A love story about forest drought detection: the relationship between MODIS data and Climate time series.

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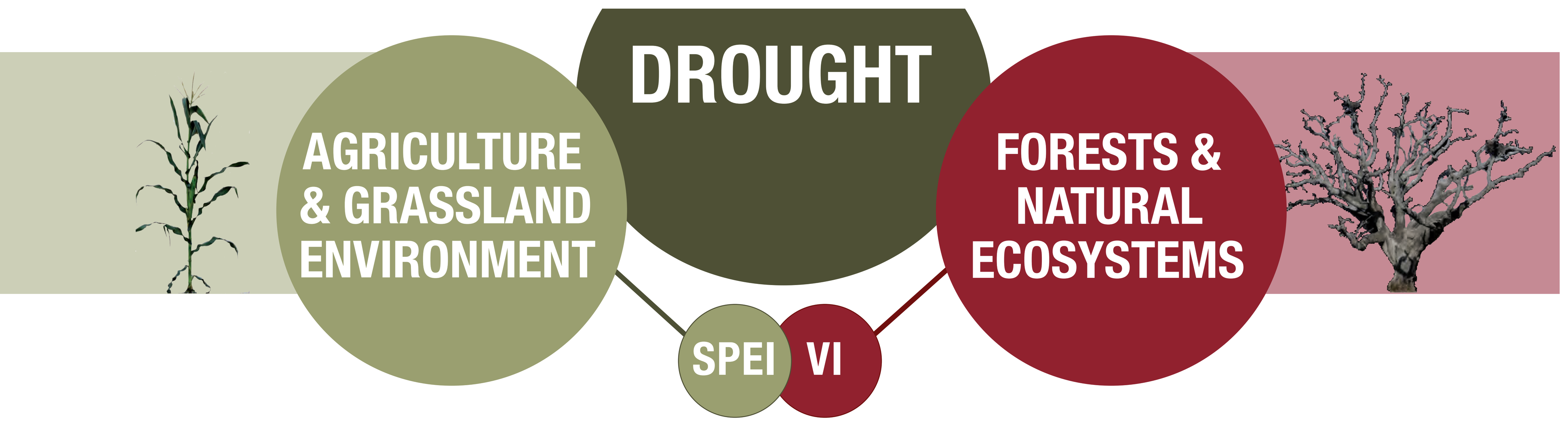
1 Introduction & aims

Research on drought affection is essential, not only for agriculture ecosystems, which are the most studied because are the first economic sector to be affected, but also for **forest ecosystems**[1] providing invaluable services to society. However, these two ecosystems present different drought characteristics in terms of duration, due to different life cycle length, in terms of intensity, given the difference between the water reservoir capacity, and in terms of the topography of the area affected.

Therefore a **different perspective** analysis should be used **to study forest drought affection**.

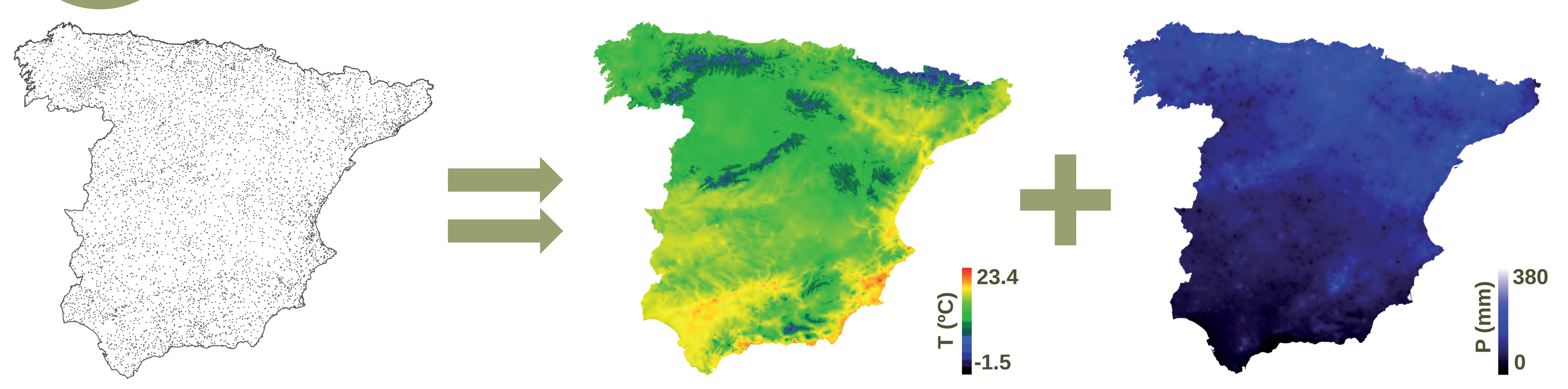


This work integrates the climatic anomalies, traditionally used in an agricultural drought framework through the SPEI index (Standardized Precipitation Evapotranspiration Index)[2] with information related to the real physiological state of the vegetation through vegetation indices (VI) derived from remote sensing data.

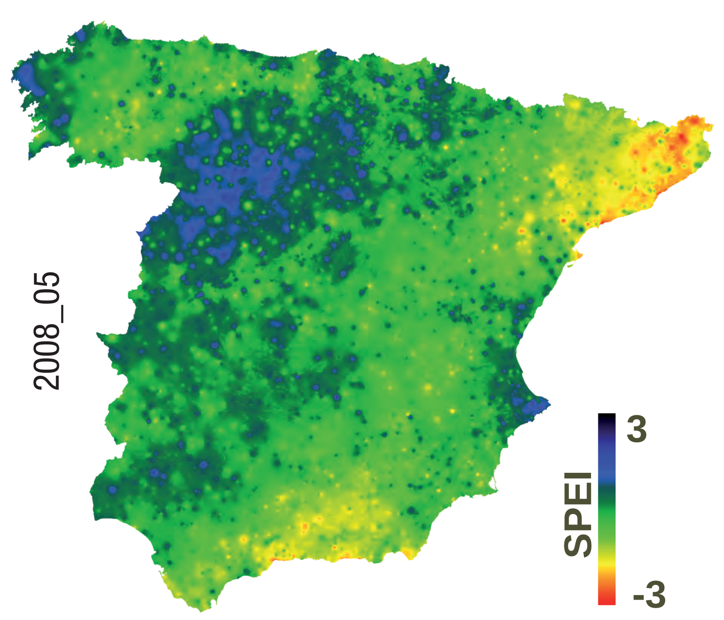
The **aim of this research** is to show the necessity to understand biological spatio-temporal drought patterns for drought monitoring by integrating both climate and remote-sensing data. This is accomplished by:

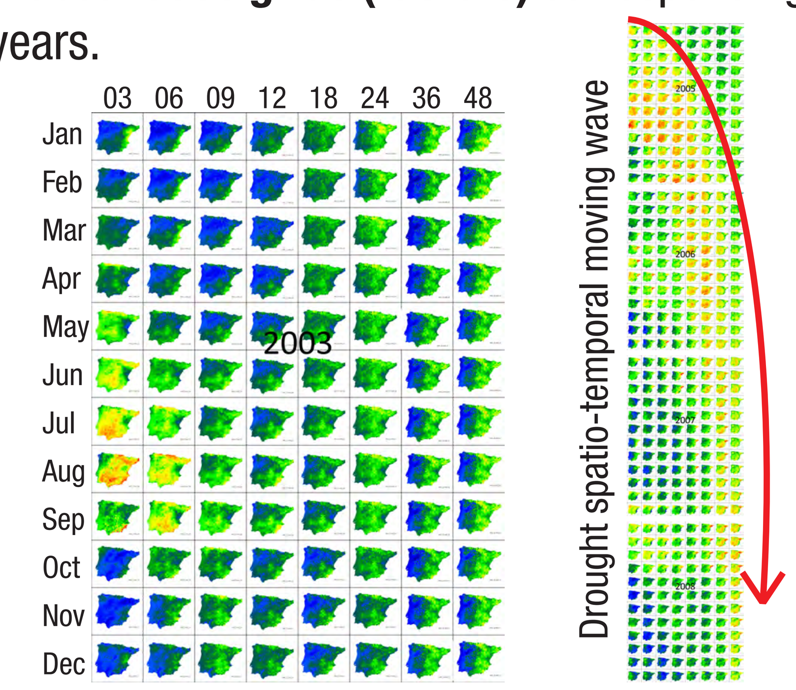
- Investigating drought patterns derived from a continuous spatio-temporal climate data
- Ascertaining the potential of RS data to determine drought events on forest areas

2 SPEI-Climate Anomalies Data Set



Meteorological data from 7180 stations distributed along conterminous Spain (1950 to 2012) was assembled. Monthly mean temperature and monthly total precipitation were interpolated, considering the appropriate geographical factors[3], obtaining 100 m resolution grids for the whole Spain. An SPEI tool, developed in the MiraMon software framework, was used to compute a spatially continuous SPEI useful to identify climate drought anomalies. SPEI was calculated at different time-scales: 3, 6, 9, 12, 18, 24, 36 and 48 months. The more negative the index value, the higher the intensity of drought. Altogether configured a **SPEI Big DataBase** of about **6000 grids (rasters)** corresponding to one grid per month per time-scale for 61 years.





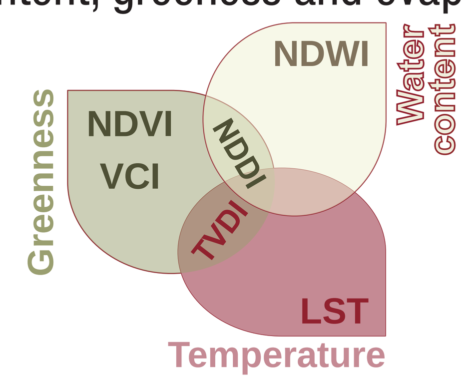
3 Vegetation Indices (VI) Estimation

MODIS data used[4,5]:

- MOD09GA-Daily Surface Reflectance-500 m
- MOD11A1-Daily Land Surface Temperature (LST)-1 km
  - From 2001 to 2012 (validation period)
  - Improved **Quality Assurance Data Set** masks due to their **regular quality**

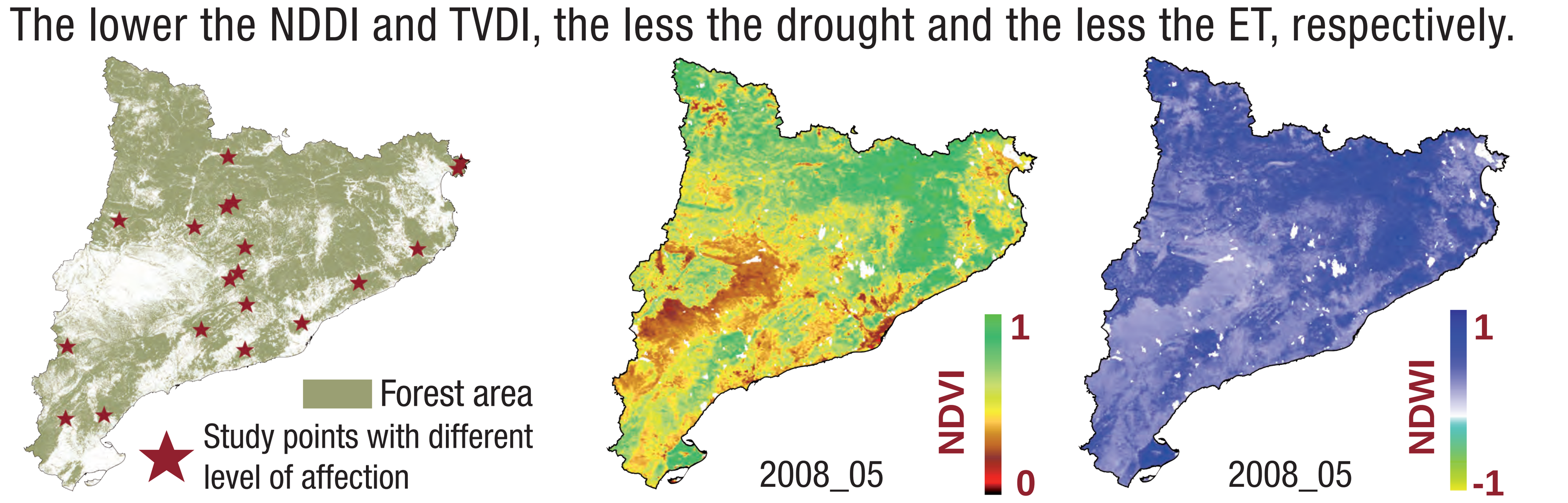
4331 scenes downloaded ⇒ AUTOMATIC ALGORITHM SELECTION[6,7] ⇒ 1204 scenes selected ⇒ 5 MONTHLY VI COMPOSITES

The monthly VI composites are related to three vegetation characteristics: water content, greeness and evapotranspiration (ET)



VCI: Vegetation Condition Index[8]
NDVI: Normalized Difference Vegetation Index[9]
NDDI: Normalized Difference Drought Index[10]
NDWI: Normalized Difference Water Index[11]
TVDI: Temperature Vegetation Dryness Index[12]
LST: Land Surface Temperature

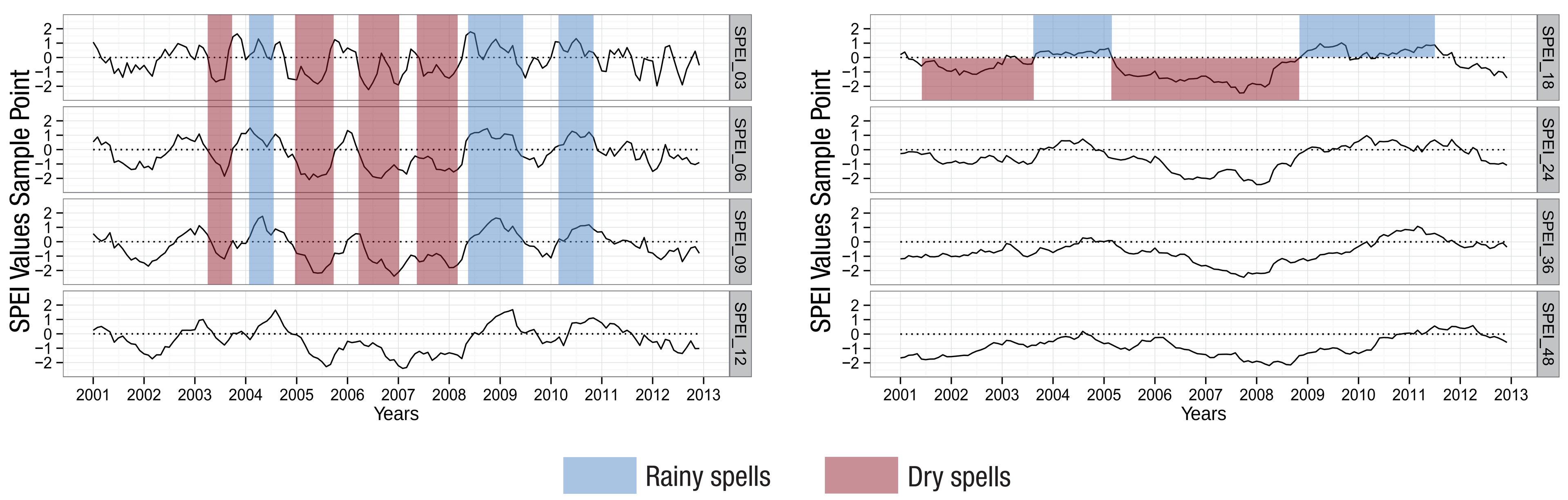
The higher the NDVI/VCI and NDWI, the greener and wetter, respectively.
The lower the NDDI and TVDI, the less the drought and the less the ET, respectively.



4 Results for the study case & conclusions

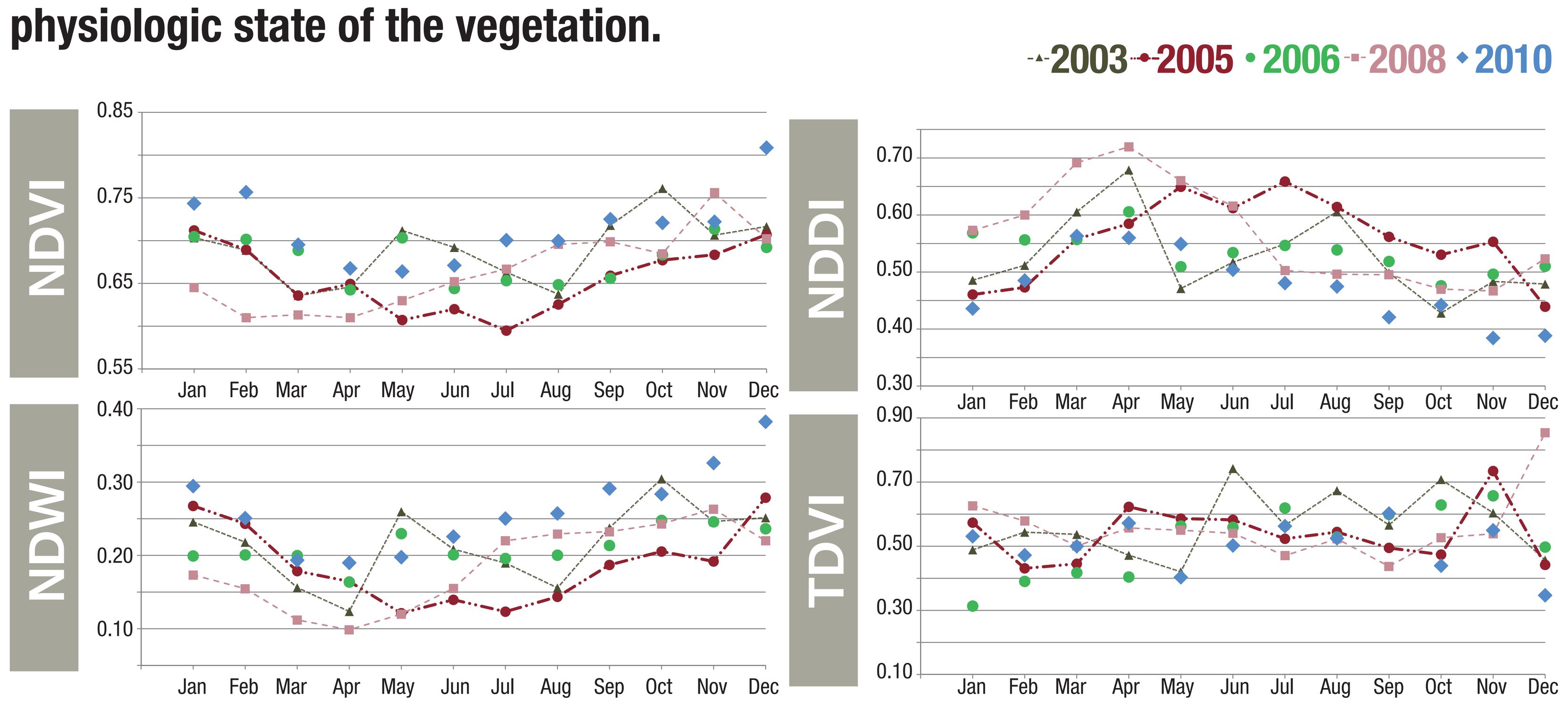
The analysis of **SPEI temporal characteristics** for the study case show different interpretations according to different time-scales.

- **Short time-scales** (3, 6 or 9 months) are characterized by an intense above zero and below zero patterns. Negative peaks **denote short-term drought** relative to Mediterranean summer or winter precipitation shortages, such as summer 2003 and 2005, and winter 2007–spring 2008. Positive peaks denote the rainiest periods, for instance, 2004 and from 2008 to 2010.
- **Long time-scales** are characterized by their significant and persistent negative values episodes, crucial to **identify hidden dry periods** that, combined with any short-term drought, might develop into a fatal event for forests, such as wildfires.

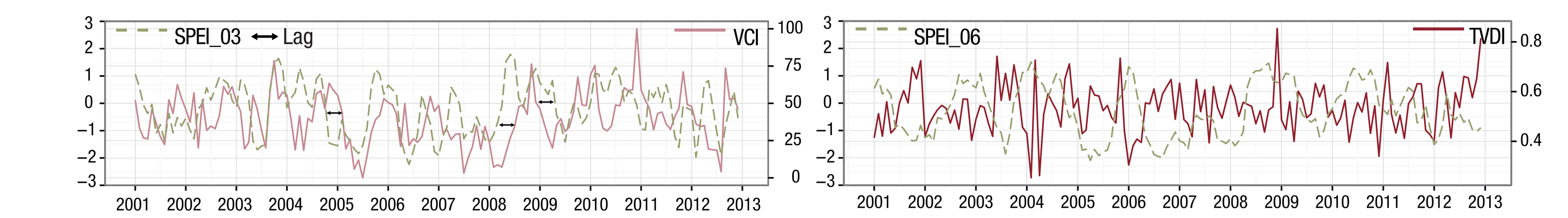


MODIS signal is sensitive to vegetation responses to drought and concurs with SPEI pattern.

- Summer 2005 was dry according to SPEI and NDVI-NDWI show a sustained decrease indicating changes in greenness and water content, respectively.
- Winter 2008 drought event also affected forest activity, given the decrease in the NDVI and NDWI indices.
- On the contrary, summer 2003 drought does not appear causing strong impact on forests according to VI, thus **remote sensing data is essential to understand the real physiologic state of the vegetation.**



- **Regression analyses** between SPEI and VI: a positive correlation between SPEI and NDVI, NDWI, VCI and a negative correlation between SPEI and NDDI, TVDI, LST, are found. A lag period between the SPEI and the vegetation response is observed.



- **Regression analyses according to time-scales** present an inverse behavior between SPEI and VI. The shorter the time-scale, the better the temperature indices correlate ($R^2 \approx 0.56$). VI related to greenness or water content gains importance as the time-scale increases ($R^2 \approx 0.38$). Scales longer than 24 months have weaker relationship. Indeed, the longer the time-scale, the lower the correlation.
- **Regression analyses according to years** indicate that SPEI and VI are not correlated for normal to rainy years, while SPEI explains up to 60% of the VI variability for dry years.

Conclusions[13,14]

- SPEI grids are appropriate to monitor drought distribution patterns. Shorter time scales monitor almost real time drought events while longer time-scales identify long-term precipitation deficits.
- MODIS filtering data is essential and VI are good representatives of drought affection on forest areas.
- This multi-source methodology is specially indicated to monitor large regions or areas with difficult acces suitable, to drought vulnerability.

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