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Water governance in Chile: Availability, management and climate change

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SUMMARY

Chile has a unique geography that provides an extraordinary variety of climatic conditions and availability of water resources. The objective of this manuscript was to describe and analyze the spatial and temporal distribution patterns, as well as the management of water resources, along a country with a narrow distance from the Andes Mountains to the Pacific Ocean. This presents challenges to water governance from data collection and analysis perspectives, and for administration of the resource. The Water Resources Directorate (*Dirección General de Aguas*, DGA), is the federal government organization in charge of the water resources of the country. The DGA and other relevant public and private institutions are examined in terms of competition and conflict resolution across different scales and levels of interaction associated with water resources governance. Both monitoring stations (rainfall, streamflow, water quality, groundwater, sediment and snowfall), and the Chilean management and legislation of water resources are also analyzed. Finally, the success (or lack) of the national administration to upgrade its monitoring stations and equalize water resources distribution throughout the country is discussed including the influence of climate change on data collection, and decision making across different scales of water governance.

1. Introduction

The status of water resources in Chile, both qualitatively and quantitatively, is information particularly important for the country, not only because of the relevance of water for the survival of the population, but also because its entire economy relies on the use of this resource to ensure the sustainability of its economy and productivity. This is a serious problem, since an intensive use of the resource requires hydrological efficiency to guarantee economic and environmental sustainability; thus, it is crucial to have appropriate public policies to ensure an efficient governance system, as well as information on the availability of water resources in the country, where precipitation shows significant variability. The national average water availability, is close to 54,000 m^3 hab^{-1} yr^{-1} (World Bank, 2011), positioning Chile in the 20th rank in terms of water resources availability (WWAP, 2003). However, most of Chile's population is located in areas of arid and semiarid climates, where water availability is less than 1000 m^3 hab^{-1} yr^{-1}. Therefore, if such natural variability is combined with the possible effects of global warming, which could include the rising of the Zero Celsius Degree Isotherm (ZDI) within the Andes Mountain range (i.e. precipitation switching from snow to rain), the summer water availability could be reduced. This requires efficient public policies to ensure the sustainable use of water resources, in which water governance plays a fundamental role. The objective of this manuscript is to describe and analyze the spatial and temporal distribution patterns of water resources along the country, and how Chile deals with water governance and the management of water resources information, its collection, analysis, and final use.

This paper is divided in 9 sections based on different sub-sections. The territorial division of Chile in terms of administrative regions and basins, as well as topography and the types of climates are described in Section 2. An analysis of the water resources in

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Chile in terms of availability, distribution, and its use is presented in Sections 3–5, considering the current state of precipitation, streamflows, groundwater, glaciers, and the national storage based on dams and lakes. The legal and institutional management of water resources is reviewed in Section 6, from a point of view that deals with water governance aspects i.e. water rights, water regulations, water code, and institutions related to water management. The environmental aspects, as for example the current state of the national monitoring network and the water resources quality is presented in Section 7. A comprehensive review and analysis of water resources and climate change is presented in Section 8; and finally, a critical analysis of the Chilean water governance is developed in Section 9 including a discussion and suggestions to improve future scenarios of national water resources management.

2. Study area

Continental Chile has a long latitudinal extension (more than 4000 km), between latitudes 17°30′S and 56°30′S, and is divided into 15 administrative regions, each headed by a President's appointed Intendant (Fig. 1a). The national territory is compound by around 101 main hydrological basins, with more than 1200 rivers flowing mainly from East to West (Fig. 1b). The geography of the country is mainly dominated by steep mountainous terrains, with only around 20% of the continental territory being flat. The Chilean territory is also characterized by a wide variety of landscapes. It is possible to distinguish, from the morphological point of view, four major geographical units along the country, from East to West: Andes Mountains, Intermediate Depression, Coastal Mountains, and Coastal plains (coastline) (INE, 2011), as shown in Fig. 1c. Using the Köppen's climate classification (Köppen and Geiger, 1954), adapted for Chile by Rioseco and Tesser (2013), a large variety of climates exist through the country, with arid and semi-arid climates in Northern regions, temperate climates in Central-Chile, humid climates in Southern regions, and tundra and polar climates in the Andes Mountains. The oceanic influence can also be observed in the Chilean coastline (Fig. 1d).

3. Water availability

Water availability in Chile is stable. According to World Bank (2010), mean water availability in Chile is 53,953 $m^3\ hab^{-1}\ yr^{-1}$ (Table 1), much higher value than the world average (6600 $m^3\ hab^{-1}\ yr^{-1}$) and also higher than the threshold value internationally considered for sustainable development (2000 $m^3\ hab^{-1}\ yr^{-1}$). However, natural water availability in the country is unevenly distributed; since from the capital (Santiago) to the North, the average water availability is about 800 $m^3\ hab^{-1}\ yr^{-1}$, a value clearly insufficient, but representing the water supply for more than 60% of the national population. Contrastingly, South of Santiago water availability overpasses 10,000 $m^3\ hab^{-1}\ yr^{-1}$ (World Bank, 2011).

Furthermore, a more detailed analysis of water availability shows significant differences in annual volumes. In arid and semi-arid regions, located between 17°30′ and 34° (i.e. Arica y Parinacota and Metropolitan regions, where Santiago is located), water availability can reach, in some cases, 200 $m^3\ hab^{-1}\ yr^{-1}$. Water demands are larger than the available surface runoff, and the demand is covered by groundwater in order to meet municipal, industrial and mining which severely deplete the resource. Further South water availability begins to exceed the demands between O'Higgins and Los Rios regions (34°S to 40°33′S). South of Los Lagos Region (40°15′S) water supply significantly exceeds demands due to the humid climate, except for the cold semiarid zones on the extreme South of the country. This wide latitudinal variability in water offer represents an alarming future for the country in terms of water resources and management, since demands are expected to increase, while availability is expected to decrease (CONAMA, 2006; Trenberth et al., 2007).

4. Distribution of water resources

4.1. Precipitation

An understanding of the topographic variability in the country is crucial to understand its variability in precipitation. The latitudinal

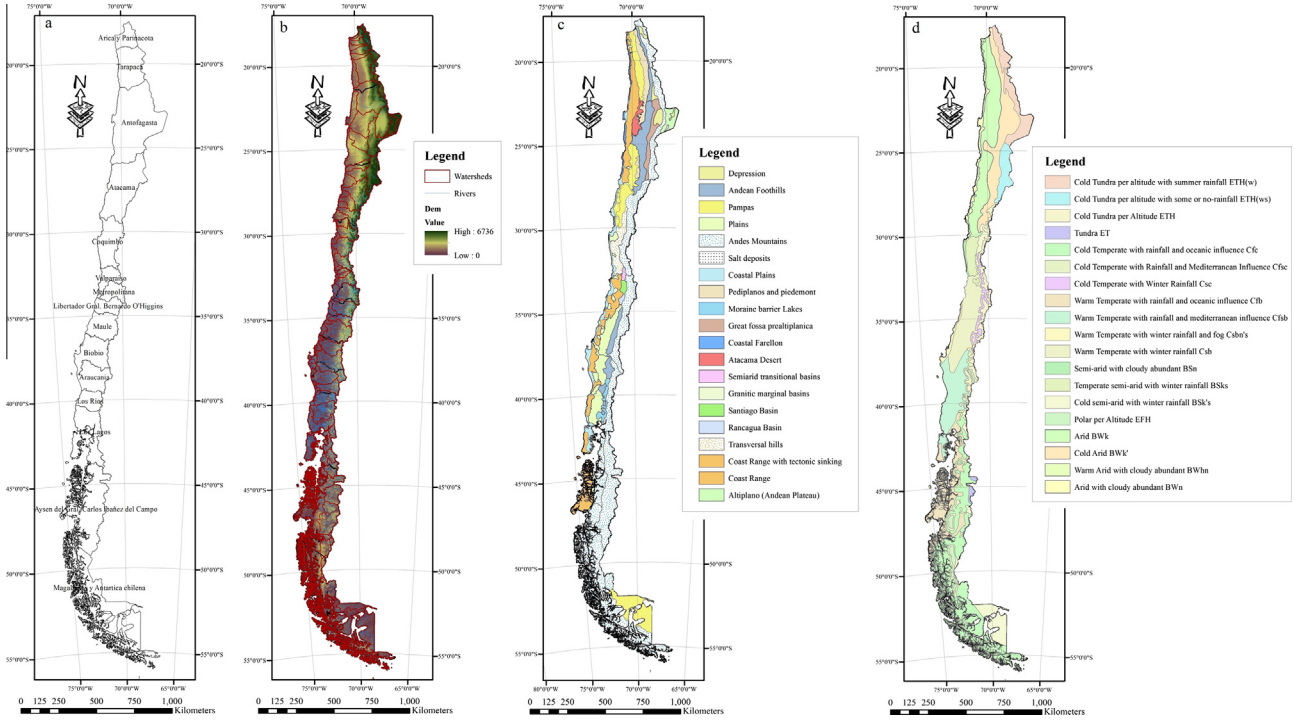

Fig. 1. (a) Administrative Regions, (b) main basins, (c) topography, and (d) climates of Chile. *Source*: Geographic Information was extracted from Albers (2012).