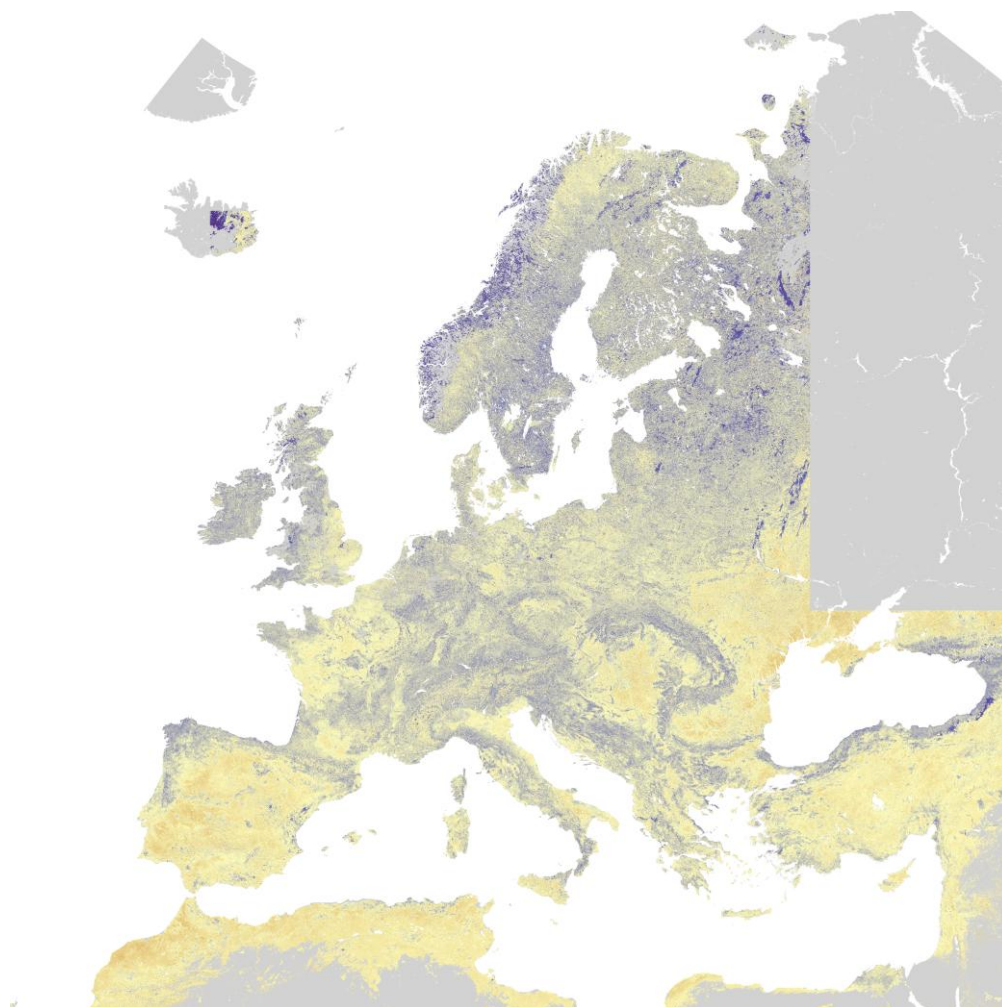


NDWI: Normalized Difference Water Index

Type	Temporal scale	Spatial scale	Geo. coverage
Vegetation response	10-day product	1 km	Europe



Key message

During drought event, vegetation canopy can be affected by water stress. This can have major impact on the plant development in general and can cause crop failure or lower crop production in agricultural areas. Early recognition of plant water stress can be critical to prevent such consequences. By providing near-real time information on the plant water stress to the stakeholders, water and agricultural management can be much improved, notably by irrigating specifically areas where plant water needs are not fulfilled anymore.

The Normalized Difference Water Index (NDWI) is known to be strongly related to the plant water content. It is therefore a very good proxy for plant water stress.

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

The Normalized Difference Water Index (NDWI) (Gao, 1996) is a satellite-derived index from the Near-Infrared (NIR) and Short Wave Infrared (SWIR) channels. The SWIR reflectance reflects changes in both the vegetation water content and the spongy mesophyll structure in vegetation canopies, while the NIR reflectance is affected by leaf internal structure and leaf dry matter content but not by water content. The combination of the NIR with the SWIR removes variations induced by leaf internal structure and leaf dry matter content, improving the accuracy in retrieving the vegetation water content (Ceccato et al. 2001). The amount of water available in the internal leaf structure largely controls the spectral reflectance in the SWIR interval of the electromagnetic spectrum. SWIR reflectance is therefore negatively related to leaf water content (Tucker 1980).

Its usefulness for drought monitoring and early warning has been demonstrated in different studies (e.g., Gu et al., 2007; Ceccato et al., 2002). It is computed using the near infrared (NIR) and the short wave infrared (SWIR) reflectance (Eq.1), which makes it sensitive to changes in liquid water content and in spongy mesophyll of vegetation canopies (Gao, 1996 ; Ceccato et al., 2001).

Technical Information

1. Product

The Normalized Difference Water Index (NDWI) is a remote sensing derived index estimating the leaf water content at canopy level.

- **Geographic coverage:** available for Europe
- **Spatial scale:** 1.2km
- **Temporal scale:** every 10 days aligned on the first day of each month, which corresponds to 3 images per month (day 1-10, day 11-20, day 21-last day of month).

- **Data source:** MODIS spectral bands 2 and 6 are provided by the German Aerospace Centre (DLR) and pre-processed by the FOREST Action (IES, JRC).
- **Frequency of data collection:** every day

2. Methodology

2.1 Calculation of NDWI

The NDWI is a remote sensing based indicator sensitive to the change in the water content of leaves (Gao, 1996). NDWI is computed using the near infrared (NIR – MODIS band 2) and the short wave infrared (SWIR – MODIS band 6) reflectance's.

$$NDWI_t = \frac{NIR_t - SWIR_t}{NIR_t + SWIR_t}$$

The EFFIS Delivery Data Products delivered by the German Aerospace Centre (DLR) are used to compute the NDWI. MODIS data are delivered per tile in ETRS_LAEA coordinate reference system (Figure 1).

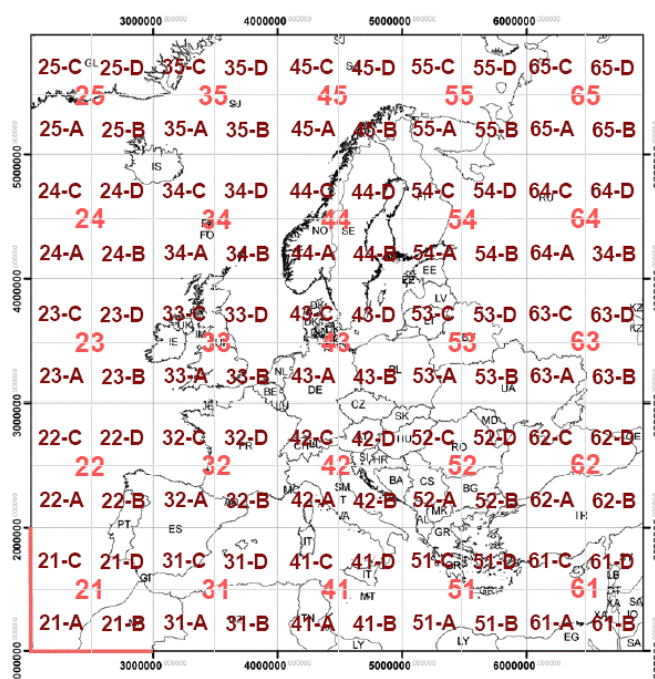


Figure 1- Subdivision in tiles of the MODIS data.

For each tile, a maximum value time composite is produced every 10-day using the daily MODIS composite files that combine all TERRA or AQUA passes of the day. Each month is split in 3 periods: from the 1st to the 10th, from the 11th to the 20th, and from the 21st to the end of the month.

The 10-days composite are then resampled from 250 m to 1 km and the ratio between band 2 and band 6 is then calculated following the equation here above. The different tiles are then mosaicked to produce a unique map for Europe. Finally, a mask derived from GLC 2000 is applied to recode

water bodies, cities, permanent snow and desert as no data.

2.2 Calculation of NDWI anomaly

- **Anomaly estimation:** NDWI anomalies are produced for every 10-day period as followed:

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

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

NDWI anomalies are produced only for pixels that have at least five years of data for the given 10-day period.

- **Baseline statistics:** The archive of NDWI covers the period from January 2006 to current day.

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

NDWI and NDWI anomalies can be presented in the form of maps and graphs, providing information both on the spatial distribution of the vegetation water stress and its temporal evolution over longer time periods. Gridded data can easily be aggregated over administrative or natural entities such as hydrological watersheds. This allows for the qualitative and quantitative comparison of the intensity and duration of the NDWI anomalies with recorded impacts such as yield reductions, low flows, lowering of groundwater levels, to cite but a few.

- **The NDWI product** is dimensionless and varies between -1 to +1, depending on the leaf water content but also on the vegetation type and cover (Figure 2). High values of NDWI (in blue) correspond to high vegetation water content and to high vegetation fraction cover. Low NDWI values (in red) correspond to low vegetation water content and low vegetation fraction cover. In period of water stress, NDWI will decrease.

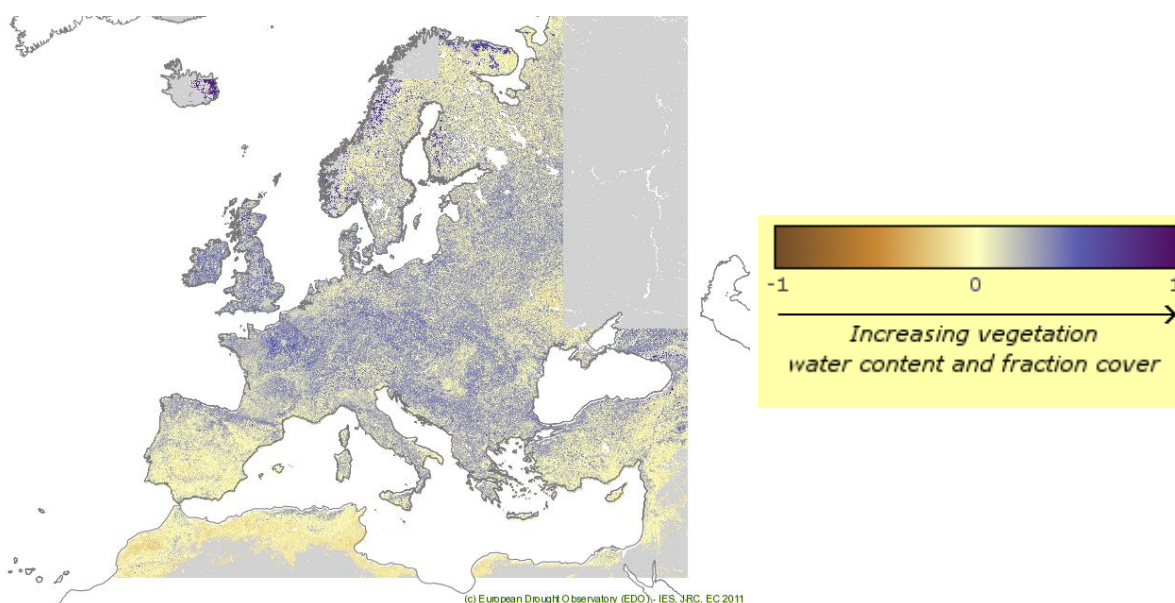


Figure 2 – NDWI of the 3rd 10-day period of May 2011.

- **The NDWI anomaly product** is given in standard deviation units. It is commonly ranging from -4 to +4 and from red to green, red showing negative anomalies (Figure 3).

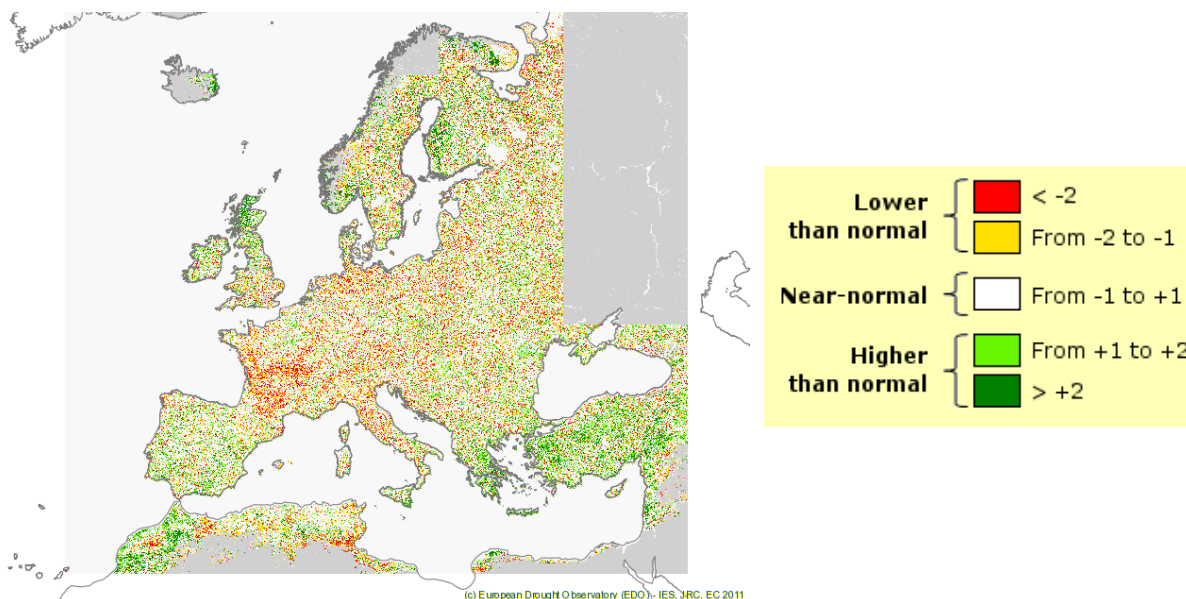


Figure 3 – NDWI anomaly of the 3rd 10-day period of May 2011.

The EDO Map server displays the latest available NDWI 10-day composite image and the NDWI anomaly image calculated by comparing this image to the historical series in the same 10-day period. Both products are easy to read. The interpretation must take into account the fact that this indicator is showing a variation in the vegetation conditions.

Quality Information

1. Strength & weaknesses

[+] Every ten days, the NDWI gives a systematic and spatially continuous picture of the vegetation water stress at a high spatial resolution (1km) for the entire Europe.

[-] Soil background effects can be important in case of partial vegetation cover (Gao, 1996). Moreover snow cover is not masked out in the current version. During winter months NDWI > 0.5 may correspond to snow cover.

[-] Drought and water stress are not the only factors that can cause a decrease of NDWI values/anomalies. Change in land covers or pests and diseases can also be responsible for such variation of the signal. Therefore this indicator must be used jointly with other indicators giving information on the deficit of rainfall /soil moisture in order to determine if the variation in the vegetation response (signal) is linked with a drought event or not.

[-] Anomalies are dependent of the time series available to calculate the mean values and the standard deviations. This period should be long enough to characterize the area where the index is calculated. The length of current archive (6 years) is too short to ensure fully the accuracy of the NDWI anomalies.

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

According to Gao (1996), NDWI is a good indicator for vegetation liquid water content and is less sensitive to atmospheric scattering effects than NDVI (Normalized Difference Vegetation Index).

MODIS NDWI has been used to detect and monitor the moisture condition of vegetation canopies over large areas (e.g. Delbart et al. 2005, Jackson et al. 2004) and tested as a drought indicator (Gu et al. 2008). Gu et al (2007) found that NDWI values exhibited a quicker response to drought conditions than NDVI. Contrary to NDWI, NDVI has limited capability for retrieving vegetation water content information, since provides information on vegetation greenness (chlorophyll), which is not directly and uniformly related to the quantity of water in the vegetation (Ceccato et al 2002).

References

- Ceccato, P., Flasse, S., Tarantola, S., Jacquemond, S., and Gregoire, J.M. 2001. Detecting vegetation water content using reflectance in the optical domain. *Remote Sensing of Environment* 77: 22–33.
- Ceccato, P., Flasse, S., and Gregoire, J.M. 2002. Designing a spectral index to estimate vegetation water content from remote sensing data: Part 2. Validation and applications. *Remote Sensing of Environment* 82: 198-207.
- Delbart, N., L. Kergoat, T. L. Toan, J. Lhermitte, and G. Picard (2005). Determination of phenological dates in boreal regions using normalized difference water index. *Remote Sensing of Environment* 97: 26-38
- Gao, B.-C. 1996. NDWI - A normalized difference water index for remote sensing of vegetation liquid water from space. *Remote Sensing of Environment* 58: 257-266.
- Gu, Y., Brown, J.F., Verdin, J.P., and Wardlow, B. 2007. A five-year analysis of MODIS NDVI and NDWI for grassland drought assessment over the central Great Plains of the United States. *Geophysical Research Letters* 34.
- Gu, Y., Hunt, E., Wardlow, B., Basara, J.B., Brown, J.F., Verdin, J.P. 2008. Evaluation of MODIS NDVI and NDWI for vegetation drought monitoring using Oklahoma Mesonet soil moisture data. *Geophysical Research Letters* 35.
- Jackson, T.J., Chen, D., Cosh, M., Li, F., Anderson, M., Walthall, C., Doriaswamy, P., and Hunt, E.R. 2004. Vegetation water content mapping using Landsat data derived normalized difference water index for corn and soybeans. *Remote Sensing of Environment* 92: 475–482.
- Tucker, C. J. 1980. Remote sensing of leaf water content in the near infrared. *Remote Sensing of Environment* 10: 23-32.