Partitioning Tree Species Biomass across Boreal North America

Goetz (TE 2021)

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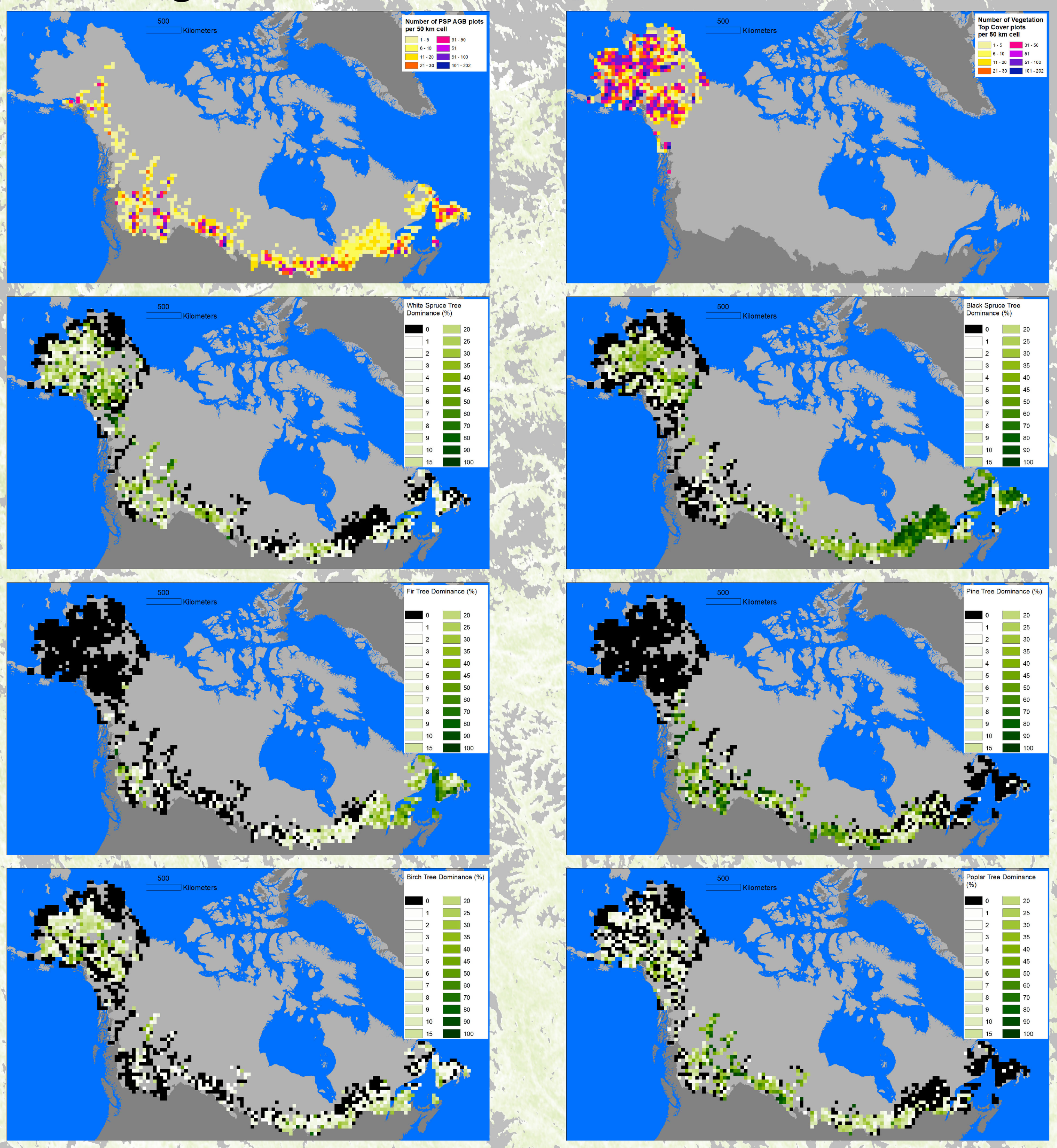
Background

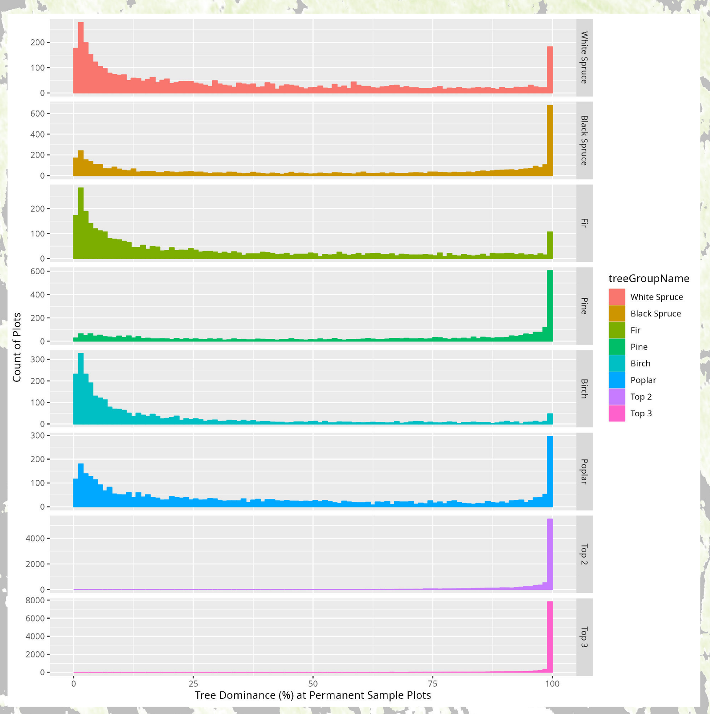
There are multiple efforts to map total above-ground woody biomass across the Arctic and boreal domains, using a combination of field measurements, airborne and spaceborne lidar, and satellite imagery. Much of the forested area is composed of a mixture of tree species, which can affect factors including fire behavior and recovery and wildlife and human use. Here we apply an extensive network of permanent sample plots (PSPs) across boreal Canada and Alaska, and tree top cover data from vegetation plots in Alaska and Yukon, to partition tree dominance for key species groups across boreal North America. Tree dominance for each group is Group AGB or Top Cover divided by Total Tree AGB or Tree Top Cover, or zero when no tree species are present.

Tree Species Groups

Tree Species Group	Scientific Names	Common Names
White Spruce	*Picea glauca, Picea lutzii, Picea engelmannii*	White spruce, Lutz spruce, Engelmann spruce
Black Spruce	*Picea mariana, Picea rubens*	Black spruce, Red spruce
Fir	*Abies balsamea, Abies lasiocarpa, Abies* sp.	Balsam fir, Subalpine fir, Fir sp.
Pine	*Pinus* sp., *Pinus banksiana, Pinus contorta, Pinus monticola, Pinus ponderosa, Pinus resinosa, Pinus strobus*	Pine sp., Jack pine, Lodgepole pine, Western white pine, Ponderosa pine, Red pine, Eastern white pine
Birch	*Betula alleghaniensis, Betula kenaica, Betula neoalaskana, Betula papyrifera,* Betula sp.	Yellow birch, Kenai birch, Alaskan birch, Paper birch, Birch sp.
Poplar	*Populus balsamifera, Populus grandidentata, Populus tremuloides*	Balsam poplar, Large-tooth aspen, Trembling aspen

Training Data





Plots with <0.5% AGB tree dominance have been removed from histogram plots (left). Some taxa (e.g. Black Spruce and Pine) are more likely to occur in single species stands than others (e.g. Fir or Birch). At almost all plots, the top 1 to 3 species account for nearly all the tree AGB.

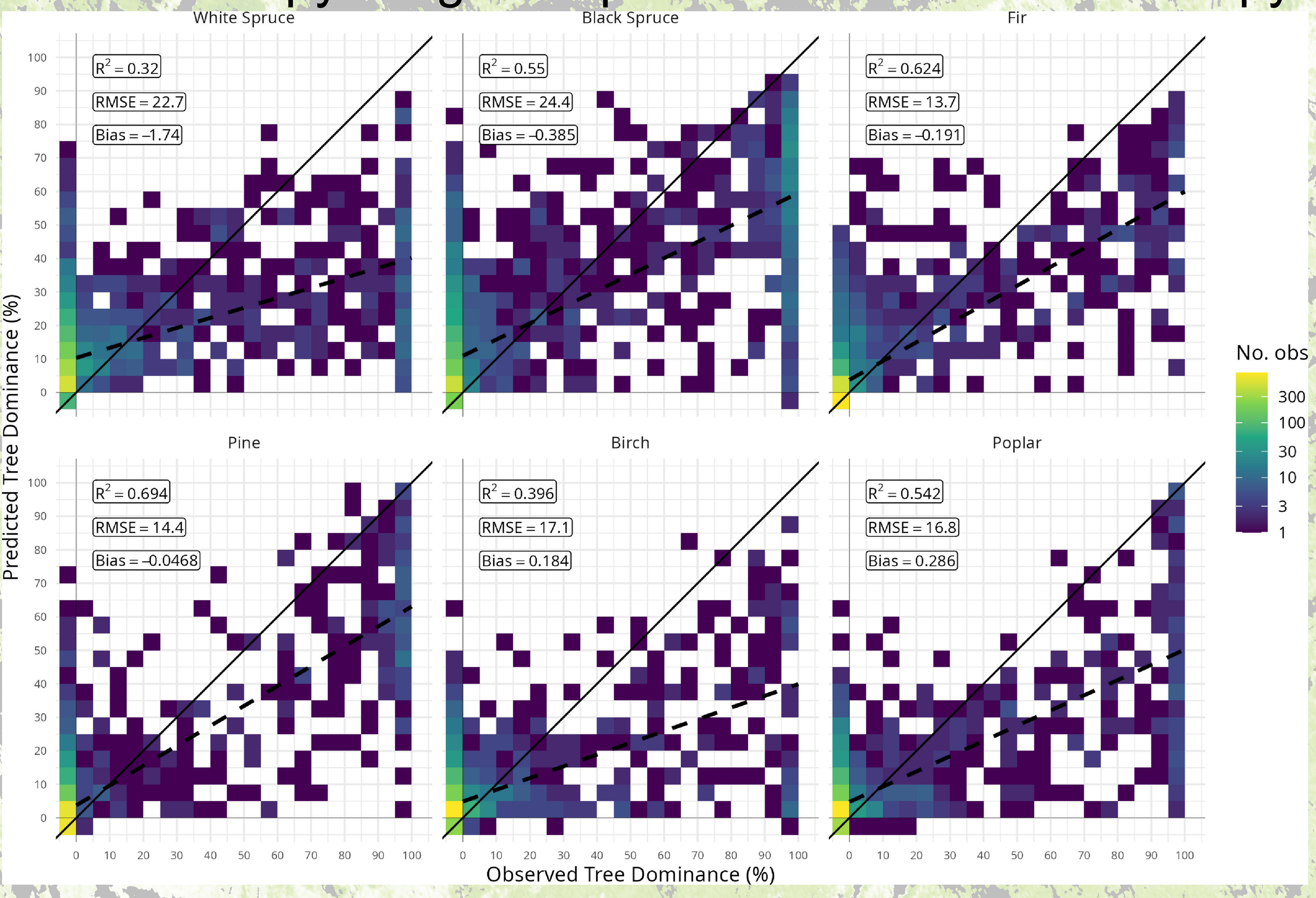
Modeling Methods

We updated and extended a suite of spectral covariates for the training and prediction of the time-series tree dominance models. The updated spectral covariates are based on Landsat TM, ETM+, and OLI data collected over 1985–2022. Seasonal synthetic reflectance composites (Zhu 2015) are geneated using the Measures Version 1 CCDC product available on Google Earth Engine. Environmental covariates representing topographic, climatic, permafrost, hydrographic, and phenological gradients across the study area are being extended from the ABoVE domain to cover eastern Canada; these are constant for all models. Currently the only environmental covariates included are 4 topographic metrics from the Copernicus DEM GLO-30 Global 30m Digital Elevation Model.

For the initial maps, we trained a random forest model (100 trees) with 80% of the training data, reserving 20% for validation. For final maps, we will apply two stochastic gradient-boosting models to map tree dominance based on the training data and spatial predictors, following the approach from Macander et al. 2022. A binary probability model will be applied to map tree species distribution and a regression model will be applied to map tree dominance. The two models will be combined for a final prediction of tree dominance.

The PSP dataset includes only plots with trees (while the Top Cover dataset includes data from many treeless plots). Areas of low vegetation structure are masked from the output map. For the current version, this mask is based on an aggregation (to 300 m pixels) of the Tolan et al. (2023) Global Canopy Height map. Pixels with a mean canopy height < 10 cm are set to zero.

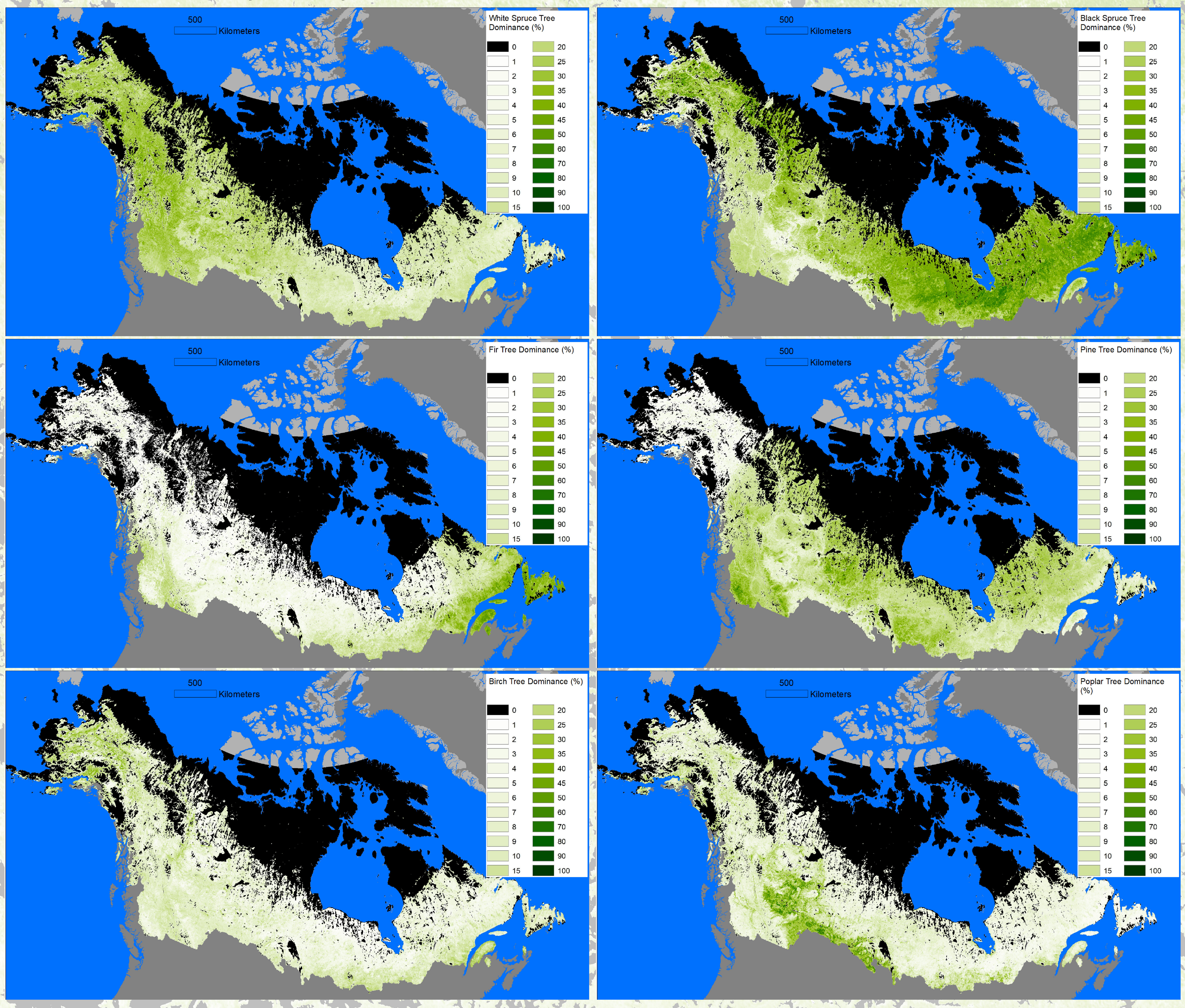
Results



Fir and Pine Dominance are the best performing models. False prediction of non-zero values was a major source of error; we expect the addition of a binary presence model will improve results. In addition, we will apply a filtering step to avoid predicting total dominance >100%.

Maps of Deciduous Shrub (Willow, Alder, Birch) abundance (e.g. Macander et al. 2020) can provide information about where substantial woody AGB is present in non-tree species. We plan to combine these results with total AGB, total woody AGB, and/or canopy height maps to provide detailed estimates of woody structure partitioned into tree species groups.

Map Models (2020)



Macander, M. J., et al. 2022. Time-series maps reveal widespread change in plant functional type coveracross arctic and boreal Alaska and Yukon. Environmental Research Letters. IOP Publishing.
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Tolan, J., et al. 2024. Very high resolution canopy height maps from RGB imagery using self-supervised vision transformer and convolutional decoder trained on aerial lidar. Remote Sensing of Environment, 300, p.113888.
Zhu, Z., Woodcock, C.E., Holden, C. and Yang, Z., 2015. Generating synthetic Landsat images based on all available Landsat data: Predicting Landsat surface reflectance at any given time. Remote Sensing of Environment, 162, pp.67-83.
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