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# Afforestation and climate mitigation: lessons from Chile

S. Gómez-González [1,2,3,12,*]
A. Miranda [2,3,4,12]
J. Hoyos-Santillan [2,5,6,7]
A. Lara [2,3,8,9]
P. Moraga [2,10] and
J.G. Pausas [3,11]

**The Chilean Climate Change Law excludes tree monocultures as a solution to the climate crisis, offering an opportunity for resilience and climate mitigation in Latin America. The Chilean experience with mega-fires in extensive, homogeneous forest plantations provides important lessons that could inform climate policies in other countries.**

## Tree planting for climate mitigation?

In response to the climate crisis, reforestation and afforestation projects have been adopted by both governmental and non-governmental institutions worldwide. These projects are based on the premise that forests are one of the main carbon sinks in terrestrial ecosystems. Examples include the Great Green Wall initiative of the African Union, The Bonn Challenge hosted by the International Union for Conservation of Nature (IUCN), and the Three Billion Tree Pledge of the European Green Deal. However, in many cases, tree-planting programs are being implemented without proper ecological guidelines or a full understanding of their potential side effects [1,2], thus putting the success of global mitigation goals at risk. A growing consensus among the scientific community is that planting trees without careful consideration of the species selection and the ecology of the targeted habitat is not a viable solution for $CO_2$ mitigation and that forest plantations are not comparable with natural ecosystems in terms of carbon storage [3].

Tree-planting programs have also been widely adopted as mitigation actions in Latin American countries under the Nationally Determined Contributions (NDC) of the Paris Agreement. However, these actions often lack clear articulation of sustainability standards and the targeted areas are sometimes too extensive to manage effectively. For example, the Low Carbon Agriculture Plan of Brazil aims to increase the area of planted forests by 3 million ha (Mha), reaching a total of 9 Mha. The sustainable management of such a huge area of plantations will be challenging (to say the least) and the ecological impacts uncertain. Colombia's NDC explicitly promotes commercial forest plantations as a mitigation measure. However, these plantations are often established as monocultures (Figure 1), which have significant socioecological impacts [4]. Policymakers promoting tree plantations may not fully consider that the benefits in terms of wood production and carbon sequestration could be outweighed by the decline in other ecosystem services that are relevant for climate adaptation and resilience. By contrast, the new Climate Change Framework Law (CCL) in Chile explicitly excludes monoculture plantations but will promote the conservation and restoration of native forests and other natural ecosystems. This marks a departure from past policies that subsidized monoculture plantations for timber production for decades. Here, we analyze this particular issue of the CCL and, based on the experience with plantation monocultures and mega-fires in Chile, we draw lessons to achieving more resilient landscapes and climate mitigation in Latin America.

## The Chilean CCL: a change of direction

Chile's CCL sets it apart from its neighboring countries in relation to climate action and represents an opportunity to achieve resilience in South America. The most relevant management instrument proposed in the CCL is the Long-Term Climate Strategy (LTCS), which defines guidelines to achieve carbon neutrality by 2050, in accordance with the NDC of the Paris Agreement. This is a relevant step forward in terms of climate mitigation, since the commitments assumed at the international level will have a specific roadmap for their implementation in Chile.

The CCL is unprecedented in its recognition of the importance of biodiversity and ecosystem services for addressing the climate crisis. In addition, this law explicitly states that it will not incentivize forest monocultures. This represents a major paradigm shift, as Chile had promoted the forestry sector with public incentives through Decree Law 701 for more than 40 years. This decree aimed to promote the forestry industry and its exports while addressing soil degradation. However, the subsides provided under the decree, in a political context of privatization of forestry companies and trade reforms, led to a rapid expansion of forest plantations across the country (from 0.29 Mha in 1974 to 3.12 Mha in 2022 [5]). Currently, this sector accounts for ~2% of the national GDP (~US$6 billion), and Chile is one of the world leaders in wood pulp exports. This expansion of forest plantations caused a massive land-use change in the country. Between 1986 and 2011, an average of 0.34 Mha, 0.51 Mha, and 0.71 Mha of native forests, shrublands, and pasturelands, respectively, were replaced by forest plantations across central–southern regions [5]. This process was accompanied by large-scale detrimental socioecological impacts, such as biodiversity loss [4], reduction in water yield [6], mega-fires [7], and a growing

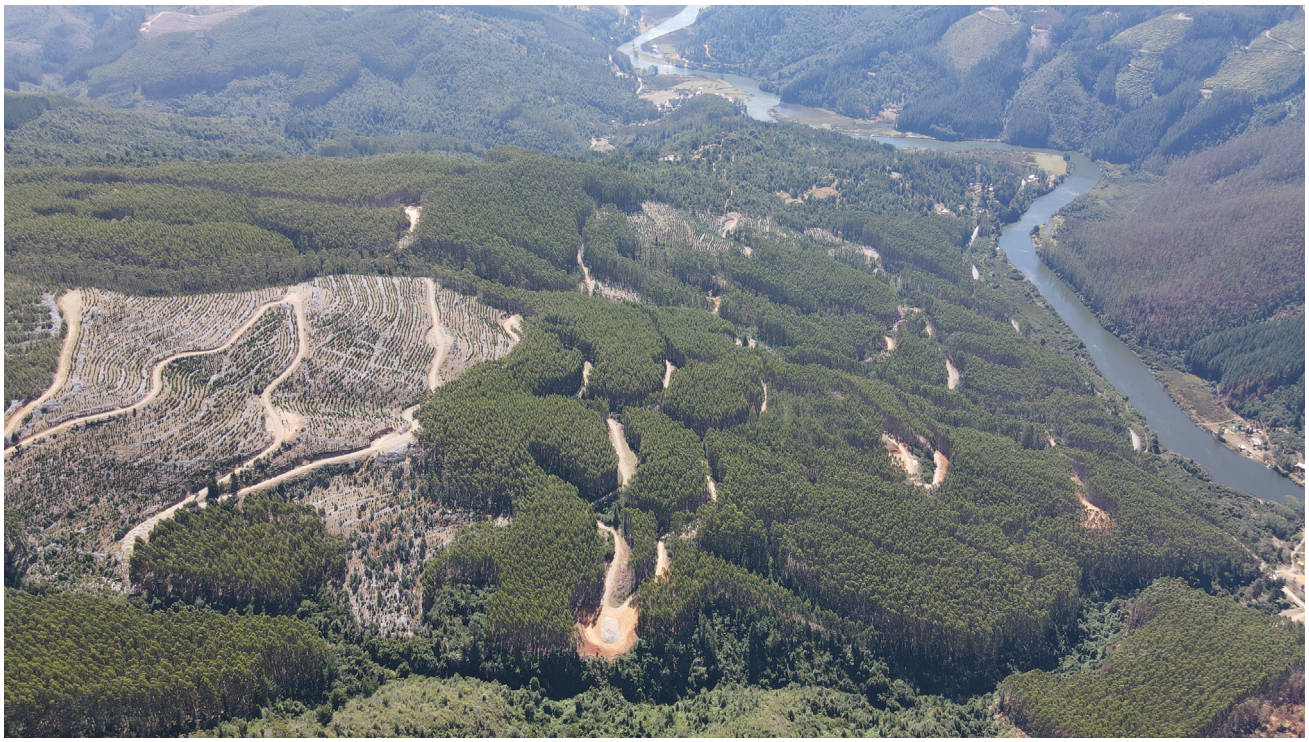


Figure 1. Landscape dominated by forest monocultures in Chile. Monocultures of the Australian native *Eucalyptus nitens* intensively managed near Futa River in Valdivia Province. Photograph by Elda Brandt (2018).

impoverishment and inequality of rural populations [8], without an increase in carbon stocks [5]. The longstanding advocacy of scientists and society for sustainable forestry [7], together with other sociopolitical conflicts, contributed to the ending of subsides in 2017.

The CCL is a significant step toward aligning scientific evidence and public policy, since the rejection of incentives for tree monocultures in favor of native forest restoration will create more resilient landscapes. This stance gains significance considering the dissatisfaction it may generate within the influential Chilean forestry sector, which could push for reintroducing afforestation subsidies. However, unlike the CCL, the Chilean NDC does not explicitly exclude the use of monoculture plantations of exotic species to achieve its restoration goals (1 Mha). Therefore, Chile's NDC needs to be modified in the near future to ensure consistency on this key science-based issue.

## Lessons learned from mega-fires

Afforestation as established in Chile increases the amount and continuity of fuel, which could lead to larger and more severe fires under warming conditions [2,7]. These mega-fires have multiple socioeconomic consequences, including the abrupt emission of large amounts of greenhouse gases [2,7]. During 2022–2023, Chile experienced a devastating fire season that has burned, thus far, 0.44 Mha, a magnitude similar to the mega-fires that occurred 6 years ago (2016–2017; 0.57 Mha burned). In both cases, exotic tree plantations, which are extensively managed as monocultures in Chile, were the main land use affected (≈50% of the total burned area in the 2016–2017 and ≈60% in the 2022–2023 fire seasons). The contribution of forest plantations to the total burned area of the country has increased substantially in the past few years (Figure 2A) and the recent 2023 wildfires exacerbate this trend. The combination of drought, heatwaves, and an homogeneous landscape with extensive monocultures of flammable, exotic trees could explain this pattern of mega-fires (Figure 1 [7]). Considering both harvesting and wildfires, the ≈3.12 Mha of Chilean forest plantations have consistently acted as a net carbon source, while the carbon sink capacity of Chile relies mainly upon its native forests (Figure 2B) [9]. For example, the combination of mega-fires and wood harvesting released ≈122.8 $MtCO_2$-equivalent emissions in 2017, surpassing the annual $CO_2$ captured by native forests for the first time in 30 years[i].

Besides being a fire hazard, predictive models suggest that increasing tree

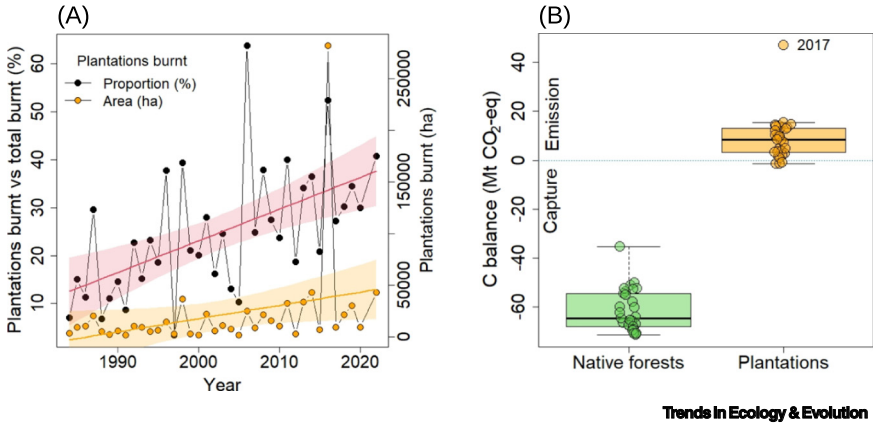


Figure 2. Role of forest plantations in wildfires and carbon emissions. (A) Area of plantations burnt annually {ha, in orange [regression slope = 1280.8; standard error (SE) = 637.3; F = 4.04; $P$ = 0.05]} and proportion of area of plantations burnt annually in relation to total area burnt, including native forests, shrublands, and grasslands [%; data in black symbols, fit in red (regression slope = 0.66; SE = 0.16; F = 16.08; $P$ = 0.0002)] for the period 1984–2022. Note that the proportion of plantations burnt increases more steadily than the area of plantations burnt, probably as an indication that plantations have become increasingly more fire-prone compared with other land uses (data from[ii]). (B) Carbon balance (million tons of $CO_2$-equivalent; including $CO_2$, $CH_4$, and $N_2O$) for the period 1990–2018, including capture (biomass increment and long-lived harvested wood products) and emissions (short-lived harvested wood products and wildfires), for native forests and plantations in Chile. Dots are mean annual values (the outlier for plantations correspond to the 2017 mega-fires) (Data from[i,iii]).

cover in Chile could reduce albedo, thereby contributing to warming [10]. Although this effect could be mitigated by the formation of clouds in mid-latitudes under normal climate conditions, the mega-drought experienced in central–southern Chile may limit this process [11]. In addition, monocultures of exotic trees, such as eucalyptus and pines, reduce water supply and soil carbon stocks, counteracting the potential benefits of afforestation [12]. Therefore, the CCL provides a framework to move toward climate mitigation through the encouragement of native forest restoration [13]. Neighboring countries that are promoting forest plantations as climate action, such as Argentina, Uruguay, and Brazil, should consider the lessons learned in Chile, since this has not been a good mitigation strategy. These programs may have served under the 20th century climate, but they are not sustainable given the climate projections for the 21st century. Climate policy agreements are needed on a broader spatial scale (e.g., southern South America) to avoid tree monocultures as a mitigation tool and the expansion of mismanaged plantations into countries with less restrictive climate laws.

## Toward resilience and climate mitigation: a forward-looking approach

Achieving resilience requires diversified landscapes, which means that forest plantations, especially monocultures of exotic species, should be strongly limited and regulated. Existing forest monocultures, in Chile and elsewhere, must be reformulated to ensure the long-term sustainability of the forest sector [7,14]. Conventional intensification systems should be replaced by management practices that integrate current ecological knowledge to maximize ecosystem services, such as ecological intensification [14]. Ecological intensification is a management practice that uses biodiversity as a tool to increase productivity and ecosystem services while reducing the detrimental ecological effects of artificial inputs (e.g., pesticides and fertilizers). By doing so, we might reconcile productivity and biodiversity conservation with a balanced nature contribution to society, which is especially important in the warming and drying scenario and increases in fire occurrence that Chile and other countries are already facing. This approach provides a foundation for maintaining or increasing relevant ecosystem services, such as water provision, nutrient cycling, carbon storage, pest control, or fire protection [14].

Conserving and restoring forests and non-forest ecosystems, as well as regulating land-use conversion, should be prioritized. Although effective incentives for promoting these activities, such as science-based approaches with public participation that consider the sociocultural context, pose a strong challenge, it is necessary to acknowledge that current land management systems are no longer suitable under increasingly extreme climate conditions. Devastating wildfire seasons, social conflicts, and environmental impacts have forced Chile to pursue a change in its forestry practices toward nature-based solutions that prioritize natural ecosystems over tree monocultures. The new CCL is a clear step toward resilience and builds a pathway to achieve carbon neutrality and adaptation over the next 30 years. The Chilean experience can provide valuable insights for climate policies in other countries worldwide.

### Author contributions

S.G-G., A.M., J.H-S., A.L., and J.G.P. contributed to conceptualization; S.G-G., A.M., J.H-S., A.L., P.M., and J.G.P. contributed to investigation; A.M., J.H-S., and J.G.P. contributed to data curation; A.M., J.H-S., and J.G.P. contributed to visualization; S.G-G. contributed to writing of the original draft; S.G-G., A.M., J.H-S., A.L., P.M., and J.G.P. contributed to review and editing.

### Data availability

All data come from public sources (see Resources and citations in Figure 2 in the main text).

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## Resources

[i]https://snichile.mma.gob.cl/wp-content/uploads/2022/06/Inventario_Nacional_de_GEI-1990-2018.xlsx

[ii]www.conaf.cl/incendios-forestales/incendios-forestales-en-chile/estadisticas-historicas/

[iii]https://bibliotecadigital.infor.cl/handle/20.500.12220/32501

[1]Departamento de Biología-IVAGRO, Universidad de Cádiz, Puerto Real, 11510, Spain
[2]Center for Climate and Resilience Research (CR)[2], Santiago, 8370448, Chile
[3]Center for Fire and Socioecological Systems (FireSES), Universidad Austral de Chile, Valdivia, 5110566, Chile
[4]Laboratorio de Ecología del Paisaje y Conservación, Departamento de Ciencias Forestales, Universidad de La Frontera, Temuco, 4811230, Chile
[5]Environmental Biogeochemistry Laboratory, GAIA Antarctic Research Centre, Universidad de Magallanes, Punta Arenas, 6200000, Chile
[6]School of Biosciences, University of Nottingham, Sutton Bonington, Loughborough, LE12 5RD, UK
[7]Smithsonian Tropical Research Institute, Ancón, 0843-03092, Panamá
[8]Laboratorio de Dendrocronología y Cambio Global, Instituto de Conservación, Biodiversidad y Territorio, Facultad de Ciencias Forestales y Recursos Naturales, Universidad Austral de Chile, Valdivia, 5090000, Chile
[9]Fundación Centro de los Bosques Nativos (FORECOS), Isla Teja, Valdivia, 5110206, Chile
[10]Centro de Derecho Ambiental, Universidad de Chile, Santiago, 6640022, Chile
[11]Centro de Investigaciones sobre Desertificación (CIDE-CSIC), Valencia, 46113, Spain
[12]These authors contributed equally to this work

*Correspondence:
susana.gomez@uca.es (S. Gómez-González).

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