DDS4Chl: A dataset of drought indices of water demand and supply and its impact on vegetation for continental Chile

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Abstract

A persistent drought is impacting Chile. It affects the hydrological system and vegetation development. Research studies have focused on the central part of the country. This is due to a persistent period of water scarcity. Scientists define this scarcity as a megadrought. This megadrought was defined by the Standardized Precipitation Index (SPI) of twelve months in December. The SPI only considers precipitation as a drought indicator. It does not account for atmospheric evaporative demand (AED), soil moisture, or their combined effect on plant growth. We present a developing database (DDS4Chl) of drought indices for continental Chile since 1981. The indices measure water demand, supply and its impact on vegetation. We derived the SPI for water demand. We also derived the Evaporative Demand Drought Index (EDDI) for water supply. The Standardized Precipitation Evapotranspiration Index (SPEI) shows the combined effect of AED and precipitation. We estimate the standardized anomaly of cumulative soil moisture at one meter (zcSM) and the standardized anomaly of cumulative NDVI (zcNDVI) to show the impact of water demand and supply. Finally, we present the historical linear trend of the drought indices in continental Chile. We cover short to long scales.

Index Terms— One, two, three, four, five

I. Introduction

The sixth assessment report (AR6) of the IPCC [1] indicates that human-induced greenhouse gas emissions have increased the frequency and/or intensity of some weather and climate extremes, and the evidence has been strengthened since AR5 [2]. There is high confidence that increasing global warming can expand the land area affected by increasing drought frequency and severity [3]. Climate change enhance atmospheric evaporative demand (AED) and modified precipitation patterns. Thus, to monitor drought, we must consider the water supply and demand. We must also consider its impact on vegetation productivity.

Chile has been facing a persistent rainfall deficit for more than a decade [4], which has impacted vegetation development [5] and the hydrological system [6]. Current drought conditions have affected crop productivity [7], [8], forest development [9], [10], forest fire occurrence [11], land cover change [12], water supply in watersheds [13], and have had economic impacts [14]. In 2019–2020, the drought severity reached an extreme condition in Central Chile (30–34°S) not seen for at least 40 years, and the evidence indicates that the impact is transversal to the land cover classes of forest, grassland, and cropland [5]. The prolonged lack of precipitation in Central Chile is producing changes in ecosystem dynamics that must be studied.

To evaluate meteorological drought (i.e., water supply), the World Meteorological Organization (WMO; [15]) recommends the Standardized Precipitation Index (SPI; [16]), a multiscalar drought index that allows to monitor precipitation deficits from short- to long-term. Following the same approach, [17] incorporates into the SPI the effect of temperature through the use of potential evapotranspiration, thus proposing the SPEI (Standardized Precipitation Evapotranspiration Index). Similarly, to evaluate solely the evaporative demand driven by temperature, [18] and [19] came up with the Evaporative Demand Drought Index (EDDI). To assess the impact of water supply and demand on vegetation, Zambrano (2018) proposed the zcNDVI. This is a standardized anomaly of the cumulative Normalized Difference Vegetation Index (NDVI). It's similar to the SPI, SPEI, and EDDI. The zcNDVI could be accumulated over the growing season or any period (e.g., months). It results in a multiscalar drought index. Several drought indices exist for soil moisture. These include the Soil Moisture Deficit Index (SDMI), a normalized index [20], and the Soil Moisture Agricultural Drought Index (SMADI) [21]. SMADI is a normalized index that uses vegetation, land surface temperature, and a vegetation condition index (VCI, [22]).

II. Methods

A. Study area

For the analysis, continental Chile was divided into five zones according to a latitudinal gradient: "Norte Grande", "Norte Chico", "Zona Central", "Zona Sur", and "Zona Austral". (Fig. 1)

B. Data

1) Earth observation data: For water supply and demand variabes, we used ERA5-Land [23], a reanalys dataset wich

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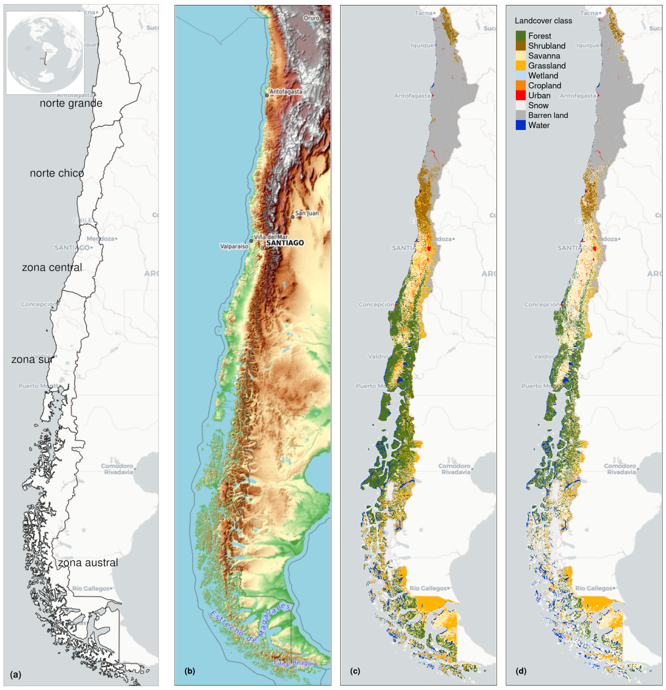


Fig. 1: (a) Chile and the five zones ‘norte grande’, ‘norte chico’, ‘zona central’, ‘zona sur’, and ‘zona austral’. (b) Topography reference map. (c) Land cover classes for 2021. (d) Persistent land cover classes (> 80%) for 2001-2021

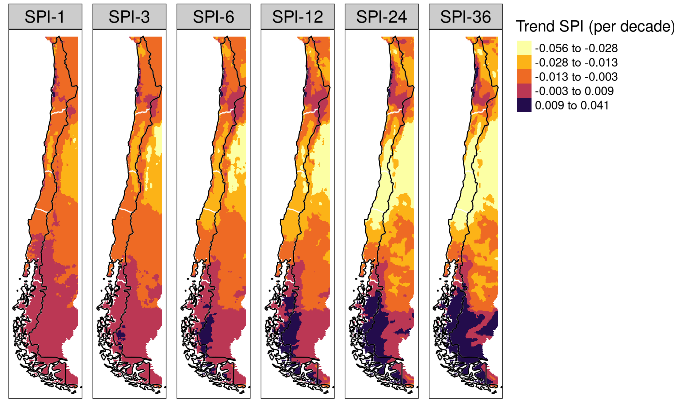
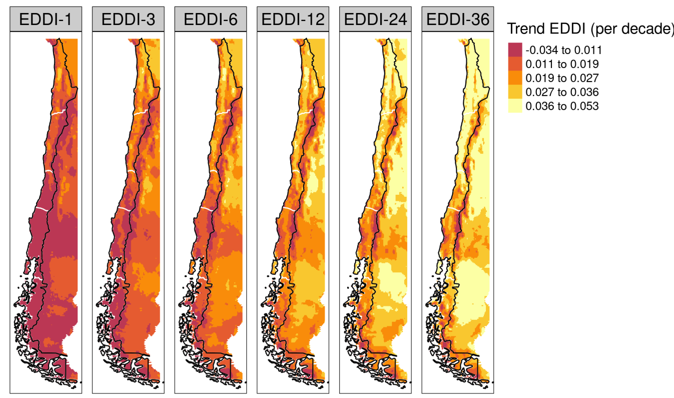
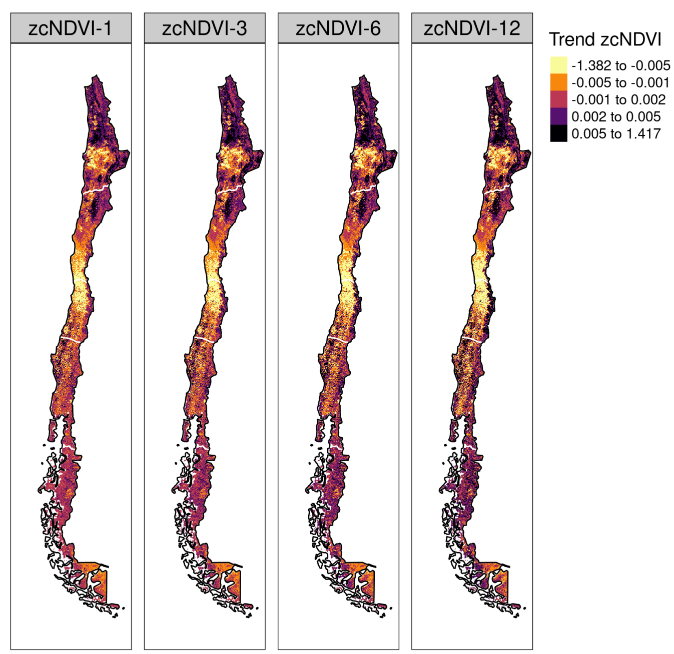


Fig. 2: Linear trend of the SPI at time scales of 1, 3, 6, 12, 24, and 36 months for 1981-2023





provides the evolution of land variables since 1950. It has a spatial resolution of 0.1°, hourly frequency and global coverage. We selected the variables for total precipitation, 2 meters temperature, and volumetric soil water layers between 0 and 100cm of depth (layer 1 to layer 3).

To derive a proxy of vegetation productivity, we used the product MOD13A3 collection 6.1 from MODIS [24]. It provides vegetation indices (NDVI and EVI) at 1km of spatial resolution and monthly frequency.

C. Drought indices

We used a non-parametric method for the procedure of normalization and derivation of the standardized anomaly (drought indices). This method obtains empirically derived probabilities using an inverse normal approximation [18]. We derived the SPI, SPEI, EDDI, zcSM, and zcNDVI drought indices. We calculate all aggregations at 1, 3, 6, 12, 24, and 36 months, except for zcNDVI, which is calculated at 1, 3, and 6 months.

III. Results

IV. Conlusion

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