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# Large-scale degradation of the Tocantins-Araguaia River Basin

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None.

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Not applicable.

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#### **Authors' contributions**

Fernando M. Pelicice conceived the idea and wrote the first draft. All authors contributed with writing, development and revision.

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All authors consent with the content of the paper.

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## **Abstract**

The Tocantins-Araguaia Basin is one of the largest river systems in South America, located entirely within Brazilian territory. In the last decades, capital-concentrating activities such as agribusiness, mining, and hydropower promoted extensive changes in land cover, hydrology, and environmental conditions. These changes are jeopardizing the basin's biodiversity and ecosystem services. Threats are escalating as poor environmental policies continue to be formulated, such as environmentally unsustainable hydropower plants, large-scale agriculture for commodity production, and aquaculture with non-native fish. If the current model persists, it will deepen the environmental crisis in the basin, compromising broad conservation goals and social development in the long-term. Better policies will require thought and planning to minimize growing threats and ensure the basin's sustainability for future generations.

Keywords: biodiversity; conservation; policy; South America; sustainability.

## **Introduction**

Among the largest river systems in South America, the Tocantins-Araguaia basin stands out due to its large drainage area (767,000 km<sup>2</sup>) and spectacular biodiversity (Ribeiro et al. 1995; Lucinda et al. 2007). Located entirely within Brazil, this basin drains a vast area of the Cerrado savanna and rainforest ecosystems. Two main rivers form the basin: the Tocantins, characterized by a unique ichthyofauna with several exclusive species, and the Araguaia, with one of the largest and most biodiverse floodplains in the world (Latrubesse et al. 2019). The Araguaia River is also one of the few large free-flowing rivers in South America, which harbors essential areas for biodiversity conservation (Latrubesse et al. 2019; Martins et al., 2021). The unique biodiversity of the Tocantins-Araguaia Basin, however, contrasts with a long history of policies and initiatives that have induced extensive environmental degradation. Over the past 40 years, the expansion of dams, croplands, irrigation, mining, and aquaculture induced extensive changes to land cover, hydrology, and environmental conditions, jeopardizing biodiversity, ecosystems, and associated services (Coe et al. 2017; Strassburg et al. 2018; Latrubesse et al. 2019).

## **Large-scale degradation**

Currently, seven large hydroelectric dams regulate the main channel of the Tocantins River, with many other dams blocking the course of tributaries (Winemiller et al. 2016; Akama 2017). There are plans to build new dams (ca. 90), mainly in the Araguaia basin (Latrubesse et al. 2019), in addition to waterways and a large-scale water diversion system between the Tocantins and São Francisco basins (Daga et al. 2020). The rapid expansion of agribusiness for soy and other commodities has caused the loss of ~50% of the Cerrado (Scaramuzza et al. 2017), and the activity has advanced progressively over remnant natural areas (Trigueiro et al. 2020). In 2018, pastures and monocultures covered more than 42 % of the basin (Fig. 1). The Tocantins-Araguaia basin is currently the most targeted area for expanding agricultural activities, as stated in the Brazilian Presidential Decree 8447 of 2015, which created the MATOPIBA Federal Plan for Development of the Brazilian Cerrado in the states of Maranhão, Tocantins, Piauí, and Bahia. In the lower portion of the basin cattle ranching has led to the clearing of extensive rainforest areas (Nepstad et al. 2014). Broad changes in land use have eliminated riparian forests (Swanson and Bolhman 2021) and altered hydrological dynamics (Coe et al. 2009). Moreover, agriculture expansion has dramatically increased

the use of pesticides (Martinelli et al. 2010), which invariably end up in aquatic ecosystems. The increasing demand for irrigation has affected regional water supplies (Morais et al. 2014), leading to growing water conflicts. Other activities generally overshadow mining, but its impacts are severe. The basin hosts the two largest iron ore deposits globally: the Carajás mine in Pará State (with 17 billion tons) and the Serra do Carmo iron deposit in Tocantins State (with 159 billion tons). Future exploitation of these deposits is a significant threat, as shown by the recent environmental disasters in southeastern Brazil (Salvador et al. 2020). Terrestrial and aquatic biodiversity has responded negatively to these impacts, as evidenced by major losses in fish diversity (e.g., Araújo et al. 2013; Perônico et al. 2020; Pereira et al. 2021; Santana et al. 2021). Fish constitute a megadiverse and endemic group in the Tocantins-Araguaia basin with over 700 species (Dagosta and de Pinna 2019). According to ICMBio (2018), this basin has 51 endangered fish species, most of them endemic.

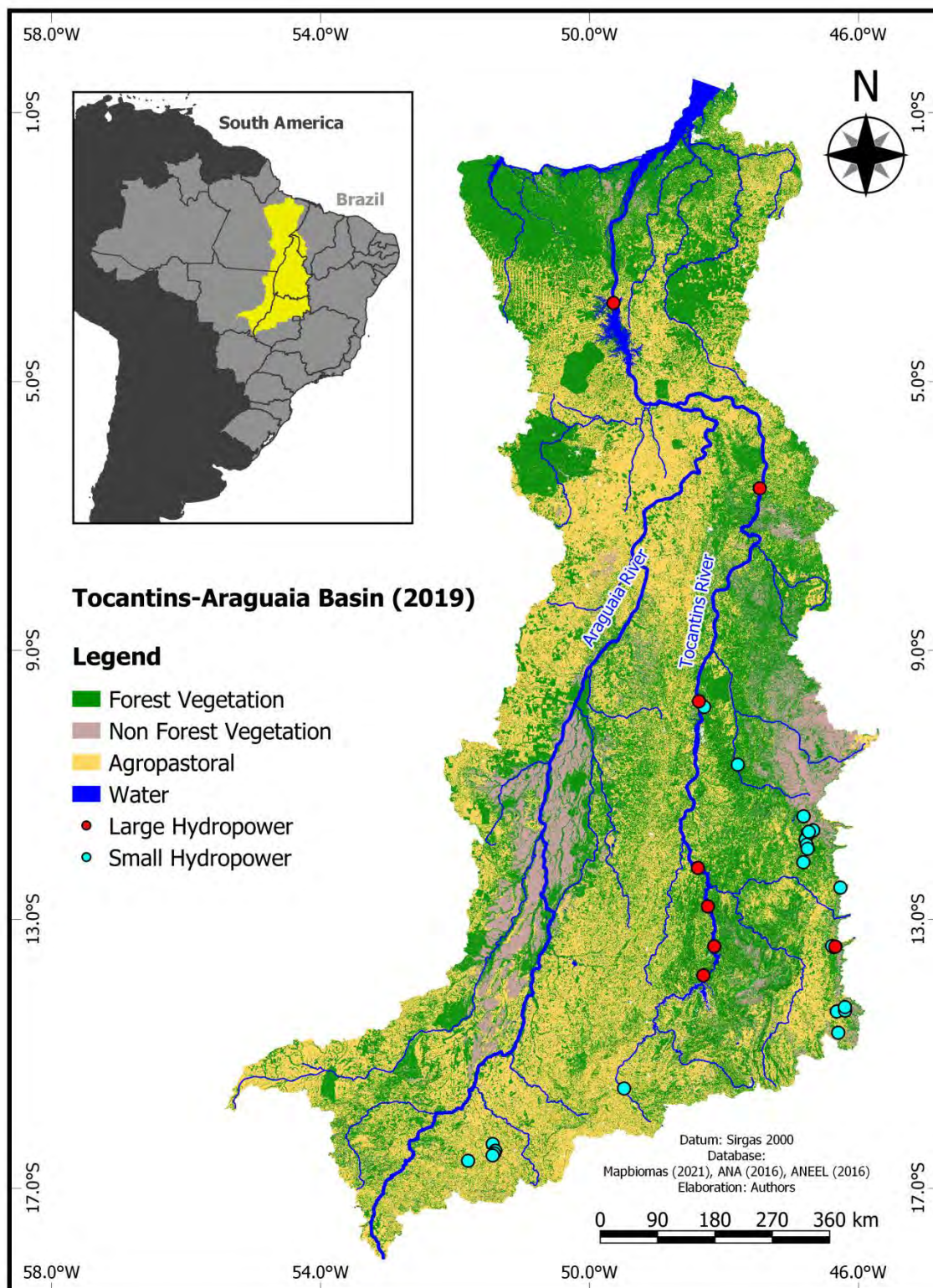


Figure 1. Land use and land cover (LULC) map of the Tocantins-Araguaia River Basin, Brazil. The map shows the scenario in 2019, indicating the area covered by natural vegetation (forest and non-forests), water and agro-pastoral activities (pastures and crops), and the location of small and large hydroelectric dams. Data source: MapBiomas (2021).

### New threats



Threats are escalating as public policies continue to prioritize maximizing economic growth at the cost of environmental sustainability (Pelicice et al. 2017). The recent expansion of aquaculture is exemplary. Historically, aquaculture in Brazil has been based on low standards of socio-environmental sustainability (Agostinho et al. 2007; Lima Junior et al. 2018), involving non-native organisms subjected to poor confinement conditions and inadequate management practices. Government policies have encouraged the expansion of aquaculture in the Tocantins-Araguaia basin, particularly in hydroelectric reservoirs. Many aquaculture parks have been planned (Lima et al. 2018) and, in 2021, cage aquaculture was authorized in the area impounded by the Peixe Angical Dam (<https://www.gov.br/pt-br/noticias/agricultura-e-pecuaria/2021/04/liberada-aquicultura-em-hidreletrica-no-rio-tocantins>). The authorization is valid for 35 years, and it is the first to be issued in the country after updates in legislation (Federal Decree n° 10.576, 2020) that reassigned responsibilities and facilitated the authorization process. This grant was issued shortly after the permission for the farming of the Nile tilapia (*Oreochromis niloticus*), an invasive species, in aquaculture cages in Tocantins State (<https://seagro.to.gov.br/noticia/2018/12/6/criacao-de-tilapia-em-tanque-rede-e-liberada-no-tocantins/>). At the same time, a state decree (State Decree n° 337, 2019) allowed farming non-native fishes (i.e., grass carp *Ctenopharyngodon idella* and Nile tilapia) in the Araguaia basin and other drainage basins in Mato Grosso State. In Tocantins State, a bill is moving towards a vote that would allow the cultivation of the striped catfish (*Pangasianodon hypophthalmus*) (<https://al.to.leg.br/noticia/gabinete/jorge-frederico/9889/peixe-panga-jorge-frederico-apresenta-projeto-de-lei-que-autoriza-o-cultivo-no-tocantins>), an Asian fish with high invasive potential that is already cultivated in other Brazilian states (Garcia et al. 2018). These initiatives must accelerate the expansion of aquaculture with non-native fish in the Tocantins-Araguaia Basin.

This episode illustrates how government policies, guided by short-term economic profits, ignore scientific advice and the costs of environmental degradation. Non-native organisms are primarily absent from aquatic ecosystems in this basin (Santana et al. 2021), and aquaculture expansion will change this scenario, triggering species invasions into other Amazonian drainage basins. The literature on socio-environmental impacts resulting from aquaculture is vast (Agostinho et al. 2007; Diana 2009; Vitule et al. 2009). It includes the unavoidable escapes and invasions (e.g., Azevedo-Santos et al. 2011; Forneck et al. 2021), and direct and indirect negative impacts caused by the Nile tilapia (compiled by Canonico et al. 2005; Pelicice et al. 2014), striped catfish (compiled by Garcia et al. 2018), and many possible synergistic effects between non-native species and other anthropogenic stressors (e.g., Bezerra et al. 2019). The potential for local biodiversity to boost fish production is enormous. Supported by science, many native fish species in the basin could provide a basis for local initiatives and markets (Pelicice et al. 2014). There is a research facility concerned with aquaculture development in the basin (Embrapa Pesca e Aquicultura, Palmas, Tocantins State), which could provide adequate expertise and innovation – but it has focused extensively on using non-native fishes.

### **The need for better policies**

For decades, Brazil has fostered policies that pursue development “at any cost”. Previous setbacks have brought severe consequences for environmental policies (de Souza et al. 2011; Fearnside 2016; Latrubesse et al. 2017; Dobrovolski et al. 2018), and

current trends have had immediate impacts on the conservation of the Amazon (Ferrante and Fearnside, 2019; Pelicice and Castello, in press). This approach found fertile ground in the current political scenario, characterized by scientific denialism and widespread disregard for the environment (Thomaz et al. 2020). The Tocantins-Araguaia basin proved highly vulnerable to these trends and setbacks since it has been historically targeted for economic development (e.g., Fearnside 2001), and has experienced a rapid expansion of human activities over the last ten years. The persistence of this scenario will deepen the environmental crisis in the basin, compromising broad conservation goals (e.g., UNESCO biosphere reserves for biodiversity hotspots), national policies (e.g., the National Strategy for Exotic Species and the National Action Plan for the Conservation of Endangered Species), and international agreements (e.g., the Convention on Biological Diversity and the United Nations sustainable development goals). The costs arising from environmental degradation are enormous and irreparable, considering the remarkable biodiversity and endemism that characterize the basin. Cultural risks are no less considerable (Doria et al. 2018), threatening ancestral knowledge and the ways of life of several native and traditional groups that live in the basin (Lopes et al. 2021), in addition to archeological and paleontological heritage (Lopes et al. 2019). Prevailing policies fail to recognize that environmental degradation generates socioeconomic impacts, threatening the persistence of human activities in the long-term (Burger et al. 2013). The impacts and costs include overexploitation of hydroelectric resources, loss of freshwater, pollution, deforestation, soil degradation, and losses caused by invasive species. In a situation of high environmental degradation (e.g., river regulation, deforestation, biological invasion), restoration efforts are complex, costly, and sometimes impracticable, especially in aquatic environments, where ecological impacts are less readily perceptible (Vitule 2009). Climate change must complicate this scenario (Colli et al. 2020), with risk of affecting current policies, intensifying environmental degradation, and compromising conservation efforts.

We recommend greater caution, responsibility, and planning when dealing with environmental issues in the Tocantins-Araguaia basin. Any development in the basin must account for its high regional biodiversity value to establish balanced policies combining economic development, environmental preservation, the best available scientific knowledge, and the interests of the different social groups involved. Protected areas are limited in number and area, especially in the Tocantins River (Azevedo-Santos et al. 2018), so development policies must incorporate some basic tenets (Azevedo-Santos et al. 2021). For example, maintenance of the connectivity and natural flow regimes of remaining free-flowing rivers (especially in the Araguaia Basin), more-stringent control of irrigation projects, climatic monitoring, preservation of riparian forests, control of deforestation in both the savanna and rainforests (especially in the headwaters), revoking the authorization of aquaculture with non-native species, and improving the inspection and control of these activities. Still necessary to achieve these goals are integrative and multidisciplinary studies to explicitly evaluate the impacts of environmental and anthropic drivers on distinct components of biodiversity and at different spatial scales, especially because basic and important knowledge gaps persist (Carvalho and Tejerina-Garro 2019; Machado et al. 2019; Colli et al. 2020). The economic importance of this basin is beyond question (i.e., production of hydroelectricity and commodities), but it does not justify the ongoing environmental degradation. The human-dominated scenario in the Tocantins-Araguaia Basin provides the ideal candidate to marry the already existing economic agenda with conservation of remaining ecosystems in ways that can serve as a model for replication elsewhere. It

would be feasible through the involvement and engagement of a wide base of stakeholders, including local and indigenous peoples, farmers and ranchers, the hydropower industry, academia, the governmental and non-governmental sectors, and maybe the international community. At this moment, economic development and biodiversity preservation require much better planning to minimize escalating conflicts and ensure the sustainability of resources for coming generations.

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