ANNUAL ABOVEGROUND BIOMASS MAPPING FOR NORTH AMERICA'S BOREAL FOREST DURING 1984-2022 WITH GROUND PLOTS, AIRBORNE LIDAR, AND LANDSAT TIME SERIES

Wanwan Liang[1], Kai-Ting Hu[2], Piotr Tompalski[3], Mark A. Friedl[2], James T. Randerson[4], Olivier R. van Lier[3], Douglas C. Morton[5], Hans-Erik Andersen[6], Jonathan A. Wang[1]

[1] University of Utah, [2] Boston University, [3] Natural Resource Canada, [4] University of California, Irvine, [5] NASA Goddard Space Flight Center, [6] U.S. Forest Service

1. Background

Accurate time series maps of aboveground biomass (AGB) are crucial for characterizing how the carbon cycle is responding to rapid climate change and increasing disturbances like wildfire. Regionally consistent field-calibrated maps with high spatial and long temporal resolutions are currently unavailable for the entire North American (NA) boreal zone for characterizing carbon dynamics in the Arctic-boreal. Therefore, our primary goal here is to generate spatially exhaustive annual AGB maps for the North American Boreal region from 1984 to 2022, with a subsequent focus on the Arctic region.

2. Objectives

- Calibrate machine learning models to generate preliminary annual 30-meter wall-to-wall AGB maps for NA boreal forest
- Evaluate AGB maps and compare with three published maps
- Evaluate whether the preliminary AGB maps can detect and reflect the temporal change of AGB and canopy height (CH), respectively

3. Dataset

- **Ground plots**: 2,171 ground plots were compiled from Cooperative Alaska Forest Inventory, Canadian National and Enhanced Forest Inventory, and arctic synthesis dataset[1] (**Fig. 1**).
- **Airborne LiDAR**: airborne laser scanning (ALS) data were acquired from multiple programs for Canada and G-LiHT for Alaska.
- **Landsat**: Continuous Change Detection and Classification (CCDC) algorithm[4] was applied on Landsat Collection 2 Surface Reflectance to create synthetic spectral features.
- **Ancillary data**: land cover maps from this project, topographical variables, and long-term mean climate from WorldClim were used.

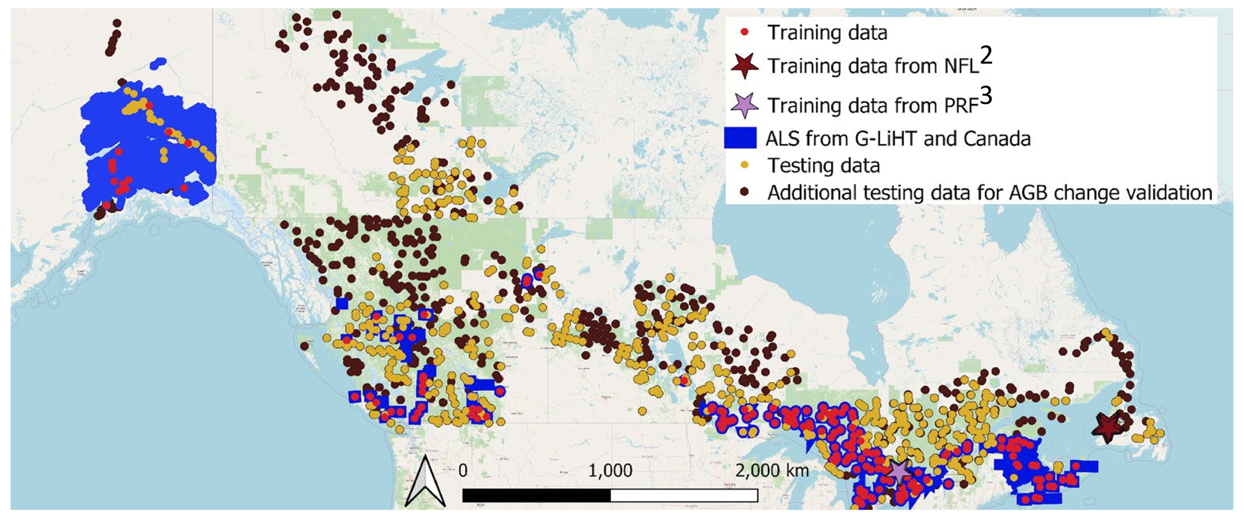

Fig. 1. Ground plots and ALS used for model calibration and validation; 637 and 1534 ground plots used for training and testing, respectively

4. Methods

- **Model calibration:** two-step calibration with area-based approach[5]

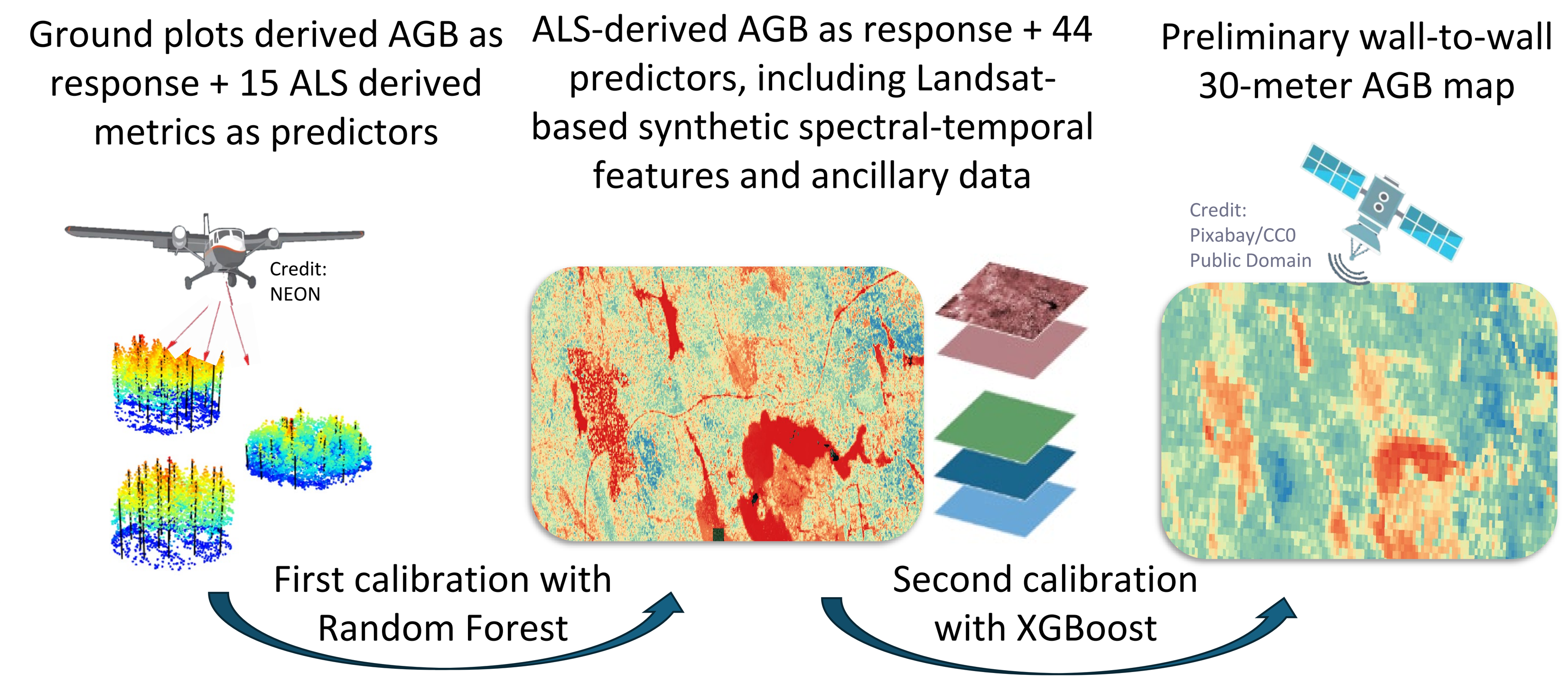

Fig. 2. diagram of two-step calibration

- **Validation of AGB prediction and comparison with published maps** (**Table 1**)
  - Testing plots (**Fig. 1**) surveyed since 2009 without fire record after last survey were used
  - Testing plots surveyed before 2019 and between 2016-2020 were used to evaluate Wang's and Duncanson's/Guindon's map (Table 1), respectively.
- **Validation of AGB temporal change detection**
  - All testing plots with repeated field surveys were used (Fig. 1).
- **Validation of CH temporal change reflection**
  - ALS-derived CH change and the predicted AGB change between 2018 and 2012 for PRF[3] were used.

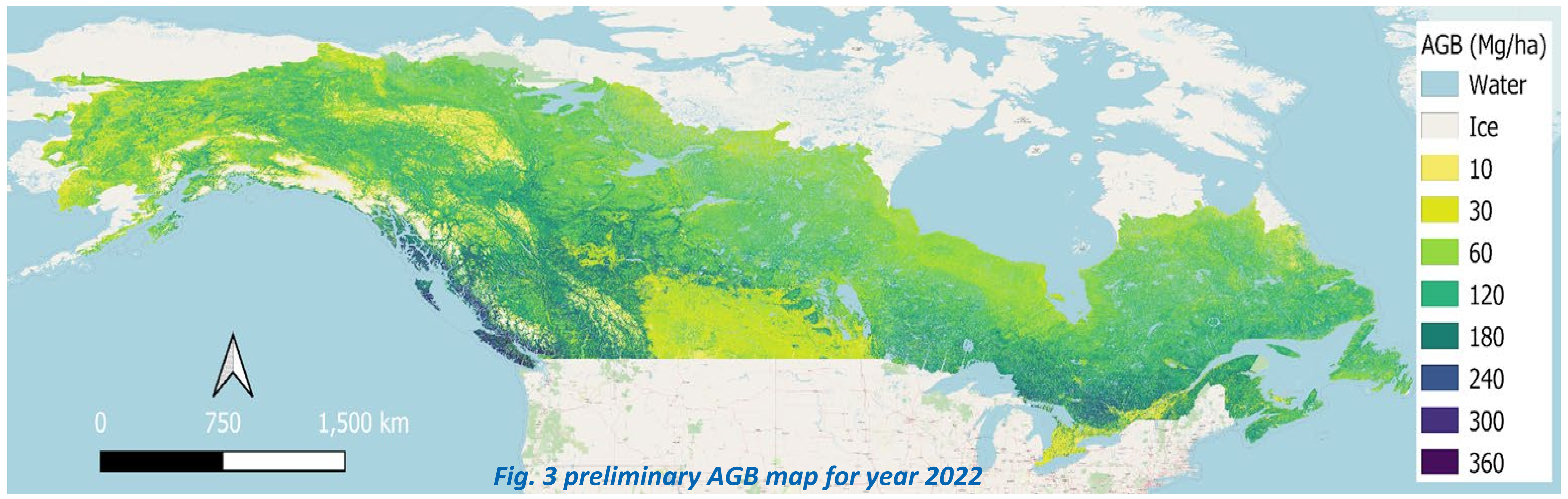

Fig. 3 preliminary AGB map for year 2022

7. References

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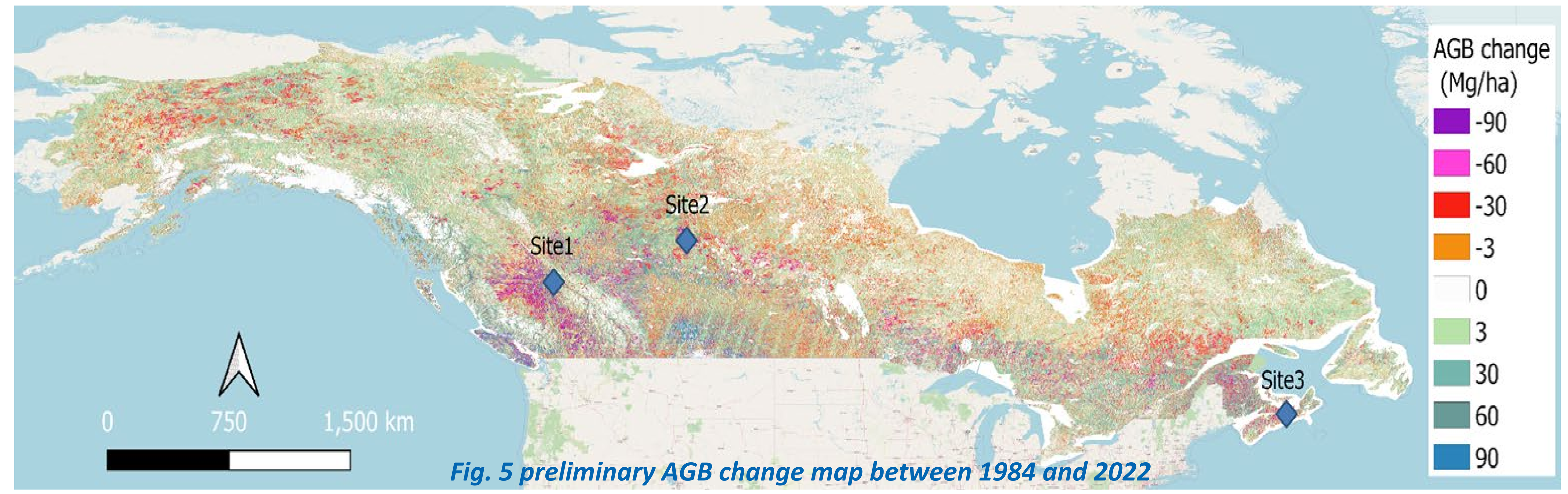

Fig. 5 preliminary AGB change map between 1984 and 2022

5. Results

Our preliminary map overall showed best accuracy, but severely overestimated AGB at relatively low levels

- Our preliminary AGB map for 2022 well captured the overall pattern of AGB in NA boreal forest (**Fig. 3**).
- Overall, the preliminary map showed best accuracy with an exception of comparison with Guindon's map using mean absolute error (MAE) (**Fig. 4, Table 2**). However, our map showed severe overestimation of AGB when AGB < 100 Mg/ha (**Fig. 4**).
- A consistent underestimation of AGB at high AGB levels was observed in all maps analyzed (**Fig. 4**), while maps from Duncanson[6] and Wang[8] also underestimated AGB before 100 Mg/ha is reached.

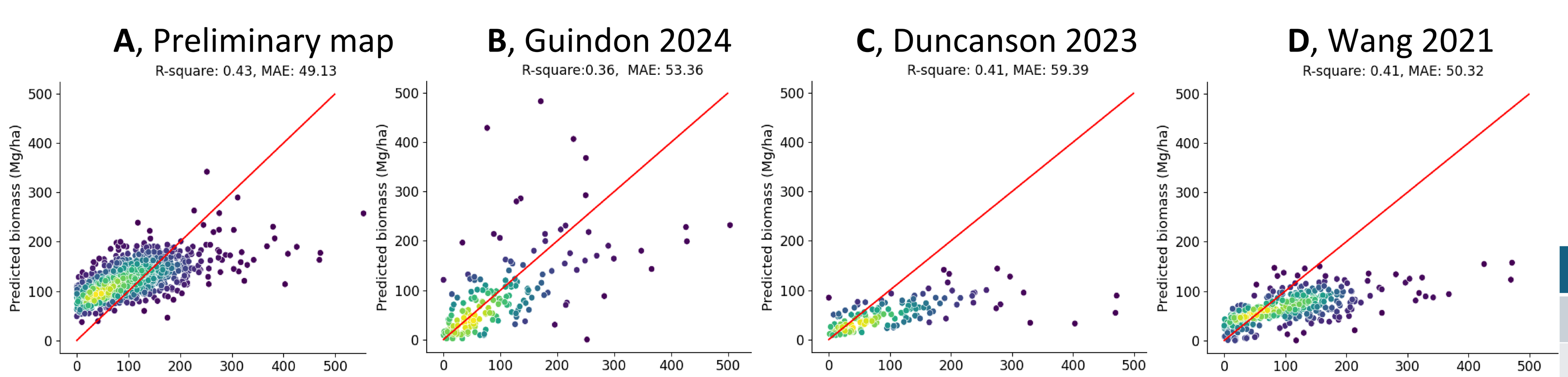

Fig. 4 scatter plot between observed and predicted AGB for independent testing plots

Our preliminary map captured well the temporal change in AGB and CH

- The AGB change map between 1984-2022 well captured the negative impact of fire and harvest disturbances on AGB (**Fig. 5, Fig. 6**).
- The correlation between predicted and observed AGB change and predicted AGB and observed CH change is both 0.54 (**Fig. 7**).
- Our preliminary AGB map captured the sign of temporal AGB and CH change in 70% and 81% of cases, respectively (**Fig. 7**), suggesting good potential for the AGB map to detect greening and browning trend.

Table 1. existing maps compared with our preliminary map

Map	Temporal, spatial coverage
Duncanson[6]	2020, NA high latitude forests
Guindon[7]	2020, Canada non-arctic area
Wang[8]	1984-2014, ABoVE core domain boreal forest

Table 2. Accuracy with shared testing plots between our map (shown in blue) and published map (shown in black)

Map	Guindon, 2024	Duncanson, 2023	Wang, 2021
Testing size	169	152	383
R-square	0.52, 0.36	0.53, 0.41	0.48, 0.41
MAE (Mg/ha)	58.85, 53.36	56.12, 59.39	48.93, 50.32

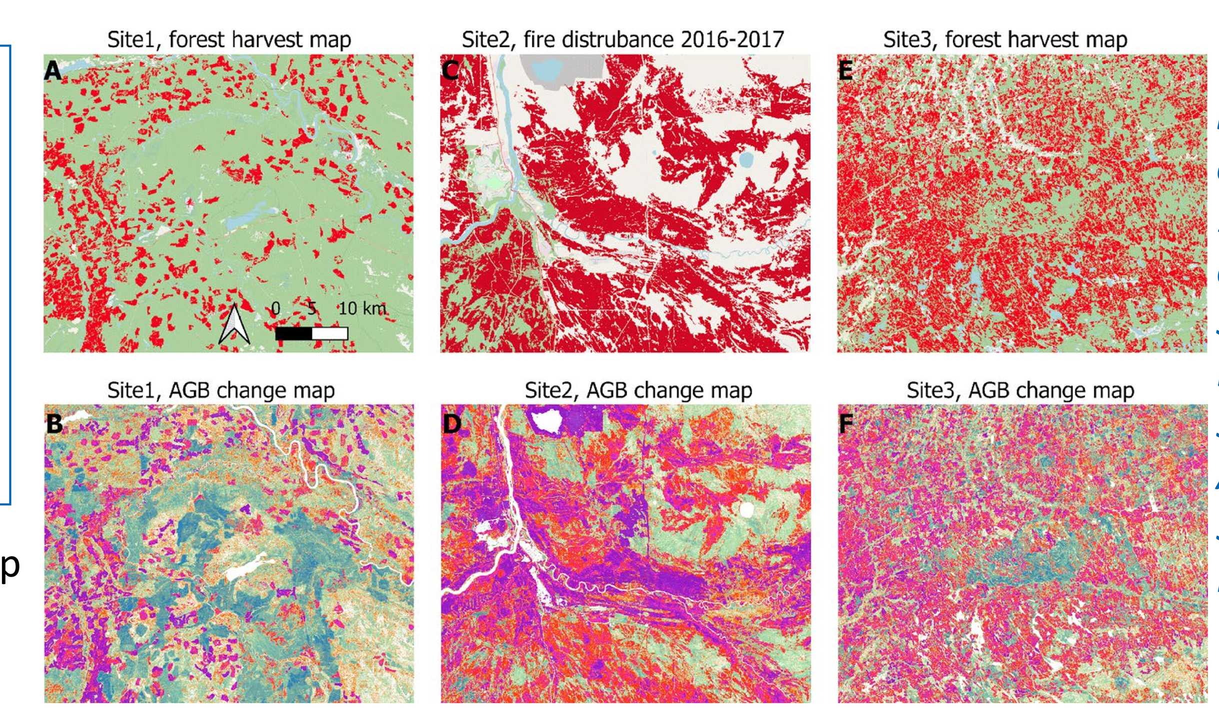

Fig. 6 preliminary AGB change map between 1984-2022 for three disturbed sites; Site 1: Prince George British Columbia, Site 2: McMurray Alberta, Site 3: Pictou County Nova Scotia

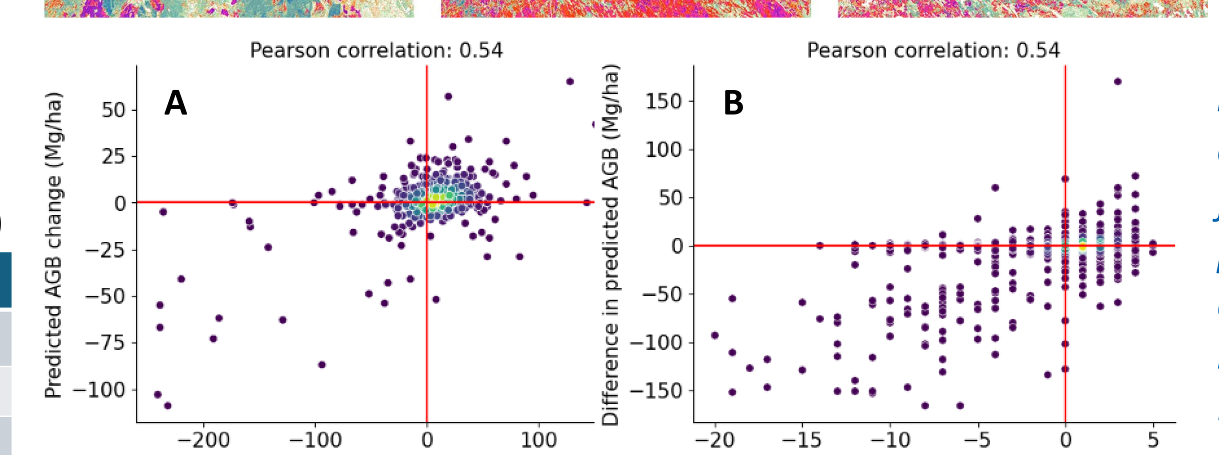

Fig. 7 A: predicted and observed AGB change for ground plots, and B: predicted AGB change and observed canopy height (CH) change for PRF[3]

6. Next steps

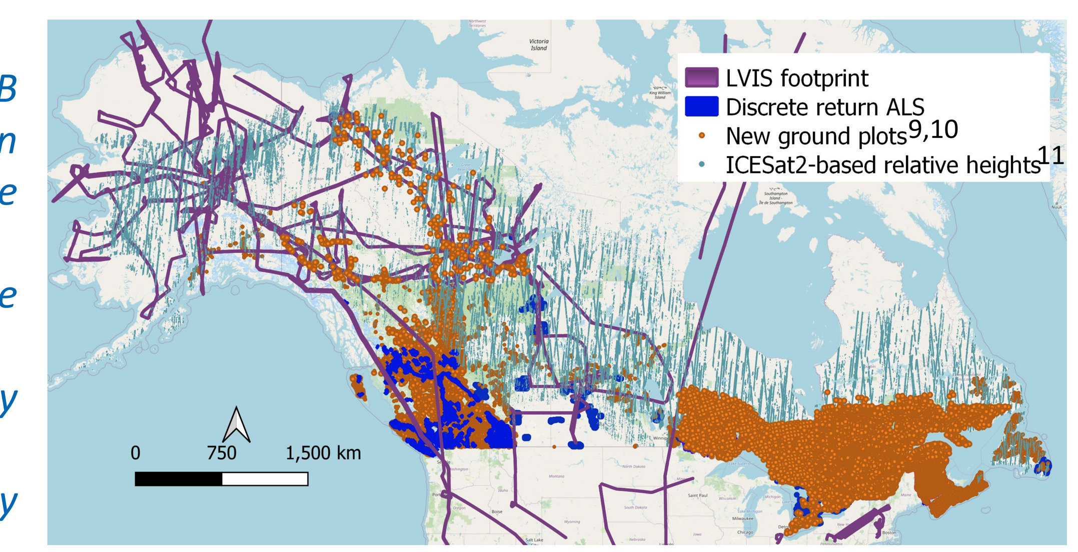

Fig. 8 New ground plots from Permanent Sampling Plot[9] (PSP) and MAGPlot[10], and new LiDAR data for model calibration

To improve AGB maps, we will integrate newly acquired ground plots (>30,000) from PSP and MAGPlot programs and synthesizing additional airborne data from LVIS and spaceborne LiDAR from ICESat-2 (**Fig. 8**). This comprehensive analysis is expected to significantly contribute to the advancement of AGB mapping techniques and enable robust quantification of the impacts of climate change and disturbance on the Arctic-boreal carbon cycle.