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Drought's trends over continental Chile using climatic variables of water demand and supply, soil moisture, and vegetation productivity

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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. This scarcity has been found to be 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 vegetation productivity, which are key to understanding the impact of climate on ecological and agricultural drought. We use monthly climatic variables for precipitation, temperature, and soil moisture (1 meter depth) from the ERA5-Land reanalysis product for 1981–2023. Also, we used the Normalized Difference Vegetation Index (NDVI) from the Moderate Resolution Imaging Spectroradiometer (MODIS) for 2000–2023. We calculated the atmospheric evaporative demand (AED) using temperature and the Hargreaves-Samani equation. Then, to evaluate water supply, we derived the SPI. For water demand, we calculated the Evaporative Demand Drought Index (EDDI). We propose the standardized anomaly of cumulative soil moisture at one meter (zcSM) as a multi-scalar drought index for soil moisture. The above indices were calculated for time scales of 1, 3, 6, 12, 24, and 36 months. Lastly, we calculated a drought index for vegetation (a proxy for vegetation productivity), the standardized anomaly of the cumulative NDVI of six months (zcNDVI-6). We use the zcNDVI-6 to assess the impact of variations in water demand and supply on vegetation. We use a Mann-Kendall test to analyze the historical trend of the drought indices in continental Chile. Also, we calculated the temporal correlation between the indices of water supply, water demand, and soil moisture with the zcNDVI. To summarize the results, we divide Chile into five macrozones regarding a latitudinal gradient (north to south): i) "Norte Chico," ii) "Norte Grande," iii) "Centro," iv) "Sur," and v) "Austral." The analysis of trend showed that in the macrozones "Norte Chico," "Centro," and "Sur," the SPI has a decreasing trend that increases at longer time scales (from 1 to 36 months). The trend on EDDI reaches its maximum in the macrozones "Norte Grande" and "Norte Chico," being higher at longer time scales. Regarding the correlation with zcNDVI-6, it was higher for the drought index of soil moisture accumulated over 12 months (zcSM-12), having a r-squared of 0.49 for the "Norte Chico" and 0.44 for the "Centro." Followed by a r-squared of 0.41

with SPI-36 (precipitation accumulated over three years) in the macrozone “Norte Chico.” We conclude that Chile has a persistent decline in water supply for the central part of the country ("Norte Chico" and "Centro") and an increase in water demand in the north ("Norte Grande," "Norte Chico," and "Centro"). The combined effect has contributed to exacerbate the impact on vegetation in the "Norte Chico" and "Centro." The variability of drought conditions in vegetation can be explained in ~50% by de zcSM-12.