

# GLOBAL DROUGHT OBSERVATORY COMBINED DROUGHT INDICATOR: EVALUATION IN SOUTHERN SOUTH AMERICA

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## 1) INTRODUCTION

Droughts pose serious threats to the agricultural sector, especially in rainfed-dominated agricultural regions like those in Argentina's Humid Pampas. This region was recently impacted by slow-evolving and long-lasting droughts as well as by flash droughts, resulting in losses reaching thousands of millions of US dollars. Improvements of drought early warning systems are essential, particularly given the projected increase in drought frequency and severity over southern South America. The spatial and temporal relationship between precipitation deficits, soil moisture and vegetation health anomalies are crucial for better understanding and representation of the agricultural droughts and their impacts. The Global Drought Observatory Combined Drought Indicator (GDO-CDI, Cammalleri et al., 2021) considers the causal and time-lagged relationship of these three variables. The study's objective is twofold: (1) Analyze the time-lagged response between precipitation deficits, soil moisture and satellite fraction of Absorbed Photosynthetically Active Radiation (fAPAR) anomalies; and (2) Evaluate the CDI's capability to characterize the severity of drought events on the Humid Pampas against agricultural yield estimations and simulations, as well as agricultural emergency declarations.

## 2) DATA AND METHODOLOGY

The dataset used for the CDI computation is based on the operational Copernicus GDO (<https://drought.emergency.copernicus.eu/tumbo/gdo/map/?id=2001>) data. The Global Precipitation Climatology Centre (GPCC,  $1^\circ \times 1^\circ$ ) is used in GDO to construct monthly-updated Standardized Precipitation Index (SPI) over two different accumulation periods (1 and 3 months), for soil moisture anomalies an ensemble product is used ( $10$  day and  $0.1^\circ \times 0.1^\circ$ ), and the fAPAR 10-day standardized anomalies from MODIS ( $0.08^\circ \times 0.08^\circ$ ) are used as a vegetation biomass indicator. The CDI is designed to reproduce the cascading effect of drought from precipitation to soil moisture and vegetation, exploiting regularly updated soil moisture and fAPAR data with dekadal (10 day interval) frequency, and monthly SPI-3 and SPI-1. In order to evaluate the delay in response in dekadal soil moisture and fAPAR anomalies to monthly SPIs, a simultaneous and lagged Pearson correlation was carried out as in Sepulcre-Canto et al. (2012): SPI of a specific month is compared with the anomalies of soil moisture and fAPAR of the 2nd and 3rd dekad of that month (lags  $-1d$  and  $0$  respectively) and with the 1st, 2nd and 3rd dekads of the following month (lags  $+1d$ ,  $+2d$  and  $+3d$  respectively). This was performed for the austral warm months (September-March, from 2001 to mid-2022), since the fAPAR better represents the crop phenology during this period (Sepulcre-Canto et al., 2012). Summer crop yields and agricultural emergency declarations are also used for the CDI evaluations. The CDI consists of 6 categories: Watch, Warning, Alert, Temporary Soil Moisture Recovery, Temporary Vegetation Recovery and Full Recovery. As shown in Table 1, the Watch category represents a precipitation deficit and corresponds to a  $SPI-3 \leq -1$  or  $SPI-1 \leq -2$ ; the Warning category corresponds to a Watch category + soil moisture anomaly  $\leq -1$ ; meanwhile, the Alert category implies a  $SPI-3 \leq -1$  or  $SPI-1 \leq -2$  and fAPAR anomalies  $\leq -1$  (for more detail see Figure 1 of Cammalleri et al., 2021).

### 3) RESULTS AND CONCLUSIONS

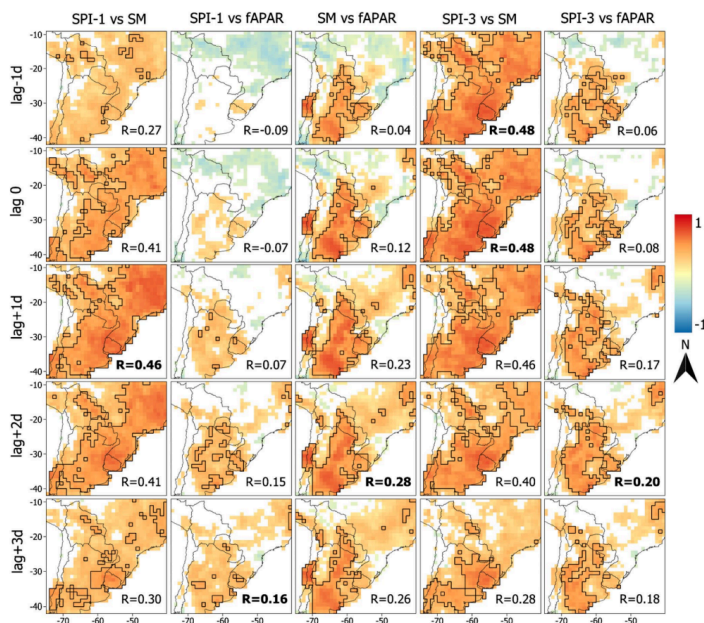


Figure 1. Pearson correlations between the different variables and temporal lags represented by dekads (d, i.e.  $+1d=10$  day period). Black contour represents the  $r=0.40$  value and points with no significant correlation values were masked out ( $p < 0.05$ ). Warm months September to March for 2001-mid 2022 period. Sample size for correlations with SPI was  $n=150$ , and between soil moisture and fAPAR was  $n=450$ . The median spatial correlation is shown in the lower right corner of each panel, where the bold represents the highest correlation for each column

Based on Figure 1, the highest correlation was found at temporal lags ranging from 0 to 20 days (0 to  $+2d$ ) between the precipitation deficit and soil moisture anomalies, lags of 0 to 20 days between soil moisture and fAPAR anomalies, and a lag of 10 to 30 days ( $+1d$  to  $+3d$ ) between SPI and fAPAR anomalies within the Humid Pampas. Then, a more detailed analysis was performed focusing on 14 sites within the Humid Pampas of Argentina. The correlation

values across these sites were slightly higher compared to those documented over Europe by Sepulcre-Canto et al. (2012) when comparing SPI-3, soil moisture and fAPAR anomalies (not shown). It is worth mentioning the higher correlation values between soil moisture and fAPAR observed over the Humid Pampas compared to Europe ( $r=0.54$  vs.  $|r|=0.35$ ). While this could be related to the difference in the analyzed period and/or to the region, it could also be due to a better representation of the ensemble soil moisture product currently used in the CDI. Given that the CDI evaluation performed by Sepulcre-Canto et al. (2012) used only soil moisture outputs from an hydrological model. Furthermore, despite the different climatic regimes, the temporal lag of maximum correlation across the 14 sites aligns with those documented in Europe, highlighting similarities in temporal signals across variables over both agricultural regions. Although the CDI has limitations, such as its coarse spatial resolution and monthly temporal resolution of precipitation data, it effectively tracks the progression of major drought events in the region (not shown). The CDI's frequency of Watch+Warning+Alert drought categories, aligns well with below normal estimations and simulations of soybean and corn yield (see Table I), as well with official declarations of agricultural emergencies.

Crop	Period	Yield estimations			Yield simulations		
		Median	Max	Min	Median	Max	Min
Corn	2001/02 to 2021/22	-0.30	-0.61	-0.06	-0.36	-0.61	-0.14
Corn	Dec to Feb	-0.40	-0.66	-0.13	-0.50	-0.55	-0.20
Soybean	2001/02 to 2021/22	-0.28	-0.49	-0.18	-0.29	-0.61	-0.05
Soybean	Dec to Mar	-0.46	-0.60	-0.29	-0.50	-0.60	-0.23

*Table I. Median, maximum and minimum Tau correlations, over the 14 location sites, between corn and soybean yield estimations/simulations and the frequency/sum of dekads under CDI categories of WATCH, WARNING and ALERT. The complete crop campaign (September-March) and the critical growth periods for both summer crops were considered over the 2001–2022 period.*

Insights from this study provide a basis for discussing potential improvements to the CDI, based on the regional agreement shown in Figure 1. Furthermore, this study highlights the global and regional significance of evaluating and enhancing the CDI for effective drought monitoring, emphasizing the role of collaborative efforts for future advancements in drought early warning systems.

## REFERENCES

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