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New challenges in the management of the Brazilian Pantanal and catchment area

Carolina Joana da Silva* and Pierre Girard
[1]*Federal University of Mato Grosso, Av. Fernando Correia da Costa s/n, 78060-900 Cuiabá/MT, Brazil; *Author for correspondence (e-mail: ecopanta@terra.com.br)*

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Abstract

The Pantanal wetland is a vast seasonally inundated area of extraordinary landscape and biological diversity and complexity. It is located in the upper portion of the Paraguay River basin in central South America. During the rainy season, increased stream discharge from the surrounding basin produces an annual flood pulse through the Pantanal. Increasing human impact, such as dam construction, deforestation, agricultural related activities, and the Hidrovia project in the Parana–Paraguay waterway, threaten the ecological stability of the Pantanal area. As a result, there is an urgent need to introduce new management practices in the Pantanal Basin. In this paper we present a concept for managing the Pantanal catchment based on the integration of ecological knowledge, institutional organization, and involvement of different stakeholders. We propose approaches for an integrated management of the Pantanal and its catchment based on improving data bases and the empowerment of the stakeholder groups. The latter depends on increasing the level of education and access to information, as well as implementing procedures to improve public involvement and enforcement of environmental regulations.

Introduction

The Pantanal wetland lies in a broad, shallow depression in the heart of South America. It is positioned in the upper Paraguay River Basin, south of the Amazon Basin, and east of the Andes Mountains. Annually, the upper Paraguay River and its tributaries overflow and seasonally flood more than 150 000 km^2 of land.

In spite of recent broad-based developments in its catchment, the Pantanal still has a high state of naturalness. Its ecological integrity is tightly linked to the health of its catchment area (Da Silva 2000). The indigenous people were already living and using the local natural resources before the first Europeans in this region (Oliveira 1999). More than 200 years ago, the Europeans introduced cattle ranching in the Pantanal. The ranchers and traditional communities used the Pantanal by clearing savannas and forests, fishing, using the rivers as transportation corridors, mining gold, and growing crops.

However, modern use of the Pantanal environs produced broad new environmental disturbances that threaten its ecological fabric. These threats include pollution by mercury, increased deforestation, and high sediment loads carried and deposited by rivers. A new menace, the disruption of the fundamental seasonal flood by engineering works, is also a threat to the naturalness of the Pantanal (Gottgens et al. 2001). This threat centers on the change of the annual river/wetland flood cycle through the construction of waterway-navigation improvements and large dams. Until recently, human related activities in the Pantanal did not threaten the fundamental physical and ecological functions of this floodplain. In view of these new threats, we must ask new questions, be ready to assume new challenges, and find ways to maintain the ecological integrity of the Pantanal wetland and its catchment.

In this paper, we describe the ecological status and most common traditional uses of the Pantanal, focusing on why the Pantanal and its water resources are critical to its stakeholders. Finally, we outline a mechanism for decision-making and management of conflicts among stakeholders that are aimed at reducing pressures from economic development and degradation of the Pantanal ecosystem.

The Pantanal

There is an emerging body of literature describing the physical and biological attributes of the Pantanal from which the following description was assembled (Adámoli 1981; Radambrasil 1982; Alvarenga et al. 1984; Hamilton et al. 1996; Da Silva 2000; PCBAP 1997; Junk et al. in press).

The Pantanal is located in the upper reach of the Paraguay River, one of the main tributaries of the Paraná River (Figure 1). The upper Paraguay drains an area of ~500,000 km^2, of which two-thirds lie in the Brazilian states of Mato Grosso and Mato Grosso do Sul. Based on elevation, the Pantanal basin can be subdivided into three physiographic units. First, the "Planalto" or "Palteau" (250–750 m above the sea level) is the head water region. It is a flat undulating plain. Its vegetative cover is characterized by open savanna, locally called "cerrado". Its predominant land use is agriculture, mostly in row crops and cattle ranching. Second is the "Depression", which occurs at altitudes between 180 and 250 m. This is a small region with generally steep slopes covered by a dense forest locally termed "cerradão". The last unit is the Pantanal, which ranges from 150 to 180 m. It is a low relief plain, about half the size of the plateau, with a hydraulic gradient not exceeding 15 cm per kilometer. A complex hydrographic network of rivers, including the Cuiabá, São Lourenço, Piquiri, Taquari, and Negro, dissect this vast plain. The rivers, in conjunction with a variety of soils types, give rise to a heterogeneous geomorphologic landscape. The large subunits have

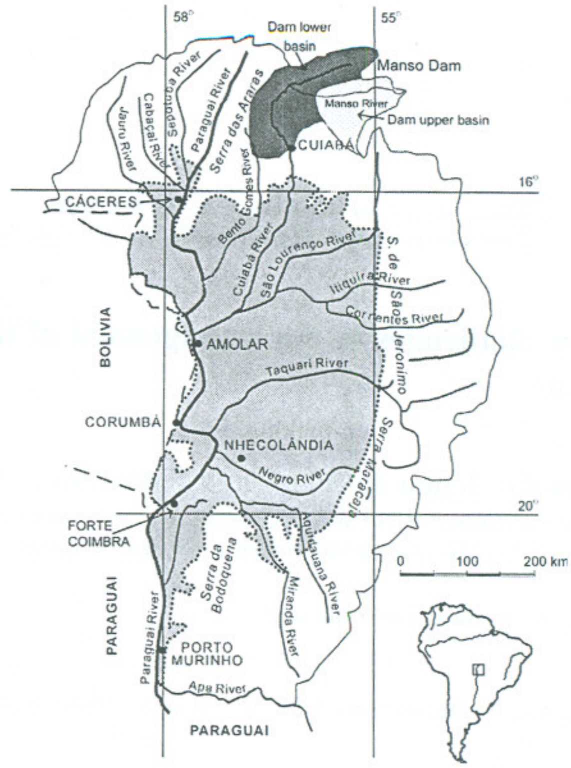

Figure 1. The upper Paraguay Basin and the Pantanal (large shaded area). Lower right corner: The Upper Paraguay River (square) and the Prata River in South America. Also shown are the impact areas of the Manso dam as specified by FURNAS. See text.

different hydrological conditions and occupy different positions on an elevation gradient. As a result different plant communities characterize each geomorphic subunit.

The climate of the pantanal is hot, with a pronounced dry season from May to September and a rainy season from October to April. Mean monthly temperature near the northern limit of the Pantanal at Cuiabá city, the capital of the state of Mato Grosso, ranges between 27.4 °C in December and 21.4 °C in July. Occasionally, ingressions of polar air masses in winter may cause the temperature to drop to 0 °C.

Annual rainfall decreases from 1250 mm in the northern Pantanal near Cáceres to 1089 mm in the south near Corumbá. Mean monthly air humidity varies in the northern Pantanal between 84% during the rainy season and falls below 60% in June and July during the end of the dry season when the floodplain is dry (Tarifa 1986). Evaporation exceeds precipitation during the dry season and, at times, during some months in the wet season. Evaporation and transpiration rates combined may be as high as 1100–1400 mm per year (Ponce 1995). Consequently, a large amount of the water transported from the Paraguay River and its tributaries into the Pantanal returns to the atmosphere. Such high evaporation reduces heat and aridity in the area.

System dynamics and ecological value

The flood pulse: uses by local communities

The most striking feature of the Pantanal is the annual flood regime. The Pantanal is essentially a huge, gently-sloping basin that receives runoff from an upland watershed. This upland plateau is twice the size of the floodplain and slowly releases the flood pulse through a single, downstream channel, the Paraguay River (Ponce 1995). In the dry season, the Pantanal appears to be a flat savanna, interrupted by gallery forests, marshes, and shrub swamps. In the wet season it appears as a shallow lake. The annual flooding is caused by the lack of a sharp gradient between the rivers and the floodplain. When river discharge increases in the rainy season, the rivers in the floodplain are unable to convey the increased volume of water and overflow onto the floodplain, flooding extensive portions of the Pantanal basin (Carvalho 1986). Rock outcrops along the Paraguay River further reduce the ability of the Paraguay River and its tributaries to drain flood waters. The annual flood pulse is monomodal, but with temporal and spatial variations (Penha et al. 1999). Along the main river channels the annual flood pulse is sharp and well defined. Farther from major river channels, the flood pulse may be subtle. In these settings, precipitation and localized overbank flow by small channels can cause flooding.

The human residents of the Pantanal, known as "Pantaneiros", have a distinctive life style that is largely dictated by constraints of the landscape. On the margins of the Cuiabá River, e.g., houses are typically built on natural river levees that are generally not submerged during annual floods. The residents use the levees to grow fruit trees, such as banana, while low lying areas are used for seasonal crops during the dry season, such as corn. During the flood period, when the water rises 3–4 m and only the levees remain dry, fishing is the most common activity. During the dry season, native grass savannas are used by the Pantaneiros as pastureland for cattle. During the flood season, the animals usually congregate on local elevated areas known as "capão" and "cordilheiras". This type of traditional ranching does not interrupt ecological processes and maintains the natural landscape of the Pantanal.

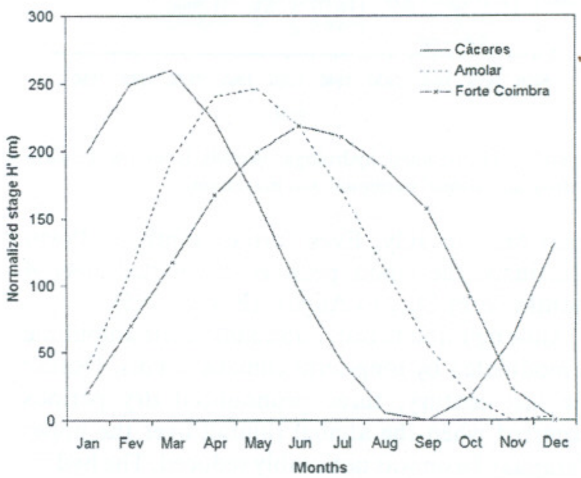

Figure 2. Flood pulse progression along the Paraguay River. Pulse at Cáceres, Amolar and Forte Coimbra. See Figure 1 for location. The normalized stage (H') at each location is given by $H' = H - H_{min}$, where H is the stage and H_{min} is the minimum stage. Data from ANEEL (www.aneel.gov.br).

The flood pulse: ecological cycles, sequence and inter-annual variations

There are two key reasons why the flood pulse slowly moves southward, producing a lag of 2–4 months between the flood peaks in the north and south (Figure 2). First, most of the water enters the Pantanal from the north. Three major rivers, the Paraguay, Cuiabá, and São Lourenço, supply the majority of flow. Second, the hydraulic inclination along the Paraguay is only about 3–5 cm per kilometer; rock nickpoints in the southern reach of the Paraguay River further reduce drainage. Near Cáceres in the northern Pantanal, the flood peak usually occurs in February and March, concomitantly with the rainfall peak. In Ladário, farther south along the Paraguay River, the flood occurs

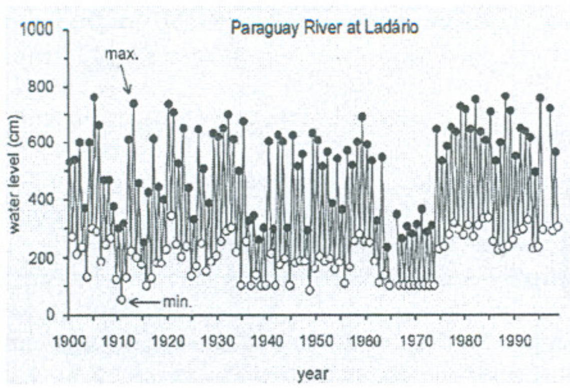

Figure 3. Pluri-annual hydrologic periods from the Ladário hydrogram (annual minimum and maximum).

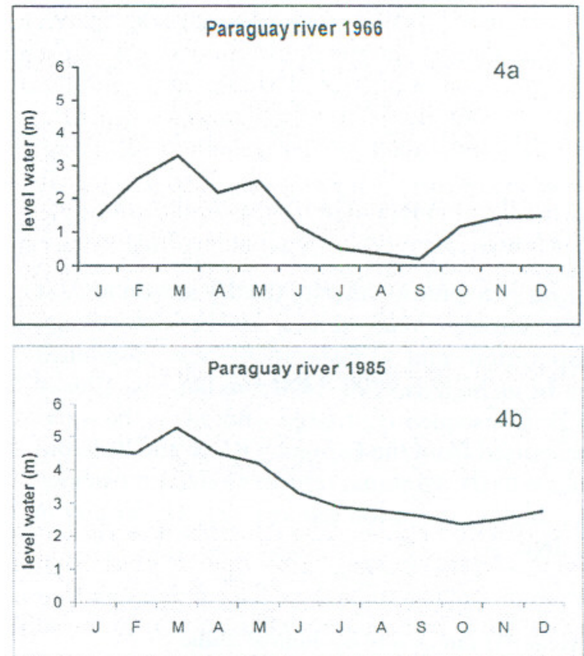

Figure 4. Stage evolution of the Paraguay River during long inter-annual dry and wet phases: (a) dry phase, (b) wet phase.

from May to July. Even farther south, in Porto Murtinho, the flood peak is distributed over 4 months from May to August (Ponce 1995).

Although floods occur annually, their amplitude is modulated by long-term climatic events. During the last century, three pronounced dry periods occurred when the annual rainfall over the upper Paraguay basin was noticeably reduced. The hydrograph of the Paraguay River at Ladário recorded these events (Figure 3), with the first occurring in the 1920s, the second in the 1930s, and the third in the 1960s. The first two lasted less than 5 years, while the one in the 1960s lasted about 12 years, ending in 1973. The reduction in flood amplitude corresponded with a reduction in flooded area. During these inter-annual dry phases, the level of the Paraguay River was considerably lower than during the inter-annual wet phases (Figure 4a). Furthermore, the low waters stage during the long-term inter-annual wet years was sometimes higher than the high waters stage (Figure 4b) during the inter-annual dry years (Da Silva 1990).

The most striking feature of the last dry phase was the diminution of the lake sizes in the northern Pantanal. The decrease in flooded area stimulated a range expansion of several terrestrial plant species. Human activities, particularly those related to ranching, also expanded. Domestic water wells inside the Pantanal also dried up, forcing many families to relocate toward the outer edges of the Pantanal (Cunha and Junk 1999; Da Silva 1990; Veloso 1972).

Several notable changes occurred following the return of the long-term wet cycle after the last extended dry period. Lakes expanded and the ranges of several species either expanded or contracted, depending on their habitat requirements. Human activities have also changed. Some areas that were used for agricultural crops and farming were abandoned in response to expanded flooding. In other cases, ranchers and farmers tried to control flooding through the construction of dikes and other structures.

Predictable biogeochemical changes occur in aquatic and wetland habitats during the dry season or terrestrial phase (Strussman 1991; Da Silva and Esteves 1993; Espindola et al. 1996; Rezende et al. 1996; Penha et al. 1998, 1999). The concentrations of total nitrogen, phosphorus, and chlorophyll-a increase as inundated areas decrease in area and volume. The density of aquatic animals, such as fishes, aquatic birds, and alligators, also increases, while the productivity of aquatic macrophytes decreases. On dry habitats, the biomass and diversity of plants increase. Conversely, during the flood pulse, there is a dilution of total nitrogen, phosphorus, and chlorophyll-a. The lateral and vertical movements of fishes, alligators, and aquatic birds increase, as does the biomass production and diversity of aquatic macrophytes. The biomass and diversity of terrestrial weedy plant species decrease.

Ecological status of the Pantanal

The current ecological status of the Pantanal can be viewed in two perspectives. First, even with nearly 250 years of agricultural use, the Pantanal still has a high degree of "naturalness". The low intensive agricultural activities, large size, remoteness, and difficult access have kept much of the ecological integrity of the Pantanal intact. Second, recent intensive economic developments in the Pantanal's catchment, mostly in intensive agricultural expansion, have caused concern. According to a conservation assessment of the World Wildlife Fund and the Biodiversity Support Program (1995), the Pantanal is "globally outstanding" (rank 1 of 4) in terms of biological distinctiveness, is "vulnerable" (rank 3 of 5) in terms of conservation, and has "highest priority" (rank 1 from 4) for conservation action. Some areas of the Pantanal have also been designated as a National Heritage site (by IBAMA, the Brazilian federal environmental agency) and some 24 million hectares of the Pantanal has been designated by UNESCO (2000) as a Biosphere Reserve, making it the third largest such area in the world.

Why new challenges?

Unprecedented economical development

At about 1974, government-sponsored economic development reached the Pantanal. The Brazilian government initiated several major development projects, such as the Program for the Development of the Pantanal (PRODEPAN), the Program for the Development of the Cerrados (POLOCENTRO), and the National Alcohol Program (PROÁLCOOL). The aim of these projects was to increase the contribution of the Pantanal and its catchment area to the national economy. Infrastructure was improved through the construction of roads and electric transmission lines. Large agro-industrial projects stimulated cattle ranching and plantations of soybean and sugarcane. In the 1980s and 1990s, additional development occurred in the northern edge of the Pantanal near Poconé in association with extensive gold mining activities.

In response to this economic development, human population increased markedly in the states of Mato Grosso and Mato Grosso do Sul. In 1970, prior to creating Mato Grosso do Sul from the south region of Mato Grosso, the population of these states combined was 1,597,090. In 1996 it was 4,163,666, of which 2,235,832 persons lived in the State of Mato Grosso and 1,927,834 in the State of Mato Grosso do Sul. A major portion of this increase occurred as immigrants from other regions of Brazil relocated to the Pantanal catchment. Accompanying this increase was a shift in population, as a larger percentage of people were now living in urban areas.

New stakeholders and scales

Traditional stakeholders in the Pantanal catchment were ranchers, state and federal governmental agencies, and Indian nations. With the rapid economical development, new stakeholders arrived. They were linked to the new economy of modern agriculture, transport industry, federal government agencies for hydroelectric energy production, and mining. Other new stakeholders included nonprofit local and international environmental organizations.

Prior to the 1970s, the traditional stakeholders had relatively little impact on the resources they used. The traditional communities took advantage of natural cycles and introduced minimal environmental change. For example, ranchers in the Pantanal owned relatively small herds and had managed the landscape without major environmental consequence (Da Silva and Silva 1995; Junk and Da Silva 1995, 1999). They owned about 90% of the Pantanal, but did not have the means to cause extensive environmental changes, such as altering the flood pulse by building dams or changing water quality by causing increased sediment loads in rivers.

Activities by the new stakeholders impacted the watershed on a large scale. The implementation of industrialized soybean, corn, sugar cane, and cotton monoculture transformed millions of square kilometers of savanna land in open fields. Riparian forests along rivers were cut or degraded (Wantzen 1998). This led to increased erosion and sedimentation, disrupting the local hydrologic pattern. The Taquari and São Lourenço rivers, both heavily impacted by sediment loads, are prime examples of this impact.

With the increase in industrialization, there was a need for improved transportation networks to transport commodities to large metropolitan areas to sea ports. Construction of several large transportation projects was initiated, including three waterway projects (the Araguaia-Tocantins, Madeira-Amazonas, and Paraguay-Paraná Hidrovia) and the Ferronorte railway. The Hidrovia, a large-scale fluvial transport project involving Brazil, Paraguay, Bolivia, Uruguay, and Argentina, is of particular concern. The goal of this project is to improve river transportation to accommodate more barge traffic and oceanic type vessels through dredging, channel modification, and port installation. This project could potentially modify various key ecological processes in the Pantanal, including the extent of the flood pulse. The full implementation of this project, especially in the upper portion of the Paraguay, between Cáceres and Corumbá, could likely alter the hydrology of the Pantanal (Ponce 1995; Lourival et al. 1999; Gottgens et al. 2001).

The development of the agro-industry and other types of industrial development was linked to the availability of cheap and secure electrical energy. State and federal governments promoted the production of electricity. A large hydro-electrical facility was recently constructed on the Manso River, a principal tributary of the Cuiabá River. The Manso accounts for nearly 60% of the Cuiabá's discharge. The project was also built to regulate seasonal flooding. A lower and shorter flood peak in the Cuiabá River could have profound ecological impacts in the northern Pantanal.

Cumulative environmental impacts and social conflicts

Activities of some stakeholders in the Pantanal catchment affect others through the hydrogeographic network of the region. The sediments produced by the developing agro-business on the plateau above the Pantanal are transported into the Pantanal by the river network. Dams and navigation improvements for the rivers in the Pantanal catchment have altered or will alter the flood pulse, river flow regimes, and sediment transport. The river-based transportation industry uses the watercourses to transport the agri-goods to domestic and foreign markets. The impacts, therefore, are all interrelated and are likely to induce stress on the Pantanal ecosystem and on traditional stakeholders, such as Indian communities that depend on the water resources and on the flood pulse to sustain their life style.

The Hidrovia, a large-scale project involving five countries, is an impending project that could result in major changes in the hydrology of the Pantanal (Gottgens et al. 2001). The Brazilian government, facing a negative response from the many stakeholders in the Pantanal and international environmental community, elected not to evaluate the cumulative project impacts. The environmental impact statement for the Hidrovia evaluated individual project components separately. As an example, the new Morrinho Port on the Paraguay River was treated in a local impact study. Fortunately, in this case, the Federal Public Ministry determined that the Paraguay River is a federal and not a State River, overriding state authority.

Examples of development that will have cumulative impact on the Pantanal hydrology are the Manso dam and the Hidrovia project noted above. The Federal agency operating this dam proposed an impact zone restricted to the portion of the basin upstream of the city of Cuiabá (Figure 1). As previously noted, operation of the dam will reduce the flood peak in the Pantanal. The Hidrovia, if fully constructed, would also reduce the area flooded in the Pantanal (Hamilton et al. 1996). Current navigation traffic on the Paraguay River has already damaged levees and riparian vegetation (Wantzen et al. 1999). Such losses have negative effects on fishermen communities.

A new management challenge for stakeholders in the Pantanal is to analyze the cumulative impacts of their activities. The environmental, economic, and social impacts can no longer be assessed as isolated, stand-alone factors. Integrated planning is required to evaluate and project impacts and solutions for the "big picture." Unfortunately, this view does not appear to be the current direction being taken by federal and state governmental agencies. For example, the federal agency responsible for the conservation of the Pantanal also financed the construction of the Manso dam. The dam was built with the intent of favoring future industrial development, ignoring the impacts it would have on downstream traditional communities and the overall impact of altered hydrologic regimes in the Pantanal.

A proposal for decision making

The following definition is cited as a guideline for the subsequent discussion. The aim of management is to promote sustainable development and minimize social conflicts between stakeholders. The proposal presented here for decision-making in the Pantanal is based on integrating three pillars: ecological networks, stakeholders' perception of land and water use, and participatory management.

Much of the existing ecological data for the Pantanal focuses on description, with little on the ecological structure and functions of the Pantanal (Da Silva 2000). Furthermore, these data have been documented by specialists for specific projects or research interests and do not address broad-based interests. An example of this is the Conservation Plan for the Upper Paraguay River Basin, the so-called PCBAP (Planos de Conservação da Bacia do Alto Paraguai 1997). This document presented extensive and useful information about the Pantanal. However, it was written for technical specialists. In order to be useful for comprehensive planning and management projects, the scientific data should have been reduced and more stakeholder input encouraged.

We propose ecological networks, linking universities, governmental agencies, nongovernment organizations, and traditional communities to facilitate the integration of ecological information into a decision-making process. The most serious challenge in networking is to involve a majority of stakeholders, including the vast silent majority. For the Pantanal catchment, this is a question of education to form public opinion intended to influence decisions at local, regional, and national levels. This is, of course, a long-term effort and such integrated networking can only be accomplished by promoting the acquisition of diverse points of views from a broad base of stakeholders.

Stakeholders present information on how they perceive their own and other stakeholders' land–water uses. Currently, there is minimal knowledge of how the various stakeholders perceive management actions by governmental authorities and the activities and impacts of other stakeholders. The exchange of this and other relevant information is essential for the prevention and ultimate resolution of conflicts among stakeholders. It may also influence the perception of land and water uses of some stakeholders. This is the first step in establishing a foundation for articulating the basis for land and water resource use by each stakeholder.

Finally, it is essential for stakeholders to have a forum to discuss management issues. Managers and government officials should invite a broad diversity of stakeholders representing different points of view to participate in a decision-making process. Through initiatives by nongovernmental organizations, there already are some efforts to gain different points of view through various representative forums. For example, the Forum for Environment and Development of Mato Grosso and Mato Grosso do Sul and the Upper Paraguay Basin Integrated Committee is composed of representatives of societal organizations, states, and Federal environmental and planning agencies, and of members of the business community. The Rio Vivo coalition (nongovernmental organizations from MERCOSUL countries, North America, and Europe) is another forum that has assumed an important role in the discussions concerning the Hidrovia. There is, however, a need for these organizations to work more closely together to maximize efficiency and effectiveness of the decision-making process. The yet-to-be-formed Basin Committees, established by a Brazilian law on hydraulic resources, could achieve this feat, reduce unnecessary actions and engineering works, and minimize conflicts between stakeholders after decisions are made.

Another opportunity for achieving more inclusive decision-making is given by the Interamerican Development Bank–Pantanal Program, a U.S. \$400-million project in the states of Mato Grosso and Mato Grosso do Sul (www.mma.gov.br). The various components of this project are to be supervised at the state level by a state committee and various local committees. Recently, the composition of the state committee was publicly discussed, resulting in a proposal to involve various stakeholders, namely state and municipal governments, universities, nonprofit organizations, agro-business, tourist industry, and fishermen. Such a forum can serve as a model to link and involve the stakeholders in decision-making, prevent conflicts, and promote a more efficient way of achieving sustainable development in the Pantanal.

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