Final Report

Assessing and mapping regional variation in potential site carrying capacity

CAFS 19.76

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Justification

- Understocked stands underutilize site resources and will not reach maximum potential productivity
- Overstocked stands are slow to develop and susceptible to wildfire, drought and insect outbreaks due to competition for limited resources.
- To date, forest carrying capacity research is regionalized, utilizes multiple modeling approaches, and not universally available spatially across the US ......

Objectives

- Synthesize a nationwide forest inventory database from publicly available data and from CAFS members,
- Standardize maximum carrying capacity modeling, and
- Create efficiencies for multi-regional forest management organizations by providing consistent, species-site-silviculturally sensitive, wall-to-wall spatial models of SDImax for commercial species of the United States.

Methods

DATA ACQUISTION

- Plot, stand data provided by FIA, State Agencies, and Industrial CAFS members

DATA CLEANING – MODEL SENSITIVITY

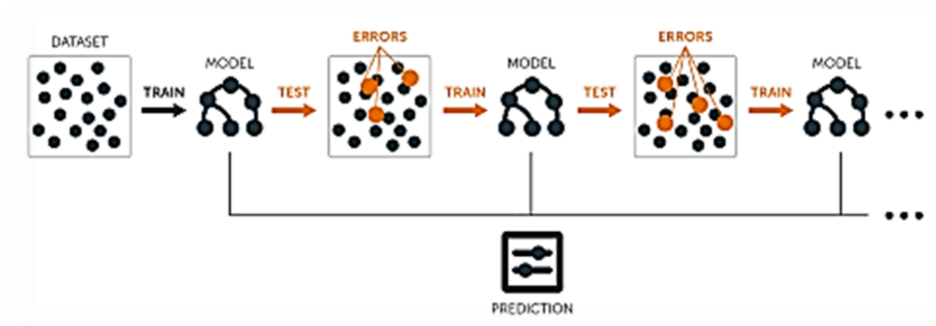
- Missing expansion factors, at least 10 TPA, QMD at least 2-inch, questionable & missing data removed

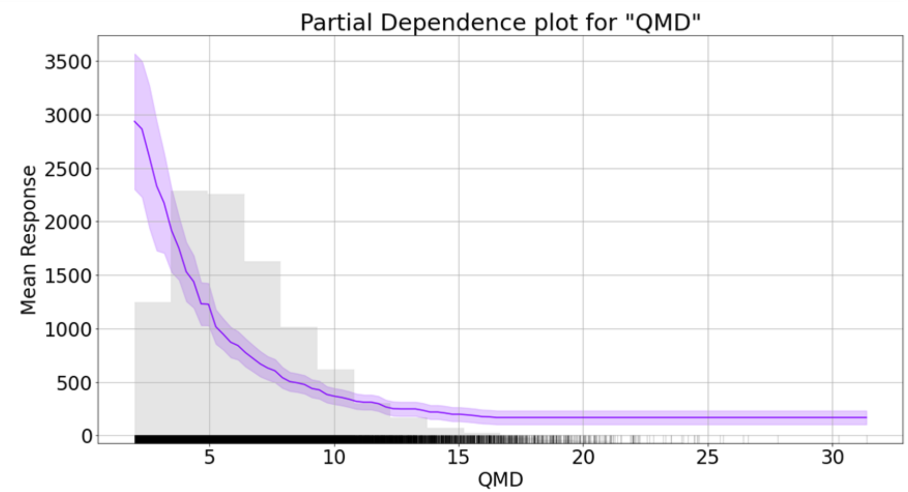
VARIABLE SELECTION

- Based on Minimum Redundancy Maximum Relevance (MRMR) algorithms

FITTING QUANTILE GBM

- The quantile GBM model minimizes deviations between predicted and observed quantiles, ensuring robust estimations at the 95th percentile of the size-density relation.





Progress 2024-25

INLAND NORTHWEST

- Inland Northwest SDImax model V2.0 launched
  - Included additional CAFS member datasets
  - Utilized new machine learning methods
  - Improved SDImax predictions in areas with data gaps from V1.0
  - Reduced to a single model from 5

PACIFIC NORTHWEST

- Obtained support from Manulife, WA DNR, and BLM to create a V2.0 PNW model utilizing machine learning
- Revised model slated for late summer 2025

KLAMATH-SISKIYOU

- V1.0 utilizing machine learning methods launched late 2024
- Current feedback is pointing to a small revision to incorporate surrounding regional datasets with higher proportions of PP

NORTHEAST & SOUTHEAST

- V1.0 models made available to CAFS members (based on Stochastic Frontier Regression)
- New datasets obtained in 2024
- V2.0 models utilizing machine learning incoming late 2025

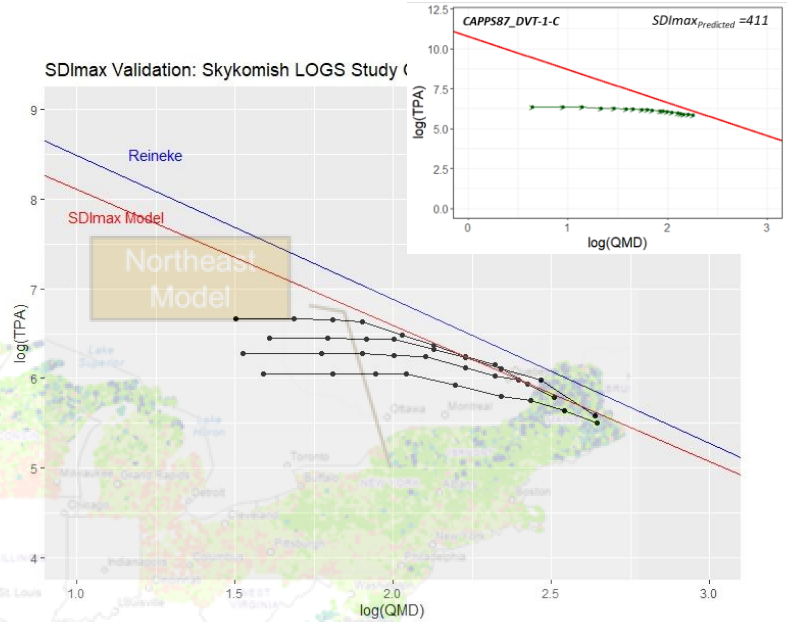
Major Findings

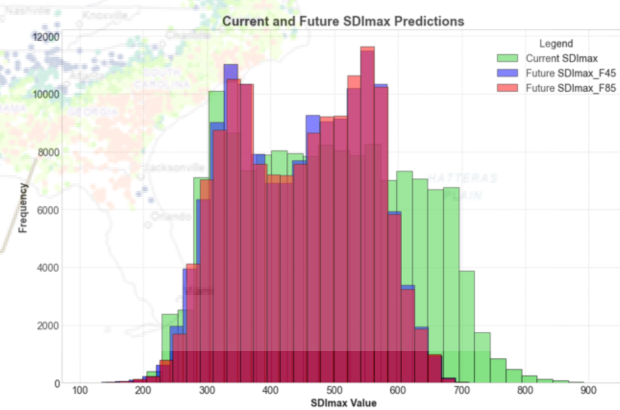
- Forest carrying capacity was defined for this project as the 95th percentile of the size (QMD) density (TPA) relationship has been modeled for all major, economically important, conifer species across the northwestern, southern, northern and Lake States

- Tested against long-term monitoring datasets (PNW LOGS study, FS-R1 100-Yr, PMRC) – predicted maximums were relevant to observed QMD/TPA trajectories

- Common drivers of carrying capacity are:
    - Ratio of drought/shade tolerant species present
    - Growing season precipitation and temperature, soil parent material, topography (elevation, solar radiation)
    - Fertilization (SE US Model)

- Machine learning models infused with projected shifts in temperature and precipitation across the broader Pacific Northwest suggest an approximate 5-20% reduction in forest carrying capacity within 60-80 yrs, with some locales indicating a small increase (i.e., higher elevations in the Cascade and Rocky Mountains)





Major Findings

- 1.605 exponent a legacy of Reineke's MaxSDI modeling and subsequent species, linear based modeling efforts
- IFC V1.0 models created using Stochastic Frontier Regression (linear models) created a revised species model exponent that could be substituted for **1.605** to compute Relative Density (RD)
- New Machine Learning approach to SDImax modeling is not linear, exponent is unique to each user input – *f*(stand, site conditions)
- Exponent critical to compute Relative Density as a function of predicted IFC SDImax after inventory updates

Reineke based SDI Equation

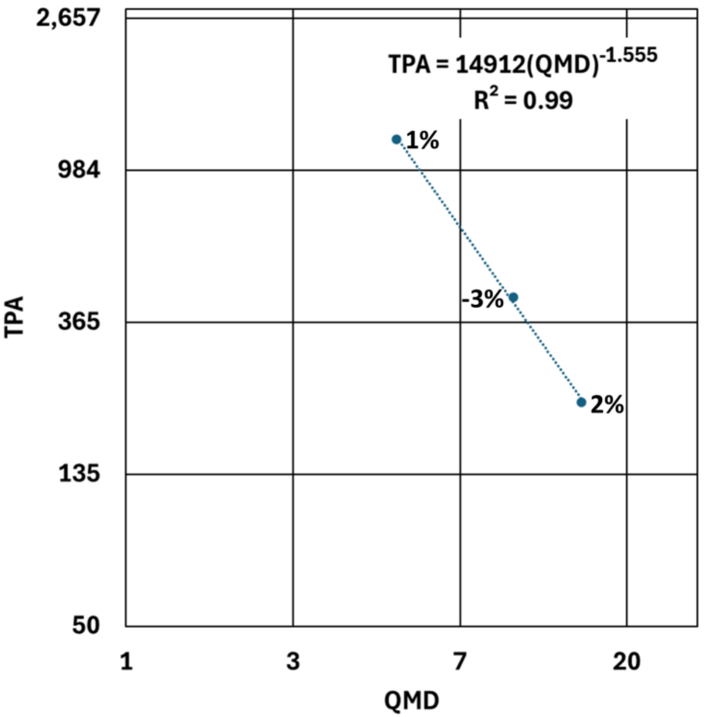
$$SDI = TPA \times \left(\frac{QMD}{10}\right)^{1.605}$$

$$RD = {}^{SDI}/_{SDImax}$$

Major Findings

CUSTOM EXPONENT COMPUTATION

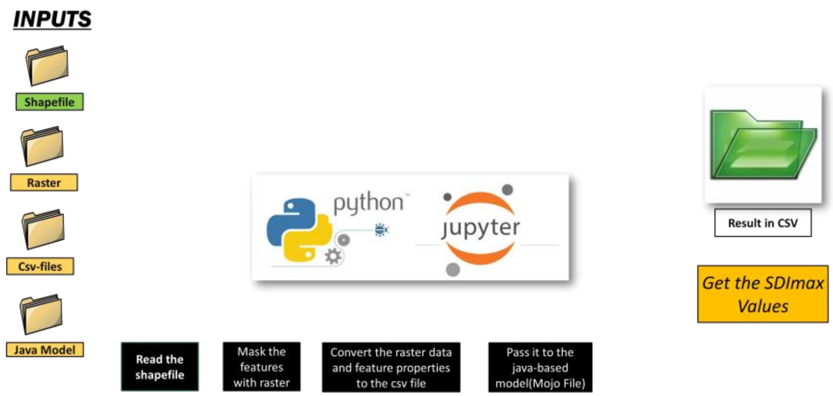
- One time computation of SDI max for a range of QMDs and User Inputs (initial stand metrics, location)
- Fit power functions to the X-Y pairs of predicted max TPA and associated QMD
- Power function exponent is the slope required to compute SDI
- Integrate slope coefficients into User database for future RD computation after inventory updates
  - No need to re-run SDImax model to update RD

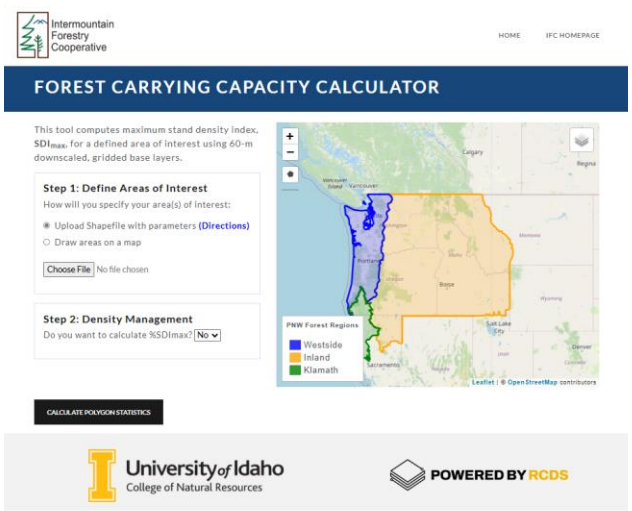


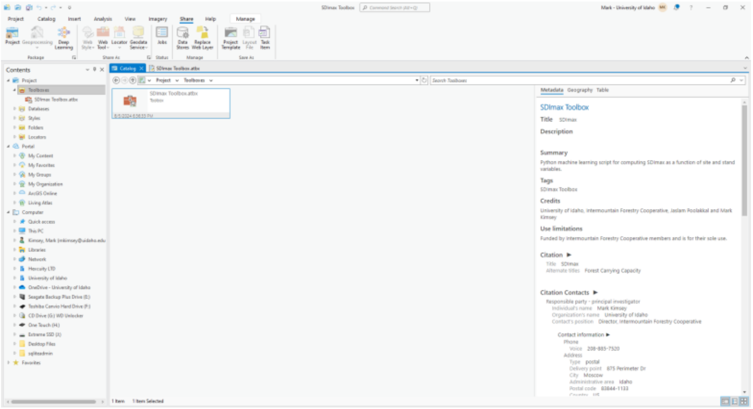
Deliverables

- SDImax models are being made available in:
  - Jupyter Notebook Python code
  - Toolbox for ESRI's ArcGIS Pro platform
  - Web deployment script Java/Leaflet/Python/Flask

- Synthesis journal publication CY25

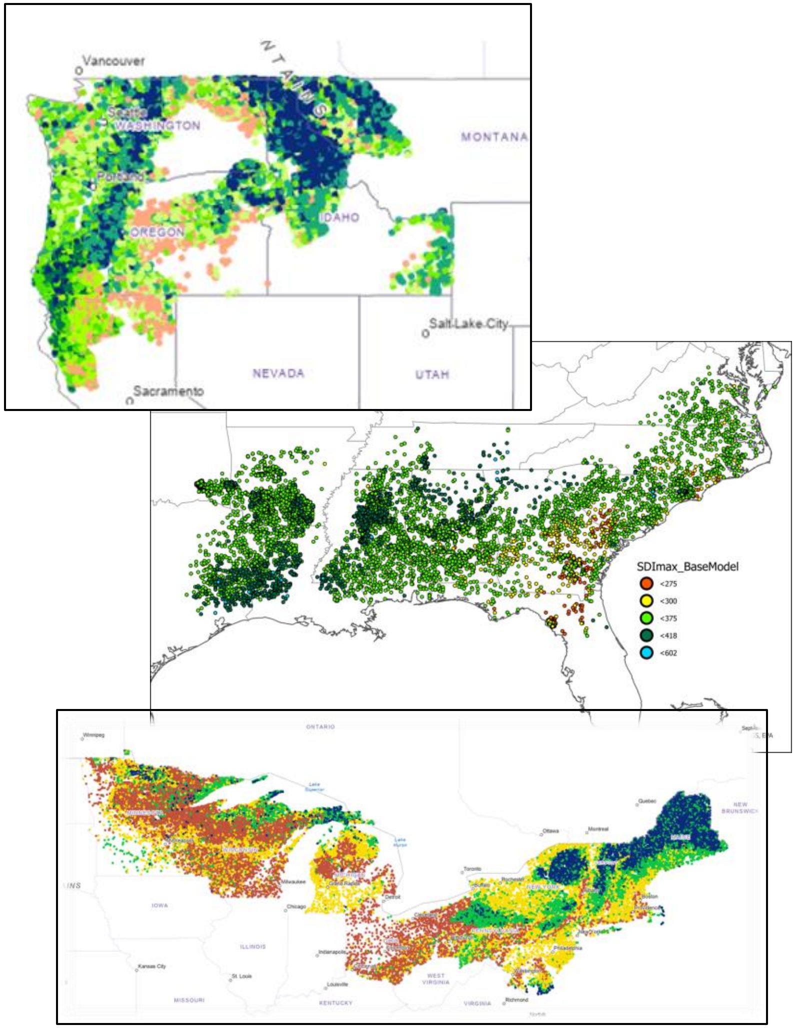






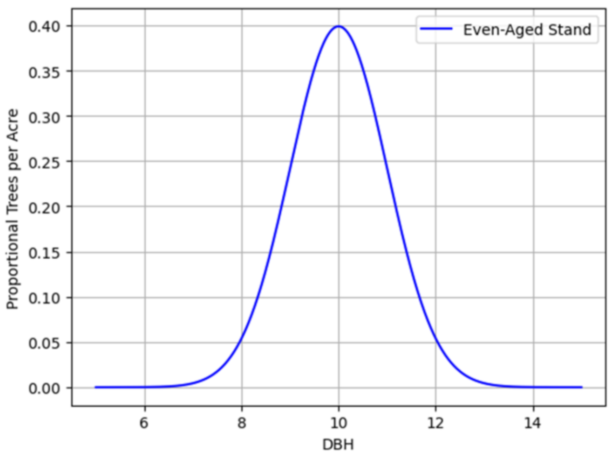
Company Benefits

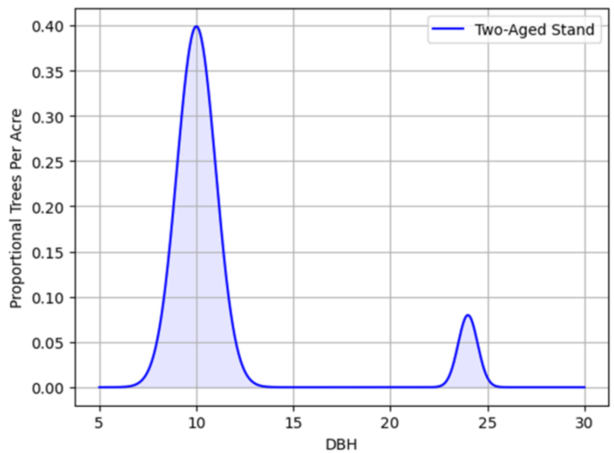
- Consistent modeling methods and seamless prediction layers across stakeholder ownership, regardless of US Region
- Tailored SDImax estimates by unique ownership Stand ID, allowing for:
  - Identification of target species for thinning and retention
  - Target densities reflective of site resources and management objectives
  - Determine effects of species conversion on site carrying capacity and its effects on long-term growth and yield
  - Improved growth and yield estimates in Forest Vegetation Simulator through use of Keyword SDIMAX
  - Identify effects of projected climate shifts on forest carrying capacity

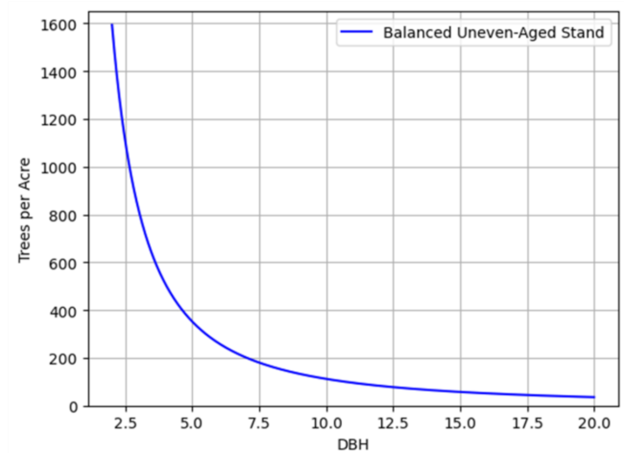


Future Plans

- Translate SDI metrics into more commonly used BA thinning prescriptions
- Proportionally distribute a target RD (SDI/SDImax) across a range of desired diameter distributions that achieves basal area targets (utilizing the summation SDI method)







Summary

- Thank you to NSF and all regional project partners and Cooperatives for financial and data support – truly a team effort that would not have been possible without
- All objectives met:
  - Standardized methods across regions
  - Site-Species driven analytics
  - Robust machine learning models
  - Flexible models for assessing projected climate impacts on forest carrying capacity
  - Deployed for operational use across the US
- Expansion underway to incorporate beetle impacts on pine mortality