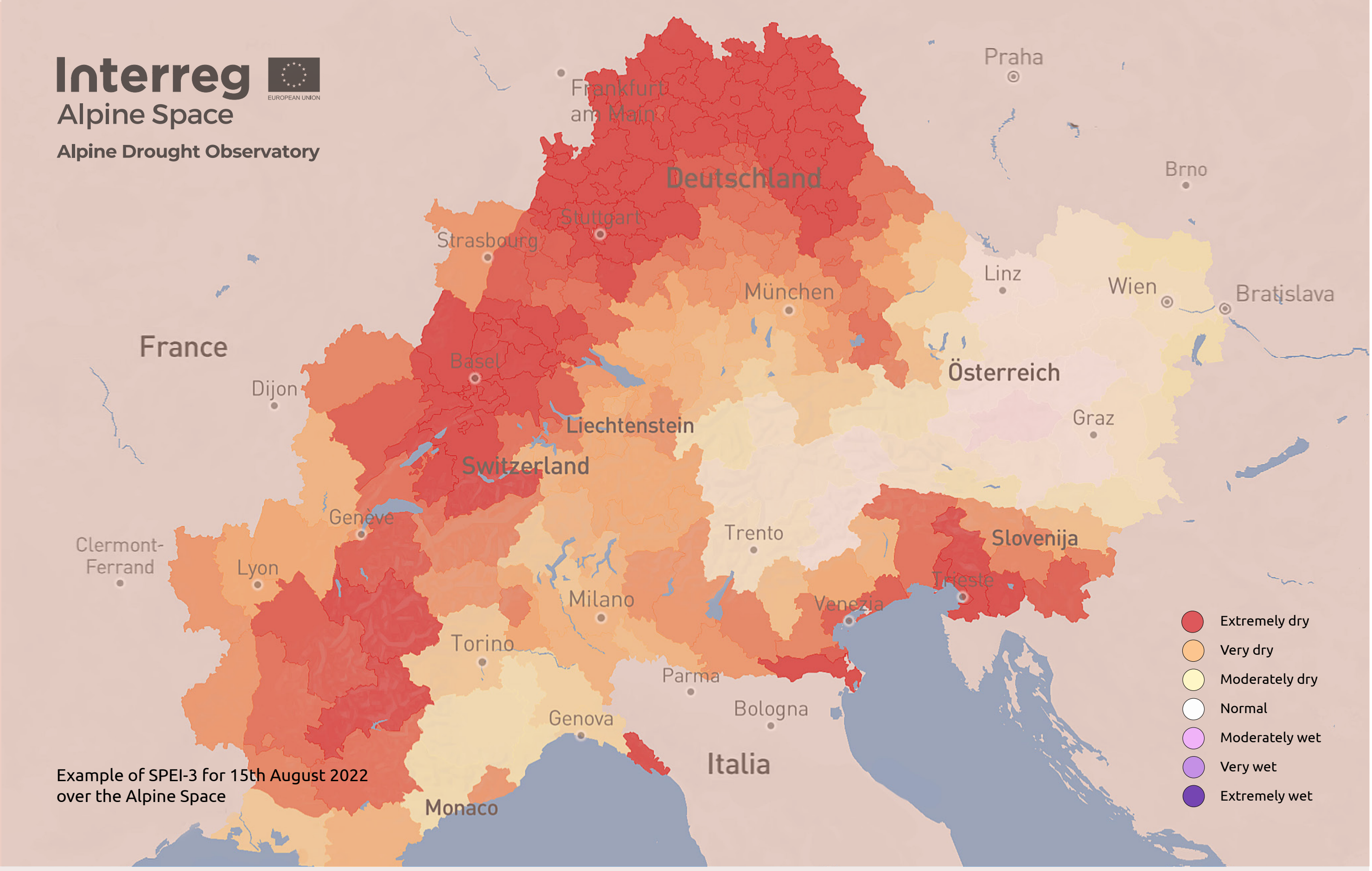
Interreg Alpine Space
Alpine Drought Observatory



Example of SPEI-3 for 15th August 2022 over the Alpine Space

SPEI

Standardised Precipitation-Evapotranspiration Index

The Standardised Precipitation-Evapotranspiration Index (SPEI) is a multiscalar drought index based on precipitation and potential evapotranspiration. It can be used for determining the onset, duration and magnitude of drought conditions with respect to normal conditions in a variety of natural and managed ecosystems such as agricultural ecosystems, forests, rivers, etc. The SPEI shows the anomalies (deviations from the long-term average) of the observed total surface water balance for any given location and accumulation period of interest. The name of the index is usually modified to include the accumulation period. SPEI-3, for example, refers to accumulation period of three months (Vicente-Serrano and Beguería, 2022).

Input variable	Type of drought	Temporal resolution	Spatial resolution	Temporal coverage	Time scale (aggregation period)	Unit
Precipitation Potential evapotranspiration	Agricultural	Daily	5 km	1979–present	1 month (SPEI-1) 2 months (SPEI-2) 3 months (SPEI-3) 6 months (SPEI-6) 12 months (SPEI-12)	Unitless / SPEI unit (unit of standard deviation from the long-term mean)

Definition

The Standardised Precipitation-Evapotranspiration Index (Vicente-Serrano et al., 2010) is an extension of the widely used Standardised Precipitation Index (McKee et al., 1993). It is calculated similarly to the SPI but in addition to precipitation includes an evapotranspiration component, allowing the index to account for the effect of evapotranspiration development through a basic surface water balance calculation (the difference between precipitation and potential evapotranspiration). It represents a standardised measure of a certain value of surface water balance over the selected time period in relation to the expected value of surface water balance for the same period. For any given region, the value of the SPEI index around 0 represents the normal expected conditions regarding the value of surface water balance in the selected time scale (accumulation period) compared to the long-term average. The values of the SPEI around 1 represent approximately one standard deviation of the surplus in surface water balance (wet conditions), while the value of –1 is approximately one standard deviation of the deficit (dry conditions). Drought is usually defined as a period when SPEI values fall below –1. Because SPEI values represent the number of standard deviations from the long-term mean, the index is applicable for all climate regimes and can be used to identify and monitor conditions associated with a variety of drought impacts.

Methodology

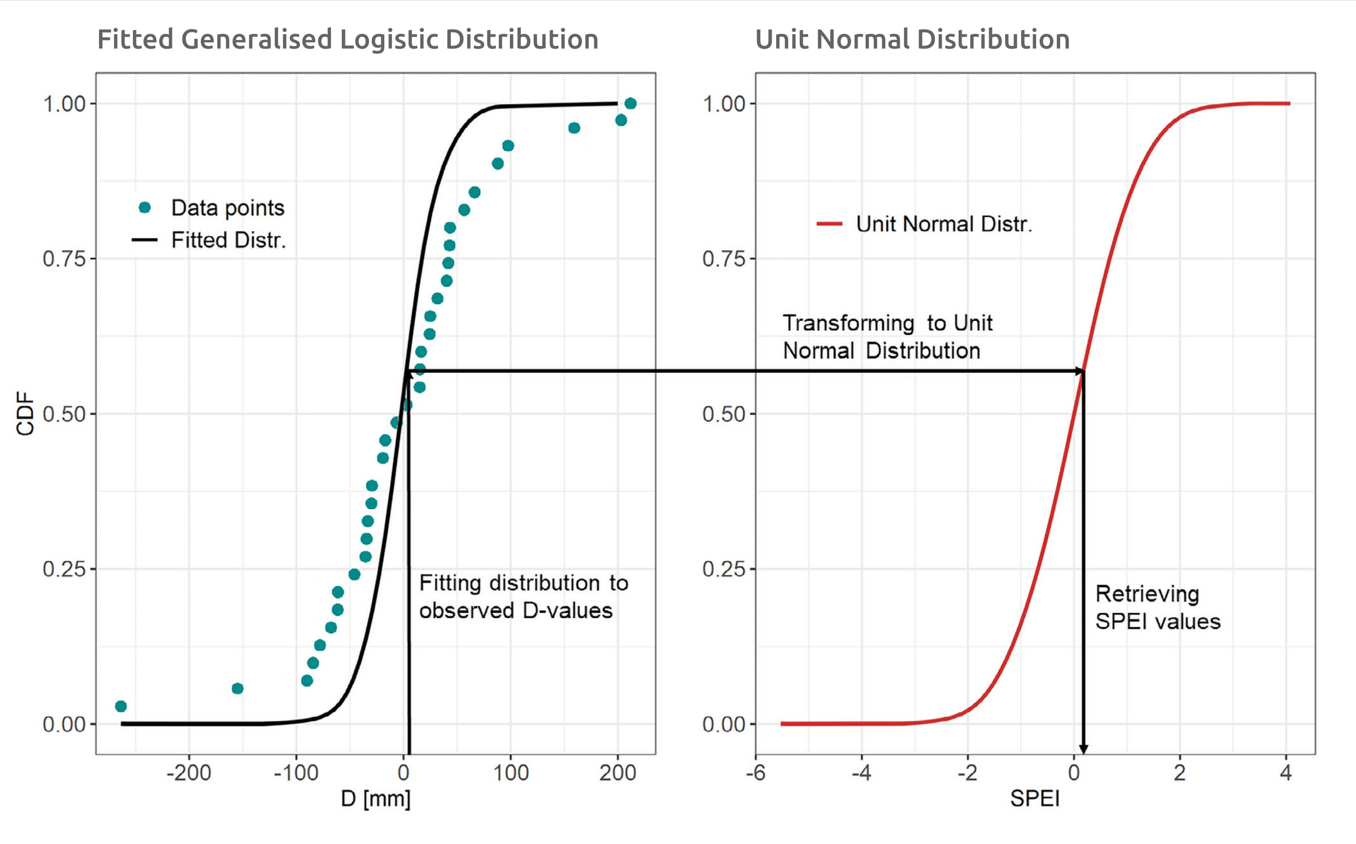
SPEI

Data source	Data provider	Index provider	Metadata
ERA5 reanalysis (Copernicus)	ZAMG	ARSO	Standardised Precipitation-Evapotranspiration Index

CALCULATION

In the ADO platform, SPEI is calculated daily on five different time scales (1, 2, 3, 6 and 12 months) with limits set between –5 and 5 (Stagge et al., 2015), using 1981–2020 as the reference period for distribution fitting. The time scale (accumulation period) corresponds to the length of the rolling time window over which the total surface water balance is calculated: 30 days for SPEI-1, 60 days for SPEI-2, 90 days for SPEI-3, 180 days for SPEI-6 and 365 days for SPEI-12. This approach varies slightly from the more common approach, where SPEI is calculated monthly according to the calendar month.

In order to compute the SPEI for a selected time scale, a three parameter continuous probability distribution known as the “generalised logistic distribution” is fitted to the total surface water balance values in the reference period. For any observed total surface water balance, the cumulative probability is then derived, based on the parameters of the generalised logistic distribution. The cumulative probability of the observed total surface water balance is then expressed as a quantile of the standard normal distribution with mean value 0 and variance value 1. This value is the SPEI.



Schematic representation of the calculation steps for the SPEI on a time scale of three months (90 days): fitting a distribution function (Generalised Logistic Distribution) to observed D values (left); probability preserving transformation into Unit Normal Distribution (right). This procedure is repeated for every day in the year.

INPUT DATA

Daily precipitation and potential evapotranspiration data used as input data for the calculation of the SPEI are downscaled and derived from ERA5 reanalysis at 0.25° resolution (Hersbach et al., 2018) to 5.5 km resolution using quantile mapping. Quantile mapping is performed using the UERRA reanalysis dataset (Bazile et al., 2017) as reference data. Precipitation data is downscaled directly, whereas potential evapotranspiration is derived from a set of previously downscaled meteorological variables (total precipitation, temperature, wind speed, relative humidity and solar radiation) using the Penman-Monteith method (Allen et al., 1998).

REFERENCE PERIOD

It is important to define a reference period long enough to realistically capture climate variability in considered regions. ADO project consortium has recommended to use period 1981–2020 as reference where possible (depends on data availability). The reference period for calculating SPEI is 1981–2020.

Index values and thresholds

In the ADO platform, the SPEI values range from –5 to 5. For any given location and accumulation period, they are classified into seven different categories (from dry to wet), as shown in the table. These also represent the commonly used thresholds for identifying drought through SPEI.

SPEI value thresholds	Classification	Probability of event [%]
SPEI < –2.00	extremely dry	2.3
–1.99 < SPEI < –1.5	very dry	4.4
–1.49 < SPEI < –1	moderately dry	9.2
–0.99 SPEI < 0.99	normal	68.2
1. < SPEI < 1.49	moderately wet	9.2
1.5 < SPEI < 1.99	very wet	4.4
SPEI > 2.00	extremely wet	2.3

Source: Vicente-Serrano et al., 2010.

Key strengths and weaknesses

+ Index requires only climatological information without assumptions about the characteristics of the underlying system.

+ It combines multi-timescales aspects of the Standardised Precipitation Index (SPI) with information about evapotranspiration. Including a variety of meteorological variables makes the SPEI more useful for climate change studies (WMO, 2016).

+ SPEI can provide information about drought conditions at shorter and longer time scales.

– Compared to the SPI, it requires an additional variable (potential evapotranspiration) which is based on a set of other meteorological variables.

– Sensitive to the method od calculation of potential evapotranspiration. The comparability among SPEI values computed by different ET formulas is limited.

– A long reference period data record is needed to sample the natural variability.

– There are strong assumptions about the reference surface in the calculation of potential evapotranspiration (hypothetical grass reference crop with an assumed crop height of 0.12 m, a fixed surface resistance of 70 s m-1 and an albedo of 0.23 according to Allen et al., 1998).

– Potential evapotranspiration is not as effective and accurate as actual evapotranspiration.

Findings from the ADO project

1. GRASSLAND MODEL BASED VALIDATION OF DROUGHT INDICES: A CASE STUDY FROM THE SLOVENIAN ALPINE REGION

The aim of the study was to make an indicative evaluation of the success of selected drought indices, addressing topsoil layer and vegetation condition, in detecting drought in agriculture. The performance of the SPEI-2, SPEI-3 and VHI was evaluated with respect to yield values calculated with the LINGRA-N model, specifically, the ratio between actual and potential transpiration, also known as drought factor (TRANRF), actual root zone water content (SMACT), leaf area index (LAI), reserve dry weight (WRE) and root dry weight (WRT). The results are available in the article published in Agronomy: https://doi.org/10.3390/agronomy12040936.

2. PIEDMONT REGION – ORCO BASIN CASE STUDY

A comparison between SPEI index calculated with ERA5 reanalysis (Copernicus) data and NWIOI local dataset* was performed over the Orco Basin (Piedmont Case Study). Main findings were:

- Very good agreement between the SPEI calculated via ERA and SPEI via NWIOI dataset at all accumulation scales:
  - Pearson coefficient: SPEI-1 = 0.75, SPEI-3 = 0.77, SPEI-6 = 0.8, SPEI-12 = 0.83;
  - Contingency tables: around 12 % of the “events” (SPEI monthly values) are not correctly described in terms of same class (see SPEI index values and thresholds).
- All major dry spells observed over the Orco Basin in the last 20 years were correctly identified by SPEI index (spring 2021, autumn 2017, winter 2016, summer 2006, 2003 and 2002).

Detailed information on the results is available from the project partner Arpa Piemonte (contact: christian.ronchi@arpa.piemonte.it).

3. VALIDATION OF SPEI IN SLOVENIA

Validation of ADO SPEI (-2, -3) against SPEI calculated from ground observations at 15 representative meteorological stations in Slovenia has shown that the indices calculated for the Alpine domain are relevant on a national level and suitable to use operationally. The linear regression model indicates high correlation, with the values of r2 for both daily index values and monthly mean index values ranging from 0.62 to 0.79.

Validation of ADO SPEI (-2, -3) against annual yield data for different crops and grassland types has shown that agreement between the two is greater for regions in the east of Slovenia, including Podravska, and for maize (grain or green) and different grassland types, with linear regression based coefficient r2 ranging from 0.15 to 0.51. In contrast to SPEI, SPI shows relatively good agreement with yield data in Gorenjska, which could indicate that in mountainous regions the evapotranspiration component in drought indices is less relevant. Generally, 2-monthly indices show better agreement with annual yield data compared to 3-monthly indices, indicating that 2-monthly indices might be more suitable for monitoring agricultural drought in Slovenia.

Detailed information on the results is available from the project partner Slovenian Environment Agency (contact: ziva.vlahovic@gov.si).

* NWIOI dataset is a daily dataset of precipitation and temperatures on a regular grid (resolution=0.125°) derived by an high density network of meteorological stations over Piedmont region (Italy) via optimal interpolation technique (http://www.arpa.piemonte.it/rischinaturali/tematismi/clima/confronti-storici/dati/dati.html)

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