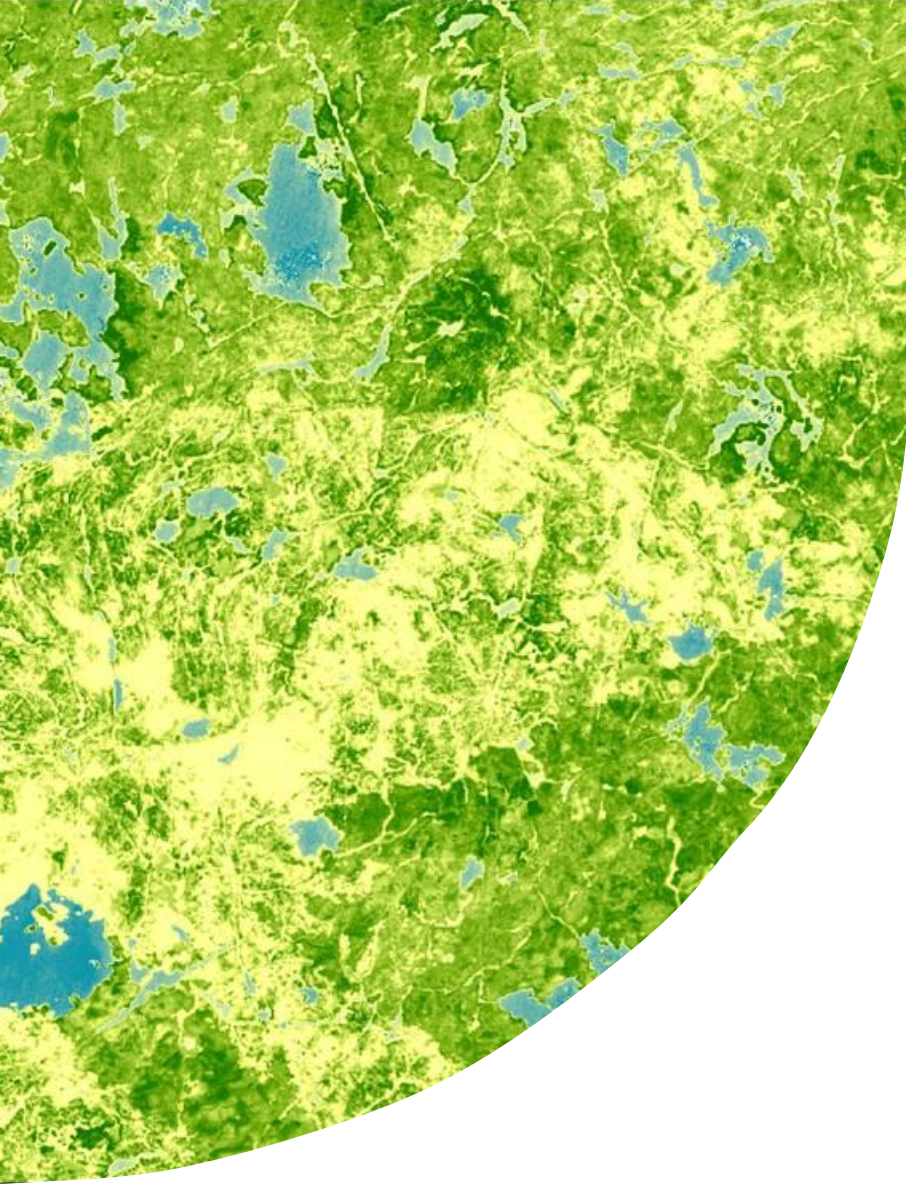




National Aeronautics and
Space Administration



Northern Minnesota Ecological Conservation

*Exploring Classification of Forest Cover Types
in Northern Minnesota Using Earth
Observations*

Betty Brown, Nettie Hitt, Isabelle Leconche
& Hailey Phillips (Analytical Mechanics
Associates)

Idaho – Pocatello | Summer 2025





Background

- To make informed management decisions, forest managers must know which trees are located
- Forest inventories provide critical data to agencies responsible for management of large public land
- Remote sensing scales-up tree species classification across large areas

Image Credit: Superior National Forest



Partner & Community Concerns

Partner

Minnesota Department of Natural Resources (MNDNR)

Division of Forestry, Resource Assessment Program
Manages the Superior National Forest (SNF)

Community Concerns

Current tree species cover data is insufficient to inform management decisions about:

- Logging
- Wildfire prevention & recovery
- Biodiversity conservation



Objectives



Improve existing species classification model accuracy



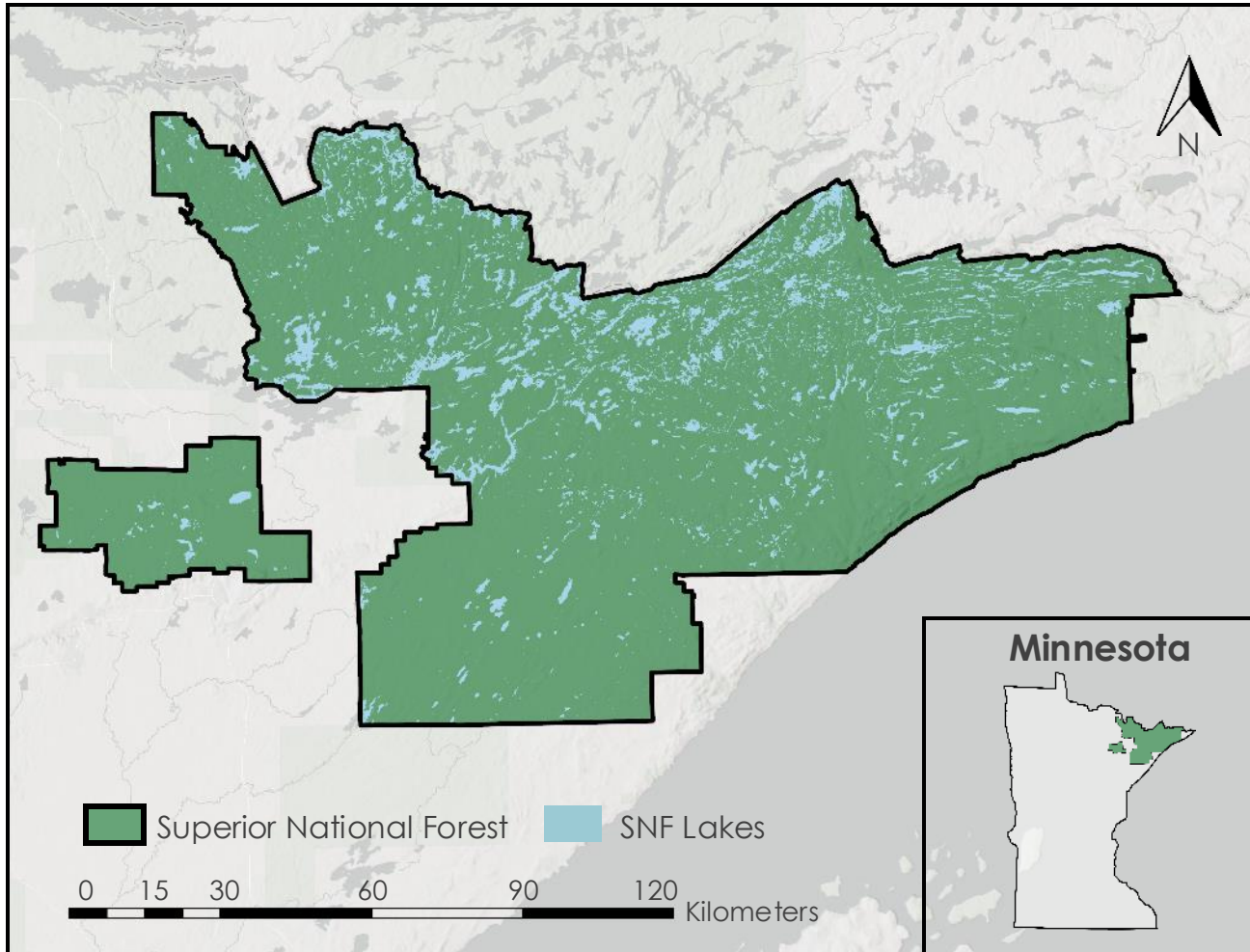
Map current tree species distribution in Superior National Forest



Determine forest composition change between 2021 & 2024



Study Area & Period



Esri, CGIAR, USGS, Sources: Esri, TomTom, Garmin, GAO, NOAA, USGS, OpenStreetMap contributors, and the GIS User Community, Sources: Esri; U.S. Department of Commerce, Census Bureau; U.S. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), National Geodetic Survey (NGS)



The Superior National Forest

- 1.2 million hectares of federally managed forest

Study Period

- Spring & Fall 2021
- Spring & Fall 2024

Earth Observations

Landsat-8 OLI
NASA



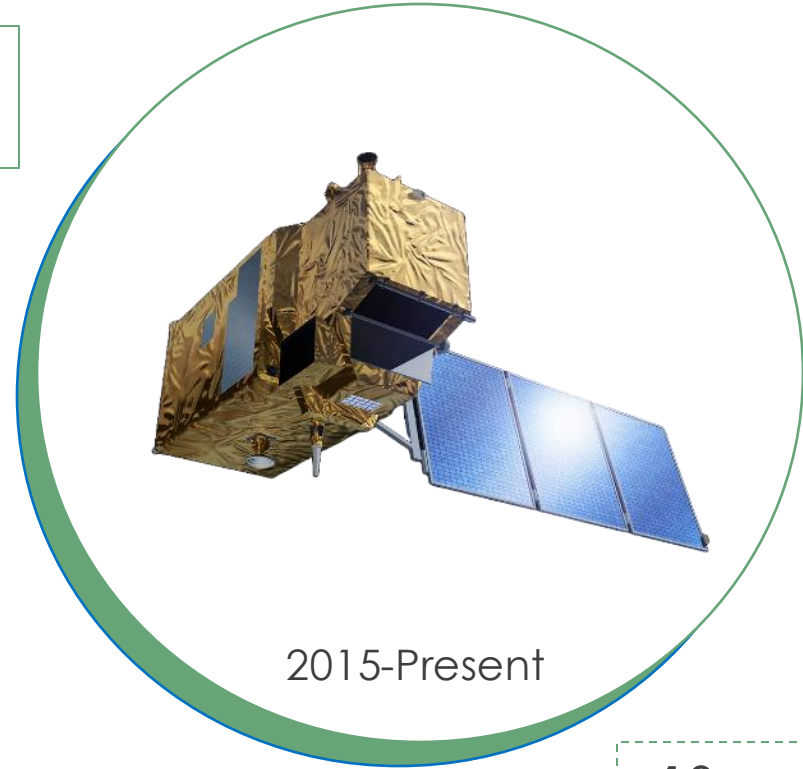
2013-Present

30-m

30-meter
resolution



Sentinel-2 MSI
ESA



2015-Present

10-m

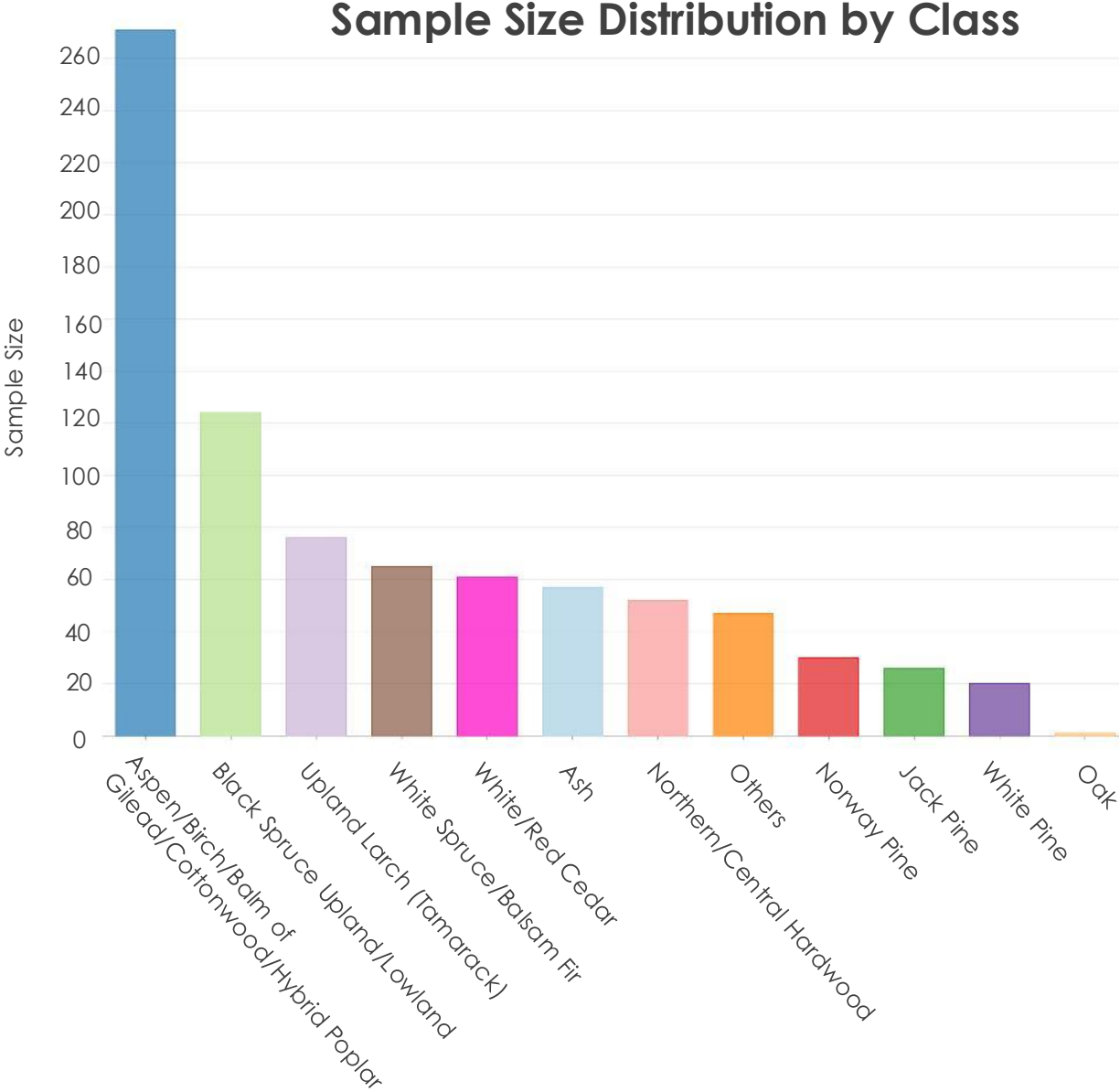
Harmonized Landsat-Sentinel-2 (HLS) Product

Image Credits: NASA, ESA



Tree Species Classification Variables

- Tree Species Classes**
- Ash
 - Oak
 - Jack Pine
 - White Pine
 - Norway Pine
 - White/Red Cedar
 - White Spruce/Balsam Fir
 - Upland Larch (Tamarack)
 - Northern/Central Hardwood
 - Upland/Lowland Black Spruce
 - Aspen/Birch/Balm of Gilead/
Cottonwood/Hybrid Poplar
 - Other

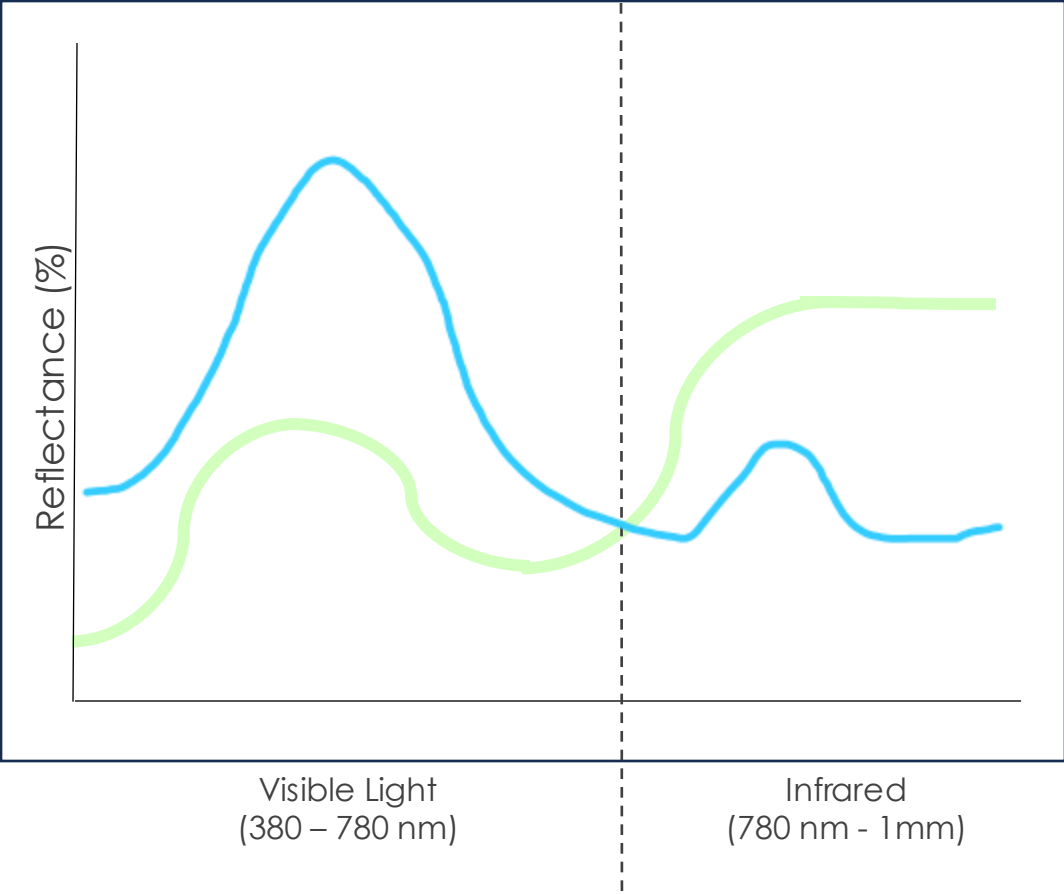


Tree Species Classification Variables

Tree Species Classes

- Ash
- Oak
- Jack Pine
- White Pine
- Norway Pine
- White/Red Cedar
- White Spruce/Balsam Fir
- Upland Larch (Tamarack)
- Northern/Central Hardwood
- Upland/Lowland Black Spruce
- Aspen/Birch/Balm of Gilead/
Cottonwood/Hybrid Poplar
- Other

Spectral Signatures

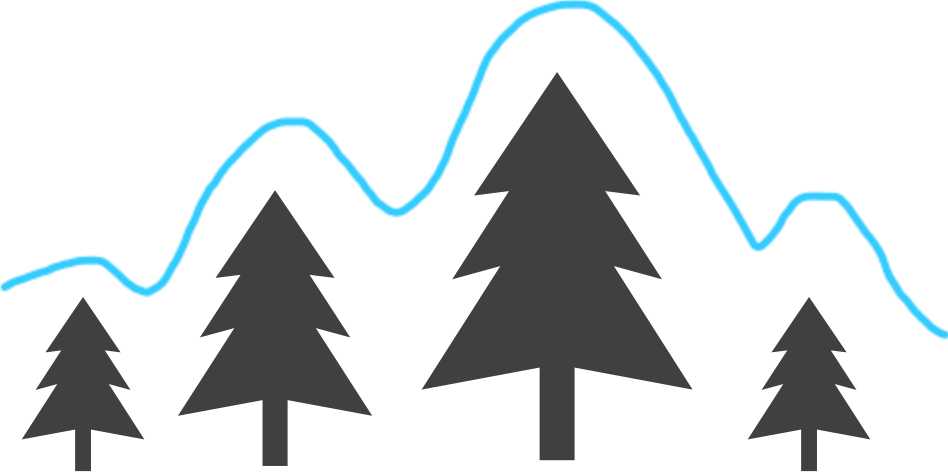


Tree Species Classification Variables

Tree Species Classes

- Ash
- Oak
- Jack Pine
- White Pine
- Norway Pine
- White/Red Cedar
- White Spruce/Balsam Fir
- Upland Larch (Tamarack)
- Northern/Central Hardwood
- Upland/Lowland Black Spruce
- Aspen/Birch/Balm of Gilead/
Cottonwood/Hybrid Poplar
- Other

Topographic

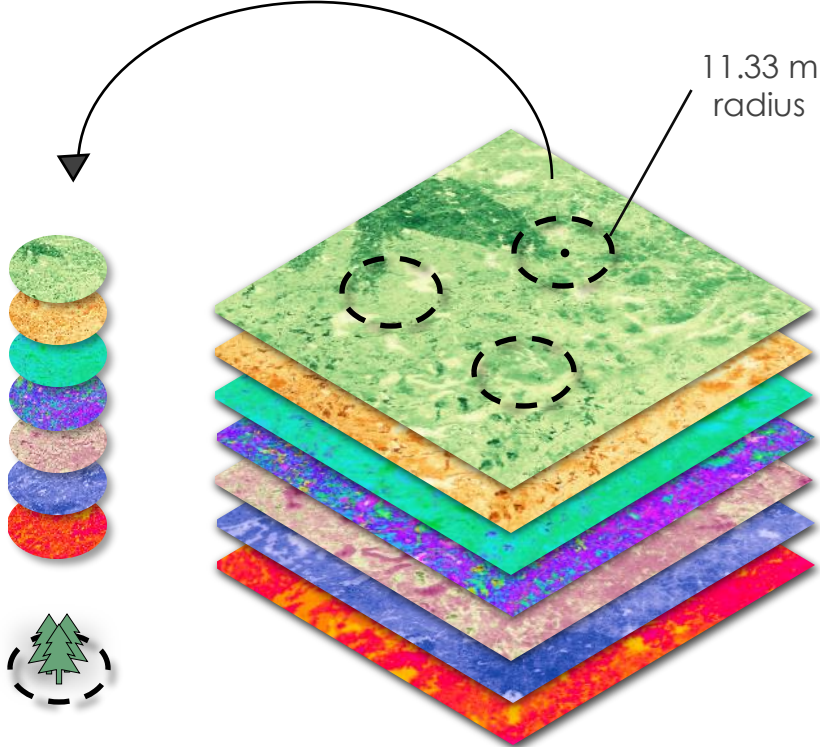


Tree Species Classification Variables

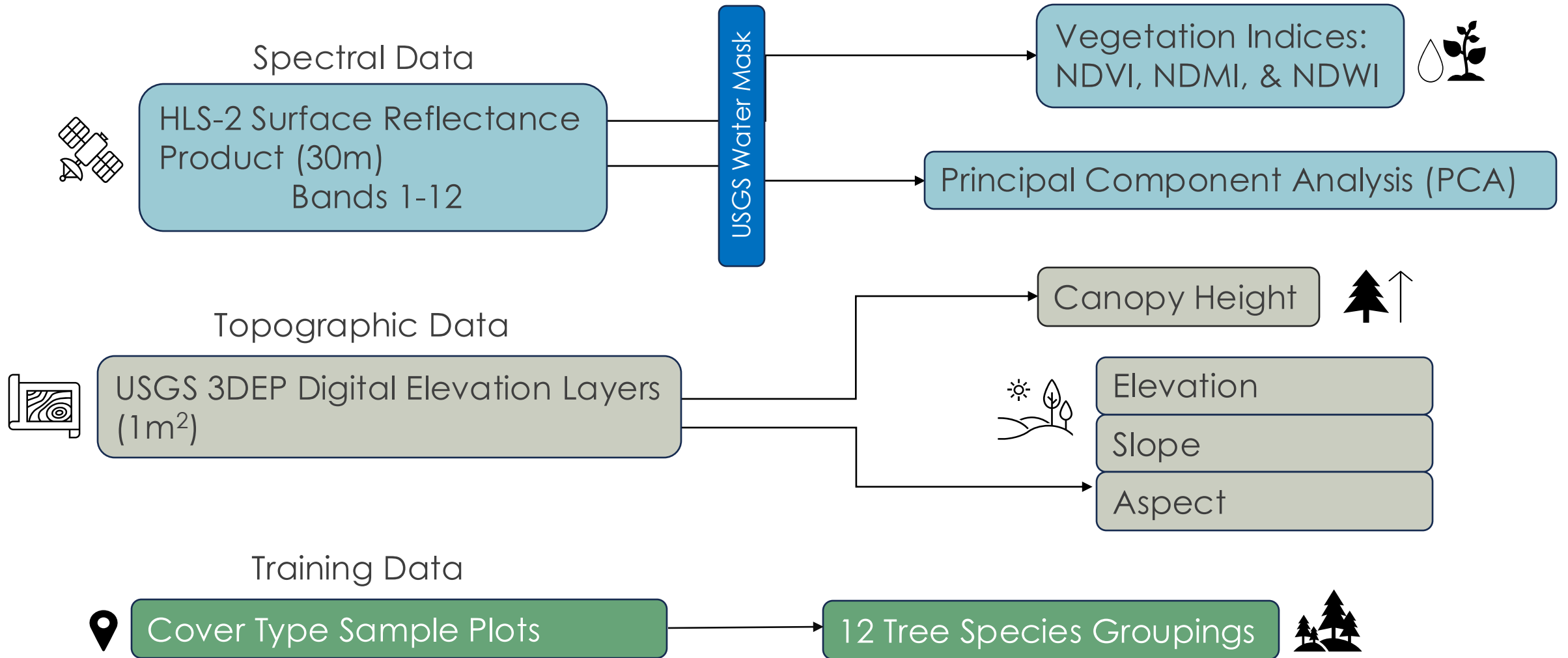
Tree Species Classes

- Ash
- Oak
- Jack Pine
- White Pine
- Norway Pine
- White/Red Cedar
- White Spruce/Balsam Fir
- Upland Larch (Tamarack)
- Northern/Central Hardwood
- Upland/Lowland Black Spruce
- Aspen/Birch/Balm of Gilead/
Cottonwood/Hybrid Poplar
- Other

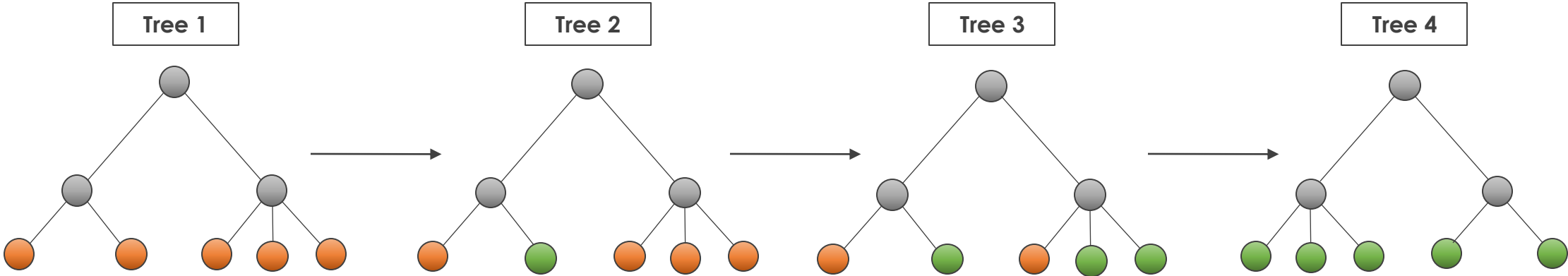
Plot Training Data + Variables



Preparing Model Inputs



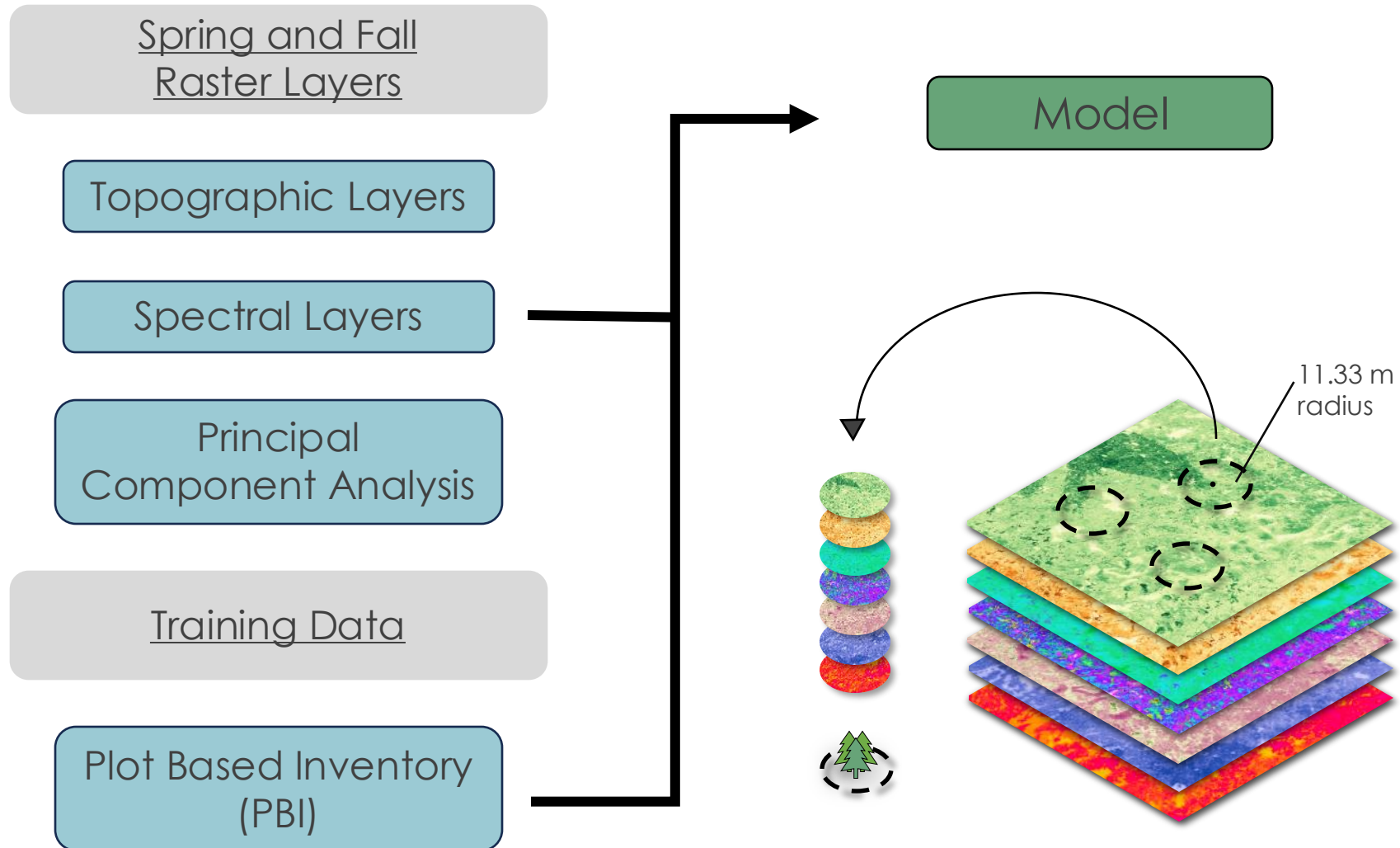
Gradient Boosted Classification Model



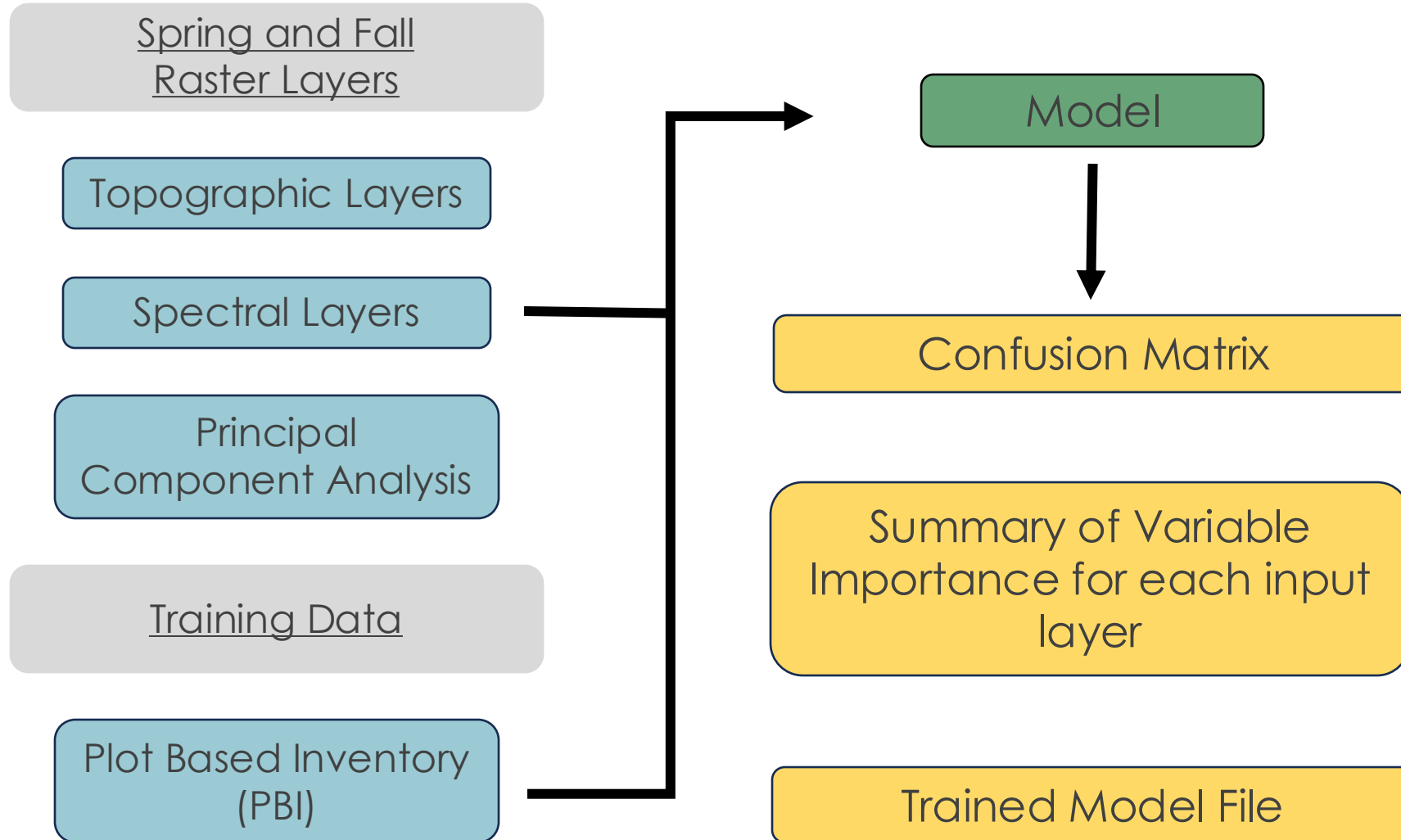
Uses decision trees to build a machine learning model

Builds trees sequentially, learning and improving accuracy as it goes

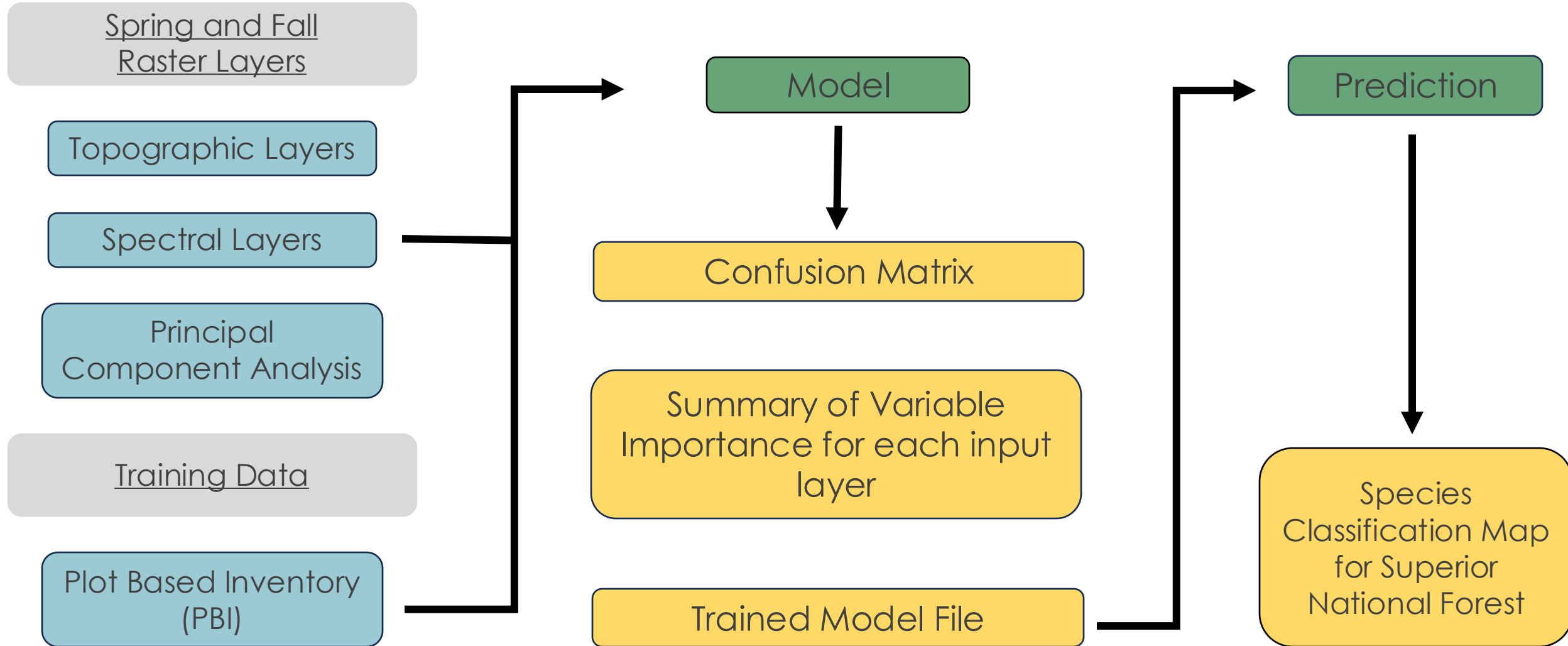
Model Workflow Diagram



Model Workflow Diagram



Model Workflow Diagram



Results

Highest accuracy version
of the model

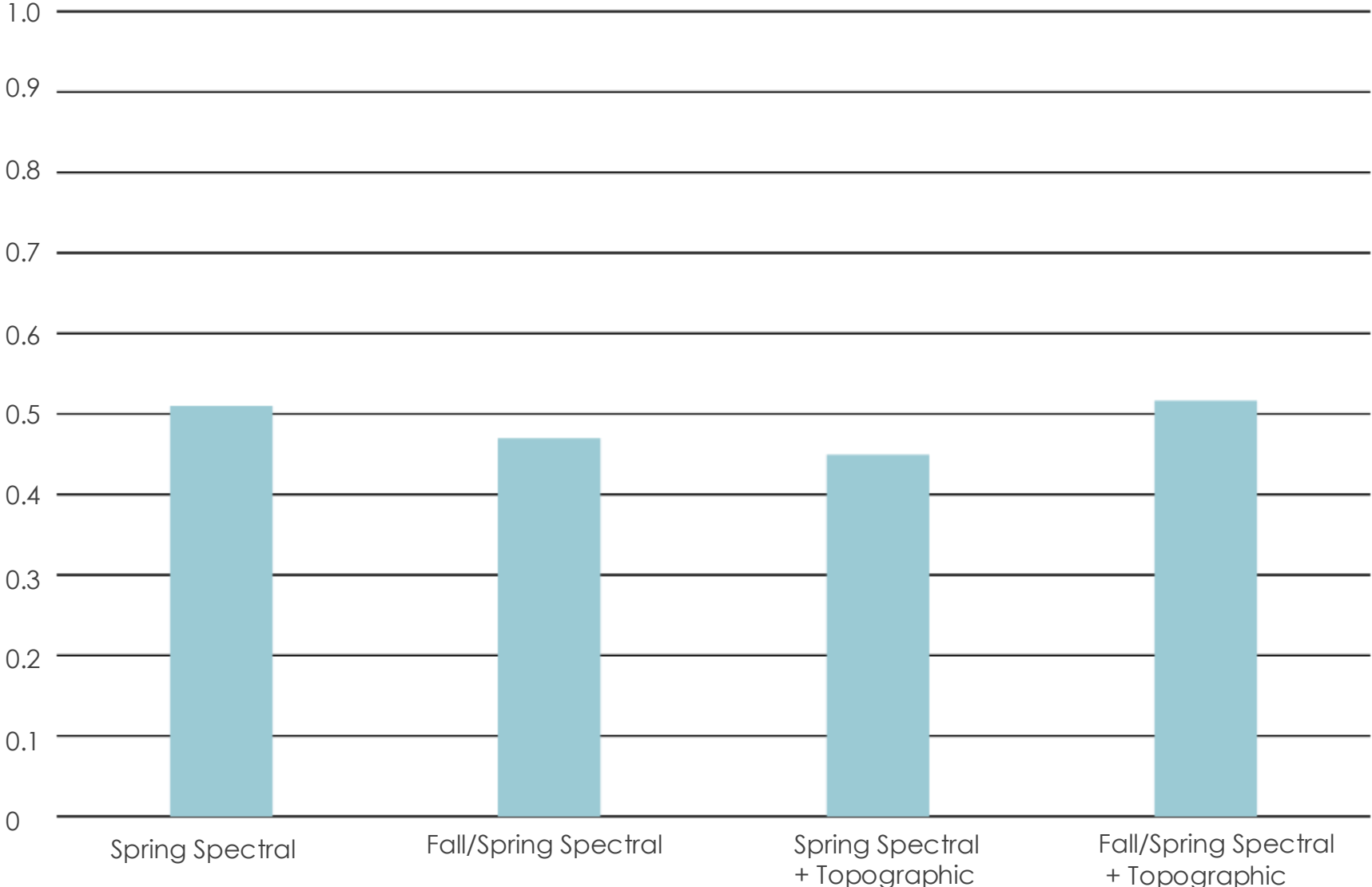
Updated land cover
classification map

Land cover change from
2021 to 2024

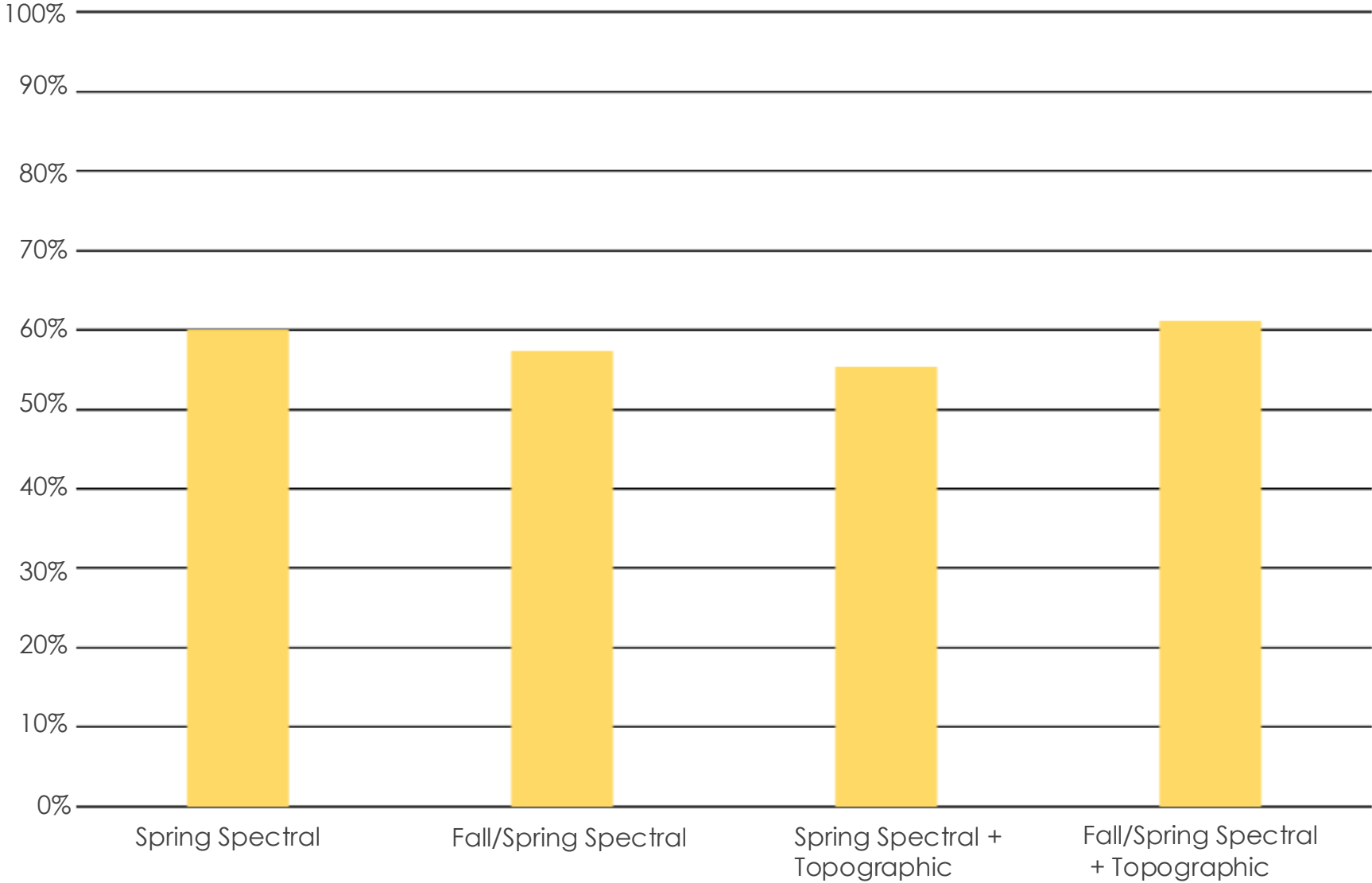
Variable Importance



Kappa Index of Agreement



Overall Classification Accuracy



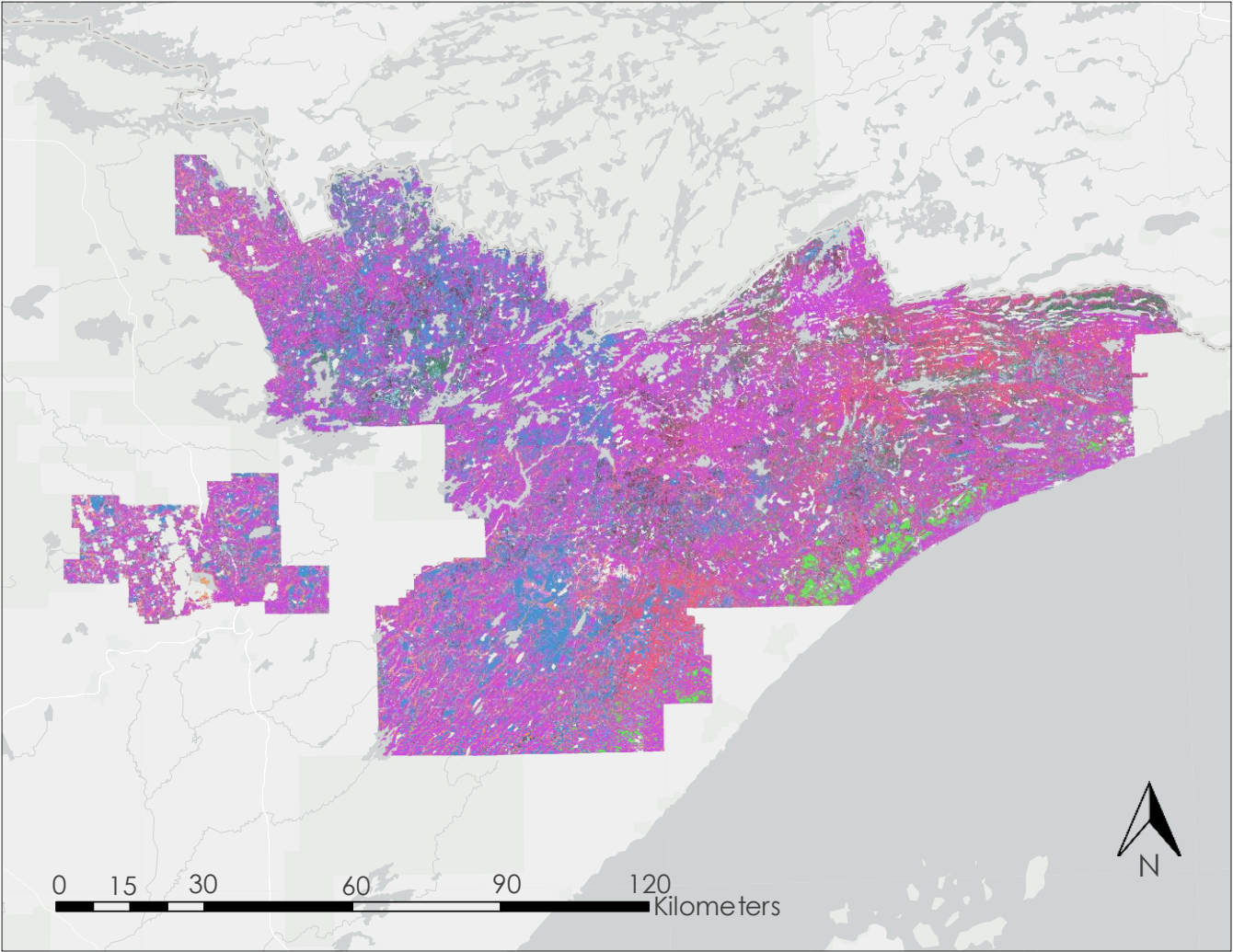
Confusion Matrix

- 1 = Ash
- 2 = Aspen/Birch/Balm of Gilead/Cottonwood/Hybrid Poplar
- 3 = Black Spruce Upland/Lowland
- 4 = Jack Pine
- 5 = Northern/Central Hardwood
- 6 = Norway Pine
- 7 = Oak
- 8 = Others
- 9 = Upland Larch (Tamarack)
- 10 = White Pine
- 11 = White Spruce/Balsam Fir
- 12 = White/Red Cedar

	Prediction												Total	PA (%)
	1	2	3	4	5	6	7	8	9	10	11	12		
Truth 1	12	4	0	0	0	0		1	2	0	1	1	26	57.1
Truth 2	17	156	9	2	11	4		13	11	1	20	6	215	62.4
Truth 3	2	3	96	3	0	1		2	11	0	9	5	150	71.1
Truth 4	0	1	0	4	0	1		0	0	0	0	0	6	66.7
Truth 5	0	3	0	0	19	1		0	0	0	1	0	29	79.1
Truth 6	0	1	3	1	0	11		0	0	2	1	2	11	52.3
Truth 7	0	0	0	0	0	0		0	0	0	0	0	0	NA
Truth 8	3	1	4	0	1	0		7	1	0	2	0	28	36.8
Truth 9	0	1	5	1	0	0		5	24	0	0	2	57	63.1
Truth 10	0	2	0	0	0	1		0	0	8	1	0	14	66.7
Truth 11	1	6	4	4	1	1		3	0	0	5	3	15	17.6
Truth 12	0	3	3	3	2	0		1	1	2	4	21	43	52.5
Total	38	181	124	18	34	20		32	50	13	44	40	594	
UA (%)	31.5	86.1	77.4	22.2	55.8	55		21.9	48	61.5	11.4	52.5		OA = 61.1 %



2021 Land Cover Classification Map

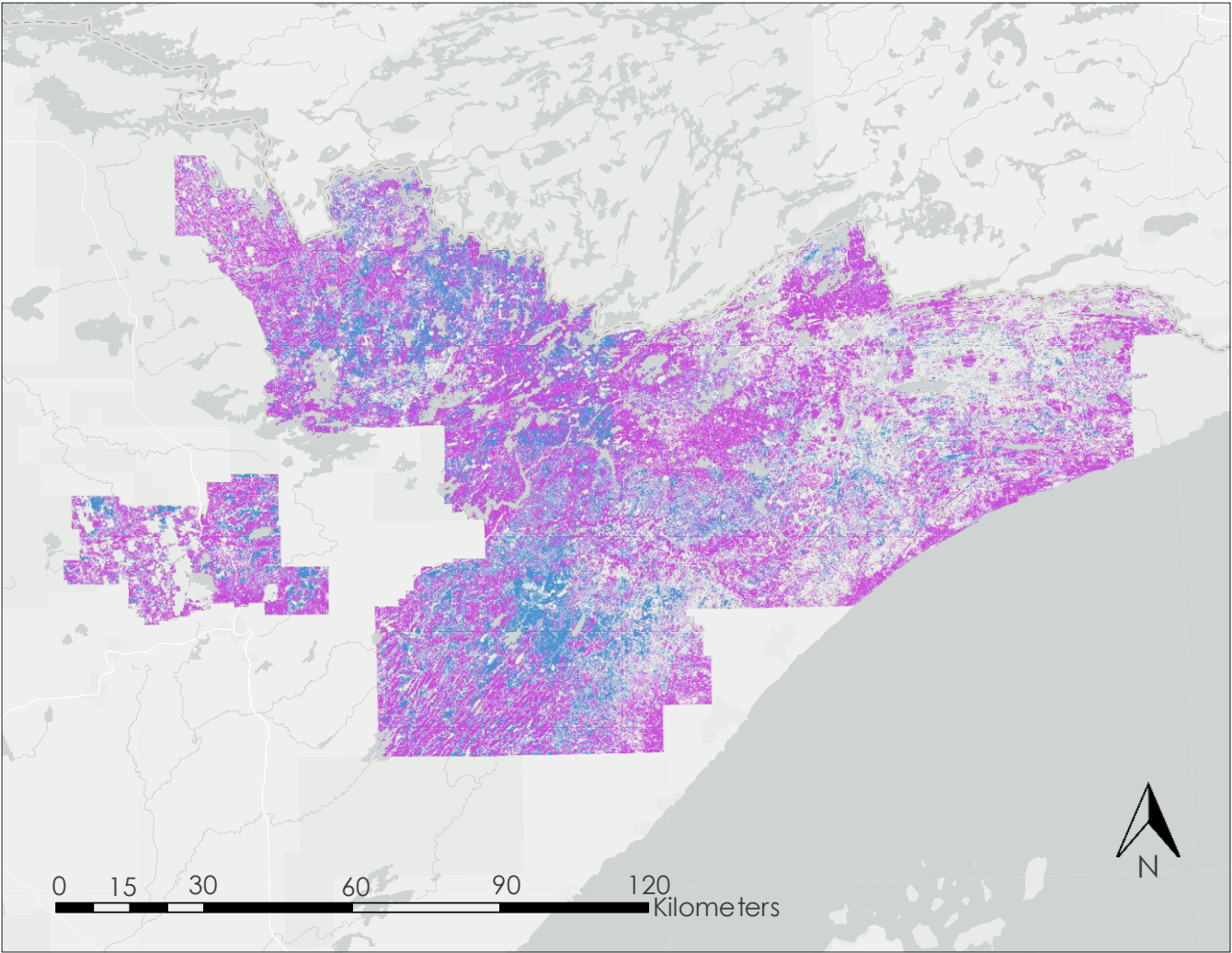


Forest Cover Type



- Ash
- Oak
- Others
- Jack Pine
- White Pine
- Norway Pine
- White/Red Cedar
- White Spruce/Balsam Fir
- Upland Larch (Tamarack)
- Northern/Central Hardwood
- Black Spruce Upland/Lowland
- Aspen/Birch/Balm of Gilead/Cottonwood/Hybrid Poplar

Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

2021 Most Accurate Classes



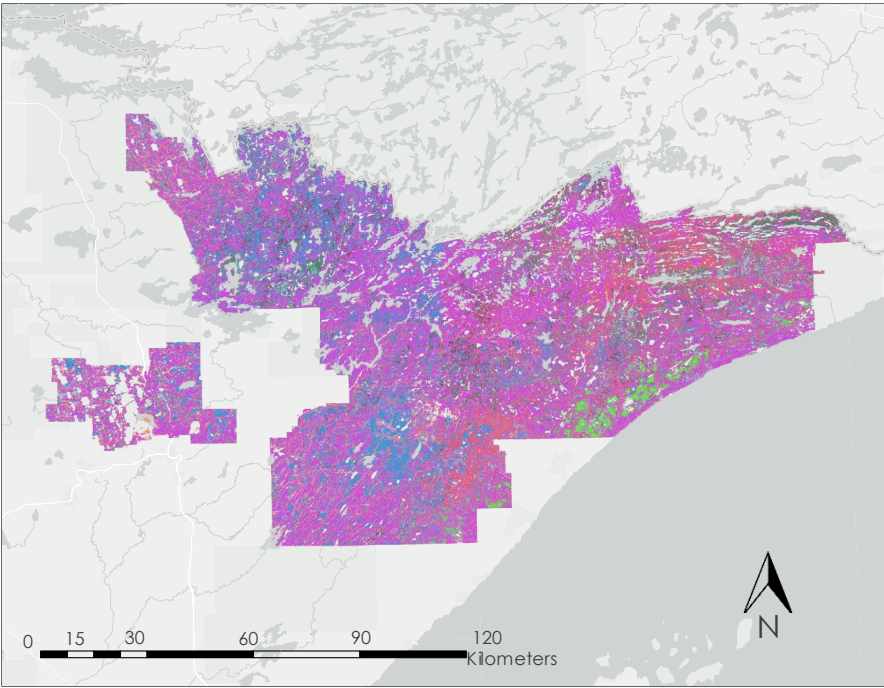
Forest Cover Type

-  Black Spruce Upland/Lowland
-  Aspen/Birch/Balm of Gilead/Cottonwood/Hybrid Poplar

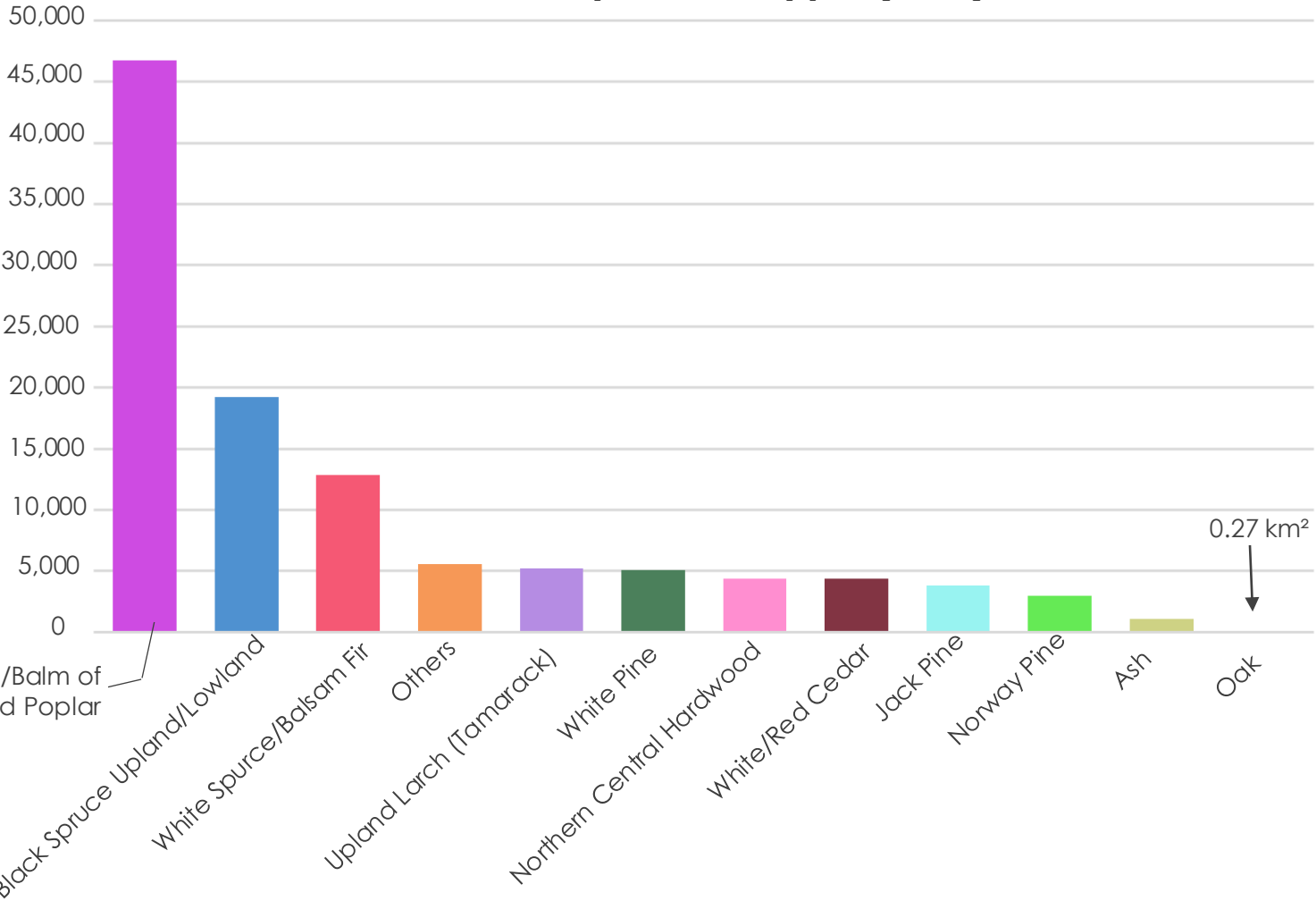
- Black Spruce Upland/Lowland
User Accuracy: 77.4%
- Aspen/Birch/Balm of
Gilead/Cottonwood/Hybrid
Poplar User Accuracy: 86.1%

Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

2021 Land Cover Classification Map



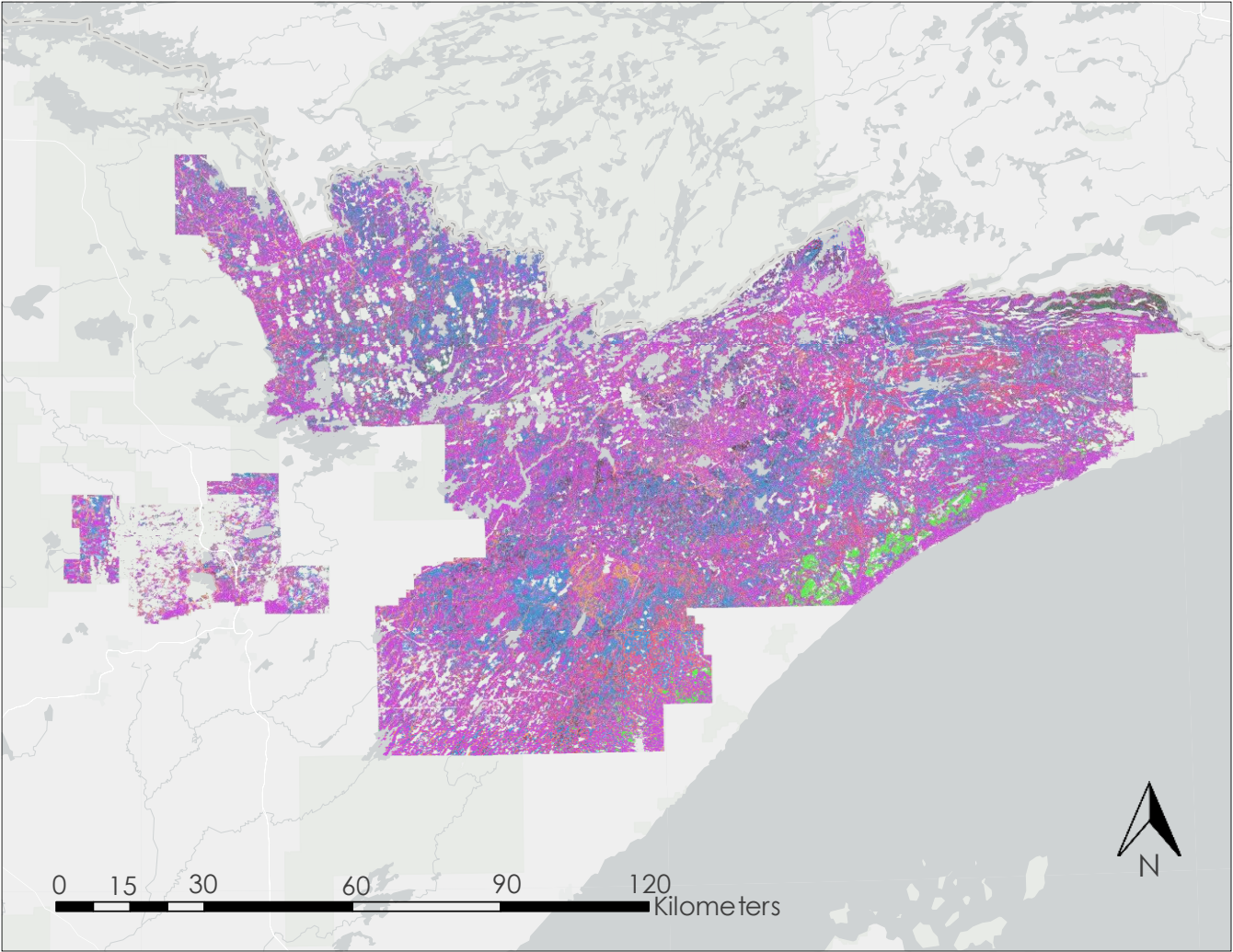
Area by Cover Type (km²)



Aspen/Birch/Balm of Gilead/Cottonwood/Hybrid Poplar

Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

2024 Land Cover Classification Map

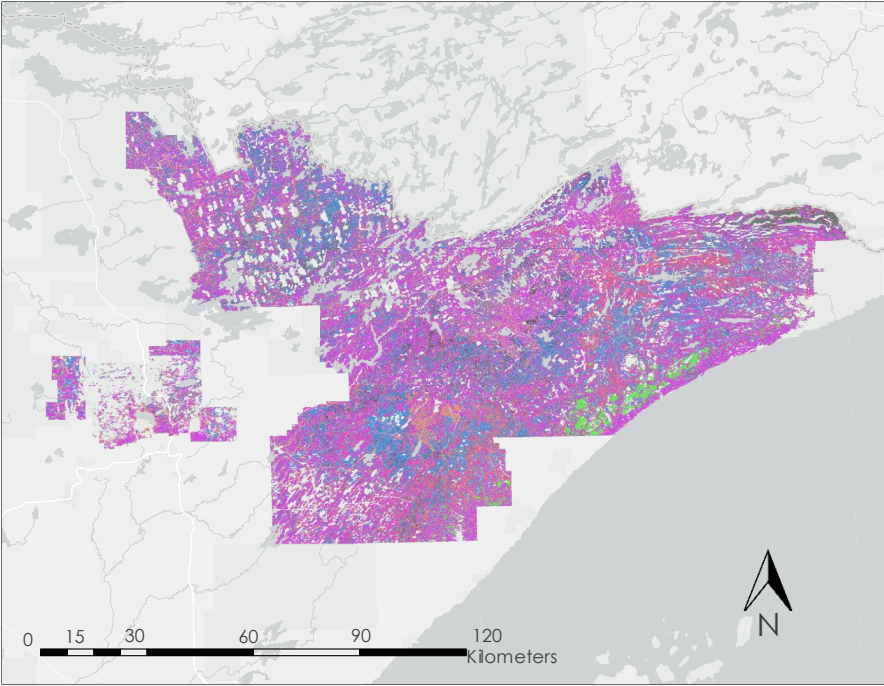


Forest Cover Type

- Ash
- Oak
- Others
- Jack Pine
- White Pine
- Norway Pine
- White/Red Cedar
- White Spruce/Balsam Fir
- Upland Larch (Tamarack)
- Northern/Central Hardwood
- Black Spruce Upland/Lowland
- Aspen/Birch/Balm of Gilead/Cottonwood/Hybrid Poplar

Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

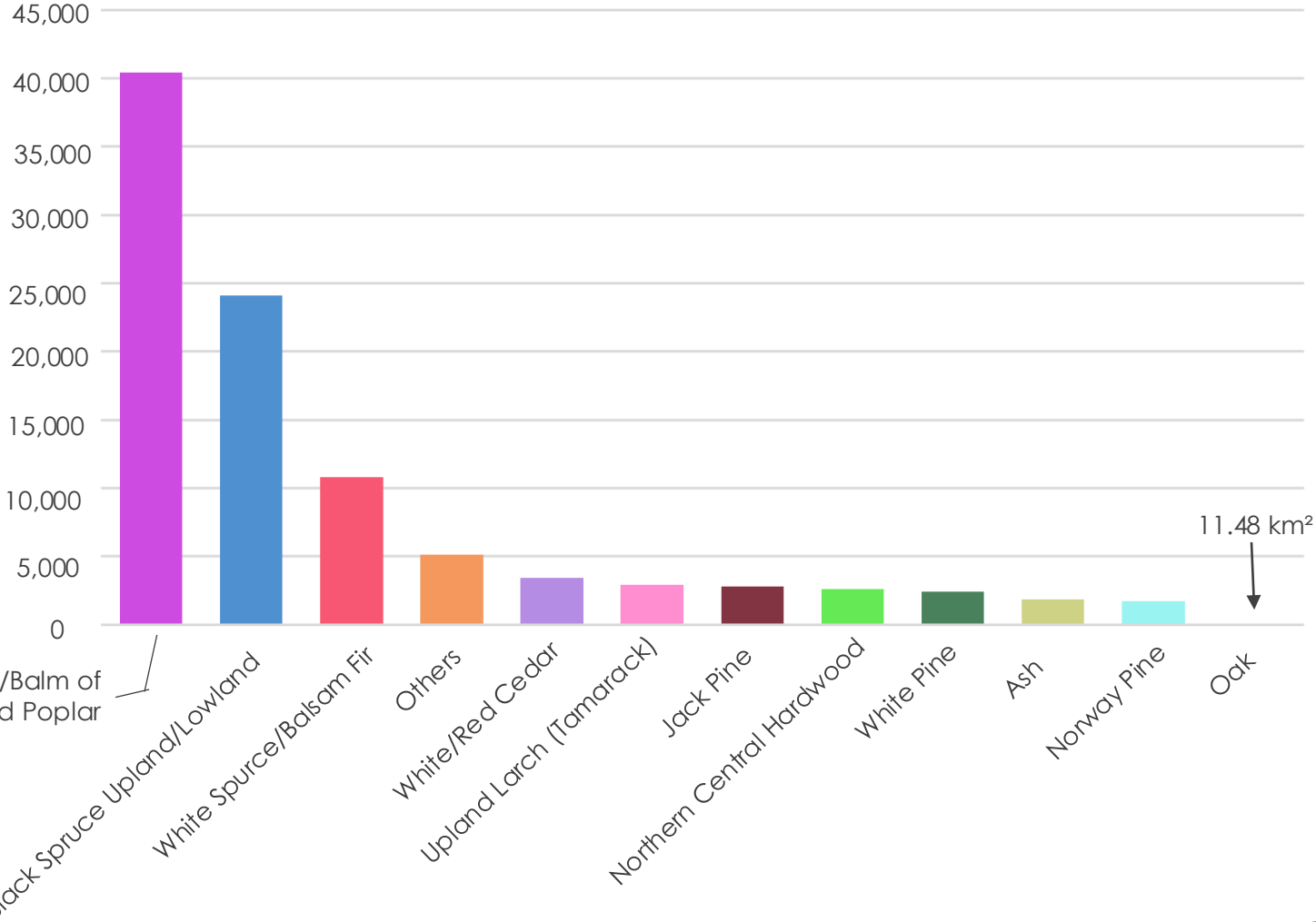
2024 Land Cover Classification Map



Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

Aspen/Birch/Balm of Gilead/Cottonwood/Hybrid Poplar

Area by Cover Type (km²)



Variable Importance

Canopy Height

Ranked most important across all models that included topographic data

Spring SWIR (short-wave infrared)

Ranked within top 5 variables of importance across all model variations

Seasonality

Multi vs single season imagery



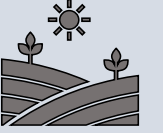
Errors and Uncertainty



Image Credit: Superior National Forest



Input Variables



- Canopy height
- LiDAR temporal resolution
- LiDAR spatial resolution

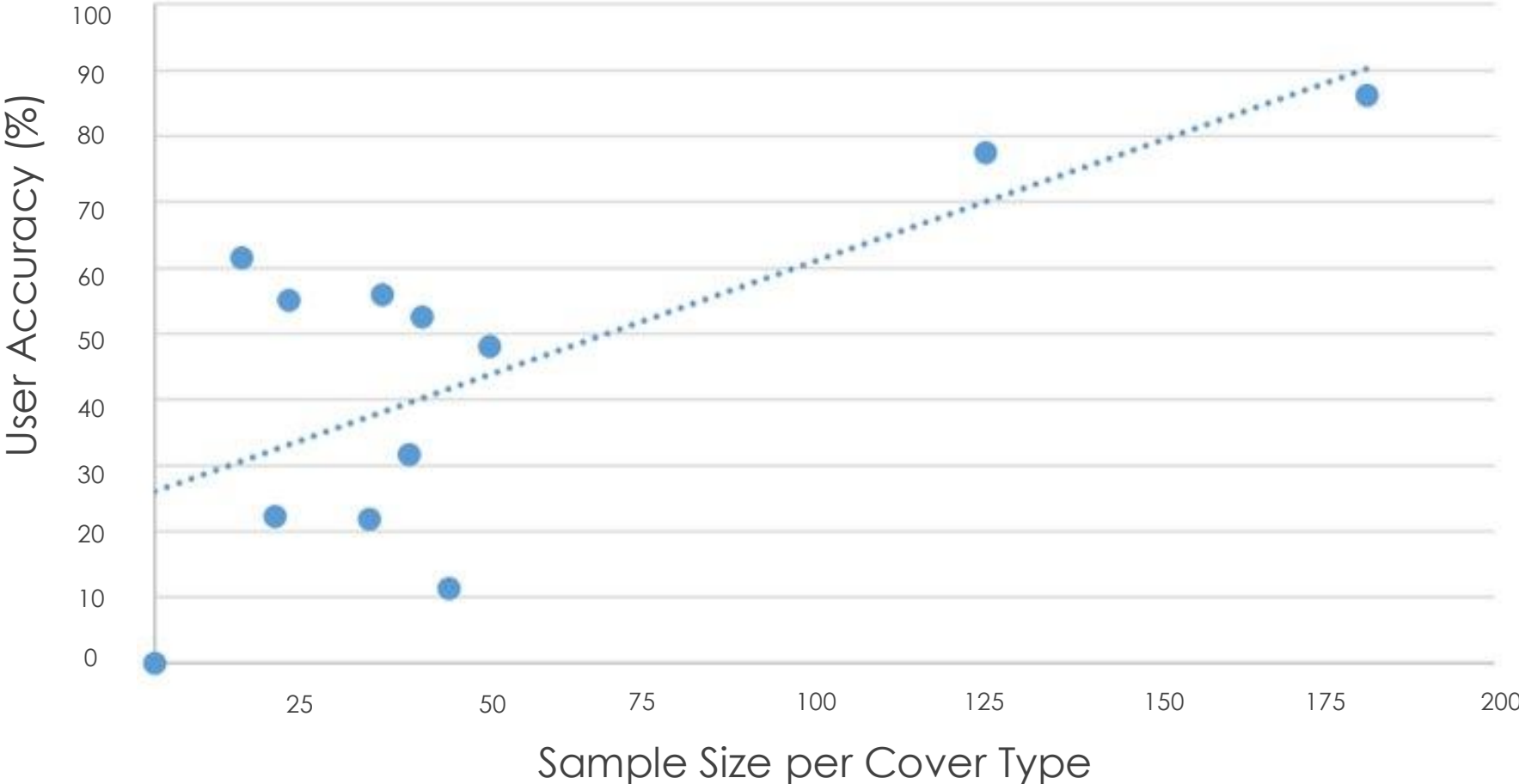
Training Data



- Positional accuracy
- Point versus plot format
- Sample size

Comparison of Sample Size Class to User Accuracy

Relationship Between Sample Size and Accuracy



Feasibility and Implementation

Classification Model

Our project demonstrates the feasibility of using Earth Observations in conjunction with a machine-learning model to classify forest types for the Superior National Forest.

Updated Tree Species Classification Map

With current model accuracy, it is not yet feasible to provide a high accurate forest type maps for 2021 & 2024.

Partner Implementation

With a new model methodology and more data, our partner can pursue further model refinements to achieve even higher model accuracy.



Conclusions



Image Credit: Superior National Forest

- We increased overall model accuracy through inclusion of spectral and topographic data
- Canopy height and spring short wave infrared bands was determined to be the most important variables to include in model development
- Larger or more balanced sample sizes would result in a more reliable model



Acknowledgements

- **Project Partners:** Kangsan Lee, Lucas Spaete (MNDNR)
- **Science Advisor:** Keith Weber (Idaho State University, GIS Training and Research Center)
- **NASA DEVELOP Node Lead:** Isaac Goldings (Idaho – Pocatello)



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