

FAPAR Anomaly

This Factsheet provides a detailed technical description of the indicator Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) Anomaly that is implemented in the Copernicus Global Drought Observatory (GDO), which is used for detecting and monitoring the impacts of agricultural drought on the growth and productivity of vegetation. The satellite-derived biophysical variable on which the FAPAR Anomaly indicator is based, as well as the indicator's temporal and spatial scales and geographic coverage, are summarized below. An example of the FAPAR Anomaly indicator is shown in Figure 1.

Variable	Temporal scale	Spatial scale	Coverage
Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)	10 days (= 1 dekad)	1/12 degree	Global

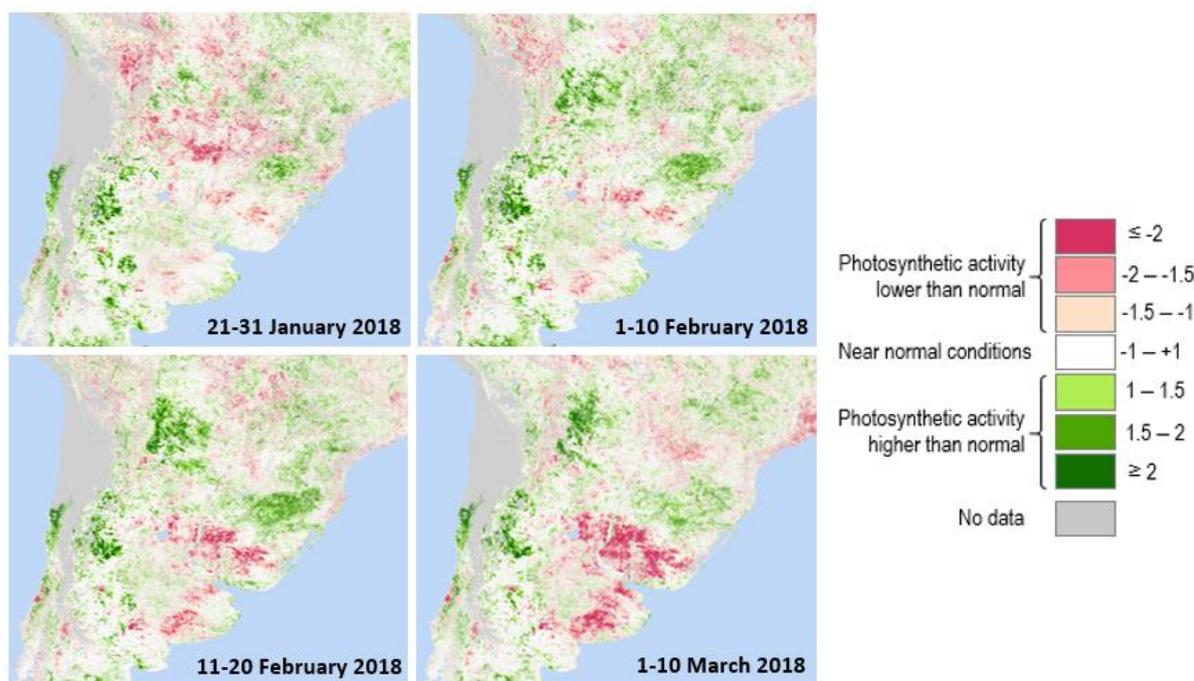


Figure 1: Example of the continuously updated FAPAR Anomaly in GDO, highlighting the conditions of relative vegetation stress (negative anomalies) in Argentina and Uruguay, during the severe drought of summer 2018.

1. Brief overview of the indicator

The FAPAR Anomaly indicator that is implemented in the Copernicus Global Drought Observatory (GDO) is used to detect and monitor the impacts on vegetation growth and productivity of environmental stress factors, especially plant water stress due to drought. The FAPAR Anomaly indicator is computed as deviations of the satellite-measured biophysical variable Fraction of Absorbed Photosynthetically Active Radiation (FAPAR, sometimes written as fAPAR or FPAR), composited for 10-day intervals, from its long-term mean values. FAPAR is one of the 50 so-called “Essential Climate Variables” (ECVs) that have been defined by the Global Climate Observing System (GCOS) as being both feasible for global climate observation, and important to support the work of the United Nations Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC) (Bojinski et al., 2014). (Of the 50 ECVs, 26 are listed as being significantly dependent on satellite observations). FAPAR values and their anomalies have been shown to be good indicators for detecting and assessing drought impacts on plant canopies, such as agricultural crops and natural vegetation (Gobron et al., 2005), and thus provide information that is potentially useful for water and agricultural management purposes.

2. What the indicator shows

Plant water stress caused by drought affects the capacity of vegetation canopies (e.g. agricultural crops and natural vegetation) to intercept solar radiation, thereby reducing vegetation growth rate. The Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) is biophysical variable, derived from satellite observations, that represents the fraction of incident solar radiation that is absorbed by land vegetation for photosynthesis. Satellite-derived FAPAR has been shown to be effective for detecting and assessing drought impacts on vegetation canopies (Gobron et al., 2005). The FAPAR Anomaly indicator which is implemented in GDO is computed for every 10-day interval (or “dekad”), as deviations of the FAPAR values at each location (grid-cell) from the long-term mean for a baseline period 2001-last available full year (e.g., 2001-2018 for maps in 2019). Each location with a negative FAPAR Anomaly (implying a FAPAR value lower than the long-term mean for that location), indicates conditions of relative vegetation stress, especially plant water stress due to drought, during that 10-day interval. Conversely, each location with a positive FAPAR Anomaly (implying a FAPAR value higher than long-term mean for that location), indicates relatively favourable vegetation growth conditions during that 10-day interval.

3. How the indicator is calculated

The FAPAR Anomaly agricultural drought indicator which is implemented within GDO is computed based on the freely available global FAPAR products (MOD15A2H, Collection 6) that are derived from surface reflectances obtained by the MODIS (Moderate Resolution Imaging Spectroradiometer) sensor carried on board NASA’s Earth orbiting satellite, Terra. The main algorithm generating the MOD15A2H FAPAR products is based on a three-dimensional radiative transfer model in which atmospherically-corrected reflectances observed by MODIS and a global “biome” map (see below) are used to generate the retrievals (Myeni et al., 2002; Myeni et al. 2003). The MODIS FAPAR retrieval algorithm utilizes a Look-Up Table (LUT) approach, whereby global vegetated land is stratified into eight biomes (i.e. canopy architectural types): grasses and cereal crops; shrubs; broadleaf crops; savanna; deciduous broadleaf forests; evergreen broadleaf forests; deciduous needle forests; evergreen needle forests (Yan et al., 2016a; Yan et al., 2016b).

In order to obtain the 10-day composite FAPAR maps that are required in GDO, the 8-day composites of the MOD15A2H FAPAR products are interpolated to 10-day time-steps using a weighted average (inverse distance in time) of the two closest images, and a temporal smoothing is performed by means of an exponential filter ($\alpha = 0.5$) of the 10-day data (Brown and Meyer, 1961). Low quality data are first masked according to the quality flag in the MOD15A2H product. Data are also spatially average to 0.1 degree starting from the original 500 m resolution.

The FAPAR anomalies are calculated by comparing the 10-day composite FAPAR maps with a MODIS-consistent baseline of FAPAR statistics, covering the period from 2001 up-to the last available full year (e.g., 2017 in the case of maps produced in 2018).

For every 10-day period (starting from January 2001), the FAPAR anomalies are computed as follows:

$$fAPAR\ anomaly_t = \frac{X_t - \bar{X}}{\delta}$$

where X_t is the FAPAR of the 10-day period t of the current year, \bar{X} is the long-term average FAPAR and δ is the standard deviation, both calculated for the same 10-day period t using the available time series.

4. How to use the indicator

As shown in Figure 2, the GDO MapViewer displays the latest available 10-day composite FAPAR map and the corresponding FAPAR anomaly map, which is calculated by comparing the FAPAR map with the historical time-series for the same 10-day period. The FAPAR values and their anomalies can be presented in the form of maps and graphs, providing information on the spatial distribution of vegetation photosynthetic activity, and its temporal evolution over long periods. The FAPAR values are dimensionless, ranging from 0 (yellow) to 1 (green, corresponding to maximum vegetation photosynthetic activity), while the FAPAR anomalies are given in standard deviation units, commonly ranging from -4 (red, showing negative anomalies) to +4 (green, showing positive anomalies).

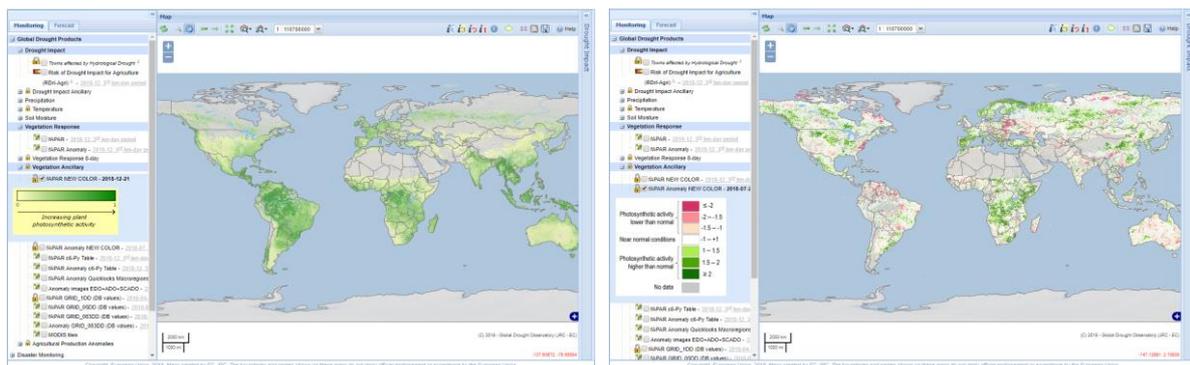


Figure 2. Maps of FAPAR values (left) and FAPAR anomalies (right) for the 10-day interval 21-30 July 2018, produced by the processing chain in the Copernicus Global Drought Observatory (GDO).

5. Strengths and weaknesses of the indicator

Strengths:

- Every ten days, the FAPAR maps and FAPAR Anomaly maps produced by GDO give a spatially continuous, up-to-date picture of the vegetation productivity and/or health status, at a high spatial resolution (about 1 kilometer) for the entire globe.
- Within GDO, gridded data are easily aggregated over administrative or natural entities such as hydrological watersheds, allowing both qualitative and quantitative comparison of the intensity and duration of FAPAR anomalies with recorded impacts such as yield reductions, low flows, reduced groundwater levels.

Weaknesses:

- While GDO's FAPAR and FAPAR Anomaly products are easy to read, interpretation of the displayed information must take account of the fact that this indicator shows variations in the vegetation health and / or cover which may be due to a rainfall or soil moisture deficits, but may also be due to other stress factors, such as plant diseases. Therefore this indicator must be used jointly with other indicators giving information on the deficit of rainfall and / or soil moisture, in order to determine if the variation in the vegetation response (FAPAR) is linked with a drought event or not.
- The computed FAPAR anomalies are dependent on the time-series available to calculate the mean values and the standard deviations. The FAPAR Anomaly maps are based on the assumption that the base-line time-series (starting in 2001) is sufficiently long to compute the long-term reference conditions.
- Finally, it should be noted that the MODIS FAPAR standard product (MOD15A2H) is derived based partly on a global "biome" map of eight broad vegetation types. The inherent assumption that the vegetation cover within each MODIS pixel belongs to one of the eight biomes, clearly has a big impact on the performance of the FAPAR retrieval algorithm.

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