Interreg Euro-MED

Co-funded by the European Union

Germ of Life

Interreg Euro-MED Project GERM OF LIFE

"Digital Drought Risk Management enabling the drought mitigation and adaptation strategies for the restoration of the ecosystem equilibrium in Mediterranean European Countries".

Test Project (Thematic Project)
Mission: NATURAL HERITAGE

Duration: 33 months from 01/01/2024
Coordinator: UNIVERSITY OF PATRAS

Deliverable ID.:	**1.5.2**	
Deliverable title:	**Description of Drought Hazard Index (DHI) Calculation Algorithm**	
Planned delivery date:		
Actual delivery date:		
Deliverable leader:	University of Patras	
Contributing partners:	CMCC	
Dissemination Level:		EX = External;
	X	IN = Internal

This project has received funding from the European Interreg Euro-MED programme under Subsidy Contract No. XXXX.

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Document information and history

Deliverable description (from AF)
This document presents the methodology for calculating the Drought Hazard Index (DHI), a composite drought risk indicator developed within the Germ of Life framework.

Version N.	Date	Author [Person and Organisation]	Reviewer [Person and Organisation]	Notes
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V.02	**30/05/2025**	**M. Samouris, A. Argiriou, D. Odunayo, M. Balzarolo**		

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1 Executive Summary

The computation of Drought Hazard Index (DHI) has been agreed among the involved scientific patterns as the index to assess drought risk in the Pilot Test Areas (PTAs). It's a key component in the development of the Vulnerability Assessment Index (VAI) and quantifies the frequency and intensity of drought conditions using a composite approach based on the Standardized Precipitation Evapotranspiration Index (SPEI) and the Normalized Difference Vegetation Index (NDVI). The integration of SPEI and NDVI allows for a more comprehensive assessment of drought conditions by capturing both meteorological drivers of drought and the vegetation status.

1.1 Role of deliverable

The present deliverable is a document including the description of the necessary steps implemented to compute DHI. The calculation of this index is essential for the Vulnerability Assessment Tool (VAT) development-the project's final integrated tool for evaluating drought risk across the Mediterranean ecosystems of interest. DHI serves as the basis for the calculation of one of the Vulnerability Assessment Index (VAI) parameters and provides a robust representation of drought hazard, capturing both meteorological stress and its effect on vegetation health.

1.2 Relationship to other GERM OF LIFE deliverables

This deliverable builds upon the methodologies presented in Deliverable 1.1.2, where the algorithms to compute SPEI (Standardised Precipitation Evapotranspiration Index), CWSI (Crop Water Stress Index) and NDVI (Normalized Difference Vegetation Index) were indicated. The SPEI and NDVI indicators are then combined to get the Drought Hazard Index which is needed to calculate one of the VAI (Vulnerability Assessment Index) parameters, as presented in the Deliverable 1.3.1

1.3 Structure of the document

This deliverable is organized in the following sections:

2 Overview of the DHI concept

2.1 Input indicators

2.2 DHI calculation methodology

2.2.1 Calculation of empirical thresholds

2.2.2 Integrated DHI calculation

2.3 Example Application

2 Overview of the DHI concept

The DHI is a weighted score, based on drought occurrence probabilities, derived from classified drought severity categories (Kim et al., 2015)[1]. Within the framework of the Germ of Life project, the DHI plays a central role in the construction of the Vulnerability Assessment Index, specifically contributing to the F parameter in VAI formula, i.e. the frequency with which the area experiences a specific DCI category. It integrates both a meteorological (SPEI) and an ecological (NDVI) indicator to capture the intensity and impact of drought hazards.

2.1 Input indicators

The calculation of DHI relies on two complementary indicators: SPEI and NDVI. SPEI captures the atmospheric water balance anomalies and the NDVI represents the level of stress experienced by vegetation in response to drought conditions. Both are classified into discrete drought categories and used to compute individual DHI components that are later integrated into the final DHI value.

2.2 DHI calculation methodology

The methodology adopted for calculating the DHI is inspired by Kim et al. (2015), which proposes a weighted scoring system based on drought occurrence probabilities derived from classified drought severity categories. In their approach, daily drought values (using the Effective Drought Index, EDI) are categorized into four severity levels – Near Normal (NND), Moderate Drought (MD), Severe Drought (SD) and Extreme Drought (ED) with fixed weights assigned to each class (NND_w=1, MD_w=2, SD_w=3 and ED_W=4). These classes are then rated according to their occurrence frequency across spatial units (NND_r, MD_r, SD_r and ED_r) and the overall DHI is computed as a weighted sum of severity ratings, normalized to a [0,1] range.

$$\mathbf{DHI = (NND_w * NND_r) + (MD_w * MD_r) + (SD_w * SD_r) + (ED_w * ED_r)} \qquad \mathbf{(1)}$$

For the needs of our project this concept has been extended and adapted in several ways to better suit the objectives:

- Instead of relying solely on a meteorological-based index like EDI, this version incorporates both the SPEI and NDVI indices to reflect both atmospheric water stress and the actual ecosystem response. Each is processed independently to produce a respective DHI value, which is later combined into a single, integrated DHI score.

[1] H. Kim, J. Park, J. Yoo, and T.-W. Kim, “Assessment of drought hazard, vulnerability, and risk: A case study for administrative districts in South Korea,” *J. Hydro-Environ. Res.*, vol. 9, no. 1, pp. 28–35, 2015.

- Unlike Kim et al. (2015), who use fixed probability classes based on multiple spatial units, this implementation works at single-station level. Therefore, historical data are used to determine what constitutes "low", "medium" or "high" occurrence probabilities for each drought category. This ensures the DHI reflects local drought patterns.

2.2.1 *Empirical thresholds calculation*

To assess whether a drought severity class (e.g., Moderate, Severe or Extreme Drought) is occurring more frequently than expected, we rely on the calculation of empirical thresholds derived from historical data. These thresholds represent the long-term probability of each drought class occurring, based on the station's historical data. So, the SPEI or NDVI timeseries is first classified into the four drought severity categories:

- Near Normal (NND)
- Moderate Drought (MD)
- Severe Drought (SD)
- Extreme Drought (ED)

The classification criteria of those two indicators used are as follows:

Category	SPEI range
Extremely Wet	>= 2.0
Severely Wet	[1.5, 2.0)
Moderately Wet	[1.0, 1.5)
Near Normal	(1.0, -1.0)
Moderate Drought	[-1.0, -1.5)
Severe Drought	[-1.5, -2.0)
Extreme Drought	<=-2.0

Table 1. *SPEI classification values* [2]

[2] Vicente-Serrano, S. M., Beguería, S., LópezMoreno, J. I. (2010). A Multiscalar Drought Index Sensitive to Global Warming: The Standardized Precipitation Evapotranspiration Index. Journal of Climate, 23(7), 1696–1718.

Category	NDVI range
Near Normal	>= 0.3
Moderate Drought	[0.2, 0.3)
Severe Drought	[0.1, 0.2)
Extreme Drought	< 0.1

Table 2. *NDVI classification values*

The number of occurrences for each class is then counted over the full historical period and by dividing with the total number of data, the probability of occurrence of each drought category is calculated. Then those probabilities are sorted (ascending) and the thresholds are defined for MD, SD and ED categories.

The least frequent category (e.g., ED) gets the first threshold. The next least frequent category (e.g., SD) gets the second threshold (cumulatively), etc. Let's take as an example that from a historical dataset we derive the below occurrence probabilities: 4% ED, 9% SD and 15% MD. Then the thresholds are defined like this:

$$thres(ED) = 0.04$$

$$thres(SD) = 0.04 + 0.09 = 0.13$$

$$thres(MD) = 0.13 + 0.15 = 0.28$$

Attention: NND does not get a threshold because it is always the most frequent category. Only drought categories need dynamic thresholds to reflect their relative severity. So, rating for NND is fixed at 1 (NND_r=1) because the DHI formula is designed to penalize drought conditions and not normal/wet conditions; If NND had a threshold, it could artificially inflate DHI when normal conditions dominate.

The key idea is to evaluate how hazardous recent conditions are. Therefore, the recent frequency of occurrence of each drought severity class needs to be compared to its historical occurrence probability.

The final step to assign a rating value in each drought class is to compare their occurrence probability to the respective thresholds. Specifically, if:

$$P(DC_i) <= 0.25*thres(DC_i) \rightarrow rating=1$$

$$0.25*thres(DCi) < P(DC_i) <= 0.5*thres(DC_i) \rightarrow rating=2$$

$$0.5*thres(DC_i) < P(DC_i) <= 0.75*thres(DC_i) \rightarrow rating=3$$

$$P(DC_i) > 0.75*thres(DC_i) \rightarrow rating=4$$

where $P(DC_i)$ is the probability of occurrence of each drought category derived from the most recent data.

2.2.2 *Integrated DHI*

Once the specific-class ratings have been assigned (based on the comparison of recent frequencies with historical thresholds) the DHI can be calculated. This is done separately for each indicator-SPEI and NDVI. Based on the DHI formula (1) the index can now be calculated. Note that $NND_w=1$, $MD_w=2$. $SD_W=3$, $ED_W=4$ and $NND_r=1$, as mentioned in the above sections.

$$\text{Raw DHI(SPEI/NDVI)} = 1 + (2*MD_r) + (3*SD_r) + (4*ED_r) \quad (2)$$

Executing this calculation we get:

- A SPEI-based DHI value reflecting meteorological drought hazard
- A NDVI-based DHI value reflecting ecological drought response

This DHI raw value is then normalized to a [0,1] scale. Since the minimum rating value for MD, SD and ED is 1 and the maximum one is 4, the raw DHI value ranges between 10 and 37. Therefore, the normalized DHI value is defined as:

$$\text{Normalized DHI} = \frac{\text{Raw DHI}-10}{37-10} \quad (3)$$

The two normalized DHI values, SPEI-based and NDVI-based, are then combined into a single integrated DHI value, using a weighted average approach:

$$\mathbf{DHI_{integrated} = w_{spei} * DHI_{spei} + w_{ndvi} * DHI_{ndvi}} \quad \mathbf{(4)}$$

The w_{spei} value is equal to 0.7 and the w_{ndvi} value equal to 0.3. This way, we increase the weight of the SPEI which captures better the rapid response to meteorological drought and less weight to the NDVI which reflects the lagged vegetation impacts. However, these weights could be adjusted depending on the study region.

Furthermore, a worst-case estimate is also provided as the maximum value between DHI_{spei} and DHI_{ndvi}, offering flexibility depending on the user's needs- whether prioritizing a balanced view of the index or emphasizing on the maximum risk.

The final DHI value (whether combined or worst-case) is then categorized into one of four hazard levels: **Low**, **Moderate**, **High** or **Very High** according to the classification below:

Category	DHI value
Low	[0, 0.25)
Moderate	[0.25, 0.50)
High	[0.50, 0.75)
Very High	>= 0.75

Table 3. *DHI classification values*

2.3 Example Application

This example simulates how the DHI index would be calculated based on recent observations and historical data of a specific station.

Assume that the following SPEI values have been recorded for the past 12 months:

SPEI values = [-1.1, -1.2, -0.8, -0.3, 0.2, 1.1, -0.5, 1.3, -1.8, -2.2, 0.5, 0.0]

These values are then classified into drought categories according to Table 1. We count how many times each drought category occurred and the corresponding probability of occurrence by dividing to the total number of values:

Category	Counts observed (occurrence probability)
Extreme Drought (ED)	1 (8.3%)
Severe Drought (SD)	1 (8.3%)
Moderate Drought (MD)	2 (16.7%)
Near Normal (NND)	6 (50,%)
Wet (excluded)	1 (not interested in wet conditions)

Then let's assume that historical SPEI data for the same station yielded the following long-term occurrence probabilities:

ED: 4%

SD: 9%

MD: 15%

NND: 72%

The thresholds can be calculated according to the methodology described in Section 2.2.1:

thres(ED) = 0.04

thres(SD) = 0.04+0.09 = 0.13

thres(ED) = 0.13 + 0.15 = 0.28

To assign the rating value to each drought category, we must check in which portion of the empirical thresholds does each value fall (0.25*thres, 0.5*thres, 0.75*thres)

ED: occurred at 8.3% which is > 0.75 * 0.04 → rating=4

SD: occurred at 8.3% which is > 0.5*0.13 & < 0.75*0.13 → rating=3

MD: occurred at 16.7% which is > 0.5*0.28 & < 0.75*0.28 → rating=3

Therefore, rawDHI = 1 + (2*3) + (3*3) + (4*4) = 32 and then normalized as:

DHI = (32-10) / (37-10) = 0.81 and classified as 'Very High' risk according to Table 3.

The same implementation is derived from the historical and current data of the NDVI. Using formula (4) with the reasonable weights, we obtain the final combined DHI value.

The results can be visualized in Figure 1 as an example: the DHI derived from SPEI equals 0.81 indicating a 'Very High' risk of meteorological drought.

The DHI derived from the NDVI equals 0.44 indicating a 'Moderate' risk for the vegetation.

The combined DHI value is equal to 0.70 ('High' risk) since greater importance is assigned to the SPEI-derived DHI value (70%-30%).

The worst-case scenario between these two is the maximum DHI value, namely the DHI (SPEI)=0.81.

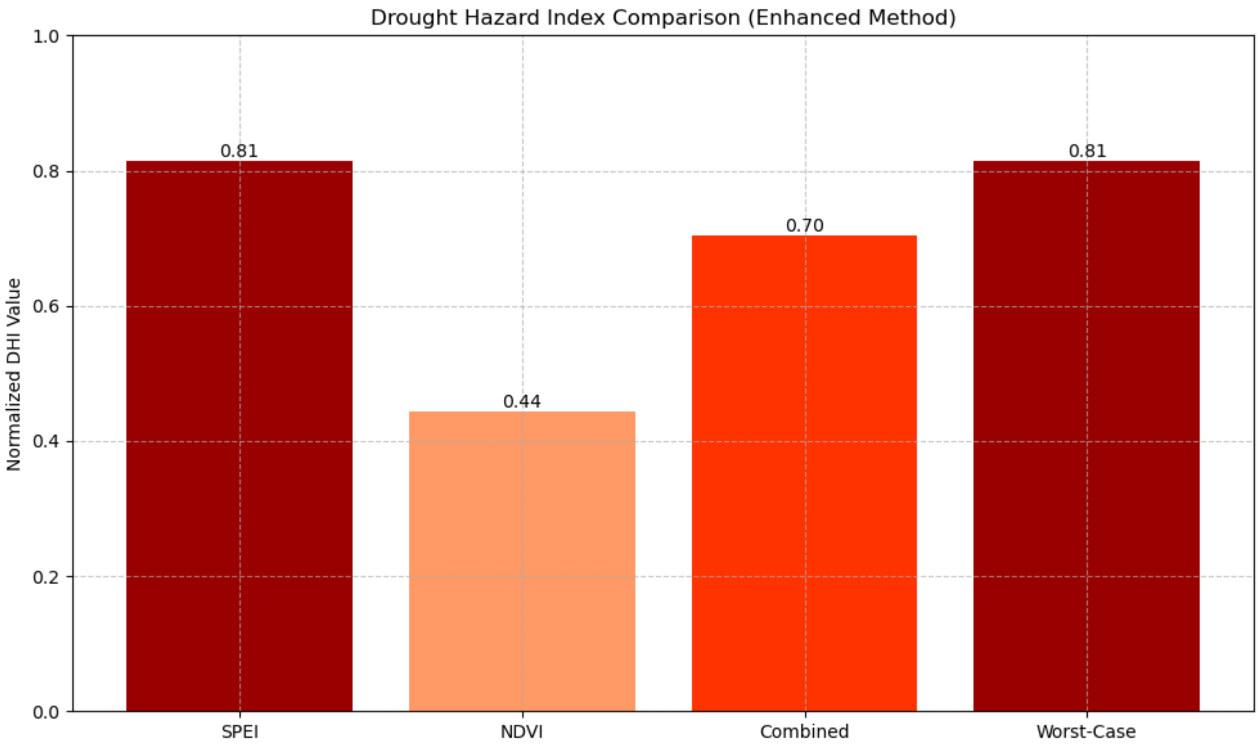

Figure 1. *Example illustrating the different DHI values.*