A PAN-EUROPEAN ANALYSIS OF DROUGHT EVENTS AND IMPACTS

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(1) ABSTRACT

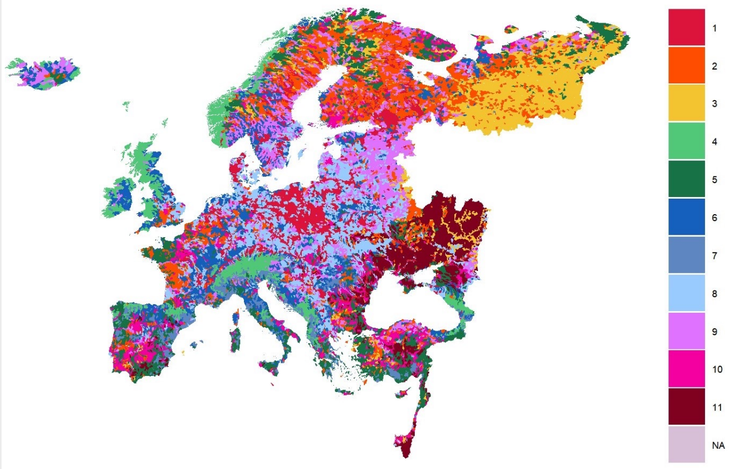
Today drought detection is becoming more and more important for supporting water management strategies, especially in a changing climate.

Here we assess the ability of traditional standardized drought indexes (the most common tools used in the literature) in detecting drought events and their impacts at the pan-European scale, using data from HydroGFD2.0 reanalysis and E-HYPE hydrological model simulations over the time period 1993-2018.

HIGHLIGHTS:

- Beside some inconsistencies across different standardized indexes, substantial disagreements emerge between observed impacts and detected droughts. Such asymmetry suggests that traditional drought indexes are not always consistent in detecting droughts impacts, especially in highly regulated contexts.
- The Framework for Index-based Drought Analysis (FRIDA) succeeds in constructing novel indexes that better capture the drought impacts on vegetation.

(2) HYDROLOGICAL SIMILARITY OVER THE PAN-EUROPEAN DOMAIN



Based on the E-HYPE hydrological model, the pan-European domain consists of 35,408 sub-basins that can be grouped into 11 clusters (Pechlivanidis et al., 2020).

For every sub-basin, eight statistical indexes have been computed on a monthly basis over the time period 1993-2018: SPI-1, SPI-3, SPEI-1, SPEI-3, SSI-1, SSI-3, SSI-6, and SRI-6.

Figure 1. *Spatial distribution of hydrological clusters. The sub-basins are grouped according to their hydrological similarity: 15 streamflow signatures from the E-HYPE hydrological model setup were analyzed, resulting in 11 clusters of different sizes and variable distributions in the signatures (Pechlivanidis et al., 2020).*

(3) COMPARISON OF STATISTICAL DROUGHT INDEXES

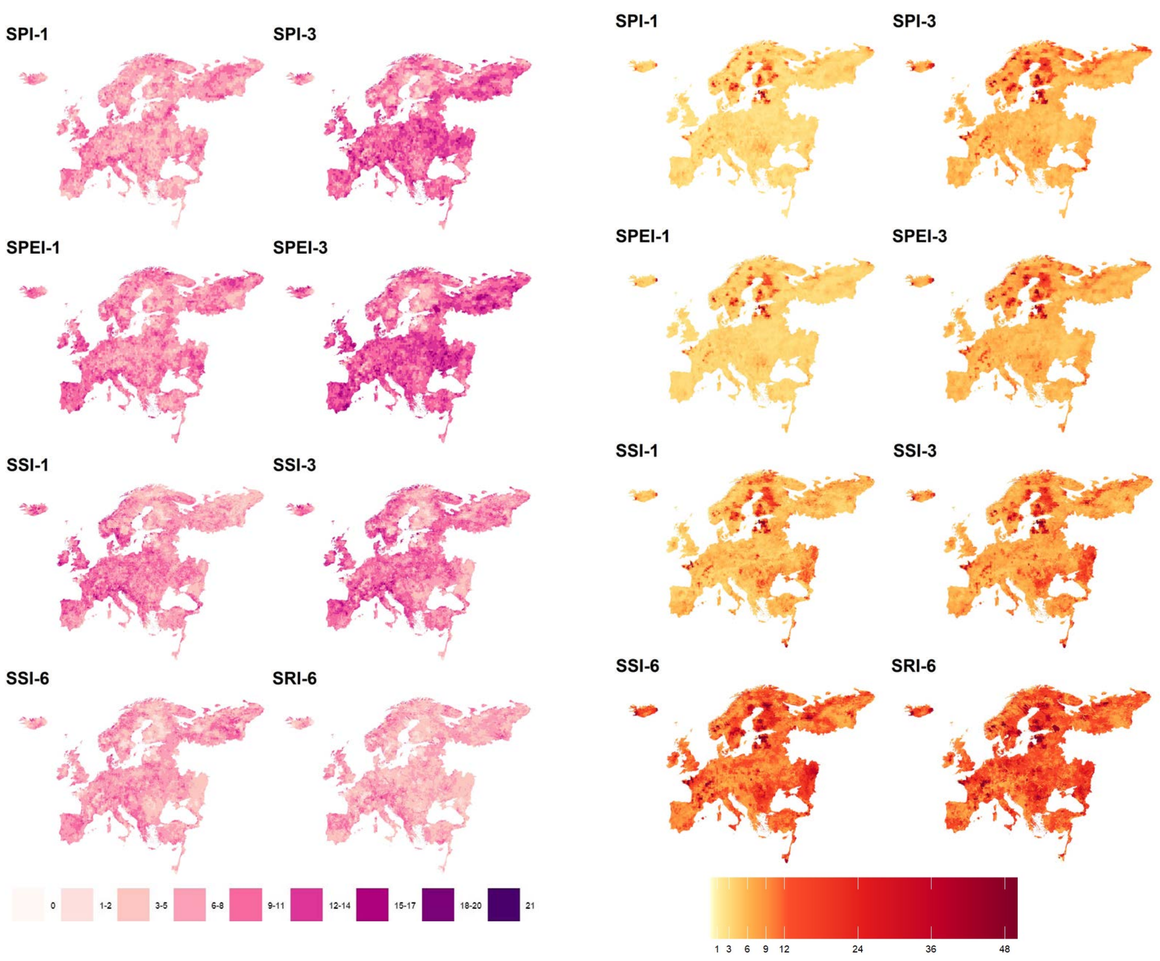


Figure 2. *Occurrence of droughts (left) and mean duration of droughts measured in months (right) in 1993-2018, according to the different statistical drought indexes.*

(4) IMPACTS USING THE FAPAN INDEX

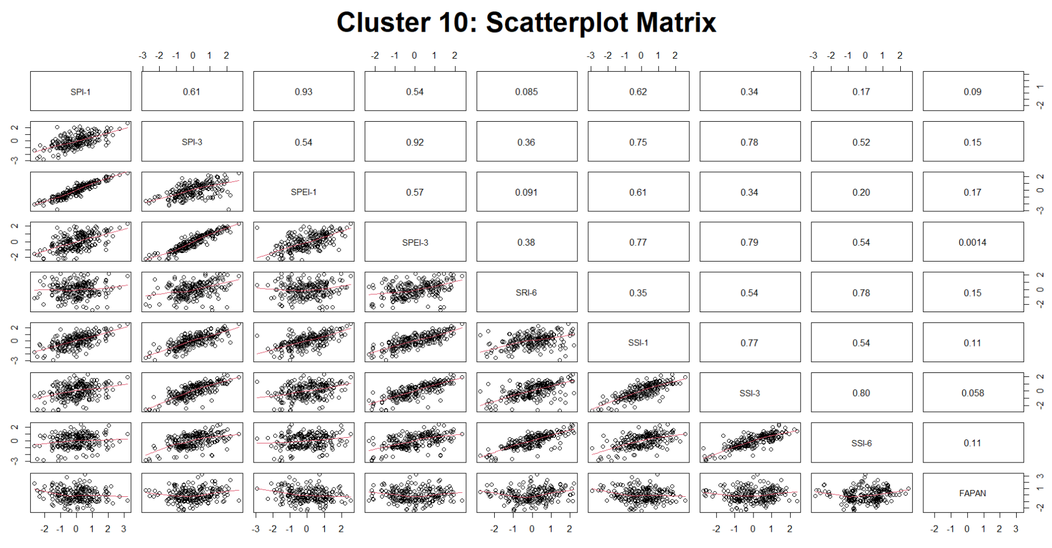


Figure 3. *Correlation between standardized drought indexes and FAPAN for sub-basins in cluster 10.*

In order to test the skill of the standardized indexes, the drought events detected by them have been compared with the Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) Anomaly index. The higher the FAPAR, the higher the photosynthetic activity, meaning a better state of vegetation. In this sense, the negative anomaly of FAPAR (FAPAN) can be considered a proxy of drought impacts.
In cluster 10, the maximum correlation between drought indexes and FAPAN (last column) is equal to 0.17. These low values suggest that traditional drought indexes are not effective in detecting impacts. Hence, the need of constructing new impact-based drought indexes.

(5) THE FRAMEWORK FOR INDEX-BASED DROUGHT ANALYSIS

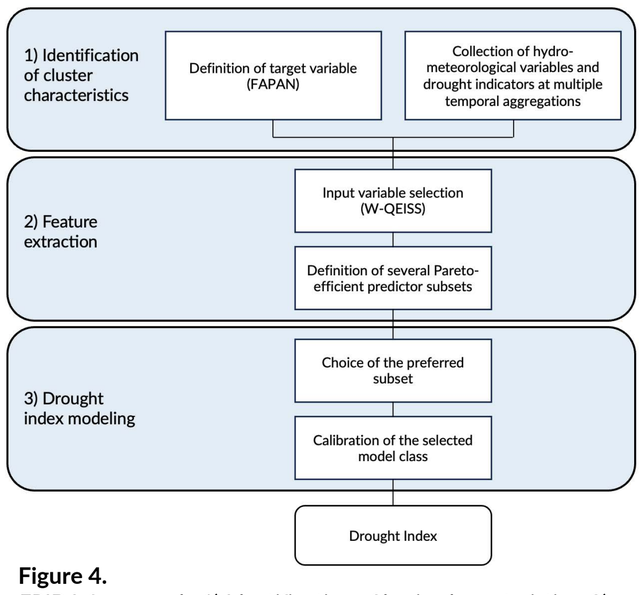
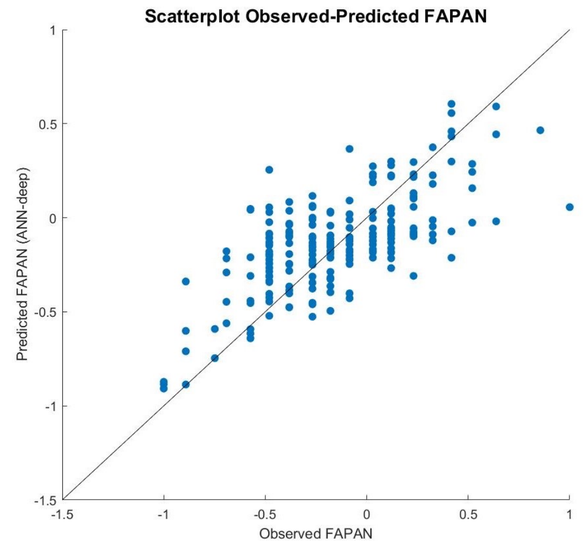


Figure 4.
FRIDA framework: 1) Identification of basin characteristics; 2) feature extraction, and 3) drought index modeling (Zaniolo et al., 2018).

The FRamework for Index-based Drought Analysis (FRIDA) was developed to support the construction of new composite drought indexes that can be tailored to the unique hydrological and meteorological conditions of a particular region, being able to better capture the impacts of a drought event. In particular, FRIDA is a Machine Learning framework that builds an index representing a surrogate of the drought conditions of the region, computed by combining all the relevant available information about the water circulating in the system identified by means of an advanced input variable selection algorithm, namely the Wrapper for Quasi-Equally Informative Subset Selection (W- QEISS).

(6) IMPACT-BASED DROUGHT INDEX FORMULATION



The new impact-based drought index designed by FRIDA is represented by the most accurate ML model in predicting the FAPAN as a function of the variables selected by W-QEISS.
For Cluster 10 the selected model structure is a neural network with 15 nodes subdivided into 3 layers, being able to reach a correlation value of 0.70.

Figure 5. *Scatterplot observed-predicted FAPAN for sub-basins in cluster 10.*

(7) IMPROVEMENT OBTAINED VIA FRIDA

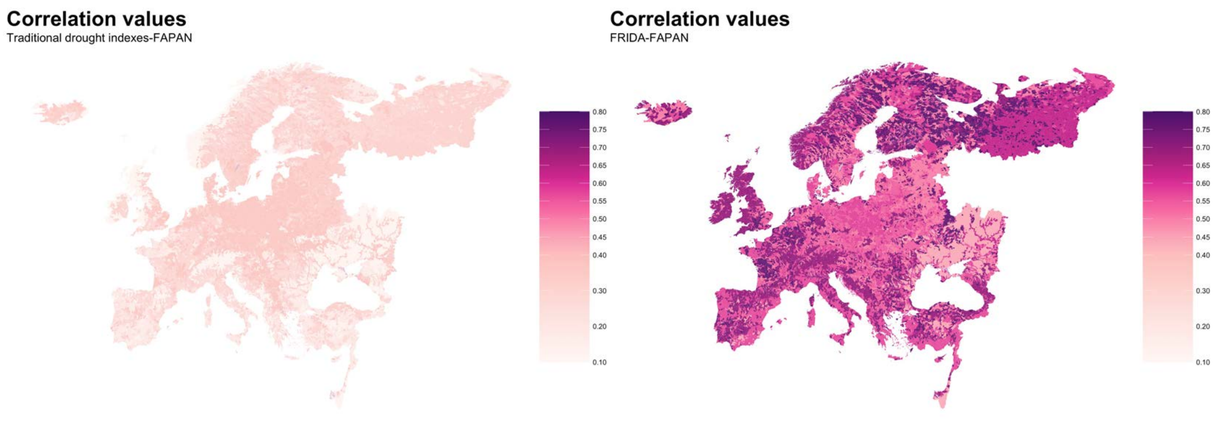


Figure 6. *Qualitatively improvement obtained via FRIDA: on the left, the initial correlation values between traditional drought indexes and FAPAN; on the right, the final correlation values obtained via FRIDA.*

On the left side the catchments are filled with light colors, representing low initial correlation values between the traditional drought indexes and FAPAN. On the right side, the situation obtained considering FRIDA indexes: the catchments are filled with darker colors, meaning higher correlation values between FRIDA indexes and FAPAN. On average, considering all the clusters, the FRIDA indexes increase the correlation with FAPAN by 0.35.

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