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Irrigation dams threaten Brazilian biodiversity

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Abstract
Brazil is among the main contributors to global biodiversity, which, in turn, provides enormous ecosystem services. Agriculture is one of the activities most benefited by these ecosystem services. However, this activity has contributed to the degradation of aquatic and terrestrial ecosystems and eroding Brazilian biodiversity. This conflict is growing, as emerging unsustainable legislative proposals to benefit the agricultural sector are likely to increase the decline of biodiversity. For instance, one such initiative (Bill 1282/2019) intends to change the "Forest Code" (Law 12,651/2012) to facilitate the construction of irrigation dams in Permanent Protected Areas; this last includes strips (with vegetation or no) along the edges of watercourses. In addition, two other similar bills are under progress in the Chamber of Deputies. Here we detailed these three bills and discuss — if approved — their consequences for Brazil's biodiversity. Expected negative impacts with changes in the legislation include, for example, increased deforestation, siltation, habitat fragmentation, introduction of non-native species, reductions in the availability of aquatic habitats, and changes in biogeochemical process. These proposals jeopardize biodiversity and may compromise the negotiations for an agreement between Mercosur and the European Union.

Keywords
Agriculture; Deforestation; Forest Code; Global warming; Habitat fragmentation; Law

Introduction

Brazil's is among the main contributors to global biodiversity (Agostinho et al. 2005). Past estimates suggested that there are around 210,000 known species in the

country (Lewinsohn and Prado 2005) — but this number is currently believed to be greater. Brazil's biodiversity provides numerous ecosystem services, including those classified as regulating, support, provision, and cultural (e.g., Ellwanger et al. 2022; Pelicice et al. 2023). This biodiversity has been increasingly threatened by the expansion of human activities (e.g., Loiselle et al. 2010; Fernandes et al. 2016, 2020; Garcia et al. 2021), including through official policies (e.g., Fearnside 2016; Pelicice et al. 2017).

Agriculture activities have generated negative impacts on Brazilian environments and biodiversity (Hepp et al. 2010; Pelicice et al. 2021). In the last 50 years, the irrigated area in Brazil increased by approximately a factor of 10, and in 2015, this area totaled ~7 million hectares, with projections indicating it would reach 10 million hectares by 2030 (ANA 2019). Irrigation occurs in different systems (e.g., center-pivots, drip) with water taken from hydroelectric reservoirs, lakes and, also frequently, rivers and streams. Streams can also be dammed to supply water for irrigation, even though these dams are in several cases illegal and negatively affect biodiversity (Maffra and Souza 2018). The expansion of irrigated fields may accelerate even further with recent legislation favoring — in an unsustainable way — the agricultural sector.

Brazil's current "Forest Code" (Law number 12,651/2012) requires the maintenance of Permanent Preservation Areas (known as "APPs" in Portuguese), which include forest strips along the edges of watercourses (Brazil 2012). Interventions in APPs are only allowed in specific cases when impacts are "low" (Brazil 2012). However, three bills currently advancing through committees in the Chambers of Deputies and the Senate would facilitate the construction of dams for irrigation in these areas. Here we explain why these proposed laws threaten biodiversity.

Facilitating the construction of irrigation dams

The importance of riparian habitats is recognized by Brazil's current "Forest Code" (Law 12,651/2012), which establishes requirements for the protection of vegetation along waterbodies, both lotic and lentic (Brazil 2012: Chapter II, Article 4°). For instance, the protection of a 30-meter-wide strip is required along each side of a stream with a width of 9 meters (Table 1). Law 12,651/2012 clearly states that deforestation in the Permanent Preservation Areas (hereafter APPs) may be done only in cases of need for "(…) public utility, social interest or with low environmental impact as foreseen in this Law" (Brazil 2012: Chapter II, Article 8). This limitation may change with the pending bills.

Three bills (two in the Chamber of Deputies and one in the Senate) have been proposed to change Law 12,651/2012 to allow interventions in APPs. Bill 2168/2021 (Chamber of Deputies) proposes a change "(…) to consider irrigation and animal watering infrastructure as public utility works, including dams or the damming of watercourses that cause intervention or suppression of native vegetation in a permanent preservation area (…)" (Brazil 2021a: 1). In turn, Bill 399/2022 (Chamber of Deputies) aims "(…) to turn the areas destined for irrigation into public utilities and social interest" (Brazil 2022: 1), thus allowing irrigation dams to be built without regard for impacts and degradation of APPs. Lastly, Bill 1282/2019 (Senate) proposes the following provisions: "In rural properties is allowed (…) the construction of water reservoirs for irrigation projects and the physical infrastructure associated with them" (Brazil 2019a: 2). The justification of the bill states that "(…) the lack of clarity in the current legislations on the subject has been, for a long time, hindering the expansion of technologies related to irrigation" (Brazil 2019a: 3), and that "(…) the insertion of this

device in the new Brazilian Forest Code will bring clarity necessary for a topic of such significance and fundamental importance for the reduction of crop losses (…)" (Brazil 2019a: 3). The reference to "water reservoirs" means that they include the riparian region (adjacent to the waterbody) that would be flooded.

Table 1. Size of Permanent Preservation Areas according to the Article 4° of Law 12,651/2012 (only Items I and II) (Brazil 2012).

Type of waterbody	Item in Law 12,651	Width or size of the waterbody	Width of the lateral strip protected (meters)
Watercourse	I	<10 wide	30
Watercourse	I	Between 10 to 50 wide	50
Watercourse	I	Between 50 to 200 wide	100
Watercourse	I	Between 200 to 600 wide	200
Watercourse	I	> 600 wide	500
Lake or lagoon	II	Any size	100 (rural areas)
Lake or lagoon	II	Up to 20 ha of surface	50 (rural areas)
Lake or lagoon	II	Any size	30 (urban areas)

Note: The width of the lateral strip protected along the watercourse (item I) may be lower in urban areas, depending on the local administration (see Azevedo-Santos et al. 2023)

These proposals can enable the degradation or the suppression of riparian forest areas by simplifying the process of dam building for irrigation — especially in streams and small rivers. This implies that interventions in APPs will occur without rigorous authorization procedures or technical assessments. These three bills, once approved, have the potential to cause a significant setback in the scenario of environmental policies and management of freshwater resources, watercourses, and associated biodiversity.

Threats to biodiversity

Facilitating the construction of dams in APPs will increase different negative impacts on aquatic and terrestrial ecosystems and their biodiversity. Below we will exemplify the expected negative impacts if any of these three bills is approved.

The most obvious consequence will be increased deforestation of APPs. Existing vegetation adjacent to the waterbody will be degraded or lost, either through direct removal or inundation created by the dam — as generally occurs (see Maffra and Souza 2018). Deforestation, beyond results in the loss of tree species, eliminates habitat for terrestrial organisms, such as insects, reptiles, birds, and mammals that live and depend on the riparian vegetation (Develey and Pongiluppi 2010; Freitas et al. 2010; Galetti et al. 2010; Marques et al. 2010; Farias et al. 2015). In addition, the removal of riparian vegetation can trigger siltation processes in aquatic ecosystems (Mittermeier et al. 1990), a phenomenon with adverse consequences for macroinvertebrates and fish (Casatti 2004; Couceiro et al. 2010). In general, the removal of riparian vegetation can also harm fish populations and assemblages (Azevedo-Santos et al. 2021) and affect biotic interactions associated with seed dispersion (Nogueira et al. 2023).

Facilitating infrastructure to block watercourses will increase habitat fragmentation. Dams, including small irrigation dams, impede the free movement of fish and invertebrates (Poff and Hart 2002; Pelicice et al. 2015; Chappell et al. 2019), affecting also drift dispersion of animal and plant propagules (Brooks et al. 2018). This phenomenon, which is documented in watercourses with barriers (e.g., Agostinho et al.

2008; Brejão et al. 2020), can affect gene flow, dispersion (including migration), and demographic dynamics.

The introduction of non-native species will also be intensified, especially considering the Brazilian scenario. Dams built to supply water, including for irrigation, have been — and may be — used for fish production in some cases (Albinati 2006; Cardoso Filho et al. 2010). Small dams used for recreational fishing and aquaculture have been a regular source of non-native species in Brazil (Vitule et al. 2006; Forneck et al. 2021). Moreover, there is a growing incentive for raising non-native fish in Brazil (e.g., Coelho and Henry 2017; Brito et al. 2018; Latini et al. 2021). The proliferation of dams, therefore, must be accompanied by the spread of non-native organism. We highlight that introduction of non-native species — including freshwater fishes — is a threat to native species (Vitule et al. 2009; Simberloff et al. 2023).

Other expected increases in negative effects relate to water use. Removing water from watercourses (either for agriculture or for urban use) reduces the availability of habitat and increases the frequency of low-water conditions; and this cause shifts in the presence and abundance of species, including invertebrates and fishes (Walters and Post 2011; Grantham et al. 2013). Small dams cause similar low-water downstream effects that negatively affect aquatic species (Couto et al. 2023).

Lastly, changes in biogeochemical processes can be expected to increase if any of the three bills is approved. The alteration of flows due to dams can also modify the concentration of nutrients such as phosphorus and nitrogen, accumulating in the impoundment area and generating eutrophication events (Maavara et al. 2020). Such nutrient buildups reduce dissolved oxygen levels, affecting aquatic communities (Wurtsbaugh et al. 2019). In addition, deforestation on the border of created reservoirs reduce the quality of water (with the input solids and iron) used for irrigation (Favero et al. 2022), as well as compromise downstream habitats. Finally, reservoirs are known to be a source of greenhouse gas (Fearnside 2002; Maavara et al. 2020). These compounds lead to global warming (Fearnside 2002), consequently affecting biodiversity at different scales (Malcolm et al. 2006; Pounds et al. 2006).

The intensification of the above negative impacts can be expected to result in biodiversity losses, especially in a context where numerous Brazilian species already are threatened with extinction (e.g., MMA 2022). For example, a total of 311 fish species have been listed as threatened, and habitat loss and fragmentation, also associated with river damming, have been the main stressors (Santana et al. 2021). In addition, threatened fish species (e.g., '*Chasmocranus*' *brachynema* Gomes & Schubart, 1958) (see Deprá and Slobodian 2024) do not have any of their habitat protected. The number of threatened species can be expected to grow with the proliferation of new dams, especially because many species are only known to occur in limited areas that are being converted to agriculture and ranching (e.g., Costa et al. 2022). In the case of fish, various species were only described in the last few years (e.g., Burger et al. 2019; Guimarães et al. 2019; Costa and Katz 2021; Deprá et al. 2022), indicating that the number of fish species present is even higher, especially for groups that also inhabit streams (e.g., characids, heptapterids, trichomycterids). The number of undescribed species of insects that live in riparian habitats is probably even more underestimated. New species are being described for plants in areas subjected to agriculture expansion (e.g., Carvalho et al. 2023), indicating that some may have been lost with no scientific record. The degradation of riparian habitats in the Brazilian Amazon, a megadiverse region, is especially concerning. This scenario stresses the need to avoid unsustainable policies like those discussed herein.

Final remarks

Various legislative proposals have emerged to weaken Brazil's current "Forest Code" (Law 12,651/2012), which would endanger Brazil's ecosystems (Table 2). These proposals include the three bills to remove restrictions on irrigation dams. All these bills must be to be defeated in the Brazilian National Congress and the discussions about them must include the participation of scientists (Azevedo-Santos et al. 2017), including experts in water resources management. We recognize that the recent increase in the representation of agribusiness interests ("ruralists") in Brazil's National Congress (Fearnside 2023) is a powerful barrier to this.

Table 2. Proposed law to make changes of the Permanent Preservation Areas of the "Forest Code" (Law 12,651/2012) and their expected main negative impacts mainly on Brazil's ecosystems.

Bill	Legislative chamber	Situation	Description	Changes	Examples of expected negative impacts
Proposed Law 5650/2016	Chamber of Deputies	In progress	"Authorizes the planting of yerba mate in a Permanent Preservation Area on small properties or family rural possessions" (Brazil 2016).	Allows the farming of *Ilex paraguariensis* in Permanent Preservation Areas	In the cultivation of *Ilex paraguariensis*, producers may use fertilizing with nitrogen and phosphorus (e.g., Alves et al. 2017). In addition, there are human activities (e.g., harvest) in an area which will have majority a single species (i.e., yerba mate). Main expected negative effects are the pollution of waterbodies (with nutrients), stomping on non-target vegetation and habitat simplification.
Proposed Law 7592/2017	Chamber of Deputies	Suspended	"Amends Law No. 12,651, of May 25, 2012, to include the construction of hospitals and schools among the activities considered to be of social interest for the purpose of suppressing the Permanent Preservation Area" (Brazil 2017).	Allows intervention (removing vegetation is included) in Permanent Preservation Areas.	Intervention in riparian regions results in deforestation, erosion and siltation, pollution, increased brightness in watercourses (Mittermeier et al. 1990; Thomaz et al. 2021; Ottoni et al. 2023). These negative effects are expected to increase if the Bill is unarchived and approved.
Proposed Law 1.282/2019	Senate	In progress	"Amends the Forest Code to allow, in areas of permanent preservation of rural properties, the construction of water reservoirs for irrigation projects and the physical infrastructure associated with it" (Brazil 2019a).	Facilitate the construction of dams for irrigation within the APPs.	See section "Threats to biodiversity" of this article.
Proposed Law 1731/2019	Senate	In progress	"Amends Law No. 12,651, of 25 May 2012, which provides for the protection of native vegetation and other measures, to deal with	Allow agriculture and the presence of houses within	Intervention in riparian regions results in deforestation, erosion and siltation, pollution, increased brightness in watercourses (Mittermeier et al. 1990; Thomaz et al. 2021; Ottoni et al. 2023).

			rules on the occupation of Permanent Preservation Areas (APP)" (Brazil 2019b).	the limits of a Permanent	These negative effects are expected to increase if the Bill is approved.
Proposed Law 2510/2019	Chamber of Deputies	Approved - Now Law 14.285/2021	"Amends Law No. 12,651, of 25 May 2012, to provide for permanent protection areas in the urban perimeter and in metropolitan regions" (Brazil 2019c).	Allows to reduce the width of Permanent Preservation Area in the urban perimeter	Intervention in riparian regions results in deforestation, erosion and siltation, pollution, increased brightness in watercourses (Mittermeier et al. 1990; Thomaz et al. 2021; Ottoni et al. 2023). These negative effects are expected to increase with the approved law 14.285/2021 (Azevedo-Santos et al. 2023).
Proposed Law 2168/21	Chamber of deputies	In progress	"Amends Law 12,651/2012, to consider irrigation infrastructure works and animal watering as of public utility" (Brazil 2021a).	Facilitate the construction of dams for irrigation and for animal watering within Permanent Preservation Areas	See section "Threats to biodiversity" of this article. Areas used to livestock are subjected to fecal pollution (Souza et al. 2006). Therefore, this is also an expected negative impact if the Bill is approved.
Proposed Law 399/2022	Chamber of deputies	In progress	"Amends Law No. 12,651, of 25 May 2012, to make areas intended for irrigation public utility and social interest" (Brazil 2022).	Facilitate the construction of dams for irrigation	See section "Threats to biodiversity" of this article.

Note: The suspension of processing does not guarantee that processing will not be resumed or that another similar law will not be proposed.

Opposing irrigation dams in APPs does not mean being against agricultural expansion, but rather taking care not to exacerbate the biodiversity crisis. The three bills removing key restrictions on irrigation dams are not compatible with minimum levels of sustainability in agriculture. This is an issue of increasing concern among Brazil's international trading partners and is currently being raised in negotiations for an agreement between Mercosur and the European Union. Defeating these bills would be an important step towards addressing this challenge. It also underlines the need for Brazilian lawmakers to radically change their outlook on questions of sustainability to ensure that Brazil's rich biodiversity — that benefit the world — is preserved.

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