Burned area and climate extremes in different land covers in southeastern Australia

Patrícia Páscoa[1,2,3], Ana Russo[2], Andreia Ribeiro[4], Célia Gouveia[*,1,2]

[1] Instituto Português do Mar e da Atmosfera, Lisboa, Portugal, *celia.gouveia@ipma.pt
[2] Universidade de Lisboa, Faculdade de Ciências, Instituto Dom Luiz, Lisboa, Portugal
[3] Centro de Investigación Mariña, Universidade de Vigo, Environmental Physics Laboratory (EPhysLab), Ourense, Spain
4 Helmholtz-Centre for Environmental Research (UFZ), Compound Environmental Risks (CER), Leipzig, Germany

Motivation

Southeastern Australia is a fire-prone region [1], with a landscape characterized by high values of vegetation productivity [1], and a temperate climate [2]. This region is recurrently affected by droughts [3] and heatwaves [4]. Large fires in southeastern Australia tend to occur in years classified as hot and dry [5], such as the Black Saturday (2009) and the Black Summer (2019-2020) extreme fires. Positive trends in BA have been identified at the continental scale and in forests [6], and some regions present an increase in BA associated with an increase in drought conditions and in T_{max} [7]. Moreover, forested areas in eastern Australia present a decrease in the number of years since the last fire [6].

Data

Data	Source	Time period	Time scale	Spatial scale
Burned Area (BA)	MCD64A1 6.1	2000-2022	monthly	500m
Land cover	MCD12Q1 6.1	2001-2021	annual	500m
Mean Temperature	CRU TS4.07	1901-2022	monthly	0.5°
Precipitation	CRU TS4.07	1901-2022	monthly	0.5°
2m Temperature	ERA5	1950-2022	hourly	0.25°

Methods

Forest, savannas, and grasslands classes were studied separately.

Monthly BA was computed for October to March, for 2000-2022.

SPEI was computed at the time scales of 1, 3, 6, 9, and 12 months for the period 1950-2022.

Daily maximum and minimum temperatures (T_{max} and T_{min}) were computed for the period 1950-2022.

For each burned pixel, SPEI, T_{max} and T_{min} were retrieved.

A monthly average of SPEI was computed, for concurrent drought conditions (lag 0) and on the previous 1 to 3 months (lag 1 to 3).

The maximum T_{max} and T_{min} were retrieved for the concurrent and the previous 30 days.

A Pearson correlation analysis was performed between $\log_{10}$(BA) and the climate variables (α=0.1).

Copula Functions

Gaussian, Frank, Clayton, Gumbel, and Joe models were fitted. Models were discarded if they showed a poor goddness-of-fit, based on the Cramér-von Mises test (α=0.1). Bayesan Information Criterion was used to chose the model.

The uncertainties were assessed by sampling 1000 times the chosen model, with a sample size the same as the number of observations, and then computing the copula parameter for each sample. If the parameters obtained with the observations fell outside the 95% confidence interval of the simulations, the model was discarded.

10,000 simulated points were derived from the chosen copula model.

Conditional probablities of BA larger than the 50^{th} and 80^{th} percentile were computed, given drought and hot conditions.

Three classes of drought intensity and three temperature percentiles were considered.

Objective

To assess the relationship between BA and climate conditions in three different land covers in southeastern Australia, namely forests, grasslands, and savannas, with correlations and bivariate copula functions.

Results

Correlation

Correlation between BA and SPEI (Fig. 1) generally decreases with the time lag.

Correlation increases (decreases) in forests and savannas (grasslands) with the time scale.

Correlation is weaker in grasslands and non-significant for lags 2 and 3. Savannas present the highest values.

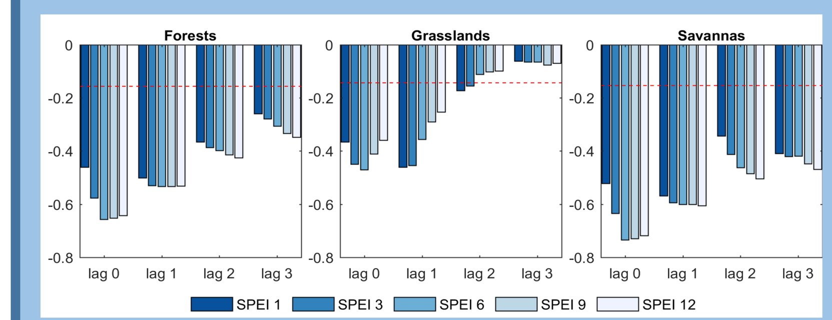

Fig. 1— Correlation between BA and SPEI. Correlation below red dashed line is statistically significant.

Correlation of T_{max} and BA (Fig. 2) increases until 10 to 15 days before the fire, starting decreasing at 15 to 20 days.

High (Low) correlation for forests (grasslands).

Correlations T_{min} and BA are much lower than for T_{max}, and they decrease earlier.

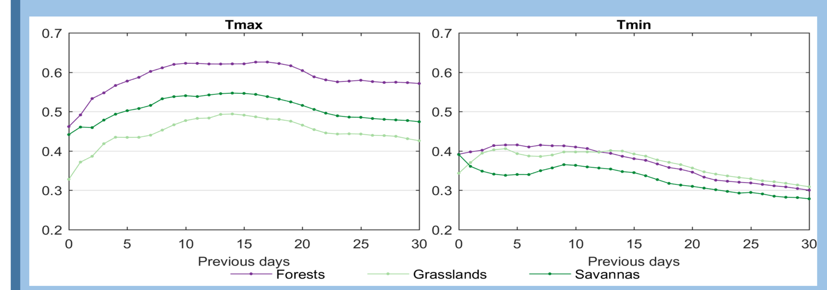

Fig. 2—Pearson correlation between BA and Tmax and Tmin. The minimum significant correlation is 0.16, 0.14, and 0.15 for forests, grasslands, and savanas.

Conditional Probability Given Drought Conditions

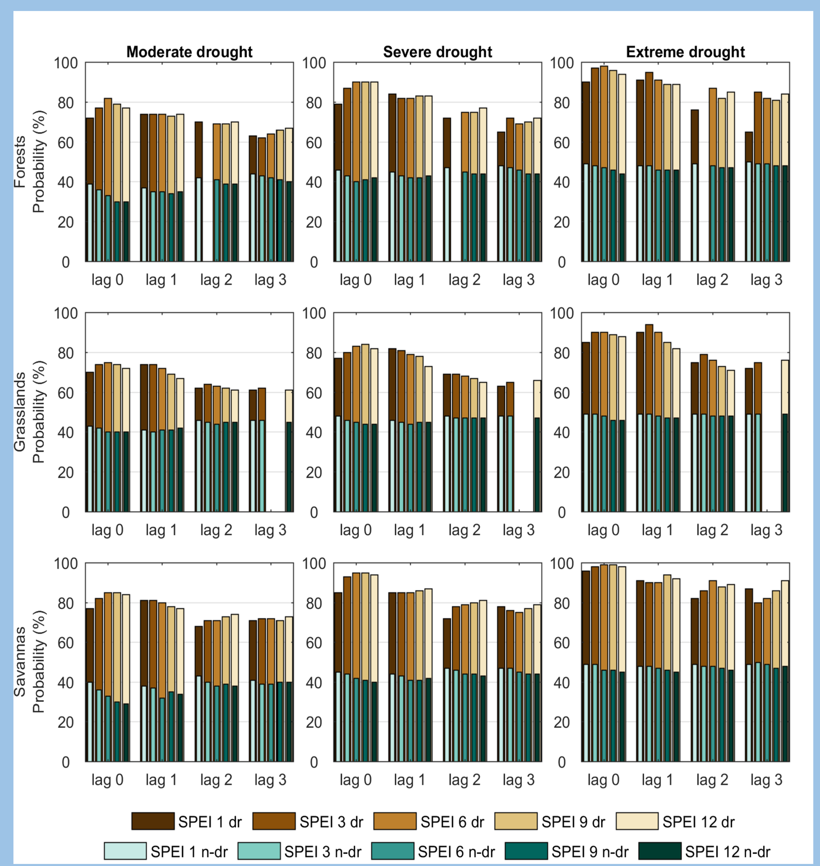

Fig. 3—Conditional probability of BA exceeding P_{50} given drought (dr, green colours), and non-drought conditions (n-dr, brown colours).

The conditional probability of BA exceeding (CPE) P_{50} (Fig. 3), given drought conditions, is generally very high and increases with the severity of the drought.

CPE is higher for lag 0 and SPEI 6, and it reaches almost 100% given extreme drought.

CPE given non-drought conditions is always lower. Grasslands present the lowest difference

For CPE and P_{80} (Fig. 4), the values are lower than for P_{50}, but even for moderate drought CPE reaches around 40%.

Under extreme drought conditions, CPE reaches 80% in several cases, and even for lag 3, CPE exceeds 60% in forests and savannas.

Differences between drought and non-drought conditions are larger than for the case of P_{50} (Fig. 3) in almost all cases under extreme and severe drought conditions.

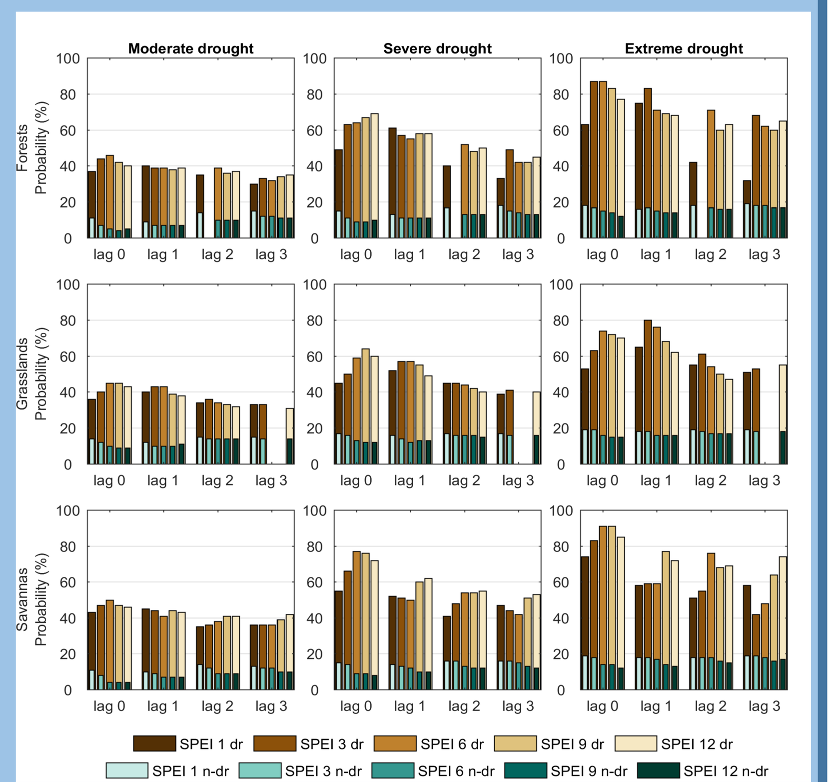

Fig. 4—Conditional probability of BA exceeding P_{80} given drought (dr, green colours), and non-drought conditions (n-dr, brown colours).

Conditional Probability Given Hot Conditions

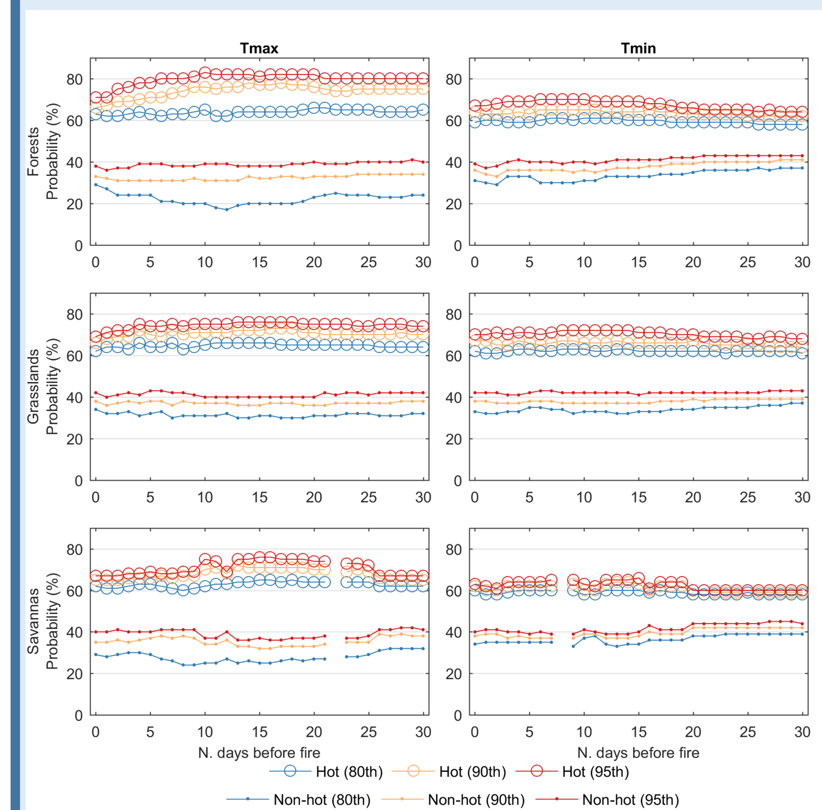

Fig. 5—Conditional probability of BA exceeding P_{50} given hot and non-hot conditions.

CPE given hot conditions and P_{50} (Fig. 5), increases with the percentile of temperature and is higher when computed with T_{max} and in forests.

CPE in grasslands is higher than in savannas, but the values of non-hot conditions are also higher.

For T_{max} and the higher percentiles, CPE increases until the previous 10 days in forests and 5 days in grasslands.

In savannas there is a sharp increase at 10 days and then a sharp decrease at 25 days, due to the different copula models used.

For P_{80} of BA, (Fig. 6), CPE is much lower than for P_{50} (Fig. 5), for both hot and non-conditions.

The highest values were also obtained in forests.

There is a small increase in CPE until around the previous 5 days in forests and grasslands.

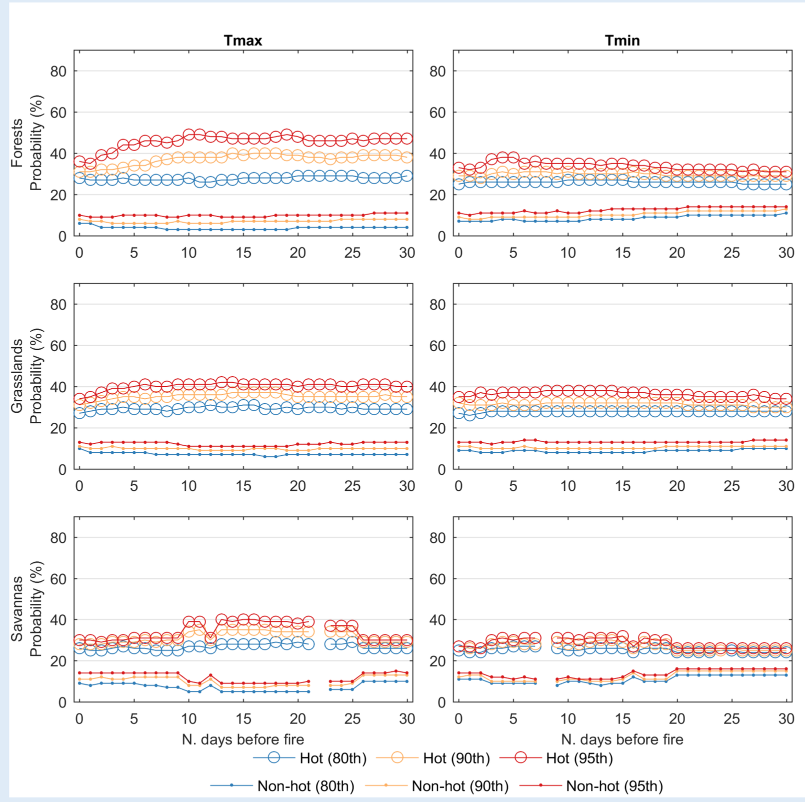

Fig. 6—Conditional probability of BA exceeding P_{80} given hot and non-hot conditions.

Concusions

- Both antecedent and concurrent drought conditions influence BA. Drought conditions up to 3 months before the fire still provide important information regarding the BA.
- The probability of BA exceeding P_{50} under drought or heat extremes conditions is very high, surpassing 60% in almost all cases.
- There is a clear increasing effect of the intensity of the drought and the percentile of the temperature on the probability of occurrence of large fires.
- Drought conditions yield higher conditional probabilities of BA, making it a more important driver than heat extremes, particu-

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