A multitemporal 30m land cover map for the ABoVE domain using dense Landsat time series and high resolution imagery

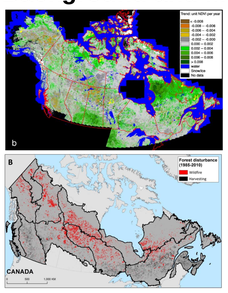
Jonathan Wang[1*], Damien Sulla-Menashe[1], Curtis Woodcock[1], Oliver Sonnentag[2], Mark Friedl[1]

[1] Department of Earth and Environment, Boston University, 685 Commonwealth Avenue, Boston, MA 02215 [2] Département de géographie, Université de Montréal, Pavillon 520 Côte-Sainte-Catherine, Montréal QC H2V 2B * Corresponding author: jonwang@bu.edu

Abstract

The rapid climate change in arctic and boreal ecosystems is resulting in drastic changes to land cover composition, including woody expansion in the arctic tundra, successional shifts following boreal fires, and permafrost thaw-induced wetland expansion. The impacts on physical climate and the carbon cycle of these land cover transformations are well-documented in field and modeling studies, but there have been few attempts to estimate overall rates of land cover on decadal and continental scales. Previous studies were either too coarse in spatial resolution or too limited in temporal range to analyze relevant rates of change. Here we present preliminary efforts to map land cover at 30m spatial resolution over the ABoVE core domain using time series of satellite remote sensing data from Landsat spanning 1984 – 2014. We utilize the Continuous Change Detection and Classification (CCDC) algorithm to analyze pixel-based time series of reflectance data and detect potential disturbances in land cover and distinguish relatively stable time segments. We utilize a combination of unsupervised clustering and supervised classification techniques to generate random forest models for predicting land cover over each pixel-time segment using a large suite of spectral and temporal features, digital elevation models, and other auxiliary data sources. Training and validation are performed using the considerable archive of high resolution imagery (0.5-4m) from DigitalGlobe over the ABoVE domain.

Background and Motivation



- Maps on the left indicate significant regional differences in arctic and boreal "greening" and "browning" (Top, Ju and Masek, 2016) and areas of land cover disturbances (Bottom, White et al., 2017) inferred from Landast time series.
- Change in land cover are implied by White's disturbance maps; land cover may explain patterns of greening and browning in Ju and Masek's map. Land cover changes may drive recent observed enhancements in northern atmospheric CO_2 cycle enhancement (Graven et al., 2013).
- Land cover changes are difficult to analyze since current land cover maps are too limited in spatial, temporal, or thematic detail to answer land cover-based hypotheses regarding greening and biome shifts in the far north.
- Landsat time series provide an opportunity to characterize land cover change at sufficient spatial resolution (30m) and temporal scale (1984 – 2014). Here we present preliminary results with maps of selected regions..

Data and Methods

Continuous Change Detection and Classification fits break points and statistical models to Landsat time series

Visual interpretation of sample using high res. imagery to develop legend. (n = 6,000)

Validation and accuracy assessment

Unsupervised clustering on spectral indices and seasonal features extracted from time segments to identify separable classes (n=40k)

Random forest classifier to predict land cover of time segments across domain (n = 14T)

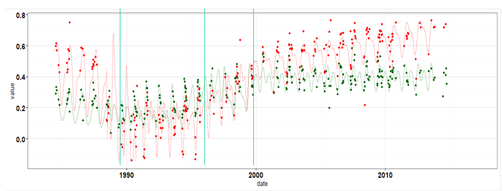
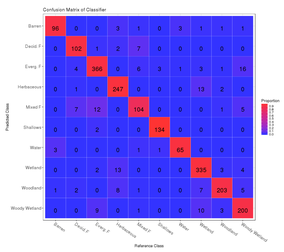


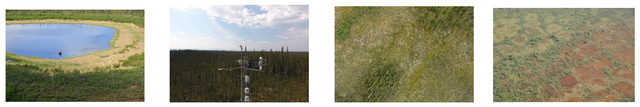
Figure demonstrates an example time series of a forest disturbance and recovery pixel. Points are Landsat data and lines are CCDC model fits indicating distinct time segmemts. Vertical lines indicate break points with stable time segments in between. Green: Enhanced Vegetation Index; Red: Normalized Burn Ratio.



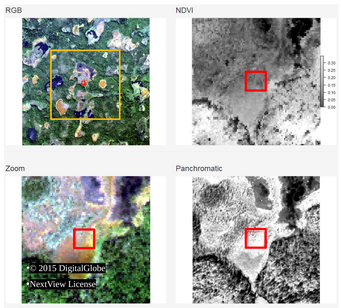
Confusion matrix for legend of prototype random forest classifier based on cross validation. Red squares indicate larger proportions of the total column values. Overall accuracy is approx. 91%.

Training Data and Legend

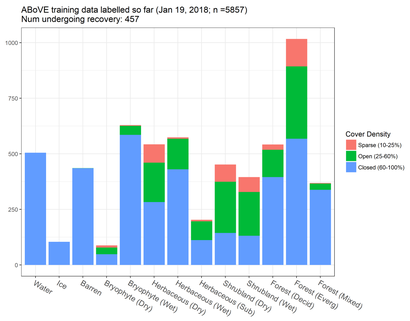
- R Shiny application developed for semi-automated hierarchical land cover labelling based on high-resolution (0.5 – 4m) DigitalGlobe repeat imagery spanning 1999 – 2017 and Landsat time series.
- DigitalGlobe imagery provides training and validation sites sampled from across the domain.
- High resolution imagery supplemented by photos from the field to help understand unique landscapes.
- Legend based on feature clustering, visual interpretation, accuracy, and optimal utility to the community (please provide feedback!)



Example field photos showing cover types, including woodlands, forests, shallows, wetlands, and shrubs in the Yukon and NWT. (Credit: Kevin Turner and Jon Wang)



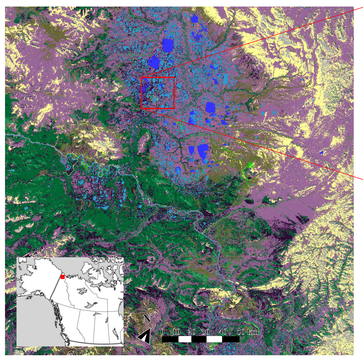
Example DigitalGlobe imagery showing wetlands and forests. Red square indicates size of a Landsat pixel; yellow square indicates a MODIS pixel.

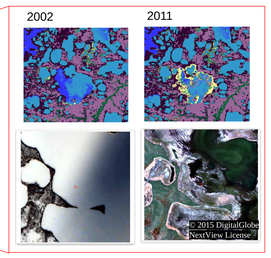


Visual interpretation process so far. Note that class labels do not exactly align with final land cover legend. Visually interpreted labels are compared with clustering results to develop optimal legend.

Selected Prototype Results

Land Cover for Bh09v05 in 2010

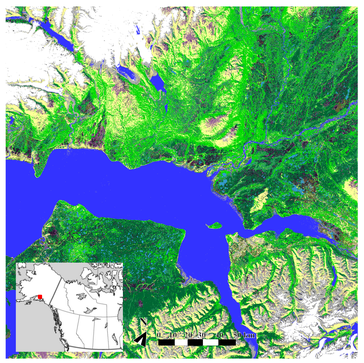




Land Cover
Everg F
Decid F
Mixed F
Woodland/Shrub
Grass
Wetland
Woody Wetland
Barren
Water
Shallows
Shadow
NA

Left: Old Crow Flats in the Yukon. Top: Detail image over two time periods showing land cover change (lake drainage) in land cover map (top row), confirmed by high res. imagery (bottom row).

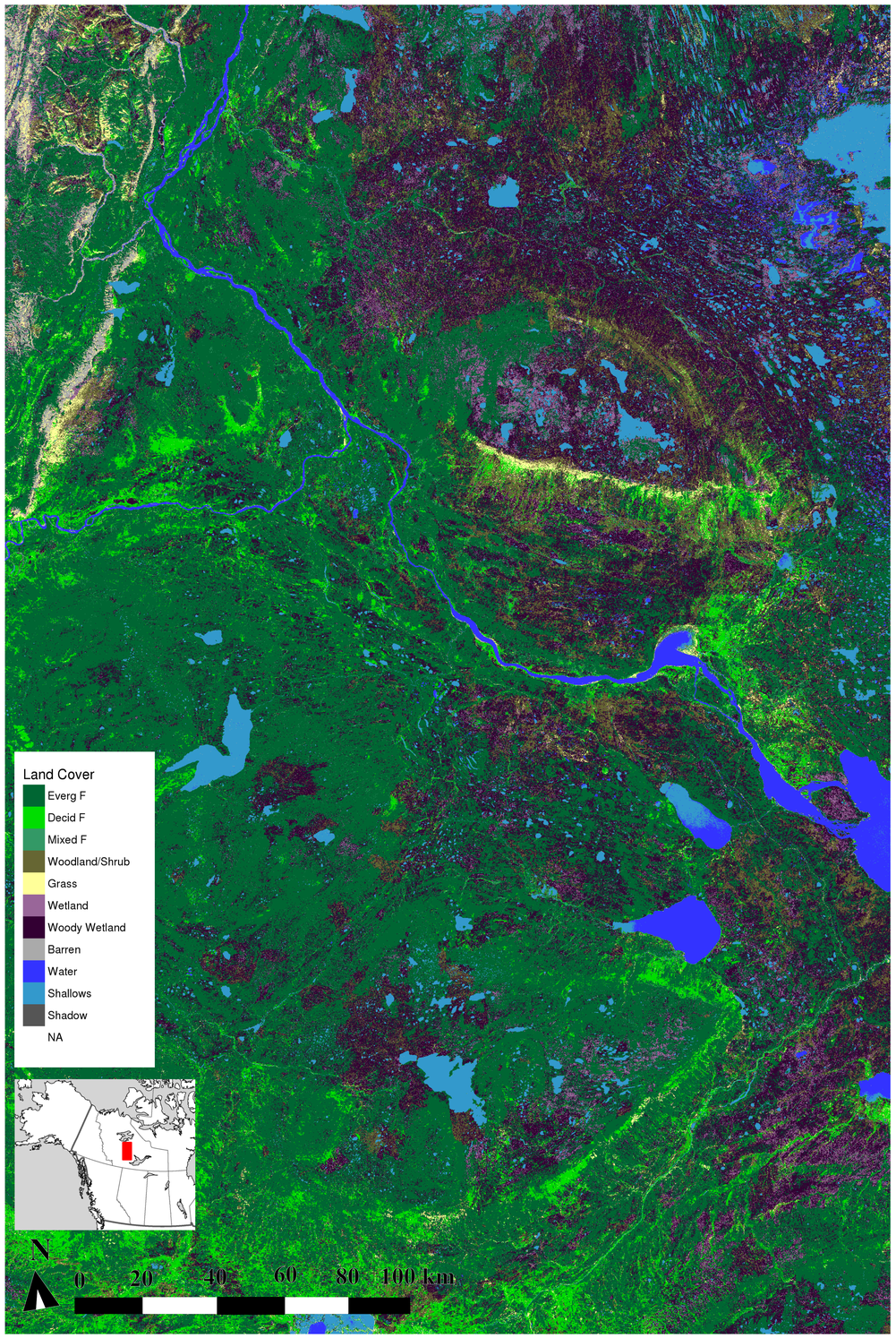
Land Cover for Bh04v06 in 2002



Land Cover
Everg F
Decid F
Mixed F
Woodland/Shrub
Grass
Wetland
Woody Wetland
Barren
Water
Shallows
Shadow
NA

The area near Anchorage, AK. NA values indicate snow-covered mountains.

Land Cover of the Taiga Plains, 2010



Map showing detail of land cover mosaicked over 6 ABoVE tiles in the Taiga Plains and Taiga Shield ecozones. Various burn scars are apparent as contiguous regions of woody wetland or shrubland that interrupt otherwise continuous evergreen forest in the south.

References

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