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Lagoa Mirim: liquid border and international political ecology

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Abstract
This article addresses Lagoa Mirim and the binational management shared by Brazil and Uruguay. It describes the environmental and ecosystem significance of Lagoa Mirim, the impacts on the biome, and the need for international cooperation for environmental protection. It highlights Brazil-Uruguay relations, the lagoon's character as a liquid border, and the challenges and bilateral international policies concerning environmental and climate security.

Keywords: Lagoa Mirim; International environmental cooperation; Brazil and Uruguay; Freshwater.

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1. Introduction

1.1. The Lagoa Mirim Basin

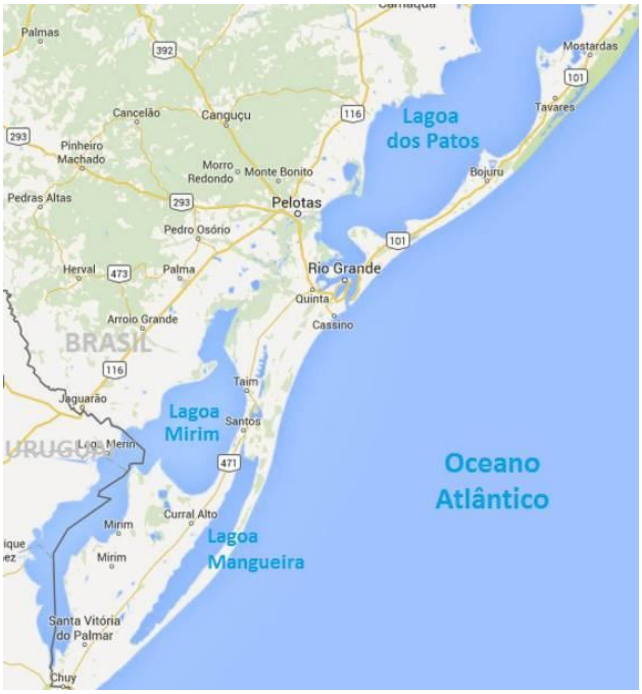
Lagoa Mirim, which extends across Brazilian and Uruguayan territories, drains through the São Gonçalo Channel into Lagoa dos Patos. Covering approximately 62,250 km², 53% of its basin lies in Uruguay, encompassing the departments of Rocha and Cerro Largo. The remaining 47% is located in Brazil, covering the municipalities of Jaguarão, Arroio Grande, Rio Grande, and Santa Vitória do Palmar. The Lagoon-Barrier System II, a depositional system associated with a second Pleistocene transgressive-regressive event dating to approximately 325,000 years ago, during the Quaternary period, was the environmental event that isolated Lagoa Mirim and Lagoa dos Patos and corresponds to the first stage in the evolution of the Complex Multiple Barrier System (ANTUNES; SCHÄFER, 2009).

Lagoa Mirim is classified as a permanent lake because rainfall and inflows contribute more significantly to its water level than evaporation. It covers an area of 3,750 km² and is approximately 185 km long and 20 km wide (Lagoa Mirim Basin Development Agency - ALM). Its area consists of alluvial deposits, sands, and silty-clayey sediments from floodplains, terraces, and channel deposits of the fluvial network. In the dune areas near the lagoons, soils are dry and sandy in texture. Flooded areas are inhabited by species adapted to high water concentrations (hygrophytes), such as geophytes and hemicryptophytes (SCUR et al., 2009).

According to the most recent population estimates from the Brazilian Institute of Geography and Statistics (IBGE, 2024), the population living in the municipalities associated with the basin on the Brazilian side exceeds one million inhabitants, concentrated mainly along the Pelotas-Rio Grande urban axis. On the Uruguayan side, the 2023 Census published by Uruguay's National Institute of Statistics (INE) showed that the Lagoa Mirim region primarily involves the departments of Cerro Largo, Rocha, Treinta y Tres, and part of Lavalleja. Together, these departments account for approximately 278,000 inhabitants directly or indirectly connected to the river basin.

In addition to its demographic relevance, the basin has considerable socioeconomic importance. A significant share of the regional population depends directly or indirectly on Lagoa Mirim's water resources for activities such as artisanal fishing, agricultural irrigation, human supply, and livestock farming. The lagoon is one of the region's principal freshwater reserves, sustaining local economies historically linked to natural-resource use and to the cross-border dynamics between Brazil and Uruguay.

Figure 1
Map of the lagoon regions



Source: 1000 dias (2014).

This study is characterized as qualitative research. Data were collected through an extensive bibliographic survey of Brazilian and Uruguayan sources, in addition to an interview conducted with authorities from the Taim Ecological Station.

1.1.1. Biodiversity and environmental importance of Lagoa Mirim

The lagoon's territory is characterized by an accumulation of substrates unsuitable for plant development and, even so, supports a wide variety of fauna and flora (PEREIRA, 2022). According to Schäfer (2009), local biodiversity is first classified by flora, comprising arboreal forests divided into dry restinga forests and swamp forests; shrub or flood-prone communities formed by maricazais; herbaceous communities divided into grassland communities (wetlands, dry fields, and dunes) and hydrophilic communities; as well as palm groves and butia groves. Fauna is classified as higher fauna, including fish such as trahira and silverside; amphibians such as toads and tree frogs; reptiles such as turtles, lizards, snakes, and caimans; birds such as the maguari stork and white-faced whistling duck; and mammals such as capybaras and coypu. Lower fauna includes aquatic snails, bivalves, leeches, and a wide variety of arthropods.

Two endangered annual fish species are found in small wetlands within the urban perimeter of the floodplains of the Chuí Stream, Lagoa Mirim, and Lagoa Mangueira. These fish, belonging to the family Rivulidae, have a short life cycle and inhabit temporary pools that emerge after heavy rainfall, often forming from the lagoon (JUNIOR; ROSSATO, 2009). The environment is divided into two major zones: the littoral

zone and the pelagic or central zone, which includes a region with greater solar incidence and a profundal zone with little light and organic-matter decomposition. Between these zones lies another area known as the compensation zone, where phenomena common to both neighboring zones occur (SCHÄFER, 2009).

Lagoa Mirim can therefore be understood as a setting of remarkable biodiversity, harboring an immense number of plant and animal species and serving as a refuge for several endangered species. Intraspecific and interspecific ecological relationships occur there, shaping the relationships between organisms and the environment. In addition to being a liquid border that integrates the political and social relations of two countries, Lagoa Mirim is home to countless living beings and may be viewed as a place of resistance that, in an increasingly gray and anthropocentric world, safeguards diverse forms of life.

According to Saito and Steinke (2008), land use in the basin consists of grasslands, in some cases associated with isolated forests and beef-cattle farming, as well as intensive use for mechanized agriculture. Flat and flood-prone areas, known as "lowlands," are extensively used for irrigated rice cultivation. Highlands above 60 meters are widely used for raising highly competitive beef cattle for the international market. On the Brazilian side, agricultural occupation through soybean planting has increased, aiming to diversify the regional economy.

The environmental importance of the Lagoa Mirim Basin is therefore broad. As a wetland, and thus part of some of the most productive ecosystems on the planet, the lagoon benefits the population's social and economic life, particularly by supplying freshwater. Its resources also provide several benefits, including water, fish, timber, medicinal plants, and wildlife. As a wetland, its functions include regulating floods and droughts, retaining sediments and nutrients, removing toxic substances, stabilizing microclimates, regulating carbon, and recharging aquifers; its attributes include socio-environmental importance and genetic resources (SAITO; STEINKE, 2008). Rational and respectful use of the Lagoa Mirim environment can therefore benefit human life without disrupting wildlife.

1.1.2. Environmental risks faced by Lagoa Mirim

After presenting the environmental importance of Lagoa Mirim, it is necessary to discuss the risks faced by this major basin. The Lagoa Mirim Basin comprises 32 sub-basins. In a study of pollutant loads in the basin's wetlands, Saito and Steinke (2008) identified 12 sub-basins classified as having "high" to "extremely high" pollutant loads, accounting for more than 40% of the basin's territory; eight sub-basins had a "moderate" load, and the remaining sub-basins had "low" or "very low" loads.

Thus, despite the human and environmental importance of the basin's waters, their quality is not uniformly high. Several factors contribute to this situation, including water contamination by pollutants

generated in local rice plantations. In addition to being sources of pollutants, these crops, which are characteristic of the region, are the principal source of water demand because fields are supplied by hydraulic pumping systems that move water from the region's lagoons into an extensive network of distribution channels. Consequently, hydraulic use of the lagoon and wetlands through consumption, drainage, and altered flow velocity drastically changes evaporation, infiltration, water availability, and water quality (COSTA; SATO, 2021 apud BULÉ et al., 2021).

The area occupied by forestry is also steadily expanding. However, this form of production hinders the growth of typical native vegetation, alters rainwater flow and wind circulation, directly affects seed dispersal, and limits the expansion of several plant species (COSTA; SATO, 2021). Replacing native forest with artificially introduced plants for commercial purposes inevitably produces negative environmental impacts, and many of these species also have a high invasive capacity.

Soils in several parts of the area contain substantial organic matter, which is often exposed to intense oxidation as a result of agricultural activity, rapidly rendering the soil sterile. Livestock farming is the principal human activity developed in the area, leading to cattle use in many locations, including Permanent Preservation Areas (APPs). Because cattle have unrestricted access to the lagoons for water and pasture, trampling commonly causes material erosion (COSTA; SATO, 2021).

BR-471, the highway section connecting Rio Grande and Chuí, is also the subject of considerable debate because it runs along the edge of the Taim Ecological Station (ESEC), a fully protected conservation unit that supports rich flora and numerous animals. When these animals attempt to cross the highway or graze nearby, they are frequently struck and killed. Roadkill rates are particularly high during rainy periods, when the lagoon's water level rises and forces animals closer to the highway. Waste disposal is another major problem in the region, as is the risk of fire (IENSSE; SIMIONI; WOLLMANN, 2016).

Fire risk in the Lagoa Mirim Basin and its surroundings is considered a serious regional environmental threat. According to Alba et al. (2020), temperature must be considered and monitored because hotter conditions make vegetation drier and more susceptible to fire. Meteorological variations and rainfall patterns have major effects. In addition to natural factors, areas with greater human movement, such as roadsides, present a higher fire risk. Flooded areas and areas with vegetation cover present lower risk. Grasslands and locations near roads are more prone to fire. When combustible materials are not restricted and controlled, conditions become favorable for fire to spread from either natural or human sources.

Human activity and the population living in contact with the lagoon interfere with annual fire cycles. Thus, where human contact with the lagoon is greater, fire risk also increases. The regional climate must also

be considered because the rainfall and harsh winter that affect the lagoon area are followed by a dry and very hot summer, increasing the number of fire outbreaks (BRAZ et al., 2015).

Lagoa Mirim, despite its size and importance to fauna, flora, and people, is therefore exposed to numerous environmental risks. Problems caused by natural factors must be studied so that measures can be developed to understand how they occur, protect the lagoon, and prepare professionals and relevant agencies to reduce damage when they recur. Environmental risks of anthropogenic origin must be firmly addressed, because uncontrolled and unsupervised human action is destructive to the environment. As long as, for example, pesticides from rice production contaminate the lagoon, cascading contamination will continue, causing animal deaths, soil poisoning, and even human poisoning through the consumption of contaminated animals and water.

1.2. The Lagoa Mirim Basin Development Agency

1.2.1. Creation and activities

The Lagoa Mirim Basin Development Agency (ALM) was established by Decree No. 1,148 of 26 May 1994. Before this milestone, the Superintendency for the Development of the Southern Region (SUDESUL) was responsible for administering the engineering structures and the technical-scientific and patrimonial collection of the Lagoa Mirim Department. These responsibilities were transferred to the Federal University of Pelotas (UFPel). Together with Uruguay, ALM manages the natural and water resources of the Mirim-São Gonçalo River Basin (BHMSG), because the basin is shared by both countries.

Its activities are also a landmark of the Brazilian-Uruguayan Joint Commission for the Development of the Lagoa Mirim Basin (CLM, created in 1963) and of the 1977 Lagoa Mirim Cooperation Treaty. Under Decree No. 4,258 of 2002, ALM serves as the Executive Headquarters of the Brazilian Section of the CLM, confirming its role as an administrative, technical, and financial support institution, hosting CLM meetings and complementing the work of the Ministry of Regional Development. ALM therefore coordinates with the ministries associated with the CLM - the Ministry of Foreign Affairs, the Ministry of the Environment, and the Ministry of Regional Development - and works toward the development of the BHMSG, while supporting the Brazilian Section of the CLM and carrying out the required maintenance and support activities for its structures.

1.2.2. Structures

- **São Gonçalo Channel Dam and lock**

Inaugurated in 1977, the São Gonçalo Channel Dam and Lock complex resulted from activities developed since the creation of the CLM. The Brazilian and Uruguayan governments secured support from

the United Nations Development Programme (UNDP) and the Food and Agriculture Organization of the United Nations (FAO) for the CLM/FAO/UNDP Lagoa Mirim Basin Development Project (VIANNA, 2012). The dam and lock are hydraulic structures in the São Gonçalo Channel that prevent saltwater from the Atlantic Ocean from entering Lagoa Mirim. This makes it possible to control the quality of freshwater used for irrigation, livestock, and human consumption, while the lock allows navigation through the channel.

The dam, built across the channel, is 245 meters long and extends 217 meters. The lock is 17 meters wide, 120 meters long, and 5 meters deep. The water level in the chamber is controlled by gates installed at both ends of the lock, allowing vessels to pass. In this way, the dam prevents saline intrusion from Lagoa dos Patos into Lagoa Mirim through the São Gonçalo Channel, safeguarding freshwater quality for several uses, including human consumption and agriculture, while also providing a stable environment for the development of regional species (ALM UFPel Collection, 2022).

- **Arroio Chasqueiro Dam Irrigation District - DIBAC**

Considered a pilot irrigation project, DIBAC resulted from studies conducted under the CLM/FAO/UNDP Lagoa Mirim Basin Development Project, completed in December 1976. With an irrigable area of approximately 10,000 hectares, it made it possible to cultivate rice, soybean, and other crops uncommon in the region, helping to overcome challenges faced by the food industry in Pelotas and the surrounding area.

- **Water and Effluent Laboratory**

The ALM Water and Effluent Laboratory monitors water in the BHMSG and also provides services to municipalities and other public and private bodies in the basin region, promoting environmental control (ALM UFPel Collection, 2022).

- **Hydrological and Hydrometric Monitoring Network**

The Hydrometeorological Monitoring Network seeks to ensure proper and healthy water use by diagnosing the basin's environmental condition. Collection points are located in tributaries, along the shoreline, and within Lagoa Mirim and the São Gonçalo Channel (ALM UFPel Collection, 2022), covering twelve locations with monthly sampling campaigns.

In 2021, the Integrated Water Resources Information System (SIIRH) was created. Developed by ALM in partnership with the Center for Teaching, Research, and Extension in Hydrometry and Sediments for Watershed Management (NEPE-HidroSedi), the platform provides environmental data to support water-resource management, including historical analyses of water level, precipitation, flow, and water quality.

- **Aquaculture Station**

Associated with DIBAC and located in the municipality of Arroio Grande, the Aquaculture Station began operating in 1983 and has a production capacity of approximately one million fingerlings per year. “The Station’s principal goal is to promote the regional development of fish farming and may implement development and technology-transfer projects, as well as produce fingerlings for distribution to producers and research institutions” (ALM UFPel Collection, 2022).

2. Brazilian-Uruguayan Joint Commission for the Development of Lagoa Mirim - CLM

2.1. History and general aspects

Brazil-Uruguay cooperation concerning Lagoa Mirim is a pioneering intergovernmental interaction involving direct international cooperation over transboundary river basins in South America. Water is often viewed as a natural boundary that demarcates frontiers, positioning it as a divider of territories and a source of conflict. In reality, however, the fluidity of this vital element enables contact among peoples, deepens relations between countries, and supports multiple perspectives on water use, which may also lead to more rational approaches (COLLARES; CORTELETTI; FERNANDES, 2021). ALM currently serves as the Brazilian headquarters of the CLM, which comprises Agency members together with representatives of the Ministry of Regional Development, the Ministry of Foreign Affairs, and the Ministry of the Environment.

Following the independence processes of the nineteenth century, the Boundary Treaties of 1851 and 1909 defined the 1,069-kilometer border between Brazil and Uruguay (PUCCI, 2010). Under the 1909 treaty, Brazilians and Uruguayans were legally permitted to navigate the Jaguarão River and Lagoa Mirim. In August 1961, Brazil’s Minister of Roads and Public Works requested technical cooperation from the United Nations Special Fund to address problems affecting Lagoa Mirim (ALM UFPel Collection, 2022). One month later, Uruguay’s National Council of Government requested technical assistance from the Food and Agriculture Organization (FAO) to restore the Rocha wetlands. On 8 December 1961, in Rio de Janeiro, Brazil and Uruguay committed through a memorandum to establishing a bilateral commission to address Lagoa Mirim matters, including navigation, the hydrographic system, and administrative procedures (CLM, 1961).

Accordingly, in 1963, the governments of João Goulart (Brazil) and Daniel Fernández Crespo (Uruguay) established the Brazilian-Uruguayan Joint Commission for the Development of Lagoa Mirim in Montevideo. In 1964, the Commission secured support from the United Nations Development Programme (UNDP) and FAO and implemented the CLM/FAO/UNDP Lagoa Mirim Basin Development Project.

2.2. History of agreements

Treaties between Brazil and Uruguay concerning the Lagoa Mirim Basin date back to 1851, when the boundaries between the Empire of Brazil and the Oriental Republic of Uruguay were delimited. In 1909, the Boundary Treaty modified the frontier at Lagoa Mirim and the Jaguarão River. Brazil ceded part of its territory to Uruguay, a new boundary was established, and freedom of navigation was maintained (CLM, 1909). Today, 53% of the lagoon lies in Uruguay and 47% in Brazil.

In 1918, the Administrative Agreement on the Authorization of Ports for Traffic on Lagoa Mirim and the Jaguarão River between the Republic of the United States of Brazil and the Oriental Republic of Uruguay recorded Uruguay's authorization of the ports of Villa Rio Branco, Charqueada, Puerto Gómez, and San Miguel. The Brazilian government authorized the ports of Jaguarão and Santa Vitória, while São Miguel, Afogados, Canoas, Arroito, and Palmas on Lagoa Mirim and Bahianos and Charqueadas on the Jaguarão River remained simple shelter ports, demonstrating flexibility within previously established agreements (CLM, 1918).

In 1963, the CLM was established and formally began operating. In 1964, the CLM/FAO/UNDP agreement was concluded for the Lagoa Mirim Basin Development Project. In 1965, a supplementary agreement concerning the creation of the Joint Commission for the utilization of Lagoa Mirim between Brazil and Uruguay established the CLM regulations. In 1967, Decree No. 60,819 approved the CLM's internal rules. In 1971, the Brazilian Section of the CLM was transferred to SUDESUL, and the Lagoa Mirim Department was created in Pelotas to implement the FAO project.

In 1974, the Agreement on the Joint Commission for the Utilization of Lagoa Mirim between the Federative Republic of Brazil and the Oriental Republic of Uruguay was signed. It recorded FAO-UN approval, in cooperation with both governments, of the Jaguarão River Basin Development Project and defined the rights and duties of each country's section of the commission, marking another instance of FAO cooperation with the Bilateral Joint Commission and another environmental agreement between neighboring Latin American countries (CLM, 1974).

The 1975 Treaty of Friendship, Cooperation and Trade between the Federative Republic of Brazil and the Oriental Republic of Uruguay, intended to "increase and make more operational the mutual collaboration between both countries" (CLM, 1975, n.p.), established the Brazilian-Uruguayan Commission to strengthen cooperation, examine matters of common interest, and propose relevant measures to the respective governments. Its principal objective was the definitive demarcation of the mouth of the Chuí Stream and the lateral maritime boundary, achieved in July 1972 and incorporated into the Commercial Expansion Protocol.

The agreement sought to make better use of trade opportunities and provide more favorable conditions to Uruguay, which had a lower level of development (CLM, 1975).

In 1977, the Cooperation Treaty for the Utilization of Natural Resources and the Development of the Lagoa Mirim Basin resulted in the construction of the São Gonçalo Channel Dam and Lock, DIBAC, the Jaguarão River irrigation system, and the Passo do Centurião hydroelectric development (ALM UFPel Collection, 2022). In 1985 and 1986, the treaties focused on the utilization of the water resources of the Jaguarão River and Lagoa Mirim. In 1990, SUDESUL was dissolved, and ALM became the new headquarters of the Brazilian Section. In 1994, it assumed responsibility for the technical-scientific collection, assets, and projects of the Integrated Development Plan for the Lagoa Mirim Basin.

In 1930, the Barão de Mauá Bridge over the Jaguarão River, connecting the municipalities of Jaguarão and Río Branco, was inaugurated. As international traffic increased, the bridge became insufficient and unable to accommodate heavy loads, requiring restoration. In 1994, a memorandum was therefore signed for the construction of a second bridge over the Jaguarão River connecting the Herval region with the city of Melo. The bridge has not yet been built. The memorandum nevertheless institutionalized bilateral cooperation on border infrastructure and served as a preparatory stage for subsequent agreements on a second international bridge and the modernization of the basin's logistical integration, with works expected to begin in 2026.

In 2002, the internal rules of the Brazilian Section of the CLM were approved, and the Section was linked to the Ministry of National Integration. In 2006, the Lagoa Mirim and São Gonçalo Channel River Basin Management Committee was established. Also in 2006, supplementary adjustments were made to basic Brazil-Uruguay cooperation agreements concerning projects such as "Environmental impact of lowland agricultural systems: the case of the Lagoa Mirim Basin," "Collaborative production of environmental information for biodiversity conservation in the Lagoa Mirim River Basin: consolidating a network of partner institutions and adapting a GIS database," and "Training in environmental education and collaborative production of teaching materials for biodiversity conservation in the Lagoa Mirim River Basin."

2.3. Binational and integrated water-resources management project in the BLM - GEF Fund

In October 2020, the project "Binational and Integrated Management of Water Resources in the Lagoa Mirim Basin and Coastal Lagoons," also known as the GEF Lagoa Mirim Project, was launched. Approved in 2022 and supported by the Global Environment Facility (GEF), the project has a five-year implementation period and seeks to engage public and private institutions and water users in joint and integrated water-resources management (IWRM) in the Mirim-São Gonçalo, Jaguarão River, and coastal-lagoon basins.

Through this project, the transboundary dimension of binational water relations can be actively examined and can structure Brazil-Uruguay environmental relations through the harmonization of legislation and the monitoring of environmental threats, benefiting both countries. The waters of the Lagoa Mirim Basin thus cease to be treated as a territorial dividing line and begin to be understood as a factor of integration.

This joint initiative received approximately USD 4.85 million - more than BRL 24 million - in financing from the Food and Agriculture Organization of the United Nations (FAO). On the Brazilian side, the Lagoa Mirim Basin Development Agency (ALM), an agency of UFPel, is responsible for administering and applying these resources.

The GEF Lagoa Mirim Project is divided into two principal work fronts. First, an atlas will be produced by combining the information collected during a diagnosis of the physical region that forms the BHMSG. Factors of vulnerability will also be considered, including the connection with Lagoa dos Patos and reverse flows in the São Gonçalo Channel. The collected data will then support the creation and development of related projects in areas such as tourism, aquaculture, and governance.

Sustainable cross-border regional integration through water as a political resource is highly relevant. At the federal level, the GEF Lagoa Mirim Project is a pioneering initiative for promoting and managing transboundary river basins within the Southern Common Market (Mercosur). According to Pucci (2010), river and lake resources are frequently perceived as “natural boundaries” dividing two or more countries, as reflected in the historical development of Brazilian boundary policy.

The separatist view of water, perpetuated for many years and associated with major naval conflicts, is increasingly being transformed into an element that encourages interdependence and integration. Understandings of water use and applicability directly affect the possibilities for regional development and the consolidation of cross-border relations. According to the Minister of Integration and Regional Development, Waldez Góes, “This cooperation will also reaffirm a guideline of President Lula’s administration, which is to promote integration between Brazil and the other countries of South America.”

Lagoa Mirim remains overlooked by many people, and its value is not fully recognized. Understanding and disseminating the idea that this liquid border is fundamental to the region’s economic and productive activity, as well as to the fauna and flora it shelters, are necessary to properly value this ecological setting and consolidate the binational importance of the Lagoa Mirim-São Gonçalo River Basin. In the binational sphere, legal and policy reforms may also be undertaken to ensure equitable access to the basin’s resources.

3. Final considerations

Protecting the Lagoa Mirim Basin means protecting millions of native plant species, millions of animals, and endangered species; protecting the quality of life of local populations; and protecting an entire ecosystem that directly affects everyone's life. Recognizing the basin's geological dimension is essential, but recognizing its significance in all respects and understanding the risks to which it is exposed are also necessary to achieve the desired socio-environmental balance, in which human beings respect the environment they inhabit as it supports them.

The CLM institutionalizes this protection. Its creation brought Brazil and Uruguay even closer. Its treaties took into account the political and economic circumstances each country faced at the time, and governments made concessions when they believed they could assist the other country. The creation of ALM, now headquartered at a federal university, is another highly positive outcome of these treaties because it supports research and helps safeguard the basin. Another landmark associated with this liquid border was attracting the attention of UNDP, FAO, and the GEF Fund to a region that, without proper use and protection, might otherwise have been treated as just another river basin in the world.

Observing this movement of governmental cooperation through water, a natural resource of fundamental importance and utility, means recognizing state action that strengthened the idea of water as an integrating rather than separating resource in border societies. In this way, two countries deeply connected through their Mercosur economies created a bond of liquid fraternity.

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