Spatial and temporal analysis of vegetation response to meteorological droughts in California 1984-2018.

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Photography encouraged

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Abstract

Vegetation productivity is directly influenced by weather characteristics such as precipitation and temperature. The response is usually not immediate, with a time lag period between a weather anomaly and vegetation response. This study focusses on the vegetation response to droughts during the summer period in California, USA. The procedure consisted in comparing several timescales of the Standard Precipitation Evapotranspiration Index (SPEI) with the Normalized Difference Vegetation index (NDVI) anomalies in the following months. The Pearson correlation coefficient was analyzed for different scenarios and types of vegetation. The performance was firstly analyzed in a point study, followed by a spatial study for the region of California. Point study results indicated that two to four months SPEI timescales were significant predictors (r>0.5) to the following three-month vegetation anomaly in grassland regions. The correlation maps showed that a SPEI timescale of 3 months, with a 1 month lag was the most accurate predictor of vegetation health for the region. The study also showed that the SPEI index has a better performance in grassland regions when compared to desert and forest regions.

Introduction

- Droughts have globally affected 1.5 billion people and caused 124 billion USD losses during the period of 1998 to 2017 (United Nations Office for Disaster Risk Reduction, 2017). Thus, the modelling of droughts can play an important role in risk management and damage mitigation.
- Droughts are usually measured by indexes that consider abnormalities in the regional climate over a defined timespan. The SPEI is a drought index that can be calculated over different timescales using monthly evaporation and precipitation as inputs.
- Droughts have an impact on vegetation productivity that will vary according to biomes. The productivity can be measured thought remote sensing indexes such as the Normalized Difference Vegetation index (NDVI).
- The response of vegetation to climate change have a time lag that varies according to the biome analyzed.

Research Questions

1. How do the SPEI perform as a tool for accessing vegetation health in different timescales ?
2. What are the differences in the SPEI performance for different vegetation types?
3. How could the delayed vegetation response be represented by the NDVI?

Study Area

The region of California was chosen due to its wide variety of vegetation types and precipitation regimes (Fig. 1, Table 1);

The region has a dry summer, with a negative water balance from April to October and a positive balance during the rest of the year.

Table 1: % of the land for the respective land use in the region

Land Use	% of the Land
Urban Area	7
Cropland	10
Forest	26
Grassland	12
Wetland	1
Shrubs	38
Bare Soil	5
Water	1

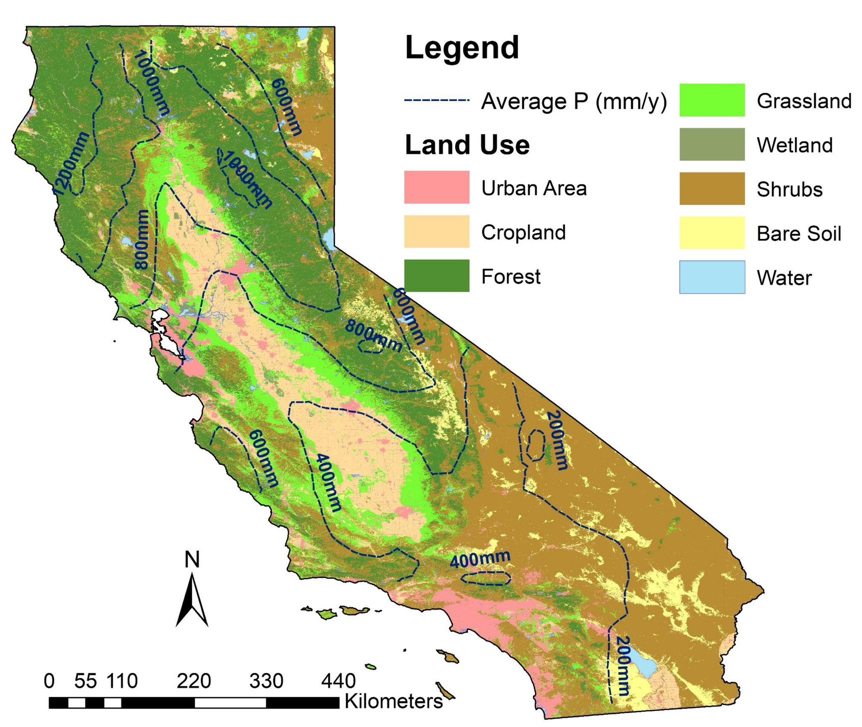

Figure 1: Land use and yearly precipitation in the study region

Methodology

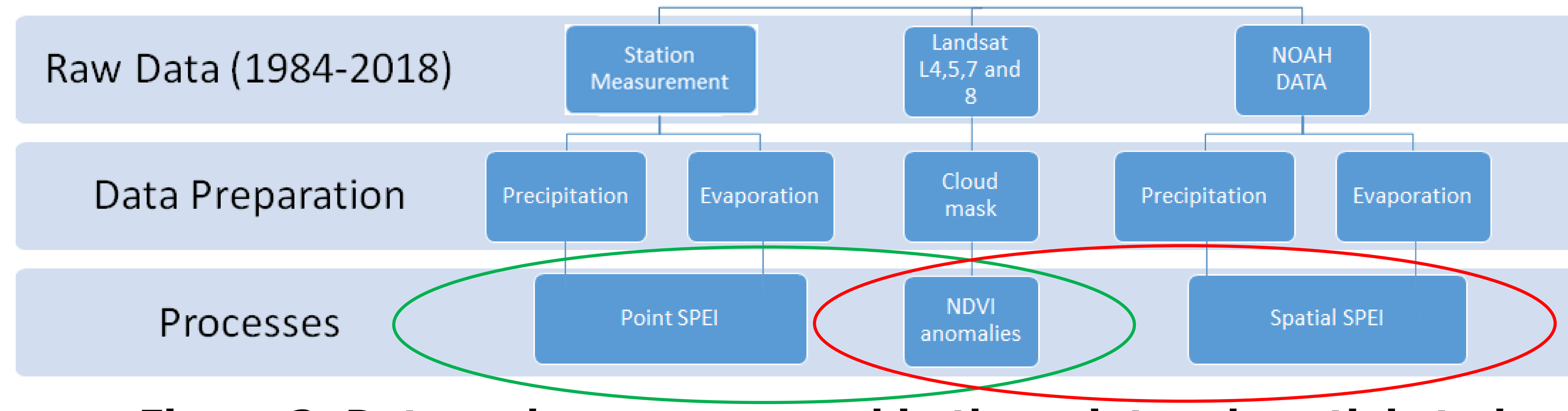

Figure 2: Data and processes used in the point and spatial study

Point Study (Travis Station, Fig 3):

- Vegetation type: grassland;
- SPEI timescales: 1 to 6 months;
- NDVI anomaly: Cumulative three month anomaly.

Figure 3: Travis Station location

Spatial Study (Fig. 4):

•Vegetation types analyzed: shrubs, forest and grassland;
•SPEI timescales: 2 to 4 months;
•NDVI anomaly: Cumulative of 2, 3 and 4 months anomalies;
•Analysis considered solely the end of the precipitation period (March to May). Focusing on an the summer vegetation productivity vs dryness of the previous winter;
•NDVI scenarios with no lag and 1 month lag were analyzed aiming to identify delays in vegetation response.

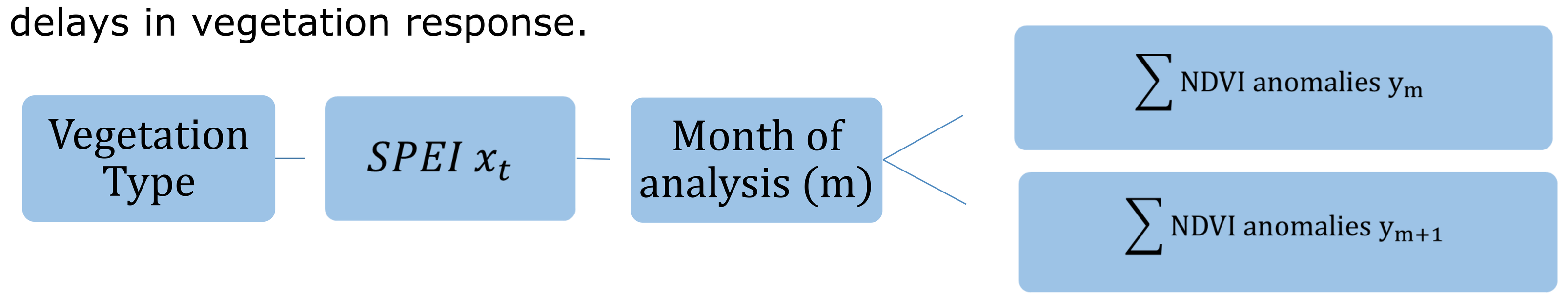

Figure 4: Scenario variation for the Spatial study

Point Study Results

- The SPEI index and the three months sum of the NDVI anomalies present good correlation (>0.5) during summer months. Indicating a correlation between the SPEI index during winter and NDVI anomalies during summer (Fig. 5).
- There is no correlation between the SPEI index and the NDVI index in the wet season (Fig. 5).
- Good correlations were found for the timescales of SPEI 2,3 and 4 months, further analyzed in the spatial study (Fig. 5).

Different Time Scales of SPEI

Monthly SPEI

May-Jul	SPEI1m	SPEI2m	SPEI3m	SPEI4m	SPEI5m	SPEI6m
Jan	0.02	0.03	0.04	0.05	0.03	0.03
Feb	0.05	0.06	0.07	0.07	0.09	0.07
Mar	0.38	0.37	0.25	0.33	0.33	0.33
Apr	0.28	0.53	0.49	0.33	0.40	0.41
May	0.07	0.30	0.51	0.51	0.34	0.41
Jun	0.12	0.10	0.33	0.50	0.48	0.33
Jul	0.01	0.03	0.05	0.27	0.43	0.43
Aug	0.02	0.01	0.02	0.04	0.23	0.40
Sep	0.01	0.01	0.02	0.01	0.03	0.21
Oct	0.00	0.00	0.01	0.02	0.00	0.02
Nov	0.01	0.02	0.03	0.03	0.04	0.00
Dec	0.05	0.01	0.01	0.00	0.00	0.00

Figure 5: Different Time Scales of SPEI vs Three Month Sum of NDVI Anomaly

Spatial Study Results

- Shrubs vegetation presented better correlation between longer SPEI timescales and longer NDVI anomalies sums. The best correlations occurred in the month of march, last month of positive water balance for the region (Table 2, Fig. 5).
- Forests also had a better correlation between longer SPEI timescales and NDVI anomalies (Table2, Fig. 5). However, the best correlations occurred in the month of may period where the region already presents a negative water balance for more than 75% of the years analyzed.
- Grassland presented correlations that were very distributed among the different timescales of SPEI, NDVI and month (Table 2, Fig 5).

Table 2: Correlation between SPEI and NDVI for the different scenarios studied.

Vegetation	SPEI	Month	NDVI (No lag) 2m	3m	4m		NDVI (1 month lag) 02m	03m	04m
Shrubs	2m	March	-0.03	-0.01	0.01		0.05	0.07	0.07
		April	-0.04	-0.03	-0.03		0.03	0.03	0.03
		May	-0.15	-0.12	-0.12		-0.08	-0.09	-0.09
	3m	March	0.07	0.07	0.11		0.12	0.15	0.17
		April	0.02	0.04	0.06		0.06	0.09	0.08
		May	0.01	0.02	0.05		0.07	0.05	0.06
	4m	March	0.18	0.19	0.21		0.19	0.21	**0.24**
		April	0.17	0.13	0.16		0.13	0.16	0.17
		May	0.04	0.05	0.05		0.06	0.06	0.07
Forests	2m	March	-0.13	-0.08	-0.06		0.00	0.03	0.04
		April	-0.04	-0.02	0.01		0.10	0.12	0.13
		May	-0.08	-0.03	-0.06		0.07	0.09	0.10
	3m	March	-0.07	-0.06	-0.05		0.00	0.01	0.06
		April	-0.01	-0.04	0.00		0.01	0.05	0.09
		May	-0.01	0.03	0.08		0.14	0.19	**0.17**
	4m	March	-0.06	-0.01	0.01		0.03	0.04	0.09
		April	-0.02	0.02	0.04		0.01	0.07	0.11
		May	0.03	0.07	0.08		0.08	0.11	0.09
Grassland	2m	March	-0.01	0.03	0.05		0.14	0.14	0.14
		April	0.13	0.14	0.15		0.19	0.18	0.18
		May	-0.06	-0.05	-0.06		-0.01	-0.03	-0.05
	3m	March	0.06	0.09	0.11		0.18	0.20	**0.22**
		April	0.12	0.13	0.15		0.13	0.20	0.16
		May	0.20	0.23	0.03		0.13	0.15	0.13
	4m	March	0.10	0.14	0.15		0.18	0.19	0.22
		April	0.10	0.18	0.20		0.15	0.19	0.20
		May	0.10	0.11	0.12		0.07	0.09	0.06

The 1 month lagged NDVI presented overall better results when correlated with the SPEI indexes, indicating the presence of a delayed response of vegetation to droughts in the region (Table 2).

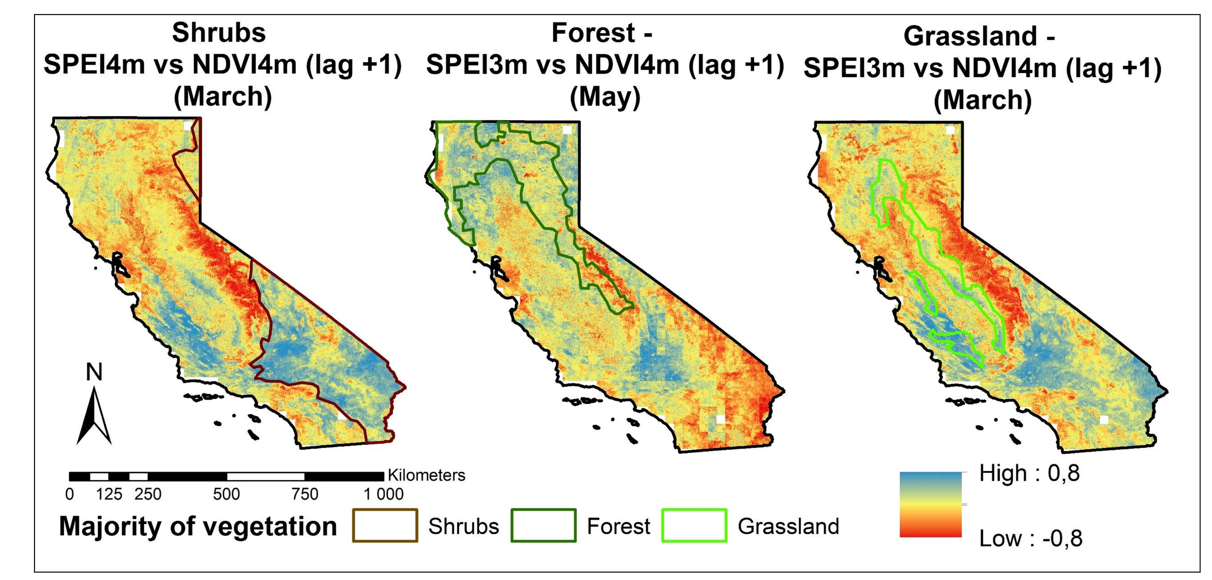

Figure 5: Spatial Correlation for each vegetation best case scenario

Conclusions

The SPEI index and NDVI anomalies, in the three types of vegetation analyzed, present an average correlation superior to 0.2 for certain scenarios, reaching values above 0.7 for specific areas. Lagged NDVI anomalies correlate better with the drought index, indicating a delay in vegetation response. It is possible to conclude that Shrubs are quickly affected by drought while forests have a delayed response.

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The code for the spatial correlation between NDVI anomalies and SPEI can be found at: https://github.com/fsn1995/Drought-Analysis