DOES FIRE BEHAVIOR CHANGE WITH STAND AGE IN BLACK SPRUCE FORESTS OF INTERIOR ALASKA?

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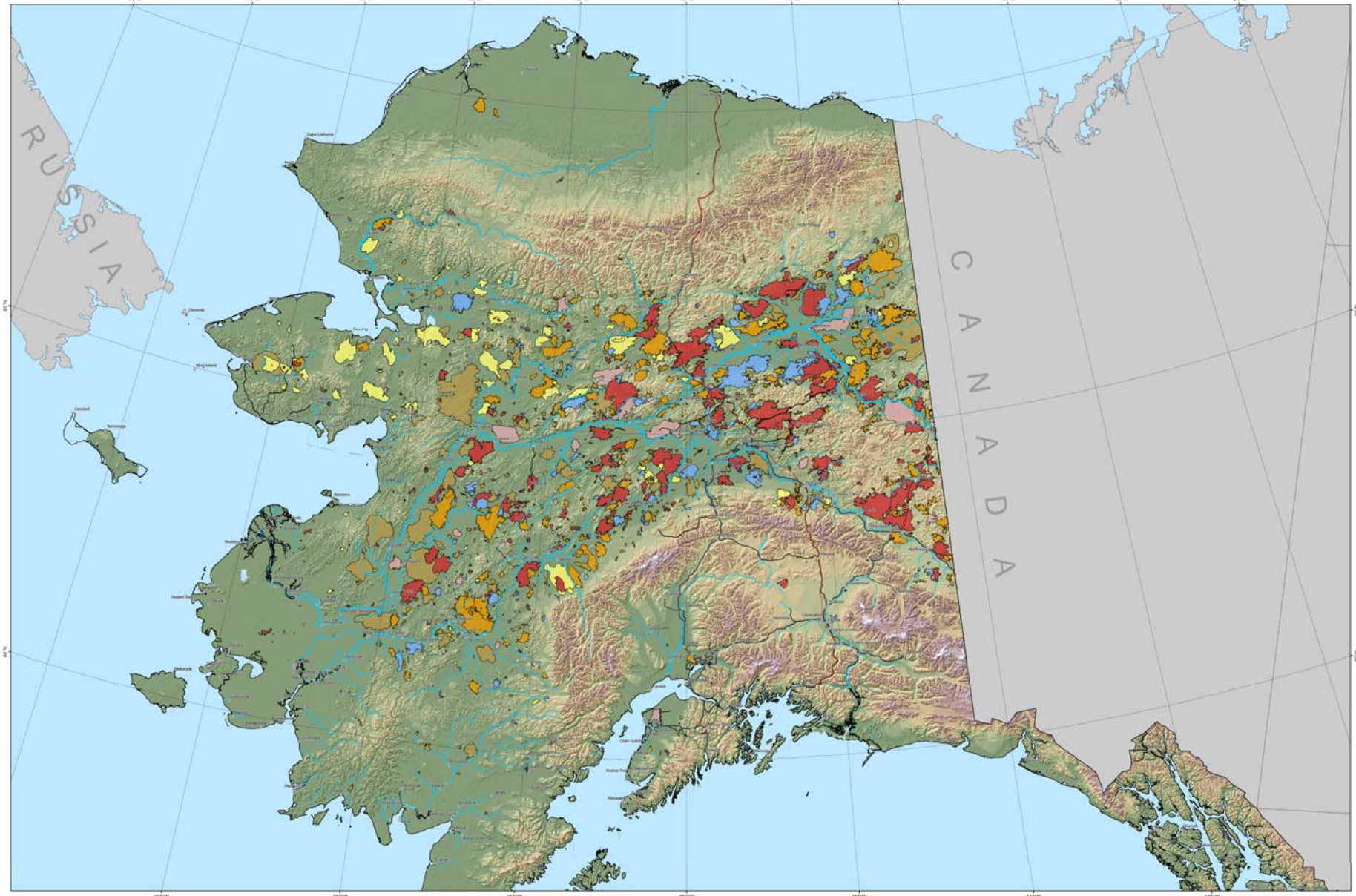
OBJECTIVES

- Build fire event dataset
- Assess standard use of fire behavior prediction programs in Alaska fuel types
- Create a standard fire behavior/effects forms for use by fire management personnel in the field.
- Flammability curve for a successional gradient of the black spruce forest type
- Extend results of flammability curve to predict of fire severity over an age gradient



Legend

- Year Unknown
- 1950 - 1959
- 1960 - 1969
- 1970 - 1979
- 1980 - 1989
- 1990 - 1999
- 2000 - 2004

- Primary Road
- Secondary Road
- Light Duty Road
- Trans-Alaska Pipeline
- Major Alaska Rivers

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Alaska Fire History
1950 - 2004

Miles: 0 50 100 150 200

Kilometers: 0 100 200 300 400

GIS Support Group
Alaska Fire Service

Questions about the information displayed on this map should be directed to :
Bureau of Land Management, Alaska Fire Service
P.O. Box 35005, Ft. Wainwright, AK 99703. Phone (907) 356-5582

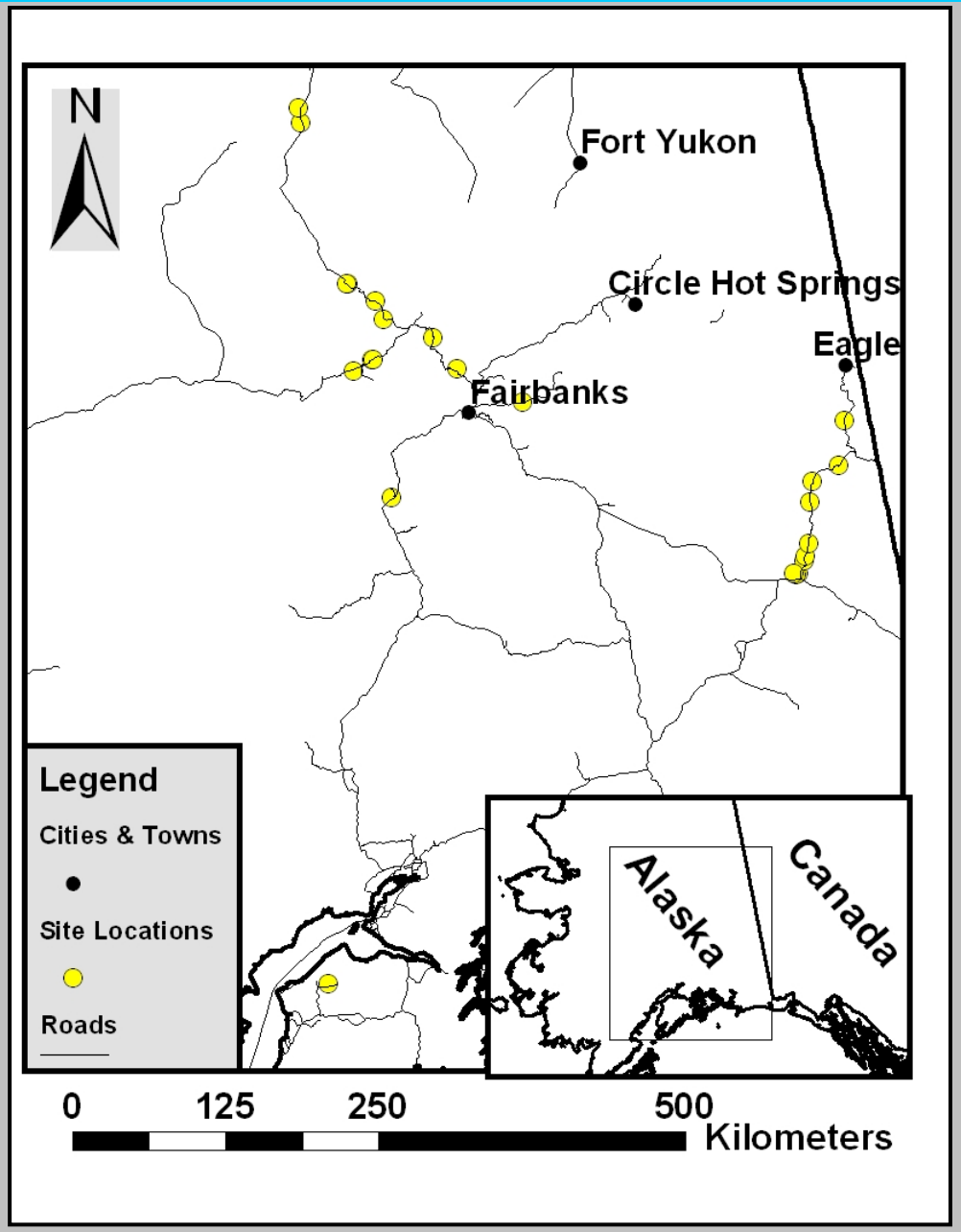
Map Location

BACKGROUND

- Similar Studies
- Fahnestock 1976 - northern Montana
- Agee and Huff, 1987 - Olympic Nat. Park
  - declining fire intensity with age
- Romme, 1982 – Yellowstone Nat. Park
  - increasing fire intensity with age
- Bessie and Johnson, 1995 – Alberta
  - no relationship (stands over 50 years old)
- Schimmel & Granström, 1997 – Sweden
  - increasing fire intensity with age

METHODS

- Study Area
  - Interior Alaska
  - Upland black spruce
  - 24 sites
- Selection Criteria
  - Black spruce is dominant overstory tree
  - Dry
  - Evidence of fire as previous disturbance
  - Slope less than 5°
- Stand Age

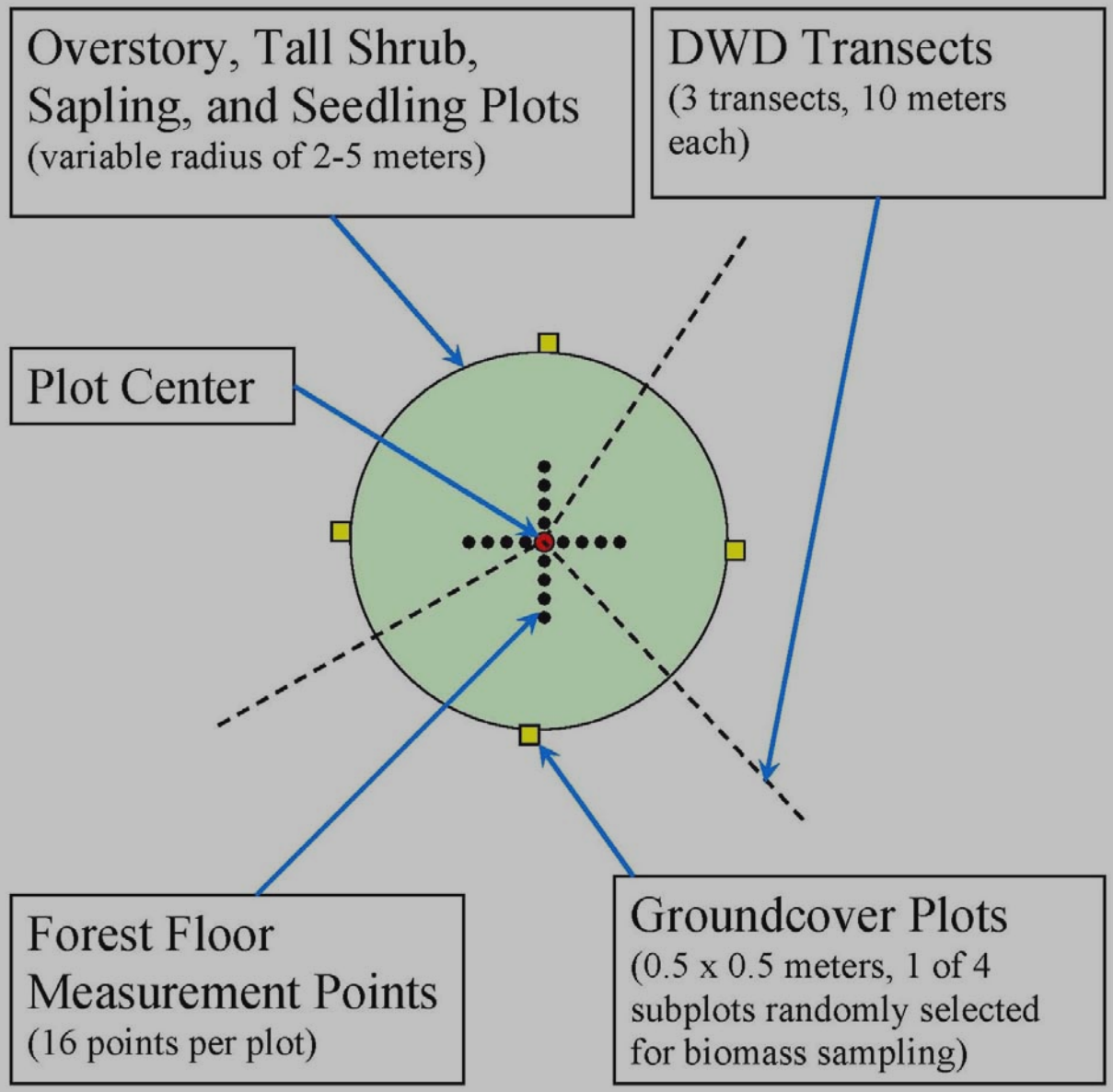


METHODS

- 2004 Fire & Vegetation Plot Design

METHODS

- 2005 Vegetation Plot Design



MODELS

- Rothermel's surface spread model in BehavePlus 3.0

$$R_{surface} = \frac{I_R \xi (1 + \phi_w + \phi_s)}{\rho_b \varepsilon Q_{ig}}$$

I_R = Reaction Intensity (kW/min/m²)

ξ = Propagating flux ratio

ϕ_w = Wind Coefficient

ϕ_s = Slope Factor

ρ_b = Oven-dry Fuelbed Bulk Density (kg/m³)

ε = Effective Heating Number

Q_{ig} = Heat of Preignition (kJ/kg)

$R_{surface}$ Rate of Spread for a Surface Fire (meters/min.)

MODELS

- Inputs for Rothermel's Spread Model
- Extrinsic Fuel Properties
  a. Down and dead fuel loading (tonnes/hectare)
  b. Live Herbaceous Loading (tonnes/hectare)
  c. Live Woody Loading (tonnes/hectare)
  d. Fuel Bed Depth (meters)
  e. Forest Floor Loading
- Intrinsic Fuel Properties
  a. Surface Area to Volume (SAV) Ratio (m^2/m^3)
  b. Moisture of Extinction for Dead Fuels
  c. Heat Content (kJ/kg)

MODELS

- Van Wagner's crown fire initiation equation

$$I'_{Initiation} = \left(\frac{CBH(460 + 25.9FMC)}{100} \right)^{3/2}$$

CBH = Canopy Base Height

FMC = Fuel Moisture Content

$I'_{Initiation}$ = fireline intensity required to initiate a crown fire (kW/meter).

MODELS

- Van Wagner's active crown fire initiation equation

$$R'_{Active} = \frac{3.0}{CBH}$$

CBH = Canopy Base Height

R'_{Active} = Rate of spread required to initiate an active crown fire (m/min).

MODELS

- Cruz; Alexander; Wakimoto, 2005

  Active Crown Fire Rate of Spread Equation

$$CROS_A = I\beta_1 U_{10}^{\beta_2} x CBD^{\beta_3} x e^{(-\beta_4 EFFM)}, U_{10} > 0$$

$CROS_A$ = Active Crown Fire Rate of Spread

β = Constants

U_{10} = 20 foot windspeed (km/hr)

CBD = Crown Bulk Density (kg/m^3)

EFFM = Estimated Fine Fuel Moisture Content

MODELS

- Cruz; Alexander; Wakimoto, 2005

  Passive Crown Fire Rate of Spread Equation

$$CROS_P = CROS_A x e^{(-CAC)}$$

$CROS_P$ = Passive Crown Fire Rate of Spread

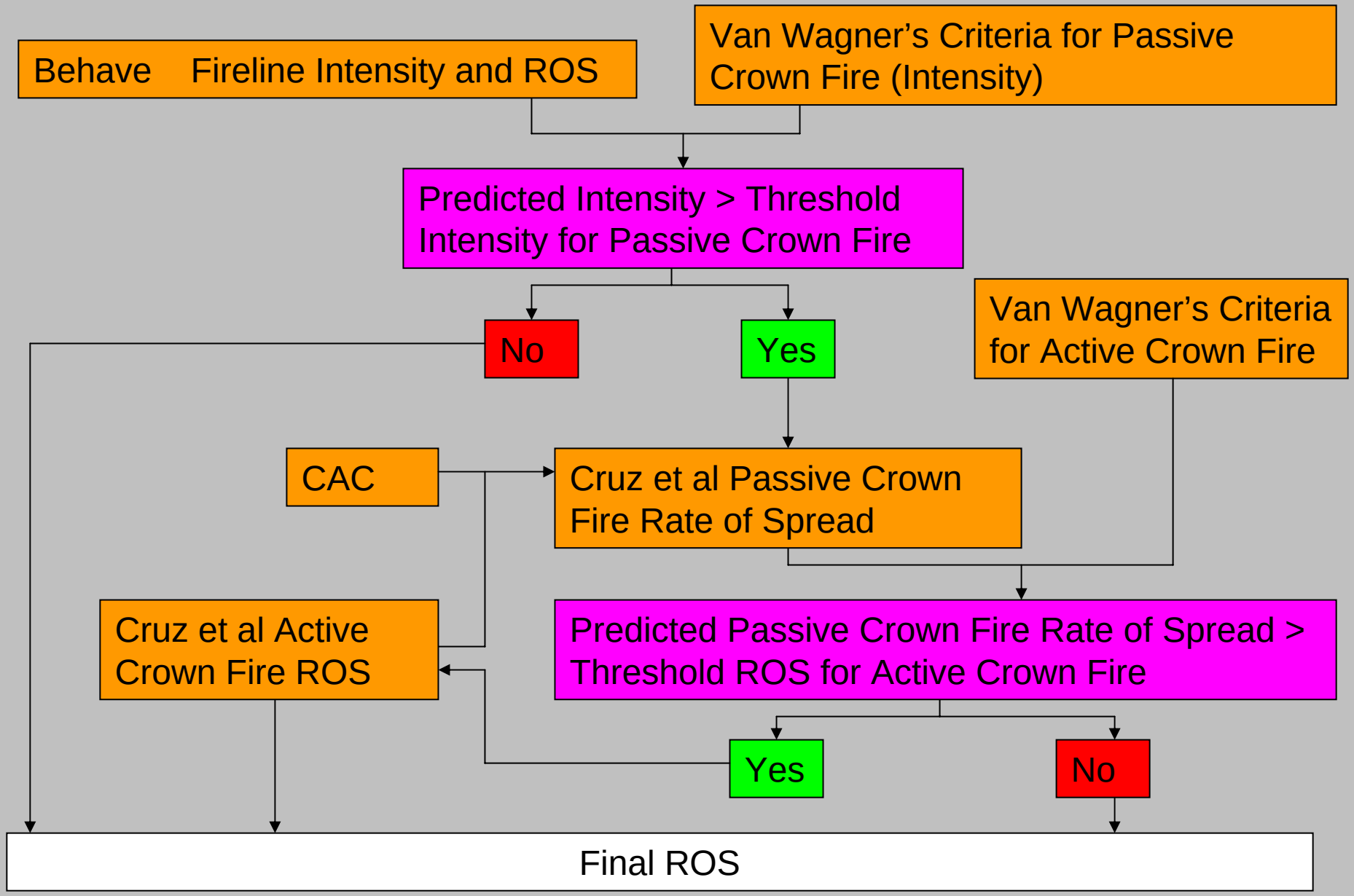
$CROS_A$ = Active Crown Fire Rate of Spread

$CAC = \frac{R_C}{R_O}$ = Criterion for Active Crown Fire

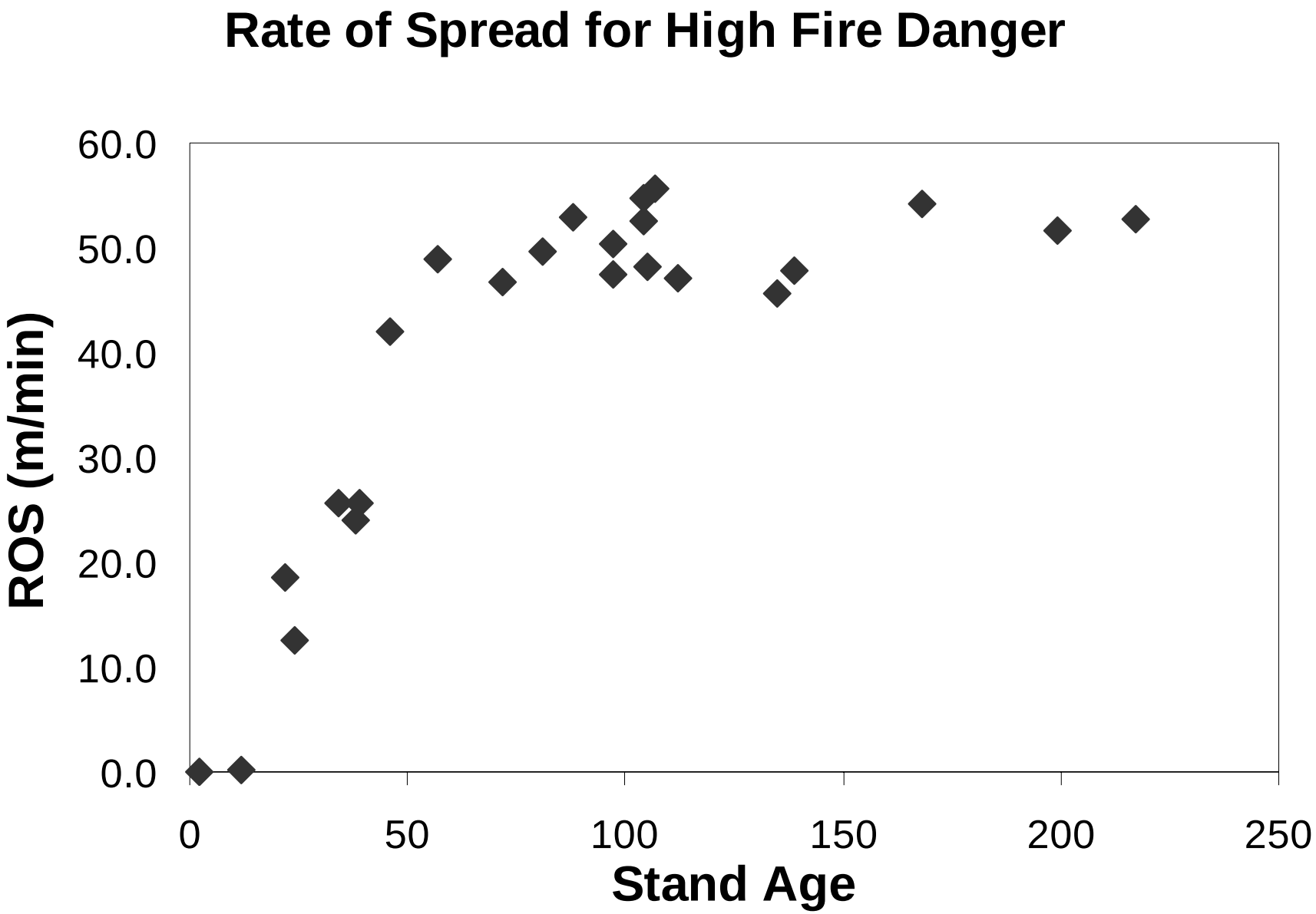
R_C = Observed or Predicted ROS (m/min)

R_O = R'_{Active}

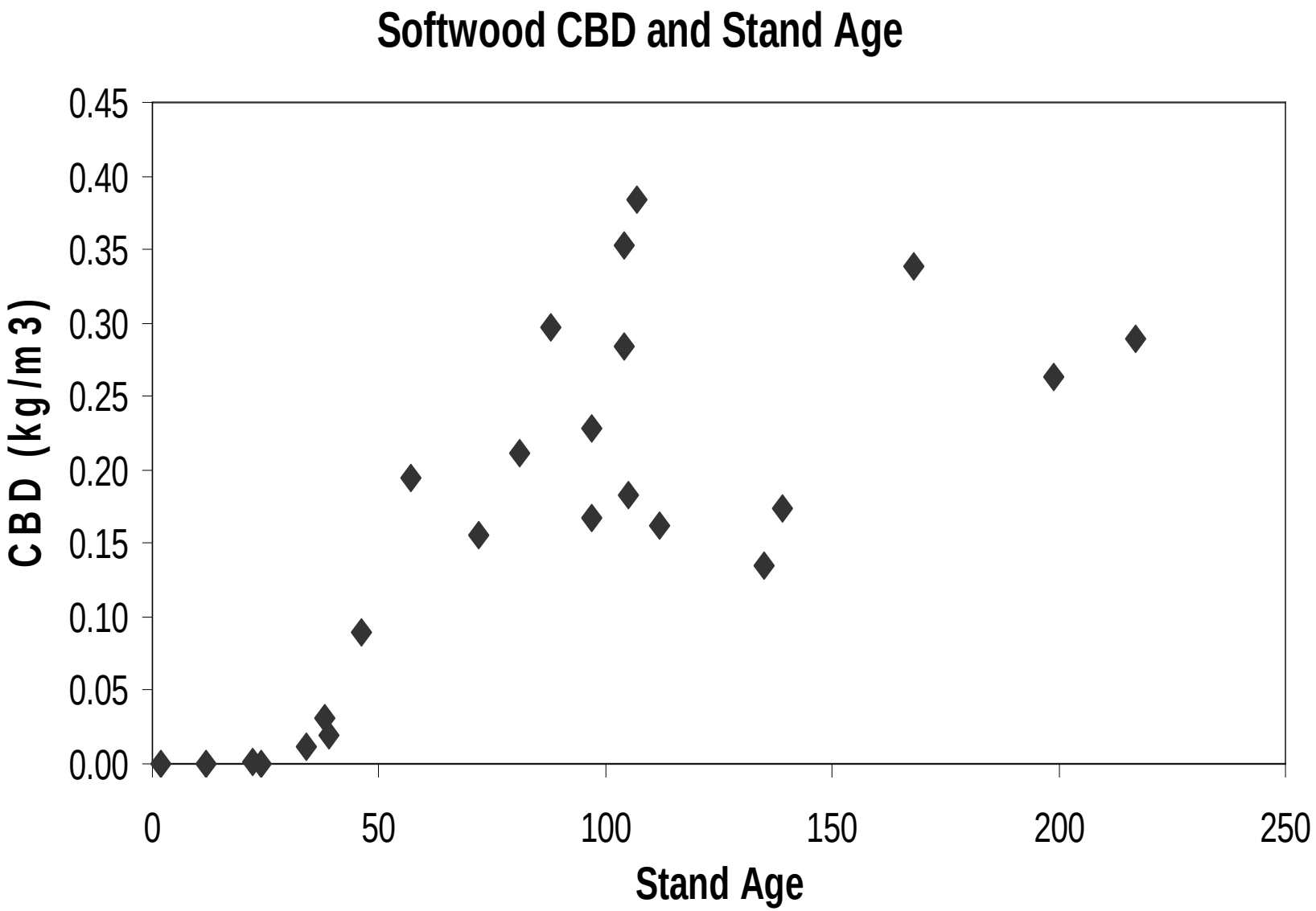
MODELS


Behave Fireline Intensity and ROS
Van Wagner's Criteria for Passive Crown Fire (Intensity)
Predicted Intensity > Threshold Intensity for Passive Crown Fire
No
Yes
Van Wagner's Criteria for Active Crown Fire
CAC
Cruz et al Passive Crown Fire Rate of Spread
Cruz et al Active Crown Fire ROS
Predicted Passive Crown Fire Rate of Spread > Threshold ROS for Active Crown Fire
Yes
No
Final ROS

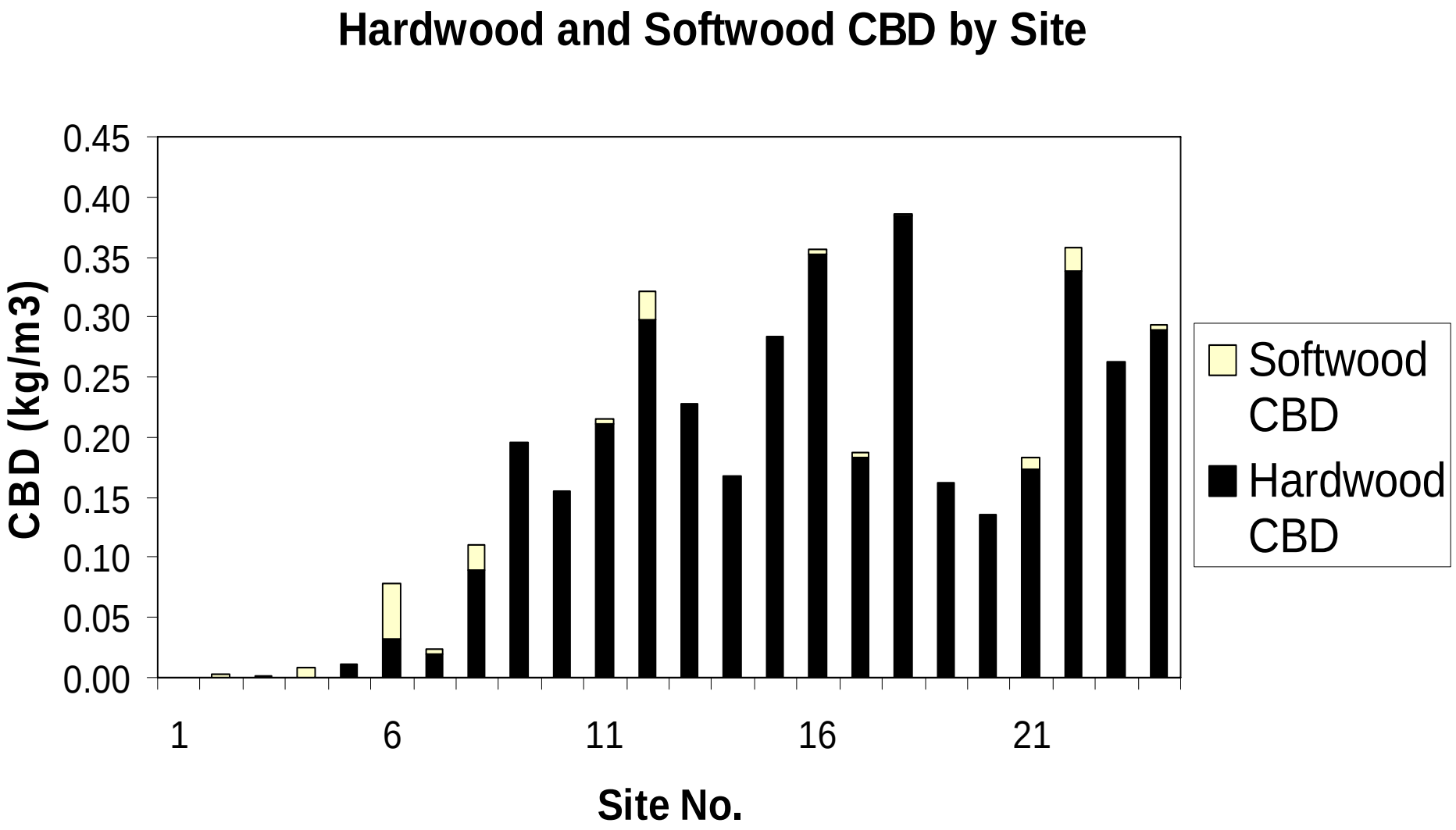
RESULTS


Rate of Spread for High Fire Danger
ROS (m/min)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
50
100
150
200
250
Stand Age

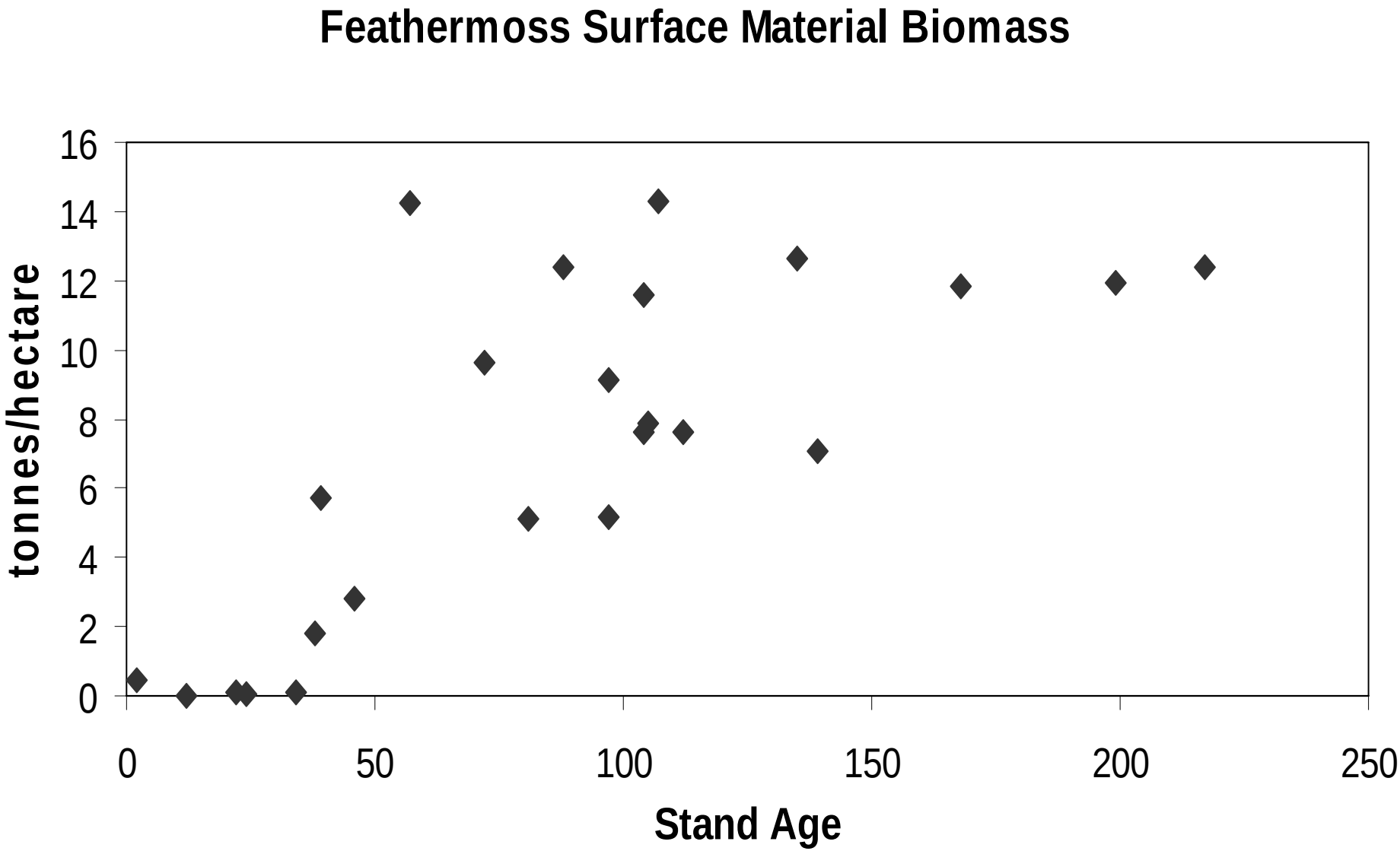
RESULTS


Softwood CBD and Stand Age
CBD (kg/m3)
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
50
100
150
200
250
Stand Age

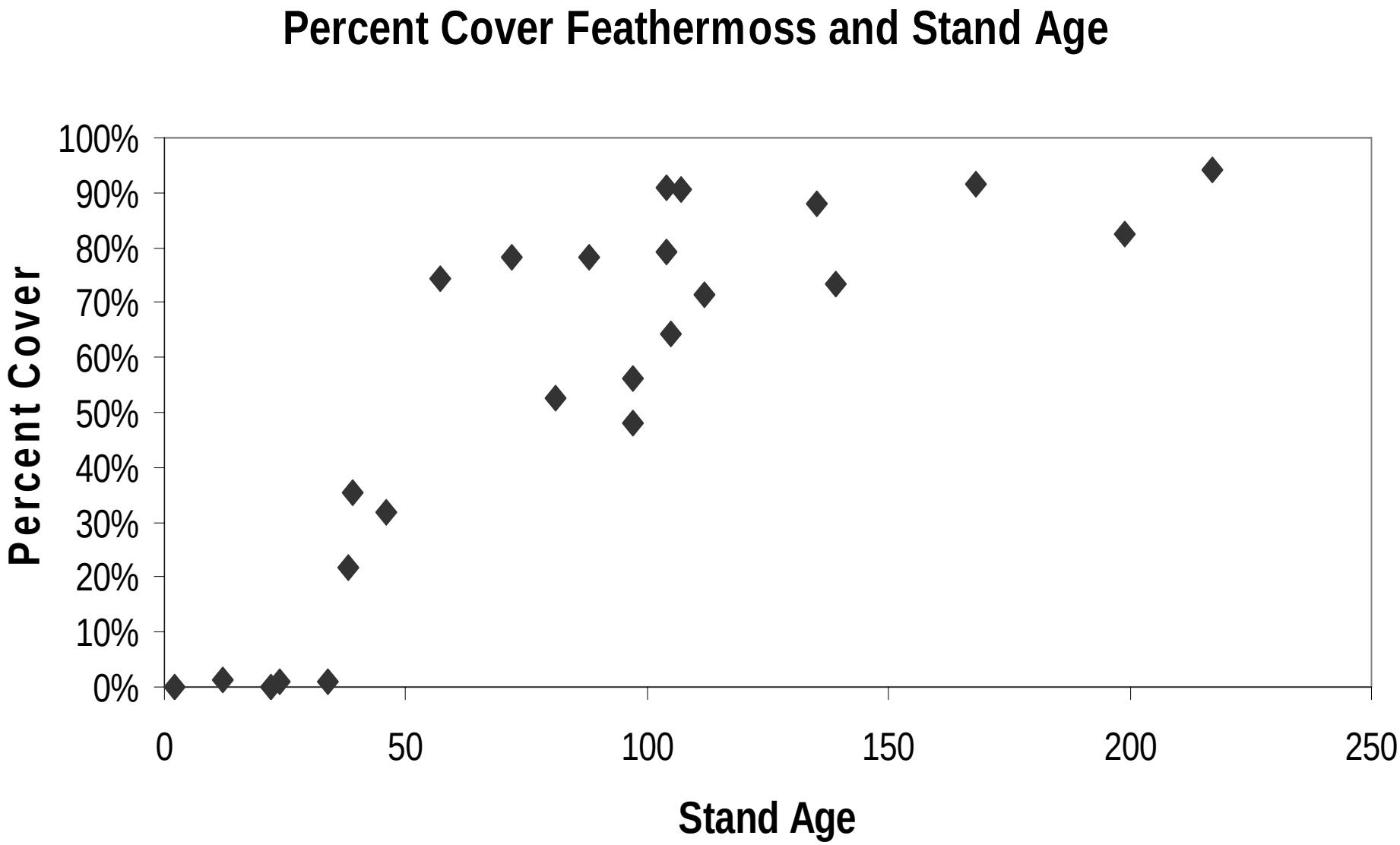
RESULTS


Hardwood and Softwood CBD by Site
CBD (kg/m3)
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1
6
11
16
21
Site No.
Softwood CBD
Hardwood CBD

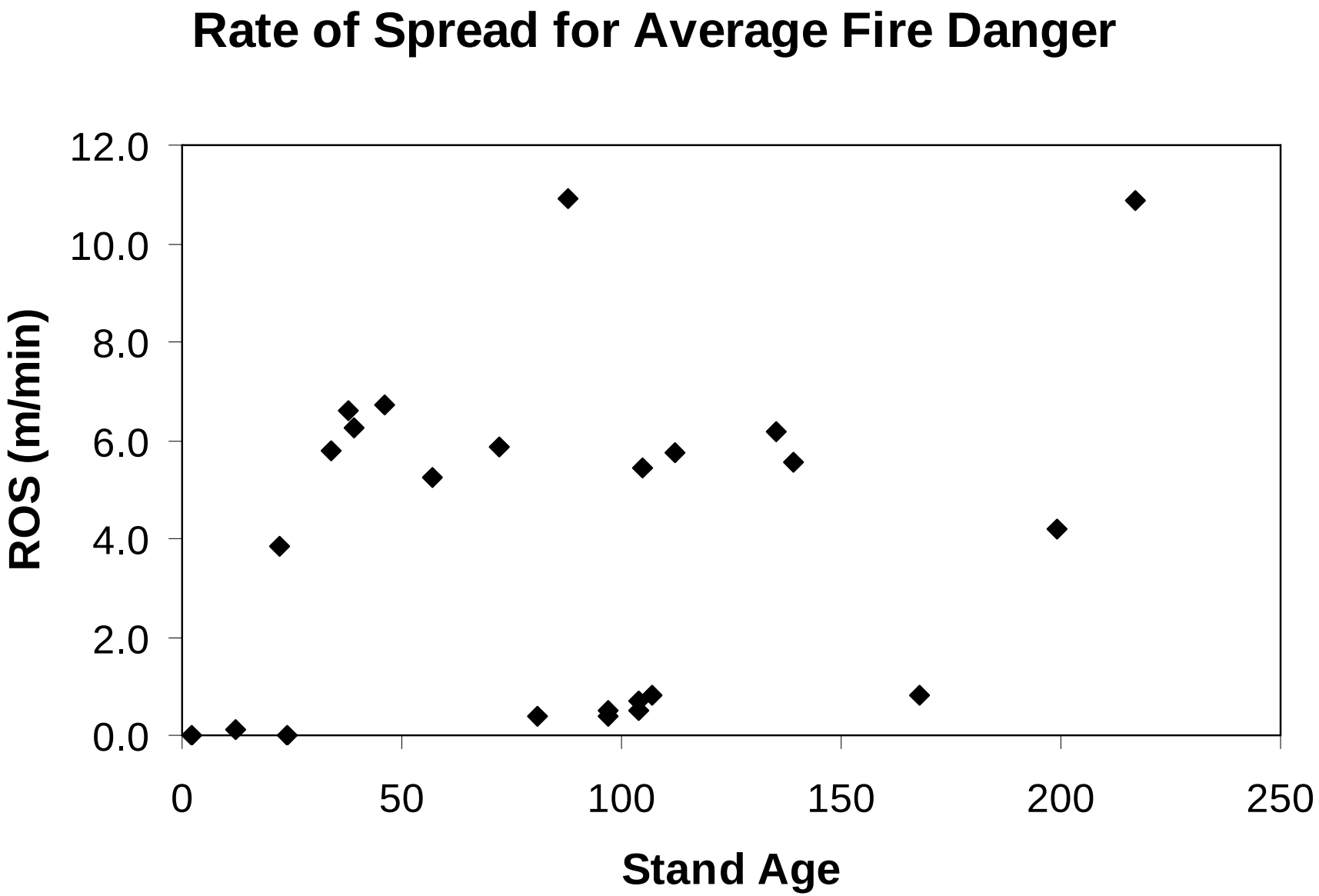
RESULTS


Feathermoss Surface Material Biomass
tonnes/hectare
16
14
12
10
8
6
4
2
0
0
50
100
150
200
250
Stand Age

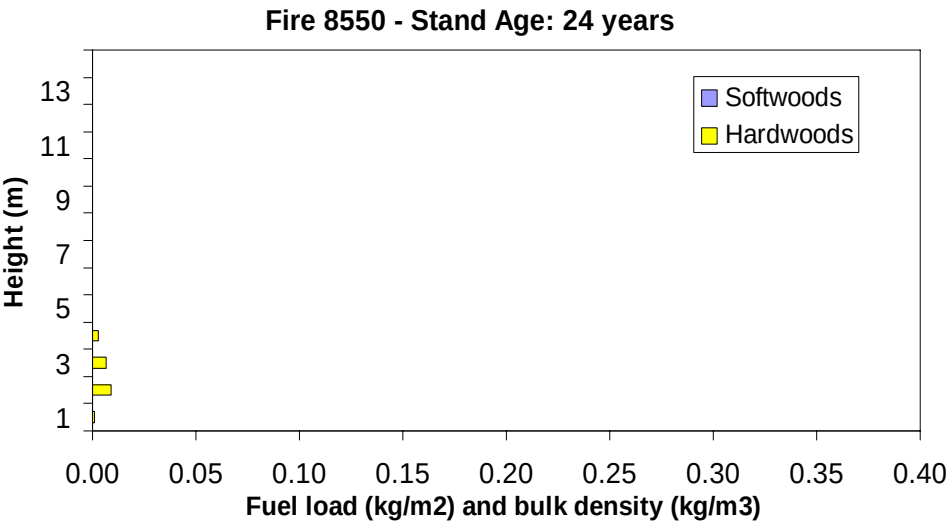
RESULTS

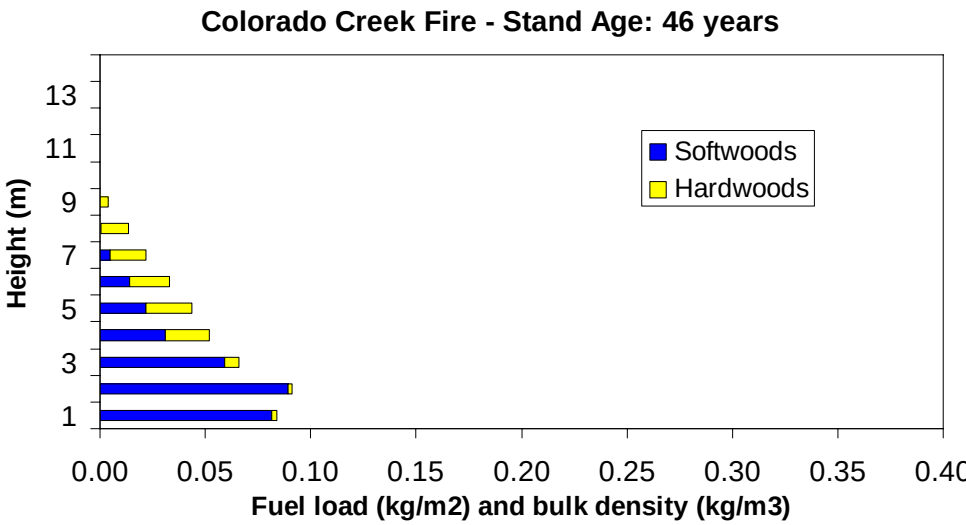

Percent Cover Feathermoss and Stand Age
Percent Cover
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
50
100
150
200
250
Stand Age

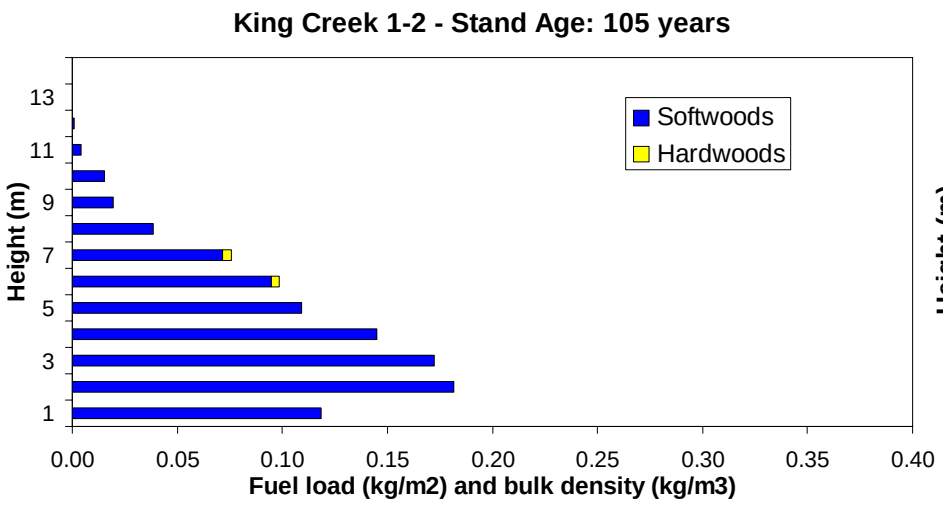
RESULTS

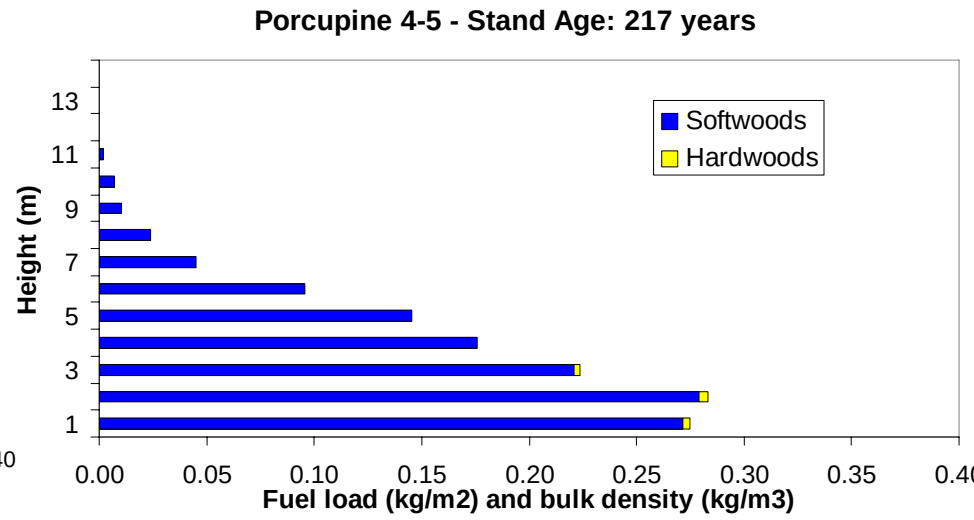

Rate of Spread for Average Fire Danger
ROS (m/min)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
50
100
150
200
250
Stand Age

RESULTS

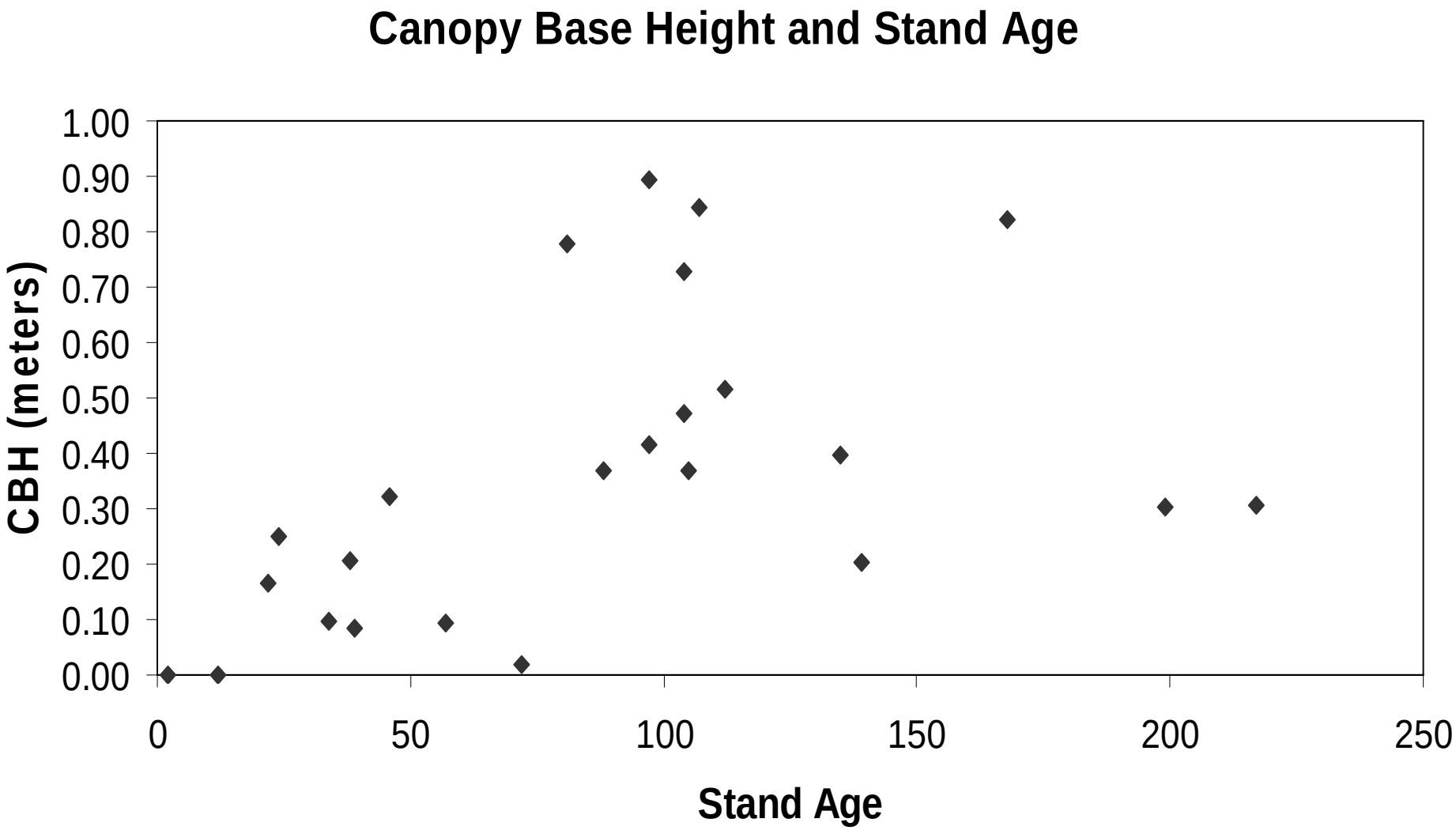

Fire 8550 - Stand Age: 24 years
Softwoods
Hardwoods
Height (m)
13
11
9
7
5
3
1
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Fuel load (kg/m2) and bulk density (kg/m3)


Colorado Creek Fire - Stand Age: 46 years
Softwoods
Hardwoods
Height (m)
13
11
9
7
5
3
1
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Fuel load (kg/m2) and bulk density (kg/m3)

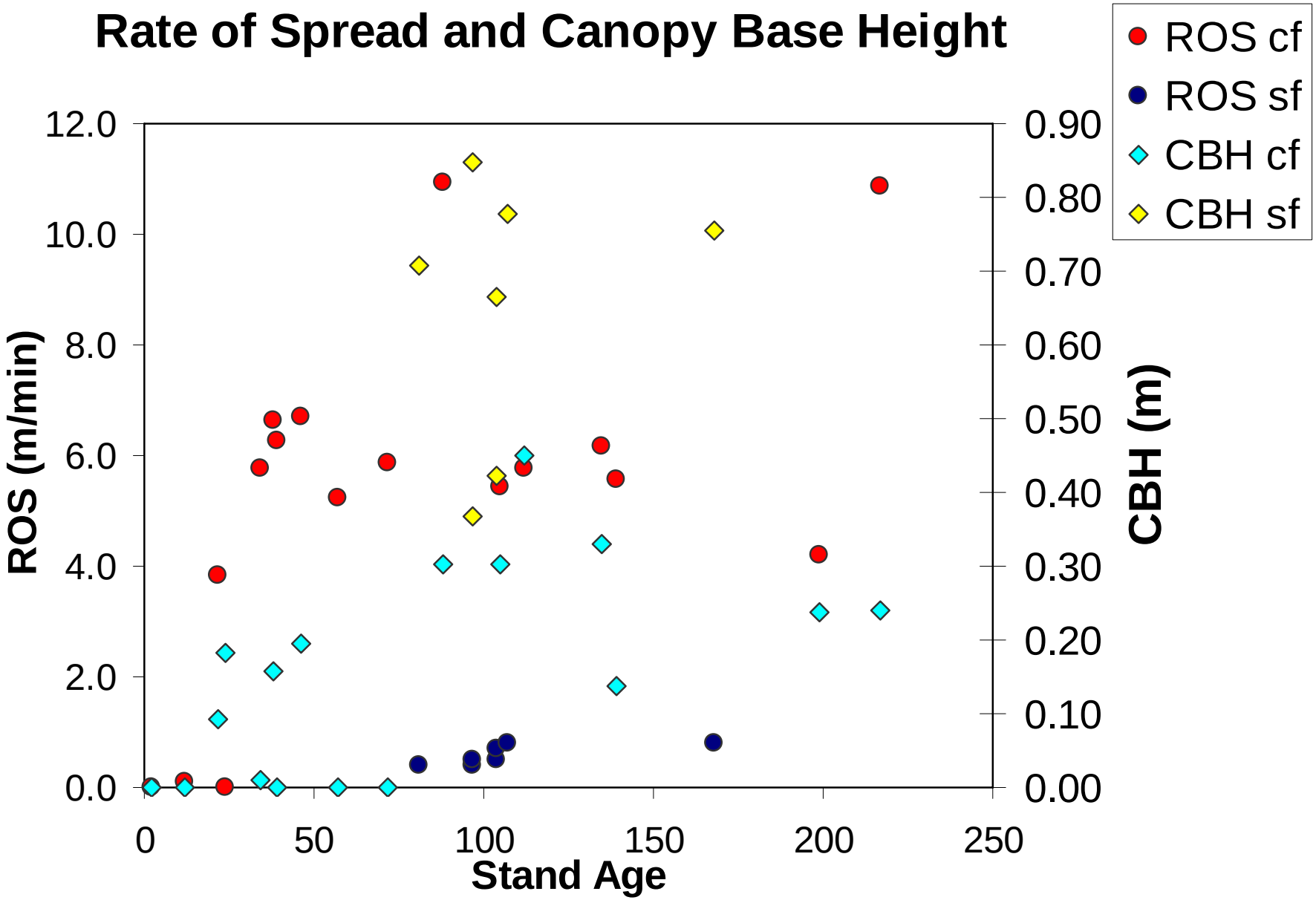

King Creek 1-2 - Stand Age: 105 years
Softwoods
Hardwoods
Height (m)
13
11
9
7
5
3
1
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Fuel load (kg/m2) and bulk density (kg/m3)


Porcupine 4-5 - Stand Age: 217 years
Softwoods
Hardwoods
Height (m)
13
11
9
7
5
3
1
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Fuel load (kg/m2) and bulk density (kg/m3)

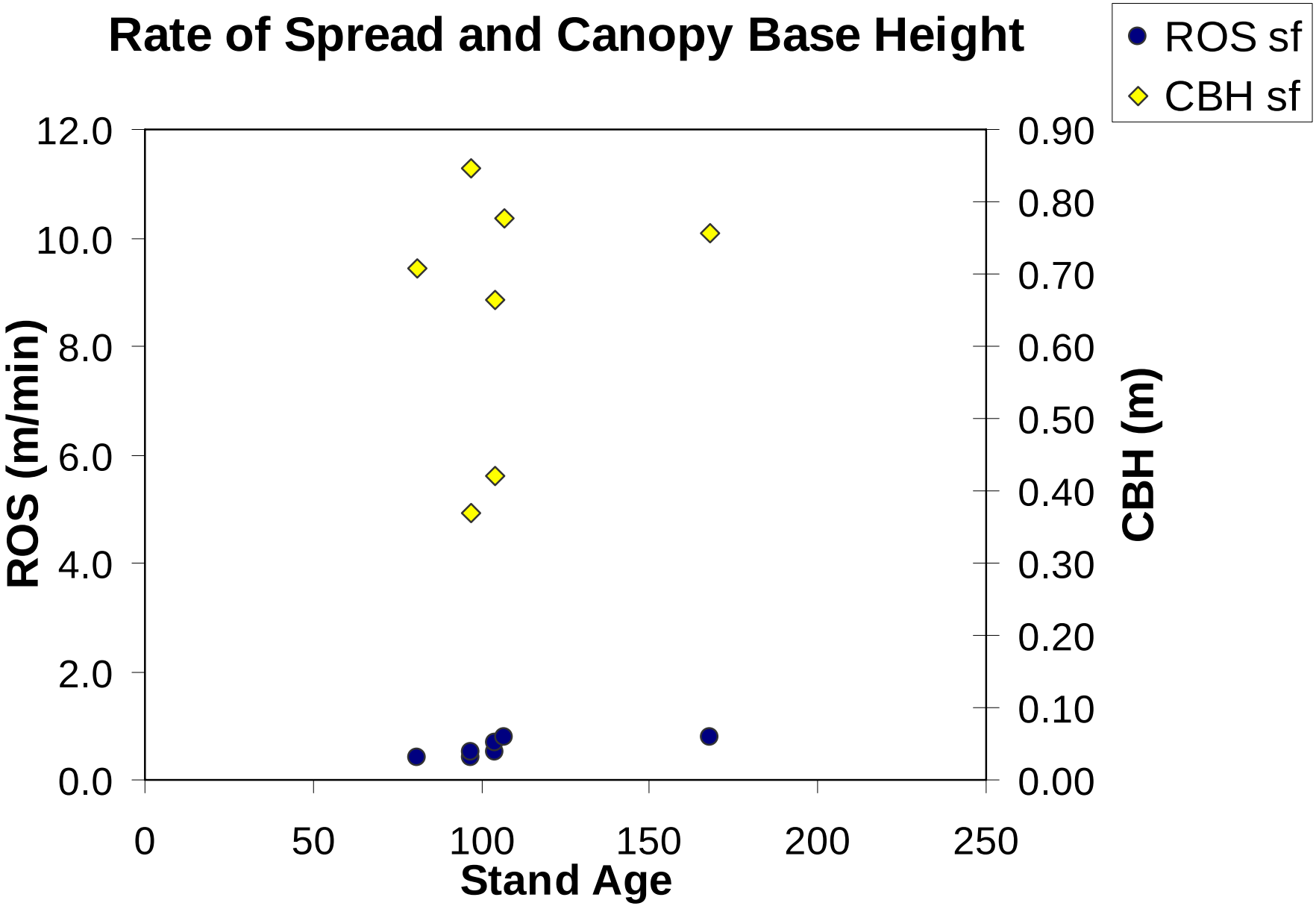
RESULTS


Canopy Base Height and Stand Age
CBH (meters)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
50
100
150
200
250
Stand Age

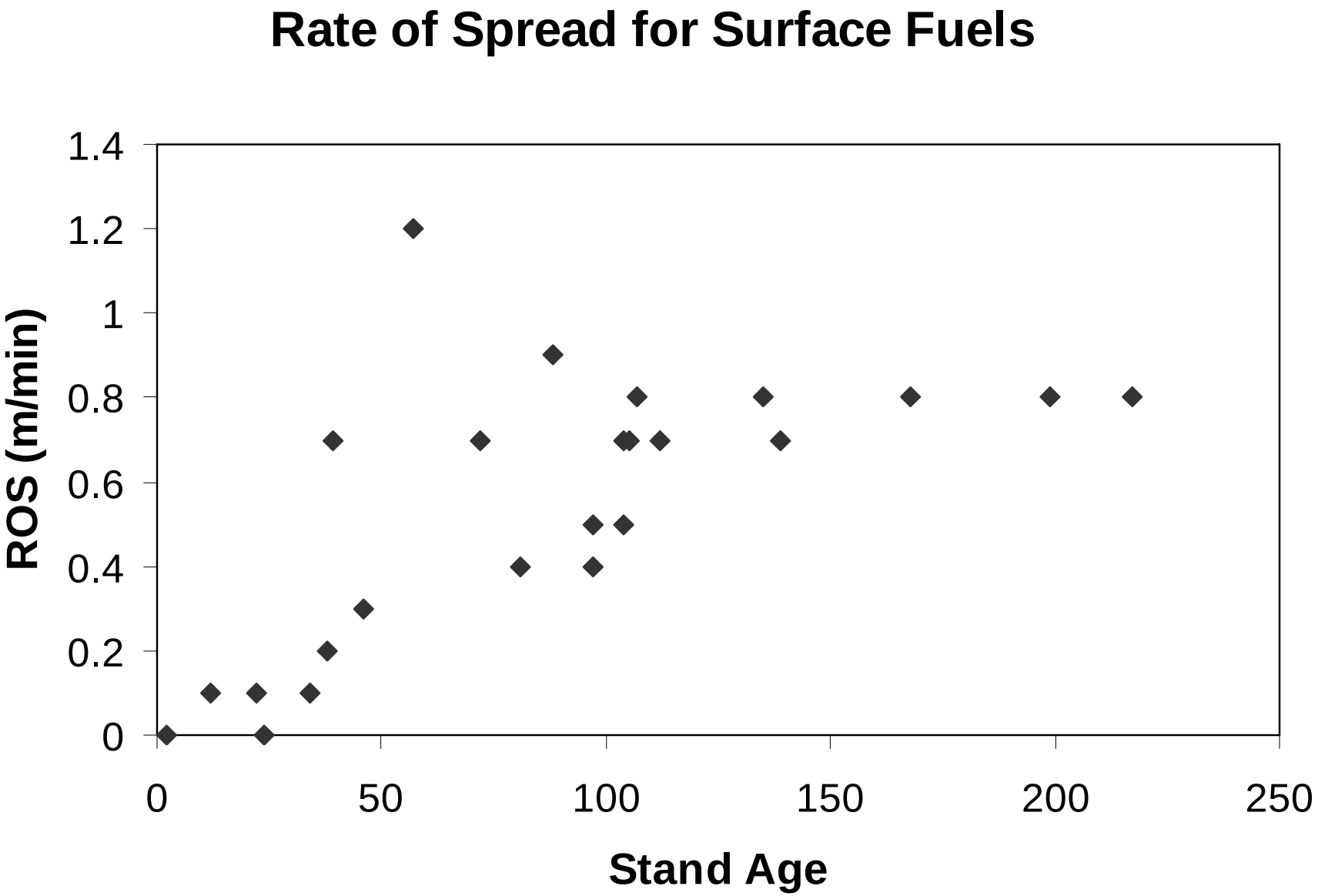
RESULTS


Rate of Spread and Canopy Base Height
ROS cf
ROS sf
CBH cf
CBH sf
ROS (m/min)
CBH (m)
Stand Age
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
50
100
150
200
250

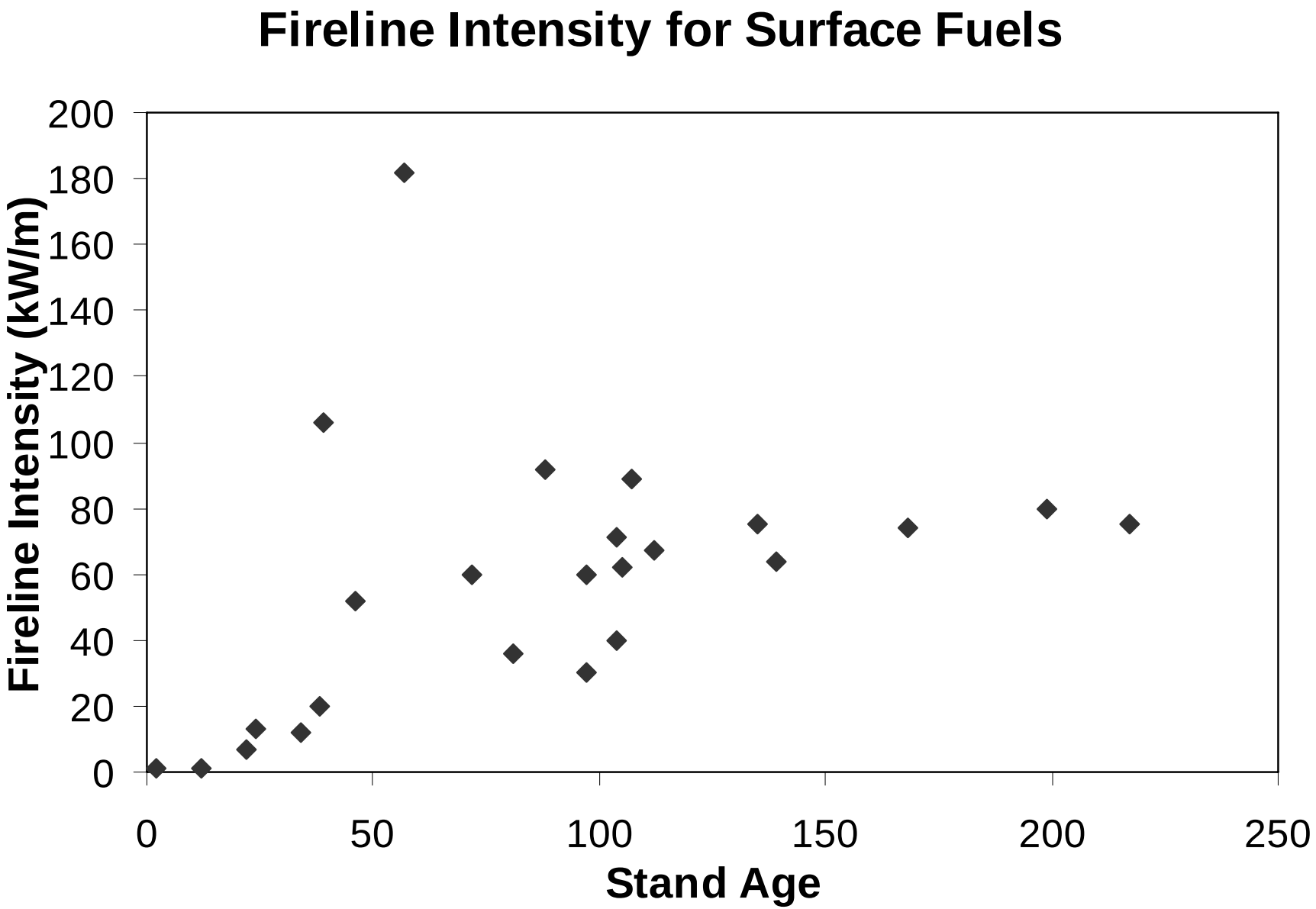
RESULTS


Rate of Spread and Canopy Base Height
ROS sf
CBH sf
ROS (m/min)
CBH (m)
Stand Age
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
50
100
150
200
250

RESULTS


Rate of Spread for Surface Fuels
ROS (m/min)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250
Stand Age

RESULTS


Fireline Intensity for Surface Fuels
Fireline Intensity (kW/m)
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
250
Stand Age

CONCLUSIONS

- Fire behavior seems to become more active in stands approximately 40 years old.

Joan Foote’s dense tree: 30 and 55 years.

- Fire behavior curve levels of in stands approximately 100 years old.

Foote’s mature spruce stage: 90+ years.

- Canopy bulk density, canopy base height, feathermoss biomass and feathermoss percent cover are important determinants of fire behavior in black spruce.
- Fuel bed depth is important but poorly modeled.

PENDING ANALYSIS

- Anova and Manova tests to determine significance of trends of and among fuel components.
- Comparing predicted with observed ROS.
- Cluster analysis top determine age brackets based on fuel properties.
- CART Analysis based on Foote’s seral catergories to determine if importance of different fuel components.

DATA CONCERNS

- Sapling and large shrubs are not factored into fuels analysis.
- BehavePlus is not able to model influence of ground fuels (i.e. duff) on fire behavior.
- Pioneer mosses are not included in fire behavior predictions.