MACHINE LEARNING TO OPTIMIZE STAND DENSITY AS A FUNCTION OF MANAGEMENT OBJECTIVES AND SITE RESOURCES

RYAN HEIDERMANN
OVERVIEW

1. IFC Max SDI Summary
2. Westside Project Overview
3. Data
4. Modeling Approach
5. Variable Selection
6. Results
MAXIMUM STAND DENSITY INDEX

DESCRIBES CARRYING CAPACITY

- Density – function of the number of trees and their size
  - Maximum – the limit on # trees that can exist
  - % of max (relative density) predict key phases of stand development
    - Establishment (density indp.) > Crown Closure (onset) > Self Thinning (density depn.)

- Stand Density Index (SDI) modeled as a function of TPA and QMD
  
  \[ SDI = N \left( \frac{QMD}{10} \right)^b \]
  
  \[ \log(N) = \beta_0 + \beta_1 \log(QMD) \]

- Site and Species effects on slope and intercept of the self-thinning line
\[ \ln N = (\beta_0 + k_i) + (\beta_1 + k_i)\ln QMD \]

Where \( k_i \) is the site/species effect on the intercept and slope of the self-thinning line.
IFC – MAXIMUM STAND DENSITY INDEX

INLAND MODEL

Influence of site characteristics and species composition

Site sensitive maximum stand density index models for mixed conifer stands across the Inland Northwest, USA

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Explore and model the influence of site characteristics and species composition on stand carrying capacity in Westside PNW forests. Cascade crest, west to the coast in Oregon and Washington.

- Focus on important conifer species
- Incorporate effects of species mixing (BA proportion)
- Topography – slope and aspect transformations, elevation
- Influence of soils and volcanic ash
- Climatic Variables
- Future climate scenarios
DATA

Sources – IFC members

- Hancock, Olympic Resource Management, Roseburg Resources Co.
- WA DNR, ORDF, USFS (FIA and FSVEG)

n = 188,159 initial records in area of interest

- Plot level data where plot coordinates available
- Stand level using stand centroid (~10% of data)

QMD and TPA of each record

Species BA proportions (DF, WH, RC, RA, Hwd, Conf)

Topography extraction from 30m DEM

- Transformations with R-terrain (slope & aspect)

ClimateNA – 247 variables (Annual, Month, Season)

Geology and Soil layers
DOUGLAS-FIR
MODELING APPROACH

1 155,083 plots with at least 10% Doug-fir by BA

2 Data cleaning
   - Missing expansion factors, at least 10 TPA (24.7 TPH), QMD at least 1 inch (2.54 cm), questionable data

3 Use Linear Quantile Mixed Models to determine the 95% quantile line of log(TPH)~log(QMD)
   - Mixed model where each record has random intercept, giving each record a unique 95% max SDI value

4 Use Random Forest with SDI values to find variable importance
   - Ensemble of many trees

5 Stochastic Frontier Analysis with selected variables
DOUGLAS-FIR VARIABLE SELECTION

RANDOM FOREST

- Geographic Location
- Topography
- Other Species’ BA
  - Base model as pure DF
  - Coef for Species BA proportion (+)
    - WH, RA, RC, OtherC, OtherH
- Timing of precip
- Interaction of precip and temp
**Doug-fir Maximum SDI (trees ha⁻¹)**

- **n** = 155,083

<table>
<thead>
<tr>
<th>Min</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>95%</th>
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</thead>
<tbody>
<tr>
<td>839</td>
<td>1203</td>
<td>1301</td>
<td>1415</td>
<td>1579</td>
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**Max SDI**

<table>
<thead>
<tr>
<th>Max SDI</th>
<th>Source</th>
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<tbody>
<tr>
<td>1360-1470</td>
<td>Reineke, 1933</td>
</tr>
<tr>
<td>1450</td>
<td>Long, 1985</td>
</tr>
<tr>
<td>1451</td>
<td>Weiskittel et al, 2009</td>
</tr>
<tr>
<td>1376</td>
<td>Woodall et al, 2005</td>
</tr>
<tr>
<td>1478</td>
<td>Long et al, 1988</td>
</tr>
<tr>
<td>1815 (BC,CAN)</td>
<td>Comeau et al, 2010</td>
</tr>
<tr>
<td>1491 (GB)</td>
<td>Comeau et al, 2010</td>
</tr>
</tbody>
</table>
50% Western Hemlock BA Proportion in model
WESTERN HEMLOCK

MODELING APPROACH

- 52,578 plots with at least 10% W. Hemlock by BA
- Data Cleaning same as DF
- During modelling process, records without Doug-fir responded different than records with Doug-fir
  - Plots with DF tended to be dominated by DF (~37% had >50% Doug-fir BA)
  - DF BA proportion was extremely influential in model, lowering Hemlock maxSDI significantly
- Removed plots with DF BA, leaving 13,737 records of Hemlock plots
  - Wetter, less droughty locations
- Random Forest on calculated 95% quantile SDI (LQMM) for Variable Selection
- Stochastic Frontier Analysis
Focus on these records

WH > 10% and 0 DF
WESTERN HEMLOCK VARIABLE SELECTION

RANDOM FOREST
- Geographic Location
- Topography
- Other Species’ BA
  - Base model as pure WH
- Timing of precip
- Interaction of precip and cool temps
- Relative Humidity
Western Hemlock Maximum SDI (trees ha⁻¹)

Min 25% 50% 75% 99%
890 1355 1500 1654 1973

Max SDI   Source
1688   Weiskittel et al, 2009
1950   Long, 1985
2100   Hyink et al, 1987

n=13,137
FUTURE SCENARIOS

RUN MODEL WITH CLIMATE PROJECTIONS

- Under changing patterns on precipitation, temperature
- Atmosphere-Ocean Global Circulation Models (AOGCMs)
  - Ensemble of 15 GCMs from the Climate Model Intercomparison Project 5 (CMIP5)
- Representative Concentration Pathways (RCPs)
  - RCP4.5 – emission peak in 2040’s and decline
  - RCP8.5 – emissions continue to increase throughout the century
- Doug-fir ran with future changes in ratio of Growing Season Precip to Annual Precip and interaction of precip and cool temps
- W. Hemlock ran with future changes in precip ratio, RH and interaction of precip and cool temps

“Historical climate data are necessary for understanding relationships between climate and biological response of organisms, or general patterns of ecological adaptations to local climate environments. Such insight can be used to build mechanistic or statistical models...”
DOUGLAS-FIR

FAIRLY RESILIENT – 6% AVG DROP (LOCATION SPECIFIC)

Historic 2050’s RCP 8.5 2080’s RCP8.5
1579 (95%q maxSDI) 1513 (95%q maxSDI) 1480 (95%q maxSDI)
WESTERN HEMLOCK
LESS RESILIENT – 13% AVG DROP (LOCATION SPECIFIC)

Western Hemlock Maximum SDI (trees ha⁻¹)

<table>
<thead>
<tr>
<th>Historic</th>
<th>2050’s RCP 8.5</th>
<th>2080’s RCP 8.5</th>
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<tbody>
<tr>
<td>1973 (99%q maxSDI)</td>
<td>1783 (99%q maxSDI)</td>
<td>1720 (99%q maxSDI)</td>
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CONTINUED WORK

1. Continue exploring variable importance in DF and WH
2. Examine future scenarios further
3. Other Species
4. Other Modeling Approaches
   - Quantile Regression
   - Non-parametric ensemble approach – RF, GBM
5. Explore diameter distributions and cutoffs where data available
6. Combining regional models
ACKNOWLEDGMENTS

Data providers
USFS for funding and guidance
University of Idaho
Intermountain Forest Coop Members