Calibration and Validation of Fractional Lichen Cover Mapping

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Abstract

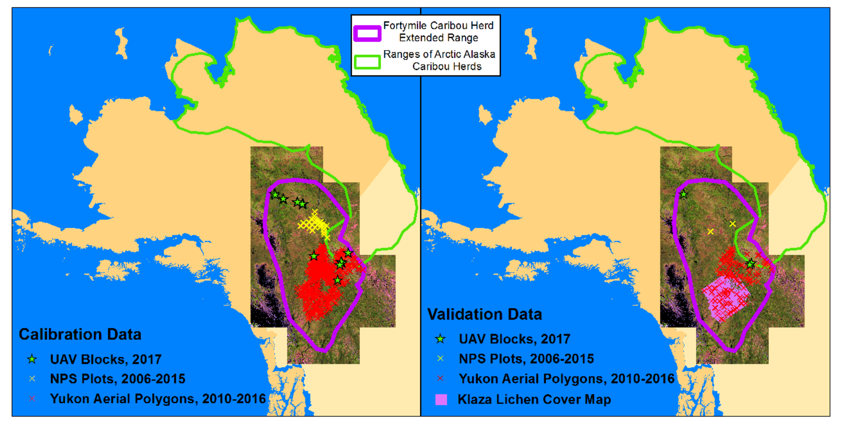
Cover maps are being developed for selected tundra plant functional types (PFTs) across >500,000 sq. km of arctic and boreal Alaska and adjacent Canada at 30 m resolution. Training and validation data include a field-based training dataset based on both point-intercept and ocular estimation sampling methods at thousands of plots spanning bioclimatic and geomorphic gradients. In 2017, we also compiled over 20 blocks of 1-5 cm resolution RGB image mosaics in Alaska (White Mountains) and the Yukon Territory to provide supplementary training and validation data for mapping Light Macrolichen cover in the range of the Fortymile Caribou Herd. The mosaics and associated surface and canopy height models were developed using a consumer drone and structure from motion processing. We summarized both the in situ measurements and drone imagery to determine cover of Light Macrolichens. We applied these data to train 2 m (limited extent) and 30 m (wall to wall) maps of fractional cover for lichen for c. 2015. Predictors for 2 m models were commercial satellite imagery such as WorldView-2 and Worldview-3, analyzed on the ABoVE Science Cloud. Predictors for 30 m models were percentile reflectance composites and spectral metrics, developed from Landsat imagery using Google Earth Engine. Next steps include extending the mapping to Arctic Alaska and Canada; expanding to include mapping of shrub PFTs; and applying models to historical Landsat data to estimate c. 2000 shrub and lichen cover.

Background

The distribution and abundance of forage lichens are critical factors influencing the movements, distribution, and nutritional ecology of caribou in arctic and boreal regions. They provide critical winter nutrition. Forage lichens are mainly light-colored genera, primarily *Cladonia, Cladina, Cetraria,* and *Flavocetraria* spp. They are terricolous (i.e. occurring on the ground, not in trees) macrolichens (i.e. fruticose or foliose growth forms, not crustose).

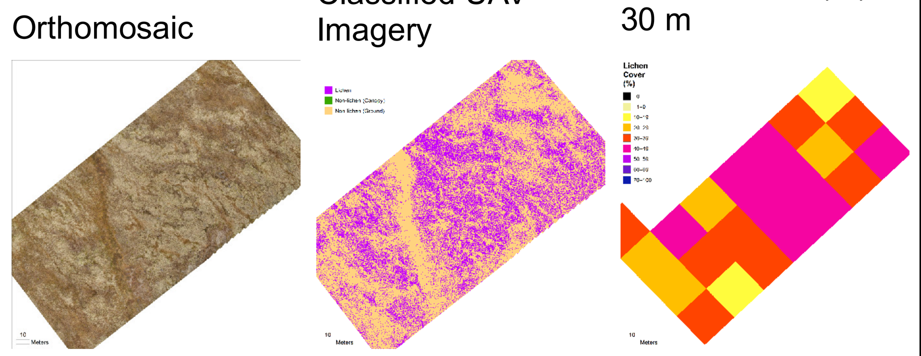
The range of the Fortymile caribou herd is expansive, stretching from the White Mountains near Fairbanks, Alaska into Canada. The herd has been increasing since the 1970s but recent indications of declining nutritional condition suggest that the herd could be near carrying capacity, leading to declining body condition and recruitment, as well as overgrazing of upland habitat (Boertje et al. 2012). Little is known about the spatial distribution of potential overgrazing effects, due to the lack of spatially explicit habitat characteristics over the extensive range.

Study Area and Calibration/Validation Data

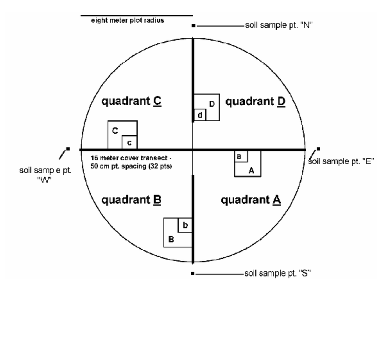


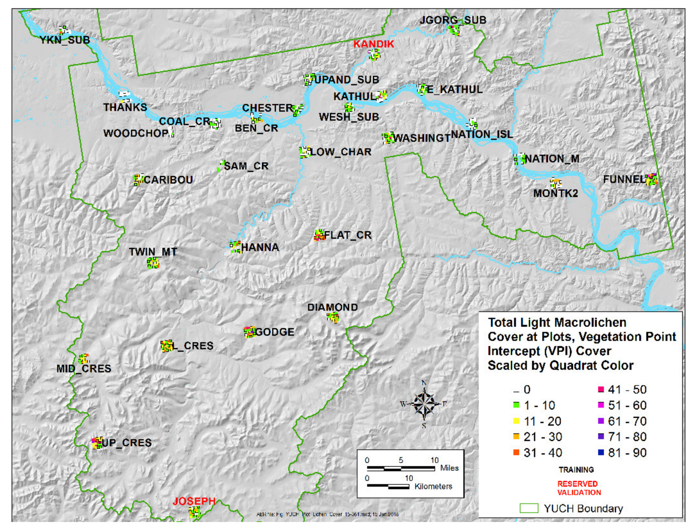
Training and validation data were compiled from several data sources using a mixture of sampling methods and with varying taxonomic precision.

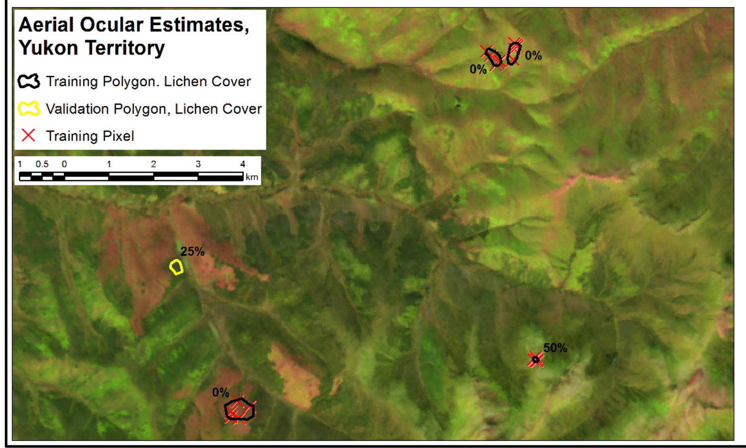
UAV Blocks, 2017
The UAV data from 19 sites provided fractional lichen cover training data for 1,437 Landsat pixels (30 m). An additional 3 sites (90 pixels) were reserved for validation. See Palm poster for details on UAV data collection and analysis.



NPS plots
Systematic vegetation point intercept sampling was performed at 527 plots (29 sampling grids) grids in Yukon–Charley National Preserve in 2006–2015 by the Central Alaska Network Vegetation Program of the NPS. Lichen color group data was inferred from quadrat data. Data from 42 plots (2 sampling grids) was reserved for validation.



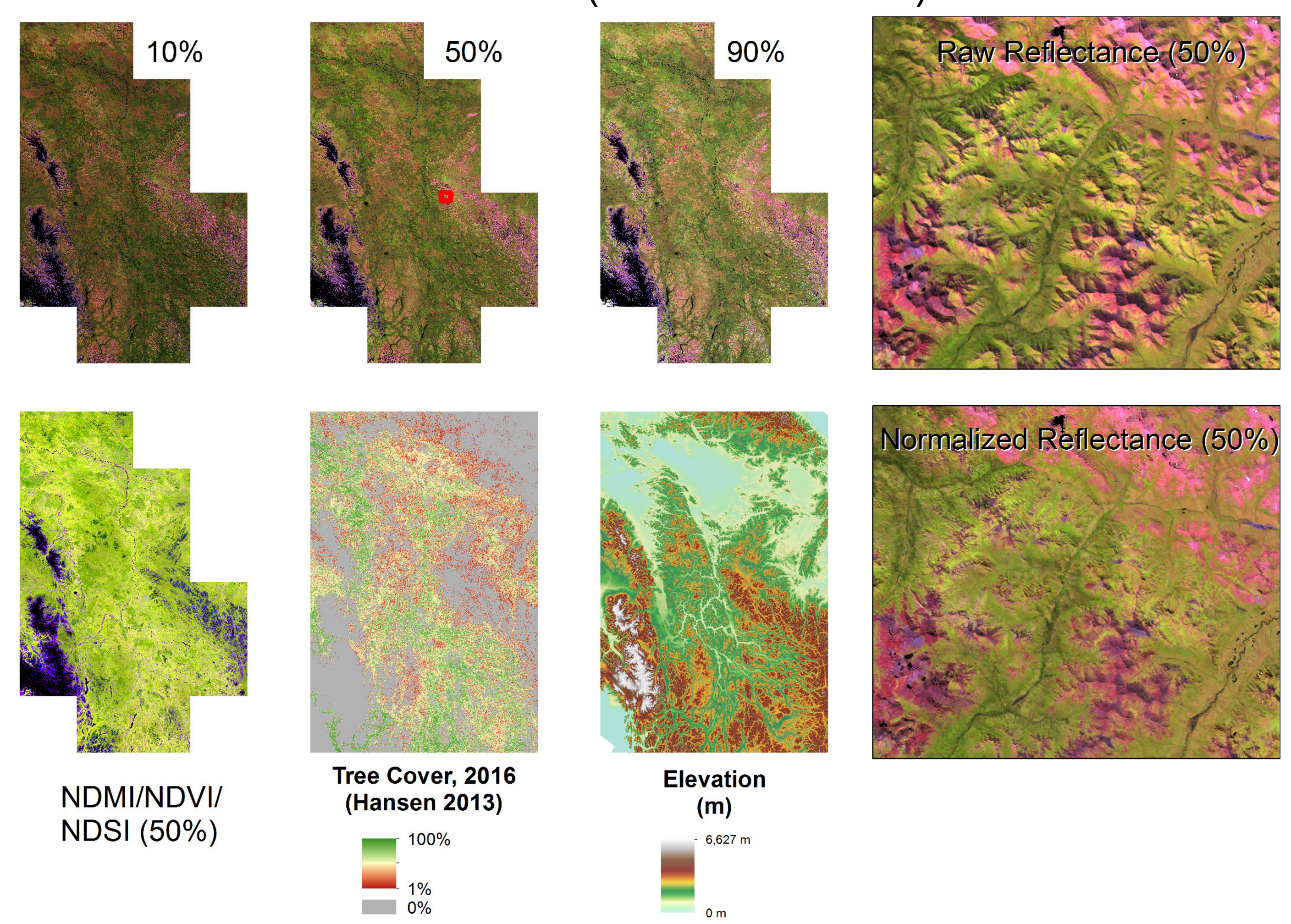




Yukon Territory aerial plots
Visual estimates of lichen cover were collected during 2010–2016 helicopter surveys for 838 polygons in the Yukon Territory to support land cover mapping. Polygons were 5–439 Landsat pixels in area. 5 pixels were sampled from each of 684 polygons for training the lichen cover model. 154 polygons were reserved for validation. Mean modeled lichen cover was calculated for each validation polygon from the lichen cover map.

Predictors

Landsat Surface Reflectance (TM 5/4/3 shown)



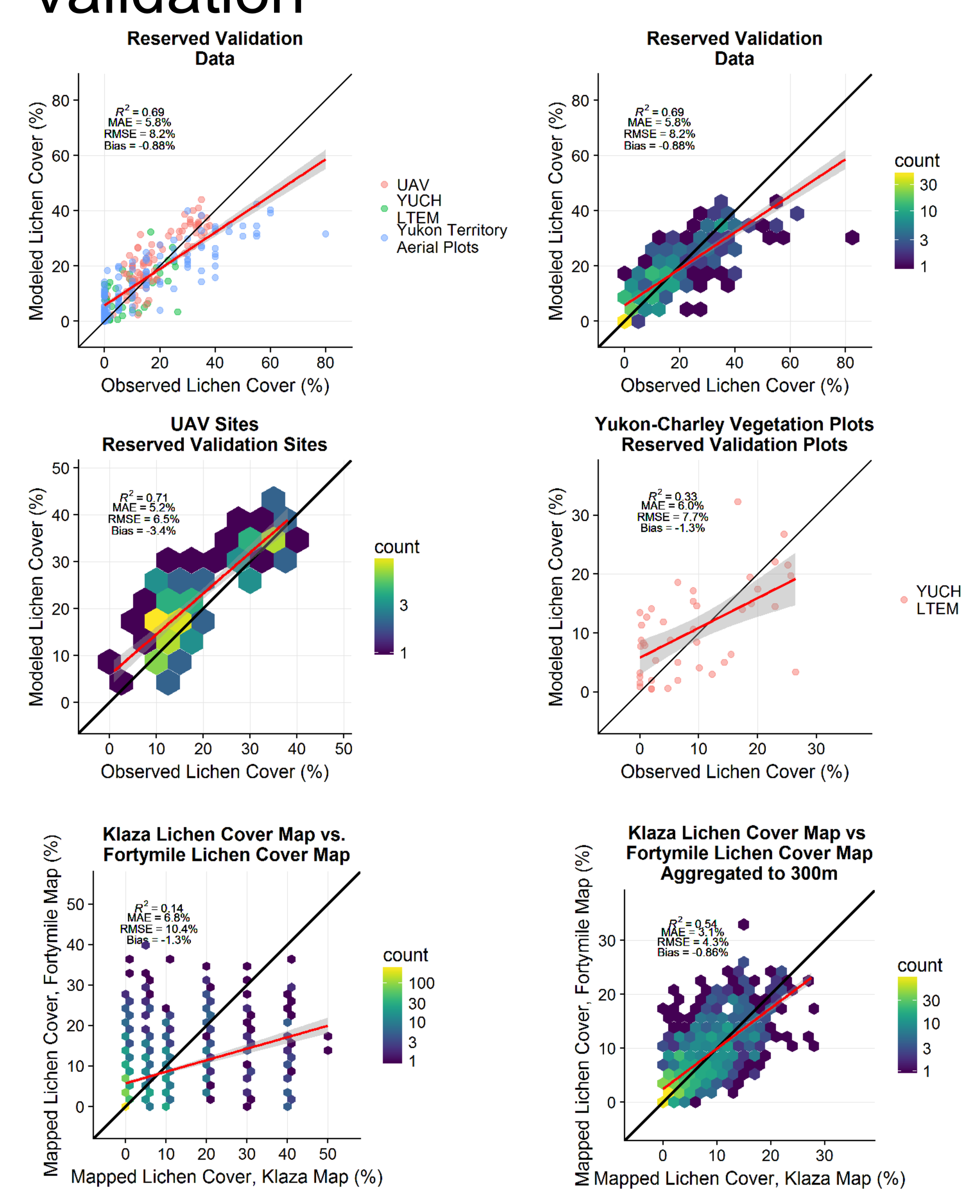
Surface reflectance composites were produced using all available Tier 1 Landsat 5, 7 and 8 images acquired in May–September, 2014–2017. Images were filtered to remove clouds, snow, shadows, and water. Then, percentile composites were generated from all remaining observations using Google Earth Engine. For each band (blue, green, red, near-infrared, SWIR1, and SWIR2), the percentiles 10%, 25%, 50%, 75%, and 90% were included as predictors.

To normalize for the effects of terrain slope and aspect on signal values, the Modified Sun–Canopy–Sensor topographic correction function (Soenen 2015) was applied to each image before composites were generated. However, the models built using uncorrected imagery had slightly better performance. This may be due to artifacts in the DEM used.

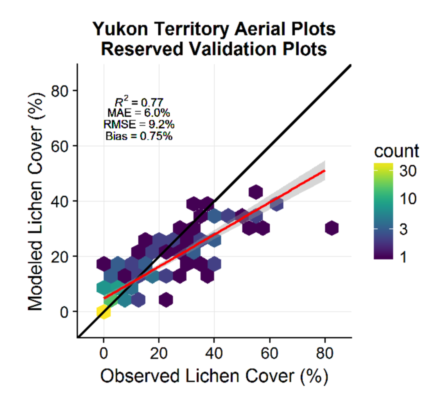
Six spectral indices (NDVI, EVI, NBR, NDWI, NDMI, and NDSI) were calculated from the Landsat imagery and the same percentiles were extracted. Other predictors were elevation (m) and forest cover in 2016 (%, Hansen et al. 2013). Forest cover in 2016 was estimated from forest cover in 2000 by setting forest cover to zero in all areas with forest cover loss between 2000–2016.

Fire history is an important factor controlling the patchy distribution of lichen at the landscape scale, with lichen generally being killed in forest burns. The forest cover layer (which incorporates forest cover loss during 2000–2016) and spectral indices such as the Normalized Burn Ratio (NBR) allow fire history to inform the lichen cover model.

Validation



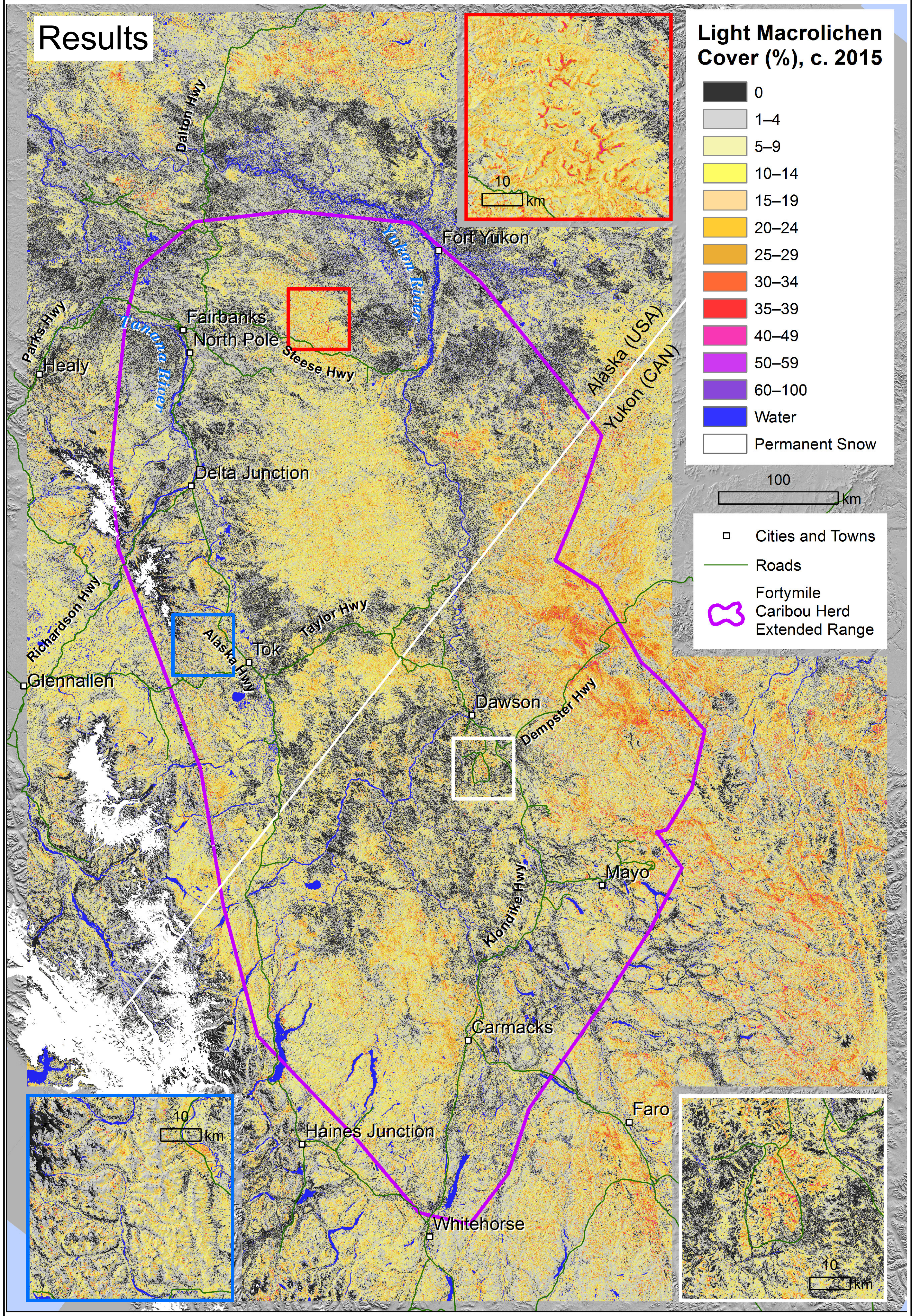
All Reserved Validation Data
Validation results are presented as a scatterplot (left) and as a binned hex plot (right). In all plots, the 1:1 line is black and the linear fit line is red (with gray 95% confidence interval). The patchy distribution of light macrolichens results in large areas with zero or trace lichen cover. Overplotting makes it difficult to determine how much data occurs near zero lichen cover in the scatterplot, so the binned hex plots are preferred.
Overall model performance is good based on the pooled, reserved training data, with a root mean square error of 8.2% light lichen cover and mean absolute error of 5.8%. There is some underprediction of lichen cover at high values.



Reserved Validation by Dataset
The lichen cover model performance was excellent based on the 3 reserved UAV blocks. The aggregated UAV data matches the scale of the Landsat imagery exactly. There was close to a 1:1 best fit between the observed and modeled lichen cover data at the UAV sites.
Model performance was lower based on the data at two reserved sampling grids in Yukon–Charley. The YUCH plots include some older data (back to 2006) and so there is a greater opportunity for lichen cover change since the data were collected. There is also a mismatch between the plot size (16 m diameter) compared to 30 m Landsat imagery.
Model performance was very good based on the reserved 154 polygons in the Yukon Territory aerial survey dataset, with the highest correlation coefficient but also the largest error magnitudes.

Comparison to Klaza Herd Lichen Cover Map
We compared the new lichen cover map to an existing map that covered a small portion of the study area. The Klaza map was based on the Yukon Territory aerial plot data and 22 June 2009 Landsat imagery. Agreement between the two maps was low when comparing individual 30 m pixels, but was much better when the data were aggregated to 300 m resolution. This suggests that much of the fine-scale difference could be related to pixel misregistration.

Results



Fractional cover of Light Macrolichens was mapped at 30 m resolution for the range of the Fortymile Caribou Herd. A random forest model was trained using aggregated UAV imagery, aerial vegetation plot data, and vegetation point intercept sampling plot data. Next steps include incorporating additonal field plot data; expanding to include the ranges of other Arctic caribou herds in Alaska and northwestern Canada, and back-casting the models to characterize historical lichen cover (c. 2000). Similar predictors and training data, along with airborne lidar, are also being applied to develop fractions shrub cover models for Arctic Alaska and adjacent Canada.

Acknowledgments

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