2017-2018 Webinar Series

February 15, 2018

Quantification of understory fuels in Superior National Forest using LiDAR Data

Jeff Irwin

USGS Earth Resources Observation and Science Center

Audio will start at 2 PM Eastern / 1 PM Central

This webinar is listen only – to ask questions please use the chat box in lower right of screen

USGS
science for a changing world

Quantification of Understory Fuels in the Superior National Forest using Lidar Data

Jeffrey Irwin
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Geographer

Kurtis Nelson
Physical Scientist

United States Geological Survey
Earth Resources Observation and Science Center (USGS EROS)

The True Lessons Learned

IF YOU DO NOT LIKE:

- **Getting Rained on Everyday**
- **Or**
- **Having your Tent Blow Away**
- **Or**
- **Being Eaten Alive by Mosquitos**

Then Fieldwork in Northern Minnesota during July is Just Not for You!

Source: https://storytellerscampfire.wordpress.com/tag/alaska/

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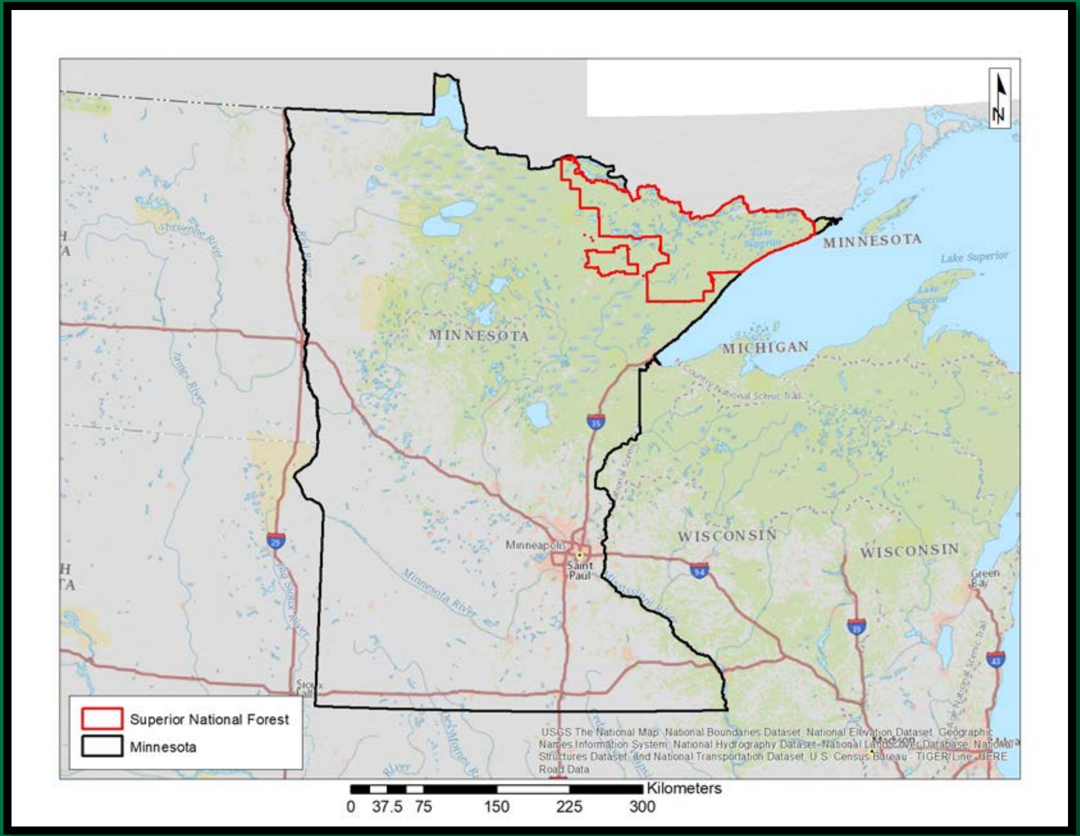
Superior National Forest



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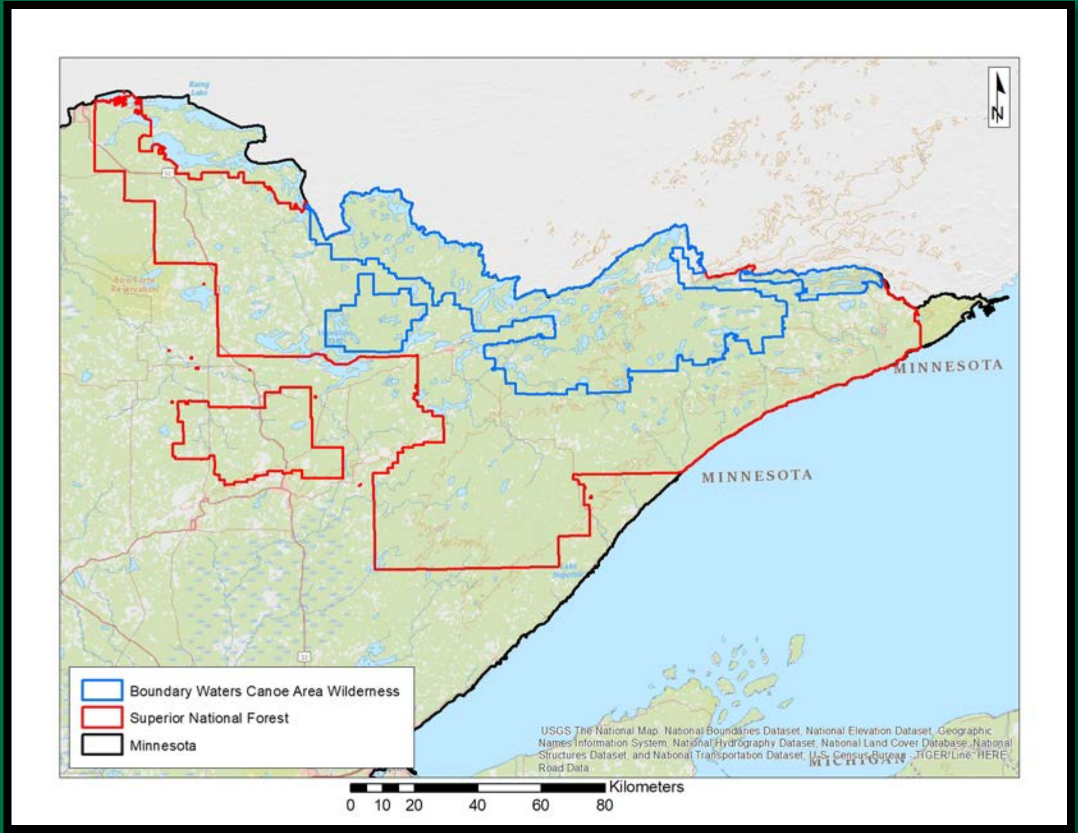
Superior National Forest



Introduction
The Problem

Great Lakes Region Ecosystems are Changing

- **Historically Fire Return Intervals were less than 100 years**

***Primary Causes For Change Include*:**

- **Logging Practices**
- **Fire Suppression**

Has Lead to an Increase in Shade Tolerant Species

- **Balsam Fir (*Abies balsamea*)**

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The Problem
Balsam Fir

Balsam Fir

- Flamable
  - Resinous Bark
  - Easily Ignited Needles
- Susceptible to Spruce Budworm Infestation
  - Needle Cast – Leads to More Fuel Loading
- Continuous Ladder Fuel

Photo by Nancy Wenner
Source: https://www.na.fs.fed.us/spfo/pubs/howtos/ht_bfir/ht_bfir.htm

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The Problem
Balsam Fir

Spatial Extent and Magnitude are Unknown

- **Large Amount of Remote Area**
  - **Requires large amounts of time for field crews to measure**
- **Difficulty of Mapping Under and Mid-Story Vegetation Remotely**
  - **The overstory canopy obscures the lower vegetation components**

Source: https://www.weather.gov/dlh/Ham_Lake_Fire_of_2007

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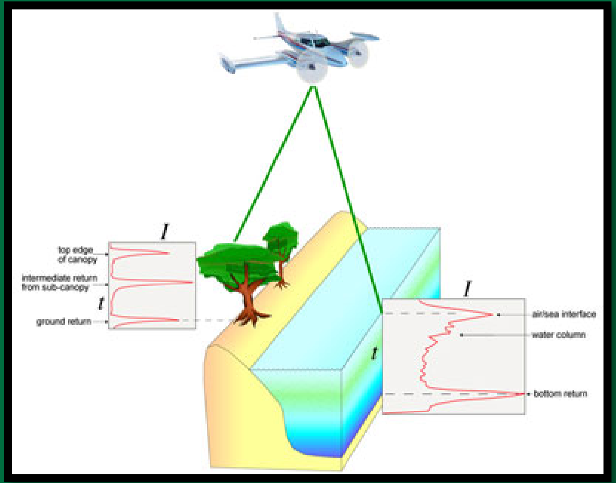
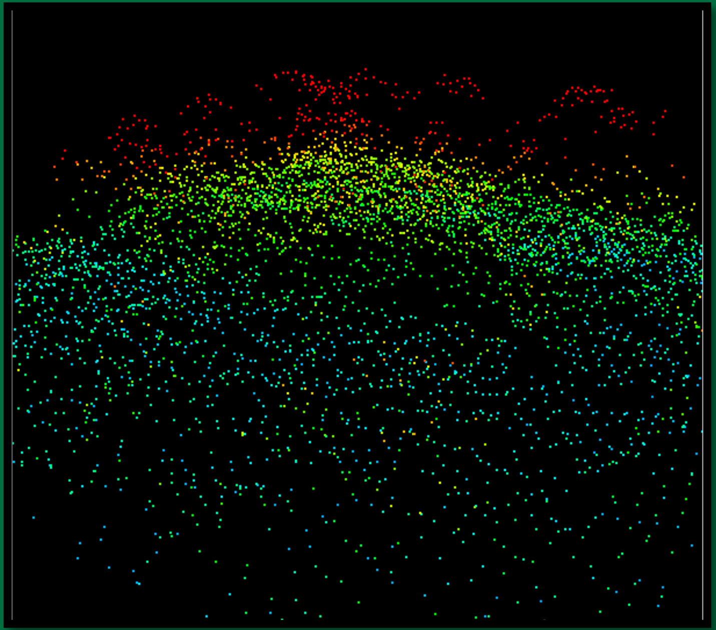
Proposed Solution:
To Map the Understory Fuels using Lidar

Airborne Lidar Data are Commonly Used to Map Vegetation Characteristics

- **Canopy Height**
- **Canopy Cover**



Source: https://soundwaves.usgs.gov/2010/02/meetings5.html



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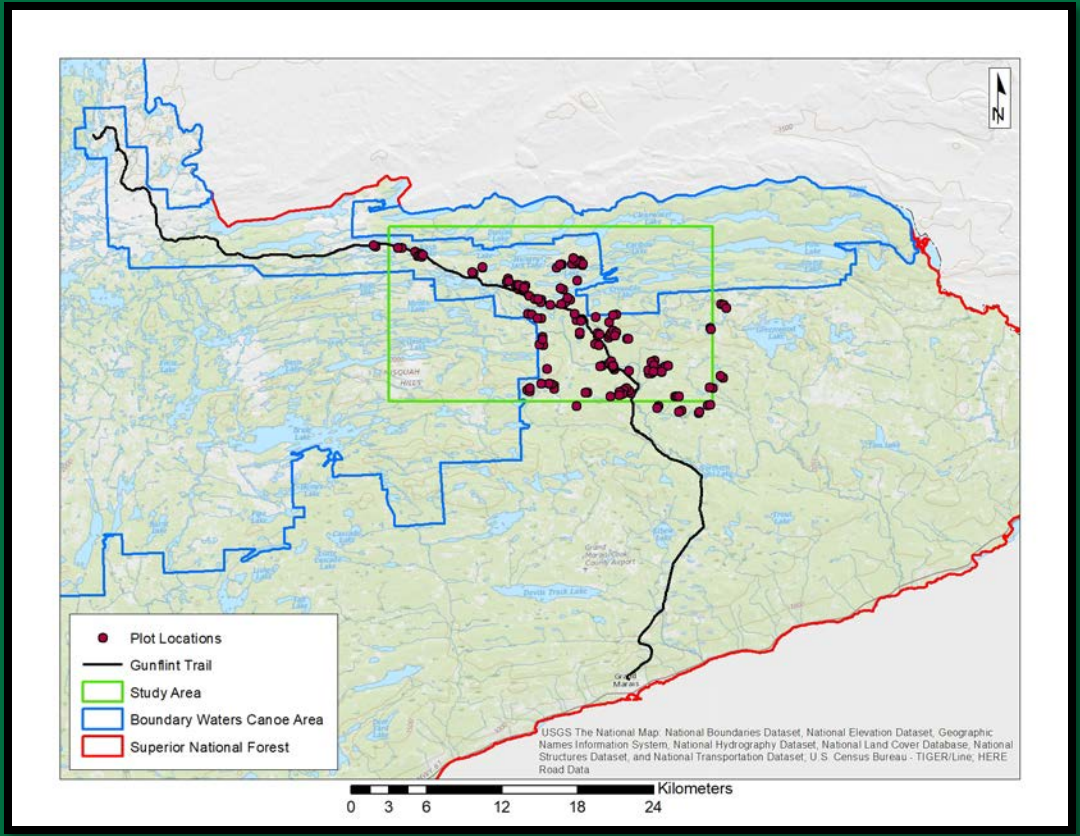
Data Collection

Field Work



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Data Collection
Field Work

<u>Cover Line Intercept (CLI) Method</u>

- **Establish a Plot Center**
- **Measure one to four 66’ (20 m) transects in each of the cardinal directions in order of North, East, South, West**
- **Working from the plot center out, each tree canopy that intersects the transect is measured**

Figure LI-1—The measuring tape is stretched taught below, in, or above the canopy vegetation, whichever position allows the easiest estimation of cover without the tape zigzagging around plants.

USDA Forest Service Gen. Tech. Rep. RMRS-GTR-164-CD. 2006

Data Collection

Field Work

Cover Line Intercept (CLI) Method

- **The maximum height of the tree, over the transect, is recorded**
- **Species and size class of the tree are recorded**
- **Multiple trees of the same species that have canopies that are continuous over the transect are counted as one intercept, with the size class of the largest tree being recorded**

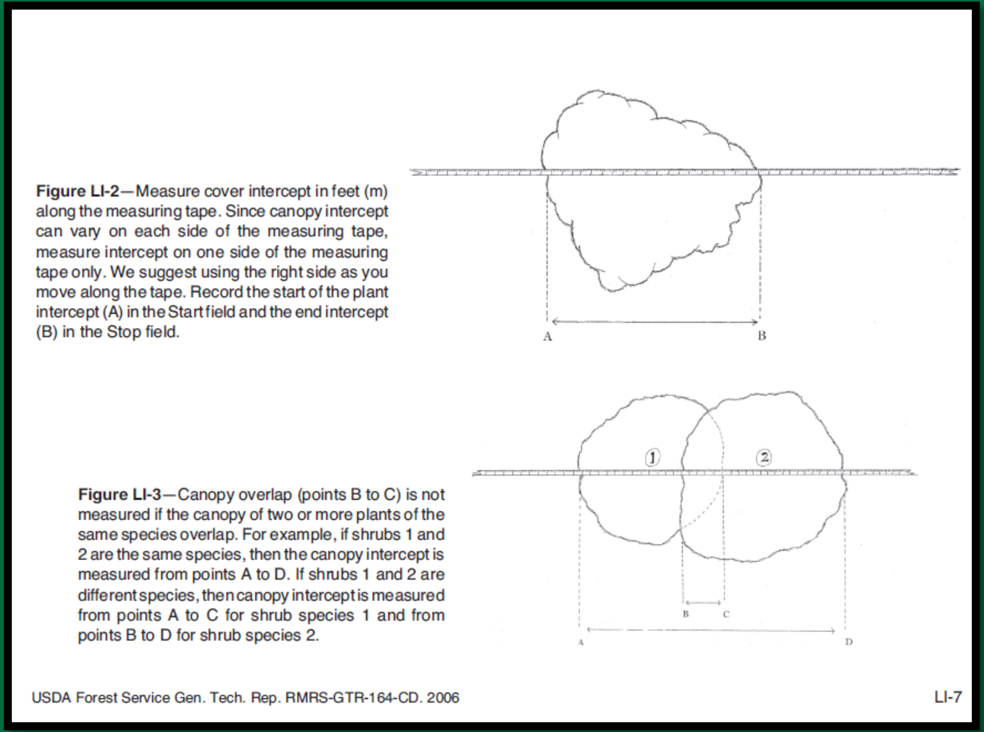

Figure LI-2—Measure cover intercept in feet (m) along the measuring tape. Since canopy intercept can vary on each side of the measuring tape, measure intercept on one side of the measuring tape only. We suggest using the right side as you move along the tape. Record the start of the plant intercept (A) in the Start field and the end intercept (B) in the Stop field.

Figure LI-3—Canopy overlap (points B to C) is not measured if the canopy of two or more plants of the same species overlap. For example, if shrubs 1 and 2 are the same species, then the canopy intercept is measured from points A to D. If shrubs 1 and 2 are different species, then canopy intercept is measured from points A to C for shrub species 1 and from points B to D for shrub species 2.

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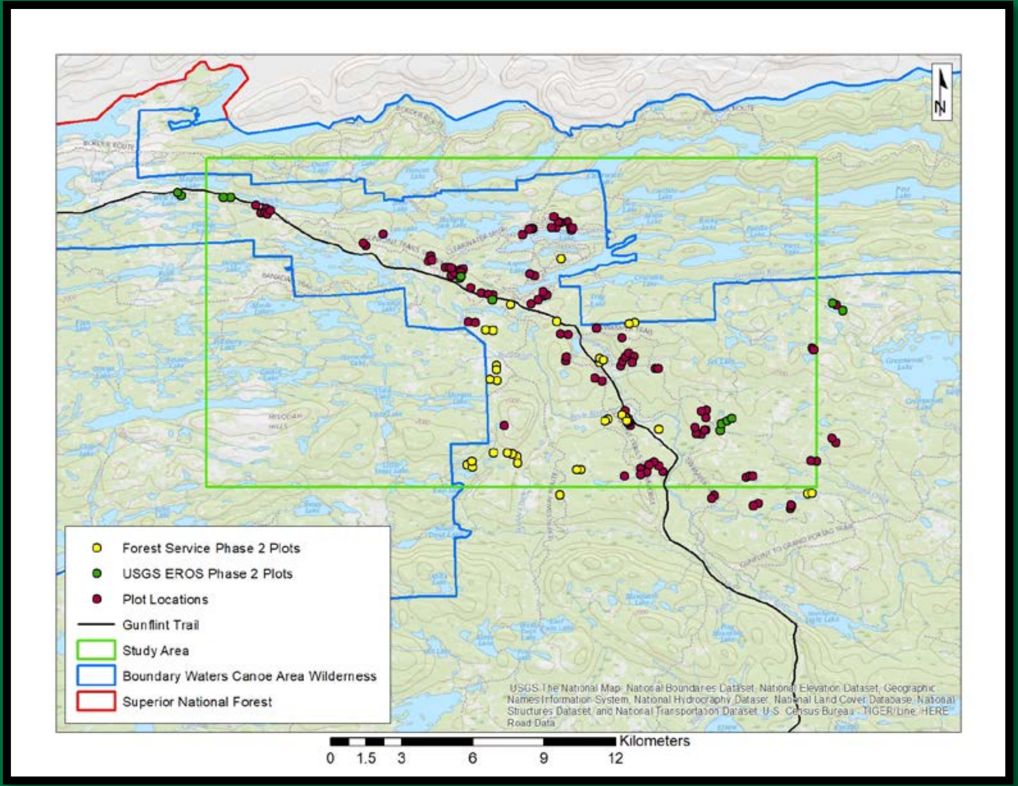
Data Collection
Field Work

Cover Line Intercept (CLI) Method

- **Phase 1 - Trees 12.5 cm DBH and Larger (Overstory)**
- **Phase 2 - Trees less than 12.5 cm DBH (Understory)**
- **US Forest Service**
  - **Phase 1 – 130 Plots**
  - **Phase 2 – 33 Plots**
- **USGS EROS**
  - **Phase 2 – 13 Plots**
  - **Densiometer and Photographs – 20 Plots**



Data Collection

Field Work

Photo taken by
Kurtis Nelson

USGS

Data Collection

Field Work

Photo taken by
Kurtis Nelson

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Data Collection

Field Work

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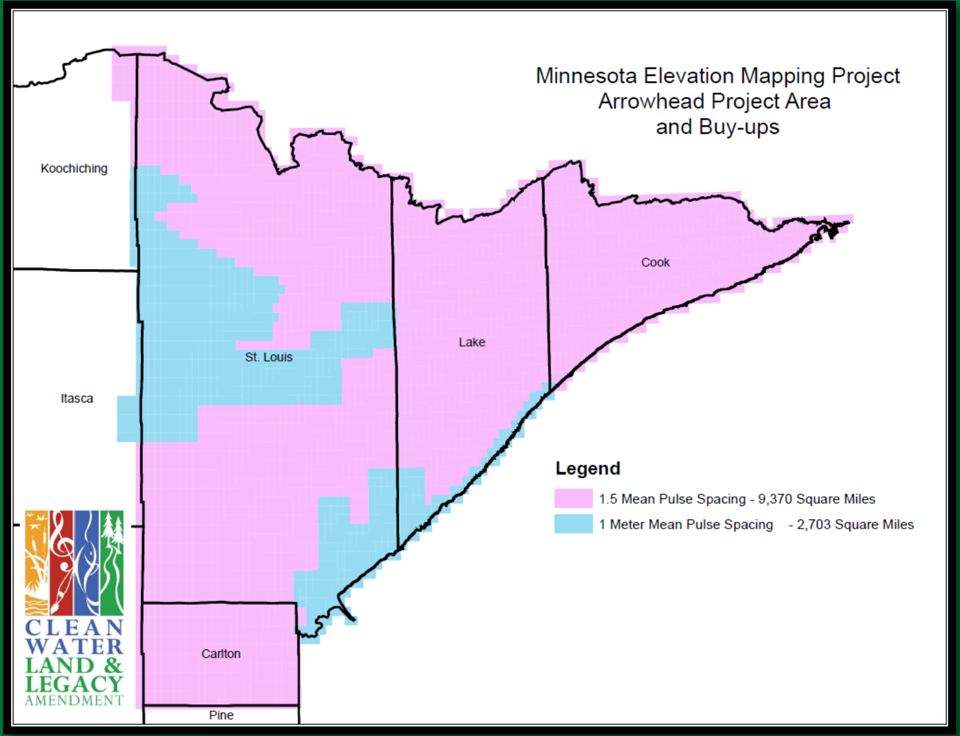
Data Collection
Lidar Data

Minnesota Department of Natural Resources

- Data Acquired Spring of 2011
- Minnesota Elevation Mapping Project
- Woolpert, Inc. was the Vendor
- Available at: https://gisdata.mn.gov/dataset/elev-lidar-arrowhead2011



Source: www.mngeo.state.mn.us/committee/elevation/mn_elev_mapping.html

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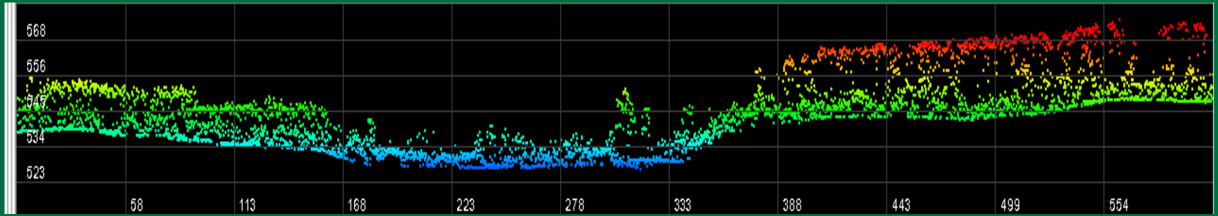
Lidar Point Cloud Data

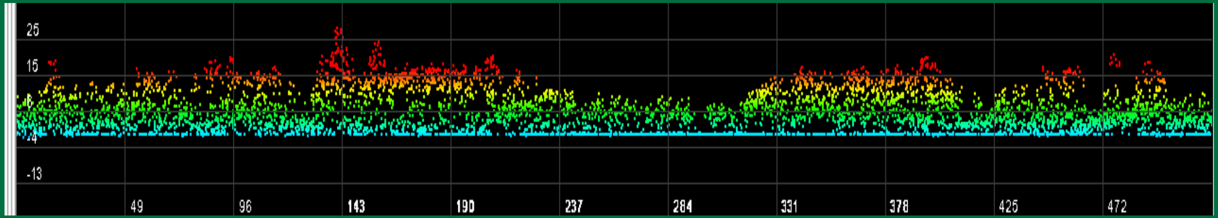
Lidar Metrics

LAStools

- **Normalized and Converted to Height Above Ground (HAG)**



Regular Profile



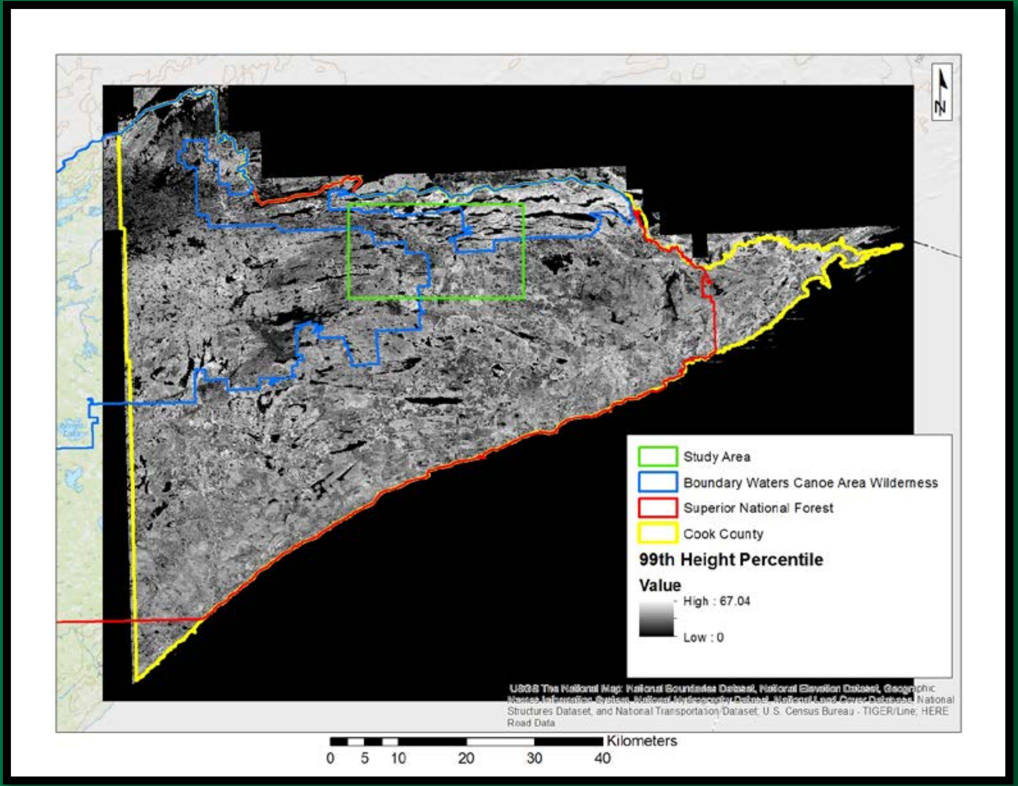
Normalized Profile

Lidar Point Cloud Data

Lidar Metrics

LAStools

- Normalized and Converted to Height Above Ground (HAG)
  - Height Percentiles
  - Covers – “the number of first returns above the cover cutoff divided by the number of all first returns and output as a percentage.”
  - Relative Densities – the number of points in a certain height range divided by all points in the same horizontal area.



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Understory Canopy Model

Combining the Field Data with the Lidar Metrics

Understory Canopy Model Generation

- **Field Data**
  - **Averaged the Amount of CLI Transect Canopy for the Phase 2 Data**
- **Lidar Data**
  - **Calculated the Lidar Metrics for a 20 m Radius for each Plot**
- **Simple Regression**
  - **$r^2 \approx 0.47$ with the relative density 2 – 4 meters metric**

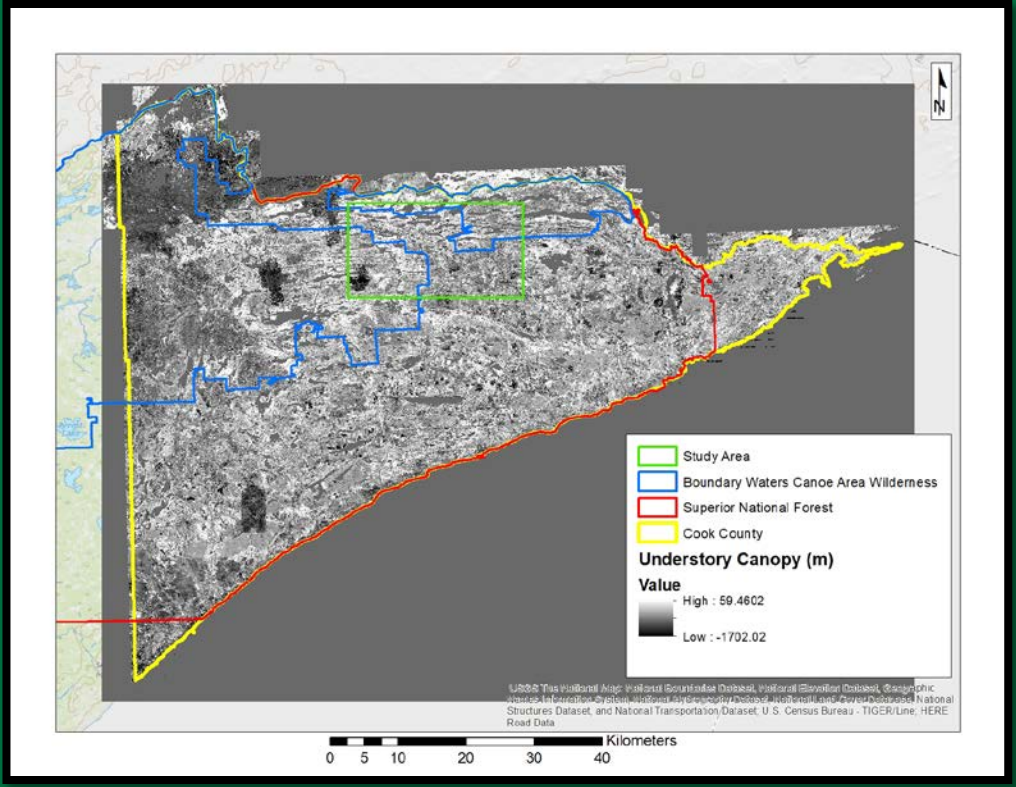
Lidar Metric Name	Divisions
Height Percentile	5th, 10th, 20th, 30th, 40th, 50th, 60th, 70th, 80th, 90th, 95th, 99th
Cover	Total Cover, Cover > 4 m, Cover > 6 m, Cover > 8 m, Cover > 10 m, Cover > 12 m, Cover > 14 m, Cover > 16 m, Cover > 18 m, Cover > 20 m, Cover > 25 m, Cover > 30 m, Cover > 35 m, Cover > 40 m
Relative Density	0 to 2 m, 2 to 4 m, 4 to 6 m, 6 to 8 m, 8 to 10 m, 10 to 12 m, 12 to 14 m, 14 to 16 m, 16 to 18m, 18 to 20 m, 20 to 25 m, 25 to 30 m, 30 to 35 m, 35 to

Understory Canopy Model

Combining the Field Data with the Lidar Metrics

Understory Canopy Model Generation

- Trial and Error Multiple Regression
  - $R^2 \approx 0.63$
- Multiple Regression with the Leaps Package
  - $R^2 \approx 0.65$
  - Height of the 50th Percentile of Returns
  - Relative Density from 8 to 10 m
  - Total Cover



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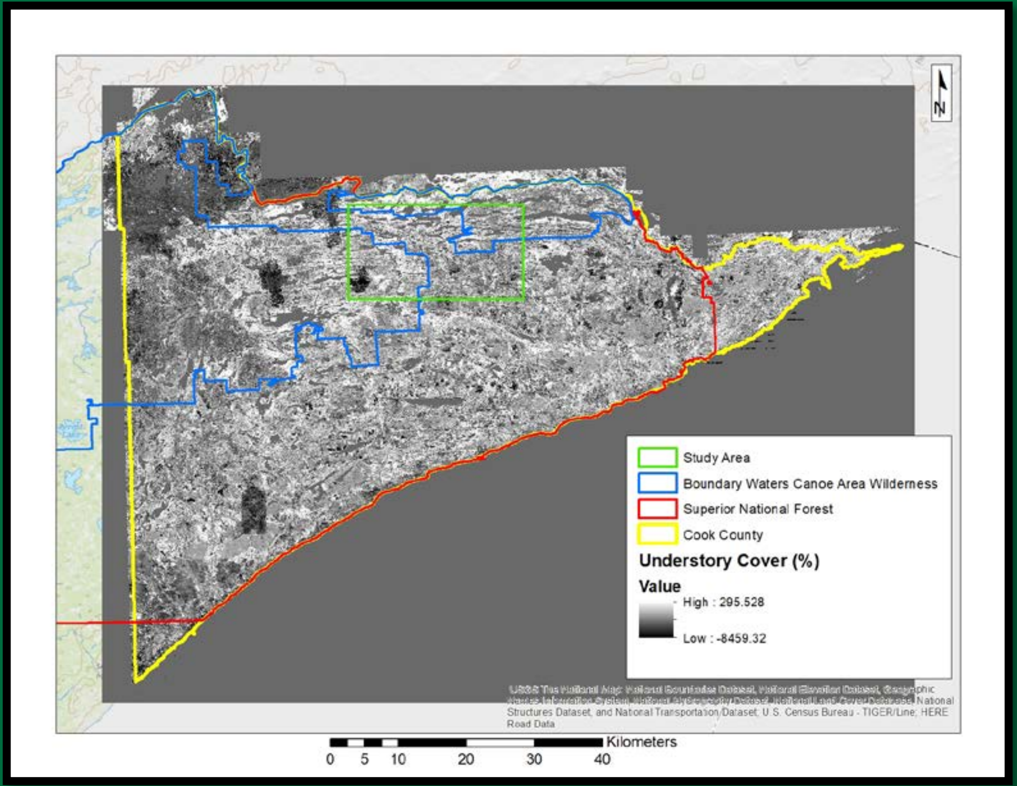
Understory Canopy Model

Initial Model Validation

<u>***Understory Canopy Model Inspection***</u>

- Values < 0
  - Inspection Did Not Reveal Extreme Negative Values
  - Math Confirmed at 44 Random Pixels
- Large Areas with Low Amounts of Canopy



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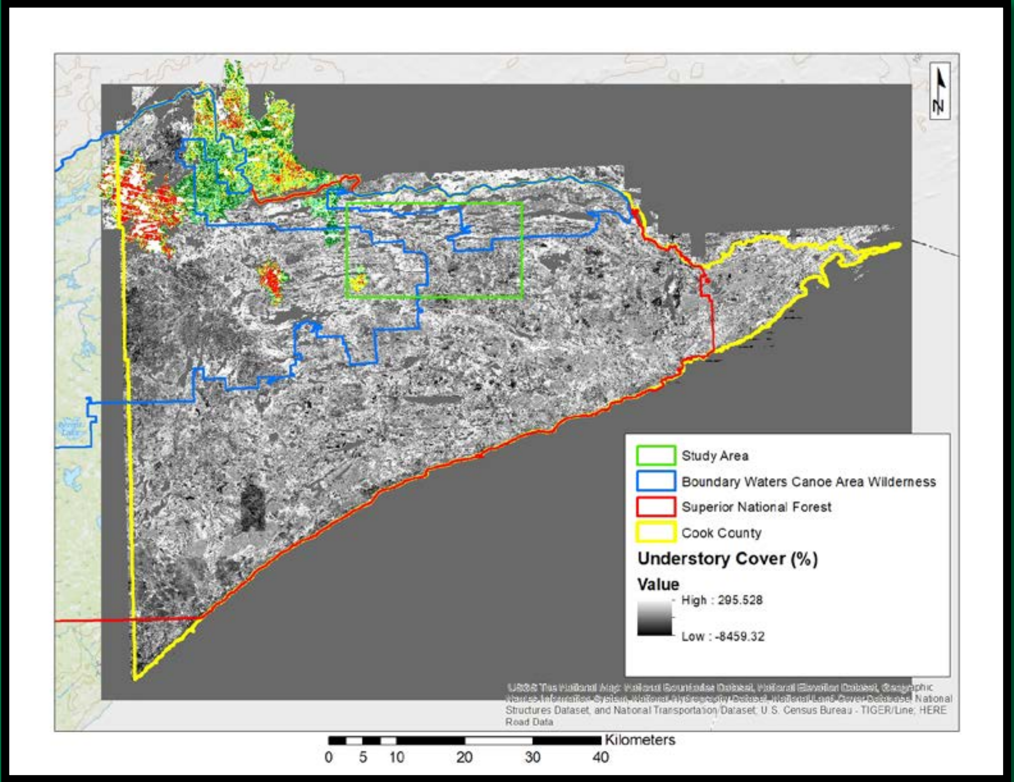
Understory Canopy Model

Initial Model Validation

Understory Canopy Model Inspection

- Monitoring Trends in Burn Severity (MTBS) Data
    - Dark Areas Appear to be Fire Scars
    - MTBS only Maps Fires that are Greater Than 500 Acres



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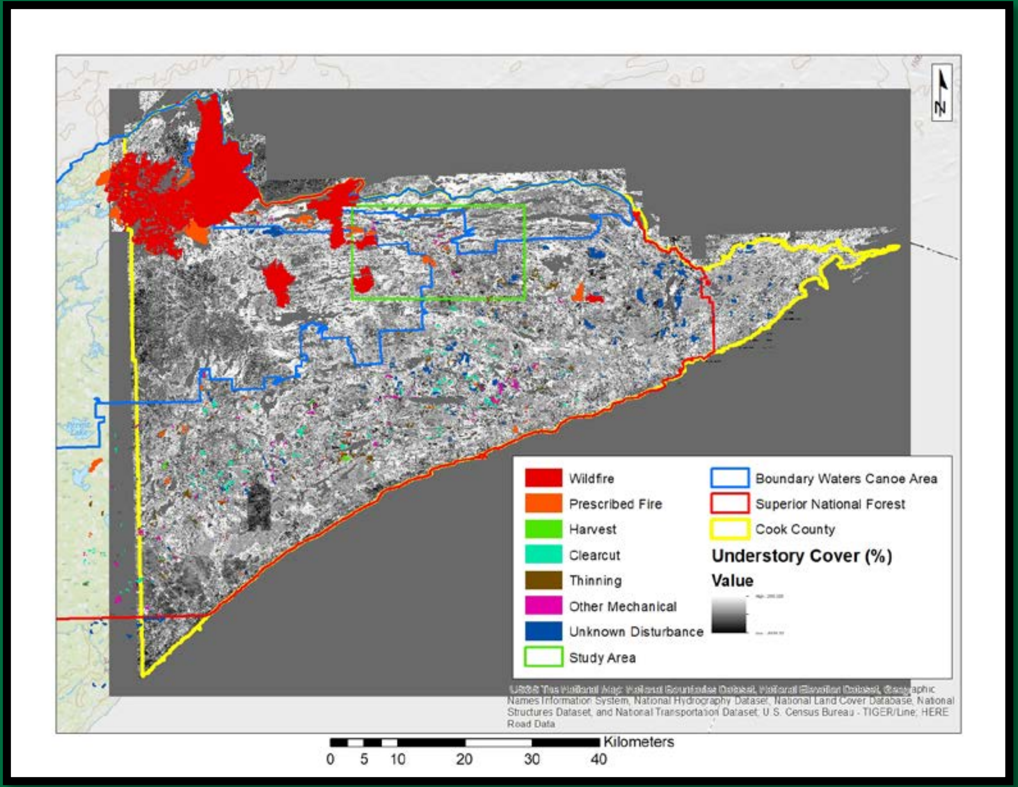
Understory Canopy Model

Initial Model Validation

Understory Canopy Model Inspection

- LANDFIRE Disturbance Data
  - 1999 - 2012



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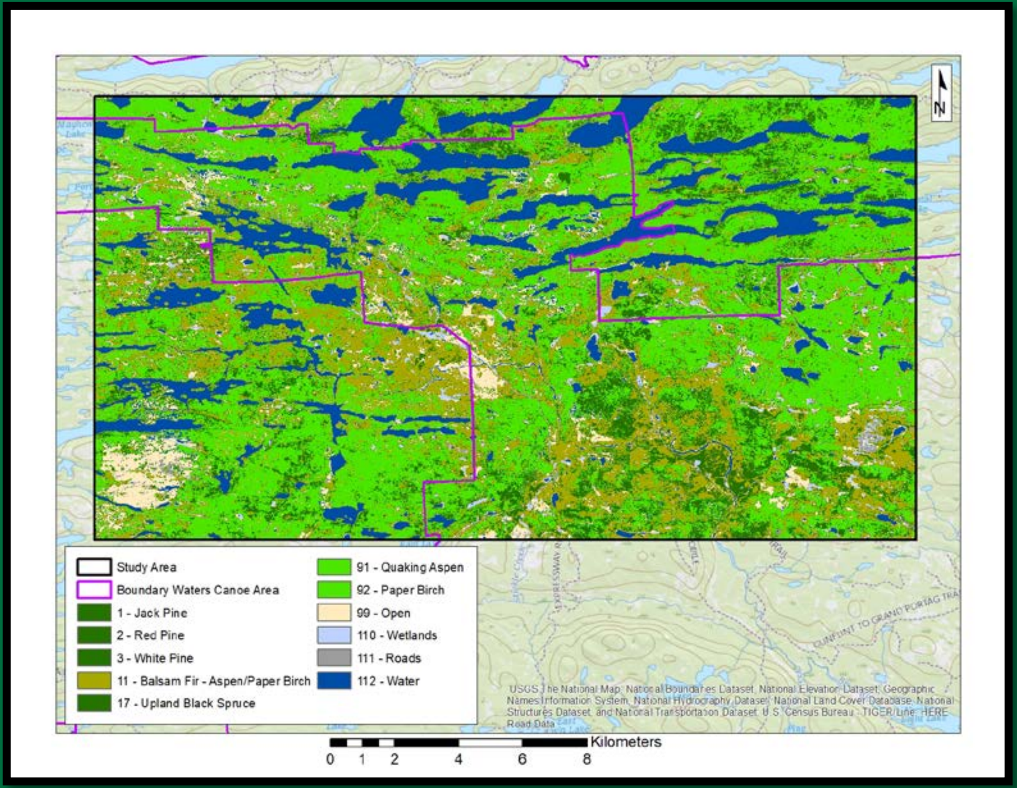
Exploring Other Data Sets

Aaron Poznanovie and Michael Falkowski, University of Minnesota

Products of Interest

- **Forest Type Map**
- **Live Crown Base Height Model**
- **Crown Fuel Base Height Model**

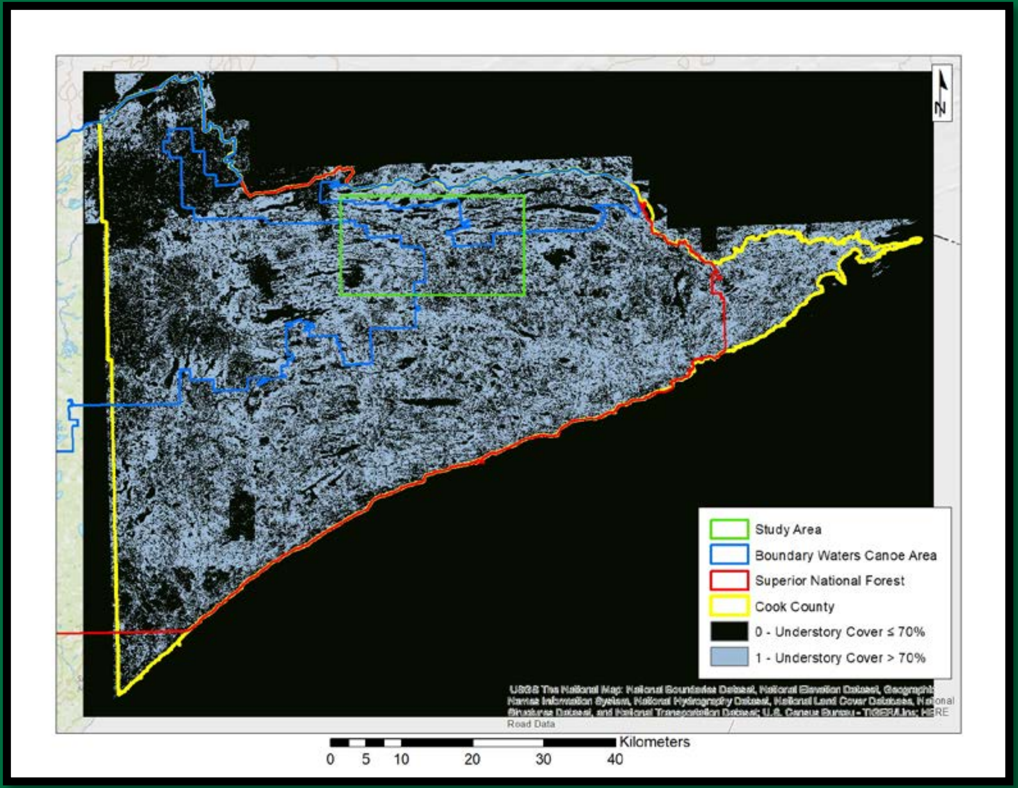


Exploring Other Data Sets

Aaron Poznanovie and Michael Falkowski, University of Minnesota

Binary Rasters

- Used to compare the understory cover model to the forest type map
- Series generated at selected thresholds of understory cover



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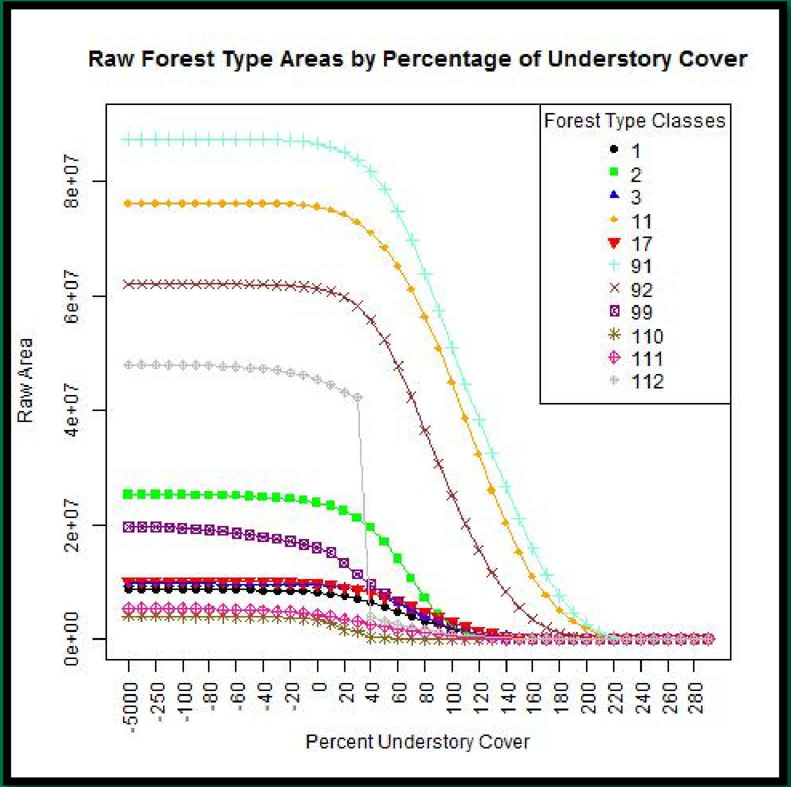
Exploring Other Data Sets

Aaron Poznanovie and Michael Falkowski, University of Minnesota

Forest Type Map

- Compared to Understory Canopy Model through Binary Raster Data
- Raw Area Results were Uninformative



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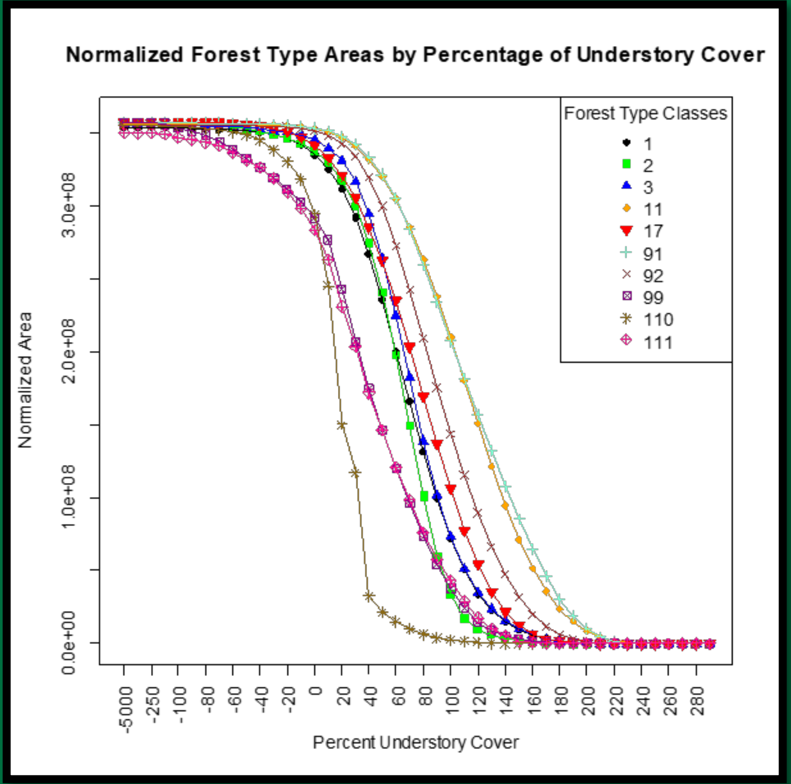
Exploring Other Data Sets

Aaron Poznanovie and Michael Falkowski, University of Minnesota

Forest Type Map

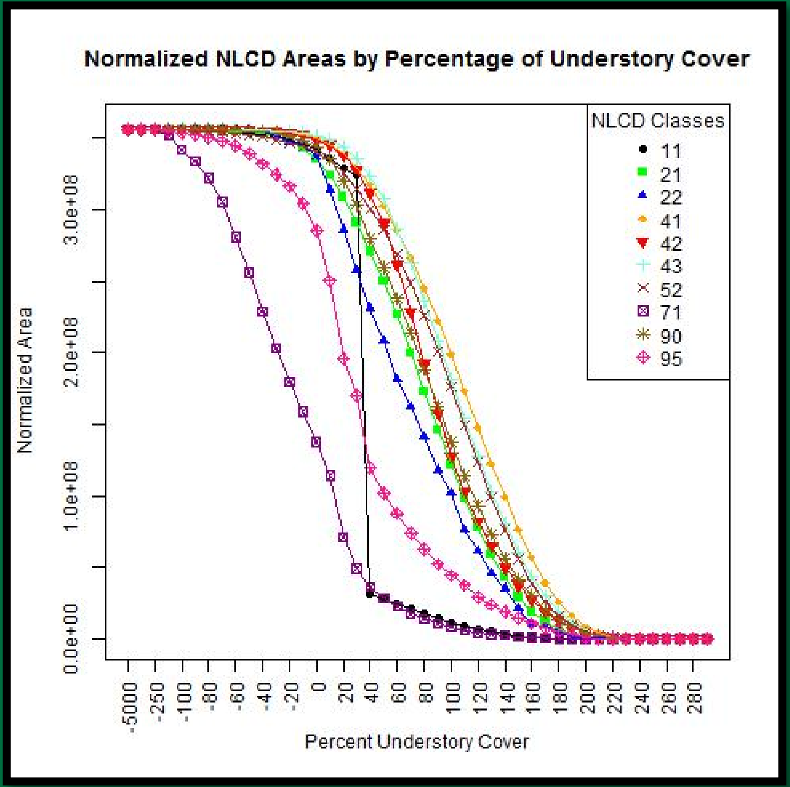
- Compared to Understory Canopy Model through Binary Raster Data
- Raw Area Results were Uninformative
- Normalized Results
    - Balsam Fir – Aspen/Paper Birch
        - EV Code 11
    - Quaking Aspen
        - EV Code 91
    - Paper Birch
        - EV Code 92



Exploring Other Data Sets
National Land Cover Database (NLCD)

NLCD Data

- Compared to Understory Canopy Model through Binary Raster Data
- Raw Area Results were Uninformative
- Normalized Area Results
    - Deciduous Forest
        - Class 41
    - Mixed Forest
        - Class 43
- Results Seem to Agree with Forest Type Results



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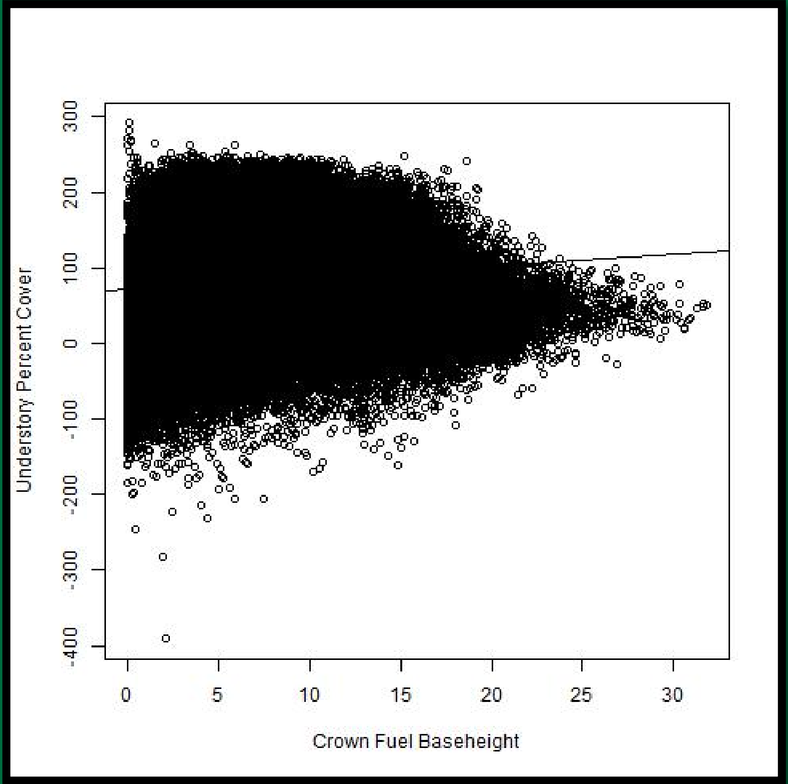
Exploring Other Data Sets

Aaron Poznanovie and Michael Falkowski, University of Minnesota

<u>*Crown Base Height (CBH)*</u>

- **Two Products**
  - **Crown Fuel Base Height**
  - **Live Crown Base Height**
- **Compared to Understory Canopy Model**
  - **Hypothesized an Inverse Relationship**
  - **No Relationship Found**
    - **Crown Fuel Base Height $R^2 \approx 0.02$**
    - **Live Crown Base Height $R^2 \approx 0.05$**



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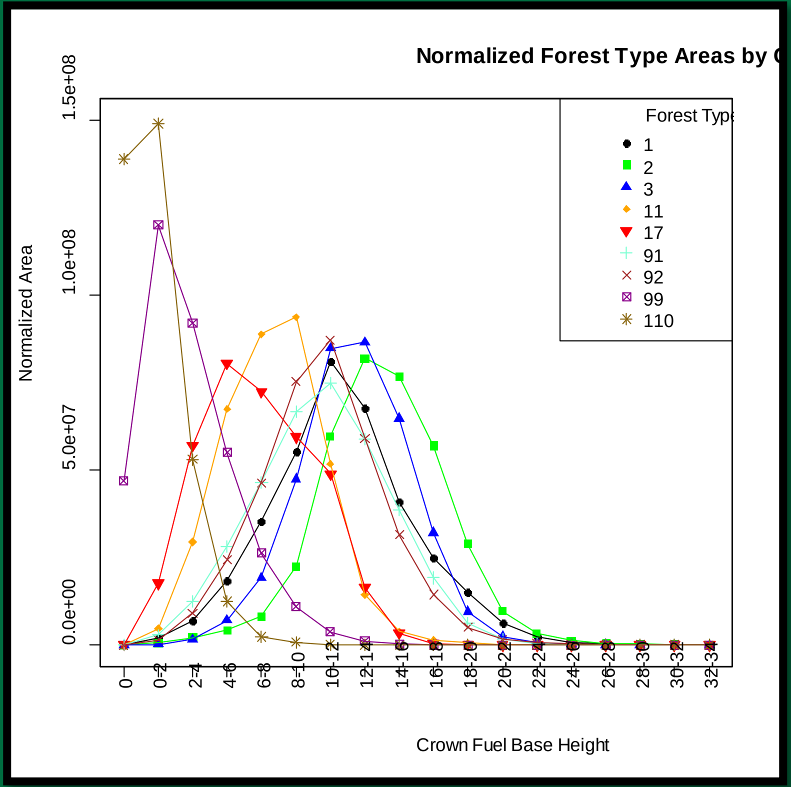
Exploring Other Data Sets

Aaron Poznanovie and Michael Falkowski, University of Minnesota

Crown Base Height (CBH)

- Compared to Forest Type Map through Binary Raster Data
- Two Approaches Taken
    - Break CBH into a Series of Greater than the Threshold Height Rasters
    - Break CBH into a Series of Height Interval Rasters
- As CBH Increases the Pine Classes were Found to be Prominent
    - Red Pine – Code 2
    - White Pine – Code 3
    - Jack Pine – Code 1



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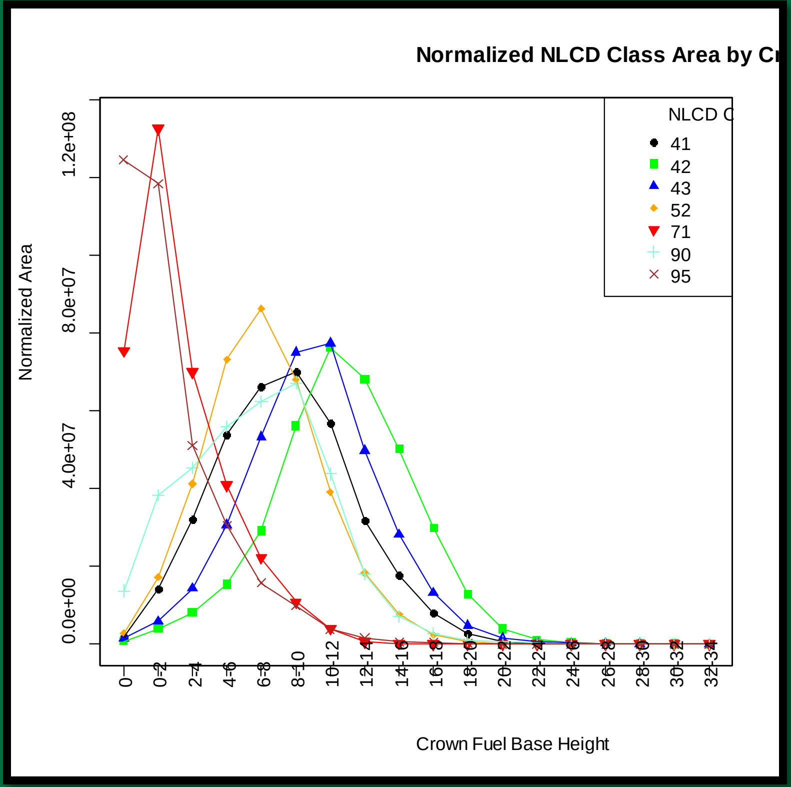
Exploring Other Data Sets

Aaron Poznanovie and Michael Falkowski, University of Minnesota

<u>*Crown Base Height (CBH)*</u>

- Compared to NLCD Data through Binary Raster Data
- Two Approaches Taken
  - Break CBH into a Series of Greater than the Threshold Height Rasters
  - Break CBH into a Series of Height Interval Rasters
- As CBH Increases the Evergreen Forest Class (Class 42) was Found to be Prominent
  - Results Appear to be in Agreement with the Forest Type Results



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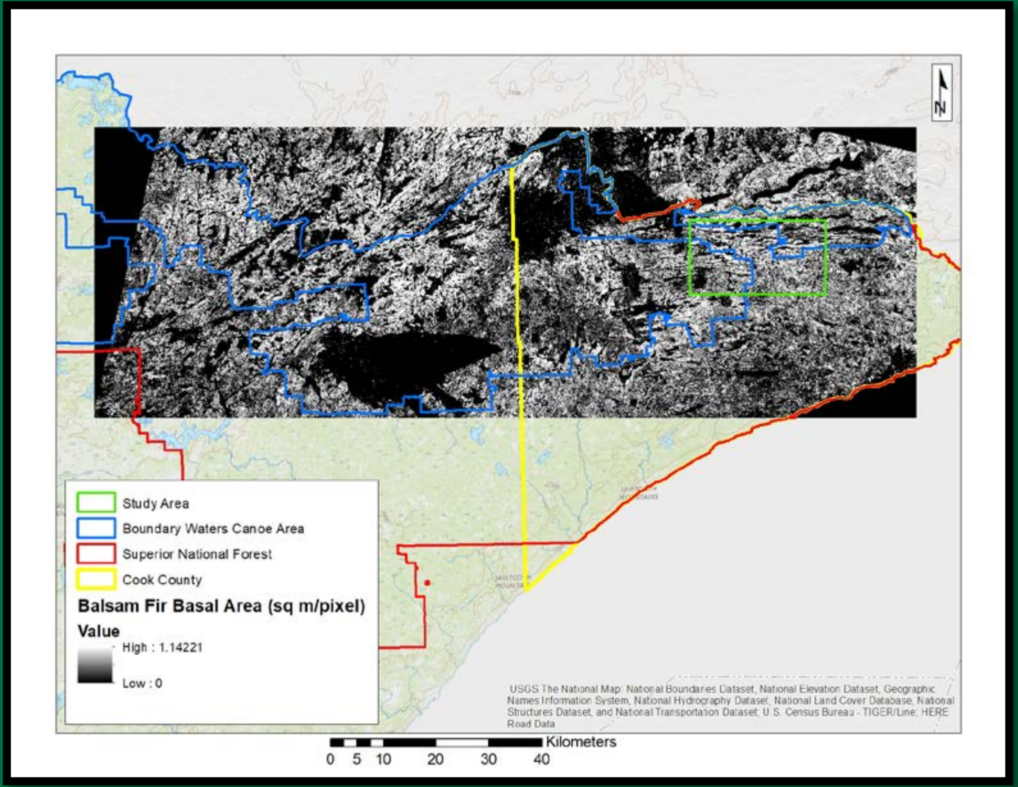
Exploring Other Data Sets

Peter Wolter, Iowa State University

Maps of Basal Area for Tree Species

- Total
- Conifer
- Hardwood
- Balsam Fir
- White Spruce
- Black Spruce
- White Pine
- Red Pine
- Jack Pine
- Cedar
- Tamarack



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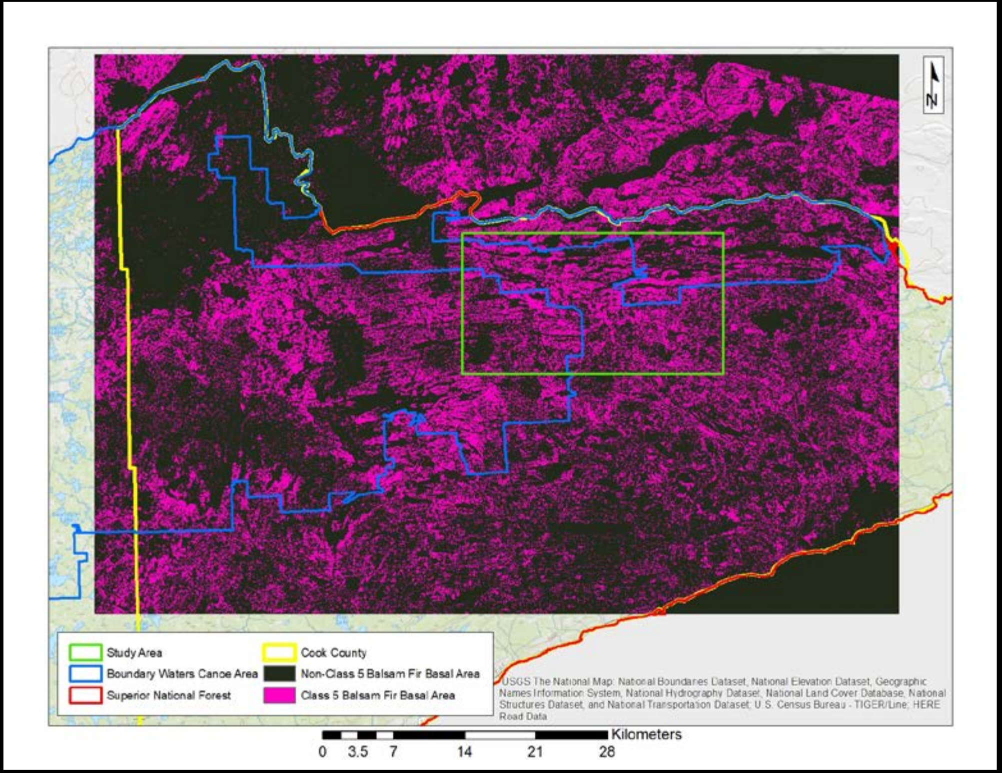
Exploring Other Data Sets

Peter Wolter, Iowa State University

Balsam Fir Basal Area Map

- Broken into Binary Rasters for 5 Classes
  - Class 1: 0 to 0.134 sq. m per pixel
  - Class 2: 0.134 to 0.309 sq. m per pixel
  - Class 3: 0.309 to 0.457 sq. m per pixel
  - Class 4: 0.457 to 0.614 sq. m per pixel
  - Class 5: 0.614 to 1.142 sq. m per pixel

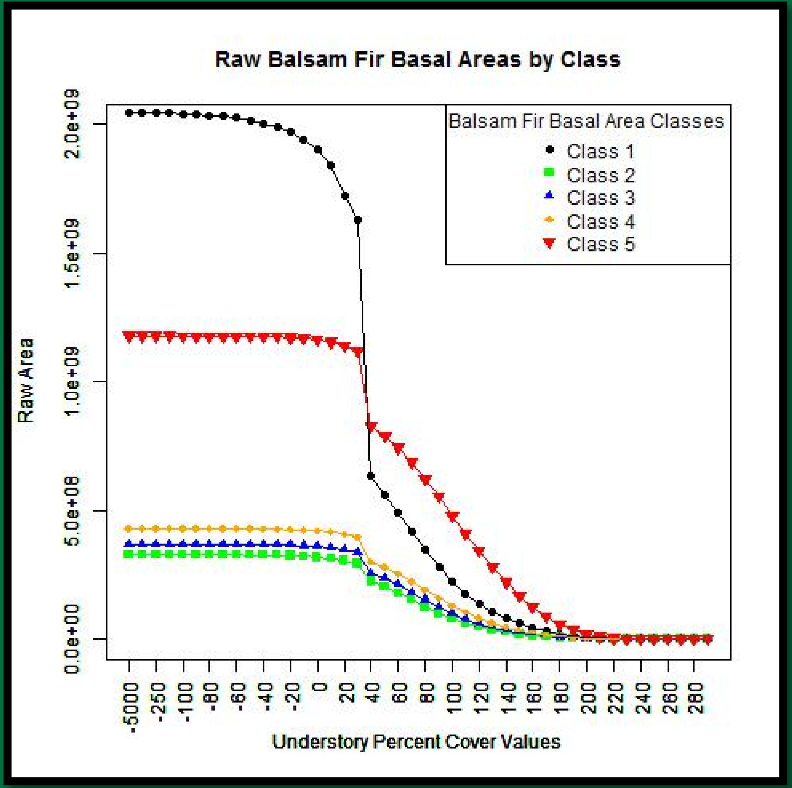


Exploring Other Data Sets

Peter Wolter, Iowa State University

<u>*Balsam Fir Basal Area Map*</u>

- Balsam Fir Basal Area Class Raster Data Compared to Understory Cover Binary Raster Data
  - Raw Area
    - Class 5 Prominent in the Mid to High Range of Understory Percent Cover (UPC > 40% to UPC >200%)
  - Normalized Area
    - Class 5 Prominent in the Mid to High Range of Understory Percent Cover (UPC > 40% to UPC >200%)



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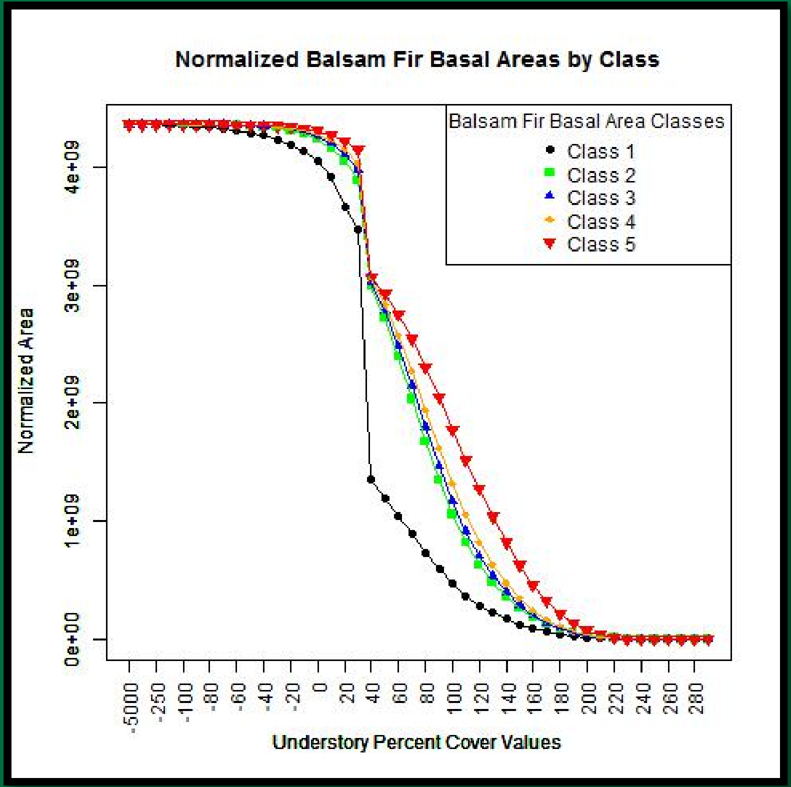
Exploring Other Data Sets

Peter Wolter, Iowa State University

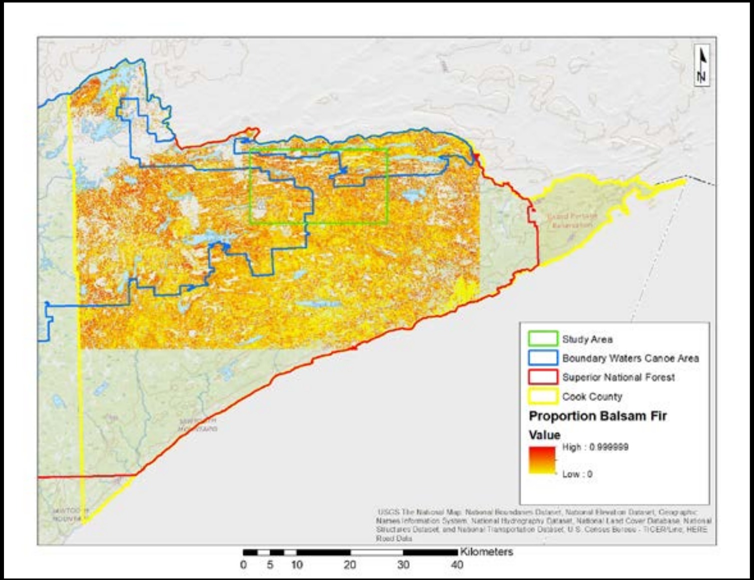
Balsam Fir Basal Area Map

- **Balsam Fir Basal Area Class Raster Data Compared to Understory Cover Binary Raster Data**
  - **Raw Area**
    - **Class 5 Prominent in the Mid to High Range of Understory Percent Cover (UPC > 40% to UPC >200%)**
  - **Normalized Area**
    - **Class 5 Prominent in the Mid to High Range of Understory Percent Cover (UPC > 40% to UPC >200%)**



Exploring Other Data Sets

Peter Wolter, Iowa State University



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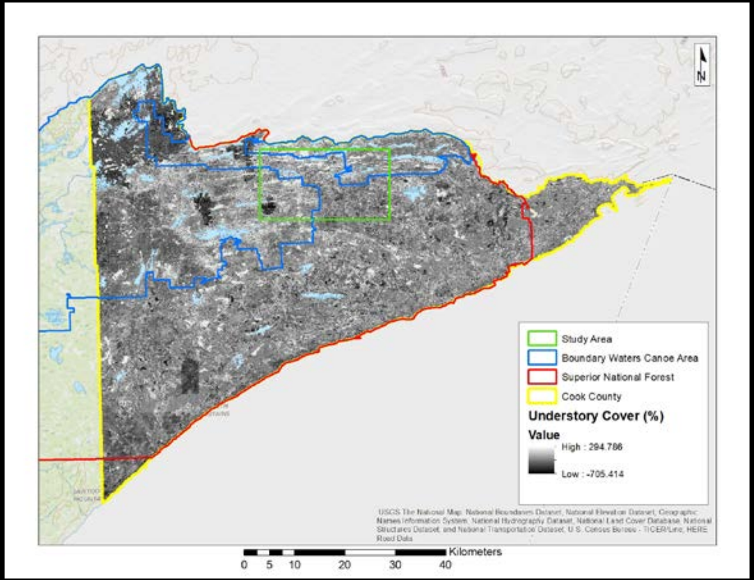

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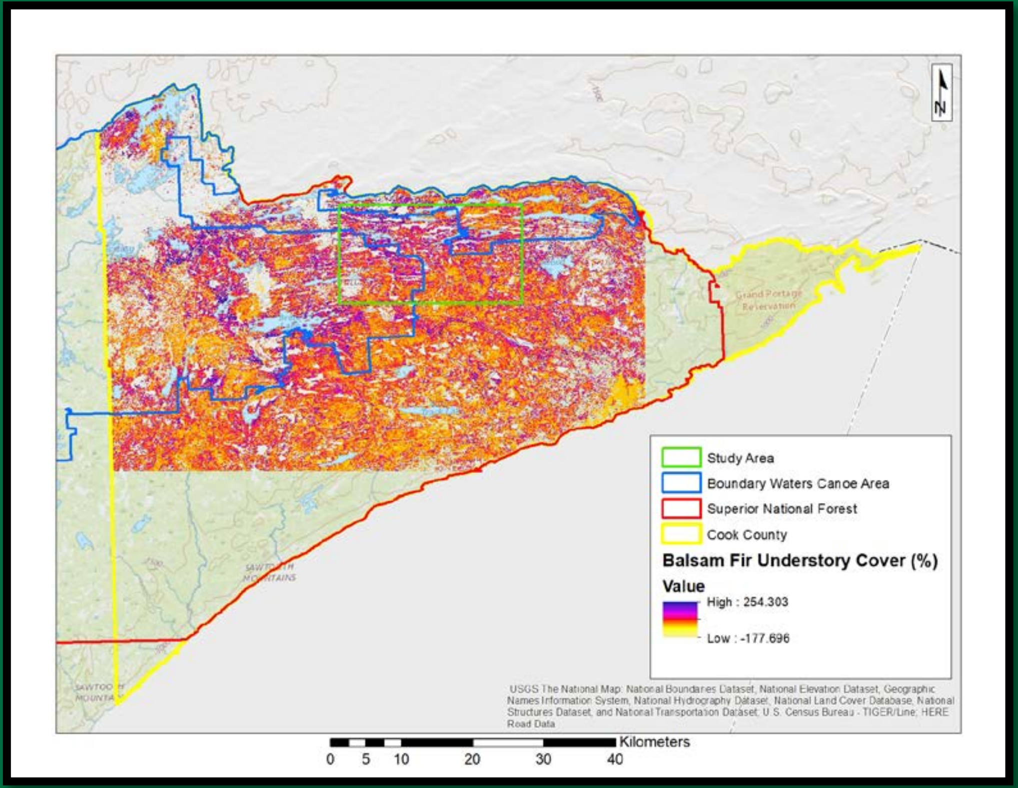
Exploring Other Data Sets

Peter Wolter, Iowa State University

<u>Balsam Fir Understory Cover Map</u>



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Are these products any good?

Field Validation
Field Work

May Learning Experience

- **Few Mosquitos**
- **But you might see Snow and Frost**

Photo taken by Jeff Irwin

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Field Validation
Field Work

May Learning Experience

- Few Mosquitos
- But you might see Snow and Frost
- Plus, it's a good time to meet new friends

Photo taken by Jeff Irwin

Field Validation
Field Work

Cover Line Intercept (CLI) Method

- May 2017
- 24 Phase 2 Plots
- Densiometer Readings
- Photographs

Photo taken by Jeff Irwin

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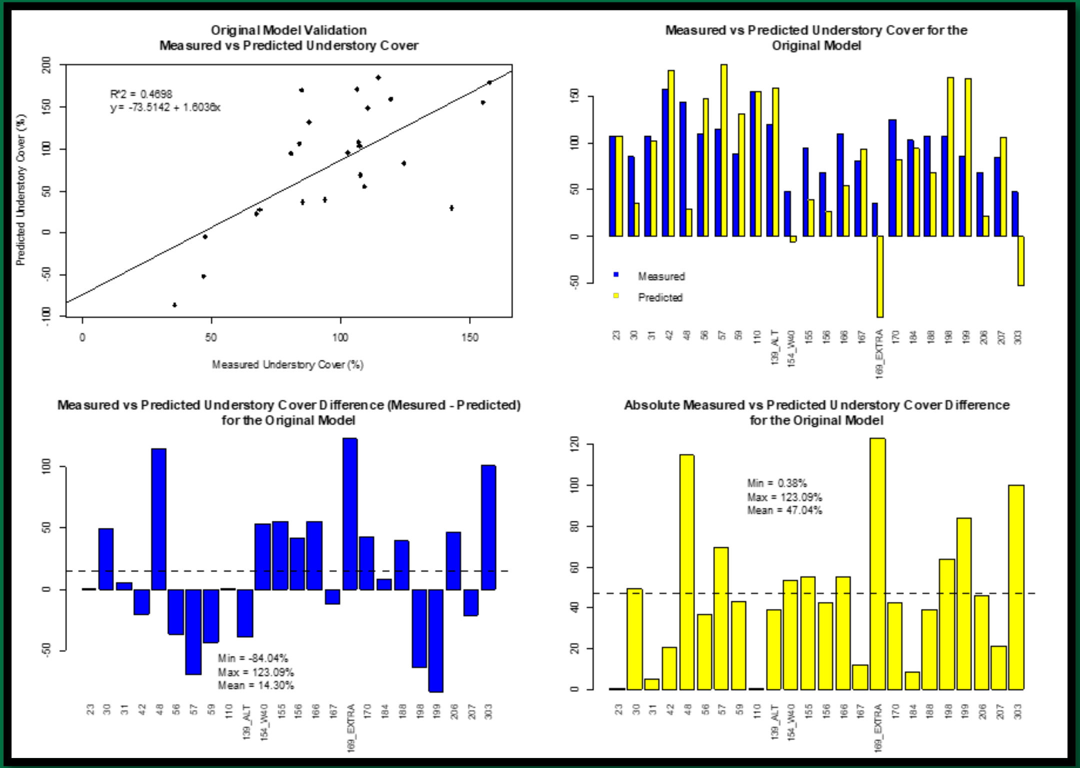
Field Validation

Comparing the Plot Data to the Understory Cover Model

<u>Measured versus Predicted Results</u>

- $R^2 \approx 0.47$
- R ≈ 0.69
- Mean Difference ≈ 14.3%
- Mean Absolute Difference ≈ 47.0%



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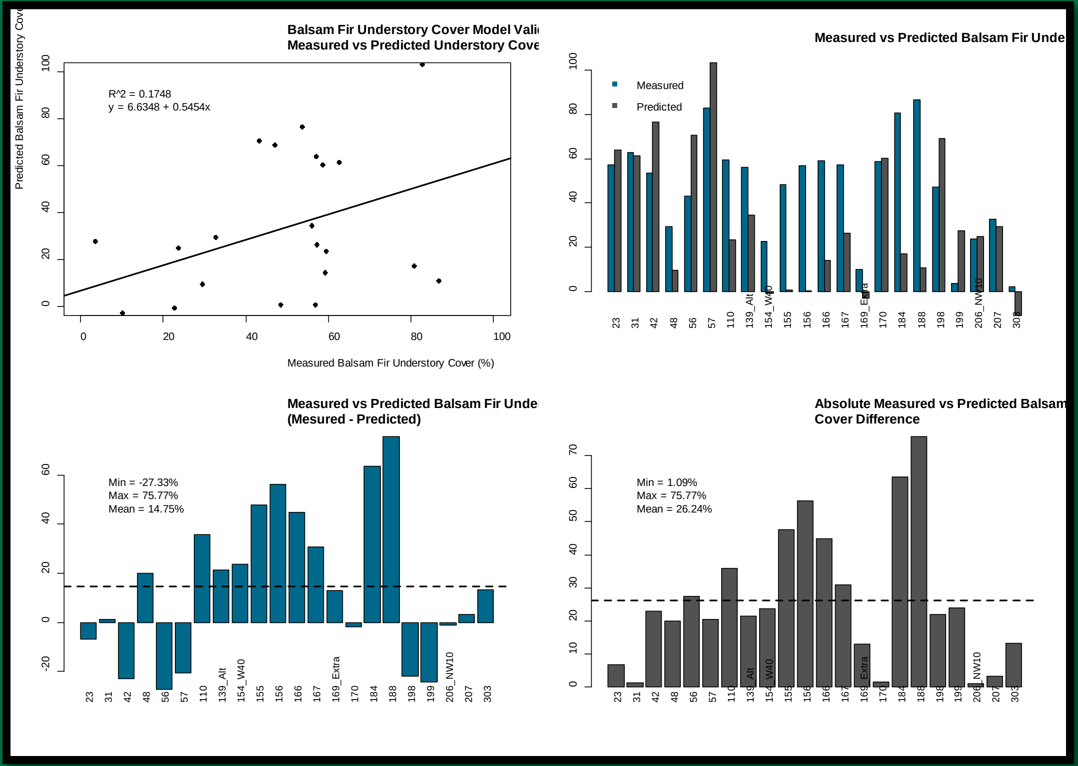
Field Validation

Comparing the Plot Data to the Balsam Fir Understory Cover Model

Measured versus Predicted Results

- $R^2 \approx 0.17$
- R ≈ 0.42
- Mean Difference ≈ 14.8%
- Mean Absolute Difference ≈ 26.2%



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More Models

Building and Validation

Model	Stratified Random Sample 1	Stratified 75 -35 Random Sample 2	80% Training 20% Testing Random Sample 3	80% - 20% Random Sample 4 (Plot 62 Withheld)	70% Training 30% Testing Random Sample 3	Original	4 Transect Training - 1 Transect Test	Original with Plot 121
R^2	0.5551	0.4285	0.5035	0.5223	0.5133	0.6504	0.4619	0.6547
Variables	p50 d8-10m TotCov	p40 d14-16m TotCov	p50 d8-10m TotCov	p50 d8-10m TotCov	p50 d8-10m TotCov	p50 d8-10m TotCov	p50 d8-10m TotCov	p50 d8-10m TotCov
Validation R^2	0.3567	0.2547	0.3551	0.3721	0.4739	0.4698	0.5828	0.4698
Mean Difference	-0.43%	4.11%	0.81%	8.38%	-19.44%	14.30%	8.79%	14.18%
Mean Absolute Difference	28.89%	34.26%	25.81%	37.42%	26.06%	47.04%	33.47%	46.88%

Summary

- An understory cover model has been produced
- MTBS and LANDFIRE disturbance data have increased confidence in the model
- Comparison of the understory cover model to the University of Minnesota forest type map revealed an apparent correlation between the amount of understory cover and the balsam fir – aspen/paper birch, paper birch, and quaking aspen forest types
- NLCD data supports that agreement

Summary

Continued

- No relationship was found between the understory cover model and CBH
- Areas with high CBH seem to be occupied by pine species
- A relationship between the understory cover model and the amount of balsam fir basal area appears to exist – areas with medium to high amounts of understory cover appear to have higher amounts of balsam fir basal area
- A balsam fir understory cover model seems possible

Summary

Continued

- Fieldwork has been conducted to validate the understory cover model and the balsam fir understory cover model
- Additional models have been built from random subsets of the plot data and the models seem to be honing in on:
    - Height of the 50^{th} percentile of returns
    - Relative density between 8 and 10 meters
    - Total cover

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Conclusions

- With lidar data, it appears to be possible to map understory cover
- More plot measurements could improve modeling
- In this instance, lidar data alone could not be used to identify tree species
- Lidar data need to be combined with other data sets to map understory balsam fir
- Determining which factors influence the location of understory balsam fir is a challenging problem


Questions?

2017-2018 Webinar Series
March 15, 2018

Monitoring the response of moose to large fires in Minnesota.

Mike Schrage
Wildlife Biologist
Fond du Lac Resource Management Division