Improving access to FORest GENetic resources Information and services for end-Users

Deliverable D2.4

Database of time series of relevant heat and water stress indicators for the GenRes collection

Planned delivery date (as in DoA): M39 31/03/2024

Actual submission date: 19/04/2024, month M40

Workpackage: WP2

Workpackage leader: CREAF

Deliverable leader: CREAF

Version: 1.0

Project funded by the European Commission within the Horizon 2020 Programme	
Dissemination Level	
PU Public	**PU**
CI Classified, as referred to Commission Decision 2001/844/EC	
CO Confidential, only for members of the consortium (including the Commission Services)	

Research and Innovation action: GA no. 862221
Start date of the project: January 1st, 2021

TABLE OF CONTENTS

1 Summary

The objective of this deliverable was to produce a dataset of indicators of heat and drought stress across the current collection of Genetic Conservation Units (GCUs), with the goal to characterise the GCUs with data suited for a spatio-temporal assessment of climate-related stresses and risks. To explore the multiple dimensions of drought and heat stress on forest trees, the assessment integrates a wide array of data sources, observation techniques and platforms. It includes remote sensing retrievals of land surface temperature, greenness, and leaf water content, complemented by assimilation products and ground-based observations from a comprehensive network of weather stations. The remote sensing data were derived from the output of multiple missions, including data collected by optical, thermal, and passive microwave sensors. A non-parametric indicator was developed to quantify drought and heat stress conditions. The indicator was designed in such a way that it would apply to variables with different statistical properties. The development of these stress indices advances the work undertaken as part of Work Package 1 (WP1), by combining data from multiple distinct sources with the aim of more accurately identifying and assessing the occurrence of stress events.

2 Introduction

The work undertaken under D2.4 involved the development of a pipeline for the collation and analysis of several data sources to produce heat and water stress indicators. Data extraction was performed through two primary means: leveraging a multi-petabyte catalogue available via cloud computing platforms and utilising specialised data portals. A comprehensive list of these data sources is detailed in Table 1 (Results section).

Depending on the level of processing, heat or drought indicators can be broadly characterised into two types. The first type includes indicators that are directly accessible, requiring no additional processing beyond the extraction of values for each GCU. The second type involves datasets that require the calculation of specific indicators. This category includes Land-Surface Temperature and several spectral indices derived from the MODIS (Moderate Resolution Imaging Spectroradiometer) archive, as well as data from the Vegetation Optical Depth (VOD) Climate Archive (VODCA) (see Table 1 in the results section for details).

For the indicators requiring calculation from raw data series, temporal time series anomalies–i.e. deviations from the long-term median of a given variable–were computed. Prior to the calculations, data were aggregated on a temporal scale at the 16-day interval, and spatially, i.e. the values of the variable of interest for each time step were aggregated at the GCU level. This decision to aggregate at the GCU level was driven by the trade-off between the datasets' relatively coarse resolution and the small extent of some polygons.

For a given variable $X_{i,y}$ where i indicates the time window within each year and y indicates the year, we define the standardised anomalies as

1. $X'_{i,y} = (X_{i,y} - X_{i,50}) / (X_{i,75} - X_{i,25})$,

where $X_{i,50}$ is the 50th percentile computed for each time step of the year, considering all years. Similarly, $X_{i,75}$ and $X_{i,25}$ are the 75th percentile and the 25th percentile, respectively.

The standardization was based on quantile statistics (median and interquartile range) instead of parametric estimators like average and standard deviations, to cope with the potential asymmetry in the distribution of some stress metrics.

Following the standardization of data at the 16-day resolution, an annual stress index was computed by averaging the stress metric for the degree of greenness of the canopy. Using the notation defined above, it is possible to define the annual integrated stress indicator with respect to a prescribed threshold T as:

2. $S_X(y,T) = \sum_{X'_{i,y} > T} [\, NDVI_{i,CLIM} \cdot (\, X'_{i,y} - T \,)\,] \,/\, \sum_{i = 1, N_i} NDVI_{i,CLIM}$

if T > zero, or

3. $S_X(y,T) = \sum_{X'_{i,y} < T} [\, NDVI_{i,CLIM} \cdot (\, T - X'_{i,y} \,)\,] \,/\, \sum_{i = 1, N_i} NDVI_{i,CLIM}$

If T < zero, where $NDVI_{i,CLIM}$ is the long-term average of NDVI for the i^{th} time-window. Weighting the integration of the stress indicator using the climatological NDVI values ensures that the stress indicator is sensitive only to the anomalies occurring during the active phenological stage of the plants. Only positive T values are considered for heat stress. Negative values of T are considered for all other drought-related variables.

As an additional remark, the weighting for the NDVI allows for nuanced comparisons across areas with differing vegetation densities. This adjustment ensures that the measured anomalies reflect actual environmental deviations, rather than baseline differences in vegetation across broad environmental gradients.

3 Results

The deliverable consists of a series of comma-delimited files (CSV) containing time-series data for 23 indicators. The data originate from a variety of sources, including remote sensing archives from satellite missions such as NASA's MODIS mission, Vegetation Optical Depth (VOD) data, ground-based based network of weather stations, and other information systems including the European Drought Observatory.

The deliverable consists of a series of comma-delimited files (CSV) containing time-series data for 23 indicators. The data originate from a variety of sources, including remote sensing archives from satellite missions such as NASA's MODIS mission, Vegetation Optical Depth (VOD) data, ground-based based network of weather stations, and other information systems including the European Drought Observatory.

3.1 Table of indicator

Type of indicator	Variable	Description	Temporal aggregation	Period	Data source
Drought stress	Normalized Difference Water Index (NDWI)	Anomalies & Weighted Anomalies	16-day	2001-2022	MODIS Terra
Drought stress	Normalized Difference Vegetation Index (NDVI)	Anomalies	16-day	2001-2022	MODIS Terra
Drought stress	Vegetation optical depth (VOD) C band, K band and X band datasets.	Anomalies	16-day	2003-2018 (C band) 1998-2016 (K BAND) 1998-2018 (X BAND)	VODCA dataset
Drought stress	Soil moisture	Anomalies	10-day	1995-2023	European Drought Observatory
Drought stress	Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)	Anomalies	10-day	2002-2022	European Drought Observatory
Drought stress	Standardized Precipitation Index (SPI)	Dimensionless Index	10-day	1991-2022	European Drought Observatory
Drought stress	Maximum no. of consecutive dry days (CDD)	Maximum count of consecutive days with minimal or no rainfall.	Annual	1950-2023	e-OBS - ECMWF
Drought stress	Ratio of actual transpiration to potential evaporation (ET/ETP)	Anomalies	16-day	1980-2022	GLEAM
Heat stress	Land Surface Temperature	Anomalies & Weighted Anomalies	16-day	2001-2022	MODIS Terra MODIS Aqua
Heat Stress	Duration of heawaves active in the given day.	Maximum value	Daily	1980-2023	European Drought Observatory

Table 1. Simplified list of the drought and heat stress indicators provided as part of the deliverable. All the data are provided at the GCU-level. Detailed information on files names and their contents are provided with the metadata file accompanying the dataset

3.2 Anomaly time series example

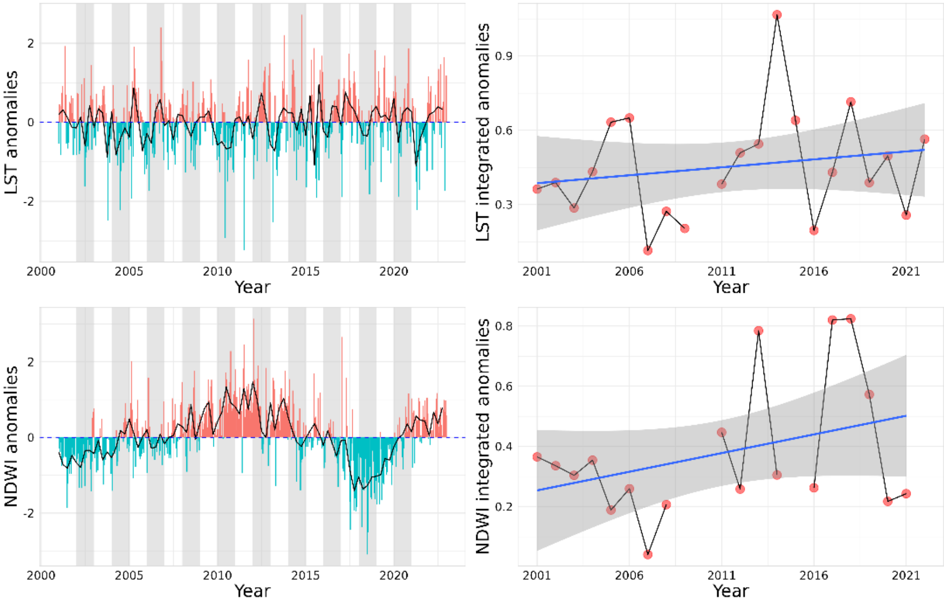

Figure 1. Time series of two indicators of heat and drought stress—*based on land surface* temperature (LST) and canopy water content (NDWI)—for a specific GCU. Integrated indicators shown in annual time series plots, were obtained by weighting each indicator by the climatological NDVI, following the procedure explained in the main text. Similar time series are available in the database for each index mentioned in Table 1 and for every GCU.

3.3 Anomalies across all GCUs

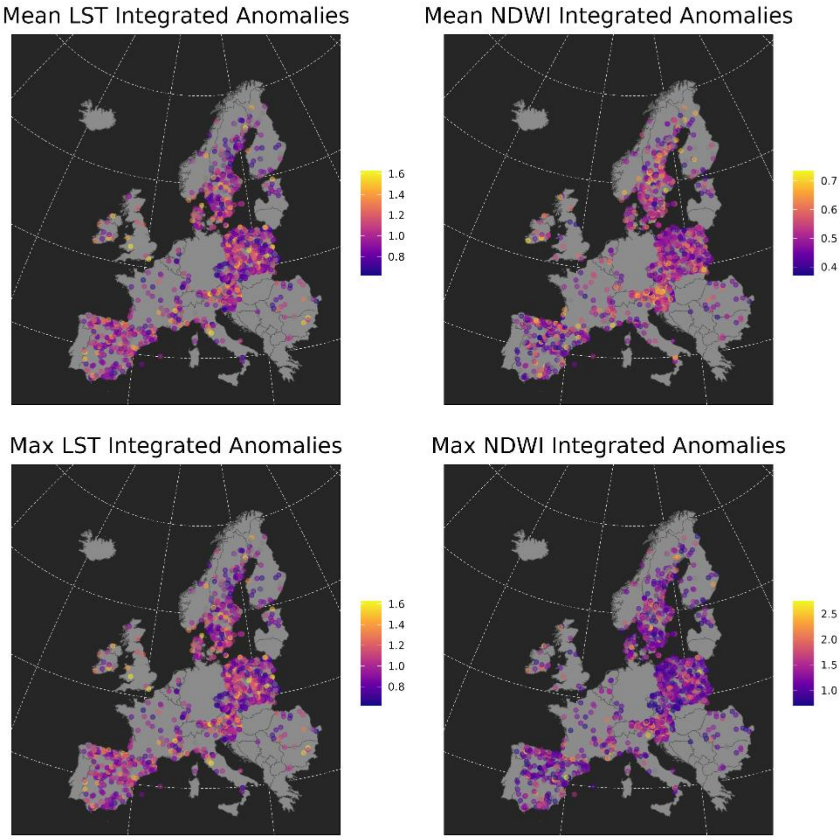

Figure 2: Average and maximum of annual anomalies in Land Surface Temperature (LST) and Normalized Difference Water Index (NDWI) calculated for each GCU across the period 2001-2022.

3.4 *Anomaly trends*

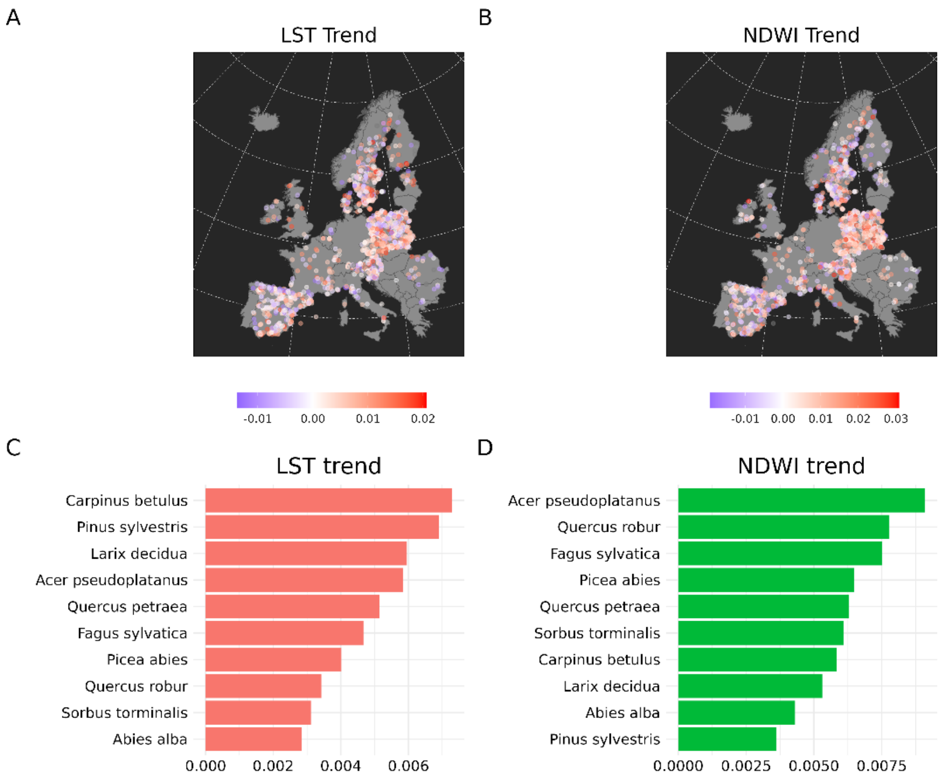

Figure 3. GCU-Level Trends in Integrated Annual Heat and Drought Stress Indicators (Panels A and B), derived from Land Surface Temperature (LST) and the Normalized Difference Water Index (NDWI). Trends were calculated by fitting an ordinary least squares regression model (OLS) to the time series data of each indicator for every GCU. The maps depict the slope of the year term from the model. Bar charts (Panels C and D) present the average trend for the ten most common species across the GCUs.

4 Conclusions

We have successfully developed and implemented a pipeline designed for collating a diverse array of data sources. This enabled us to derive a range of heat and drought indicators effectively. Our analytical framework serves as a solid foundation for establishing an operational framework aimed at regularly calculating these indicators for the GCU collection. In the future, this framework has the potential to be further refined, allowing for the creation of two comprehensive combined indicators that accurately reflect heat and drought stress.

5 Partners involved in the work

JRC led the Data collation analysis. INRAE collected and harmonised the geographical data of the GCUs (polygons describing the contours). CREAF contributed to the identification of appropriate data sources.

6 Annexes

Annex A1: A zip file containing CSV files with individual heat and stress indicators, accompanied by a metadata document describing the contents of each CSV file.