Environmental costs of water transfers

To the Editor — Central Chile (30–37° S) is home to ~10 million inhabitants and hosts intensive agriculture, mining, forestry and electricity generation. These activities are already constrained by limited freshwater availability in this semi-arid region that has been regularly affected by short-lived (<3 years) but intense (>50% rainfall deficit) droughts in the past. More recently, a large portion of this territory has experienced a megadrought, an uninterrupted sequence of dry years since 2010, partially driven by climate change[1]. Model-based climate projections for the rest of twenty-first century suggest a poleward expansion of the Hadley cell and the arid belt, thus causing further warming and drying across most of Mediterranean regions of the world, including central Chile, southern Africa and parts of western North America and Australia. Under a heavy carbon emission scenario, annual precipitation in central Chile would reduce by up to 30%, and mean temperature would increase up to 2.5 °C[2]. These trends would further decrease freshwater availability. The present and future acute shortages in freshwater access in different regions worldwide, such as in central Chile, have led some private initiatives to propose water diversion from the more humid south-central part of the country (Fig. 1). These 'hydrological roads' involve large-scale capture, storage and transfer of freshwater across 2,000 km. One argument to justify such proposals in different regions of the planet is that freshwater is wasted when it reaches the sea. However, many studies recognize that riverine influxes of organic matter and nutrients exported from rivers are extremely important for supporting coastal biological productivity and biogeochemical cycles[3]. For instance, the Maule, Rapel and Biobío rivers in Chile export hundreds of tons of nitrogen, and thousands of tons of silicon and carbon[4] daily, which could contribute to a significant fraction of the high fish biomass typically recorded along Chilean coast.

Besides, if the water transferred is sourced from human-intervened river basins, it may also contain toxic and other elements with negative ecosystem impacts for the recipient area. In Chile, the pulp and paper-mill industries discharge their treated effluents into some rivers, such as Biobío River in Central Chile, and standard treatment systems will not prevent the

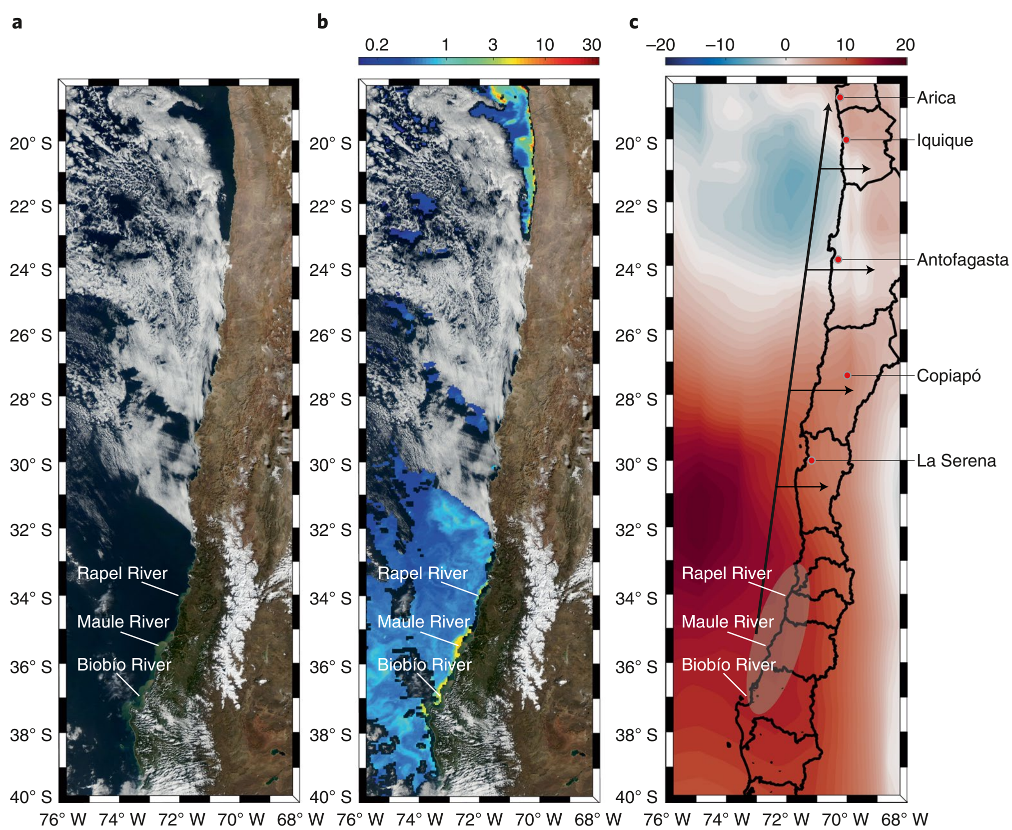

Fig. 1 | River discharges and the biogeochemistry and productivity of coastal oceans upon climate change scenarios. Satellite images illustrating the influence of river discharge on coastal oceans and the projected precipitation scenarios in Chile. **a**, Moderate Resolution Imaging Spectroradiometer (MODIS) visible colour image illustrating the sediment river plumes on 23 May 2008 (adapted with permission from ref. [10], Elsevier). **b**, MODIS satellite-derived phytoplankton chlorophyll (mg m^{-3}) on 23 May 2008 (https://oceancolor.gsfc.nasa.gov/cgi/browse.pl?sen=amod). **c**, Projected changes in mean annual precipitation for the period 2045–2070 under the Representative Concentration Pathway (RCP) 8.5 scenario (heavy CO_2 emissions) relative to the current climate (1985–2005). The future scenario minus the present difference is divided by the present values and expressed as a percentage, considering 28 Coupled Model Intercomparison Project - Phase 5 (CMIP5) global climate models, taken from ref. [2] (http://simulaciones.cr2.cl/). Red shading represents a precipitation decrease. The main river basins from which freshwater may be taken (oval) and transferred to northern Chile (arrows) are shown.

release of pollutants (for example, trace elements[4], pesticides, dioxins and furans, and hydrocarbons[5], or even the transport of invasive microorganisms). Moreover, under climate change scenarios, precipitation within the provider basins will substantially decrease, which in turn could limit freshwater access in these communities and their capacity to water crops for agriculture or to use it for other activities. Indeed, this region is a major producer and exporter of cherries, nuts, berries and chemical pulp (https://www.oecd.org/chile/).

These water transfer projects have several precedents around the world, mostly in Mediterranean regions (for example, Ebro, Spain and California, United States)[6]. Defining whether these projects are beneficial for society requires at least a sound cost–benefit analysis (CBA) that: ensures the estimation of the opportunity costs associated with alternative water uses in the provider basins; avoids overestimating receiver benefits (for example, increasing the accuracy of estimated marginal values for agriculture, which tend to be very low)[7]; and incorporates total economic value of environmental impacts[6] in donor basins. This analysis should also assess other management strategies (for example, water quality protection and promotion of sustainable uses) that could provide the same water supply and create other social and environmental benefits, such as pollution reduction, ecotourism and recreation, or an increase in the value of ecosystems. Additionally, a sound evaluation should also consider other incommensurate environmental values that cannot be measured using money[8] and the implications of altering community relationships and social capital[9] in both the receiver and provider basins.

Under ever-intensifying water scarcity across much of the presently semi-arid regions of the world, water transfers may become inevitable to ease regional water deficits. However, to assure water sustainability, the design and enforcement of future water-use regulations must consider their long-term implications, recognizing the connections between inland and marine ecosystems, and understanding their socio-ecological consequences under future climate change. Chile, a country where large-scale hydraulic roads are presently under consideration, may raise the bar with the development of stringent regulations and standards. ❐

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