Dependence between Area and Duration of Wildfires:

Distribution Patterns and Extremal Behavior

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Fire statistics 1960 – 2010

Wildland fires have been a recurring phenomenon on the forestland in US.

1960 – 2010: A total of 5.45 million wildland fires burned 86.45 million hectares in the United States, with an annual average of 106,890 fires and 1.70 million hectares burned.

1991 – 2010: 78,842 fires, 2.10 million hectares per year.

More large fires are observed in recent years.

The proportion of large wildland fires has increased dramatically in recent years, and consequently, the suppression costs have increased even faster.

Wildland fires, especially catastrophic fires, have caused severe economic and environmental consequences and endangered the safety of human life.

How to measure large fires?

Fires are an inherently multivariate phenomenon and can be characterized by several correlated features: land area burned,fire duration, ...

Area burned by fires has been widely reported in fire statistics, but fire duration has usually been ignored.

Joint analyses of fire features are needed.

When analyzing patterns of wildland fires, each individual feature can be modeled using univariate techniques. However, there are strong arguments for also assessing their relationship.

A longer-burning fire would cover more lands, and create higher risk to adjacent properties and life. In a multivariate model, data on each variable may inform inferences on each of the others.

Catastrophic fires are not outliers.

Catastrophic fires result in more damages than ordinary fires and should receive more attentions. This is similar to earthquakes.

Extreme value statistics quantify stochastic behavior of a process with abnormally large or small observations.

Bivariate extreme value statistics are needed.

Several studies were published using univariate extreme value statistics.
No study has used bivariate extreme value statistics.

Beverly and Martell (2005): Ontario over 1976 – 1999

Holmes et al. (2008): 600 fires in California over 1910 – 2003

de Zea Bermudez et al. (2009): Portugal over 1984 – 2004

Sun and Tolver (2012): Mississippi over 1991 – 2007

Objectives

The objective of this study was to analyze distribution patterns and extremal behavior of wildland fires in Mississippi.

The analyses were based on area burned and fire duration.

Methods – three sets of techniques

- **Descriptive statistics**: patterns and guides of model selection for extreme value analyses
- **Univariate extreme value statistics**: separate analyses on area and duration
- **Bivariate extreme value statistics** : joint analyses on area and duration

Methods – type and return level

The patterns were assessed by several types: for all the fires combined, and individually by period, ecoregion, cause, and extremal degree.

After selecting appropriate distributions and fitting the corresponding models, the return levels of wildland fires by area burned and fire duration were predicted.

Data 1991 – 2007

A complete dataset of fire occurrences in Mississippi between January 1991 and December 2007 was used in the analyses.

For each fire, 210 items were reported: size, start time, location,...

Data – Mississippi

Historically, the southern states have not been prone to wildfires of such disastrous proportions as those experienced by the western states. Therefore, limited fire studies have covered the South.

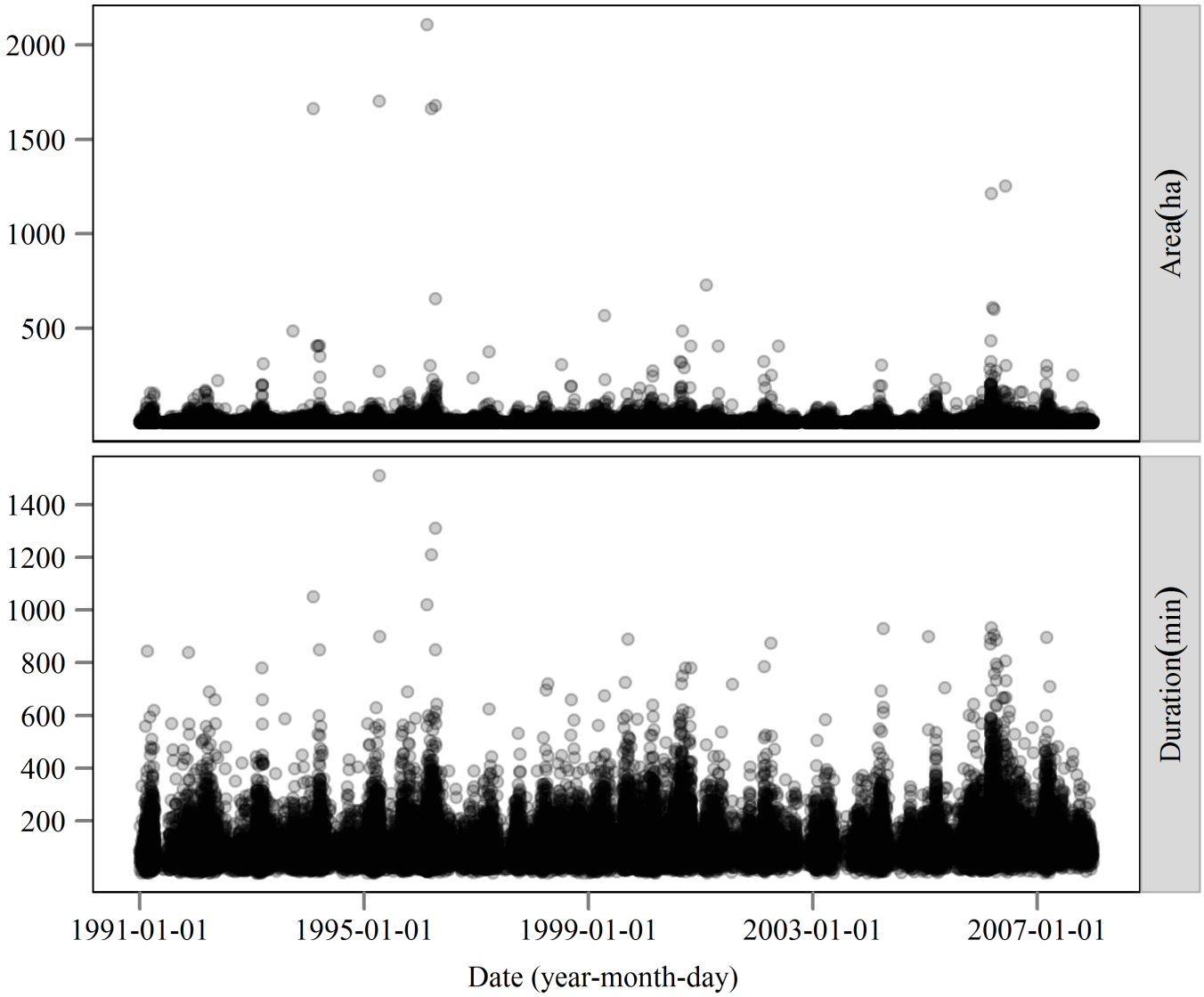
As Mississippi is a typical southern state, its fire records present a valuable opportunity for analyzing the patterns of wildfire occurrences.

Descriptive statistics for all the fires

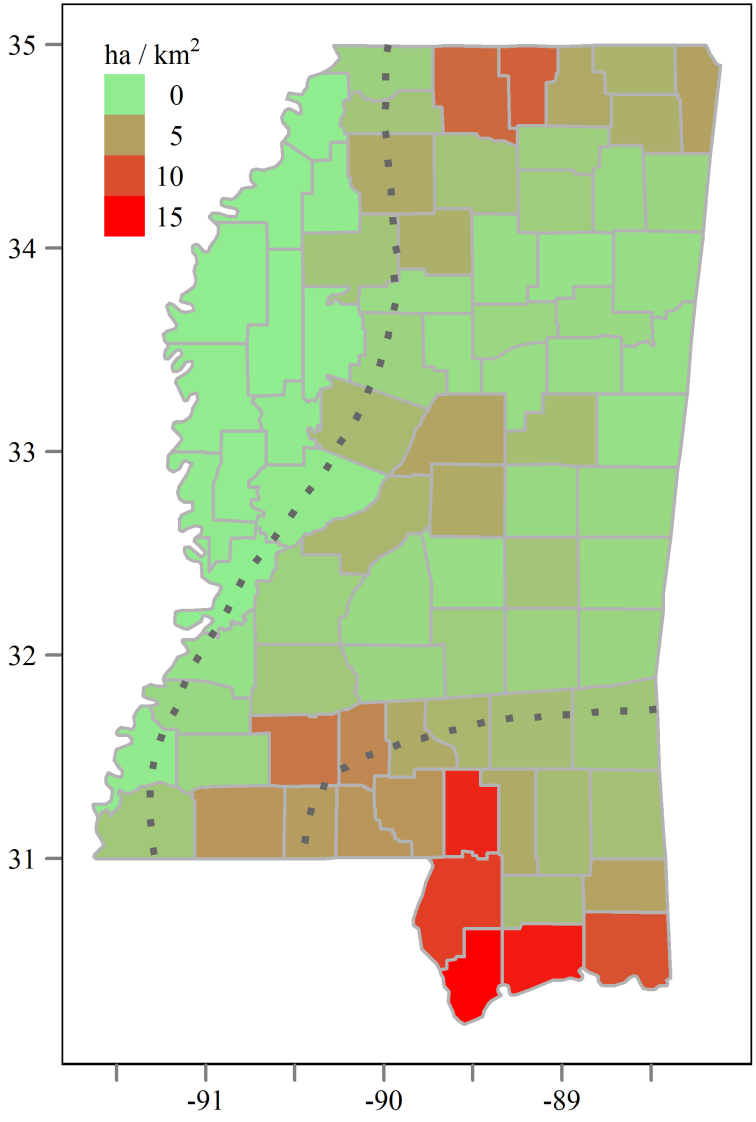
There were a total of 64,474 wildland fires in Mississippi between January 1991 and December 2007 with at least 0.405 hectare (i.e., one acre) burned and fire time documented.

The average fire size was 5.8 hectares and the standard deviation was 22.6 hectares; the average fire duration was 100.3 minutes and the standard deviation was 68.4 minutes.

Temporal distribution patterns

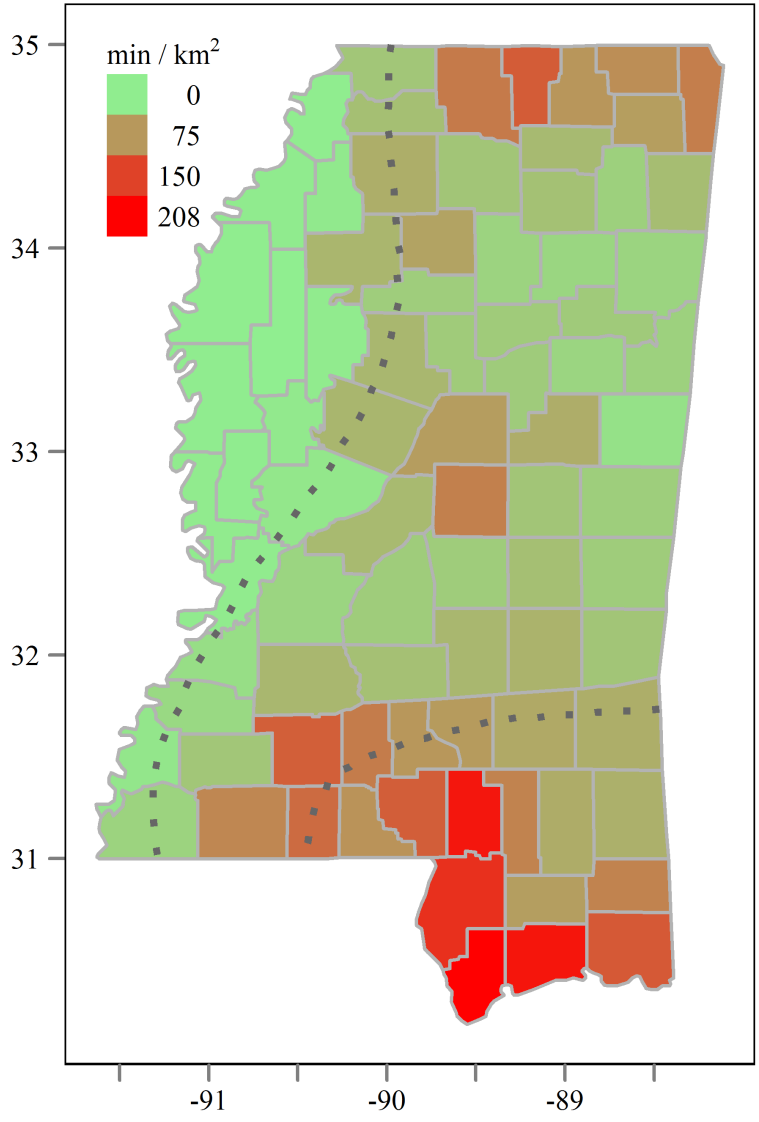


Size Density



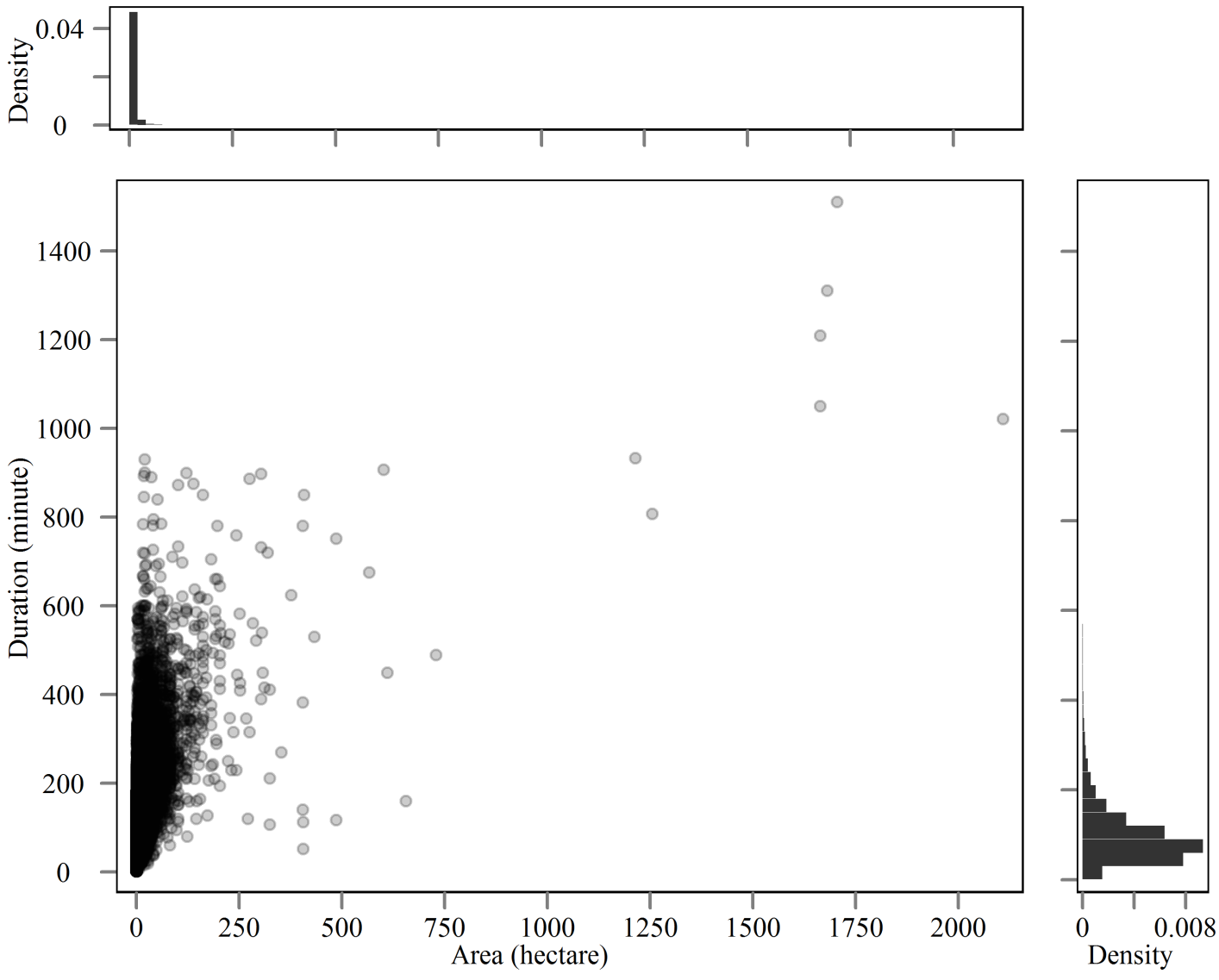
(a) Density of area burned

Duration Density



(b). Density of fire duration

Association between area and duration



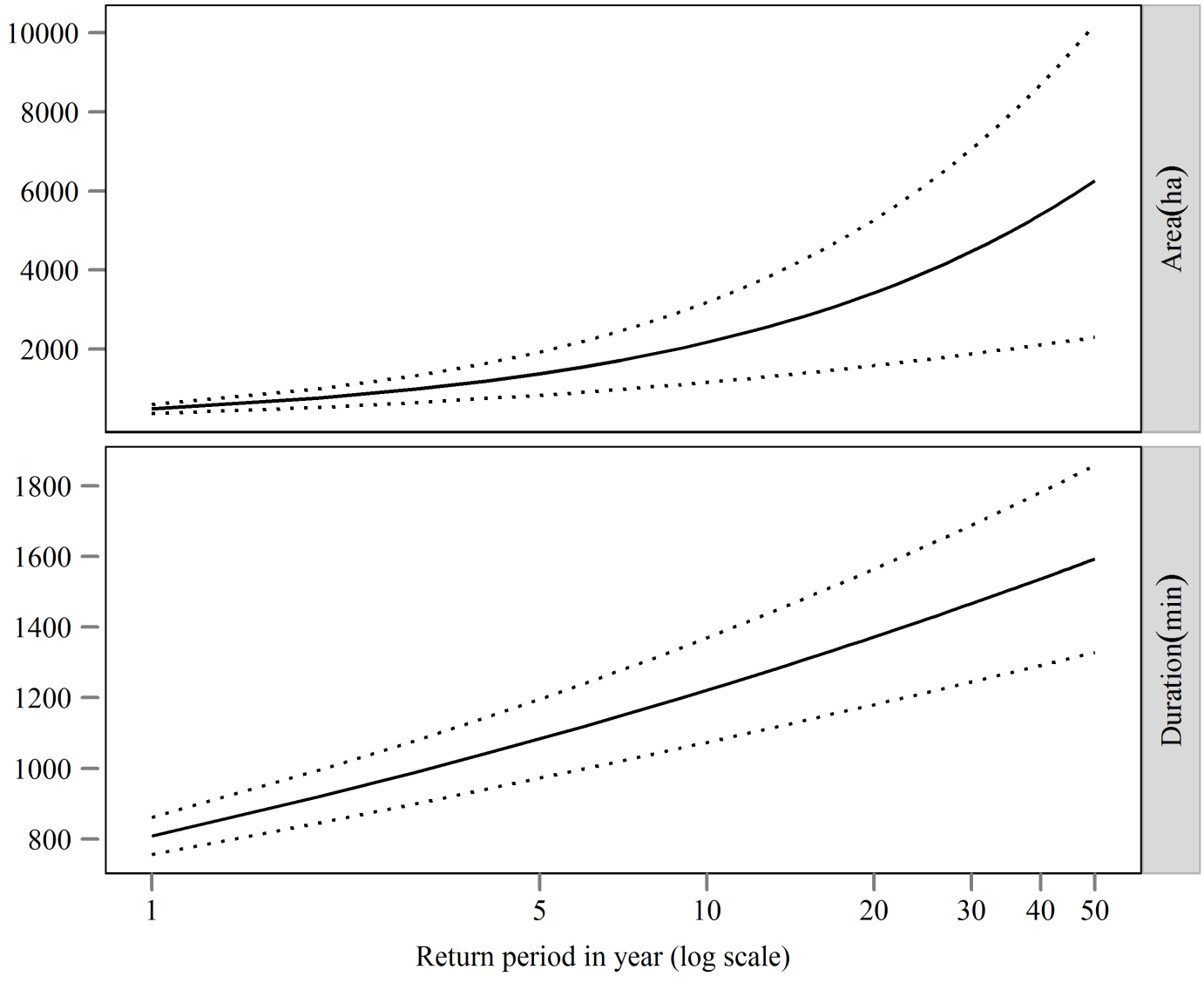
Results from univariate analyses

Evaluation of the quantile plot and density plot revealed that the generalized Pareto distribution fitted the data well.

The estimated parameters could be used to extrapolate and predict the return levels of fires. For Mississippi as a whole, a wildfire resulting in 2,171 hectares of burned area could occur with a probability of 0.0026 % in a year, or once in 37,927 fires, or approximately once in 10 years.

The largest wildfire by duration within 10 years in Mississippi would burn for 1,221 minutes.

Return levels from the univariate analyses

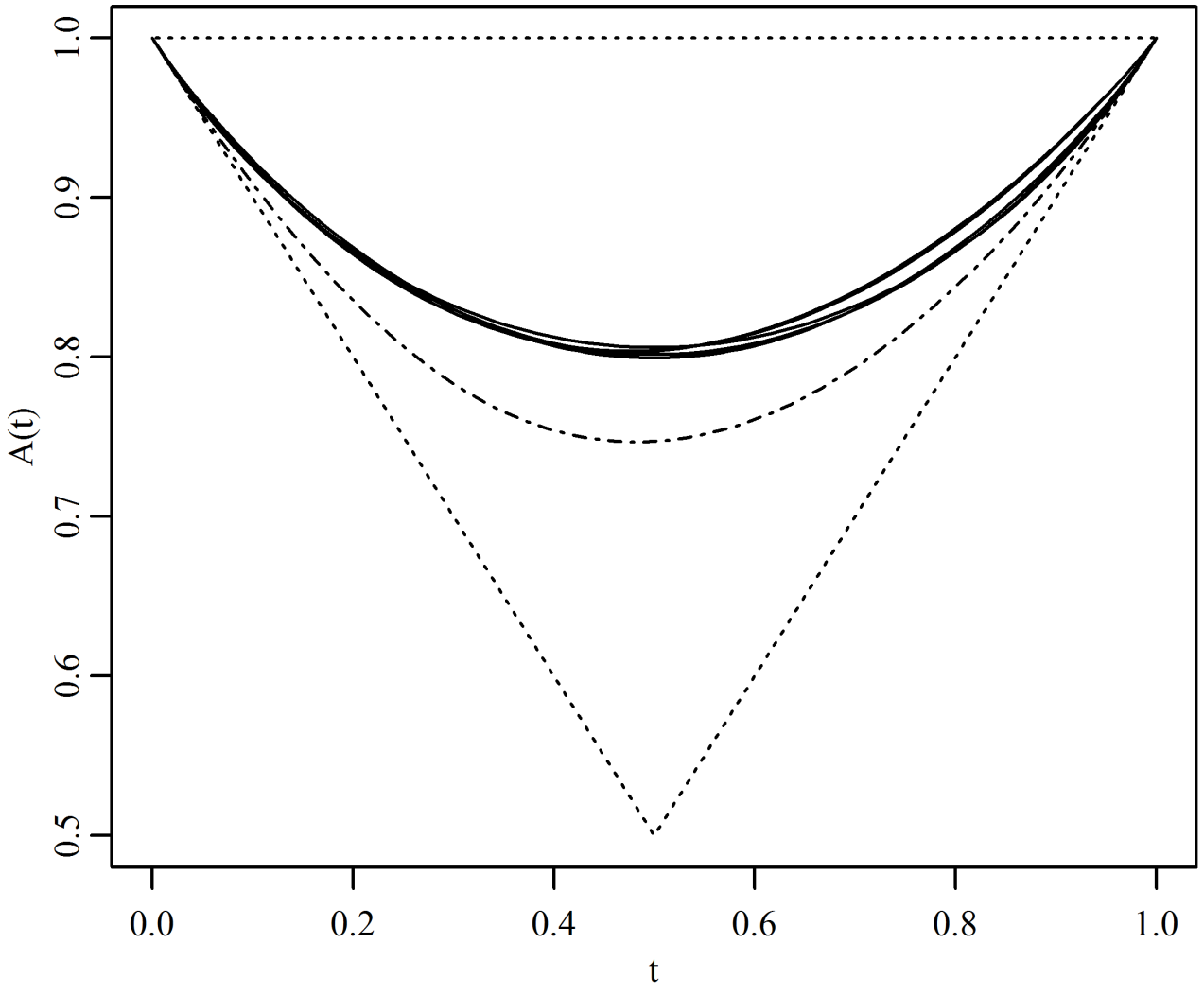


Results from bivariate analyses

Five distributions were fitted on all the fire records in Mississippi. These models produced very similar results, as revealed by the Pickands dependence function. The asymmetric negative logistic distribution had the best fit.

The Pickands dependence measure was 0.391 for all the fires combined.

Pickands dependence function by distribution

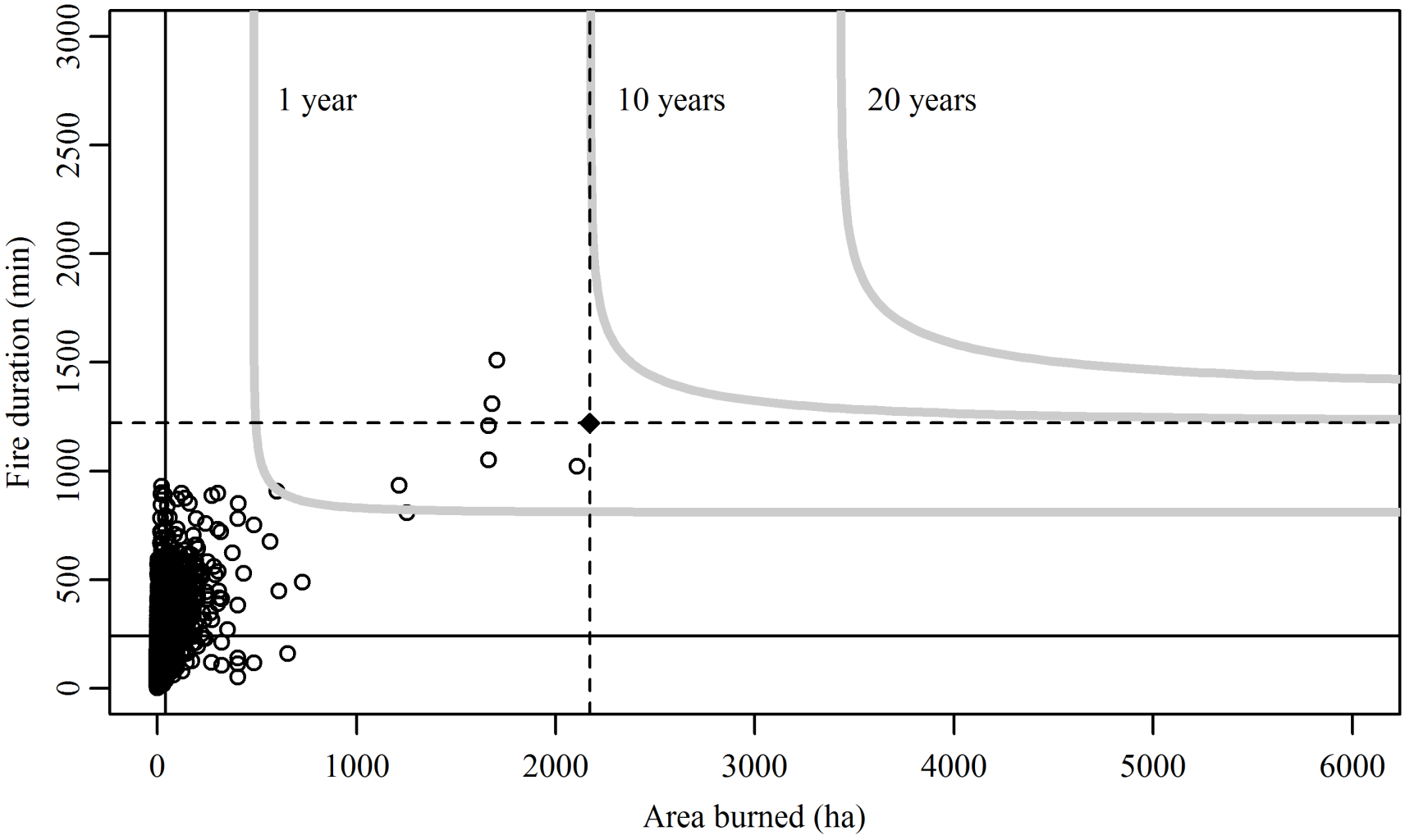


Return levels from bivariate analyses

A simple combination of the univariate values from 10 years, i.e., (area, duration) = (2,171, 1, 221), corresponded to a risk of about 8 years from the bivariate analyses.

The bivariate quantile plots provided more accurate predictions since the association between the two variables was significant and considered.

Bivariate return levels



Summary

Severe economic and environmental consequences are associated with catastrophic wildland fires. Fires are an essentially multivariate phenomenon. It is of great significance to develop appropriate models for predicting large fires.

Two aspects of large wildland fires (i.e., area burned and fire duration) were assessed by univariate and bivariate extreme value statistics.

Summary

The outcomes have great implications for forest planning and management activities. The degree of extremal behavior and probability of catastrophic fires can aid landowners in their forest management activities.

A more accurate prediction of catastrophic wildland fires will help landowners and agencies in making sound decisions related to fire budgets and facility investments.

. . . many thanks . . .