Identifying driving processes of drought recovery in southern Andes natural catchments

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Introduction

Drought effects on terrestrial ecosystems produce hydroclimatic stress with variable extensions. Particularly, hydrological drought duration can provide a better understanding of recovery together with catchment characteristics and climatology. This study focuses on the impacts of the multi-year drought experienced in Chile for more than a decade. The recovery of relevant catchment variables to quantify the drought termination (DT) and drought termination duration (DTD) after the hydrological drought is presented. A composite analysis (CA) over natural catchments of the CAMELS-CL data set discharge (1988-2020), k-NDVI (2000-2020) and soil moisture (1991-2020) provides the average response of the recovery after severe droughts. This work enables the identification of drought vulnerability, which is valuable for managing water resources and ecosystems and is helping to predict drought recovery in regions with a lack of observations. In this study we aim at 1) quantifying the length of the drought recovery in their extension and magnitude, 2) identifying spatial patterns related to drought recovery and, 3) analyzing and relating drought events to environmental factors such as hydrological properties.

Methods

Main objective

Study impacts of climate and catchment properties on hydrological drought recovery in natural undisturbed catchments in Chile.

Data

- Discharge of 163 natural catchments from CAMELS-CL at daily m^3/s.
- Vegetation productivity (kNDVI) from MODIS, daily and 500m resolution.
- Soil moisture from CCI, daily and 0.25 degrees resolution from first 10 cm.

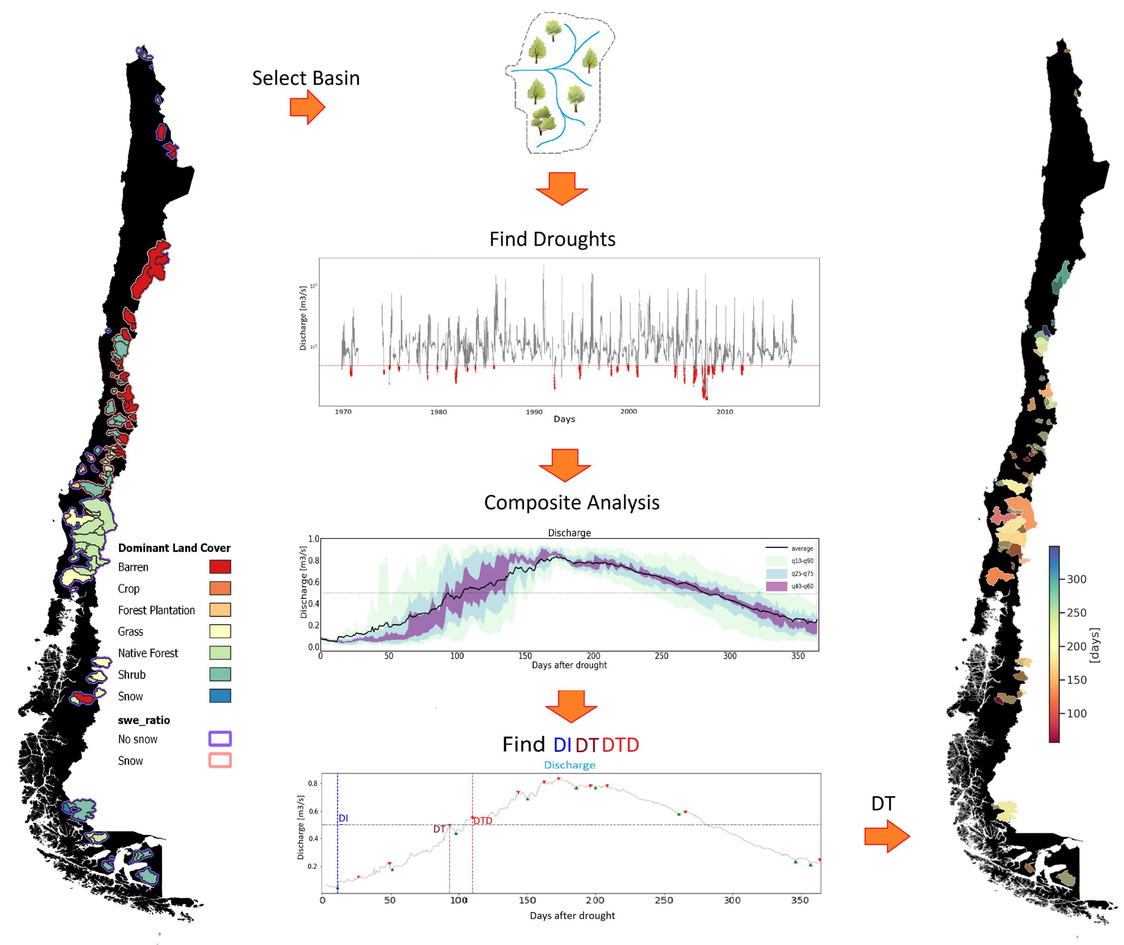
$$kNDVI = \tanh\left(\left(\frac{NIR - red}{2\sigma}\right)^2\right)$$

Drought events and Composite Analysis

A fixed threshold approach was used to define drought events with a percentile threshold of 80% for the daily streamflow anomalies following Wanders and Wada (2015) & Van Loon *et al.* (2016). In the case of drought events, a negative response to droughts from discharge, vegetation productivity, and soil moisture is expected for a year after the event. If drought events satisfy our selection criteria, the timing of those events is selected as key times and grouped per catchment. The drought response signal for each of the variables is isolated by calculating the average drought behaviour in time, over which the DT and DTD are determined.

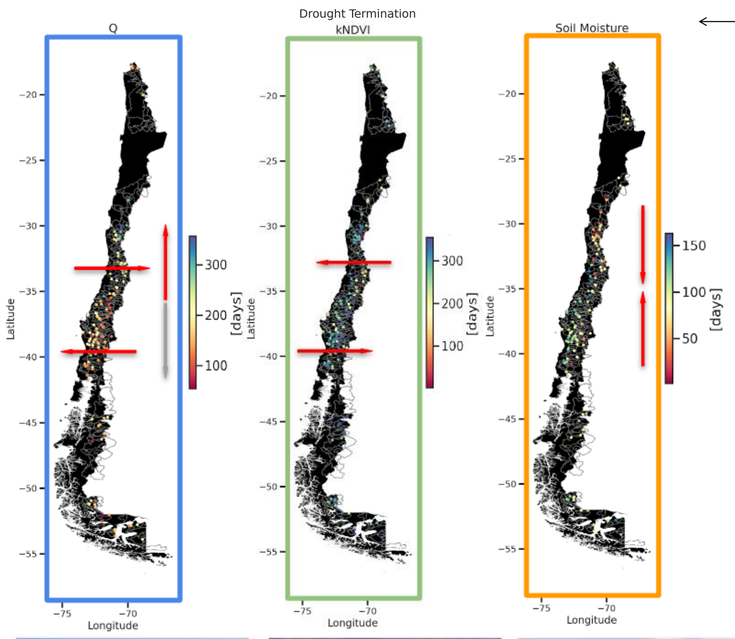
Drought Termination

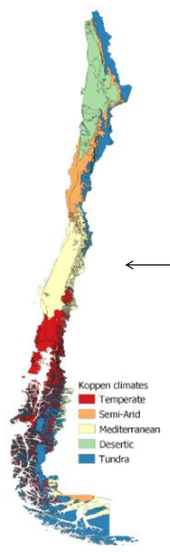
Drought termination can be characterized by its duration, rate of recovery, and seasonality. The ensemble mean from the CA was used for the identification of the Drought development and Drought Termination. The first day of the drought termination corresponds to the day where a minimum peak is reached after the drought event starts (DI in Figure). The drought ends when the signal exceeds the Q80 threshold, however, the last day of the drought termination (DT) phase is found when the normalized threshold of 0.5 is reached. This threshold is selected due to the normalization method (Parry *et al.,* 2016).



Results and Conclusions

Recovery after hydrological drought





Drought recovery patterns

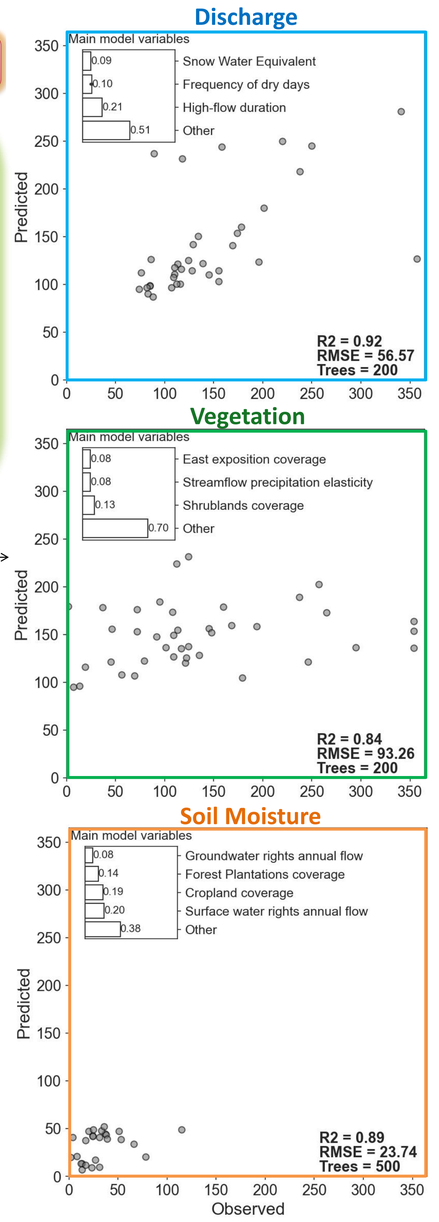
The discharge patterns show longer recovery over environments dominated by shrublands with less precipitation and higher temperatures (in central Chile). Higher latitudes with higher vegetation cover, increasing precipitation, and lower temperatures present shorter recovery times.
The vegetation productivity shows longer recovery over highly vegetated mountains in central Chile.
The soil moisture recovery spatial distribution presented patterns that connect them with the discharge recovery (opposite of discharge).

Drought recovery predictors

The explanatory variables for discharge are connected to precipitation, extreme discharge, and snow accumulation.
Vegetation recovery explanatory variables are linked to exposition, stream Flow precipitation elasticity, and land cover.
Soil moisture recovery explanatory variables to superficial wáter extraction, groundwater extraction, and land cover.

Drought recovery over climates

Discharge and vegetation recovery are faster in semi-arid environments, while in the tundra are always slower. Soil moisture recovery is slower in a semi-arid climate and faster in Mediterranean, temperate, and tundra.



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