

EDO - European Drought Observatory



EDO INDICATOR FACTSHEET

Combined Drought Indicator (CDI)

This Factsheet provides a detailed technical description of the Combined Drought Indicator (CDI) as implemented in the Copernicus European Drought Observatory (EDO), and which is used for detecting and monitoring areas that either are affected or have the potential to be affected by agricultural drought. The meteorological, hydrological and satellite-derived biophysical variables upon which the CDI indicator is based, as well as the indicator's temporal and spatial scales and geographic coverage, are summarized below. An example of the CDI indicator is shown in Figure 1.

Variables	Temporal scale	Spatial scale	Coverage
Precipitation,	10 days	5 km	Europe
soil moisture, and	(= 1 dekad)		
vegetation response.			

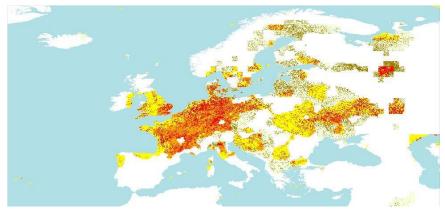


Figure 1: Example of the continuously updated Combined Drought Indicator (CDI) in EDO, computed for the first 10 days of June, during the 2011 severe spring / summer drought in northern Europe.

1. Brief overview of the indicator

The Combined Drought Indicator (CDI) that is implemented in the European Drought Observatory (EDO) is used to identify areas affected by agricultural drought, and areas with the potential to be affected. The CDI, which was developed by Sepulcre-Canto et al. (2012), is derived by combining three drought indicators produced operationally in the EDO framework - namely the Standardized Precipitation Index (SPI), the Soil Moisture Anomaly (SMA), and the FAPAR Anomaly - in such a way that areas are classified according to three primary drought classes: (1) "Watch", indicating that precipitation is less than normal; (2) "Warning", indicating that soil moisture is in deficit; and (3) "Alert", indicating that vegetation shows signs of stress. Two additional classes - namely "Partial recovery" and "Recovery" - identify the stages of the vegetation recovery process.

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2. What the indicator shows

Agricultural drought, which is one of the three main types of drought (the others being meteorological and hydrological droughts) that are defined according to the affected variables of the hydrological cycle, is characterized by a reduced crop production due to insufficient soil moisture.

The Combined Drought Indicator (CDI) identifies areas with the potential to suffer agricultural drought, areas where the vegetation is already affected by drought conditions, and areas in the process of recovery to normal conditions after a drought episode. The CDI is based on the cause-effect relationship for agricultural drought, whereby a shortage of precipitation leads to a soil moisture deficit, which in turn results in a reduction of vegetation productivity. The indicator is computed by combining anomalies of precipitation, soil moisture and satellite-measured plant growth - as measured by, respectively, the EDO drought indicators Standardized Precipitation Index, Soil Moisture Anomaly, and FAPAR Anomaly – using a classification scheme consisting of five drought levels (corresponding to the different stages of the cause-effect relationship for agricultural drought), as shown in Table 1.

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#	LEVEL	INTERPRETATION			
1	Watch	A relevant precipitation deficit is observed.			
2	Warning	The above precipitation deficit is accompanied by a soil moisture anomaly.			
3	Alert	The above two conditions are accompanied by a negative anomaly of vegetation			
		growth.			
4	Partial	After a drought episode, meteorological conditions have returned to normal, but not			
	recovery	vegetation growth.			
5	Full recovery	Both meteorological conditions and vegetation growth have returned to normal			

Table 1: The five drought impact levels used in the Combined Drought Indicator (CDI).

3. How the indicator is calculated

The Combined Drought Indicator (CDI) is derived by integrating the following three main drought indicators, which are implemented operationally within EDO:

- Standardized Precipitation Index (SPI): The SPI indicator measures precipitation anomalies at a given location, based on a comparison of observed total precipitation amounts for an accumulation period of interest (e.g. 1, 3, 12, 48 months), with the long-term historic rainfall record for that period (McKee et al., 1993; Edwards and McKee, 1997).
- Soil Moisture Anomaly (SMA): The SMA indicator is derived from anomalies of estimated daily soil moisture (or soil water) content represented as standardized soil moisture index (SMI) which is produced by the JRC's LISFLOOD hydrological model (de Roo et al. 2000), and which has been shown to be effective for drought detection purposes (Laguardia and Niemeyer, 2008).
- FAPAR Anomaly: The FAPAR Anomaly indicator is computed as deviations of the biophysical variable Fraction of Absorbed Photosynthetically Active Radiation (FAPAR), composited for 10-day intervals, from long-term mean values. Satellite-measured FAPAR represents the fraction of incident solar radiation that is absorbed by land vegetation for photosynthesis, and is effective for detecting and assessing drought impacts on vegetation canopies (Gobron et al., 2005).

The one-month and three-month Standardized Precipitation Index (SPI-1 and SPI-3) are used for computing the CDI. Several studies (e.g. Ji and Peter, 2003; Rossi and Niemeyer, 2012) have shown that SPI-3 has the strongest correlation with the vegetation response, and is therefore the most

suitable for identifying agricultural drought, whereas SPI-1 can detect extreme short-term dryness that can dramatically affect the vegetation condition depending on its stage of development.

For SPI-3, FAPAR Anomaly and Soil Moisture Anomaly (SMA) indicators, a threshold of minus one (-1) standard deviation is used, which equates to a return period of 6.3 years, and corresponds to "moderate drought", according to the SPI classification of McKee et al. (1993). In the case of SPI-1, a threshold of minus two (-2) standard deviations is used, corresponding only to cases identified as extreme drought. The classification scheme that is used to assign areas to one of the five drought classes is summarised in Table 2, as well as the colour scheme used for depiction in the CDI maps.

Table 2: Classification scheme used for computing the Combined Drought Indicator. Note that the delta symbol (Δ) is used as a prefix to indicate anomalies, and "m-1" is used as a suffix to indicate the month previous to the current one.

LEVEL	COLOUR	CLASSIFICATION CONDITION
Watch		SPI-3 < -1
		or
		SPI-1 < -2
Warning		SMA < -1
		and
		(SPI-3 < -1 or SPI-1 < -2)
Alert		ΔFAPAR < -1
		and
		(SPI-3 < -1 or SPI-1< -2)
Partial recovery		(Δ FAPAR < -1 and (SPI-3 $_{m-1}$ < -1 and SPI-3 > -1))
		or
		(Δ FAPAR < -1 and (SPI-1 $_{m-1}$ < -2 and SPI-1 >-2))
Full recovery		(SPI-3 $_{m-1}$ < -1 and SPI-3 > -1)
		or
		$(SPI-1_{m-1} < -2 \text{ and } SPI-1 > -2))$

In applying the classification scheme in Table 2, a temporal lag between the three components of the CDI is implemented. Thus, SPI of a given month is contrasted with soil moisture anomalies of the 2nd and 3rd dekads of that month, and with the 1st dekad of the following month, and with FAPAR anomalies of the 3rd dekad of that month and the 1st and 2nd dekads of the following month. Each month is assumed to have three dekads (days 1-10; days 11-20; day 21 to the end of the month).

4. How to use the indicator

An assessment of the behaviour of the Combined Drought Indicator (CDI) for the main European droughts between 2000 and 2011 demonstrated the CDI's capability to discriminate the areas where the drought impacts were most severe, and highlighted its potential as an early warning system (Sepulcre-Canto et al., 2012). Figure 2 shows an example of the use of the CDI to monitor the evolution of the severe spring drought in northern Europe in 2011¹, when large parts of southern Britain, northern France, Germany, Switzerland, Austria and other northern and eastern European countries experienced their driest three-month spells in more than 50 years, receiving just 25-60% of their long-term average rainfall since February, and resulting in parched soils and difficult growing conditions for farmers, as well as river levels that were dangerously low for wildlife².

As can be seen in Figure 2, the CDI was able to identify the areas suffering more severely the drought

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http://edo.irc.ec.europa.eu/edov2/php/index.php?id=1051
 https://www.theguardian.com/environment/2011/may/31/europe-dry-spring-power-blackouts

effects. It also shows its potential as an early warning system, identifying the areas with potential to suffer drought effects in April (i.e. "Watch"), confirming this in May (i.e. "Warning") and identifying the areas where the vegetation condition was being affected in June (i.e. "Alert"). The indicator also provided information on the areas where the vegetation had recovered after drought conditions (i.e. "Full recovery") and the areas where the vegetation was more damaged (i.e. "Partial recovery"), identifying as pixels which, despite receiving normal precipitation amounts, were still showing the effects of drought (with FAPAR anomalies below -1).

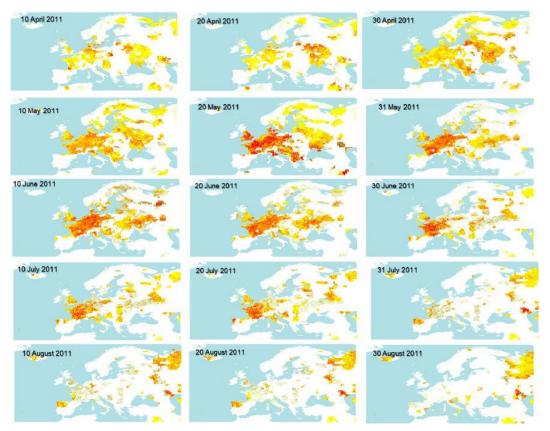


Figure 2: Temporal evolution of the severe spring drought in northern Europe in 2011, as shown by maps of the EDO's Combined Drought Indicator (CDI), computed for every 10 day period (or "dekad") from April to August 2011.

5. Strengths and weaknesses of the indicator

Strengths:

- Generally the assessment of drought is done using individual indicators that are based on meteorological or hydrological data, or remote sensing imagery. The development of a combined indicator that integrates meteorological, hydrological and remote sensing data, can help to reduce false alarms, which may arise for example in the case of vegetation-based indicators (e.g. FAPAR Anomaly) where a biomass reduction can be caused by factors other than a drought-induced water stress.
- An integrated approach that provides a convergence of indicators and therefore evidence of drought, can also support policy-makers in effective risk management and decision-making.

Weaknesses:

- The Alert impact levels should only be considered during the growing season, which in Europe may be defined to be, on average, from April to October. However, southern countries in Europe have longer growing seasons, and advanced with respect to the mean. Further research should include the use of spatial indicators of phenology, for example, for different regions.
- The satellite-derived FAPAR Anomaly indicator is based on reflected solar radiation, with wavelengths in the optical (i.e. visible and infrared wavelength) region of the electromagnetic spectrum, and is therefore not effective in the presence of clouds. Clouds are generally masked out before the indicator is computed. However, low clouds are not always detected, resulting in erroneous indicator values. This is a particular problem in northern European countries. One way to address this issue would be to use more than one indicator related to vegetation growth.

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