Effects of climate, grazing, and gas development on tundra ecosystems of the Yamal Peninsula, northwestern Siberia

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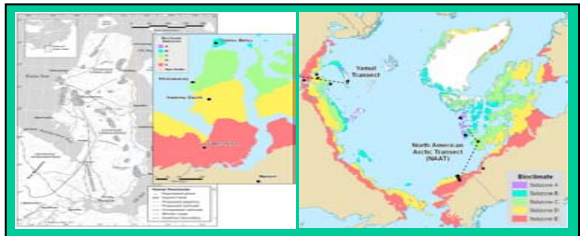
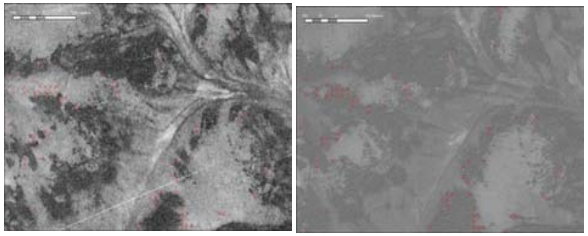


Study sites along the Eurasian (Yamal) Arctic Transect (EAT)

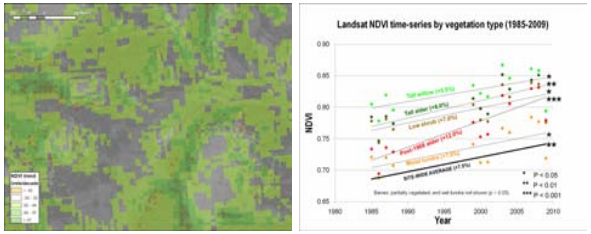
Vegetation dynamics in northwest Siberian forest-tundra

Tall shrub and tree proliferation in tundra-dominated regions represents a fundamental change to ecosystem structure and initiates a suite of changes to biophysical attributes including surface energy balance, hydrology, and biogeochemical cycling. Our objective is to quantify changes in tall shrub abundance (principally alder [*Alnus fruticosa*]) at two sites in northwest Siberia—Kharp and Tazovskiy (map, right)—by comparing high-resolution satellite imagery from 1968 and the 2000s.

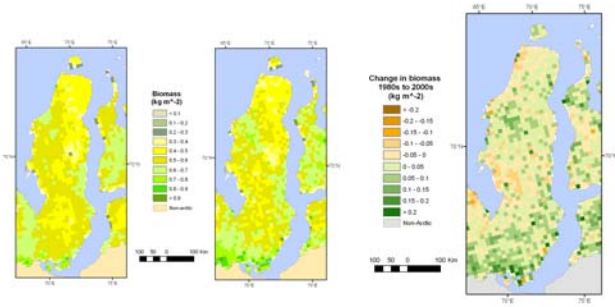
Satellite photo-comparisons indicate that rapid shrubland development has occurred at Kharp and Tazovskiy, but apparently only under circumstances where exceptionally favorable edaphic conditions have been brought about by wildfire (Kharp) or geomorphic disturbance (Kharp and Tazovskiy). Thus, disturbance in eco-tonal areas can initiate persistent, non-sucessional changes in vegetation structure. A systematic field data-collection effort planned for these two sites in summer 2011 seeks to elucidate relationships between shrub proliferation and geomorphic and wildfire disturbance.



High-resolution satellite imagery for the Kharp study area from 1968 (Corona KH-4B, above left) and 2003 (QuickBird, upper right) showing alder shrubland development. The red markers indicate areas of shrub infilling; total cover of alder increased by 8% across the 64 km² study site. Most shrub recruitment has occurred on mineral-dominated substrates, where surface organic material was removed by an old (≥ 100 YBP) high-intensity fire. Periglacial disturbance processes, such as active layer detachment and nivation, also appear to be vital in initiating shrubland development elsewhere in the southern Yamal and Tazovskiy Peninsula regions.

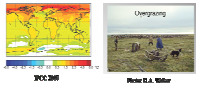


Graphic of spatio-temporal trends in NDVI derived from Landsat TM/ETM+ data (1985-2009) for the Kharp study area (above left). Colored areas correspond to areas with a statistically significant trend ($p < 0.05$). As expected, new shrublands tend to have the strongest positive NDVI anomalies. However, several other vegetation types show significant positive trends; the figure at upper right displays mean NDVI values for common vegetation communities across the Kharp study area, with alder shrublands showing the highest rates of greening.



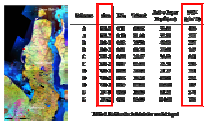
Simulating climate and grazing effects

The Yamal Peninsula is an area occupied by Nenets nomadic reindeer herders and also affected by climate change. Research questions include: 1) How does climate change and herbivory affect tundra vegetation dynamics? 2) Do these effects differ across the latitudinal tundra gradient of the Yamal Peninsula?

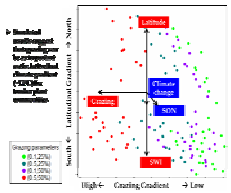


ArcVeg – Arctic tundra vegetation dynamics model

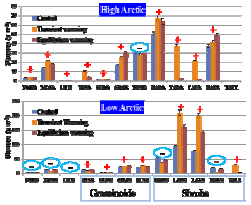
Model setting



Results – NDVI estimation

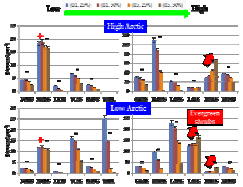


Warming effects on PFT biomass



Results indicate that warming has differential effects with respect to climate zone and plant functional types. Nearly all PFTs increase with warming in the High Arctic, but several understory PFTs decline with warming in the Low Arctic.

Grazing effects on PFT biomass

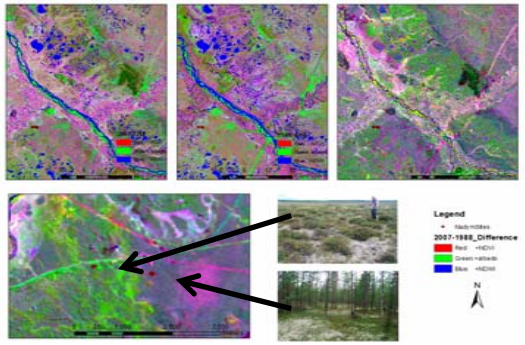


PFTs such as evergreen shrubs may benefit from increased grazing intensity. Mosses exhibit a nonlinear response to increased grazing pressure.

Remote sensing of land cover and vegetation change in the gas-developed Nadym region

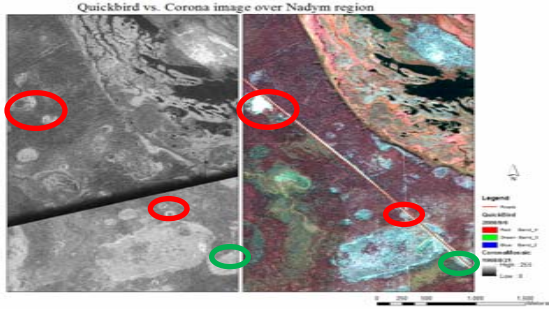
Landsat imagery from 1988 and 2007 were collected and preprocessed before deriving NDVI, albedo and Normalized Difference Water Index (NDWI). To minimize any seasonality effect, we normalized the data with the mean difference between images . Then we can calculated the changes in NDVI, albedo and NDWI by subtracting 1988 data from normalized 2007 data. Natural recovery of vegetation occurs around old roads and is detected with an increased NDVI of ~0.25. Development disturbances such as new buildings and new roads can cause NDVI to decrease significantly (-0.58), while albedo can increase by approximately 0.1. The final difference map shows that NDVI in both forest and tundra sites has declined with a greater decline in the tundra site (-0.064) than in the forest site (-0.036), suggesting that tundra vegetation may be more vulnerable than forests to land use change.

Changes detected with Landsat imagery near Nadym field sites



High resolution remote sensing imagery can be used to detect fine-scale spatial patterns within disturbed areas. We collected satellite Quickbird imagery (acquired 2006/9/6) and aerial Corona imagery (acquired 1968/8/21) within our Landsat study region. Corona images were co-registered and georeferenced with Quickbird images. The Quickbird image shows new roads, and along the roads, there are regions with conspicuous vegetation decline. We are continuing to analyze the spatial patterns of vegetation change with respect to nearby disturbances such as roads.

Quickbird vs. Corona image over Nadym region



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