BUILDING AN OPERATIONAL DROUGHT FRAMEWORK

Arianna Di Paola[1], Edmondo Di Giuseppe[1], Ramona Magno[2*], Sara Quaresima[1], Leandro Rocchi[2], Elena Rapisardi[2], and Massimiliano Pasqui [1]
[1] National Research Council of Italy, Institute for BioEconomy, Rome, Italy;
[2] National Research Council of Italy, Institute for BioEconomy, Florence, Italy
Corresponding Author: arianna.dipaola@ibe.cnr.it

DROUGHT CENTRAL Osservatorio Siccità

Consiglio Nazionale delle Ricerche | Istituto per la BioEconomia

Introduction

Effective climate services are essential for decision-makers to navigate and respond to the challenges posed by drought. By leveraging insights gained from the climate service CNR-IBE "**Drought Central**" and direct engagement with decision-makers, we present a novel operational drought framework that offers a comprehensive view of drought at the river basin scale.

Methods: The three pillars framework

1 A critical examination of a set of **Standardized Precipitation Index** (1) **{SPI}** and **Standardized Streamflow Index {SQI}** estimated across continuous month-scales.
In this case the set embraces **1-36 month-scales**.

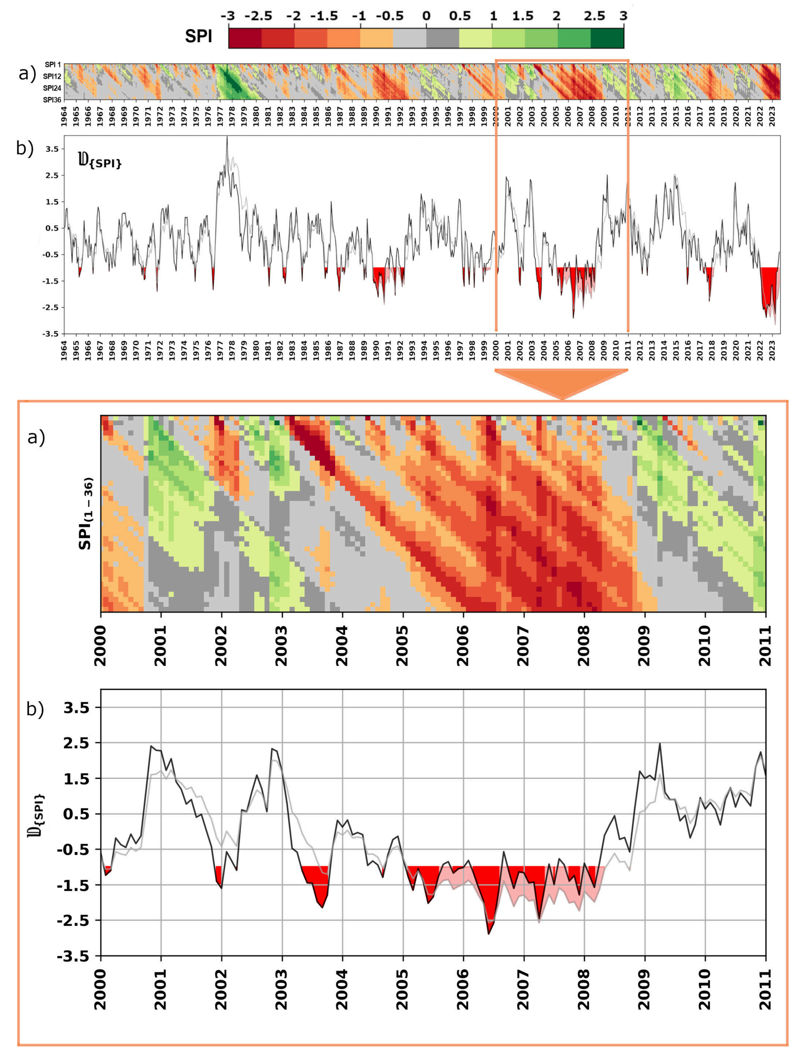


Figure 1.
a) SPI1-36 heat map.
A meteorological drought ("drought shot"), if intense or overlapping with previous drought events, could propagate into subsequent month-scales (temporal propagation, red diagonals) and lead to severe droughts (red areas highlighted by $\mathfrak{D}${SPI} (panel b).,
b) $\mathfrak{D}${SPI} estimated with logarithmic decreasing weights (*lgdw*, black line) and equal weights (*ew*, grey line). The shaded area represents $\mathfrak{D}${SPI} < -1 (i.e., the severe phase of drought). The orange box zooms the period 2000-2011 for a better visualization.

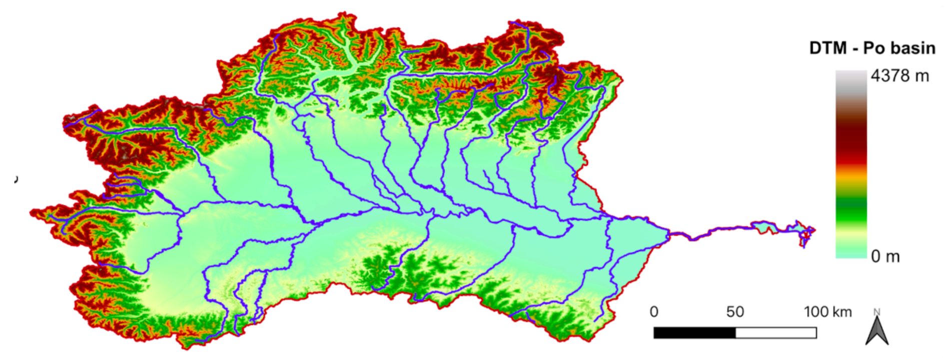
2 The computation of the **Standardized Integrated Drought Index** ($\mathfrak{D}$), as a multi-scale **weighted mean** of the SPI and/or SQI set, which is then standardized as Z-score. This process aids in the identification and effective communication of severe phases of droughts.

3 The contextualization of severe droughts into the surrounding water supplies, here accounted by means of the **Cumulative Deviation of SPI1 from the Normal (CDN)**, where the CDN serves to gain insights into whether the system has received an adequate supply of water resources to cope with upcoming drought events (2,3).

$$CDN = \sum_{i=1}^{T} SPI_1, i$$

Where *i* is the *i*-month of the SPI1 time series of T length (the same holds for SQI1).

Showcase: Po River Basin



Area: ~71000 Kmq
Annul Precipitation: 925 mm
Mean monthly discharge: 1415 mc/sec

Nationsl shares:
23% of the national territory
35% of the national agricultural production
55% of the Italian livestock
48% of the national hydropower production

About the weights (pillar 2)

Should the "month-scales" assume equal weights in the computation of $\mathfrak{D}$? The choice was guided by testing several weighting functions and determining which one provides the best correlation between $\mathfrak{D}${SPI} and the SQI1 (i.e., the standardized monthly streamflow). Additionally, correlations between SPI and SQI1 were also measured for comparison.

*The **logarithmically decreasing weights (lgdw)** resulted as the optimal weighting function for computing $\mathfrak{D}${SPI}, allowing for a 10% increase in the explained variability in SQI1 compared to the single top-ranked SPI*

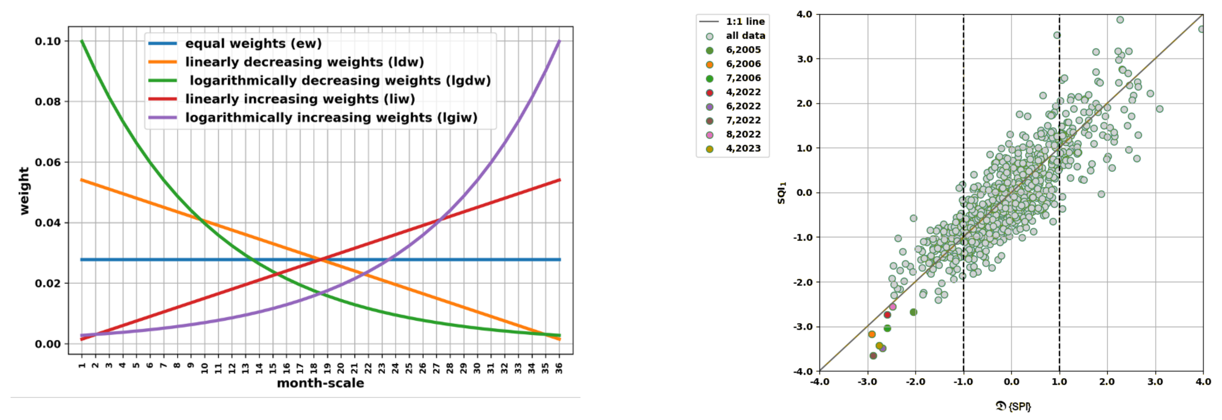


Figure 2.
a) proposed and tested weighting function; b) $\mathfrak{D}${SPI} - estimated by means of *lgdw*- vs. SQI1 scatter plot.

Tables 1 and 2. Performance of single, top-ranked, weighting functions (left table) and SPI (right table) in explaining the variability of SQI1. Squares of pearson

Weight type	$\mathfrak{D}${SPI} vs. SQI1
lgdw	**0.73**
ldw	**0.62**
ew	**0.48**
liw	**0.33**
lgiw	**0.22**

Month-scale	SPI vs. SQI1
SPI4	0.63
SPI3	0.62
SPI5	0.61
SPI2	0.58
SPI6	0.08

Results

Severe droughts identified by $\mathfrak{D}${SQI} <-1 are totally aligned with those found in the literature. seMulti-years precipitation patterns that drive the system under alternate wet and dry periods are highlighted; during prolonged dry periods, single or cumulative meteorological droughts could propagate into hydrological severe droughts (I.e., $\mathfrak{D}${SQI}<-1). Vice versa, under wet conditions the hydrological system is able to absorb the propagation without substantial impacts.

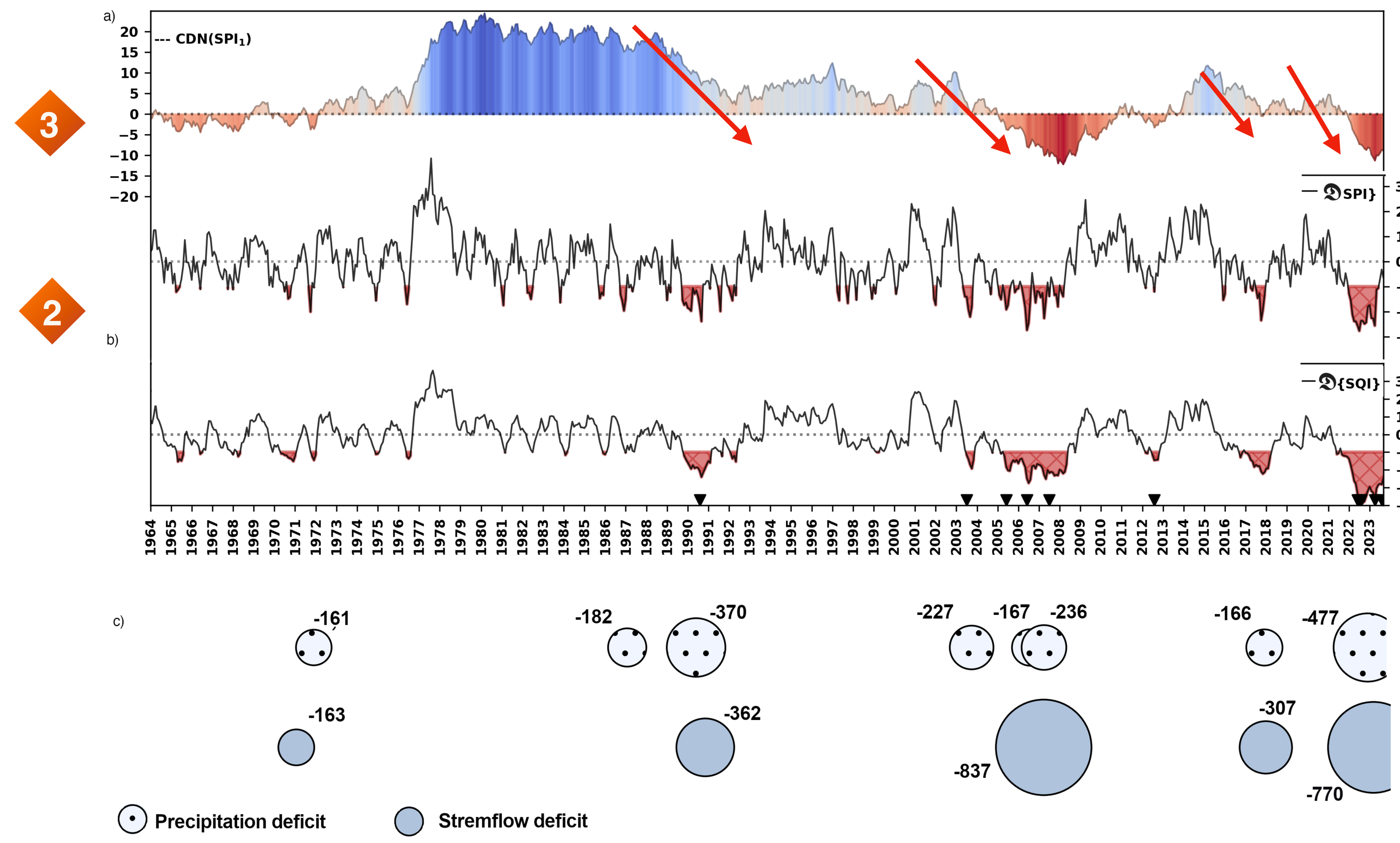


Figure 3. Drought synopsis from SPI and SQI analysis. Blue (surplus) to red (deficit) shaded area (left y-axis): CDN; black lines (right y-axis): $\mathfrak{D}${SPI} and $\mathfrak{D}${SQI}. Red areas as in FIg.1; red arrows indicate the major drop in the CDN; cyan and light blue circles show the cumulated deficit (only if >-150mm) of precipitation and streamflow under the severe phase of droughts.

Conclusion

The novel operational framework aimed at providing a synoptic view of droughts, while increasing the knowledge of triggers (single or cumulative drought shots), propagation across time (diagonals) and segments of the water cycle (from precipitation to river streamflow), recovery requirements (deficit and CDN), as well as the simplification of information through an ensemble index ($\mathfrak{D}$) and the contextualization of severe phases in the long-term surrounding water supplies (CDN phases and trends).

References

(1) McKee, T. B., Doesken, N. J., & Kleist, J. (1993a). The relationship of drought frequency and duration to time scales. *Proceedings of the 8th Conference on Applied Climatology*, *17*(22), 179–183.
(2) Smail, R. A., Pruitt, A. H., Mitchell, P. D., & Colquhoun, J. B. (2019). Cumulative deviation from moving mean precipitation as a proxy for groundwater level variation in Wisconsin. Journal of Hydrology X, 5, 100045. https://doi.org/10.1016/j.hydroa.2019.100045
(3) Weber, K., & Stewart, M. (2004). A critical analysis of the cumulative rainfall departure concept. Ground Water, 42(6–7), 935–938. https://doi.org/10.1111/j.1745-6584.2004.t01-11-.x

Finanziato dall'Unione europea
NextGenerationEU