Forest composition, structure and productivity of browning and greening forests in Interior Alaska

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Motivation and Objectives

Previous remote sensing analyses of boreal forests found:

(1) A widespread trend toward declining Normalized Difference Vegetation Indices (NDVIs), which suggests decreasing forest productivity ("browning") over the past decades (Goetz et al. 2005, Beck & Goetz 2011), and

(2) Large changes in surface reflectance and brightness temperature with and following wildfire, which implies large shifts in biophysical properties during fire recovery (Alcaraz-Segura et al. 2010).

These observations provide a powerful tool for assessing boreal forest structure and function at large spatial scales (McMillan & Goulden 2008). Yet, they also underscore the challenge of linking remotely-sensed observations to the actual conditions on the ground.

Here, we used field surveys of recently burned forests to inform how surface reflectance and brightness temperature change during post-fire forest succession and recovery. We also assessed the biophysical properties of old-growth forests (>100 yrs since last fire) with known 30-yr trends in surface properties. Our data will advance our ability to interpret greening and browning trends, and to differentiate natural ecosystem variability from regional scale responses to external forcing, including climate change.

Study Area and Methods

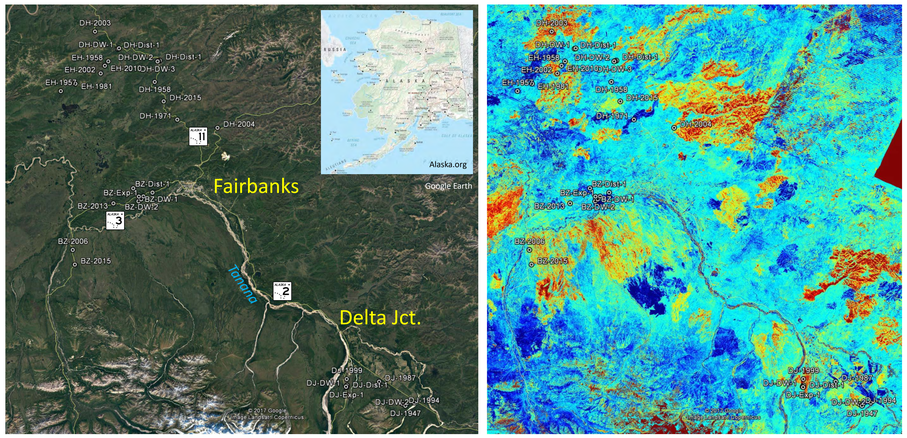
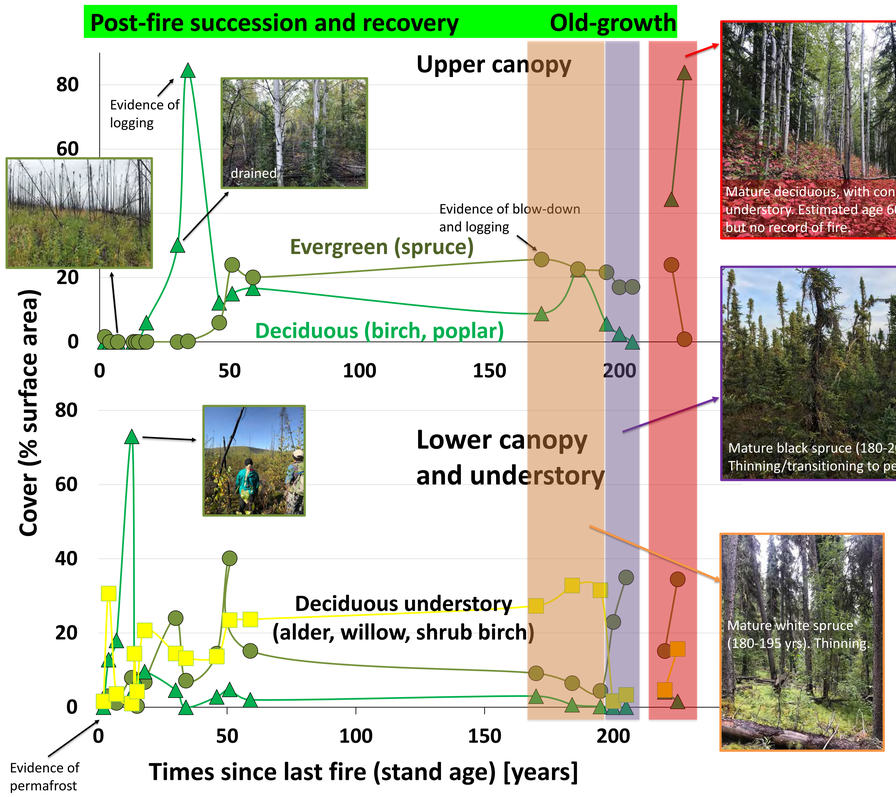


Fig. 1. (Left) Location and (Right) 30-year summer wetness trend from Landsat of 32 forest stands in interior Alaska. Letters indicate region, with DH = Dalton Hwy. (#11), EH = Elliott Hwy., BZ = Bonanza Creek LTER, DJ = Delta Junction; year indicates year of last fire. Red areas show a decreasing wetness over the last 30 years; many of these locations burned since ~1995. Blue areas show an increasing wetness trend; many of these areas burned during ~1970-1995. Some areas showed either increasing or decreasing wetness in the absence of a recent fire. A selection of these locations were labeled as "expanding" (Exp; increasing wetness and increasing NDVI), "deciduous washout" (DW; increasing wetness and decreasing NDVI) or disturbed (DIST; decreasing wetness and increasing NDVI), and targeted for field surveys in 2017.

We surveyed the composition and structure of 20 boreal forest stands that over the past 30 years displayed increasing, decreasing or no change in Landsat TIR, NDII, NDVI, Brightness, Greenness and, or Wetness (Fig. 1). 13 of these sites had recently burned; 7 were considered old-growth (>100 yrs since last fire).

At each site, we surveyed 3-5 100-m transects (stratified by tree canopies and ground) for vegetative cover, height, diameter, fraction and type of standing and downed dead trees, and leaf area index (LAI). Data were recorded by tree species and ground cover type (moss/lichen, forb, grass). We also collected cores or disks for 2-5 trees per species to reconstruct stand fire history and productivity.

Results



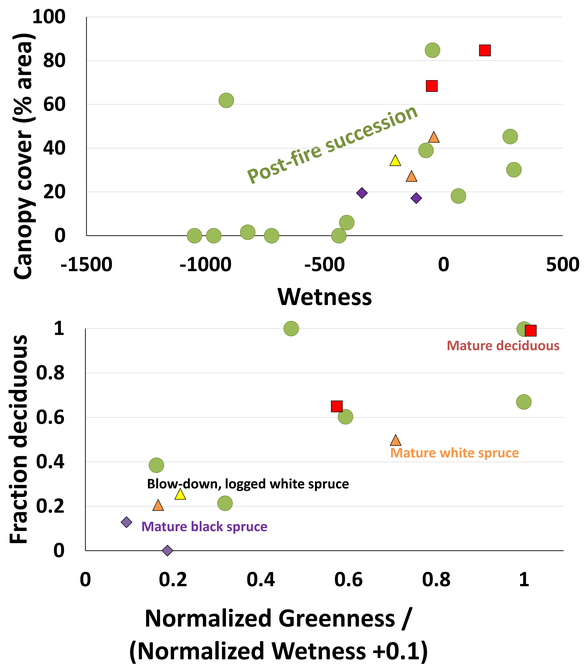


Fig. 3. (Top) Correlation between normalized wetness vs. canopy height and between Normalized Greenness / (Wetness +0.1) vs. fraction deciduous in the upper canopy for forests in interior Alaska. Remote sensing parameters detect changes in forest structure related to disturbance (fire, wind, logging) as well as aging and transitions to non-forest vegetation types associated with peatland and permafrost dynamics.

Fig. 2. Structure of boreal forest stands during post-fire succession. Young stands are dominated by deciduous trees, with coniferous trees in the lower canopy. Mature stands are mixed white spruce/deciduous or black spruce, often with deciduous understory.

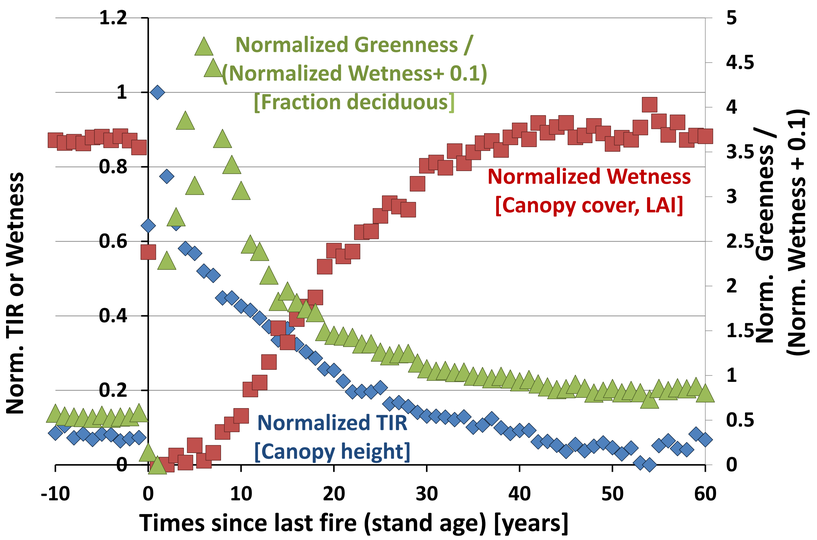


Fig. 4. Trajectory of boreal forest remote sensing indices during post-fire succession. Trends were calculated for all reported fires since about 1960 in a 22° longitude × 4° swath cutting across Manitoba and Saskatchewan, Canada. Points are averages of all high quality Landsat pixels as a function of time since fire. Field measurements in Manitoba (McMillan & Goulden 2008) and Alaska (this study) indicate (1) wetness is related to canopy closure, (2) TIR is related to canopy height, and (3) the ratio of greenness to wetness is related to deciduous fractional cover.

Key Findings

Following stand-replacing fires, spruce-dominated boreal forest stands in North America undergo distinct changes in forest structure, including vegetative cover, canopy height, and fraction of deciduous canopy (Fig. 2). These changes correspond to changes in remotely-sensed surface reflectance and brightness temperature (Fig. 3). Thus, productivity can be monitored remotely for sites with known fire history (Fig. 4).

In younger forests, fire-related successional changes can overwhelm other impacts of disturbance (e.g. permafrost thaw and collapse, logging of burnt trees, changes in drainage) on surface properties. In older stands, however, natural changes (e.g. self-thinning, transition to peat plateaus) and other disturbances (wind, logging) strongly impact surface properties (Fig. 2, 3).

Together our data show that remotely quantifying forest productivity requires knowledge of disturbance history and regional succession and landscape trajectories.

References
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