Diagnosis of catchment water allocation in Chile in a non-stationary natural system

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ABSTRACT

The geography of Chile, characterised by a narrow and long strip of land located between the high ranges of the Andes mountains and the Pacific Ocean, provides an exceptional scenario for analysing spatial and temporal variability of climate and water resources. Chile is positioned in the 20th rank of water availability per capita, however, around a 70% of the national population is located in arid and semiarid regions. These regions have experienced significant water shortages during the last decade, which have affected water security and ecosystems.
Therefore, water shortages and water governance are major issues to be addressed in Chile in the Anthropocene. Regarding water governance, the Chilean water allocation system is based on a water use rights (WURs) market, with limited regulatory and supervisory mechanisms, where the volume to be granted as permanent and eventual WURs is calculated from streamflow records when they are available. A recent study on a semi-arid catchment in central Chile emphasized the urgent need to revise the water allocation methodology, which at the moment does not account for the non-stationarity of hydrological processes. This limitation has caused an over-exploitation of water supplies in the study catchment.
To further explore these allocation system limitations and to provide robust recommendations, in this study we extend the former study and provide the first large sample diagnosis of water use rights and water supply, covering 516 basins from the catchment dataset for large sample studies in Chile, CAMELS-CL. With this approach, we are shortening the geographical gap of information, covering regions that are poorly documented, such as high elevation or austral catchments of Chile. Furthermore, we postulate this information as a tool to prioritise the resources to address water scarcity and water management in the country.

METHODOLOGY

According to the Chilean Water Directorate (Dirección General de Aguas, DGA) and as governed by the Water Code, the available water supply in a catchment for granting WURs is determined on a monthly basis as follows:

Permanently exercisable water rights (PEWRs): $Q_{available\ permanently\ i} = Q_{85\ i} - Q_{ecol\ i}$

Where,
$Q_{85\ i}$ = 85% probability of exceedance runoff for month i
$Q_{ecol\ i}$ = Ecological runoff for month i

Monthly ecological runoff is calculated as follows:
If 50% of the $Q_{95\ i}$ is less than 20% of mean annual runoff, then

$$Q_{ecol\ i} = 0.5 \times Q_{95\ i}$$

If 20% of mean annual runoff is less than 50% of $Q_{95\ i}$, then

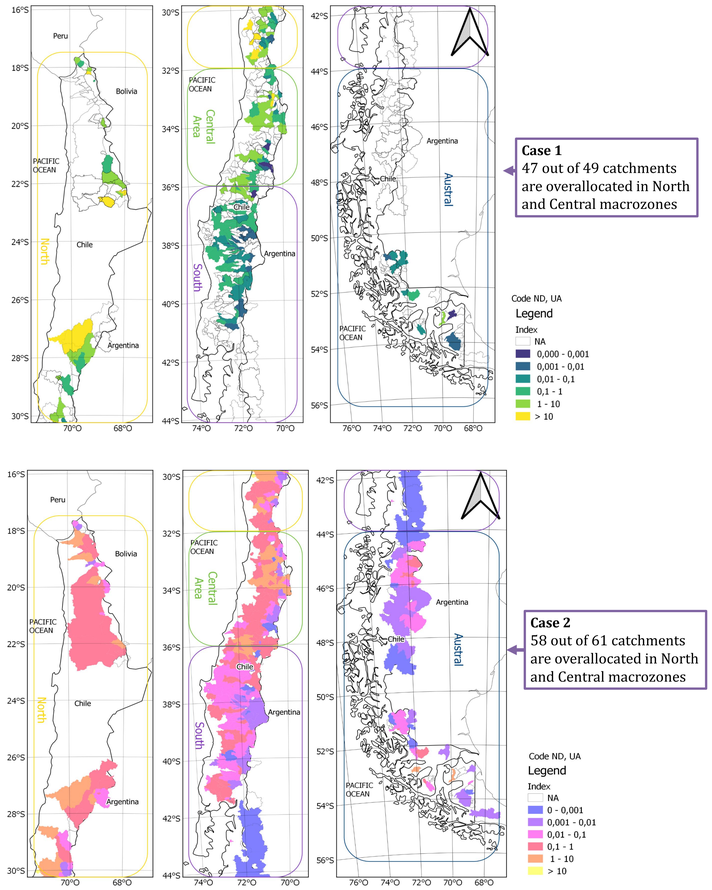
$$Q_{ecol\ i} = 0.2 \times Q_{annual}$$

On the other hand, the DGA considers only WURs that were granted after the Water Code promulgation in 1981 (Code ND and UA) in the estimation of the Water Balance, under the assumption that older WURs (code NR) are already discounted from runoff measurements normally operating after 1970.

To explore the performance of the allocation system we calculated indices that account for the degree of intervention in a large sample catchments dataset (Camels-CL; Alvarez-Garreton et al., 2018) considering four cases:

(1) Granted PEWRs following the DGA procedures (ND+UA codes)
$$I_{intervention} = Granted\ PEWR / \ Q_{available\ permanently}$$
(2) Granted PEWRs following the DGA procedures (ND+UA codes) normalized by the 85% probability of exceedance annual precipitation $I_{intervention} = Granted\ PEWR / \ P_{85}$
(3) Granted PEWRs including "old" WURs (ND+UA+NR codes
$$I_{intervention} = Granted\ PEWR / \ Q_{available\ permanently}$$
(1) Granted PEWRs including "old" WURs (ND+UA+NR codes) normalized by the 85% probability of exceedance annual precipitation $I_{intervention} = Granted\ PEWR / \ P_{85}$

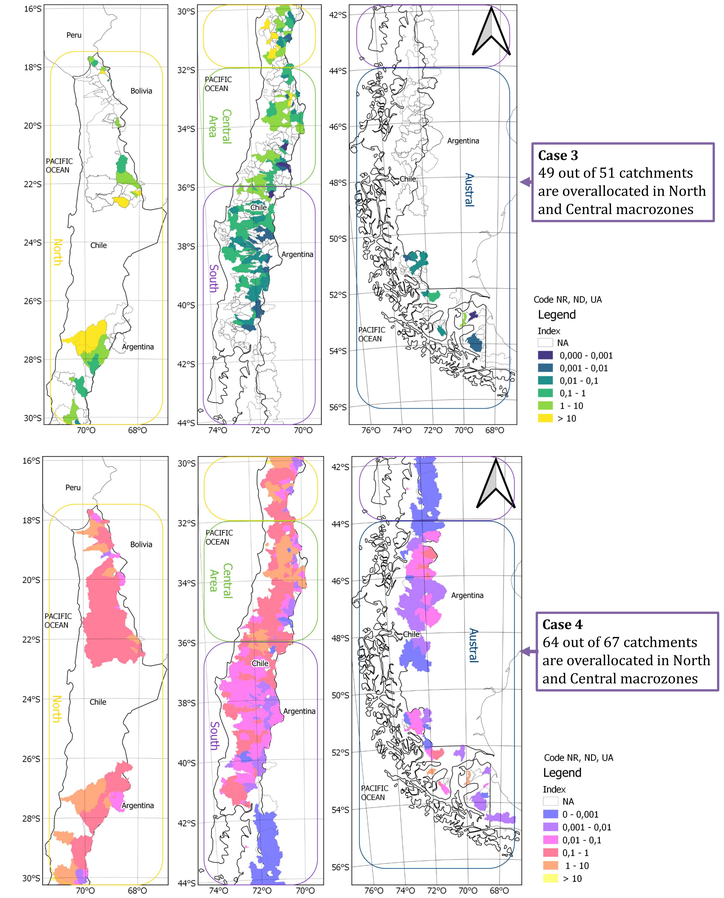
RESULTS CONSIDERING ONLY NEW WURs (ND+UA)



Case 1
47 out of 49 catchments are overallocated in North and Central macrozones

Case 2
58 out of 61 catchments are overallocated in North and Central macrozones

RESULTS CONSIDERING ALL GRANTED WURs (ND+UA+RN)



Case 3
49 out of 51 catchments are overallocated in North and Central macrozones

Case 4
64 out of 67 catchments are overallocated in North and Central macrozones

CONCLUSIONS AND FUTURE WORK

In conclusion, the methodology used by the DGA to estimate the water balance and the water availability for granting WURs in Chile requires the runoff time series to be stationary, which considering current negative trends of runoff (Barria et al, 2018) is not an accurate assumption. Currently most of catchments located in the North and Central areas of Chile are over-allocated. That result is observed under the four cases here analysed, and is more critical when old WURs (NR) are included in the analysis. WURs' calculations need to be reviewed and revised in order to improve water use and distribution and ensure the conservation of ecological flows and ecosystem services in the region. Similarly, legal frameworks for water management in Chile require important reconsiderations in order to ensure their coherence with the biophysical framework of the country, especially in the context of climate change.

Following Barria et al. (2019) methodology, **future work** considers to estimate water availability and to test the water allocation system in the 516 catchments collated by Camels-cl (Alvarez-Garreton et al., 2018) under different climate change scenarios. Then, we aim to provide guidelines for water management based upon our results.

References

Alvarez-Garreton, C., Mendoza, P. A., Boisier, J. P., Addor, N., Galleguillos, M., Zambrano-Bigiarini, M., ... & Ayala, A. (2018). The CAMELS-CL dataset: catchment attributes and meteorology for large sample studies-Chile dataset. *Hydrology and Earth System Sciences*, *22*(11), 5817-5846.
Barria, P. A., Peel, M. C., Walsh, K. J., & Garreaud Salazar, R. (2018). Analysis of within and between-GCM uncertainties of runoff projections in Mediterranean-like catchments.
Barria, P., Rojas, M., Moraga, P., Muñoz, A., Bozkurt, D., & Alvarez-Garreton, C. (2019). Anthropocene and streamflow: Long-term perspective of streamflow variability and water rights. *Elem Sci Anth*, *7*(1).