We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

Chapter

The Availability of Water in Chile: A Regional View from a Geographical Perspective

Javier Lozano Parra, Manuel Pulido Fernández and Jacinto Garrido Velarde

Abstract

Chile is famous for being the longest country in the world from north to south. It means it ranges from polar to desert conditions, water being one of the main limiting factors. In fact, Chile stores a high amount of water (695 mm y^{-1}), but people are not located in the regions where water is more abundant (e.g. in the south). This territorial imbalance is accompanied both by a global context of climate change in which water will be presumably scarcer and by the effects of the current economic activities that are progressively more demanding in water consumption. In this work, we have compared both the current and future availabilities of water for the different regions of Chile in order to provide relevant and useful information on the water balance for land planners. The Metropolitan and Valparaíso regions (Mediterranean climate) along Antofagasta, Atacama, and Tarapacá regions (desert climate) showed the lowest mean values of water availability from 1970 to 2000 (<125 m^3 person y^{-1}). In addition, both the optimistic and pessimistic projections for 2050 forecast a significant increase in the aridity of these two central regions, where the crucial axis between the two most important cities (Santiago and Valparaíso) is located.

Keywords: territorial imbalances, climate change, dynamics, metropolitan areas, sustainability

1. Introduction

Water satisfies several key roles for environmental sustainability and human development: it guarantees the people health and economic development and constitutes the backbone of ecosystems. However, it is irregularly distributed in space and time and frequently is carelessly used to the development of economic activities. According to different economic sectors, just agriculture uses, on average, more than 70% of the water resources in the world to produce food. Thus, the variation of climate patterns will necessarily have an impact on the food supply and its price.

The evidence that mankind faces hydrological and environmental issues is increasingly frequent and visible to the society. This became especially clearer after the last UN Climate Change Conference COP 25, since several countries (such as Spain or France) have declared the climate emergency. Despite this, the results of this meeting have been criticized by several scientific sectors because of their lack of ambition, so that it is valuable to continue making visible the importance of water resources studies and how they will be affected by future climate variations.

In a national context, available water should not be a problem for Chile since it is one of the countries with the highest amounts of water per person [1]. From the year 1970 to 2000, Chile averaged an annual rainfall of 1006 mm (main input) and evapotranspiration of 311 mm as main output, so it has 695 mm of surplus [2]. In terms of storage, it has supposed to be more than 500 km^3 of water susceptible to be used in human activities every year.

Nonetheless, this significant global amount hides a great spatio-temporal variability depending on natural and socio-economic features of each region. A good example of this contrast between regions is the existing difference between the southern regions where water is abundant but people are few and the northern and central ones where population densities are too high in comparison to the availability of water.

There are many situations in which natural conditions are combined with factors, such as economics, to give place to a long water crisis in Chile [3]. For example, if economic activities by sectors are considered, the largest user of water resources in Chile is agriculture, which consumes up to 75% of the water resources at a national scale [4]. This could be justified because it supplies water for an irrigated land of larger than 1 million ha, which is mostly located in the central zone of Chile [5]. Irrigated areas have significantly increased the use of water resources in the last decade. Besides, some products have increased the area for its cultivation.

Among themselves, the crops of avocado (*Persea americana*) have increased 43% in terms of land surface during the last decades, Chile being the second producer country in the world. Avocado is indeed a species that records a water print of 715 l/kg exported, significantly higher than more traditional crops [6]. Most of the Chilean economy is based on natural resources, with a strong export-focused activity [7]. Despite this, in many regions of the country, the uncontrolled exploitation exceeds the actual availability of water resources. This has led to declare numerous regions as depleted in both surface and groundwater [4].

This situation could be even more worrying according to the effects of climate change foreseen by the scientific community. In the particular case of Chile, a reduction between 20 and 40% of total rainfall has been already reported [8]. Added to this, the lack of vegetation management in the upper areas of the watersheds and the elevation of the isotherms have increased water demand and reduced snow deposits, respectively, giving place to a strong decrease of river discharge. An intensive demand for water resources and a decrease in them requires knowing the water availability both in the present and in the future, in order to develop hydrological plans to guarantee economic and environmental sustainability.

Taking into account the abovementioned, this work is focused on the analysis of both the current and future water balance of each one of the administrative regions of Chile since they are the appropriated scale in which decisions on land planning should be made. The reasons of choice this scale work is twofold; on the one hand, Chile is divided into longitudinal regions easily assignable to climatic belts, and, on the other hand, they are the regional governments who are in charge of the regional administrations and consequently in charge of their land and water management. In addition, this research should be also useful to become aware of the upcoming effects of climate change, foreseen by reliable predictive models in every scenario (optimistic and pessimistic), that serve to discuss about the sustainability of many of the current human activities.

DOI: http://dx.doi.org/10.5772/intechopen.92169

2. Material and methods

2.1 Study area

The study was carried out in the whole continental territory of Chile, excluding its islands and the Chilean Antarctic Territory. The size of the study area is 4270 km of distance from north to south and a width (from west to east) ranging from 90 to 445 km involving a great sort of different climate types (cold, temperate, Mediterranean, desert, and high mountain). The limits of the Continental Chile are Peru and Bolivia in the north, the Andes in the east, the Pacific Ocean in the west, and the Drake Passage in the south, Argentina being the country in whom Chile shares more kilometers of border.

This territory is inhabited by around 18 million people with a relatively high standard of living (according to the main macroeconomic indicators) within the context of Latin America. It is divided since 2017 into 16 regions, 56 provinces, and 346 communes. Each region has its own regional government headed by the intendant and the member of the Regional Council (elected every 4 years). These regions keep its original Roman number from I to XII following a gradient from north to south. The Metropolitan Region has the number XIII; and three new regions recently created have continued this tradition (**Figure 1**).

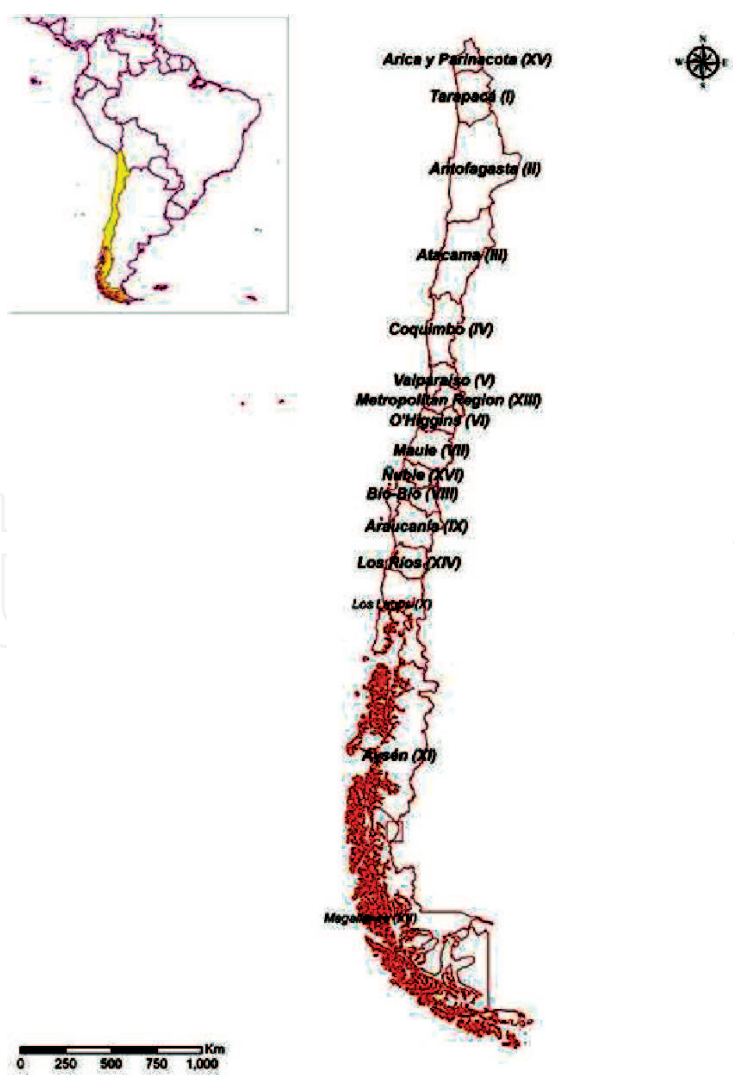

Figure 1.
Geographical distribution of the Chilean regions.

2.2 Water balance

The water balance by region at an annual scale was estimated considering precipitation as the main input and evapotranspiration as the main output of the system, i.e. a positive surplus means precipitation > evapotranspiration and a negative surplus evapotranspiration > precipitation. These data were obtained from Fick and Hijmans [2] for the period 1970–2000 that is considered as the reference period to study changes in climatic variables. Evapotranspiration was determined by using the Turc method [9]. The total land surface of each one of the 16 regions (used to estimate the total amount of water expressed in km^3) and their population (used to quantify the total amount of available water per person) was sourced by Chilean official statistics. Since Ñuble Region (XVI) was officially created in September 2018, its values have been considered within the region of Bio-Bio in which Ñuble was previously included.

2.3 Predictive models

The predictive models utilized in this work were proposed by the Intergovernmental Panel on Climate Change (IPCC) in 2013 [10]. Within those global models used in the fifth stage of the inter-comparison of coupled models, we have chosen the predictions given by the model MIROC5 for 2050 because it has been successfully tested in neighbor countries such as Peru [11]. We have considered two scenarios: (a) RCP 4.5 that assumes an increasing trend in the concentration of greenhouse gases (GHG) until 2040 (the most optimistic) and (b) RCP 8.5 that assumes an increasing trend in GHG concentration for the whole twenty-first century (the most pessimistic).

3. Results

3.1 Regional differences in water availability

Figure 2 shows the mean values (1970–2000) of water surplus per person for each one of the Chilean regions. The lowest values have been recorded in the Metropolitan Region (due to its high population density) and the desert regions of Antofagasta y Tarapacá. Contrariwise, the highest values were observed in Aysén, Magallanes, and Los Lagos. The regions of the north of Chile show relatively low values of annual water comparing inputs by rainfall and losses by evapotranspiration. Of particular interest are the central regions of the country where, on the one hand, the dominant climate is Mediterranean (naturally erratic) and, on the other hand, the pressure for water resources is particularly higher (the Metropolitan region of Santiago is inhabited by more than 7 million people, for instance).

In fact, the highest spatial variability was observed in the central regions of the country where, regardless people and their activities, they show a significant contrast in natural water surplus. These differences start to be visible in the Region of Valparaíso (V) where climatic conditions change to Mediterranean and evapotranspiration is significantly reduced. The five northern regions of Chile (Arica and Parinacota, Tarapacá, Antofagasta, Atacama, and Coquimbo) are scarce in precipitation (<250 mm y^{-1}), and their evapotranspiration is also high (>600 mm y^{-1}), but their needs in water keep in consonance with other regions because their population density is less than 20 people km^{-2} in the best of the cases. These values contrast to the Metropolitan Region (462 people km^{-2}) and Valparaíso Region (111 people km^{-2}).

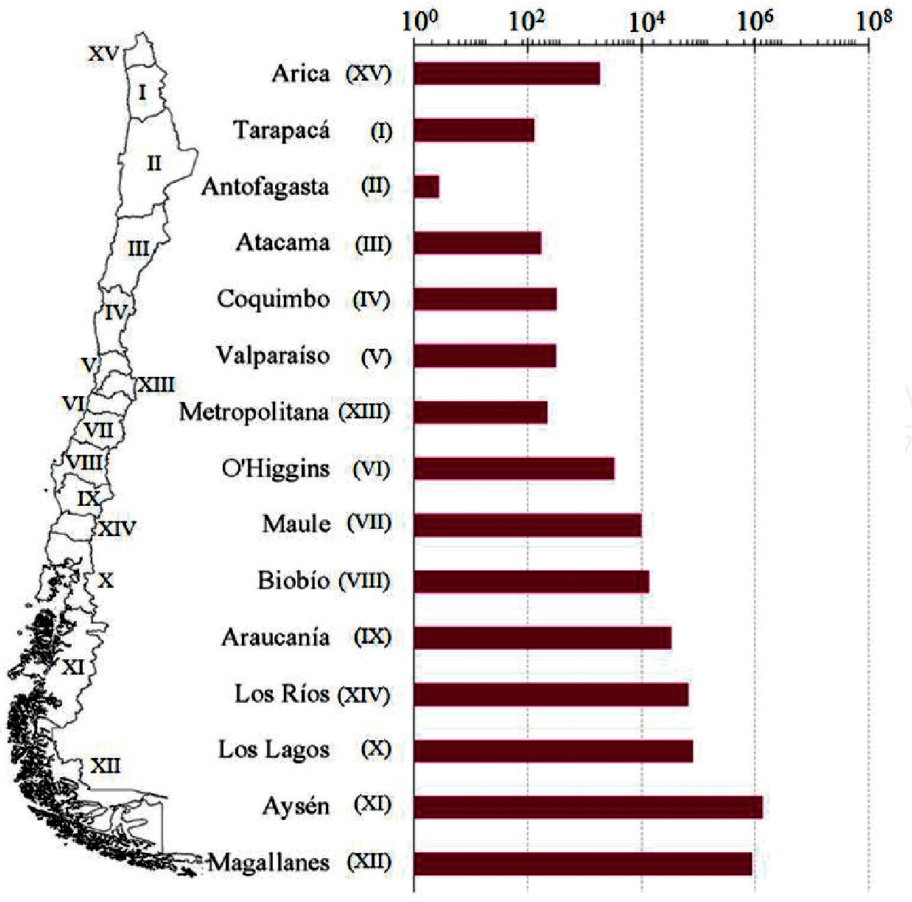

Figure 2.
Regional distribution of the mean annual values of water surplus in Chile (period: 1970–2000).

3.2 Future scenarios

The (optimistic and pessimistic) predictions considered in this research returned similar values for 2050. It means the effects of climate change will be particularly remarkable in the central regions of Chile, characterized by their Mediterranean climate type and their high population densities. Both scenarios foresee the highest decrease in annual precipitation (**Figure 3A**) and increase in evapotranspiration (**Figure 3B**). Regarding water surplus they forecast annual losses of about 1000 mm y^{-1} in many regions of the country (**Figure 3C**). These losses are particularly worrying in the centre where most of Chilean people are now living.

The existing differences between both scenarios (optimistic vs. pessimistic) are not significantly different between them. For instance, the most optimistic foresees a reduction of 936 mm y^{-1} in precipitation and the pessimistic one of 1052 mm y^{-1}. Regarding water surplus, both scenarios forecast losses around 1000 mm y^{-1} (optimistic, 968 mm y^{-1}, vs. pessimistic, 1094 mm y^{-1}) regardless of the number of people and the water consumption of their agricultural activities. In the south of the country, the model returns predictions of an increase in precipitation much higher than the foreseen increase in evapotranspiration. It means much more available water will be in the south, and perhaps it can suppose migrations from the north and central of the country to these regions. Regarding the desert regions of the north of Chile, the future situation will be presumably similar than the current one. So, no significant effects on local population are expected.

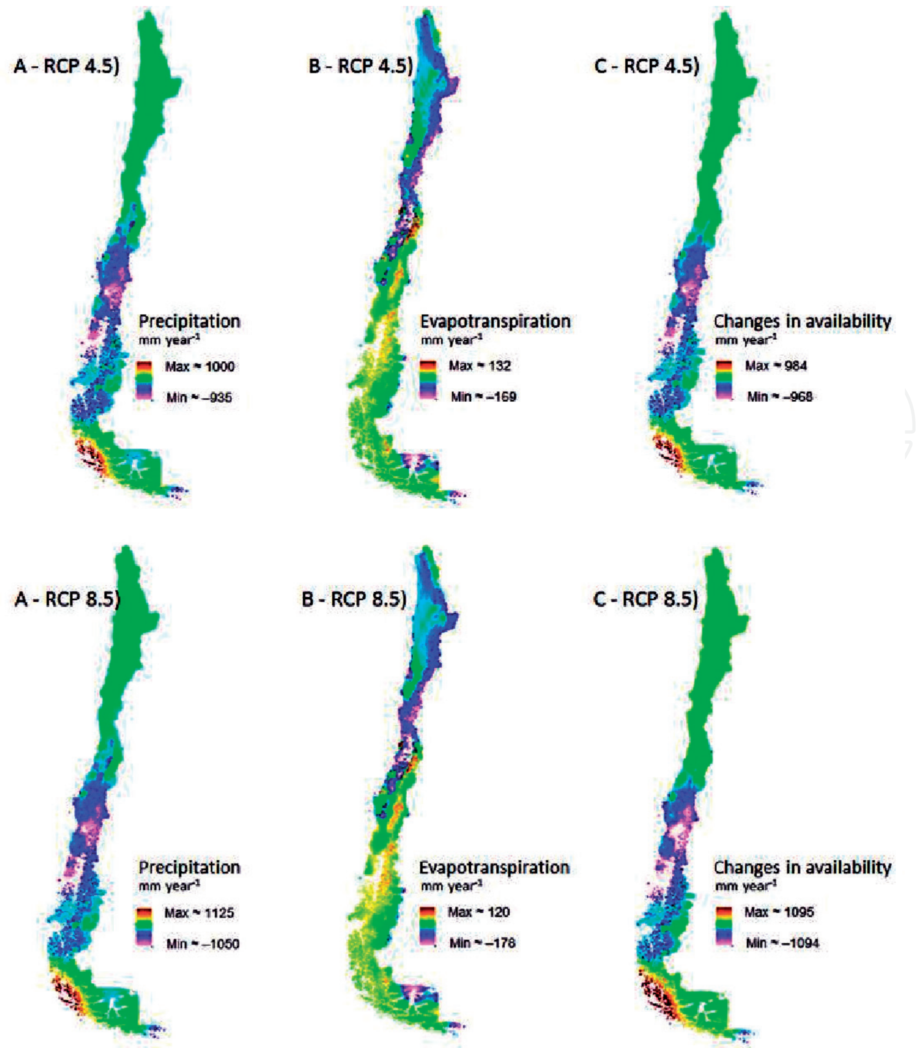

Figure 3.
Differences between the averaged values of the period 1970–2000 and those foreseen by the predictive models for 2050.

4. Discussion

Although the effects of climate change on the water availability of Chile are well-known, or well-guessed, by the majority of people, their needs and demands in water are continuously increasing. For instance, the official organization in charge of water management (DGA, Dirección General de Aguas in Spanish) is still granting new rights for water exploitation in the regions of the north of Chile in spite of the thresholds of natural recharge of the aquifers having been already exceeded [5]. In addition, in this work we are not addressing further effects of this water scarcity such as salinization, really negative in semiarid countries such as Algeria [12].

In the north of Chile, the use of water is related to mining activities. The price of copper has significantly increased and it has supposed catalysis in mining activities, i.e. a much higher consumption of water by these companies [4]. Other sectors such as the energetic (e.g. hydroelectric) are also intensifying their pressure on water resources since they are now living an expansionist time [3], perhaps provoked by many decades of criticism against the use of fossil energies such as petrol and coal or the pressure exerted by conservationists that consider wind turbines to be dangerous for birds [13].

Regarding the agricultural sector, water is progressively being more demanded because of the growth of population in Chile and the increase in the amounts of products exported to the global market [14]. It is provoking a higher scarcity and more competition for water in the whole country. In fact, Larraín and Poo [3] have reported a worrying increase in the number of conflicts related to (spatially unequal) water management. Most of these conflicts are happening in the central and north of Chile where water has become a valuable good due to erratic climatic conditions (Mediterranean and semiarid climates) and increasing pressure of the economic sectors [4].

Water management will be a challenging question for any regional and national government of Chile. The reserves of water in the aquifers and the estimation of the accurate consumption of water by people, mining, and different commercial crops such as avocado will decide the sustainability of this valuable resource. Specifically, in the agriculture, the recent crops (thought for exportation) are important consumers of water. In fact, most of them grow naturally in tropical conditions, and they are produced in Chile by using irrigation water [15].

The branch of knowledge, with an outstanding global success, that is dealing this problematic is being the ecohydrology, recently popularized and key as scientific support for making decisions on water and land management properly by the political power [16]. So, we consider countries at risk of having serious problems of water availability; Chile, Spain, and Israel, for instance, should pay more attention and promote more specific research programmes for ecohydrologists. Studies on land capability of some crops and on the sustainability of traditional systems such as the *espinal* we think are more necessary than ever.

Another challenging task both for scientists and decision-makers is the proper scale of work. Here we have emphasized about the existing differences between the 16 administrative regions of Chile, but it is totally necessary to know the mechanisms that rule in a leaf, plant, farm, and catchment, among other work scales. In addition, the rights for water exploitation granted by the DGA should be very strict in terms of the total amount of water per year that each company must utilize. These rights should vary in time according to the rainfall variability or presumably increasing in evapotranspiration, i.e. companies and/or public agencies should have tools for monitoring water reserves constantly.

Another aspect that can be also discussed by the scientists and decision-makers, although it is not the *leitmotiv* of this work, is the usefulness of using long-term datasets. It means an extraordinary effort in monitoring many parameters linked to water and vegetation is still needed since datasets of more than 10 years are still infrequent [17]. Some published works based on long-term datasets [18, 19] have contributed to understand the interrelationships between ecohydrological processes and the time of adaption with respect to the arrival of environmental changes.

In this study, we have shown the variation in water surplus for 2050, but nothing has been mentioned about the synergetic interaction between water and vegetation. The presence of vegetation is a cause and consequence of the presence of water and vice versa [15]. For instance, the spatial vegetation patterns exert a strong control on the spatio-temporal variability of soil moisture and, consequently, on water infiltration or redistribution of water through soil macropores [20]. In addition, it is soil moisture content who determines species phenology and biomass production [21].

The works published on this topic in the last decades have served to understand that the existing relationships abovementioned between water and vegetation parameters are nonlinear. According to Scheffer et al. [22], these relationships are based on thresholds, i.e. some properties keep on a stable status until they cross a certain threshold. It means that ecosystems of Central Chile that traditionally have been Mediterranean (dry subhumid) can change to semiarid and keep steady for decades and centuries. Nonetheless, the concept of stable status has just arrived to the studies of ecohydrology. So, further research is still necessary to draw definitive conclusions.

Every ecosystem is controlled by the availability of water that it is naturally provided, but it can be worn up by human activities. In the ecosystems in which water is naturally abundant, the control of ecohydrological processes is ruled by the level of the water table [15]. Meanwhile in Mediterranean and semiarid ecosystems, ecohydrological processes are adapted to different moment or pulses ruled by water surplus or deficit in the non-saturated soil zone [23]. To investigate these mechanisms and processes to better understand the sensitivity of each ecosystem face environmental disturbs is the main challenge of the ecohydrology.

5. Conclusion

The availability of water in Chile is of crucial interest for the near future since it is one of the countries that will be more affected by climate change. The regions that show a higher risk are those located in the central part of the country that are ruled by dry subhumid conditions (Mediterranean climate type) and inhabited by almost half of the total population. This forecast should serve the decision-makers to prepare a new scenario in which high consuming crops in water such as avocado (*Persea americana*) and mining activities perhaps cannot be exploited due to lack of water. Another controversial question that should be treated in the future is the role in water management of the DGA (*Dirección General de Aguas*) since it is a national agency and the regional differences detected can be a good indication of the necessity of making decisions at a regional level, i.e. by the regional governments of each one of the current 16 regions of the country. Finally, more efforts in data collection are still needed both by part of the scientists and by governments that grant research programmes, funds, and scholarships.

Acknowledgements

This study has been possible by funding provided by the Fondo Nacional de Desarrollo Científico y Tecnoóógico [FONDECYT 11161097] and by the Programa de Cooperaóión Internacional para la Formóción de Redes Internacionales de Investióación [REDI170640], both granted by the Government of Chile.

Author details

Javier Lozano Parra[1*], Manuel Pulido Fernández[2] and Jacinto Garrido Velarde[2]

1 Pontifical Catholic University of Chile, Santiago, Chile

2 Research Institute for Sustainable Territorial Development, Cáceres, Spain

*Address all correspondence to: jlozano@uc.cl

References

[1] Lajaunie M, Scheierling S, Zuleta J, Chinarro L, Vazquez V. Chile: Diagnóstico de la gestión de los recursos hídricos. Washington, DC, USA: World Bank; 2011

[2] Fick SE, Hijmans RJ. WorldClim 2: New 1-km spatial resolution climate surfaces for global land areas. International Journal of Climatology. 2017;**37**:4302-4315

[3] Larraín S, Poo P. Conflictos por el agua en Chile: Entre los derechos humanos y las reglas del mercado. Santiago de Chile: Heinrich Böll Foundation; 2010. pp. 362

[4] Rivera D, Godoy-Faúndez A, Lillo M, Alvez A, Delgado V, Gonzalo-Martin C, et al. Legal disputes as a proxy for regional conflicts over water rights in Chile. Journal of Hydrology. 2016;**535**:36-45

[5] Hearne R, Donoso G. Water markets in Chile: Are they meeting needs? In: Water Markets for the 21st Century. Springer; 2014. pp. 103-126

[6] Juárez Laguna YF. Impacto del cambio climático en la disponibilidad de agua para el cultivo de palta. Lima: Universidad Científica del Sur; 2019

[7] Valdés-Pineda R, Pizarro R, García-Chevesich P, Valdés J, Olivares C, Vera M, et al. Water governance in Chile: Availability, management and climate change. Journal of Hydrology. 2014;**519**:2538-2567

[8] Gironés Mompó FJ. Evaluación de las predicciones climáticas de modelos globales en Chile. Valencia: Universitat Politècnica de València; 2019

[9] Turc L. Estimation of irrigation water requirements, potential evapotranspiration: A simple climatic formula evolved up to date. Annales Agronomiques. 1961;**12**:13-49

[10] Intergovernmental Panel on Climate Change. Climate Change 2013: The Physical Science Basis: Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. New York: Cambridge University Press; 2014

[11] Moya Álvarez A, Ortega León J, Jurado PX. Evaluación del Modelo Climático Global MIROC5 y estimaciones de temperatura y precipitaciones para las zonas sur y norte del Perú. Apuntes de Ciencia & Sociedad. 2015;**5**:188-195

[12] Abdennour MA, Douaoui A, Bradai A, Bennacer A, Pulido FM. Application of kriging techniques for assessing the salinity of irrigated soils: The case of El Ghrous perimeter, Biskra, Algeria. Spanish Journal of Soil Science. 2019;**9**:105-124

[13] Sovacool BK. Contextualizing avian mortality: A preliminary appraisal of bird and bat fatalities from wind, fossil-fuel, and nuclear electricity. Energy Policy. 2009;**37**:2241-2248

[14] Rodell M, Famiglietti J, Wiese D, Reager J, Beaudoing H, Landerer FW, et al. Emerging trends in global freshwater availability. Nature. 2018;**557**:651-659

[15] Rodriguez-Iturbe I, D'Odorico P, Laio F, Ridolfi L, Tamea S. Challenges in humid land ecohydrology: Interactions of water table and unsaturated zone with climate, soil, and vegetation. Water Resources Research. 2007;**43**:1-5

[16] Eagleson PS. Ecohydrology: Darwinian Expression of Vegetation Form and Function. Cambridge University Press; 2005

[17] Lewis D, Singer M, Dahlgren R, Tate K. Hydrology in a California oak woodland watershed: A 17-year study. Journal of Hydrology. 2000;**240**:106-117

[18] Asbjornsen H, Goldsmith GR, Alvarado-Barrientos MS, Rebel K, Van Osch FP, Rietkerk M, et al. Ecohydrological advances and applications in plant–water relations research: A review. Journal of Plant Ecology. 2011;**4**:3-22

[19] Seneviratne SI, Corti T, Davin EL, Hirschi M, Jaeger EB, Lehner I, et al. Investigating soil moisture–climate interactions in a changing climate: A review. Earth-Science Reviews. 2010;**99**:125-161

[20] Lozano-Parra J, Schaik NLMB, Schnabel S, Gómez-Gutiérrez Á. Soil moisture dynamics at high temporal resolution in a semiarid Mediterranean watershed with scattered tree cover. Hydrological Processes. 2016;**30**:1155-1170

[21] Lozano-Parra J, Schnabel S, Ceballos-Barbancho A. The role of vegetation covers on soil wetting processes at rainfall event scale in scattered tree woodland of Mediterranean climate. Journal of Hydrology. 2015;**529**:951-961

[22] Scheffer M, Carpenter S, Foley JA, Folke C, Walker B. Catastrophic shifts in ecosystems. Nature. 2001;**413**:591-596

[23] Lozano-Parra J, Maneta MP, Schnabel S. Climate and topographic controls on simulated pasture production in a semiarid Mediterranean watershed with scattered tree cover. Hydrology and Earth System Sciences. 2014;**18**:1439-1456