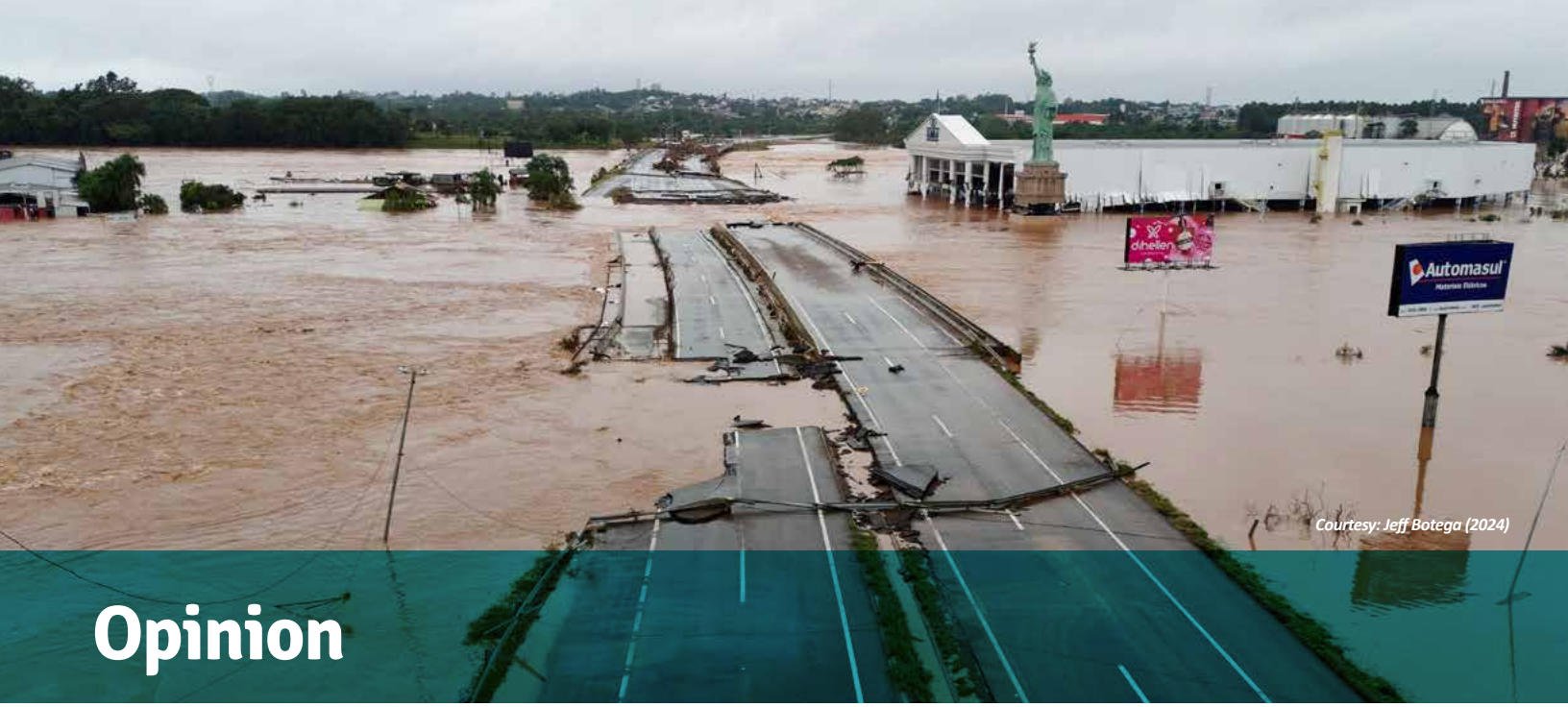

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Opinion

Southern Brazil's 2024 Floods:

CAUSES, IMPACTS, AND HOW WETLANDS CAN HELP MITIGATE EXTREME CLIMATE DISASTERS

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One of the most noticeable symptoms of global climate change is the increased frequency and intensity of extreme weather events (Lange *et al.* 2020, Wang *et al.* 2022). The progressive warming of the oceans and atmosphere, coupled with the resulting alterations in their circulation patterns, has intensified the magnitude of these natural events, leading to climatic events of unprecedented severity, such as recent droughts in the Amazon during 2023–2024 and devastating floods in southern Spain and Morocco's Sahara Desert in 2024. Among the most significant severe weather events in 2024 was the flooding that impacted Rio Grande do Sul, Brazil's southernmost state, which covers 281,707.151 km^2 (Instituto Brazileiro de Geografia e Estatística n.d.) and borders Argentina and Uruguay.

Although the tendency for increased rainfall in this region during austral autumn and spring is already well documented (Hasenack *et al.* 2023), a combination of unfavorable atmospheric conditions contributed to this extreme and catastrophic event: A prolonged heat wave induced high-pressure anomalies in the lower atmosphere over central–southeastern Brazil, intensifying the north-northwest winds of the low-level jet east of the Andes. This jet stream transported significant moisture into Rio Grande do Sul, where a low-pressure center had developed, facilitating deep convection and cloud formation. The situation worsened with the arrival of two cold fronts, the first on April 27th and the second on May 1st. Their northward progression was obstructed by the high-pressure center in Tropical Brazilian Regions (Rocha *et al.* 2024). As a result, these fronts remained stationary over central and northern Rio Grande do Sul, generating intense rainfall in the Guaíba Lake basin, which is fed by five major rivers: Jacuí, Caí, Gravataí, Taquari, and Sinos. The headwater regions of the Taquari River were initially the most severely impacted; however, over time, the floodwaters converged toward Lake Guaíba, affecting the Metropolitan Region of Porto Alegre, the state capital. Between April 26th and May 5th, total accumulated rainfall ranged from 650 to 800 mm at several locations, leading to the peak of flooding (Rocha *et al.* 2024).

Over 2.4 million people were affected by flooding in Rio Grande do Sul; more than 200 people died or went missing, and 600,000 were displaced (Pillar & Overbeck 2024). The infrastructure collapsed and left many without basic services, such as drinking water and electricity, as entire towns were submerged or isolated by the destruction of roads and bridges (Machado 2024, Martins-Filho *et al.* 2024, Pillar & Overbeck 2024, Rizzotto *et al.* 2024). Floods have also brought about a public health crisis, with possible long-lasting effects on the region's health infrastructure (Machado 2024, Martins-Filho *et al.* 2024, Rizzotto *et al.* 2024).

This disaster highlights the urgent need for improved disaster preparedness and climate mitigation efforts, particularly because underfunding in preventive measures has worsened the crisis in the region (Martins-Filho *et al.* 2024, Pillar & Overbeck 2024, Rizzotto *et al.* 2024). While much attention has been given to mitigation, adaptation, and recovery, the crucial role of natural areas, especially aquatic ecosystems, in regulating and reducing the impact of extreme events is often overlooked (Endter-Wada *et al.*, 2018; Ferreira *et al.*, 2023).

Continental aquatic ecosystems play an important and integrative role in the landscape by connecting processes between terrestrial and aquatic systems. Owing to their high vulnerability to global changes, they are frequently described as "sentinels" of anthropogenic impacts, signaling ecological shifts


Photo by Danilo Landa

across landscapes and watersheds (Adrian *et al.*, 2009, Williamson *et al.*, 2008, 2009, Zhang & Duan, 2021). Beyond acting as "whistleblowers" to climate change events, these ecosystems mitigate extreme events by recharging groundwater, reducing flood risks, and delaying droughts by storing and gradually releasing water (Endter-Wada *et al.* 2018; Ferreira *et al.* 2023). In coastal regions such as the long coastline of Rio Grande do Sul, wetlands also mitigate wave energy and reduce the impact of rising tides and storms (Endter-Wada *et al.*, 2018).

The state of Rio Grande do Sul is notable for its rich diversity of continental aquatic environments (Gonçalves *et al.*, 2024, Maltchik *et al.* 2024), ranging from tropical, subtropical, and temperate rivers to small streams, wetlands, marshes, and the extensive Patos-Mirim Lagoon system in the coastal landscape (Bastazini *et al.*, 2024; Gonçalves *et al.*, 2024; Maltchik *et al.*, 2024). The rich diversity of aquatic ecosystems supports high levels of biodiversity (Gonçalves *et al.*, 2024, Bastazini *et al.*, 2024, and references therein), which are becoming increasingly threatened by human activities (Gonçalves *et al.*, 2024, Maltchik *et al.*, 2024).

This rich diversity of aquatic ecosystems may play a significant role in mitigating the impact of extreme climate events by regulating water flow, reducing flood risks, and storing water during droughts. For instance, the Patos-Mirim Lagoon system and extensive wetlands serve as natural buffers against the rising frequency of floods and other climate-related disasters. Yet, to date, empirical evidence regarding the contribution of aquatic ecosystems to climate change mitigation in the Rio Grande do Sul region remains limited.

Insights from analogous contexts suggest that enhancing the conservation and integration of aquatic ecosystems into land-use planning strategies could strengthen the resilience of local ecosystems to climatic extremes, safeguard human populations, and protect livelihoods. However, in recent years, successive regional governments have weakened environmental legislation meant to protect native habitats, leaving aquatic ecosystems increasingly vulnerable to degradation and extirpation (Pillar & Overbeck 2024, Rizzotto *et al.* 2024, Silva 2024, Soler & Dias 2024). Thus, to fully understand the potential of these aquatic ecosystems for climate mitigation, it is crucial to conduct further research and quantify their impacts on the attenuation of extreme events. Meanwhile, policymakers must recognize the protective potential of continental aquatic ecosystems, incorporate them into climate policies, and establish mechanisms to minimize their degradation and destruction, ensuring their long-term persistence and contribution to climate mitigation efforts.

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