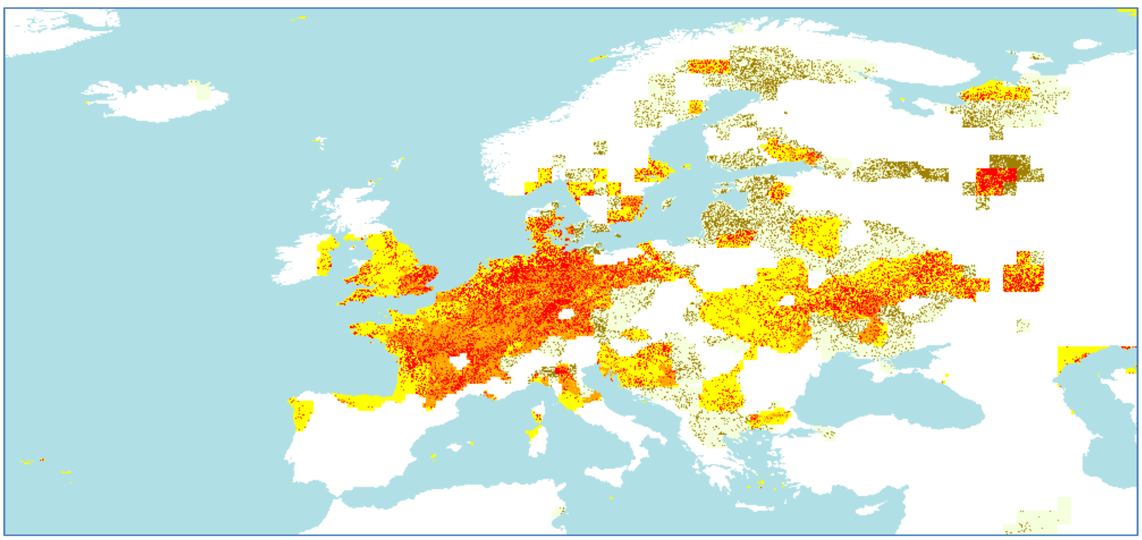
Combined Drought Indicator

Type	Temporal scale	Spatial scale	Geo. coverage
Vegetation response	10-day product	(1/24) º	Europe

Figure1: Example of the Combined Drought Indicator from the first 10 days of June 2011



Key message

A precipitation reduction respecting to the average is the primary driver of drought. When this precipitation reduction produces a decrease on soil moisture enough to not satisfy the water demand of the plants and therefore affecting its physiological processes, we are talking about agricultural drought.

Following this idea, a method that combines different drought indices (SPI, soil moisture anomalies and fAPAR anomalies) is proposed in order to identify not only areas affected by agricultural drought but also areas with the potential to be affected.

The method consists in a classification scheme based in three drought impact levels, corresponding to the different stages of the idealized agricultural drought cause–effect relationship. These levels are named as “Watch”, “Warning” and “Alert”. Two additional levels, “Partial recovery” and “Recovery”, identify the stages of the vegetation recovery process.

Relevance of the Product (to drought and/or to land degradation monitoring)

Generally the drought assessment is done using individual indices, based in meteorological data or in remote sensing images. The development of a combined index integrating meteorological and remote sensing indicators can help to reduce false alarms, for example in the case of the vegetation indices where a biomass reduction can be generated by other reasons different than a drought induced water stress.

The combined indicator proposed is based in the three main indices of EDO: the SPI, the soil moisture anomalies and the fAPAR anomalies.

- The Standardized Precipitation Index (SPI-*n*) (McKee et al, 1993) is a **statistical indicator** comparing the total precipitation received at a particular location during a period of *n* months with the long-term rainfall distribution for the same period of time at that location. It is one of the more common drought indicators. In 2010 WMO selected it as a key meteorological drought indicator to be produced operationally by meteorological services.

- Soil moisture (pF) is one of the important variables in hydrologic, climatologic, biologic, and ecological processes because it plays a crucial role in the interactions between the atmosphere and land surface.

- The Fraction of Absorbed Photosynthetically Active Radiation (fAPAR) represents the **fraction of the solar energy which is absorbed by the vegetation**. It is proposed as drought indicator due to its sensitivity to vegetation stress (Gobron et al. 2005 and 2007). Indeed droughts **can cause a reduction in the vegetation growth rate**, which is affected by changes either in the solar interception of the plant or in the light use efficiency.

Technical Information

1. Product

The Combined Drought Indicator is a composite product based in the EDO layers: SPI (SPI-1 and SPI-3), soil moisture anomaly and fAPAR anomaly.

- Geographic coverage: available for Europe
- Spatial scale: 1/24 decimal degrees
- Temporal scale: available each 10 days
- Data source: EDO
- Frequency of data collection: every month in the SPI case and every 10 days in the case of soil moisture and fAPAR anomalies.

2. Methodology

The indicator is based in five levels; “Watch” when a relevant precipitation shortage is observed, “Warning” when this precipitation shortage translates into a soil moisture anomaly, “Alert” when these two conditions are accompanied by a negative anomaly in the vegetation condition, “Partial recovery” when the meteorological conditions are recovered to normal but not the vegetation conditions, “Full recovery” when meteorological and vegetation normal conditions are recovered after a drought episode.

SPI is used to identify a precipitation shortage, the anomalies of soil moisture are used to characterize the effects of the precipitation shortage on soil moisture, and the anomalies of fAPAR are used to characterize the subsequent effects in vegetation condition.

For this study, the 3-month SPI (SPI-3) and the 1-month SPI (SPI-1) are used. The reason for using SPI-3 is that different studies (e.g. Ji and Peter, 2003; Rossi et al., 2012) have shown that the SPI-3 has the strongest correlation with the vegetation response and is therefore the most suitable for identifying agricultural drought. SPI-1 is also included in the design of the indicator for extreme cases, because one month of extreme dryness can dramatically affect the vegetation condition depending on its stage of development.

The threshold for the individual indices is set to 1 standard deviation (−1 for SPI-3 and fAPAR, +1 for soil moisture pF). This equates to a return period of 6.3 yr, and under the SPI classification of McKee et al. (1993) to “moderate drought”. In the case of SPI-1, however, the threshold selected is -2, corresponding only to the cases identified as extreme drought. Table 1 shows the description of the combined indicator and Table 2 indicates the colour scheme. The prefix Δ indicates anomalies; the suffix m-1 corresponds to the month before.

Table 1 Combined Drought Indicator description

Classification	Characteristics
Watch	SPI-3 < -1 or SPI-1 < -2
Warning	ΔpF> 1 & (SPI-3 < -1 or SPI-1 < -2)
Alert	ΔfAPAR<-1 & (SP-3< -1 or SPI-1< -2)
Partial recovery	(ΔfAPAR<-1 & (SP-3 $_{m-1}$< -1 & SPI-3 >-1)) or (ΔfAPAR<-1 & (SP-1 $_{m-1}$< -2 & SPI-1 >-2))
Full recovery	(SP-3 $_{m-1}$< -1 & SPI-3 >-1) or (SP-1 $_{m-1}$< -2 & SPI-1 >-2))

Table 2 Colour scheme of the Combined Drought Indicator maps

Colour	Legend
	Watch
	Warning
	Alert
	Partial recovery
	Full recovery
	Normal conditions
	Water bodies

To compute the indicator and do the analysis proposed in Table 1, a temporal lag between the three components of the indicator is implemented. In this way, we contrast the SPI of a determinate month with the anomalies of soil moisture of the 2nd and 3rd dekads of this month and with the 1st dekad of the following month and with the anomalies of fAPAR of the 3rd dekad of this month and of the 1st, 2nd dekads of the following month. This is done considering that each month has 3 dekads (from 1-10, from 11-20 and from 21-last day of the month). Table 3 shows an example of the implementation timing of the combined indicator for the month of January.

Table 3 example of the implementation timing of the indicator

CDI code date	SPI	SPI $_{m-1}$	ΔpF	ΔfAPAR
20121221	December	November	11-20 December	21-31 December
20130101	December	November	21-31 December	1-10 January
20130111	December	November	1-10 January	11-20 January

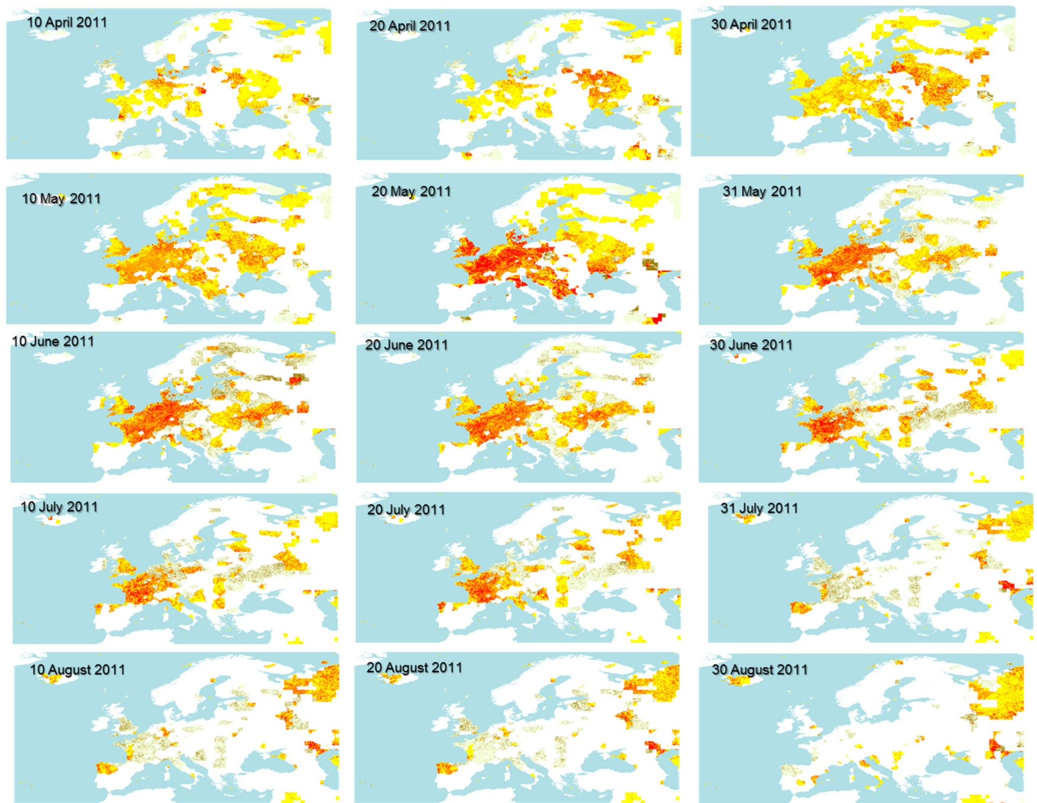
Use of the product for drought and/or land degradation monitoring

The behaviour of the indicator has been assessed for the main drought periods of Europe between 2000 and 2011, showing its capability to discriminate the areas where the drought was suffered with more severity and its potential as early warning system (Sepulcre-Canto et al, 2012).

One example of this is shown in Figure 2, corresponding to the images obtained for the first dekad of April, May and June 2011. During this period south UK, western Germany, the Netherlands, Belgium and northwest France received considerably less rainfall than is climatologically expected (http://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1051).

It can be noticed how the indicator was able to identify the areas suffering more severely the drought effects. It also shows its potential as early warning system identifying the areas with potential to suffer drought effects in April with “watch”, confirming that with “warning” in May and identifying with “alarm” the areas where the vegetation condition was being affected in June. The indicator also give information about the areas were the vegetation is recovered after drought conditions with the “Full recovery“ class and the areas were the vegetation was more damaged with the “Partial recovery” class, identifying the pixels were after receiving normal precipitation amounts still were showing the effects of drought conditions with anomalies of fAPAR lower than -1.

Figure 2: *Images of the Combined Drought Indicator for the spring/summer 2011*



Quality Information

1. Strength & weaknesses

[+] Generally the drought assessment is done using individual indices, based or in meteorological data or in remote sensing images. The development of a combined index integrating meteorological and remote sensing indicators can help to reduce false alarms, for example in the case of the vegetation indices where a biomass reduction can be generated by other reasons different than water stress.

[+] An integrated approach, showing a convergence of indicators and therefore an evidence of drought can also help to policy makers, for an effective risk management and decision making.

[-] The alarm impact should be considered only for the growing period. The mean growing period of Europe can considered from April to October, however the southern countries of Europe have longer growing periods and advanced respected to the mean. Future research will be done to include the use of phonological information per area, like spatial phenological indicators.

[-] fAPAR is an index obtained from the optical spectra, therefore is susceptible to clouds. These clouds are generally masked but sometimes low clouds are not detected resulting in erroneous values, especially in the northern countries. To solve this problem, future developments will include the use of more than one indicator related to vegetation condition.

2. Performance of the indicator (reference to literature, reports)

G. Sepulcre-Cantó, S. Horion, A. Singleton, H. Carrão, J. Vogt (2012). Development of a Combined Drought Indicator to detect agricultural drought in Europe. *Natural Hazards and Earth System Sciences,* 12, 3519–3531.

References

Gobron, N., Pinty, B., Mélin, F., Taberner, M., Verstraete, M.M., Robustelli, M., Widlowski, J.-L. (2007). Evaluation of the MERIS/ENVISAT fAPAR Product. *Advances in Space Research* 39: 105-115.

Gobron N., Pinty B., Mélin F., Taberner M., Verstraete M.M., Belward A., Lavergne T., and Widlowski J.-L. (2005). The state vegetation in Europe following the 2003 drought. *International Journal Remote Sensing Letters*, 26 (9): 2013-2020.

McKee, T.B., N. J. Doesken, and J. Kleist. 1993. The relationship of drought frequency and duration to time scales. In Proceedings of the 8th Conference of Applied Climatology, 17-22 January 1993, Anaheim, CA. American Meteorological Society. pp.179-184.