Spatio-temporal dynamics in tall shrub cover near Kharp, northwest Siberia: linkages between shrub proliferation and disturbance

Abstract

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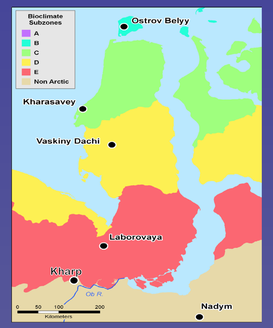
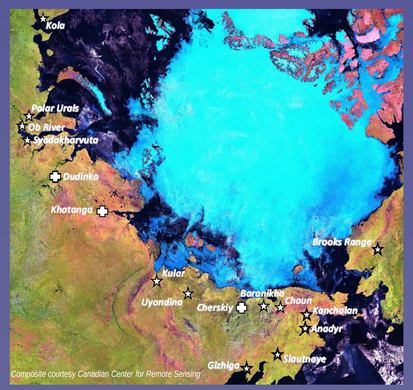
Comparison of high-resolution satellite imagery from 1968 (Corona) and 2003 (QuickBird) indicates that dramatic expansion of tall alder shrublands has occurred in the foothills of the Polar Urals near the town of Kharp, northwest Siberia. The Kharp area encompasses a broad ecotone of boreal forest and Low Arctic tundra. Observations made during a field visit in August 2009 indicate that most of the shrub expansion has occurred in areas affected by an antecedent high-intensity wildfire (≥100 yrs BP) that removed the surface organic layer. Mature Siberian larch trees are uncommon in the area visited, with all of the mature trees occurring within dense alder thickets that probably served as a firebreak. Alder recruitment both inside and outside of the burn is concentrated on microsites with mineral-dominated soils associated with cryogenic patterned-ground features. QuickBird imagery indicates that the regular spacing of small alders in much of the area mirrors the spacing of the underlying circle- and inter-circle areas. This pattern appears to be retained in well-established thickets, but the gaps between mineral-dominated circles probably become filled over time by the expansion of shrub canopies. Linkages between cryogenic patterned-ground features and shrub recruitment may explain the regular spacing of alders in open shrublands elsewhere in the low Arctic. Together, these observations highlight the role of disturbance in driving changes in shrub cover and NDVI in parts of the Low Arctic. A July 2010 field effort is tentatively planned for a ~47 km^2 study area near Kharp. The primary objective of the field effort is to determine the extent to which tall shrub expansion is associated with disturbance agents that create or maintain mineral-dominated edaphic conditions, from the landscape scale (wildfire) to the meter scale (frost boils). Soils, dendrochronology, and vegetation ground-truthing data will be collected in order to interpret the changes in shrub cover that are evident in the satellite imagery. Finally, vegetation and environmental data will be recorded at ten relevés that can be tied in with the existing relevé dataset for the Yamal Transect.

Kharp Focus Area

Kharp is located in the eastern foothills of the Polar Ural Mountains near the base of the Yamal Peninsula, northwest Siberia (right). Alder shrubs have expanded markedly in recent decades at the site, and there is evidence that trees and shrubs have become more abundant elsewhere in the forest-tundra transition of northwest Siberian in recent decades (e.g., Shiyatov et al. 2005, Esper and Schweingruber 2004). Field studies planned for 2010 at Kharp would include establishment of ten relevés that could be integrated into the existing dataset for the Yamal region. Detailed vegetation and environmental data have been collected at 69 relevés along a ~900 km transect as part of the Yamal LCLUC project. The relevés are distributed at tundra sites spanning four bioclimate subzones for Arctic tundra, and a forest-tundra site at Nadym (right). Since predominant vegetation cover, surface geology, and disturbance history differ from Nadym and relevé data from Kharp would be useful in evaluating the relationships among vegetation, environmental attributes, and NDVI along bioclimate and soil texture gradients (see Yamal relevé ordination poster, this session).



Vegetation Dynamics at the Continental Scale



The Kharp study area is part of a broader research effort examining changes in tree and tall shrub cover in Low Arctic ecosystems since ~1965, and the sensitivity of the Normalized Difference Vegetation Index (NDVI) to recent changes. This research encompasses a network of ~15 sites with a much broader geographic distribution than achieved by previous studies.

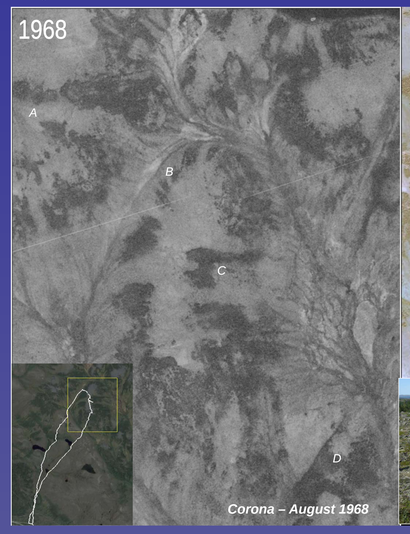
Study sites are 35-50 km^2 in size. After image co-registration, a sampling grid overlay is applied to each photo pair and vegetation attributes are determined at each grid node in a GIS. The distance between grid nodes is 25 m., resulting in about 75,000 sampling points per study site. For sites with multi-spectral QuickBird imagery, a spectral classification is used to assign vegetation attributes for water, prostrate tundra, and barrens. Sampling for shrubby areas is conducted manually in a GIS. From these data, the absolute (m^2) and relative (%) change in tree and shrub cover are determined for each photo pair. Change in tree abundance is also determined for sites with Gambit imagery.

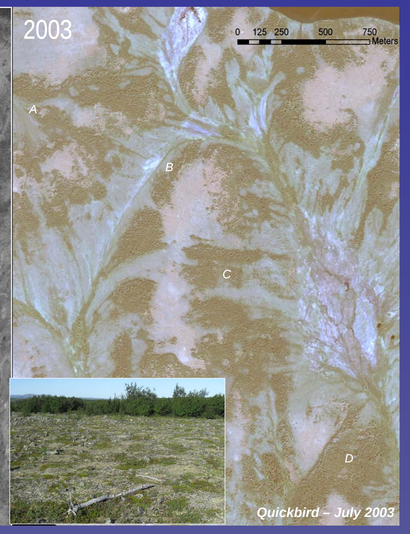
Ancillary environmental data are also incorporated into the vegetation change GIS. These data include (1) geomorphic and physiographic units digitized for each scene; (2) disturbance footprints (e.g., recent thermokarst); (3) elevation and hillslope extracted from ASTER DEM data; (4) climate data; and (5) multi-temporal NDVI data from AVHRR. These data are then used to rank the importance of local- and regional environmental factors in driving the observed changes in tree and shrub abundance.

Data summaries will relate the vegetation metrics and environmental strata within and among study areas. Inferential statistics (e.g., ANOVA) will be used to evaluate the relative influence of the environmental strata as determinants of the changes. Finally, NDVI data from AVHRR, QuickBird, and other sensors will be added to the vegetation change GIS to evaluate the relationship between the NDVI metric and recent vegetation changes, from the AVHRR-pixel scale to the meter-scale. Quantitative assessments of the pace and extent of changes in the structure of northern ecosystems will improve understanding of associated impacts to a range of climatic, hydrological, and biogeochemical processes within—and beyond—the Arctic.

Vegetation Dynamics at Kharp since 1968

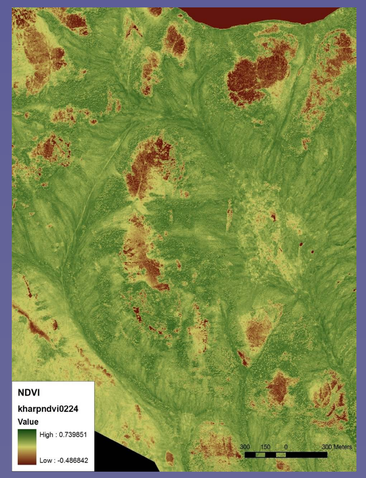
Corona (below left) and QuickBird (below right) satellite photos indicate rapid proliferation of alders (*Alnus*) in the eastern foothills of the Ural Mountains near Kharp. The area is easily accessed ~4 km from a paved road (route shown in inset, below left). A field visit revealed that most of the shrub expansion has occurred where surface organic soils were removed by wildfire ~100 YBP. Additionally, young shrubs are concentrated on mineral-dominated microsites associated with patterned ground, indicating that shrub proliferation is linked to disturbance from the landscape scale (wildfire), to the meter scale (cyrogenic disturbance).

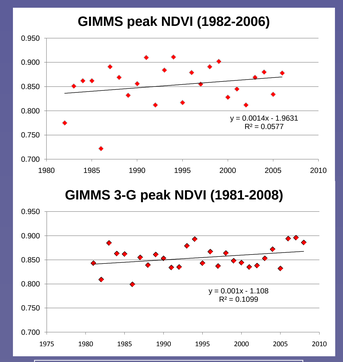




Normalized Difference Vegetation Index (NDVI)

Relating the coarse-scale NDVI record to changes in the composition and structure of Arctic vegetation is problematic due to landscape heterogeneity. Examination of NDVI at fine spatial scales—where relationships with key geomorphic and hydrologic controls can be evaluated—are useful in interpreting the coarse-scale signals and determining what parts of the landscape are greening. An NDVI map for the Kharp area based on QuickBird imagery (below left) reveals fine-scale patterns that correspond to discrete vegetation types. Comparison of 1968 and 2005 imagery indicates that relatively productive tall shrub cover has increased ~11% within the Kharp study area, and much of the expansion has occurred in areas that were formerly barren. However, coarse-scale NDVI products (such as GIMMS and GIMMS 3g; below right) reveal modest (~3%) positive anomalies in NDVI since the early 1980s for the single AVHRR pixel co-incident with the Kharp study area. This suggests that positive forcings on NDVI occur locally, rather than within the matrix of low shrub and tundra vegetation (~67% of total land cover of study area; bottom). Field observations at Kharp site suggest that shrub proliferation in recently disturbed areas constitute a strong positive forcing on the NDVI record.

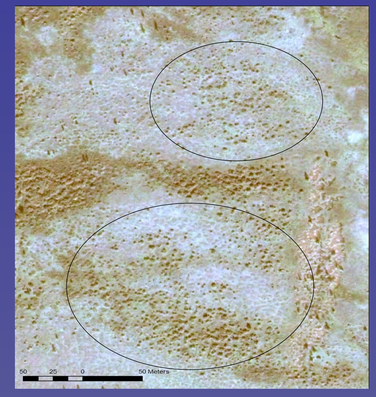




Vegetation type	Area (km^2)	Percent of total
Tall alder scrub	9.1	19.3
Low scrub	21.2	45.0
Moist tundra	10.4	22.0
Wet tundra	2.4	5.2
Partially vegetated	3.9	8.3
Water	0.1	0.2
Total	47.1	100.0

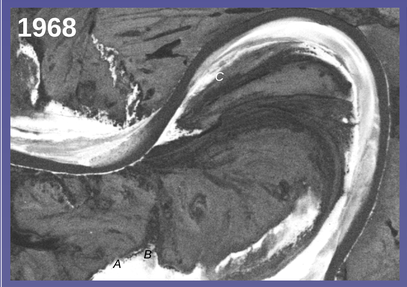
Linkages between shrub recruitment and disturbance

Field observations indicate that alder recruitment at Kharp is concentrated on the mineral-dominated centers of sorted- and non-sorted circles (right). This pattern is also evident in QuickBird imagery showing individual shrubs and the reticulate pattern of inter-circles (below left). Alder is a minerotrophic species and has relatively high growth rates that may allow it to establish on cryoturbated sites where tundra plants cannot. Linkage between alder recruitment and cryogenic processes would explain the regular spacing of alders in open tall shrublands occurring on patterned ground elsewhere in the Low Arctic (e.g., Selawik National Wildlife Refuge, northwest Alaska; below right).



Yamal Peninsula

Alder shrublands are also associated with mineral-dominated substrates on the Yamal Peninsula. 1968 Corona and 2009 oblique aerial photos along the Tanlova River indicate that most shrub expansion has occurred on dune margins (A, B) and the point bar (C). Elsewhere on the Yamal, low willow shrublands are common on landslide features, where marine silts have been exposed by permafrost degradation.



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