Shifting Patterns of Boreal Forest Succession and Browning Over the Last 30 Years

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Hypotheses

Analyses of Boreal Forest Normalized Difference Vegetation Index (NDVI) over the last 3 decades have indicated widespread canopy decline or "browning". We compared the browning trends in central Canada reported in the 8-km GIMMS3g NDVI dataset with those calculated from the 30-m Landsat record to address three hypotheses:

Hypothesis 1 The GIMMS3g NDVI browning trend is robust and consistent with independent satellite records such as Landsat; the widespread boreal forest browning trend cannot be explained as an artifact of the GIMMS record or by a "natural" pattern such as wildfire occurrence and recovery.

Hypothesis 2 NDVI browning is occurring across the boreal landscape regardless of stand age.

Hypothesis 3 The rate, patterns and mean trajectory of boreal forest succession have remained constant over the last 30 years.

Approach

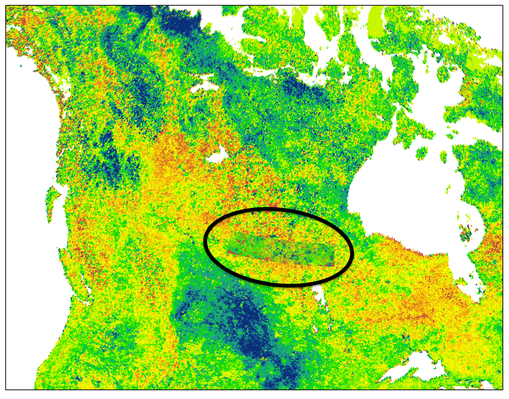


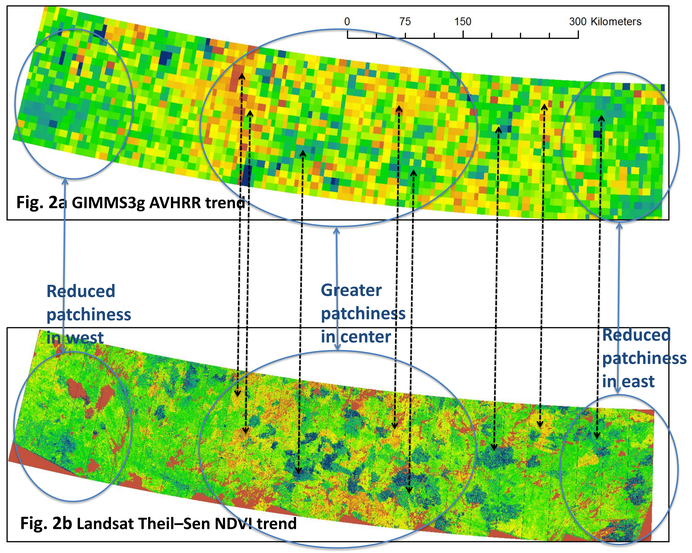
Fig. 1. Study area; image is GIMMS3g AVHRR analysis across central Canada. Blue or green pixels exhibited NDVI increase 1982-2012; brown areas show NDVI decrease. Inset over Saskatchewan and Manitoba is Landsat-based NDVI trend shown in Fig. 2b.

Focus on 800 km boreal forest transect through northern Saskatchewan and Manitoba. The eastern 150 km overlaps with the BOREAS NSA, a data rich area with many datasets from BOREAS and follow-on projects. Central Canada has good historical Landsat coverage. The transect samples a range of GIMMS3g AVHRR NDVI trends.

Compare Landsat trends with GIMMS3g AVHRR (Guay et al., https://daac.ornl.gov/VEGETATION/guides/GIMMS3g_NDVI_Trends.html). Landsat 5,7,8 CFMask, SR NDVI and NBR and TOA TIR downloaded from https://espa.cr.usgs.gov/ for all low cloud scenes doy 175-230. Images homogenized across sensor by regression, stacked, masked, and trend determined using linear regression and Theil–Sen estimator (following Ju and Masek 2016 and Sulla-Menashe et al. 2016). Fire GIS records from Canadian National Fire Database.

ROIs for individual burn scars in Manitoba's BOREAS NSA identified and checked using spring and summer MSS, TM and ETM+ images. NDVI, NBR and TIR deviation chronosequences compared as a function of observation year.

NDVI trends in northern Saskatchewan and Manitoba over the last 30 years



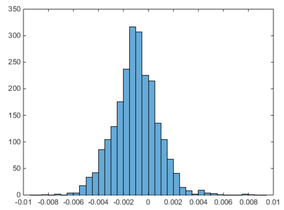


Fig. 3a GIMMS3g slope histogram (NDVI units/year).

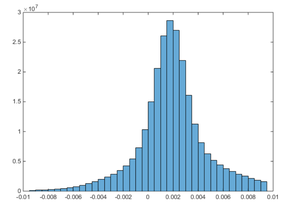


Fig. 3b Landsat slope histogram (NDVI units/year).

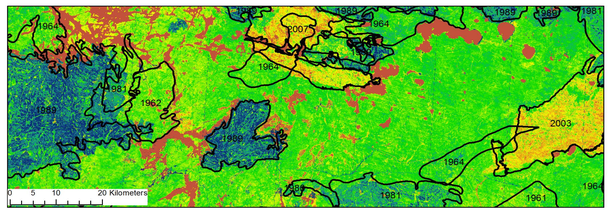


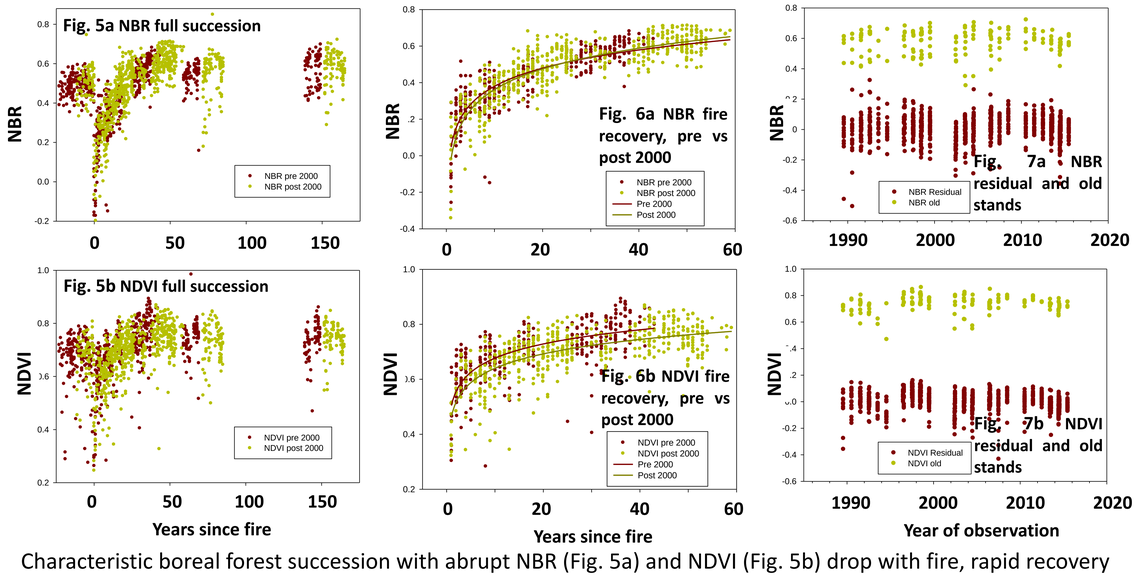
Fig. 4. Landsat NDVI trends and fire history for the BOREAS NSA region

The x-y scatter plots between GIMMS3g and 8-km Landsat NDVI look pretty bad. But the broad spatial patterns, and many of the local patterns, look ok, especially considering the differences in compositing, spatial scale, period considered and weighting between years (Fig. 2 – note 2a vs b use different color stretches).

The slope histograms for GIMMS3g vs Landsat show similar variability, but Landsat shows a positive (greening) peak compared to GIMMS (Fig. 3). The Landsat slopes are highly sensitive to the calculation method; least squares gives negative slopes on average (browning). The Theil–Sen estimator uses a median filter to exclude sudden changes; some of these changes (e.g., fire) may be real, leading to a bias if the population of true slopes is skewed; further analysis is needed.

The occurrence of boreal forest browning or greening in Landsat is largely associated with recent fires (Fig. 4); this finding was previously reported by the GSFC and BU groups.

Is boreal forest succession changing?



Characteristic boreal forest succession with abrupt NBR (Fig. 5a) and NDVI (Fig. 5b) drop with fire, rapid recovery by ~20 years, possible overshoot from ~20-50 years, gradual decline to old growth stasis at ~75-150 years.

No indication of change in NBR recovery rate (Fig. 6a, recovery residuals in 7a) over the last 30 years (pre vs post 2000 observations). Slight hint of reduction in rate of NDVI recovery post 2000 (Fig. 6b), but this difference is driven by just a few fires and a much larger sample is needed.

No indication of decline in old stand NBR or NDVI over the last 30 years (Fig 7a,b). Possible ~decadal NBR and NDVI oscillations after accounting for stand age (Fig 7a,b).

Key Findings and Future Directions

The Landsat boreal forest browning/greening trends are broadly similar to those seen in GIMMS3g across SK and MB. Much of the browning/greening reflects recent fires, with apparent greening in ~1975-1995 burns and browning in post ~2000 burns (Fig. 2,3,4).

Not much evidence of browning after accounting for stand age, though larger sample size is needed. The rate, patterns and mean trajectory of boreal forest succession appear to have remained constant over the last 30 years (Fig. 5,6,7).

Key next steps: investigate and understand sensitivity to method used to calculate trends; improve understanding of fire history and increase sample size for chronosequence analysis; explore patterns of trends across landscape and possible effects of topographic position; explore possible decadal oscillation; better link Landsat signals to surface biogeophysical and ecological properties.