Stand structure and fire intensity explain variation in fire severity in the black spruce moss bioclimatic domain

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Centre d'étude de la forêt

Project C*FIRE

NSERC CRSNG

UNIVERSITÉ LAVAL

CONTEXT

- Canadian Forest Fire Behavior Prediction (FBP) System
  - Provides estimates of the potential frontal fire intensities (kW/m) for different fuel types (e.g., C2,C3,M1,M2)
  - Intensity = rate of heat energy released per unit time per unit length of fire front

- Fire severity = ecological effects of a fire
  = % Basal area lost

- Fire severity variation within the C2 fuel type might be due to differences in stand structure (horizontal and vertical)

Creeping surface fire

Active crown fire

Source: Canadian Forest Fire Danger Rating System (CFFDRS)

OBJECTIVE

Determine the threshold (s) in fire intensity at which stand structure becomes important in explaining fire severity patterns.

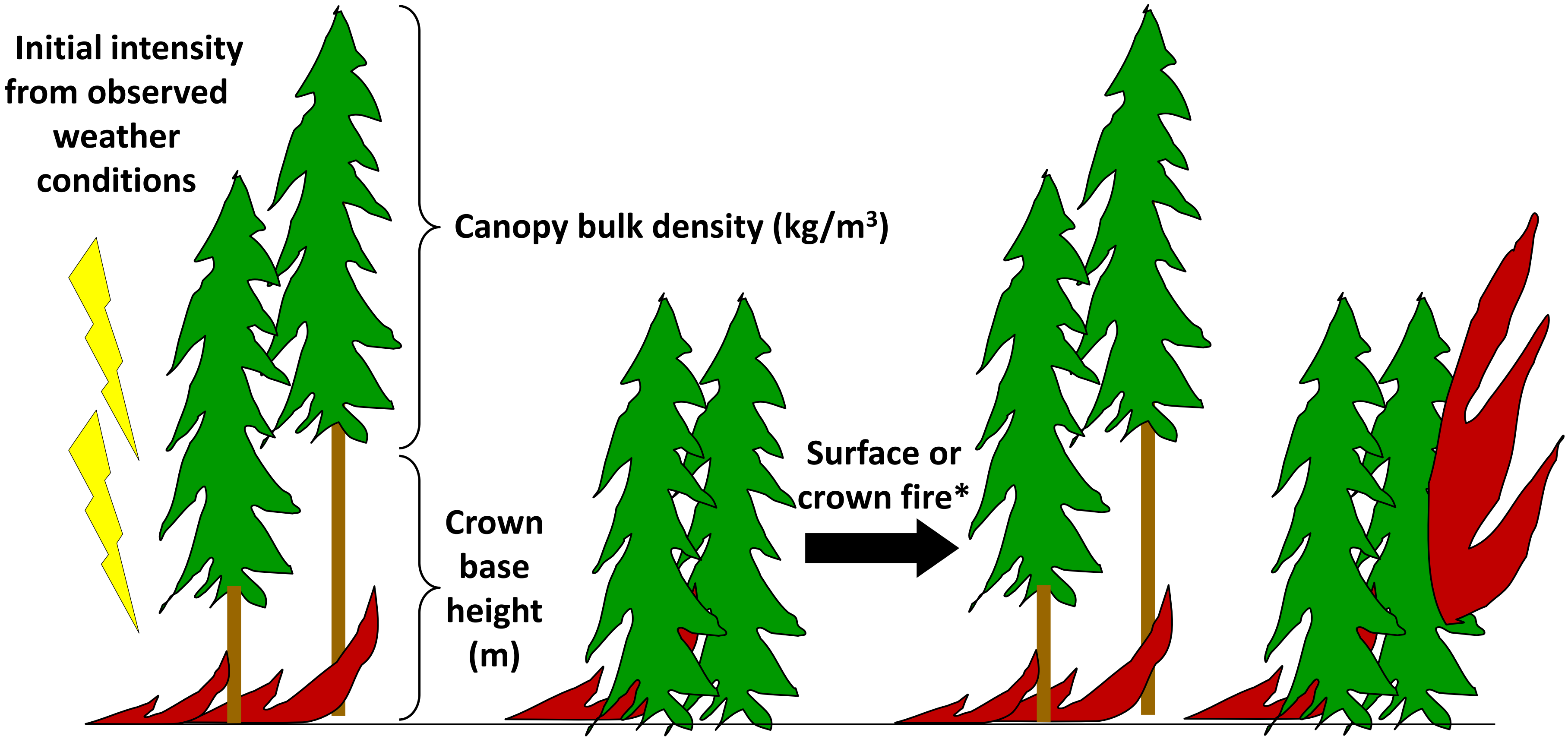
HYPOTHESIS

The importance of stand structure will be higher at lower fire intensities.

METHODOLOGY

Model to simulate non-spatially fire severity at the 1 ha patch level

(Cumming and Wong 2002)

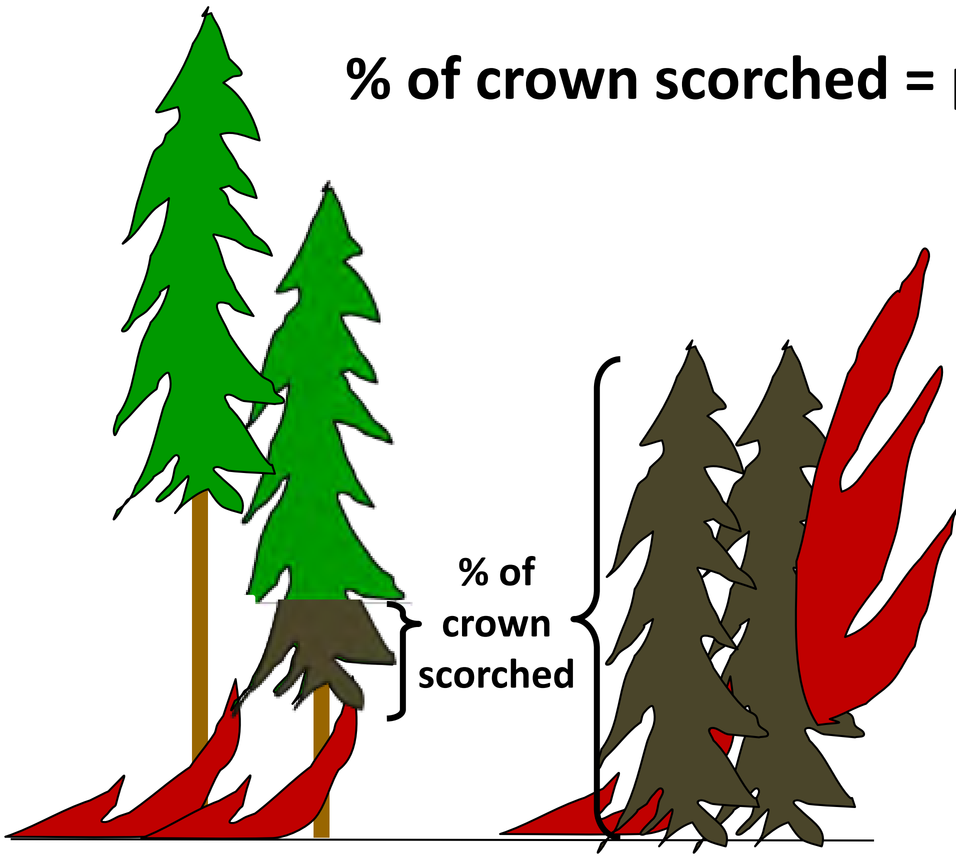


* Crown fire initiation model (Van Wagner, 1977)

METHODOLOGY

Model to simulate non-spatially fire severity at the 1 ha patch level
(Cumming and Wong 2002)

% of crown scorched = probability of mortality = severity



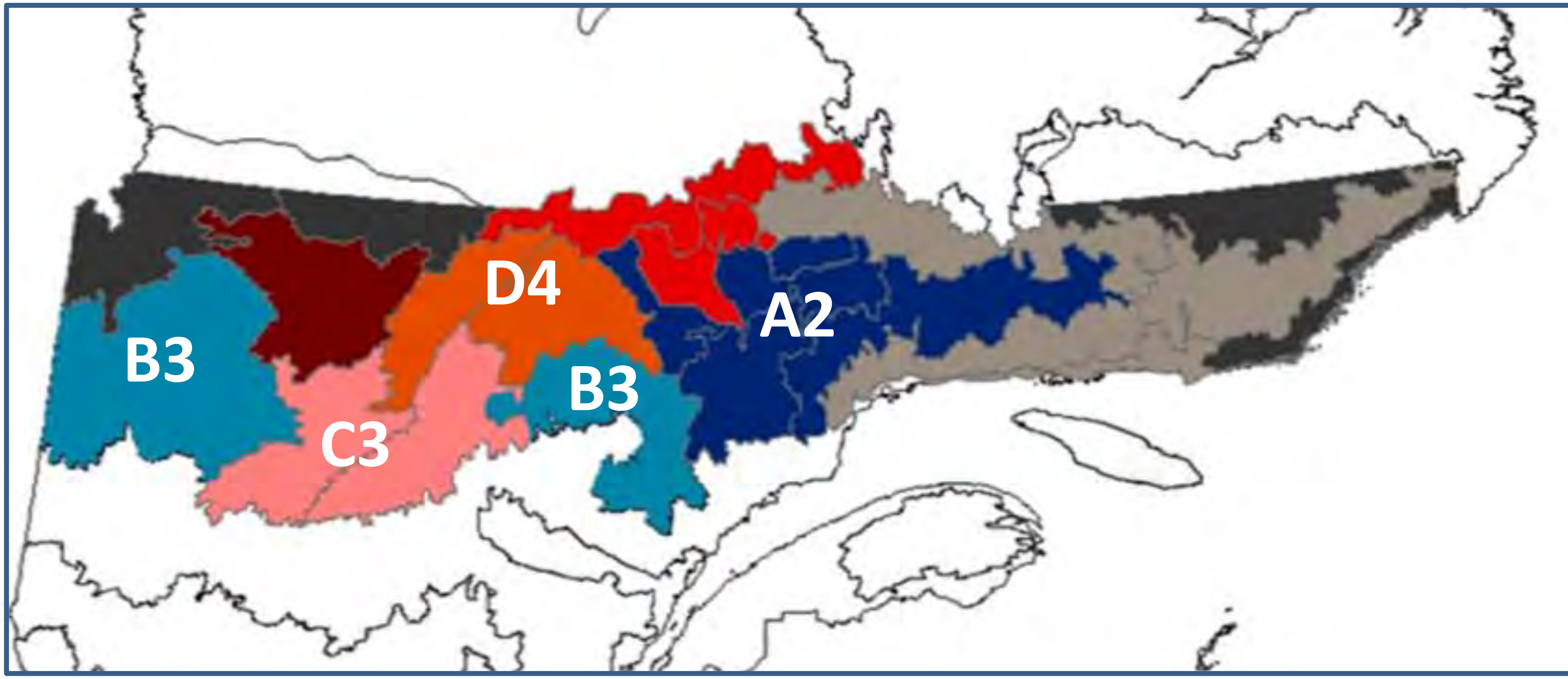
FIRE SEVERITY CALCULATION

B = Total basal area before
A = Total basal area after

% total basal area lost
=
100*(1-(A/B))

METHODOLOGY

Ecological regions under study



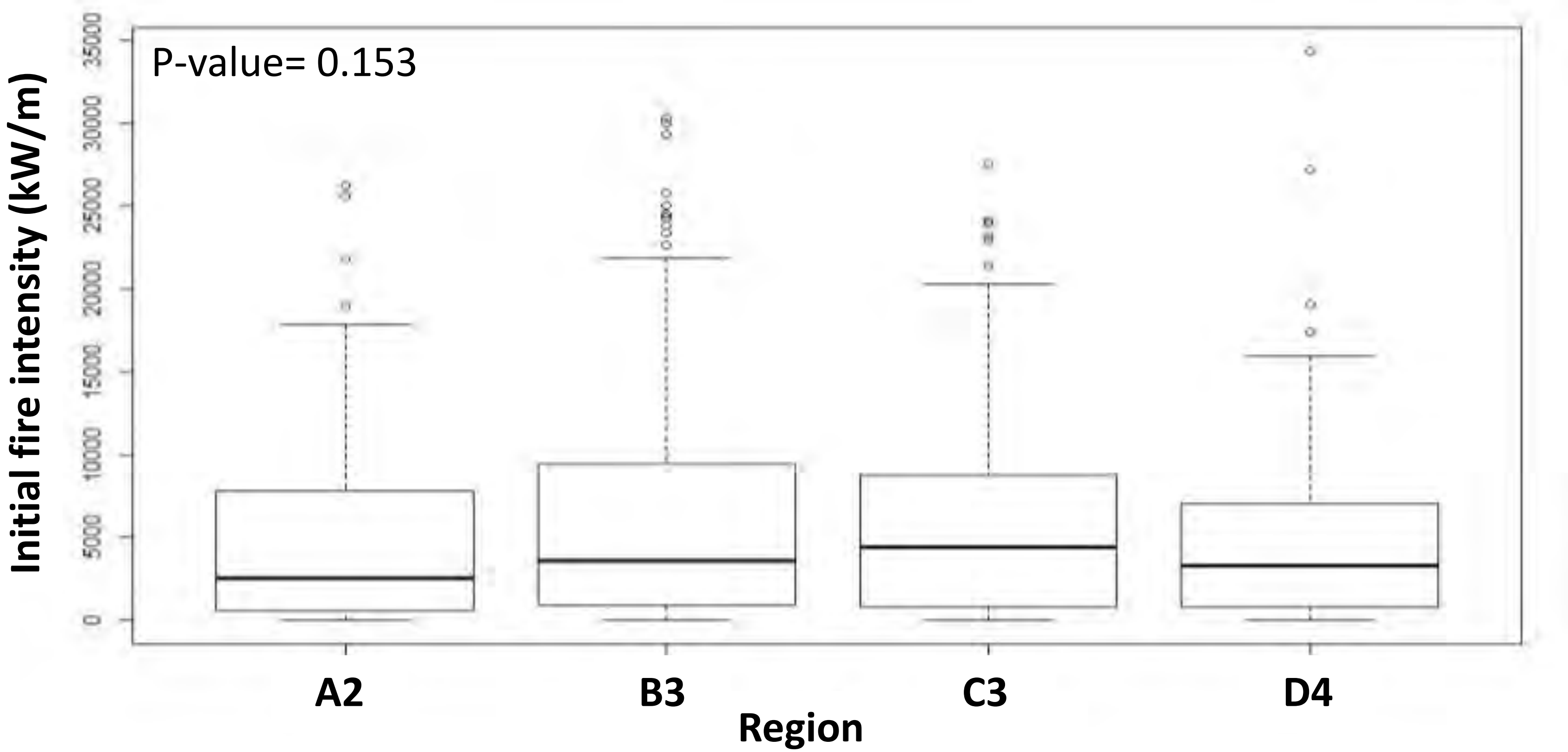
Adapted from: Chabot *et al.*, 2009

METHODOLOGY

Initial fire intensity dataset SOPFEU (1994-2010)

- Fire weather variables
- First day intensity record
- C2 fuel type
- Region

1579 fire records available for simulation



METHODOLOGY

Sampling of diameter distributions of pure black spruce and jack pine from 4882 inventory plots (MRNF)

- **Horizontal stand structure** (Boucher *et al.* 2003)
  - **Shannon-Wiener diameter diversity index**
  - **Percentage of trees in DBH class 10**
  - **Percentage of trees in DBH class 14**
  - **Coefficient of variation**
  - **Skewness**

- **Vertical stand structure**
  - **Forest canopy base height (CBH)**
  - **Forest canopy bulk density (CBD)**

METHODOLOGY

Experimental design

For each model simulation in R we randomly selected

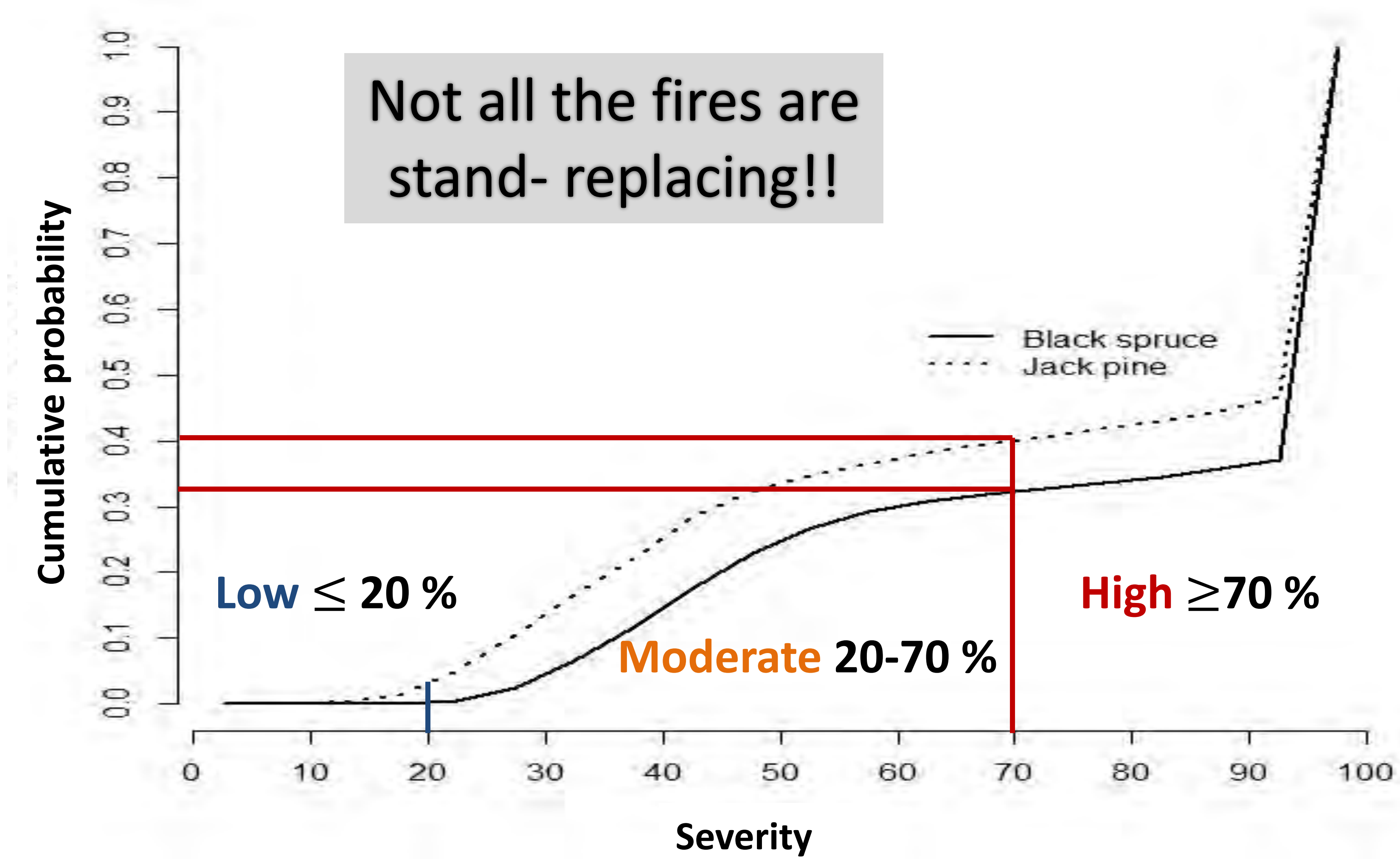
- One plot and an initial intensity for each of the four regions

- Ran the model 24 000 times (3000 per region per species)

RESULTS

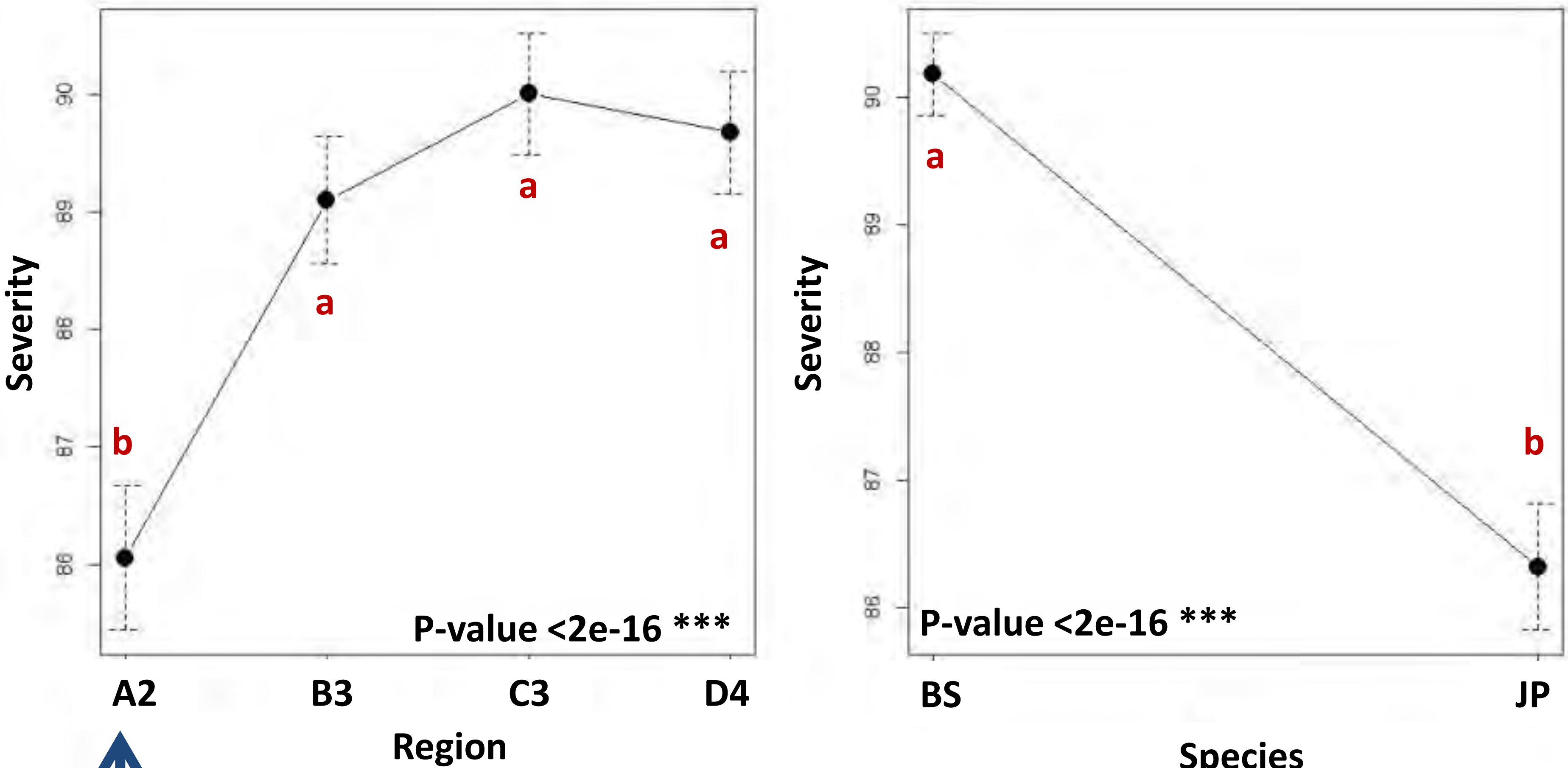
Percentage of fire starts that resulted in high severity fires

Severity thresholds are from Perry et al. (2011)



RESULTS

Differences in severity among regions and species



Longer fire cycle

Plot of means with 95% CI and Tukey's multiple comparisons

FINDING THRESHOLDS

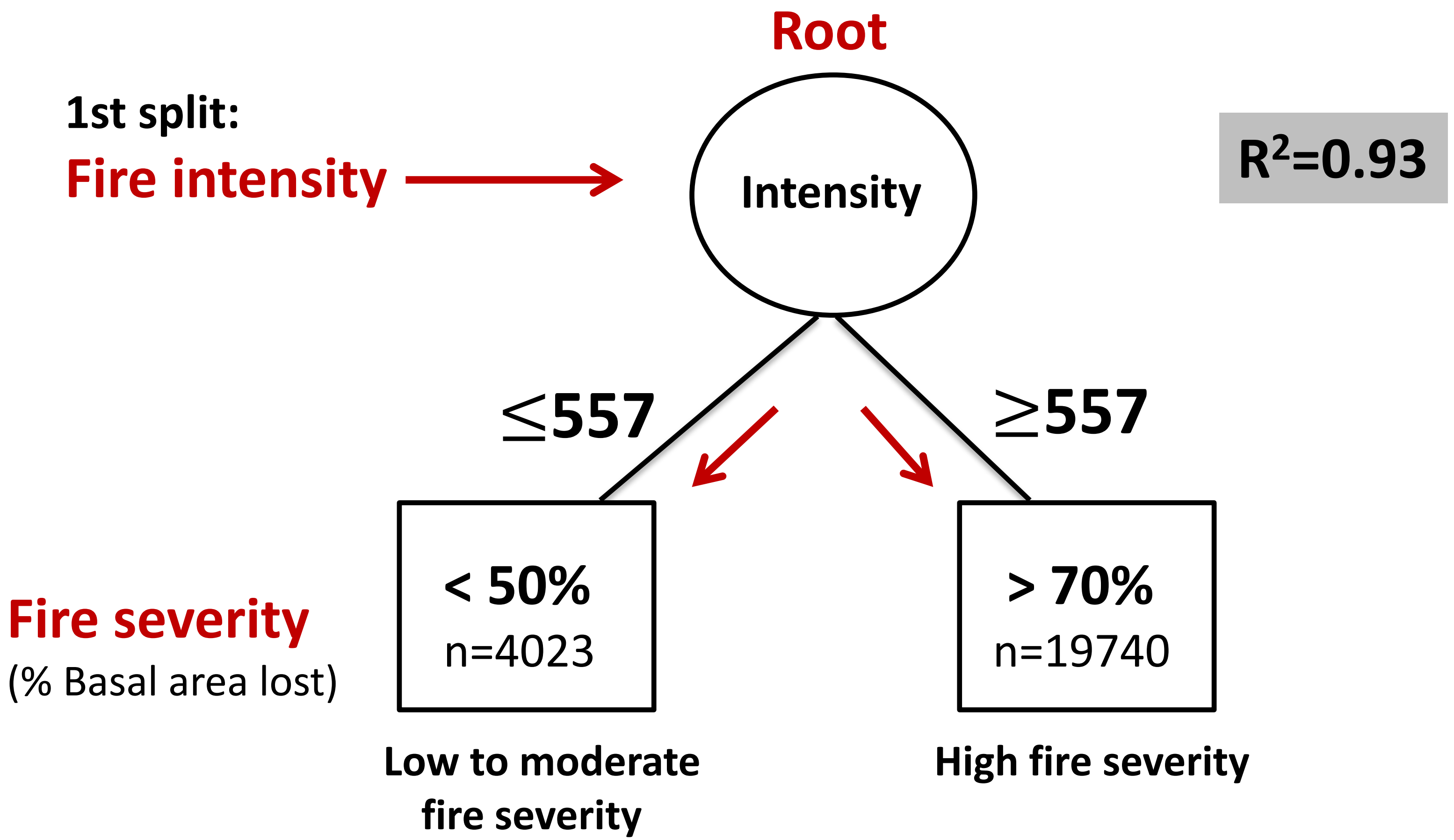
Two-step approach to model fire severity using non-parametric methods

1. **Random Forest Analysis (RFA) :** Rank importance of predictors (package R, ”randomforest”): **Intensity, Shannon, CBH, CBD, P10**

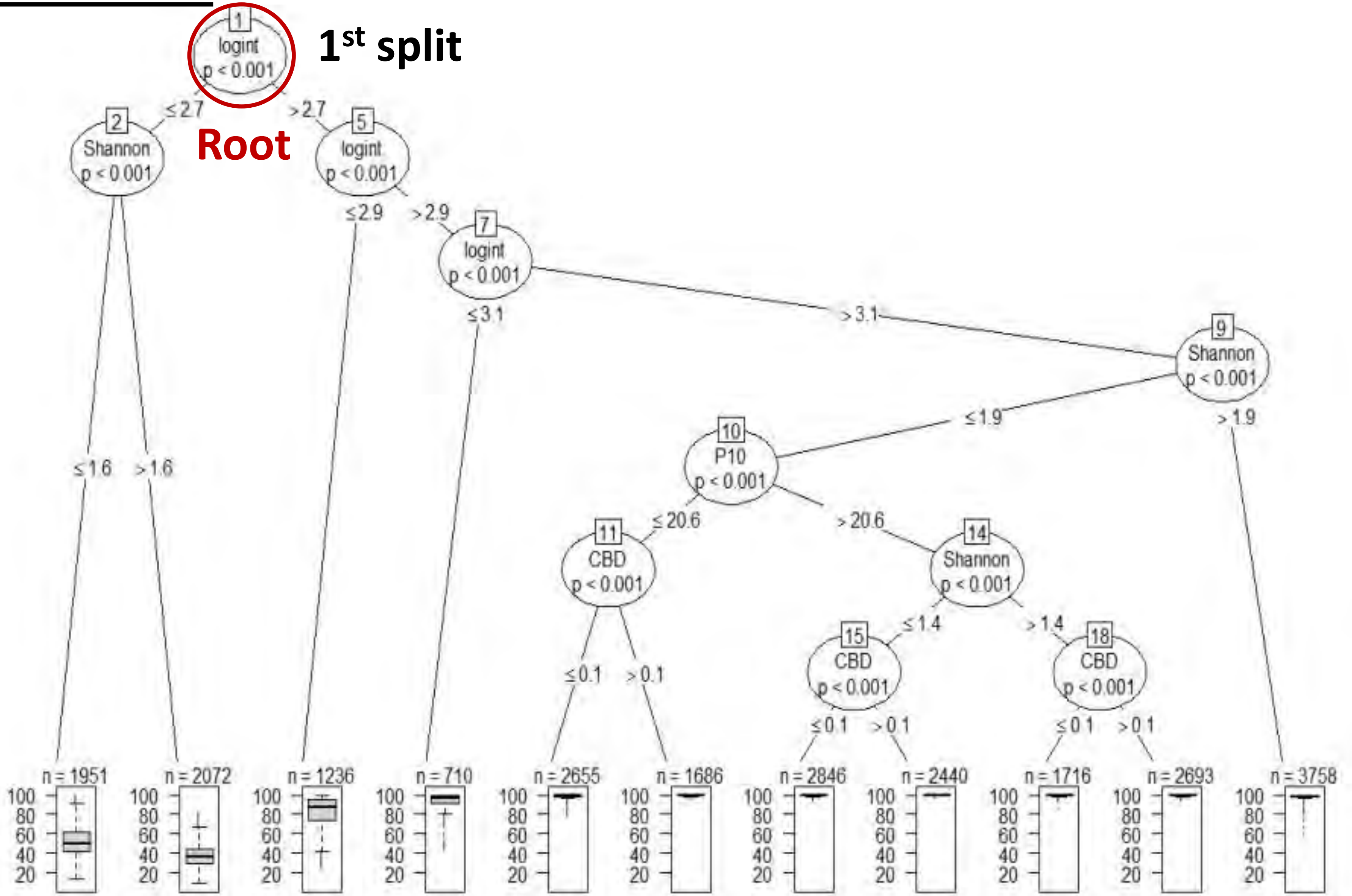
2. **Regression Tree Analysis (RTA) :** Examine relationship between the response and important predictors. Recursively partitions the data into smaller groups. Conditional inference trees based on statistical theory (package R, “party”)

RESULTS

Regression Tree Analysis



RESULTS

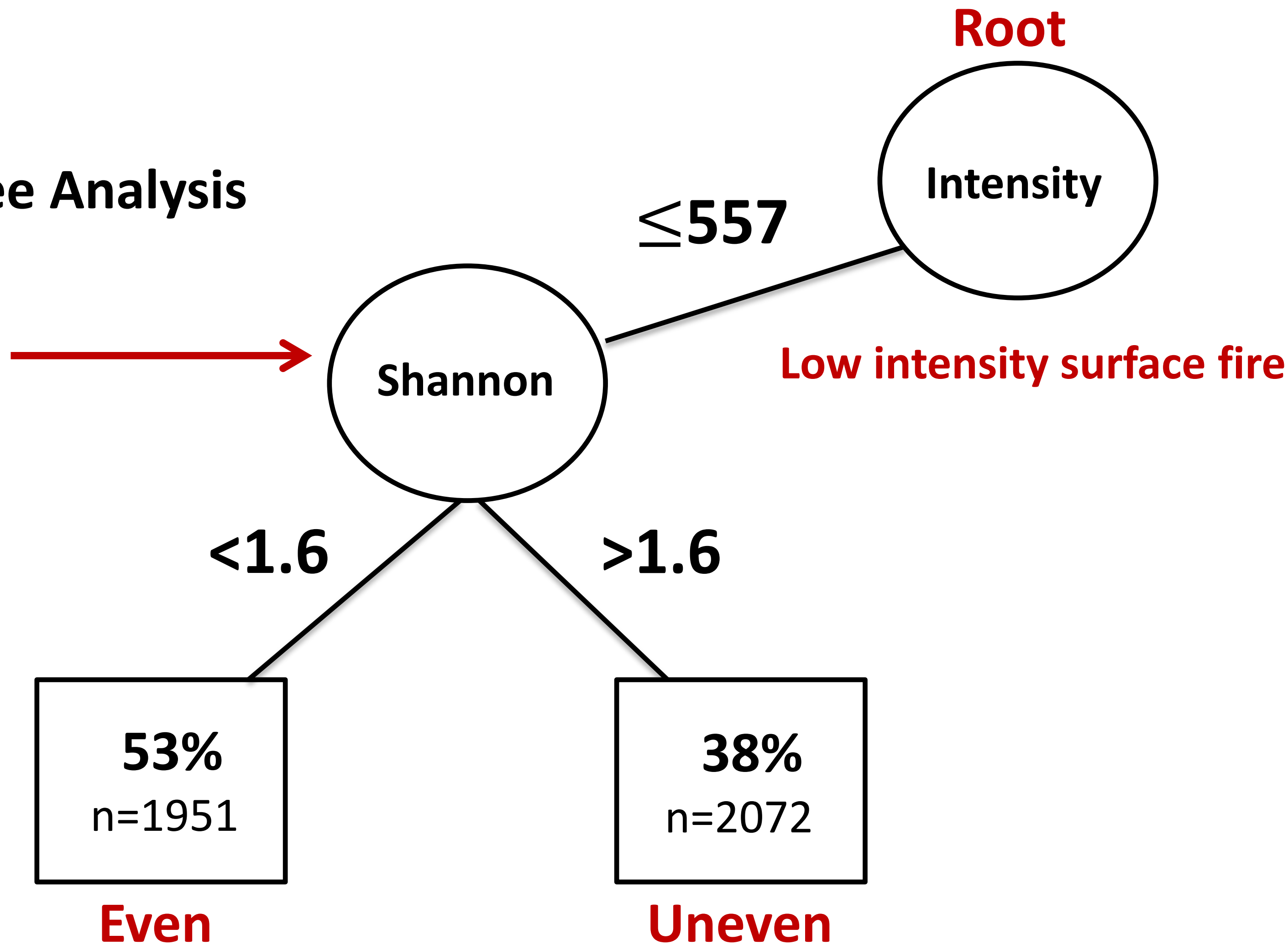


Terminal Nodes

RESULTS

Regression Tree Analysis

2nd split:
Shannon

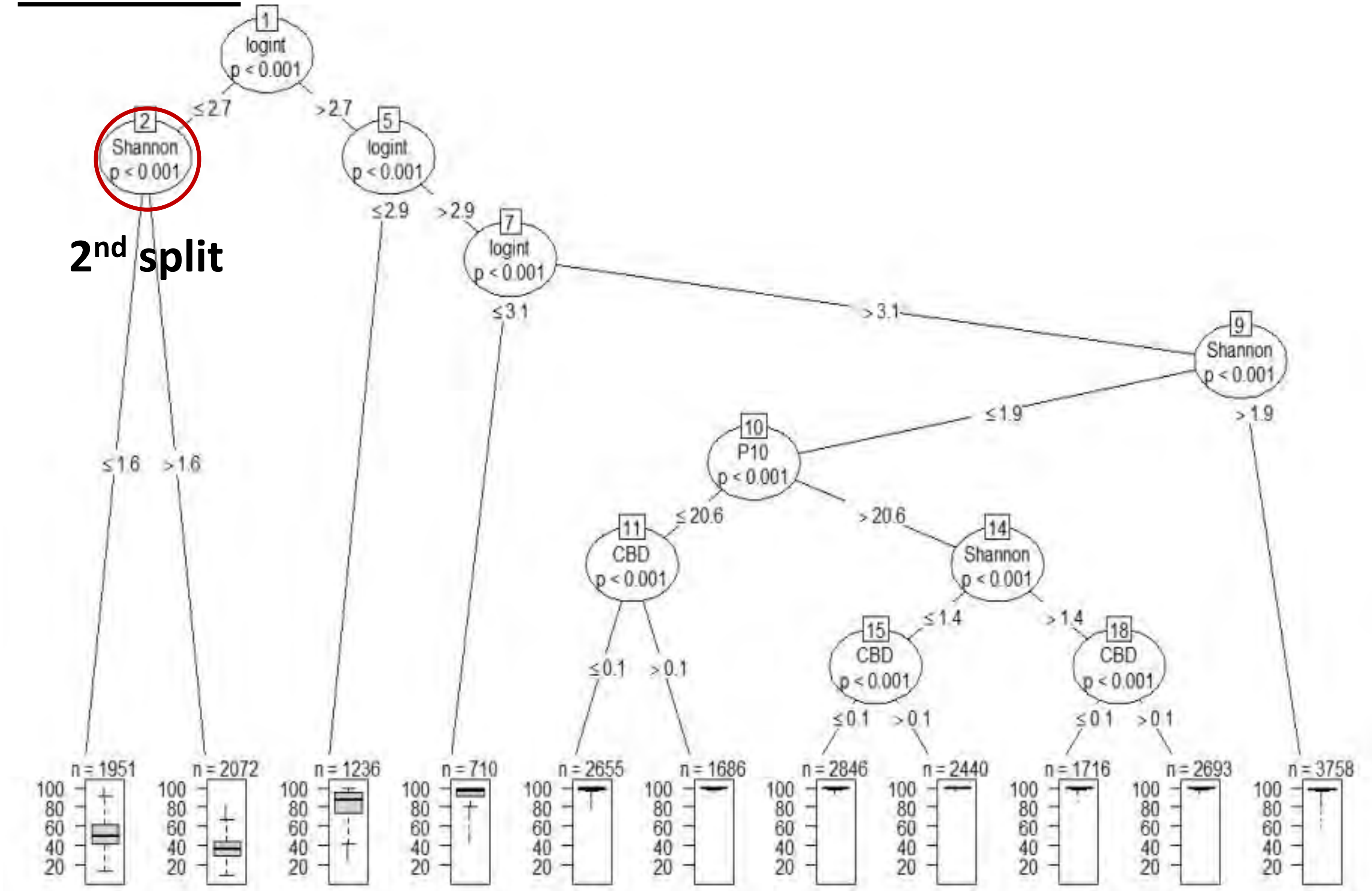


Fire severity
(% Basal area lost)

	Shannon index
Even-sized	1.4 ± 0.20
J-inverse	2.0 ± 0.17
Uneven-sized	2.2 ± 0.16

Boucher *et al*. (2003)

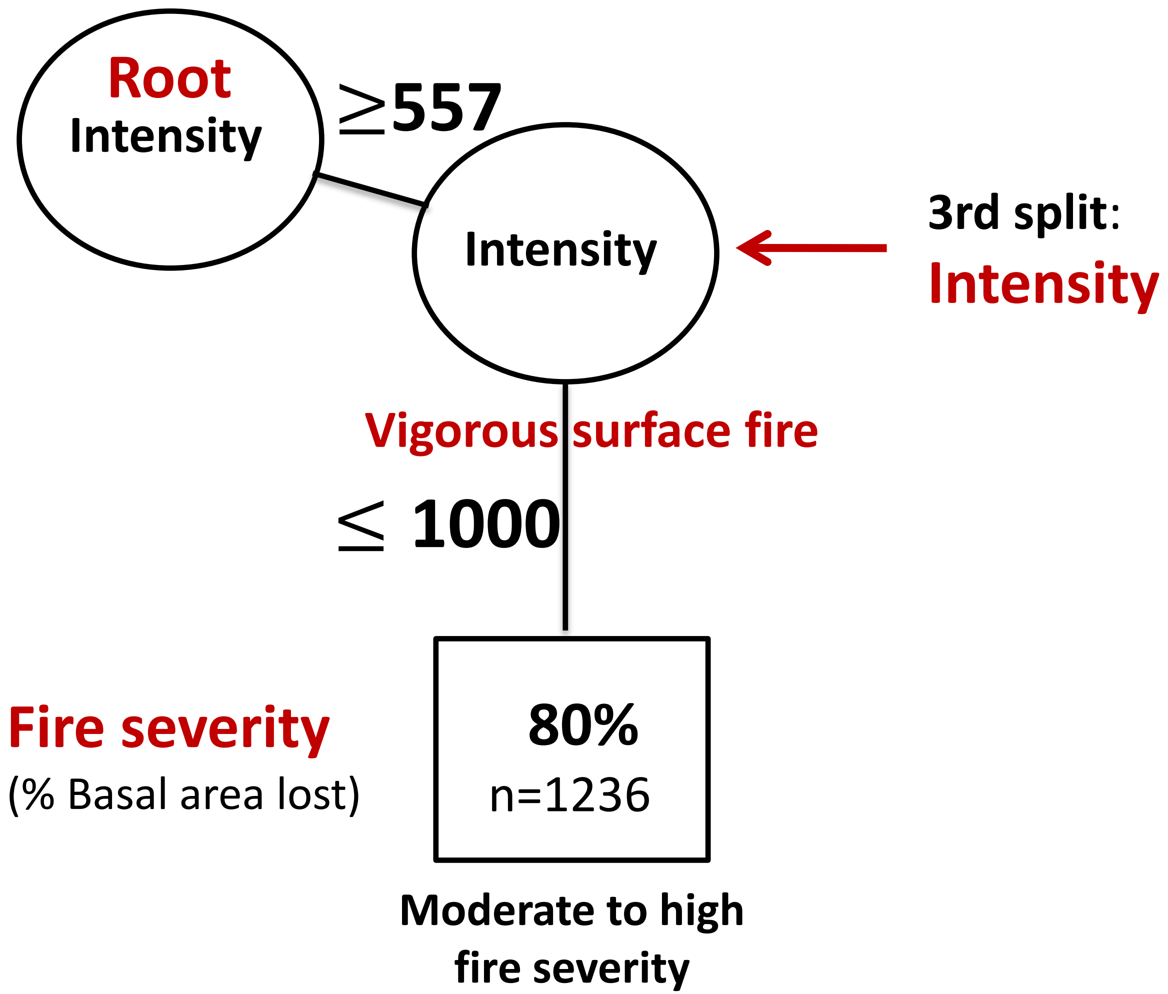
RESULTS



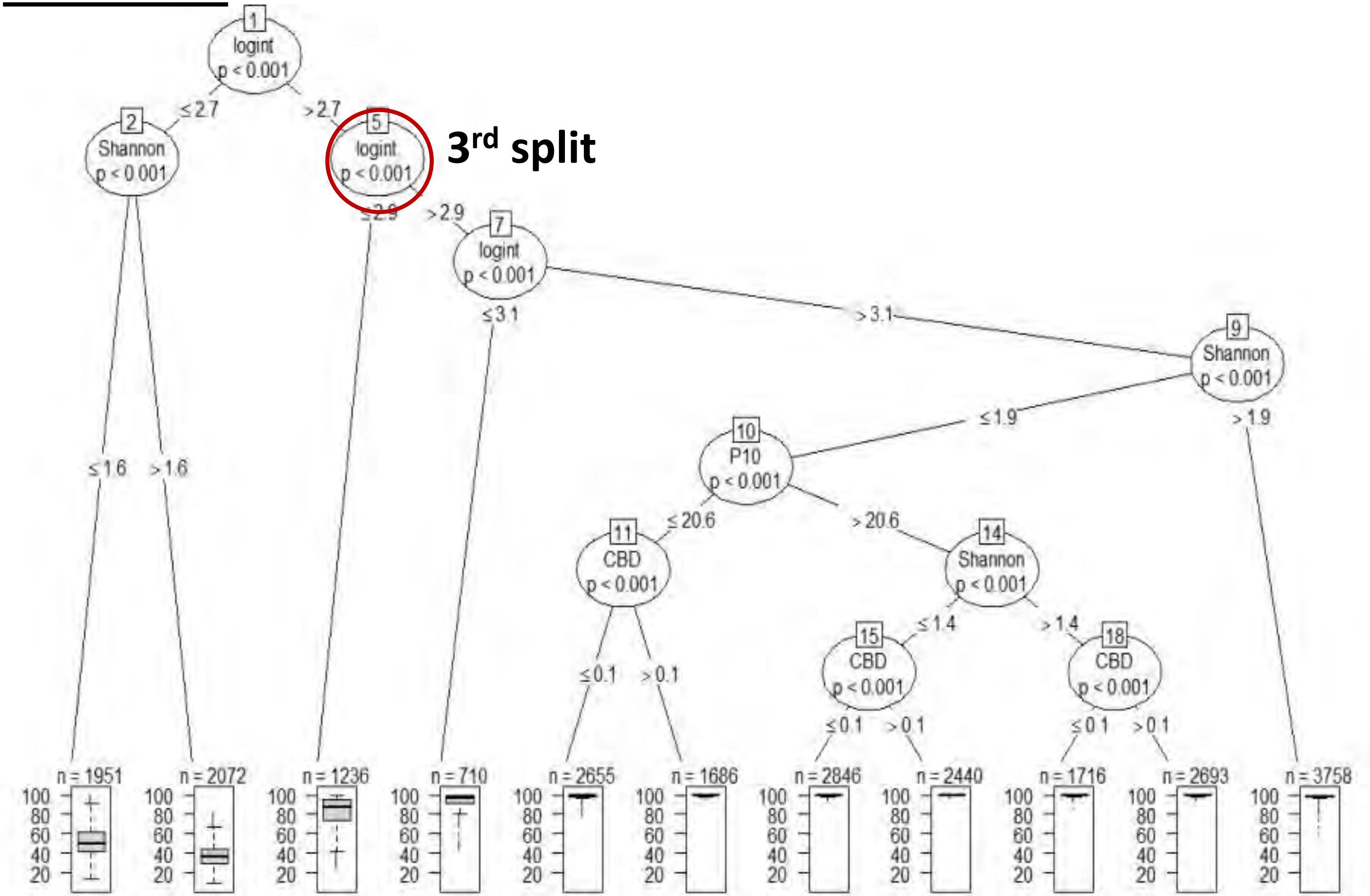
1
logint
p < 0.001
≤ 2.7
> 2.7
2
Shannon
p < 0.001
2nd split
5
logint
p < 0.001
≤ 2.9
> 2.9
7
logint
p < 0.001
≤ 3.1
> 3.1
9
Shannon
p < 0.001
≤ 1.9
> 1.9
10
P10
p < 0.001
≤ 20.6
> 20.6
11
CBD
p < 0.001
≤ 0.1
> 0.1
14
Shannon
p < 0.001
≤ 1.4
> 1.4
15
CBD
p < 0.001
≤ 0.1
> 0.1
18
CBD
p < 0.001
≤ 0.1
> 0.1
≤ 1.6
> 1.6
n = 1951
n = 2072
n = 1236
n = 710
n = 2655
n = 1686
n = 2846
n = 2440
n = 1716
n = 2693
n = 3758
100
80
60
40
20

RESULTS

Regression Tree Analysis



RESULTS



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logint
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≤ 2.7
> 2.7
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Shannon
p < 0.001
5
logint
p < 0.001
3rd split
≤ 2.9
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≤ 3.1
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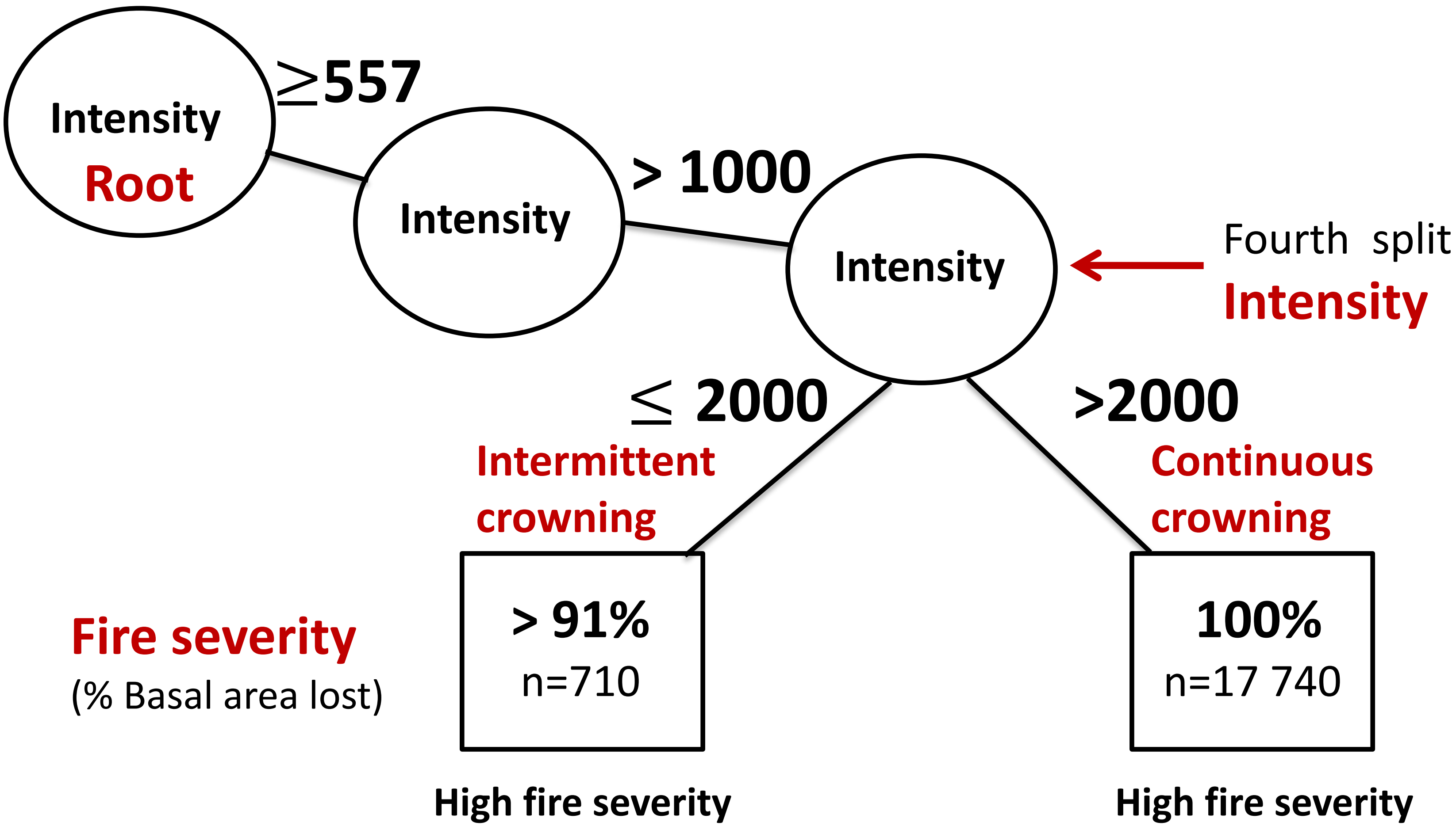
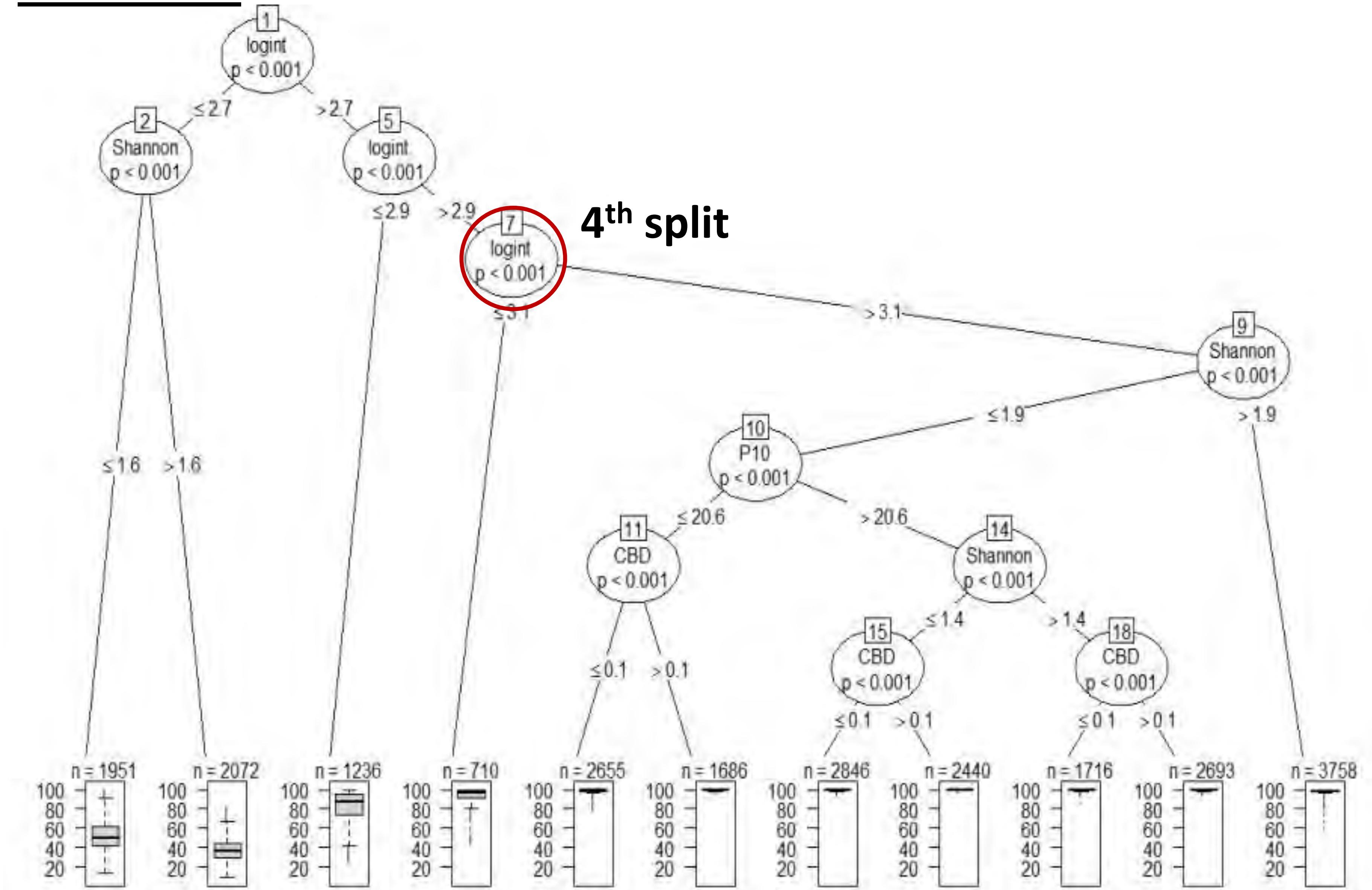
RESULTS

Regression Tree Analysis



RESULTS



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logint
p < 0.001
≤ 2.7
> 2.7
2
Shannon
p < 0.001
5
logint
p < 0.001
≤ 2.9
> 2.9
7
logint
p < 0.001
4th split
≤ 3.1
> 3.1
9
Shannon
p < 0.001
≤ 1.9
> 1.9
10
P10
p < 0.001
≤ 1.6
> 1.6
≤ 20.6
> 20.6
11
CBD
p < 0.001
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Shannon
p < 0.001
≤ 0.1
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20

CONCLUSIONS

- **Fire intensity** is the **most** important predictor of fire severity. However **stand structure** matters particularly at **low intensities.**

- **Shannon** diameter diversity index explains variation in fire severity patterns when fire intensity is lower than **557 kW/m.** Fire severity in **uneven** stands is **lower** than in **even** stands at low fire intensities.

- At high fire intensities **>2000 kW/m** the effect of **vegetation** is less pronounced.

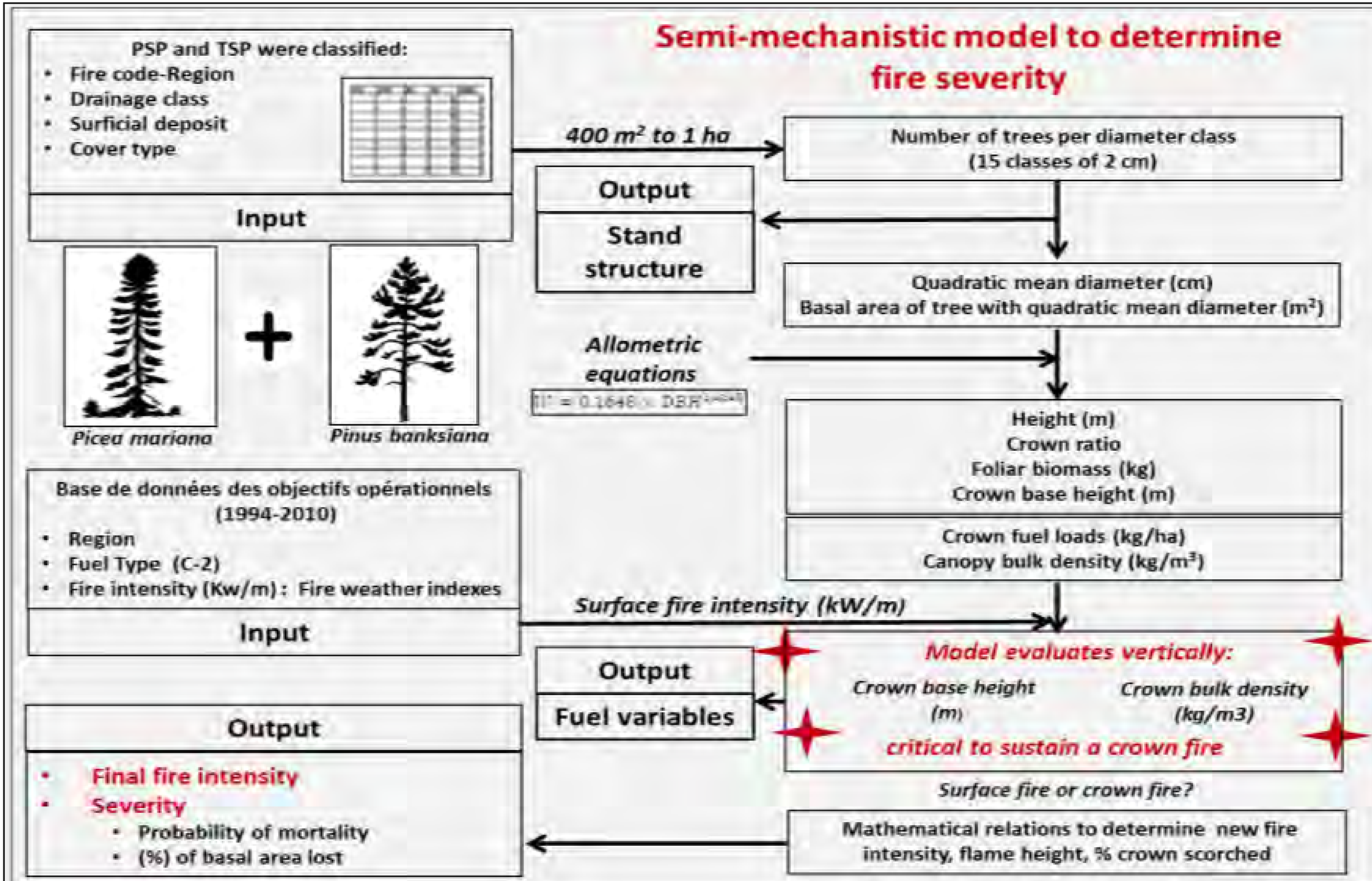
CONCLUSIONS

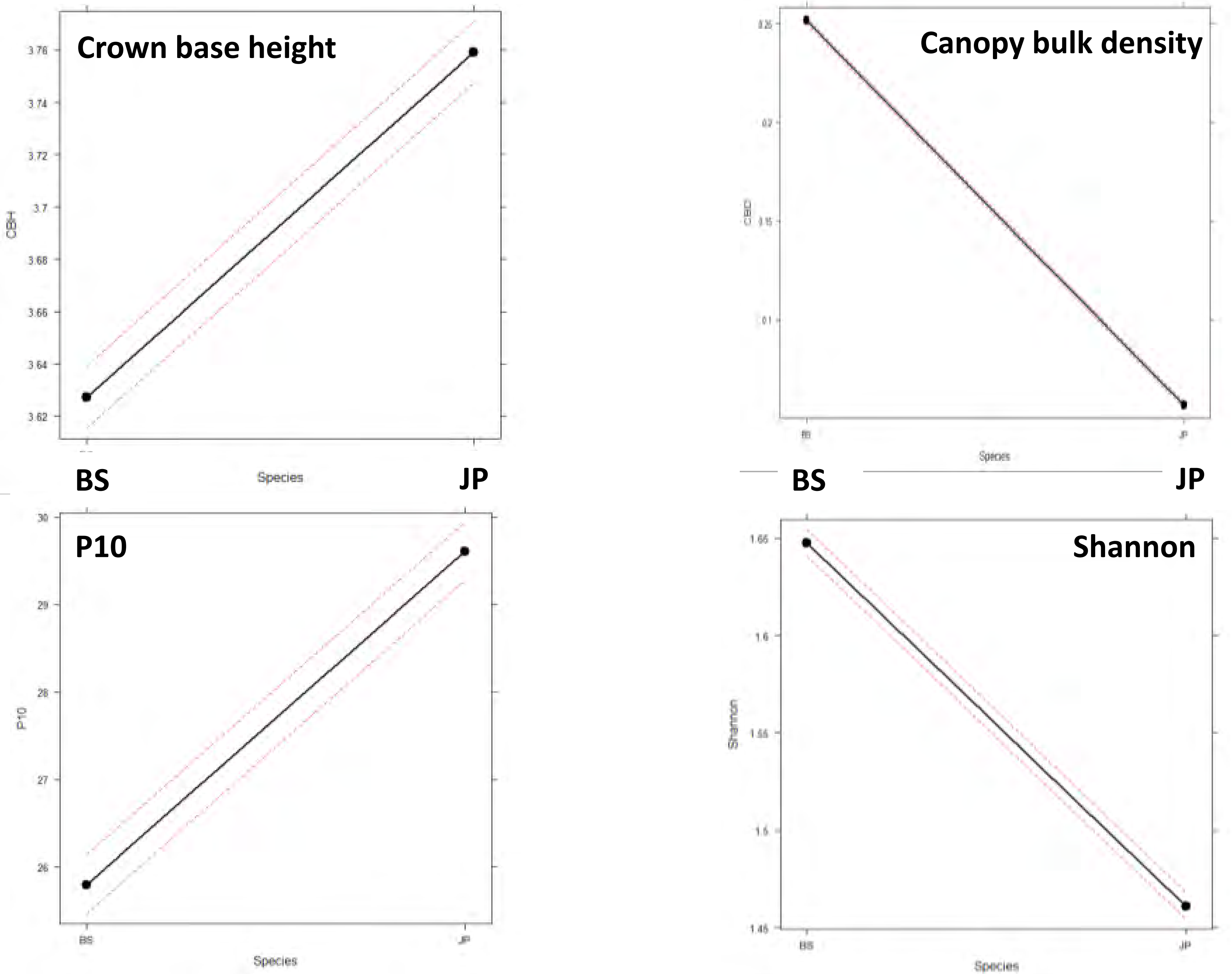
- Evidence of **heterogeneity in severity patterns** at the patch level for the boreal forest of Quebec (low-moderate-high severity).
- **Lower** fire severity in **jack pine** stands compared to black spruce might be due to differences in structure (higher CBH, lower CBD)
- **Lower** fire severity in **A2** region due to longer fire cycles and higher proportion of **uneven** stands (Boucher et al. 2003).

Questions??

METHODOLOGY

Fire model – Modified from Cumming and Wong (2002)




Crown base height
CBH
3.76
3.74
3.72
3.7
3.68
3.66
3.64
3.62
BS
Species
JP
Canopy bulk density
CBD
Species
BS
JP
P10
30
29
28
27
26
BS
JP
Species
Shannon
1.65
1.6
1.55
1.5
1.45
BS
JP
Species