Links Between Meteorological Drought and Wildfire Extent in Europe

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RESEARCH PURPOSE AND OBJECTIVES

"Climate and weather are key drivers for wildfire, with droughts and heat waves increasing wildfire risk." (Doerr 2013)

The goal of this research at the Pan-European scale is to:

- Test the link between wildfire extent and meteorological drought
- Determine the relative effect of drought indices
- Identify regional differences in wildfire causation across Europe.

These objectives are addressed by modeling monthly wildfire burned area using all possible combinations of meteorological drought indices at the subnational level while controlling for seasonal fire patterns.

DATA

The European Forest Fire Information System (EFFIS) has compiled monthly wildfire extent statistics at the national and subnational scale (NUTS 1,2,3) for 22 countries within Europe as part of the European Fire Database. This data forms the basis for this wildfire analysis.

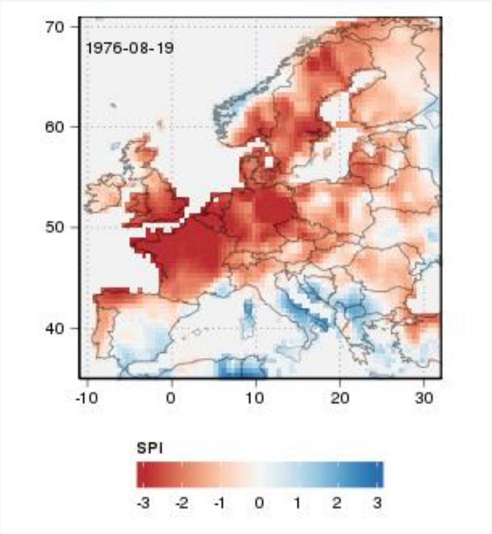
Data	Variable	Source	Coverage
Fire	Area Burned (ha)	European Fire Database	1985-2010
Climate	Daily Rainfall, Snowfall, Tmin, Tmax	Watch Forcing Data Era-Interim (WFDEI)	1979-2012
NUTS Region		Nomenclature of Territorial Units for Statistics (NUTS) Eurostat	2012
Biogeographical Regions		Biogeographic regions in Europe European Environment Agency	2011
Land Cover	Artificial, Agricultural, Forests and semi-natural, Wetlands, Water	CORINE Land Cover European Environment Agency	2006

Standardized Precipitation Index (SPI) and Standardized Precipitation-Evapotranspiration Index (SPEI)

SPI (McKee et al. 1993, Guttman 1999) and SPEI (Vicente-Serrano et al. 2010) are standard meteorological drought indices that normalize drought across regions and climates. They are recommended as a key drought indictor by the World Meteorological Organization (WMO, 2012).

Both indices convert accumulated meteorological drought to the standard normal distribution, N(μ=0, σ=1). SPI is based on precipitation, SPEI is based on climatic water balance Σ(P - PET).

The accumulated period can vary to measure short-term or long-term droughts. Periods are typically written as months; for example, SPI-6 is the normalized 6 month precipitation deficit.



Typical SPI-6 map (right) showing the severity and extent of the 1976 summer drought event

MONTHLY EUROPEAN WILDFIRE MODEL

- All analysis is based on monthly wildfire extent derived by calculating percent burned based on forested area from the CORINE land use database:

$$\text{Area Burned [\%]} = \frac{\text{Area Burned } [ha]}{\sum(\text{Forested Area}[ha])}$$

- This accounts for inflammable area (water and impervious).
- Because this measure of fire is a proportion of total flammable area, wildfire extent is modeled using logistic regression (logit function):

$$\text{logit[Area Burned (\%)]} = f(Month) + k_1 SPI\text{-}n_1 + k_2 SPI\text{-}n_2$$

where logit is the logit transform, f(Month) is a spline curve that approximates the seasonal pattern of wildfire, SPI-n is the SPI or SPEI value for the n accumulation period, and k is a linear regression coefficient.

- Separate models were fit for each NUTS2 region and the best model was determined using a 5 year cross-validation based on the RMSE and AIC.
- Variables considered include:

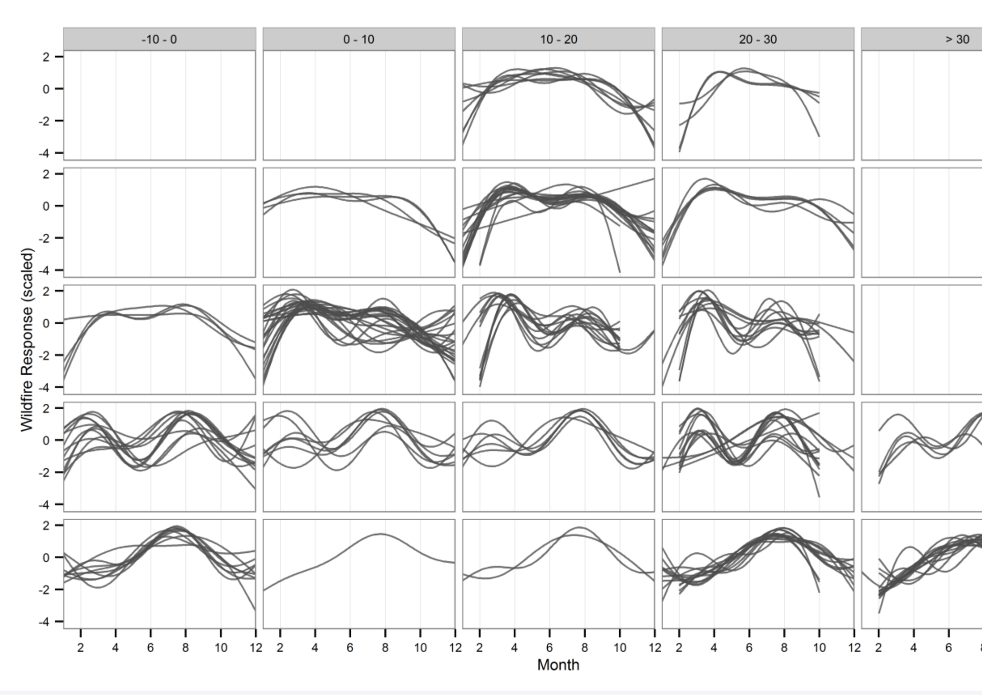
Index	Variable	Months Considered	Lags Considered
SPI	Precipitation Σ(Rain + Snow)	1, 2, 3, 6, 9, 12, 24	0, 2, 4, 6
SPEI	Water Balance Σ(Precip – PET)	1, 2, 3, 6, 9, 12, 24	0, 2, 4, 6

SEASONAL WILDFIRE PATTERNS

The seasonal (monthly) component of wildfire is relatively consistent across regions defined by latitude:

- **< 40˚lat:** The Mediterranean region tends to have a single, pronounced peak in wildfire activity between July and August
- **40˚ - 50˚ lat:** Central Europe is characterized by two distinct peaks in fire activity, in early spring (March) and again in late summer (August)
- **> 50˚lat:** Northernmost regions of Europe tend to have a much flatter curve with little change in fire likelihood between April and August

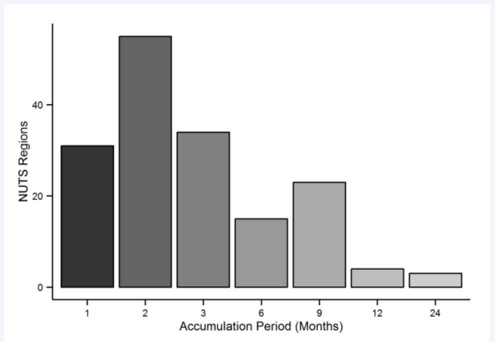
There is relatively little difference in seasonal wildfire pattern longitudinally (west to east).

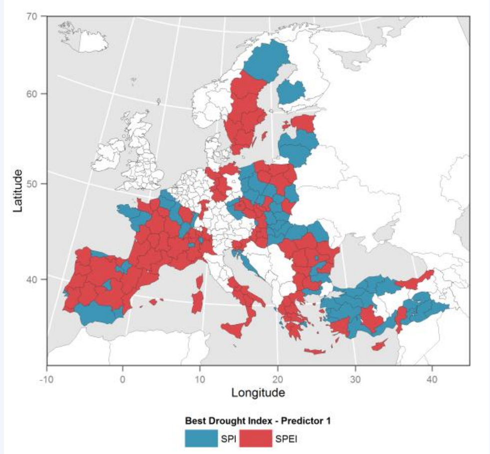


Seasonal (monthly) wildfire component for all NUTS2 regions, presented spatially by binned latitude and longitude. All wildfire responses have been scaled to allow for direct comparison.

WILDFIRE RESPONSE TO DROUGHT

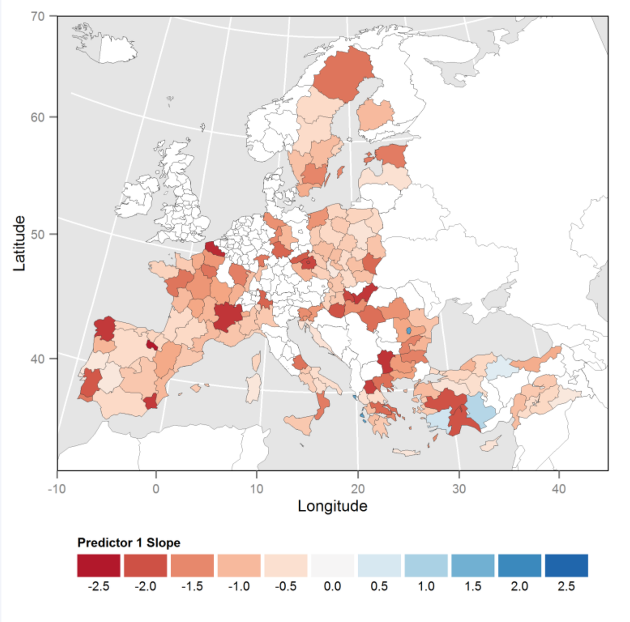
- SPEI appears to be a better predictor of wildfire extent than the SPI for the majority of Europe, particularly in the west. SPEI provides a more comprehensive measure of fuel moisture by incorporating evapotranspiration.
- Water balance 1-3 months prior to a fire is the most important predictor of wildfire extent.

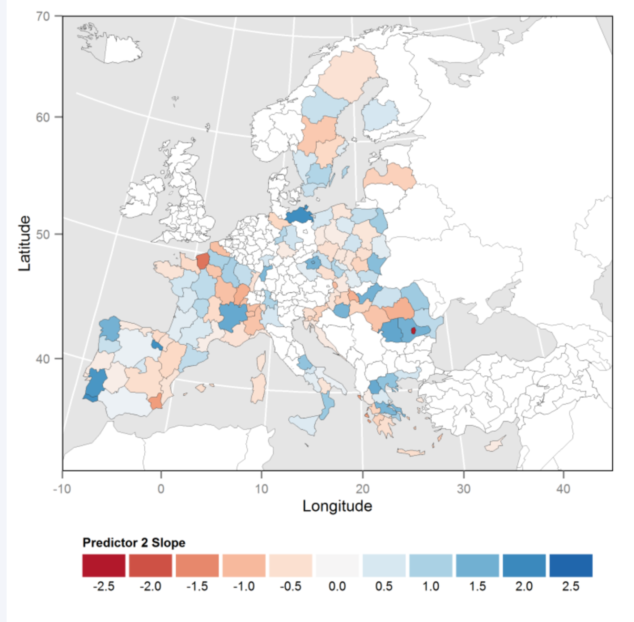




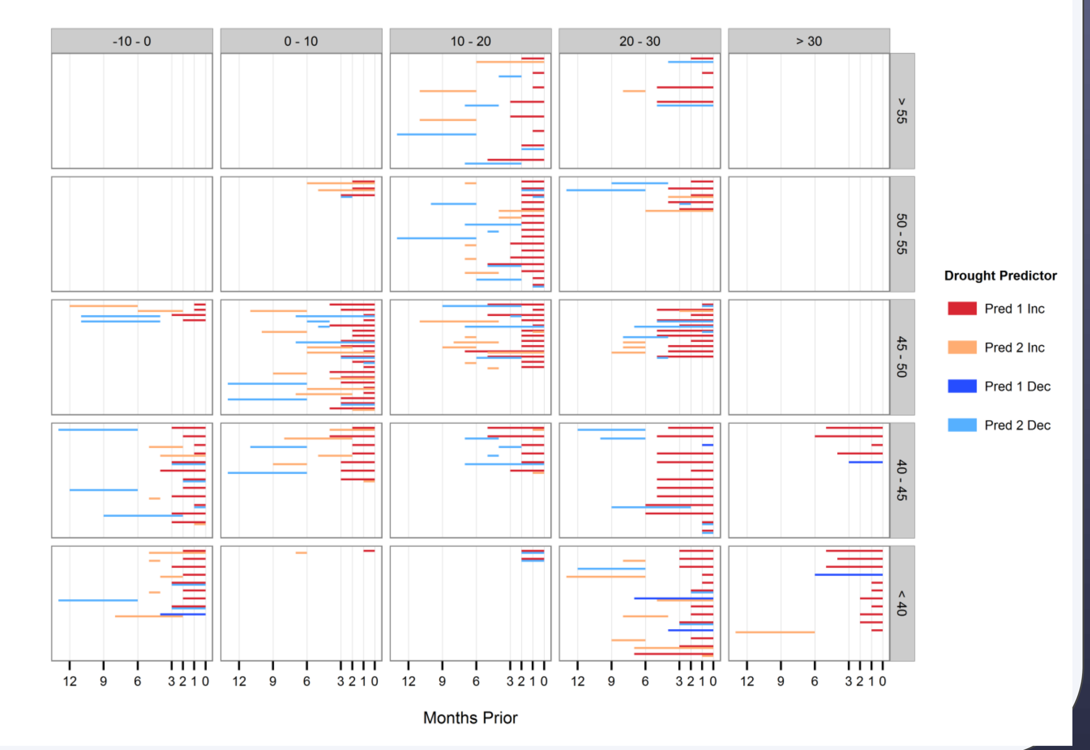
Most frequent accumulation period for the first predictor of wildfire extent (above) and the corresponding drought index, shown spatially (right).

- Wildfire response to drought is **spatially consistent** across Europe once seasonal effects and areal difference are accounted for.
- For many regions, the second most important climatic predictor for wildfire is a wet period, shown by positive slopes for Predictor 2.
- When plotted temporally, the primary **2-3 month drought period** is clear, along with a **sustained wet period** which occurs 6-12 months prior (fall or winter), agreeing with findings from Bifulco, et al. (2014).





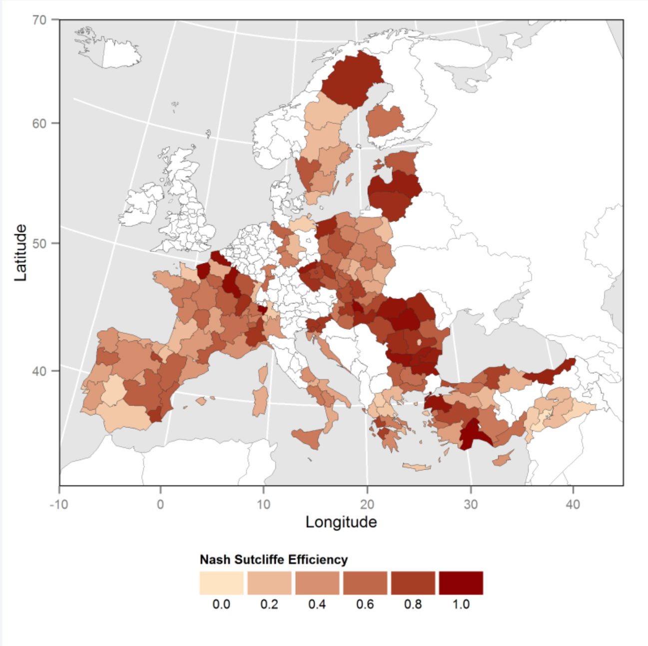
Wildfire response to drought index 1 (left) and index 2 (right). Negative slopes correspond to an increase in wildfire extent during drought (SPI/SPEI is negative).



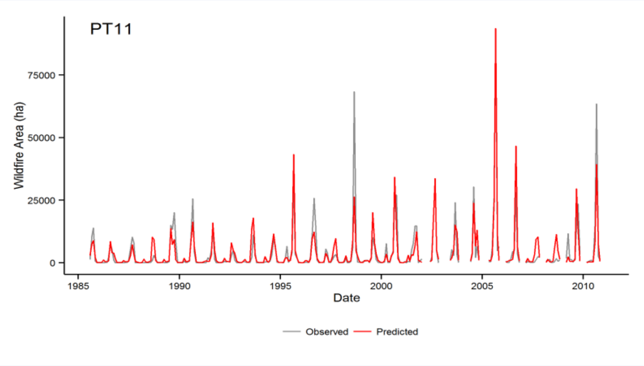
Temporal effect of drought indices on wildfire extent (right). The first two drought indices are shown with their accumulation and lag periods prior to the fire. Negative slopes (i.e. drought increases wildfire extent) are shown in red. Positive effects (i.e wet conditions increase wildfire extent) are shown in blue.

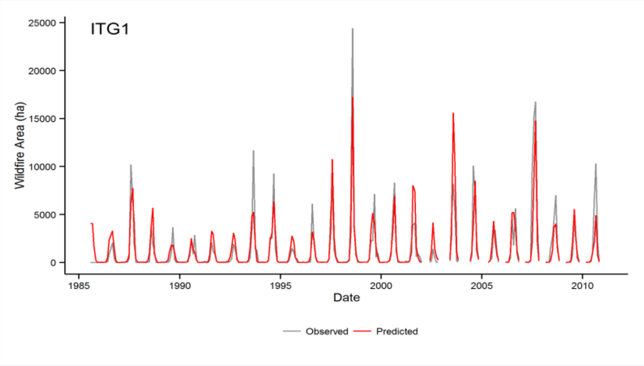
GOODNESS OF FIT

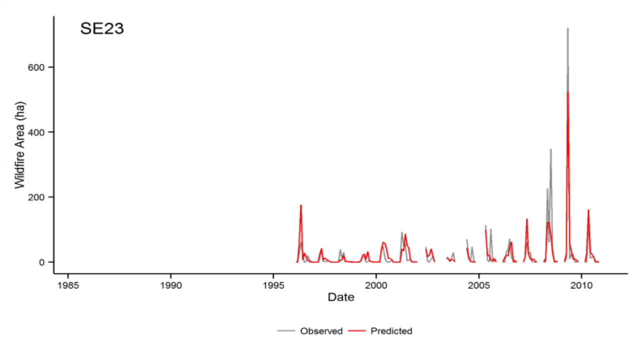
- Meteorological drought has a significant effect on wildfire extent across Europe
- Models including drought indices produced significantly **better estimates** of wildfire extent **than the seasonal wildfire climatology alone** (Nash-Sutcliffe coefficient 0.35-0.9).
- Time series show the effectiveness of including drought indices in estimates of wildfire extent.



Nash-Sutcliffe Efficiency of drought model (above).







Typical observed and predicted wildfire extents for Portugal-Norte (PT11), Italy - Sicilia (ITG1), and West Sweden (SE23).

CONCLUSIONS

- Seasonal wildfire, independent of drought, follows consistent patterns, with differences in the timing and peaks related to latitude.
- There is a **significant relationship** between meteorological drought and European wildfire extent.
- Wildfire is most related to **1-3 month anomalies** of low precipitation and high potential evapotranspiration (SPEI). **Inclusion of evapotranspiraiton** (SPEI vs SPI) is important for modeling wildfire.
- Large fires are also correlated with extended **wet periods 6-12 months prior** to the fire. This wet period is likely necesarily to build a sufficiently large amount of vegetative fuel.
- The existing model could be used to estimate fire likelihood or could be used to provide the basis for estimating fire likelihood in unmonitored regions.

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