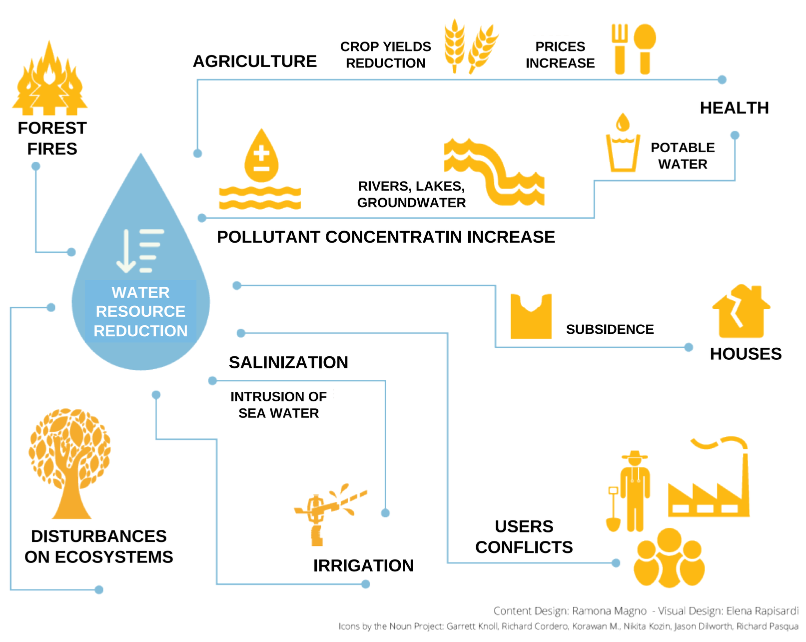
Seasonal forecasts for an effective drought climate service

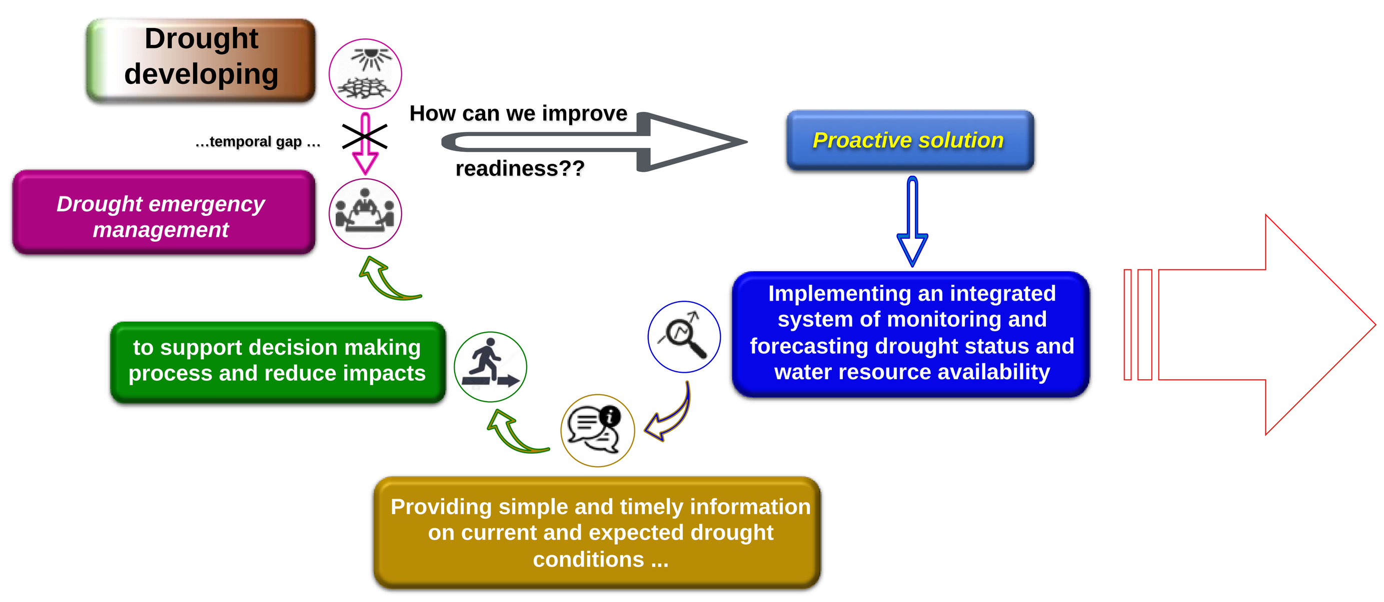
R. Magno [(1)], E. Di Giuseppe [(1)], M. Pasqui [(1)] and E. Rapisardi [(1)]

[(1)] CNR – Istituto di Biometeorologia (CNR – IBIMET), Firenze, Italia
Contacts: r.magno@ibimet.cnr.it
www.ibimet.cnr.it – www.climateservices.it

According to the IPCC, the Mediterranean Basin is one of the hot spots of the planet affected by temperature rising and rainfall distribution modifications. Moreover, it is characterized by a strong vulnerability due to centuries of natural resources overexploitation. Climate changes and land mismanagement are exacerbating pressure on natural resources, reducing their resilience. Understanding drought and its variability, and timely communicating its evolution over time and space can allow a shift from an approach of crisis management to a more proactive one, where responses are planned in advance in respect to the droughts occurrence and therefore are more effective and coordinated during the event.

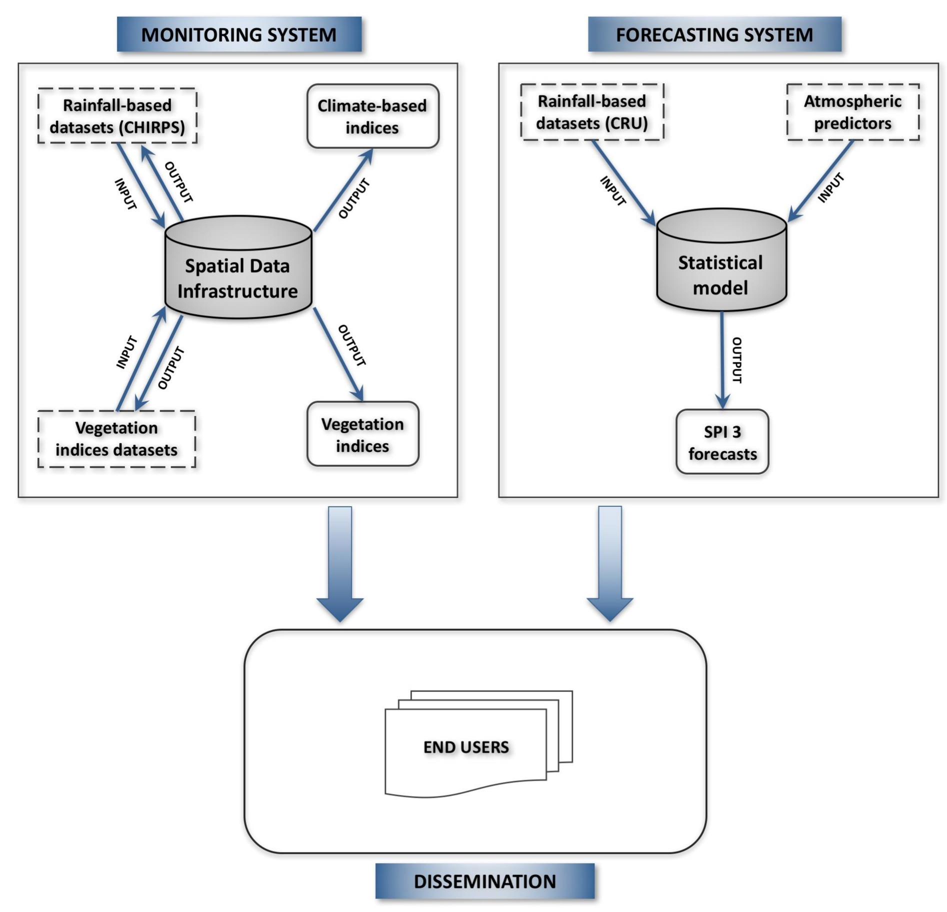
Setting the scene

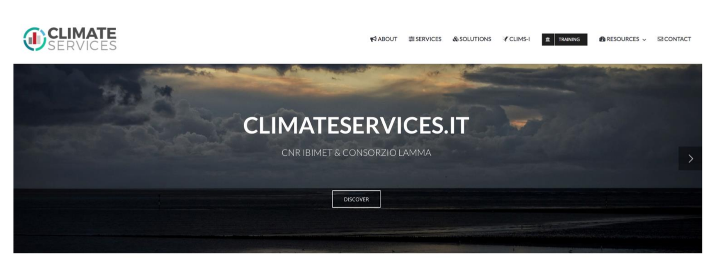




One of the main challenges to cope with drought, in fact, is reducing the temporal gap existing between the onset and development of a dry period, and the response in managing drought-related emergencies.
Following this idea, the Institute of Biometeorology of the National Research Council has developed a seasonal forecast system based on an empirical approach to predict drought using the SPI 3 index few months in advance from large scale observed climate indices (*Magno et al., 2018*).

Schematic overview





Seasonal Forecasting System

The forecasting system is based on an empirical approach to predict meteorological drought using the SPI 3, a few months in advance from large-scale observed climate indices. This seasonal forecast empirical system adopts a physically based statistical approach which uses a multivariate regression (MR) model to estimate future anomalies. Predictors are selected among observed atmospheric and oceanic climatic indices according to the list in Table 3, then they are centered and standardized by using the overall mean and standard deviation, respectively. The de-trending procedure is applied by monthly subsetting each timeseries, since an MR model is built for each forecast month. The entire procedure has been carried out at each grid cell of the spatial domain. Thus, an evaluation of the predictive performance of the best model for each SPI-3 can be done, summarizing the results obtained in each grid cell, and such an evaluation is reported in Table 4 .
This seasonal forecasting system is part of the CNR-IBIMET's "**Drought Observatory**": a comprehensive Climate Service that responds to the need of integrating a timely monitoring with a robust forecast of occurrence and evolution of drought events and reshaping scientific information into operational information and services available for end users such as policy makers, water authorities, researchers, etc.
A series of ongoing operational services, and research applications and projects (SERV_FORFIRE and Med-GOLD) for drought detection take advantage of these forecasts, aiming to increase knowledge-based information for supporting decision-making activity of a wide variety of stakeholders.

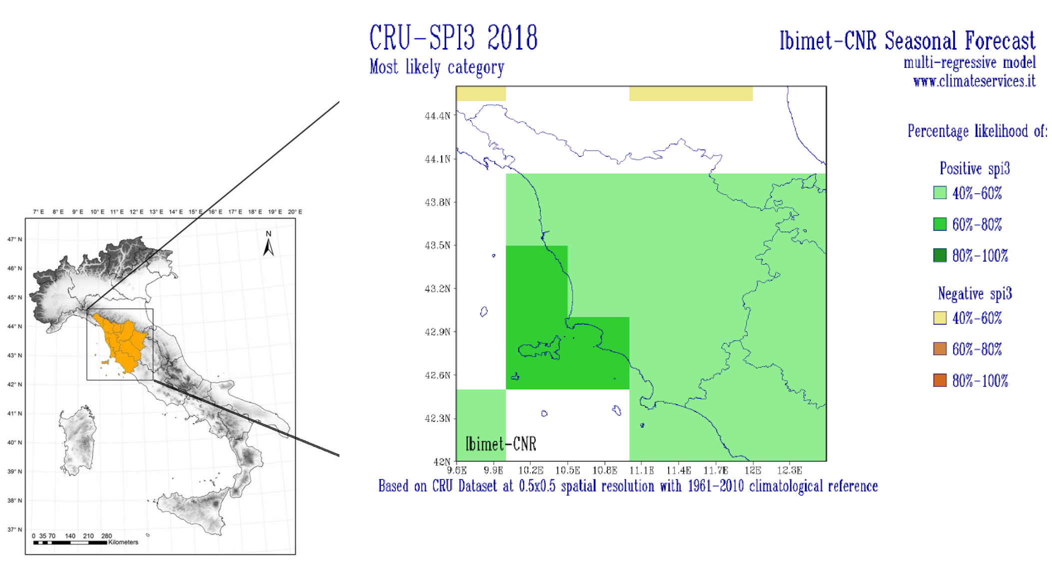


Table 3. Climatic indices identified as possible predictors.

Parameter	Long Name	Source	
AMO	Atlantic Multidecadal Oscillation	ESRL-PSD	https://www.esrl.noaa.gov
MEI	Multivariate ENSO Index	ESRL-PSD	https://www.esrl.noaa.gov
NAO	North Atlantic Oscillation	CPC	http://www.cpc.ncep.noaa.gov
SV-NAM	Seasonally Varying NH Annular Mode	HOK	http://www.bio.mie-u.ac.jp/
MZI	Modified Zonal Index	IRI-DL	http://iridl.ldeo.columbia.edu
MED-SST	Mediterranean SST, 1st EOF, 2nd EOF	CPC	http://www.cpc.ncep.noaa.gov
TRI-SST	Atlantic Tripole SST, 1st EOF	ESRL-PSD	https://www.esrl.noaa.gov
GUI-SST	Guinea Gulf SST, 1st EOF, 2nd EOF	IRI-DL	http://iridl.ldeo.columbia.edu
IND-SST	Indian Ocean SST, 1st EOF, 2nd EOF	IRI-DL	http://iridl.ldeo.columbia.edu
SISCI	Eurasian Snow Cover Extent	Rutgers GSL	https://climate.rutgers.edu

Table 4. Model evaluation and predictive performance: summary of the results obtained in each grid cell (*signif 0.05* and *signif 0.10* represent the percentage of predictors in the best model that are individually significant at level $\alpha = 0.05$ and $\alpha = 0.10$ of the t-test, respectively; $adj R^2$ and *RMSE range* are the minimum and maximum values of Root Mean Square Error obtained throughout the spatial domain; the *SPI range* contains the minimum and maximum values of the observed Standardized Precipitation Index).

Month	Evaluation			Predictive Performance	
	Signif 0.05 (%)	Signif 0.10 (%)	Range AdjR^2	Range RMSE	Range SPI
Jan	52.0	71.0	(0.18; 0.56)	(0.611; 1.042)	(−2.007; 5.349)
Feb	69.0	85.0	(0.36; 0.71)	(0.531; 0.797)	(−1.960; 3.623)
Mar	87.0	94.4	(0.61; 0.79)	(0.350; 0.632)	(−2.260; 2.581)
Apr	60.2	76.2	(0.30, 0.61)	(0.601; 0.938)	(−3.853; 2.589)
May	77.5	86.0	(0.49; 0.74)	(0.444; 0.769)	(−3.727; 2.547)
Jun	63.5	81.6	(0.48; 0.68)	(0.529; 0.832)	(−3.256; 2.485)
Jul	42.0	62.4	(0.16; 0.39)	(0.839; 1.297)	(−3.917; 5.940)
Aug	68.2	82.6	(0.29; 0.74)	(0.523; 1.235)	(−6.528; 2.801)
Sep	65.5	79.4	(0.30; 0.55)	(0.629; 0.879)	(−2.375; 2.614)
Oct	70.2	83.9	(0.24; 0.53)	(0.543; 0.782)	(−2.196; 3.130)
Nov	81.7	92.4	(0.52; 0.72)	(0.442; 0.694)	(−2.042; 2.546)
Dec	60.9	77.8	(0.26; 0.56)	(0.631; 0.881)	(−2.299; 2.233)

Magno R., De Filippis T., Di Giuseppe E., Pasqui M., Rocchi L., Gozzini B. (2018). Semi-Automatic Operational Service for Drought Monitoring and Forecasting in the Tuscany Region. *Geosciences*, 8(2), 49, https://doi.org/10.3390/geosciences8020049.

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