Changes in Tundra Vegetation over 22 Years in the Toolik Lake - Upper Kuparuk River Basin Landsat NDVI 1985-2007

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INTRODUCTION

This study analyzed changes in tundra vegetation over a 22-year period as measured by NDVI (Normalized Difference Vegetation Index) in an area of arctic Alaska. The area analyzed covered 823 km² in the northern foothills of the Brooks Range, where the vegetation is predominantly tussock sedge, dwarf-shrub tundra.

METHODS

- Six Landsat scenes (TM and ETM, 30-m pixels) were compared: 1985, 1989, 1995, 1999, 2004, and 2007. All scenes had minimal cloud cover and were collected during the peak of the growing season.
- Radiance and reflectance were calculated from the satellite data. The band reflectances were radiometrically normalized using data from light and dark pseudo-invariant features. NDVI was calculated from the normalized reflectance of Bands 3 and 4. Areas of cloud or shadow and banding due to the loss of the Landsat 6 scan line corrector were masked.
- Trends in NDVI were calculated on a pixel basis using linear regression analysis, and tested for significance. Pixels with $p < 0.20$ were mapped.
- NDVI trends were analyzed by elevation, hill-slope and aspect using data from a Star3i ortho-rectified radar image (Nolan 2003). Vegetation type, surficial geomorphology, surficial geology and glacial geology were analyzed using recently published maps (Walker & Maier 2008).

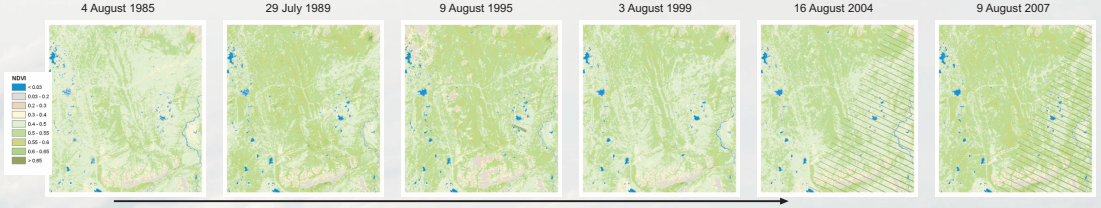


Figure 1. LANDSAT NDVI time series

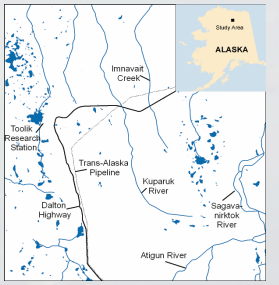


Fig. 2. Study location

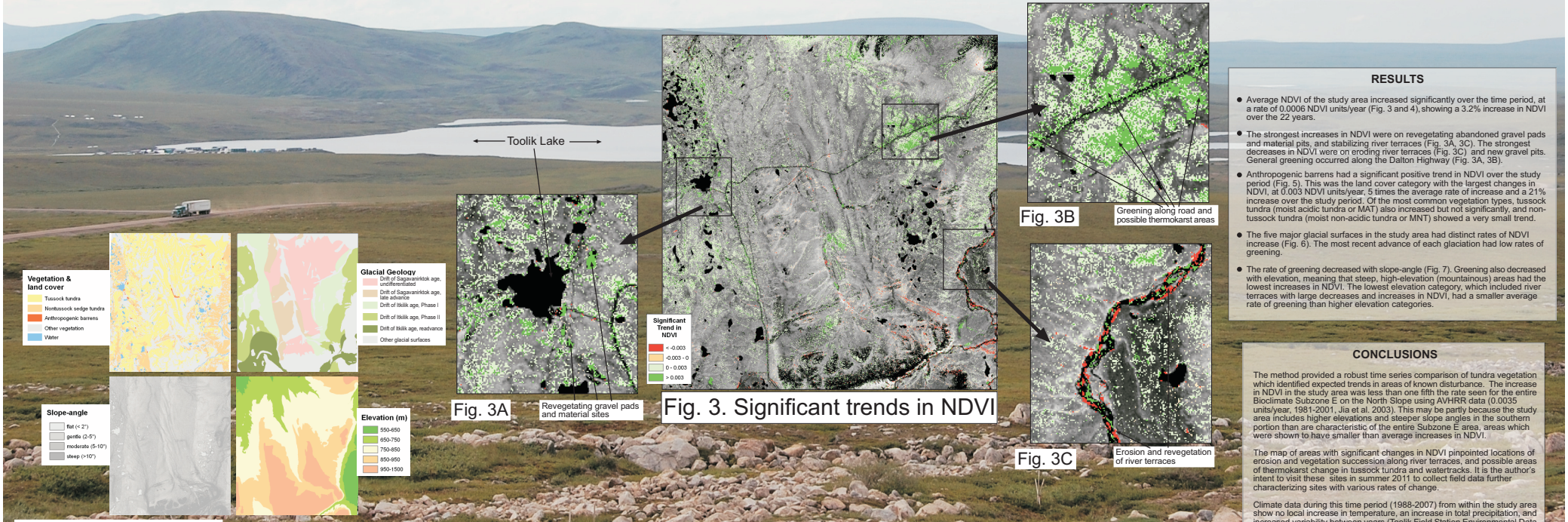


Fig. 3. Significant trends in NDVI

RESULTS

- Average NDVI of the study area increased significantly over the time period, at a rate of 0.0006 NDVI units/year (Fig. 3 and 4), showing a 3.2% increase in NDVI over the 22 years.
- The strongest increases in NDVI were on revegetating abandoned gravel pads and material pits, and stabilizing river terraces (Fig. 3A, 3C). The strongest decreases in NDVI were on eroding river terraces (Fig. 3C) and new gravel pits. General greening occurred along the Dalton Highway (Fig. 3A, 3B).
- Anthropogenic barrens had a significant positive trend in NDVI over the study period (Fig. 5). This was the land cover category with the largest changes in NDVI, at 0.003 NDVI units/year, 5 times the average rate of increase and a 21% increase over the study period. Of the most common vegetation types, tussock tundra (moist acidic tundra or MAT) also increased but not significantly, and non-tussock tundra (moist non-acidic tundra or MNT) showed a very small trend.
- The five major glacial surfaces in the study area had distinct rates of NDVI increase (Fig. 6). The most recent advance of each glaciation had low rates of greening.
- The rate of greening decreased with slope-angle (Fig. 7). Greening also decreased with elevation, meaning that steep, high-elevation (mountainous) areas had the lowest increases in NDVI. The lowest elevation category, which included river terraces with large decreases and increases in NDVI, had a smaller average rate of greening than higher elevation categories.

CONCLUSIONS

The method provided a robust time series comparison of tundra vegetation which identified expected trends in areas of known disturbance. The increase in NDVI in the study area was less than one fifth the rate seen for the entire Bioclimate Subzone E on the North Slope using AVHRR data (0.0035 units/year, 1981-2001, Jia et al. 2003). This may be partly because the study area includes higher elevations and steeper slope angles in the southern portion than are characteristic of the entire Subzone E area, areas which were shown to have smaller than average increases in NDVI.

The map of areas with significant changes in NDVI pinpointed locations of erosion and vegetation succession along river terraces, and possible areas of thermokarst change in tussock tundra and watertracks. It is the author's intent to visit these sites in summer 2011 to collect field data further characterizing sites with various rates of change.

Climate data during this time period (1988-2007) from within the study area show no local increase in temperature, an increase in total precipitation, and increased variability between years (Toolik Field Station Environmental Data Center, Wahren et al. 2005).

Fig. 4 Mean NDVI of Study Area

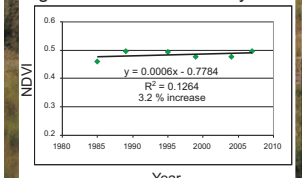


Fig. 5. NDVI of anthropogenic barrens and two most common vegetation types

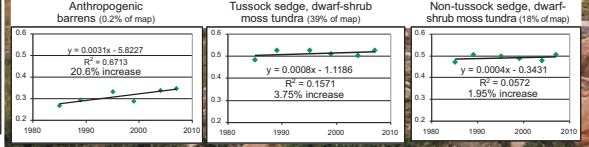


Fig. 6. NDVI trend of major glacial surfaces, arranged from oldest to youngest (Δ/yr)

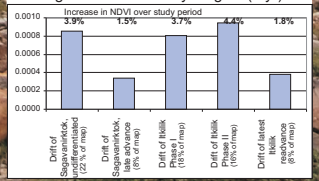
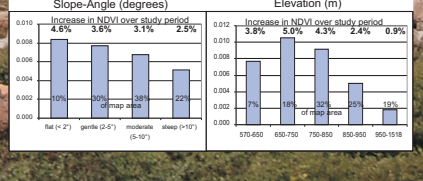


Fig. 7. NDVI trends of slope and elevation categories (Δ/yr)



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