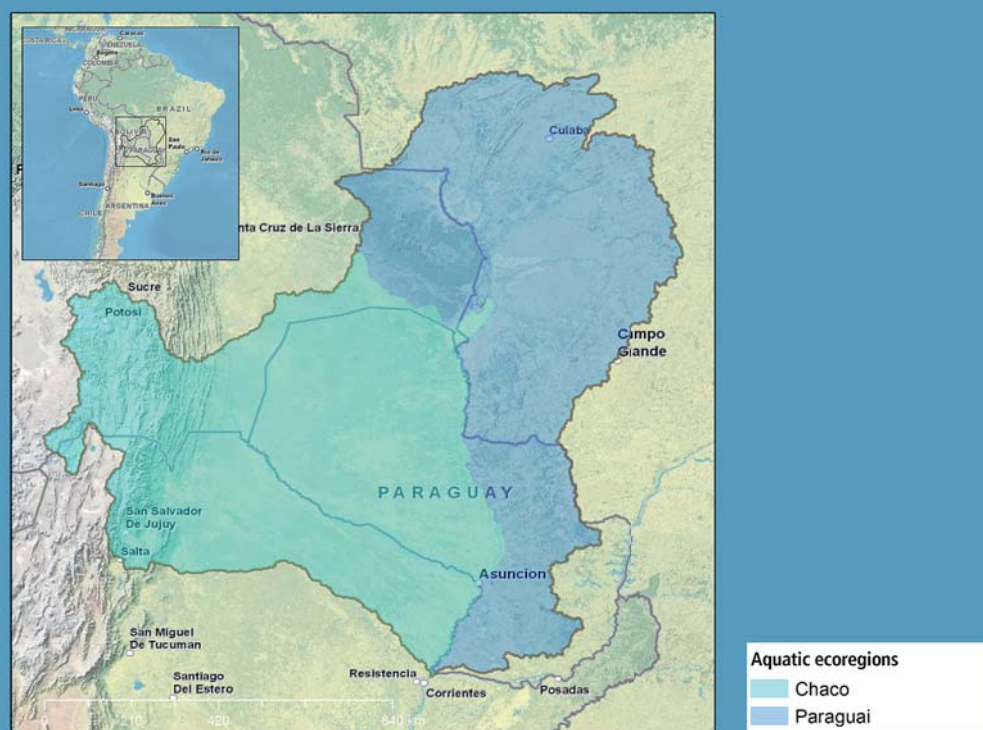
Figure 2. Aquatic ecoregions in the Paraguay River Basin: Chaco and Paraguay.

3   An aquatic ecoregion is a large area comprised of one or more freshwater ecosystems that share water species and environmental conditions and patterns, making up a protected area that sets it apart from other ecoregions.

As far as terrestrial ecoregions are concerned, the Paraguay River Basin occupies a part of seven ecoregions where unique ecosystems have been shaped by climate, topography and soil type. Covering 46% of its area, the main ecoregion in the basin is the Gran Chaco, which is formed mainly by open forests that lose their leaves during the dry season, while the ecoregions in the Cerrado and Pantanal cover 18% and 14% of the basin, respectively. The remaining 22% are covered by the High Andes, Chiquitano Forest, Atlantic Forest, and the Yungas (Figure 3).
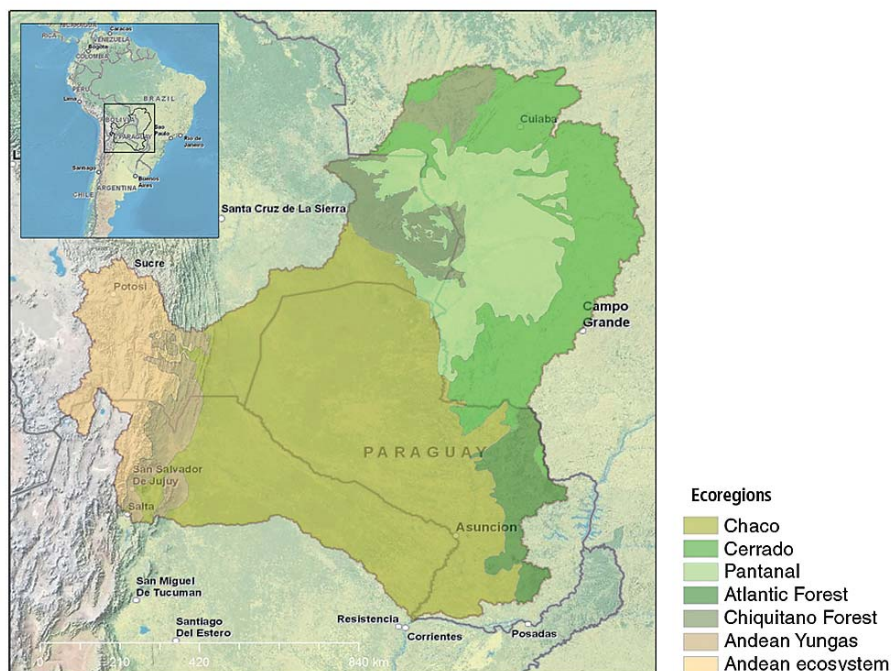
Figure 3. Distribution of terrestrial ecoregions in the Paraguay River Basin.

Ecoregions
- Chaco
- Cerrado
- Pantanal
- Atlantic Forest
- Chiquitano Forest
- Andean Yungas
- Andean ecosystem

Although 75% of the basin is still covered by native vegetation, some ecoregions are heavily threatened by human activity. The best examples are the Cerrado and the Atlantic Forest, where 54% and 48% of the land has been deforested, respectively. About 11% (123,600 sq km) of the basin are protected in some way, and only 5% (56,800 sq km) are fully protected within national or state parks and ecological stations. Despite being the most endangered area, the Cerrado is one of the least protected areas, with only 2% of its land under full protection (Table 1 and Figure 4).

In addition, more than 170 protected areas are not evenly distributed across the ecoregions, and their layout does not take into account any biodiversity considerations. The Brazilian government has been making efforts to discuss the issue in meetings with experts and through initiatives leading to different proposals for new protected areas and reorganisation of existing areas in the Cerrado and Pantanal Wetlands.

Table 1 – Conservation status of terrestrial ecoregions in the Paraguay River Basin

Ecoregions	Area (sq km)	Remnant area	%
Chaco	518.099	433.443	84
Cerrado	207.825	95.921	46
Pantanal	160.505	146.212	91
Andes	89.339	83.612	94
Chiquitano Forest	72.339	53.322	74
Atlantic Forest	45.441	23.403	52
Andean Yungas	42.445	38.175	90
TOTAL	1.135.992	874.089	77
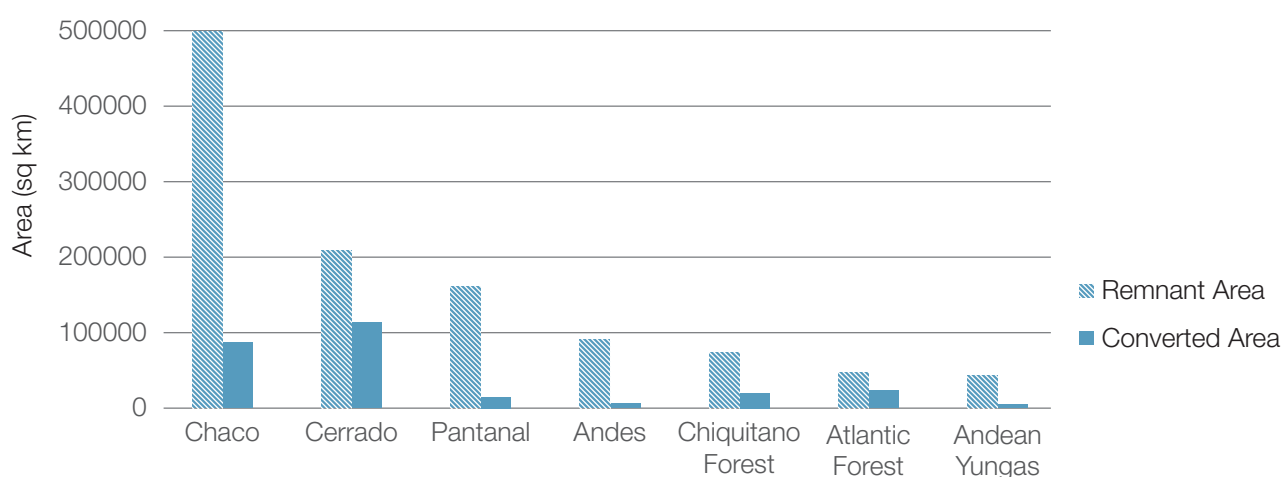
Figure 4. Conservation status of terrestrial ecoregions in the Paraguay River Basin.

The basin is home to over 8 million people, with seven out of ten living in urban areas. The largest population concentration is in the Metropolitan Area of Asunción, Paraguay, with over 2 million inhabitants. Cuiabá (Mato Grosso), San Salvador de Jujuy (Argentina), Potosí and Tarija (Bolivia) are also major urban areas, but there are large "population blanks", such as the central region of the Pantanal and north-western Gran Chaco.

The main economic activity is agriculture, with more than 30 million head of cattle and nearly 7 million hectares of croplands. There are multiple approaches to livestock management, ranging from the most rudimentary, such as extensive cattle ranching, to more technology intensive methods involving feedlots and a high degree of genetic improvement. Similarly, in the river basin region traditional and precision crop farming areas exist side by side, with the latter benefitting from large amounts of inputs and providing high yields.

Besides agriculture, the basin has key mining areas, in particular Andean regions such as that of Potosí (Bolivia), which provides natural gas and lies in the transition area between Chaco and the Andes; Mato Grosso, where gold and diamonds are prospected; and also Mato Grosso do Sul, where iron, manganese and limestone can be found.

The Paraguay River is navigable during a portion of the year, from Cáceres (Mato Grosso) to the confluence with the Paraná River and along the latter up to the mouth of the Plata River and into the Atlantic Ocean. This waterway was traditionally used for passenger traffic, but now it concentrates the transport of ore and grains. A discussion has been ongoing since the 1990s to make navigation a constant activity throughout the year in the upper stretch of the river, which would require dredging, construction of canals and dikes, and straightening of the river bed. All of this would severely affect water patterns and survival of aquatic species in the Pantanal floodplain. Despite these potential impacts, there is constant pressure to push through these changes.

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Hydroelectric plants have a significant presence in the basin, and the potential for energy generation is high, especially for Small Hydroelectric Power Plants (SHPs). There are currently 8 large Hydroelectric Power Plants (UHEs, > 30 MW); 7 very small Hydroelectric Power Plants (CGH, up to 1 MW) and 16 small Hydroelectric Power Plants (SHPs, 1-30 MW), generating around 850 MW – about 1% of the total hydropower-based generation in Brazil. On the Brazilian area alone, nearly 70 new energy projects are underway, including plants under construction and undergoing the licensing and assessment process. About 70% of hydropower capacity in the basin is already in use.

Methods

The purpose of nature conservation planning is to inform actions meant to preserve a representative and functional set of ecosystems that ensures the long-term existence of animal and plant species and the products resulting from environmental services while minimising conflicts between the different legitimate interests of the production sector and society in general.

This process depends on the ecological assessment of the areas to establish which are, or are not, essential to the health of ecosystems and for maintaining biodiversity. However, because of the scarce resources for conservation, it is also necessary to assess the degree of ecological risk involved in these areas in order to establish where conservation actions have the best chance of success.

Understanding the ecological risks in an area also helps to define the sort of action necessary to avoid or minimise adverse impacts, whether by adopting rehabilitation measures or acting quickly to prevent its degradation. Human activities cause changes in the environment that usually affect the integrity of ecosystems, leading to reduced populations or extinction of plant and animal species at local level, reduced water quality and other ecosystem services that are important to society.

Evidence shows that complete removal of natural vegetation along river banks, due to agricultural activity, for instance, increases soil erosion and sediment load into the water since the protective function of the riparian forest is lost. As a result, the sediments carried by water cause the decline or disappearance of aquatic plants and algae that rely on light for photosynthesis. With the removal of trees, less fruit will fall, thus reducing the supply of energy and food for fish, which could affect the size of their populations or even drive them to extinction, especially those that depend on a particular food.

Ecological Risk Index – ERI

Given this context, a method for assessing the level of risk to the integrity of aquatic ecosystems is necessary. According to Karr et al. (1986) and Mattson & Angermeier (2007), at least five functional aspects should be considered in determining the ecological risk and should these be altered, they could seriously undermine the integrity of aquatic ecosystems (Figure 5):

I.   Sources of energy;

II. Hydrologic Regime;

III. Water quality;

IV. Biotic interactions; and

V.   Physical structure of habitats.

Sources of Energy — Organic Matter / Trophic Chains

Water Quality — Physical Quality / Chemical Quality

Integrity of Aquatic Ecosystems

Biotic Interactions — Introduction of Exotic Species / Migration

Habitat Structure — Geometry of Canal / Riparian Vegetation

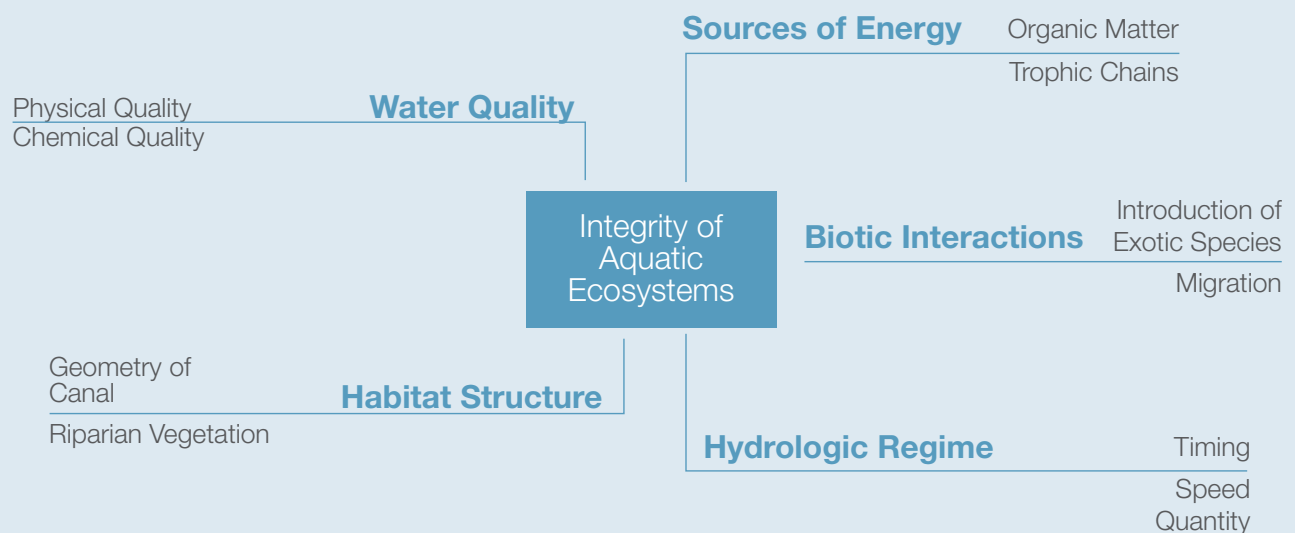**Hydrologic Regime** — Timing / Speed / Quantity

Figure 5. Ecological integrity of aquatic ecosystems and their key attributes. Modified from Karr et al. (1986) and Mattson & Angermeier (2007).

Assessment of the degree of risk to a given ecosystem may take into account the following variables:

I.   The severity of a given stressor and the degree of alteration or potential disturbance that this may cause to the individual functional aspects considered;

II. The frequency with which a given stressor causes alteration or disturbance in functional aspects.

Based on this theoretical framework, Mattson & Angermeier (2007) proposed the Ecological Risk Index (ERI), which is used to assess the stress to which a particular ecosystem or area is subjected. The ERI makes it possible to identify which areas have the highest level of ecological risk for a particular type or set of stressors and to guide conservation decisions and actions. For example, it can reveal the essence of a particular area – whether it is pristine and should be protected, or if its level of degradation prevent rehabilitation actions from being taken. It also helps determine the main stress factors in a given region and indicates targeted actions that are most effective in mitigating these stress factors.

Therefore, the ERI is the result of a combination of the severity level of a given stressor as defined above and the number of occurrences (frequency) of this stressor in the location considered. Its mathematical representation can be expressed as follows:

$$IRI_{(i)} = F_{(i)} \times S_{(i)}$$

(i) = stressor ID
F (i) = frequency of stressor 'i' in the basin considered.
S (i) = severity of stressor 'i' in the basin considered.

An important observation is that the magnitude of the impact caused by a given stressor is not always the same everywhere –

it can vary depending on the ecosystem itself. For example, a stressor such as pollution from oil spills will cause more damage to still or slow flowing aquatic ecosystems, such as a floodplain (where it will tend to accumulate) than in ecosystems with faster flows, such as river rapids, which tend to dissipate the pollutant. That said, an additional variable was considered:

III. The level of sensitivity of the individual ecosystems in relation to a particular stressor.

This variable can lessen or magnify the severity of a given stressor depending on the level of resistance of the ecosystem to its impact, which yields the Ecological Risk Index (ERI). It can be expressed as follows:

$$IRI_{(i)} = F_{(i)} \times S_{(i)} \times Z_{(i)\,(j)}$$

(i) = stressor ID
(j) = ecosystem ID
F(i) = frequency of stressor 'i'
S(i) = severity of stressor 'i'
Z(i) = sensitivity of ecosystem 'j' to stressor 'i'.

Based on the ERI, it is also possible to calculate the *Composite Ecological Risk Index* (C ERI) which is the sum of all ERIs for the individual stressors. It allows an integrated view of the risks to the individual basins.

The mathematical representation of a C ERI can be expressed as follows:

$$C\ ERI\ (k) = \sum ERI\ (i)\ (k)$$

(i)= stressor ID

(k) = ID of the river basin or area considered

In short, the ERI is a tool for decision makers, an aggregate indicator that makes it easier for non experts to understand the problems allowing for more targeted and effective actions to fight degradation of nature.

Steps of the ERI

Final computation of the ERI is a multi step process (Figure 6). Once digital maps containing data on the physical environment (climate, geomorphology and topography) are available, digital maps with data on stressors (or threats) are developed. These details make up the thematic basis of the basin. The integration of digital maps (spatial information) for the determination of the Ecological Risk Index (ERI) of the Paraguay River Basin was conducted using a Geographic Information System (GIS).

ERI - Overview

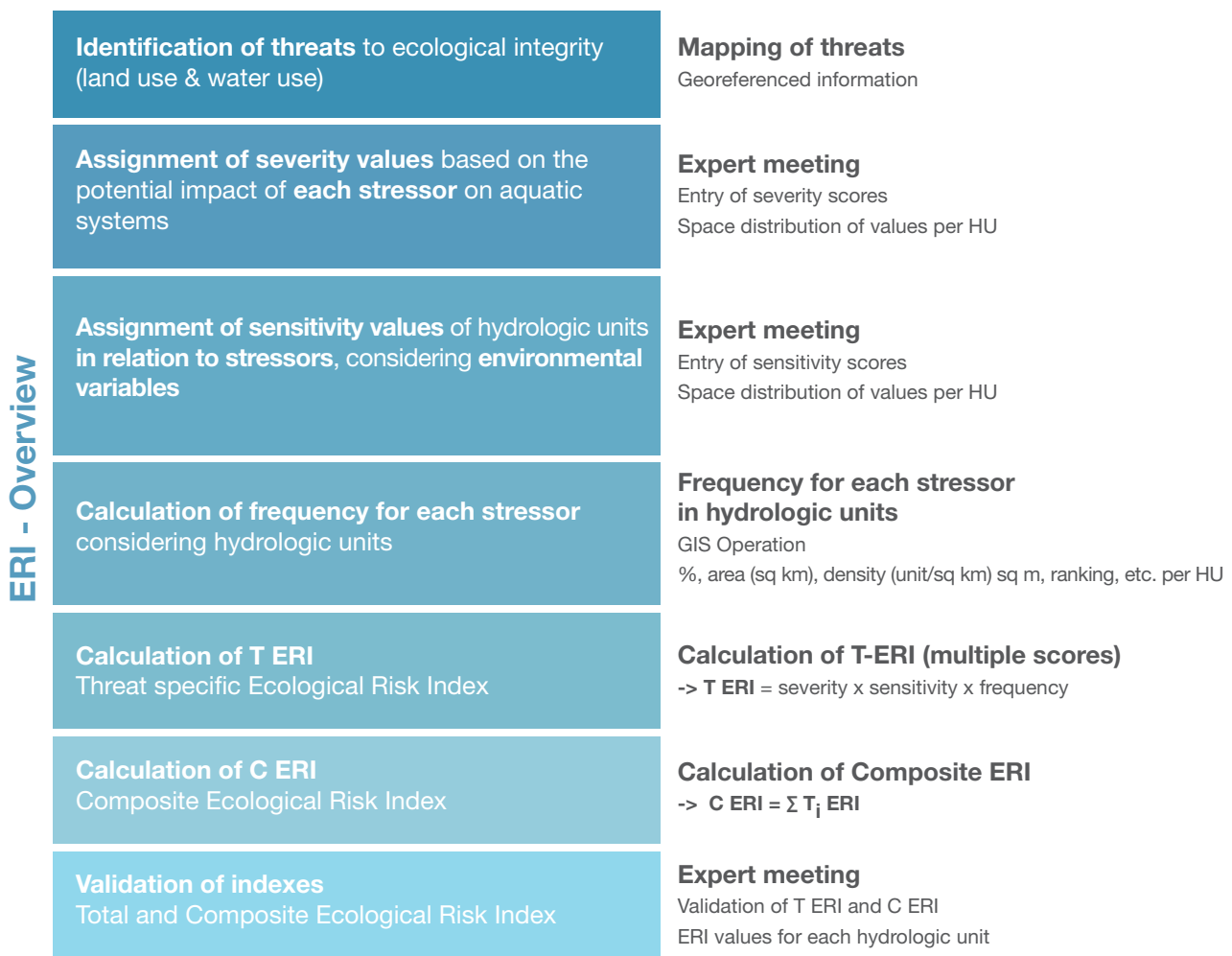|	
Identification of threats to ecological integrity (land use & water use)	**Mapping of threats** Georeferenced information
Assignment of severity values based on the potential impact of **each stressor** on aquatic systems	**Expert meeting** Entry of severity scores Space distribution of values per HU
Assignment of sensitivity values of hydrologic units **in relation to stressors**, considering **environmental variables**	**Expert meeting** Entry of sensitivity scores Space distribution of values per HU
Calculation of frequency for each stressor considering hydrologic units	**Frequency for each stressor in hydrologic units** GIS Operation %, area (sq km), density (unit/sq km) sq m, ranking, etc. per HU
Calculation of T ERI Threat specific Ecological Risk Index	**Calculation of T-ERI (multiple scores)** -> **T ERI** = severity x sensitivity x frequency
Calculation of C ERI Composite Ecological Risk Index	**Calculation of Composite ERI** -> C ERI = $\sum T_i$ ERI
Validation of indexes Total and Composite Ecological Risk Index	**Expert meeting** Validation of T ERI and C ERI ERI values for each hydrologic unit

Figure 6. Risk assessment steps for river basins

In the absence of ecosystem maps reflecting the region's environmental diversity, ecological units were identified by crossing the following environmental variables: climate, geomorphology, vegetation, and hydrologic units. Basin qualitative assessments and stressors were also included, such as the attributes of spatial information obtained through consultation with experts.

Computation of the ERI was based on information on the spatial distribution and frequency of the main stressors of aquatic ecosystems in the basin. A preliminary list of stressors was put together by looking at the literature. The list helped create a georeferenced database for preliminary analyses.

Local experts were consulted for the selection and evaluation of major stressors (Table 2). To accomplish this, experts of various scientific domains from Brazil, Paraguay and Boliva met. The selection of stressors was based on a list covering 13 relevant sources of stress to the aquatic ecosystems of the Paraguay River Basin.

The stressors were assessed individually by the experts as to their severity as a source of direct impact on the functional aspects of aquatic ecosystems, as mentioned earlier.

The sensitivity of these functional aspects against the impacts of stressors was also assessed. Each of the environmental variables was assigned a class, such as low impact (1), medium impact (2) or high impact (3). The final value of severity and sensitivity for a specific stressor and the sensitivity of the individual environmental variables is equal to the sum of all values assigned.

The assessment process involved tables that were given to each expert, which were then analysed and validated by the group. The responses provided by the experts were checked for consistency in order to determine the number of contradictory answers. The final result is shown in Table 2, which covers 13 selected stressors. It shows that hydropower plants, people and agriculture are the most important stressors as a source of impacts to aquatic systems.

The experts evaluated how each environmental variable is impacted in terms of the severity of stressors. The sensitivity was calculated from the values assigned to each environmental variable, with respect to each of the 13 stressors. Table 3 provides an example of the classes assigned to a particular environmental variable in terms of the severity of some stressors and of the sensitivity of this variable against some stressors under various climate regimes. This table was subsequently added to the spatial database, which allowed to establish the location of sensitivity by stressor.

Once the list of stressors and the associated values of sensitivity and severity were established, the frequencies of occurrence of stressors for the individual hydrologic units were calculated. This involved crossing the distributions of occurrence for each stressor with the hydrologic units. The resulting values were then scaled to "0" (not found in the hydrologic unit); "1" (low occurrence); "2" (medium

occurrence); and "3" (high occurrence). For the separation of the occurrence values in these four classes, the frequency distribution curve and the Jenks algorithm (1977) were used. The idea was to identify a set of classes with the least possible variance within group variance.

Once the frequency has been calculated and the severity and sensitivity are available, it is possible to calculate the ERI for each stressor by simply multiplying the three factors. To ensure that the result is a true reflection of the basin, a meeting was held to validate the results with experts from the four countries involved – Argentina, Brazil, Paraguay, and Bolivia. On that occasion, the results were presented for each stressor and at the aggregate level. The experts described the necessary corrections and adjustments. The results provided here reflect the adjustments made after the validation meeting.

Table 2 – Stressors identified for the Paraguay River Basin

Stressor	Weight (Severity)	Parameter
Hydro plant	2.67	Density of UHEs and SHPs at hydrologic unit (hydro plant / sq km)
Population	2.61	Population density at hydrologic unit (inhabitants / sq km)
Crops	2.61	Crop lands within hydrologic unit (sq km)
Deforestation	2.61	% of cleared land in the drainage unit (% of deforestation)
Waterways	2.28	Length of waterways within the hydrologic unit (km)
Roads	2.22	Length of roads within the hydrologic unit (km)
Mining	2.17	Mining areas within the hydrologic unit (sq km)
Fire	2.13	Average number of outbreaks of fire in 2002 2008 per drainage unit (outbreaks / sq km)
Livestock	2.11	Density of cattle within the hydrologic unit (head / sq km)
Dams	1.94	Dam density at hydrologic unit (dams / sq km)
Ports	1.67	Port density at hydrologic unit (ports / sq km)
Crossings/bridges	1.56	Density of road crossings at drainage unit (crossings / sq km)
Gas pipelines	1.17	Length of gas pipelines within the hydrologic unit (km)

Table 3. Sample severity assessment by estressor. In this case, the main climate classes considered against climate sensitivity were semi-arid, dry and sub-humid.

Stressor	Severity of impact		Sensitivity to climate classes		
			1	2	3
			Semi-arid	Dry	Sub-humid
Crops	1	Low			
	2	Medium			2
	3	High	3	3	
Population	1	Low			
	2	Medium			2
	3	High	3	3	
Roads	1	Low	1		
	2	Medium		2	
	3	High			3
Crossings/bridges	1	Low	1	1	
	2	Medium			
	3	High			3
Waterways	1	Low			
	2	Medium		2	2
	3	High	3		
...	1	Low			
	...	...	...	...	...

Hydrological analyses

For the results of the ERI to be obtained at multiple scales, different thresholds for sub-basins in a hierarchical system have been established. The data set used for these determinations was the digital elevation model Shuttle Radar Topography Mission (SRTM/2000), which is processed and available from a database called HydroSHEDS (Hydrological Data and Maps Based on Shuttle Elevation Derivatives at Multiple Scales). The HydroSHEDS database was developed by WWF and contains river basin information on a global basis and at various resolutions (Lehner et al. 2008). It is used to perform global and regional assessment of watersheds, hydrologic modelling, and freshwater planning and conservation with a level of quality, resolution and coverage that was previously impossible.

The first assessment was the delimitation of sub-basins in different size classes based on the SRTM data (2000). The minimum unit of assessment adopted in this study were catchments basins ranging from 100 to 1,000 sq km. Computation of the ERI was then based on these units.

From the altimetry data, a series of hydrologic units based on the catchment area was obtained using the method of nested watersheds developed by Fitzhugh (2005). This series includes five different basin size classes – the smallest basins ranging from 100 to 1,000 sq km, and the largest ones ranging from 1 to 10 million sq km. The different size classes have a hierarchical structure where the smallest unit will always be under the subsequent larger size unit so that work can be performed at multiple scales, and also allowing headwaters as well as small and large river beds to be delineated.

Moreover, each hydrologic unit was assigned abiotic attributes, e.g. climate, geology or geomorphology, which were used to define existing ecological units (ecosystems) and estimate the sensitivity levels of the individual hydrologic unit to different threats. Considering the altimetry data together with other hydrological data from HydroSHEDS, analyses of cumulative runoff were carried out and the average annual flow per sub-basin was calculated. Thus, the water input from the basins was divided into the following types: high, medium, low, and minimal. This assessment resulted in the map of water towers for the Paraguay River Basin, which identifies the sub-basins with the most significant inputs in terms runoff volume (Figure 8).

Results

Hydrological analyses

Through the model of nested watersheds developed by Fitzhugh (2005), 1,837 basin units were identified (Figure 7).

Drainage units
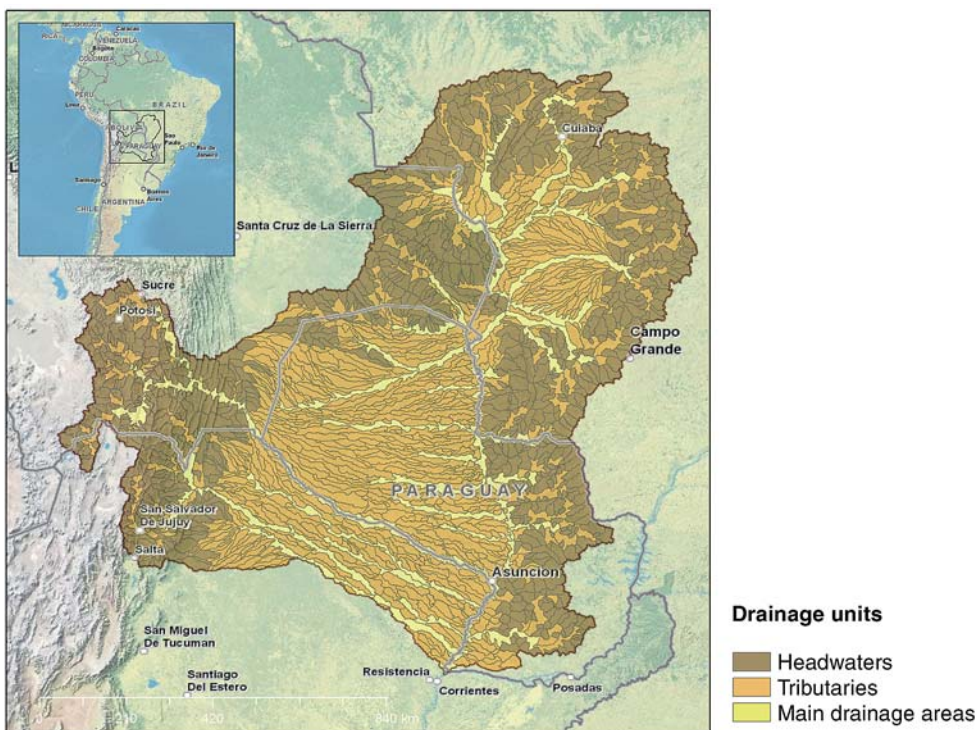
- Headwaters
- Tributaries
- Main drainage areas

Figure 7. Result of a risk assessment for 1,837 drainage units.

The slope and runoff assessment (Figure 8) clearly shows which sub-basins generate most of the flow and that contributes to the seasonal flood pulse that regulates life in the Pantanal floodplain. Standing out are the areas of high input in the sub basin of the Cabaçal and Sepotuba Rivers, tributaries on the right bank of the Paraguay River, in the state of Mato Grosso; the karst area of the sub-basin of the Salobra River, in the Bodoquena Mountains; and the Andean area where some headwaters of the Pilcomayo River emerge, in the Bolivian department of Tarija. The map clearly illustrates the importance of the connection between the central floodplain and the remote areas of springs in the adjacent headwaters. Any changes in these connections both in terms of quantity and timing of flows will have unforeseen impacts on the wetland systems of the Pantanal. Therefore, areas of high and medium input, as well as headwater systems that connect them, should be a priority for conservation efforts in the basin.

Water Input

"water towers"

☐ Low contribution
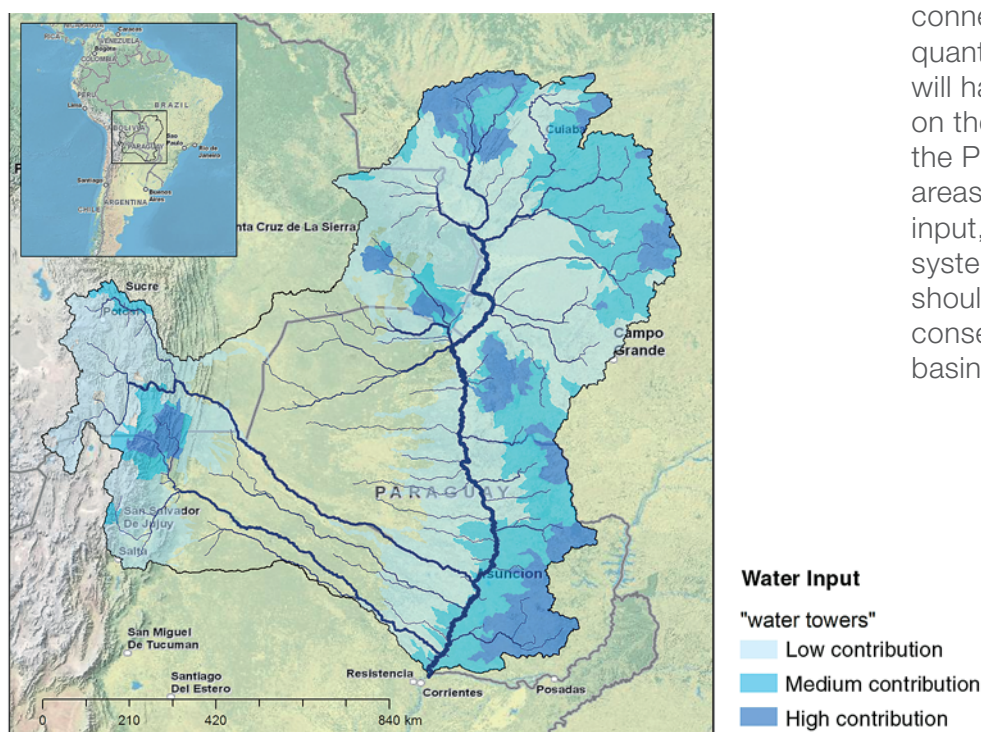☐ Medium contribution
☐ High contribution

Figure 8. Water input areas in the Paraguay River Basin (water towers), considering slope and runoff.

Risk assessment

The analysis shows that 14% of the aquatic resources in the Paraguay River Basin are at high risk of being damaged, while 37% are at medium risk and 49% at low risk. The following map (Figure 9) derives from the composite risk index C ERI:

Composite Ecological Risk Index C ERI

- Low **C ERI**
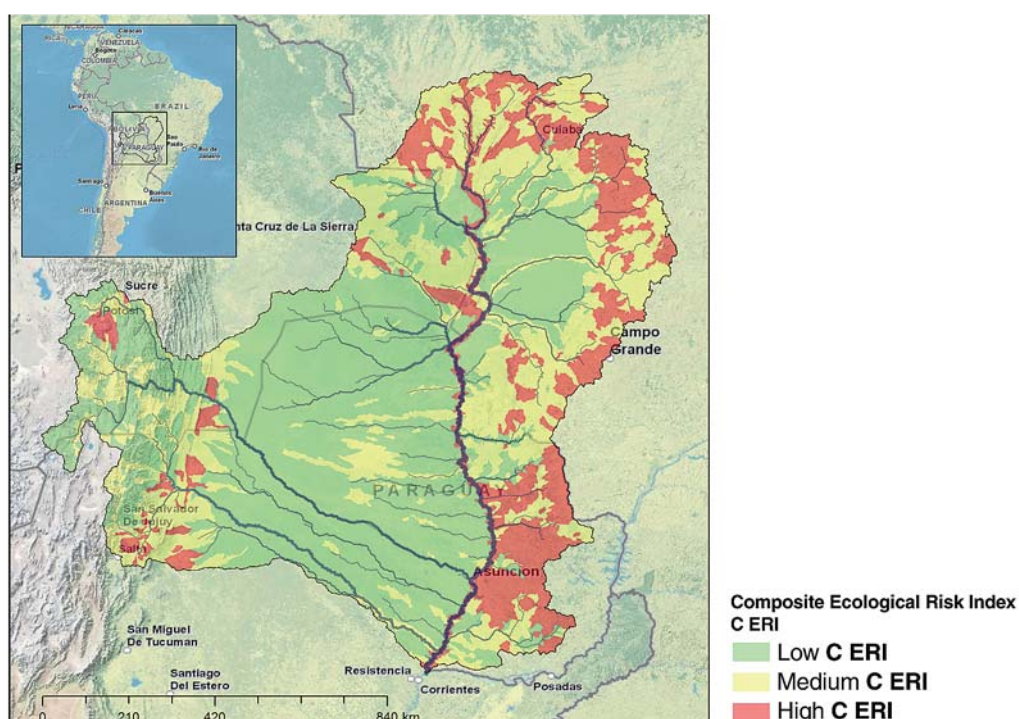- Medium **C ERI**
- High **C ERI**

Figure 9. Result of a risk assessment for 1,837 drainage units.

An assessment of the spatial distribution of the most endangered areas shows that they appear to be concentrated in four different regions that have unique environmental characteristics. These regions are:

1. Headwaters and tributaries in the Brazilian Cerrado and Chiquitano Forest areas;

2. Paraguay River Basin's Atlantic Forest area;

3. Salta Jujuy development zone;

4. Puerto Suarez and Tucavaca Valley, in Bolivia.

The stressors were divided into the three categories presented on Table 4 below.

Table 4 – Groups of stressors

Infrastructure and population	Economic activities	Environmental degradation
People, roads, bridges, ports, waterways, dams, hydropower plants, and gas pipelines	Agriculture, mining, gas/oil prospection	Fires and deforestation

1. Headwaters and tributaries in the Brazilian Cerrado and Chiquitano Forest areas

This region covers the headwaters of rivers in areas of Cerrado and Chiquitano Forest surrounding the Brazilian Pantanal, which are under strong pressure from human occupation. The rivers that begin in that area and run toward the Pantanal floodplain are impacted by a number of sources. Nearly all of these headwaters are located in Brazil, and they run through areas of Mato Grosso and Mato Grosso do Sul states (Figure 10). The importance of this region is even greater as it is the leading source of water to the Pantanal basin.
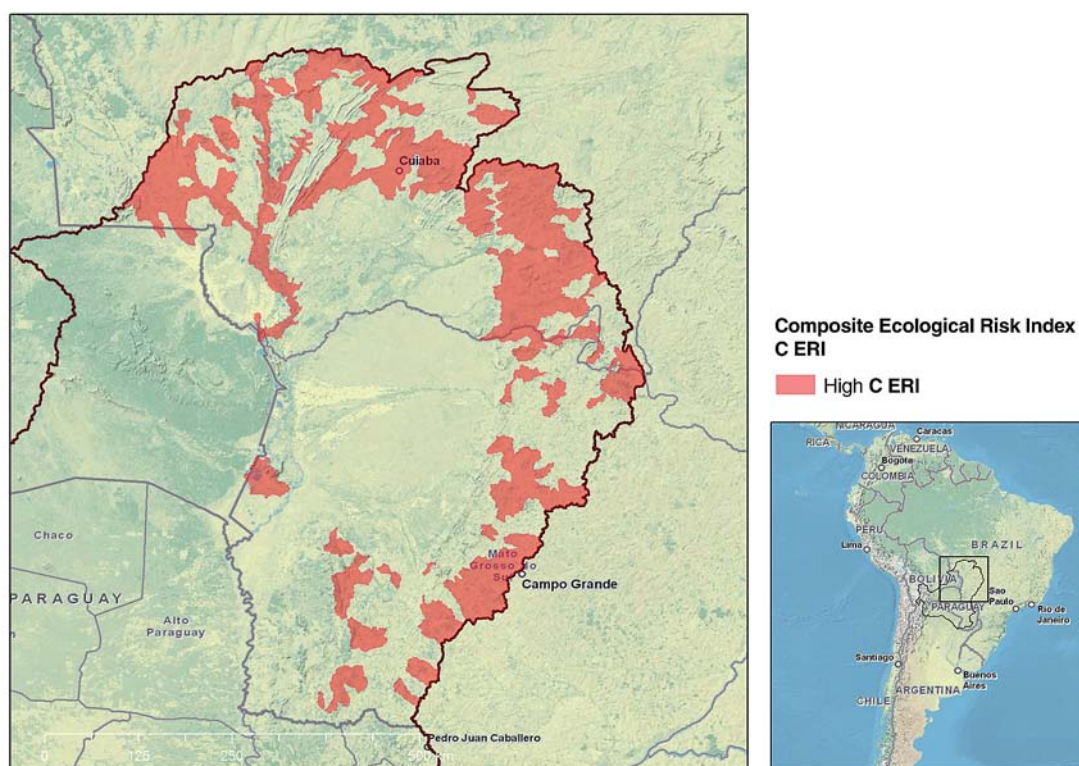

Figure 10. Composite Ecological Risk Index (C ERI) map for the headwaters and tributaries located in the Cerrado and the Chiquitano Forest region.

Just as in the entire Paraguay River Basin, the three sets of stressors operate in this region. Although they are generally evenly distributed, the set of stressors with the most significant share of the ERI is related to the impacts of infrastructure and population (39%), in particular roads and bridges density (Figure 11).

Roads have a major potential impact on water resources, especially unpaved backroads built without the technical precautions required to prevent erosion, damming or alteration of water courses (Photo on page 29). Roads built without any technical procedures are likely to be major drivers of sediments and contaminants. Intersections of roads and water courses are supposed to be the areas under greatest pressure since they are the primary entry points of materials into water courses.

With regard to the headwater region in the Cerrado, in some areas hydroelectric plants are a key infrastructure stressor. However, considering the potential establishment of tens of Small Hydroelectric Power Plants (SHPs) in the region, their impacts may increase considerably. Data on planned SHPs were not included in this study because they were not available for its entire scope.

The second set of stressors is related to economic activities, especially cattle ranching (23%) and agriculture (13%) (Figure 14). Cattle ranching is a traditional economic activity both in the headwaters area and in the Pantanal floodplain. In the recent past, there was a closer relationship between cattle ranching in these regions and rearing and breeding herds in the plain, and fattening herds in the highlands, with constant and seasonal displacement of the cattle. Nowadays, with the improvement of planted pastures and livestock genetics, rearing takes place entirely in the headwaters area, thus increasing the number of cattle per hectare in these pastures.

This process caused the herd to increase greatly over the past few decades, resulting in a bovine population that is three times larger than the human population in the area (IBGE, 2011). The impact associated with this activity is largely due to mismanagement of cattle and pastures. Examples of mismanagement include allowing the herd to drink directly from water courses and overgrazing, which exposes the soil to the erosive effects of rain, which in turn causes the soil to degrade. Large scale erosion results in sedimentation of the water and siltation of rivers and streams.

Agricultural activities are conducted in the plateaus, which are flatter and high, have deep soils and are less vulnerable to erosion since they have low concentrations of sand and high concentrations of silt and clay. Despite this location, failing to use adequate agricultural techniques for soil conservation causes serious impacts on water resources, affecting water clarity in particular. Silt and clay grains are smaller and lighter than sand, and they tend to be more easily removed from these soils and be suspended in water for longer times and larger distances.

This hinders photosynthesis in water bodies altering the aquatic food chain.

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Soil erosion caused by road-building in the Paraguay river basin.

Additionally, indiscriminate use of agricultural inputs like fertilisers, insecticides and herbicides is commonplace in Brazil. Pollution and contamination of rivers, streams and groundwater are already a reality in some areas, possibly causing the loss of sensitive species, making eutrophication events more frequent due to excessive nutrient loading. This leads to proliferation of microorganisms (especially cyanobacteria) and affects water supply in urban areas.

■ Infrastructure and Population **39%**

■ Economic Activities **34%**
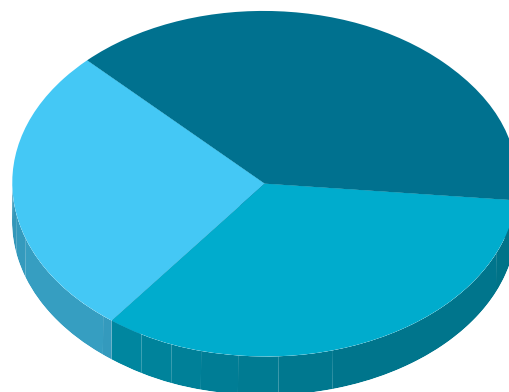
■ Degradation **27%**

Figure 11. Share of stressors by category. Stressors detailed in Table 4.

Legend:
- Livestock **23%**
- Roads **21%**
- Deforestation **15%**
- Fire **13%**
- Bridges **12%**
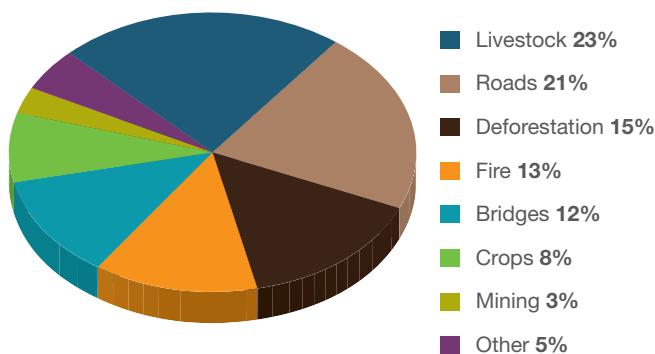- Crops **8%**
- Mining **3%**
- Other **5%**

Figure 12. Stressors in the headwaters area of the Cerrado as a share of the Total ERI.

Increased swine and poultry production in areas adjacent to soybean and corn croplands is also noteworthy. Swine farming in Mato Grosso is expected to grow 180% by 2020 (Mato Grosso Institute of Agricultural Economics – IMEA, 2010). A survey of companies operating in this industry shows that the swine herd grew 38% between 2008 and 2010.

The increase in poultry production in the region is around 7% per year. This growth comes in tandem with an expansion in soybeans and corn production used for animal feed, leading to increased pressure on rivers, springs and aquifers.

The third set of stressors is directly related to environmental degradation, including deforestation and fires (Figure 12). Even though they are often times directly associated with agriculture, they have a behaviour of their own, which is connected to land speculation and tenure issues. While the regional landscape changed more dramatically during the 1970s and 1980s, even today deforestation rates higher than 1.5% per year are still being reported, according to the Action Plan for the Prevention and Control of Deforestation and Fires in Cerrado (MMA, 2009).

This steady loss of natural environments, together with the degradation caused by the unnatural burning of native vegetation has direct and indirect impacts on water resources by altering water quality and facilitating erosion.

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2. Paraguay River Basin's Atlantic Forest area

The Paraguay River Basin area originally covered by Atlantic Forest is also a region with aquatic systems that are under high degradation risk (Figure 13). It has been long settled and the landscape is highly fragmented both due to the countless urban clusters and agricultural areas focused on dairy farming and monocultures, such as sugar cane. The Metropolitan Area of Asunción stands out with over 2 million inhabitants and nearly 1,000 square kilometres – the largest population density in the basin.

Issues related to the lack of water supply and sewage treatment capabilities are commonplace, as in most large urban areas in South America (Figure 14). It should be pointed out that about 30% of the water supply to the Metropolitan Area of Asunción comes from the Patiño Aquifer, and its uncontrolled use can lead to gradual salinisation of the water source (Foster and Garduño, 2002).

In the region are some of the Departments (states) that stand out economically in Paraguay, with a network of services supporting regional production. As far as infrastructure is concerned, the existence of the densest road network in the basin and, consequently, of bridges and crossings with drainage areas, has the most impact on aquatic systems (Figure 15).
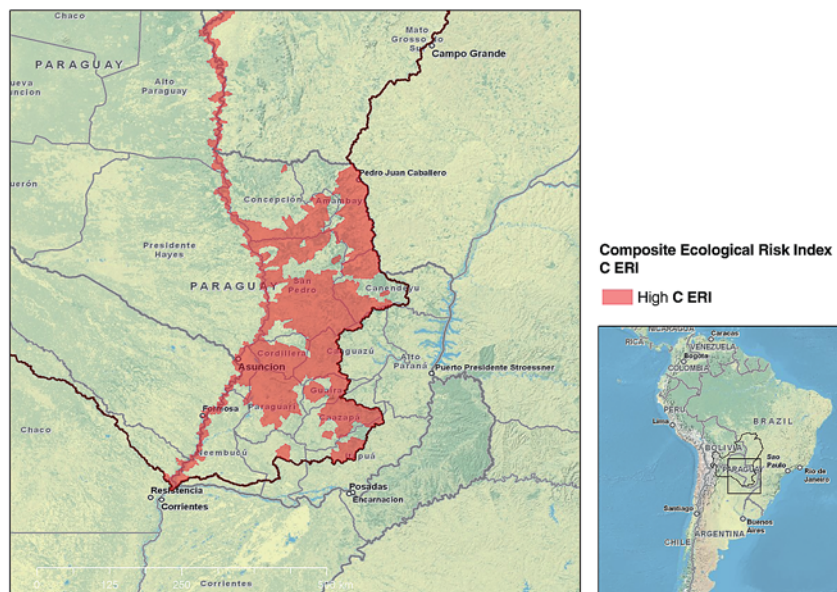

Composite Ecological Risk Index C ERI

High **C ERI**

Figure 13. Map of ERI for the Metropolitan Area of Asunción and Atlantic Forest in Paraguay.

© WWF-BRASIL/ADRIANO GAMBARINI

Asunción is also the crossing point of three development hubs in the so called Initiative for the Integration of the Regional Infrastructure in South America (IIRSA): the Paraguay-Parana Waterway; the Central Inter-Oceanic Hub, which connects Chile, Bolivia and Brazil; and the Capricorn Hub, which connects Asunción and Paranaguá. Here, the transport infrastructure tends to become denser and branch out to other areas, especially the Chaco.

The region brings together approximately 56% of Paraguay´s industrial businesses, mainly in the agricultural commodity processing sector. There are several plantations, sugar and alcohol mills, grain crushing mills, and cotton and tobacco processing plants. Agricultural production is geared to supplying urban areas, and it includes dairy farming, and vegetables and fruit production.
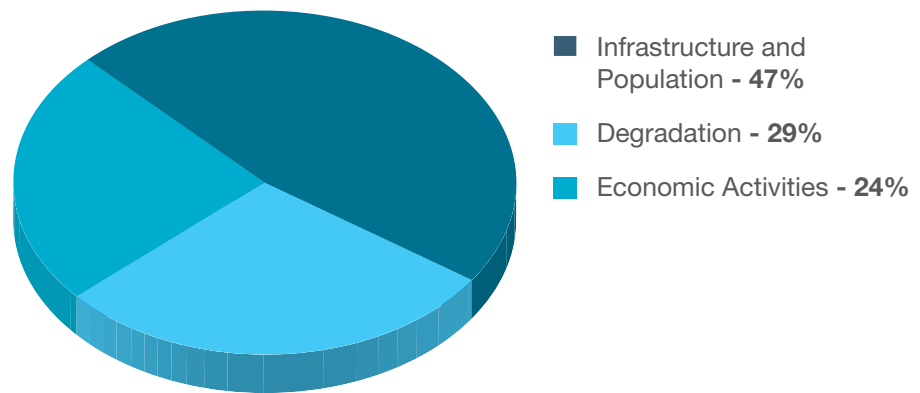
Infrastructure and Population - **47%**

Degradation - **29%**

Economic Activities - **24%**

Figure 14. Stressors in the headwaters area of the Cerrado as a share of the Total ERI.

Roads **25%**

Bridges **16%**

Fire **15%**

Livestock **15%**

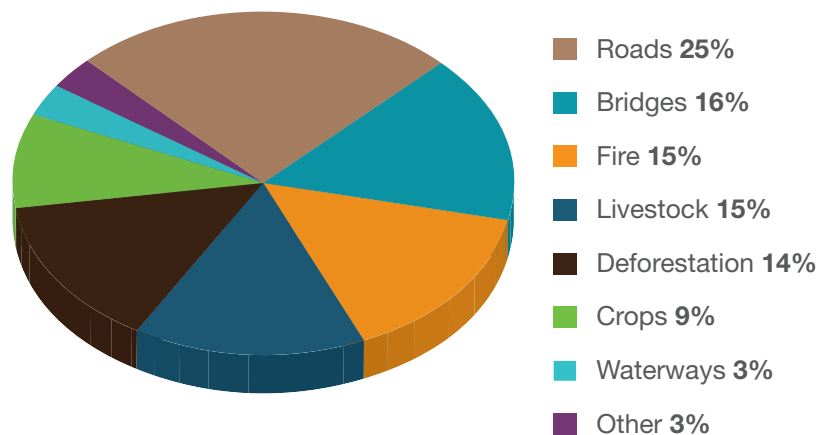Deforestation **14%**

Crops **9%**

Waterways **3%**

Other **3%**

Figure 15. Stressors in the Metropolitan Area of Asunción and Atlantic Forest in Paraguay as a share of the Total ERI.

3. Salta Jujuy development zone

The development zone in the western side of the basin, which stretches from Salta to Jujuy and goes northward into Bolivia, crossing the headwaters of two major tributaries – Bermejo and Pilcomayo – is an important area of impact on the aquatic systems in the Paraguay River (Figure 16). It is part of the IIRSA Capricorn Hub and is expected, in addition to boosting regional development, to merge with the Pacific via the Central Inter-Oceanic Hub, connecting Chile, Bolivia, Paraguay, and Brazil.

These hubs intersect the two main tributaries on the right bank of the Paraguay River – the Bermejo and Pilcomayo Rivers. These areas were originally covered by montane forests, which are known as the Yungas, and Chaco plain vegetation. This area is traditionally occupied by extensive cattle ranching and logging activities, and crop farming and oil and gas prospection are rapidly increasing activities.

Considering the grouping of stressors, those associated with infrastructure are the most relevant, and once again roads, railways and bridges stand out (Figure 17). As mentioned earlier, one of the goals of IIRSA is to improve regional transport systems by implementing a number of road-paving and duplication projects, as well as railway rehabilitation projects.

In addition, satellite imagery indicates a recent proliferation of backroads on the plains as a result of expanding agriculture.

Because this is a border area crossed by a transnational motorway, development of infrastructure as a result of an increasing population is expected to speed up over the coming decades. The pressure on natural resources, notably water, will increase as a consequence.

Emerging crops such as sugar cane, tobacco, citrus, and vegetables will also have a socioeconomic impact. Cultivation techniques may be divided in two types: the more traditional crops in fertile lands in valleys, and vast irrigated areas in the plain, which are booming. The intensification of agricultural activities leads to increased use of inputs and the potential contamination of surface or groundwater. There have been reports of contamination in the Pilcomayo Basin and the Bermejo Valley (LIDEMA, 2010).

The profile of cattle ranching is also changing. The extensive approach to cattle ranching was traditionally employed, where

seasonal grazing areas in the plains or mountains were used. Today, planted pastures have been expanding in large properties on the plain.

It should be stressed that this region is a major producer of gas and oil. In spite of being an occasional activity, both exploration and prospecting should be considered important sources of impact. In addition to prompting the creation of trails for prospecting activities – which support logging activities –, oil desalination causes huge amounts of water to be contaminated with hydrocarbons and chemicals, such as SO2 and SH2. In concentrations of a mere 0.01 parts per million (ppm), they make water unfit for human consumption.

Research studies on the environmental conservation status of Bolivia (LIDEMA, 2010) warn that contamination by organic compounds is severe in oil and gas exploration and prospecting areas. These are low solubility contaminants that are only partially degraded, and they can generate even more toxic compounds. As the local rainfall regime is extremely concentrated, dissolution of these substances risks contaminating water courses.

Degradation-causing effects stressors include fire, which is a sizeable source of regional impact. Its occurrence is largely associated with cattle ranching as it is traditionally used for the renewal of pastures (Figure 18).
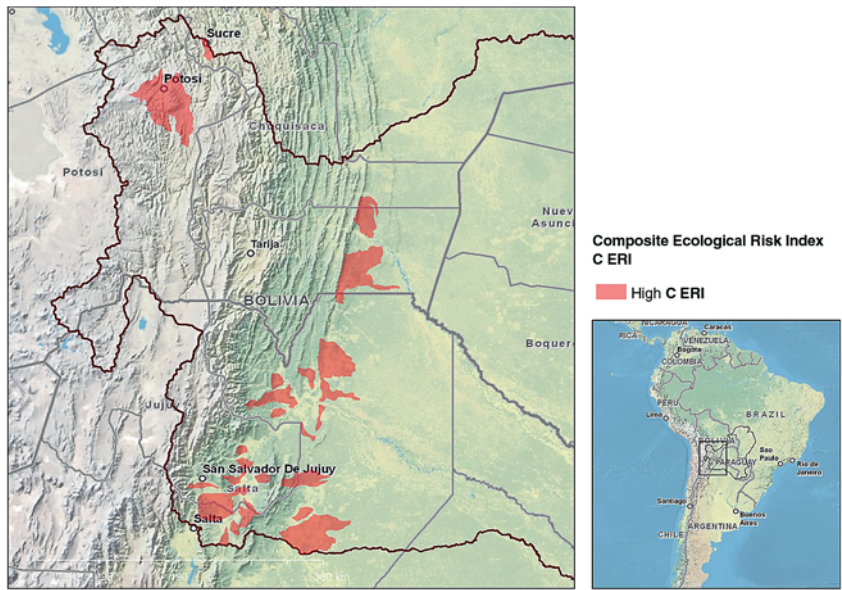
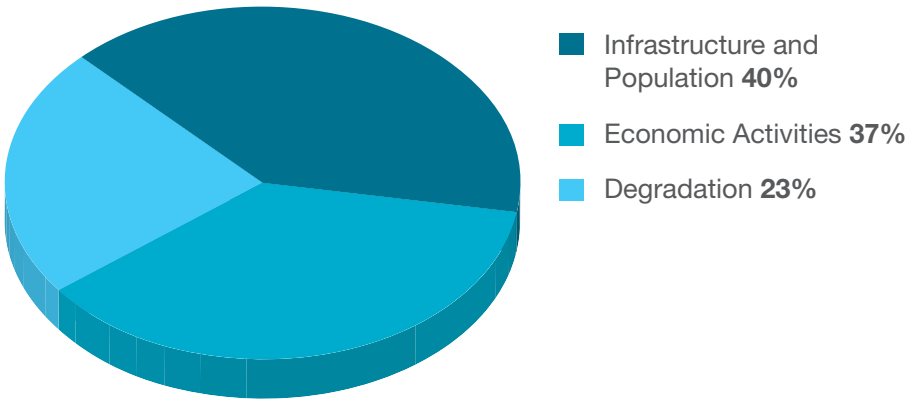Figure 16. Map of ERI for the Metropolitan Area of Asuncion and Atlantic Forest in Paraguay.

Infrastructure and Population **40%**

Economic Activities **37%**

Degradation **23%**

Figure 17. Share of stressors by category in the Jujuy and Salta region.

Fire **22%**

Crops **19%**

Roads **19%**

Livestock **17%**
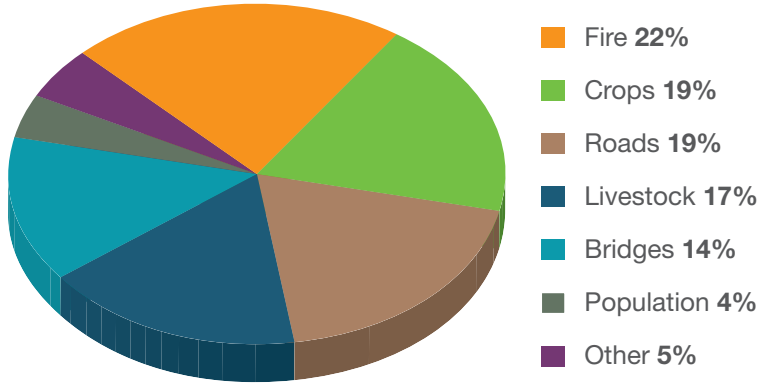
Bridges **14%**

Population **4%**

Other **5%**

Figure 18. Share of stressors in the Jujuy and Salta region. Stressors detailed in Table 4.

4. Puerto Suarez and Tucavaca Valley

Located near the Brazilian border, in the direction of Santa Cruz, along the Tucavaca River Valley (Figure 19), the ecological risk in this region is also high. The Tucavaca River is one of the main components of the southern Bolivian Pantanal, providing a large volume of water to the Paraguay River. The Tucavaca River originates in the Chiquitano Forest and runs almost parallel to the old railway and road that connect Corumbá, in Brazil, to Santa Cruz de la Sierra, in Bolivia.

With one of the lowest Human Development Indexes (HDI) of Bolivia, this region has experienced a gradual increase in environmentally degrading economic activities, mainly associated with Brazil's growing demand for timber and coal and the establishment of mining ventures. It is also covered in the planning for IIRSA's Central Inter-Oceanic development hub, which aims to improve the connection between Santa Cruz, Puerto Suarez and Corumbá and, from there, the connection between the Pacific and Atlantic oceans.
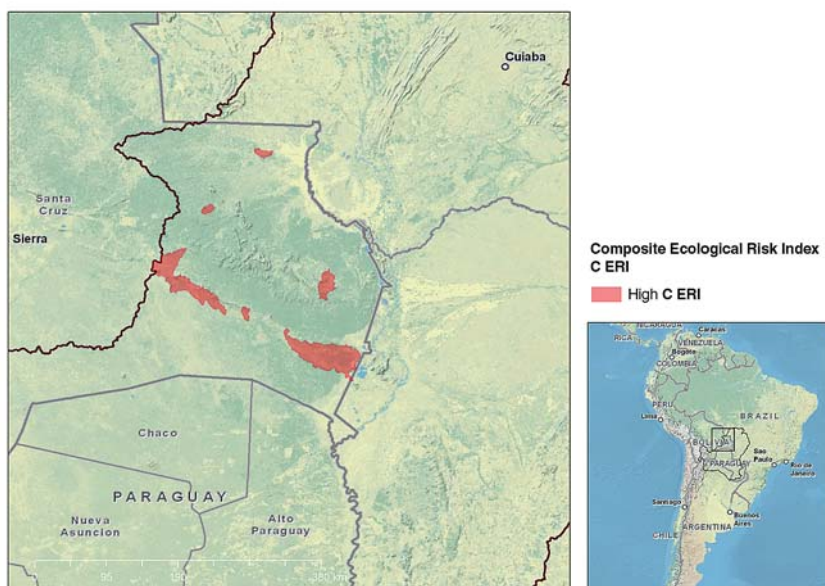

Figure 19. Map of ERI for the regions of Puerto Suarez and Tucavaca River Valley.

The risk assessments (Figure 20) show that cattle ranching in association with deforestation and burning are the primary sources of stress on water resources (Figure 21). Regional cattle ranching is traditionally extensive and uses fire to renew pastures. Deforestation has been stepped up in order to meet Brazilian steel mills´ demand for timber and coal.

This upward trend in deforestation may become even stronger once mining and steel operations are set up on the Bolivian side. The Bolivian government now recognises the importance of regulating logging in the Chiquitano Forest. According to the Human Development Report for Bolivia, forestry is a strength for the Chiquitano Forest, but this is currently being exploited in a predatory manner, where no forest management techniques are used (UNDP, 2009).

This reckless use of forests has a negative impact on water because it not only causes the loss of forest cover and the ensuing problems of erosion, siltation and alterations in infiltration and runoff, but it could also lead to these areas being used for cattle ranching,

which could make the situation worse. Although an environmental protection plan is in place for the Santa Cruz Puerto Suarez corridor, it is only partially implemented, with limited concrete results in terms of lessening impacts in the region (Arkonada & Laats, 2009).

Even though mining does not feature as a major stressor, the risks associated with activity are likely to increase. There are three regional mining development hubs: the Mutum project in the Urucum Mountain area; Rincón del Tigre; and the

Tucavaca Valley. These activities pose both direct and indirect risks to aquatic systems. For instance, the Mutum mining and steel project is using large volumes of water, and thus endangering the Laguna Cáceres (LIDEMA, 2010).
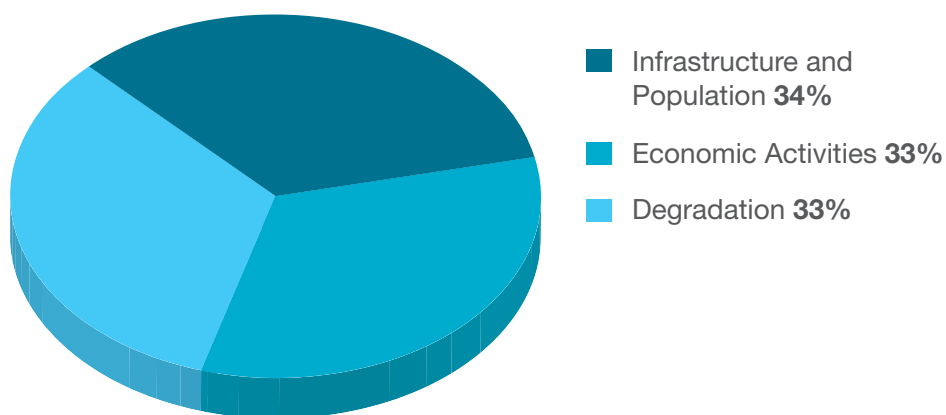

Figure 20. Share of stressors by category in the Puerto Suarez and Tucavaca Valley region.

Infrastructure and Population **34%**

Economic Activities **33%**

Degradation **33%**

Livestock **25%**

Fire **18%**

Deforestation **16%**

Roads **15%**

Bridges **14%**

Crops **5%**

Gas Pipelines **4%**
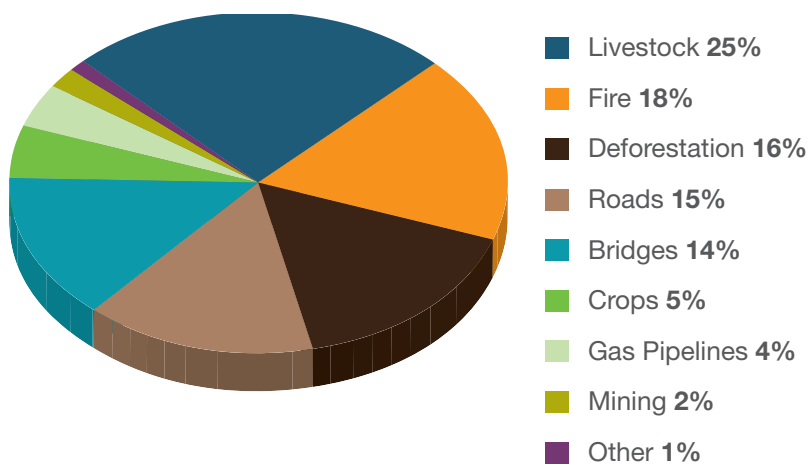
Mining **2%**

Other **1%**

Figure 21. Share of individual stressors for the Puerto Suarez and Tucavaca Valley region.

Discussion and Recommendations

The central portion of the basin, i.e., the Pantanal and the Dry Chaco, displayed low ecological risk. However, the flooding regime in the region and the interdependence between the highlands and the plains are an indication that the situation is very dynamic in hydrologic terms. In view of the high risk identified on the highlands, the cascading effect of impacts downstream will represent a proportionately high risk to the floodplain.

It is important to look at the maps in time and space, and not as a static item. In view of the above, the Paraguay River Basin has a high potential ecological risk, and requires immediate and priority action to protect its headwaters. However, the management and care of the basin should be conducted in a concerted manner by implementing effective conservation actions on the highlands and plains.

Given that the Pantanal is a floodplain fed by headwater systems located in the adjacent highlands and plateaus, the high water input areas (water towers) should be given priority in the basin conservation plans. It has been noted, however, that there is considerable overlap between middle and high water input areas and the areas at ecological risk (Figure 22).
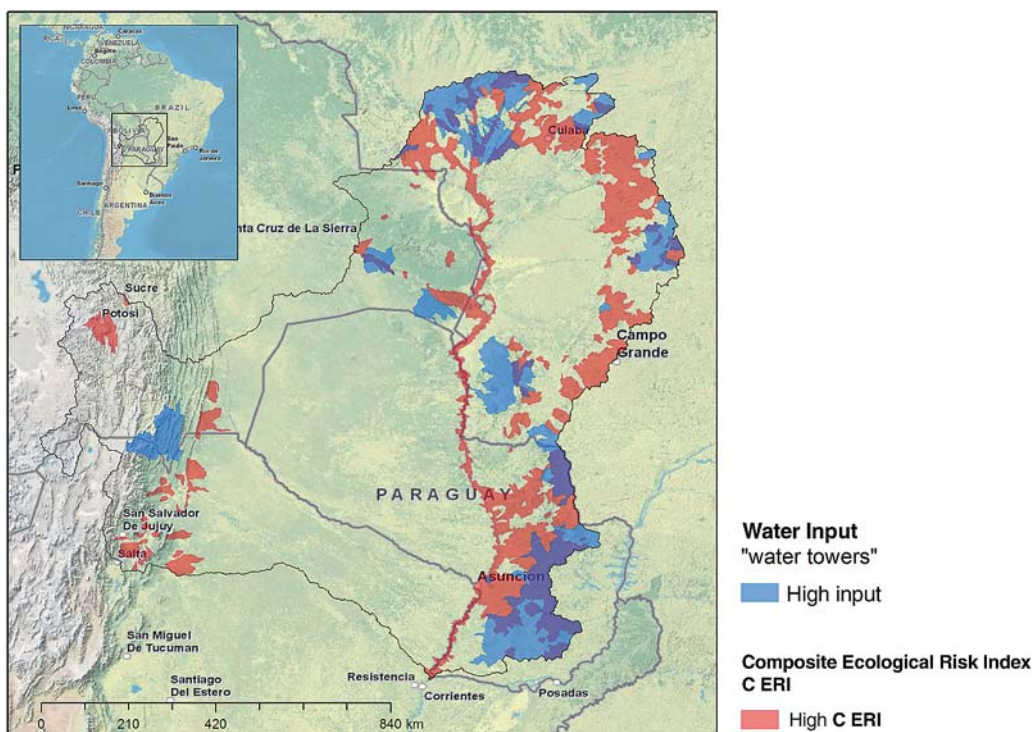

Figure 22. Overlap between areas at ecological risk in the Paraguay River Basin and medium and high water input areas.

Protecting middle and high water input areas in the highlands is key to supporting the seasonal flood pulse in the Pantanal. Considering future climate change scenarios, adaptation measures that enhance the resilience of the basin would support the flood pulse and the connectivity between the highlands and the plains, and would also protect the headwaters.

For this reason, WWF-Brazil and several partner institutions have started the Waters of Cabaçal Movement and have been developing a project to restore springs and fight erosion in the Cabaçal River

Basin, which is a region that feeds a significant amount of water into the Pantanal Wetlands in Mato Grosso.

TNC also runs the Sustainable Cerrado demonstration project in the São Lourenço River Basin – one of the main tributaries of the Paraguay River, which plays a key role in the amount of sediments carried to the Pantanal Wetlands.

Another TNC-run Pantanal protection project is being implemented in partnership with the Pantanal Research Centre (CPP) and will include several technical studies and social engament actions. It will include several

technical studies and social engagement actions. The results of this project will be used to inform conservation and sustainable development actions in the area, including ecosystem based actions for climate change adaptation.

In collaboration with its strategic partners, WWF Bolivia has been pursuing land use planning actions based on municipal development plans in areas that provide a high water input to the basin as a whole, such as the Correreca and Curichi Grande River Basins.

The Waters of Cabaçal Movement

The Waters of Cabaçal Movement was launched in late 2008, and it was the culmination of an environmental expedition to the so called "arco das nascentes" (belt of water springs) in the Pantanal, in Mato Grosso. At the time, WWF-Brazil and its partner institutions conducted an assessment of the environmental status of the springs. The Cabaçal River Sub basin is extremely important, not only for the high erosion potential of its fragile soils, but also for its abundant surface waters, sources and springs of great scenic beauty and ecological significance. The Cabaçal River Basin is a major water source for the Pantanal floodplain, which is a high input area (water tower).

The social and political mobilisation, as well as the involvement of the residents in the basin area with the environmental issues were important to kick off the movement. To strengthen the movement, WWF-Brazil set up an alliance with the University of Mato Grosso (UNEMAT); the Mato Grosso Rural Extension Agency (Empaer); the Municipality of Reserva do Cabaçal; Intermunicipal Consortium for the Economic, Social, Environmental, and Tourism Development of the Pantanal Springs Complex; and local schools.

The movement has been in existence for two years and has been a transformational force in town. The Environmental Education programme has reached about 60% of the population, including students, public authorities and citizens. In the teaching environment, 75 teachers from two local public schools and one state school have been trained, benefiting pre-school, primary and secondary shcool students, as well as university students in the region. It has involved the City Council with lectures and drama workshops. Other citizens have also been directly involved, for example a physical education teacher who has started working with solid waste recycling.

And the movement went on to involve farmers – about 50 of them became involved in activities and workshops on the recovery of water sources and the development of organic cattle ranching.

Recovery of the Dracena River – a secondary tributary of the Cabaçal River – was selected as a demonstration action that allows farmers to learn about soil and spring recovery techniques. Six thousand seedlings have already been planted in 12 springs, and a large crater is being repaired – all

supported by a seedling nursery. Women at social risk were trained to make crochet hammocks and became involved in erosion restoration efforts by making contention screens and nets. In return, they receive baskets of staple food from the local government.

The movement is now being expanded and replicated in other sub-basins along the belt of water springs. The efforts involve:

- A publication on the lessons learned in Cabaçal that will focus on low cost techniques to restore degraded areas, taking into consideration local solutions;

- Training of residents from other towns on the environmental recovery techniques employed in the Dracena micro basin;

- Technical visits and field activity days for farmers.

The Sustainable Cerrado Project

The Sustainable Cerrado Project in the São Lourenço River Basin, in Mato Grosso, is run by the Great Rivers Alliance, a TNC and partners initiative to protect the great rivers of the planet. Work began in four major river basins: Paraguay (to which the São Lourenço Basin belongs) and Paraná, in South America; Mississippi, in the United States; Yangtze, in China; and Zambezi, in Africa. Work in Brazil began in 2006.

In the São Lourenço River Basin, TNC tested a legal reserve legalisation methodology with two basic goals: reducing the costs of compliance with legal reserve regulations and rehabilitating permanent protection areas (APPs); making vegetation inspection and monitoring more effective in the region. The São Lourenço River Basin was chosen because it plays a major role in the load of sediments carried to the Pantanal and due to anthropogenic uses – especially cattle ranching. Any actions that would reduce this impact should be a priority.

TNC's field team involved local partners, which was crucial and strategic to the success of the project. Its solid technical base, good operational capabilities, leverage with local farmers (which facilitated the registration of rural properties) and a strong ability to mobilise and raise awareness in the production community was a strong point, and allowed for activities that promoted compliance with the requirements for legal reserves and permanent preservation areas, and the use of sound agricultural practices.

- Over 2,000 rural properties mapped and registered;

- Environmental liabilities identified through the use of cutting edge technology and satellite imagery;

- Technical discussion of environmental compliance processes;

- Development of more effective environmental compliance tools that involve lower costs to farmers;

- Cattle ranching best practice program launched in five municipalities across the region with a view to improving production without harming the environment;

- Innovative technologies to rehabilitate riparian forests provided to farmers.

This experience helps TNC make headway in the São Lourenço River Basin, where the Water Producer project – for the implementation of payments for environmental services – will soon be launched in collaboration with its partners. Work in the basin has also produced other results in Mato Grosso, Pará and Bahia. In the municipality of Lucas do Rio Verde (Mato Grosso), TNC mapped all rural properties – totalling 360,000 hectares – and fostered requirements for legal reserves and permanent preservation areas (APPs) as well as good agricultural practices. Thanks to these efforts, Lucas do Rio Verde became the first municipality in the country to have all of its properties registered in the Rural Environmental Registry.

Vulnerability assessment and land use planning in Bolivia

The vulnerability assessment helped identify the most susceptible basins in the Bolivian portion of the Paraguay River Basin. Two of them are key to maintaining water flows of the southern Bolivian Pantanal – Tucavaca and Cáceres –, just like the Correreca and Curichi Grande River Basins, which provide water to the northern Pantanal.

While these basins are officially considered protected areas, at municipal level in the case of Tucavaca, and at federal level in the case of Cáceres, – within the Otuquis protected area, and Integrated Management Natural Area of San Matías in the case of the Correreca and Curichi Grande Basin –, their conservation is at risk, particularly due to lack of a comprehensive development proposal that includes land use plans, but also due to the ever accelerating expansion of the agricultural frontier and charcoal production.

The data provided by the vulnerability assessment make a compelling case for the need to conserve these basins, not only for the biodiversity to which they are home, but also for the environmental services they provide to the local population and regional economic activities, mainly through water concentration and distribution.

In the municipality of San Matías, in the Correreca Curichi Grande Basin, WWF is working on a municipal development plan, where it identified, through the vulnerability assessment, the need to include adaptation and risk management strategies in this planning tool. Therefore, incorporating these items, including in the municipal land use plan, will make it easier for municipalities to implement them autonomously through public investments while respecting rights of possession and use.

Local capacities are strengthened in this process for the development and allowing for subsequent implementation of this planning tool, and helping generate and collect technical and social information so that the strategic lines of development of the municipality have sustainable development as pillars, climate change adaptation and mitigation, and appreciation of the knowledge and customs of indigenous peoples and communities living in the region, such as Chiquitano and Ayoreo.
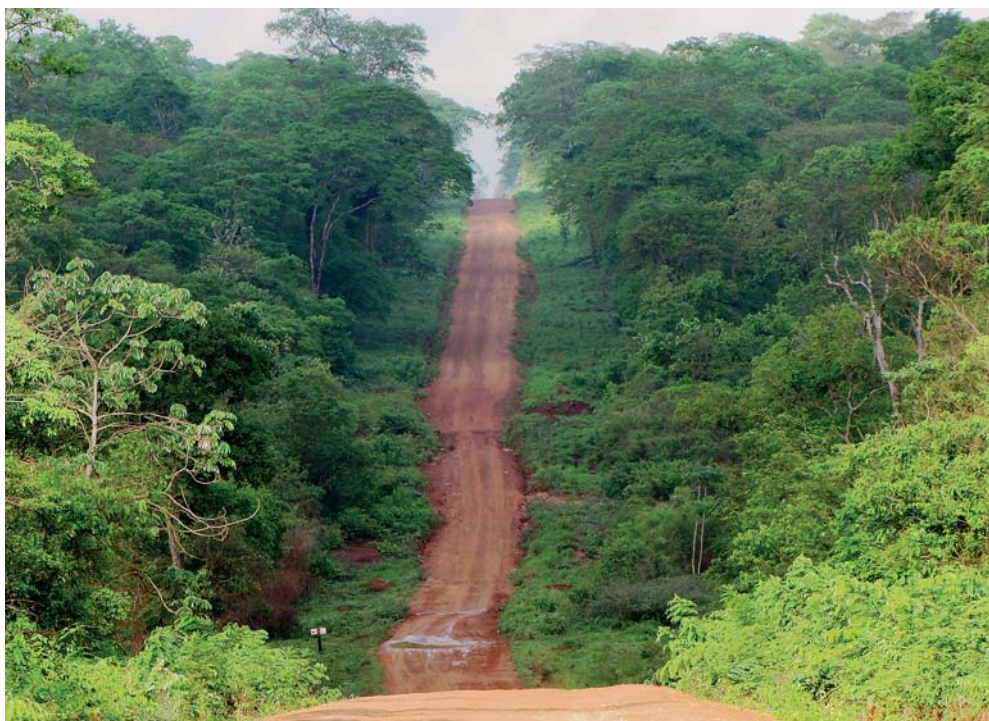
Protecting the Pantanal – The largest wetland on the planet

The Nature Conservancy and the Pantanal Research Centre (CPP) are working on a project to propose actions for the conservation of freshwater ecosystems in the Paraguay River Basin, with a focus on protecting the Pantanal.

The various actions will be outlined using the Ecological Risk Assessment as one of the main inputs. This is a key approach for the effective development of conservation portfolios.

This project has a technical and scientific profile as it involves highly complex studies, and also a profile of broad based social engagement. Along these two lines, it will benefit from the work performed as part of the SINERGIA Project, which is run by the CPP and aims to engage the scientific community and the society on the challenges of water management in the 21st century in the Paraguay River Basin, taking climate change into consideration.

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The work plan is comprised of six main steps:

1. Collecting, storing, organising, and sharing data and information

2. Engaging stakeholders

3. Applying the Ecological Limits of Hydrologic Alteration (ELOHA) approach to the Paraguay River Basin

4. Ecological management of reservoirs

5. Profiling aquatic ecosystems in the Upper Paraguay River Basin

6. Computing and assessing sustainability of the Water Footprint of hydroelectric ventures in the Upper Paraguay River Basin

The results of this study will be made publicly available through reports and publications, and will contribute to the decision making process related to conservation actions as well as sustainable economic development in the Upper Paraguay River Basin area. The studies also provide input for the assessment of ecosystem based actions required for climate change adaptation.

These projects are viewed as no regret adaptation actions[4] because efforts to protect water sources, rehabilitate degraded areas, create ecological corridors, and conduct land use planning ensure the basin itself is resilient, regardless of any risk and climate change vulnerability assessments.

The Dry Chaco is sparsely populated due to water scarcity, a limiting factor for human occupation on a large scale. It is also the region with the largest coverage of protected areas (Figure 23).
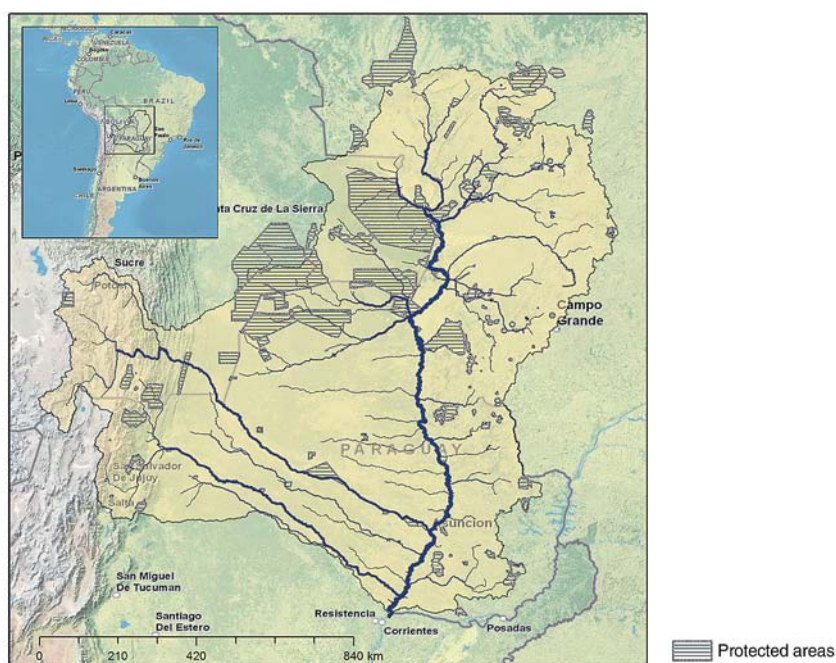

Figure 23. Protected areas in the Paraguay River Basin.

Nevertheless, the areas at greatest risk are those with the least number of protected areas. Not only are they insufficient in quantitative terms, the existing protected areas lack interconnectivity to facilitate gene flow of populations and increase regional genetic diversity and resilience to climate change (Figure 24). According to Combes, S. in Hansen, L. J. Biringer, J. L. & Hoffman, J. R. (2003), ecosystems naturally develop connectivity as a mechanism to adapt to climate change as this also supports migratory routes to provide access to thermal refuges for some species.

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4   No regret adaptation actions refer to those measures that enhance the resilience of a river basin or any ecological, geopolitical or socioeconomic systems, and reduce its vulnerability to the effects of global warming. Adaptation measures are generally identified by systematically assessing vulnerabilities. However, due to technical or financial limitations for the development of a vulnerability assessment in many cases, some measures may be implemented without a systematic assessment of vulnerabilities in view of its well known potential to enhance the resilience of a given system. Protecting water sources and sustaining the connectivity of aquatic ecosystems is an illustration of a no regret action for the adaptation of river basins.
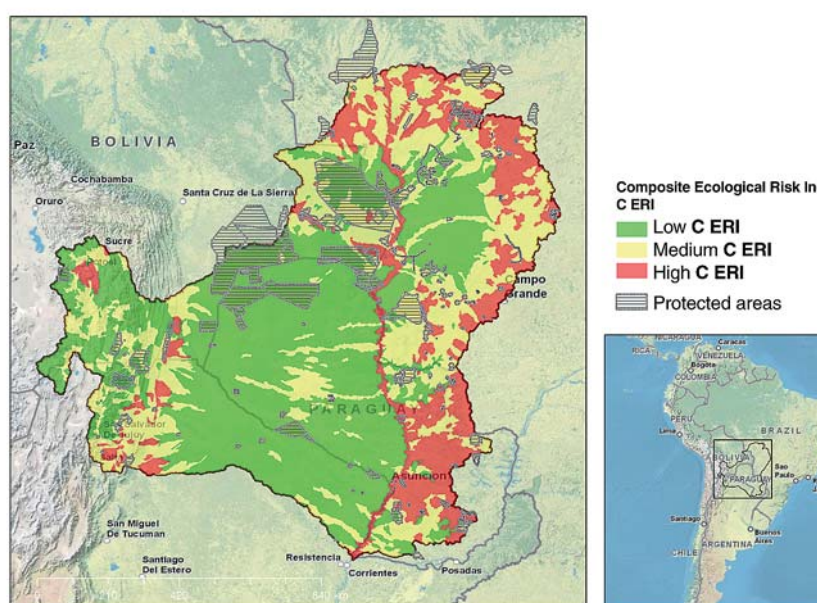
Figure 24. Crossing between protected areas and areas at ecological risk in the Paraguay River Basin.

The establishment of public or private protected areas and implementation of conservation measures on private land are essential to ensure connectivity between existing protected blocks and ensure resilience of ecosystems. As far as aquatic ecosystems are concerned, the design of protected areas should take into account important areas for the maintenance of water cycles, such as areas for the recharge aquifers, springs and sources. Protection polygons alone are not sufficient for the preservation of aquatic ecosystems.

In this case, ecological processes are vital, such as maintaining water quality, natural water regime and connectivity. For connectivity, support should be provided to ecological corridors comprised of riparian forests (longitudinal connectivity) and the connection between the river bed and floodplains and river side lakes (lateral connectivity).

Hydropower plants are also a stress factor that endangers connectivity in the basin. In this study, the stress caused by hydropower plants may have been underestimated in the maps since only local impacts are shown, and not the cascading effect along the rivers. One hundred and fifteen damming projects are expected to be implemented in the Pantanal over the next decade, the majority of which (75%) for small hydroelectric power plants (SHPs) (Calheiros et al. 2009).

To start with, SHPs cause lower environmental impacts than large hydroelectric plants, such as the Manso UHE – in the Manso River, a tributary of the Cuiabá River – as they have less capacity to store water and regulate water flows. On the other hand, the cumulative effect of various SHPs on the water regime of the Pantanal floodplain is yet unknown. A holistic approach is required to look at the impacts and viable alternatives to circumvent them.

A tool that addresses the cumulative cascading impacts of large, medium and small hydropower plants along the water course as a whole is recommended; otherwise this impact will remain underestimated and will focus on local impacts. It is also recommendable to include data on SHPs in the assessment. According to Calheiros et al. (2009), aspects of damming impact prevention in the Pantanal include hydrologic modelling, integrated environmental assessment to jointly determine the impacts along the entire basin, and prescription of environmental flows so as to quantify medium term losses and gains from the change in the seasonal flood pulse in the Pantanal.
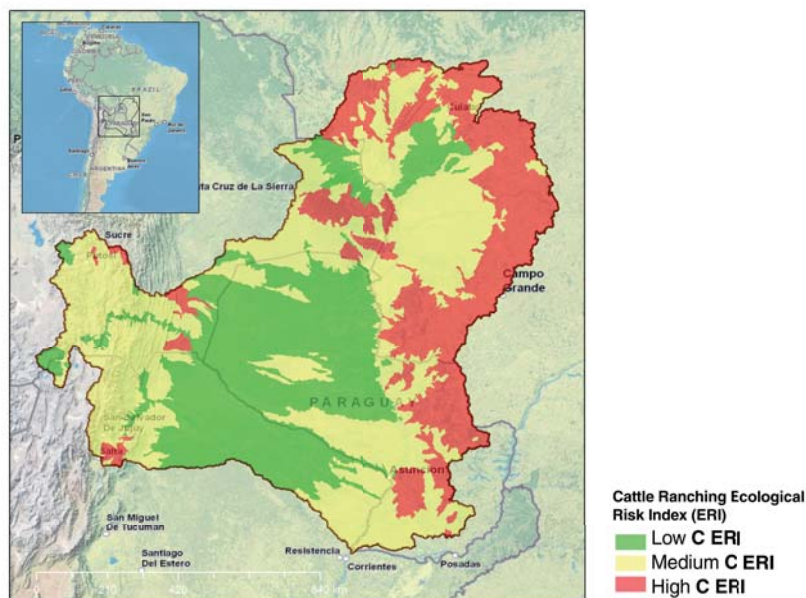
Likewise, the agricultural data

Figure 25. Risk map (T ERI) for cattle ranching in the Paraguay River Basin.

considered only large scale production, but failed to cover small scale local production. It may be that the latter is less technology intensive and has more impacts on the soil and water. Hence the importance of gathering this data set and feeding it into a revision of this study.

Cattle ranching proved to be one of the main stressors in the basin, especially in the highlands, where the Cerrado vegetation is found. The livestock risk map clearly shows this (Figure 25). Extensive cattle ranching in the Cerrado still lacks technical support, rural extension and economic incentives. The technology does exist; however, it is not made available to farmers due to the state of dilapidation of agricultural extension agencies.

Many financing banks are already changing their policies for development and rural credit as they seek to incorporate environmentally sustainable requirements to extend credit to agriculture. This is a recent development, but an important step to mitigate the impacts of cattle ranching.

As far as the Paraguay River Basin is concerned, in view of its extremely fragile hydrological system and economic importance in terms of farming production (Mato Grosso and Mato Grosso do Sul states have the largest bovine herds in Brazil), it requires an effective rural extension policy and better ranching practices, such as water and soil conservation, management and recovery of pastures and crop-livestock integration (BPA / Embrapa / WWF, 2011).

Conclusion

Although the ecological risk assessment method proposed by Mattson & Angermeier (2007) is semi-quantitative, when coupled with a GIS it proved to be an important planning tool, which can be used in a participatory manner and easily replicated in other regions.

As it relies on a digital database that can be easily fine tuned and updated, more important than being used as a risk map, it can be a dynamic portal. Therefore, it can be accessed online, and by identifying problems and conflicts, it provides quality information to managers and decision makers from different fields in a convenient and straightforward manner, thus enhancing the effectiveness of natural resource management.

The ecological risk assessment is the first step in understanding the Pantanal´s vulnerability to climate change. As noted earlier, in order to outline climate change scenarios for a river basin one must first identify and assess existing stressors (i.e., non-climate stressors). The next step is to develop a projection based on the information from the global climate or climate variability models in order to identify which existing stressors will be intense to a greater or lesser extent in the future, and also where and how these stressors will occur. This makes it possible to design and implement effective adaptation actions.

Therefore, an essential step in this sense will be to complement the results from this study with an assessment of climate change scenarios for the basin. These scenarios will be developed in collaboration with the scientific community and key stakeholders, such as governments, the private sector and civil society organisations.

In addition, socioeconomic and political/institutional vulnerability assessments will be conducted, and the ecological vulnerability assessment presented here will be the third pillar in this broader assessment. The socioeconomic assessment will look at the vulnerability of inhabitants in the basin area, from indigenous communities, traditional fishermen and farmers to major industries, such as navigation, tourism, fishing, agriculture, etc. Recommendations will

be drawn for the individual industries and communities, and they will make up the climate change adaptation plan.

The political/institutional vulnerability assessment is now underway, and it is looking at criteria for good water governance and integrated water resources management based on regional management indicators. Just a few examples of political/institutional resilience indicators include aspects such as the existence of river basin forums, boards or committees; presence or absence of natural and water resource management bodies at state and municipal levels; arenas for public participation; progress of official programme and project implementation; and level of technical capacity of state and municipal governments.

The underlying assumption is that a consistent, active and participatory "social fabric", and well prepared, trained and well equipped governments will help attenuate the impacts of climate change in the basin. This political institutional arrangement will also be an integral part of the adaptation plan.

TNC will develop a conservation portfolio for the Paraguay River Basin by identifying priority areas and actions for conservation based on the principles of Systematic Conservation Planning. This "Blueprint" also starts with the mapping of risks and vulnerabilities in the basin so that

biodiversity can be mapped. For each priority area, a detailed assessment of the conservation status and gap analysis will be carried out, and goals and priority actions will be outlined, including establishment of protected areas or rehabilitation of degraded areas.

Therefore, it should be noted that such efforts are distinct but complementary. Hence the importance of building on strategic partnerships like this. In the case of the Pantanal Research Centre, the results of all nine research subprojects under the Synergy Project will be systematized and merged in order to make up an action plan to counter the effects of climate change in the Pantanal. It will certainly be a part of all results of ecological, socioeconomic and political/institutional vulnerability assessment, as well as the Blueprint, with a view to

implementing all these studies, which is the ultimate intention of the partners involved in this publication.

Finally, the results of these studies will be widely published and disseminated to inform public policy making at the local, state, federal, and international levels so that they are mainstreamed in conservation and climate change policies and tools in the region.

WWF, TNC and CPP will collaborate to help decision making bodies work to conserve biodiversity in this important river basin and prepare it for the future uncertainties imposed by climate change. The Pantanal is, and will remain, an important sanctuary for several species and a strategic reserve of fresh water, a resource that will become even scarcer in the future.

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ISBN 978-85-60797-11-0

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