Unintended consequences of nature-based climate mitigation: Exotic natural capital and water scarcity

Ignacio Oliva

University of California, Davis

iroliva@ucdavis.edu

Over the past decades, afforestation initiatives have gained broad support from governments and civil society as a core component of nature-based climate mitigation policies. Afforestation can increase carbon sequestration and contribute to ecosystem restoration by halting environmental degradation (Mirzabaev & Wuepper, 2023). However, the environmental impacts of afforestation depend on how it is carried out. In particular, industrial tree plantation monocultures (ITPs) have been promoted as a profitable and scalable strategy to expand forested areas, yet growing evidence suggests they may limit ecosystem services, especially freshwater availability (Lewis et al., 2019; Durán & Barbosa, 2019).

Two mechanisms are commonly cited in the literature to explain how ITPs may alter the water cycle in a given basin, thereby reducing the volume of freshwater available. First, ITPs are thought to consume more water than the average species to sustain higher growth rates (Scott, 2005). Second, plantations are associated with higher evapotranspiration rates (Scott, 2005; van Dijk & Keenan, 2007), which can reduce downstream water yield.

In this paper, we examine whether ITPs limit the provision of freshwater ecosystem services. Climate change is expected to intensify water scarcity, increasing the policy relevance of freshwater impacts of afforestation (IPCC, 2023). These dynamics pose an important risk: mitigation strategies designed to slow climate change may unintentionally amplify local water scarcity.

We study this question in Chile, a country that has more than doubled the area covered by ITPs since 1975, largely through conversions from agricultural land, shrubland, and native forest (Heilmayr et al., 2016). This expansion, driven in part by public incentives for plantation forestry, makes Chile a useful case for evaluating long-term hydrological impacts. The policy stakes remain high, as Chile has committed to expanding tree plantations by 100,000 hectares under its Nationally Determined Contributions toward carbon neutrality by 2050 (Durán & Barbosa, 2019; Hoyos-Santillan et al., 2021).

Using historical land-cover data from 1986 to 2015, we measure freshwater availability as net outflow—the difference between streamflow observed at a gauge station and upstream inflows—thereby capturing the hydrological contribution of each drainage area independently of upstream conditions. We further disaggregate ITP expansion by source land cover, distinguishing conversions from agricultural, shrubland, and native forest, to assess whether hydrological impacts depend on which land cover plantations replace.

Our results consistently indicate a delayed but robust negative effect of ITP expansion on freshwater availability. A one-percentage-point increase in ITP conversion reduces annual normalized net outflow by approximately 0.23 m^3/s·year per km^2 after seven to nine years, corresponding to roughly 12% of mean annual net outflow at observed expansion rates. The magnitude of this effect varies by source land cover: conversions from agriculture and shrubland—land uses associated with relatively low evapotranspiration—generate per-unit effects approximately three times the average, whereas conversions from native forest yield a more modest incremental impact.

These findings highlight a significant trade-off between industrial tree plantations and freshwater availability that should be explicitly considered when designing nature-based climate mitigation policies. Ongoing work will further examine these trade-offs and inform afforestation investment decisions.

Aknowledgements

Bruno Pimenta is a coauthor in this project.

I have no conflict of interest to disclose.