Land surface dynamics on the Yamal Peninsula based on multi-temporal imagery

Qin Yu [1], Howard Epstein [1], Skip Walker [2]
1. Department of Environmental Sciences, University of Virginia
2. Institute of Arctic Biology, University of Alaska, Fairbanks

Background

The Yamal Peninsula region in northwest Siberia has been identified as a "hot spot" of land cover change, since it is affected by climate change and various anthropogenic forcings such as managed nomadic reindeer herding and large-scale oil and gas development in addition to expansion of the cities in these cold regions.

Remote sensing has been proved to be quite useful in detecting land use and land cover changes all over the world. A recent study using a relatively long (25 year) time series of coarse-resolution (several km) satellite imagery for the Yamal shows that much of the land surface of this region can be influenced by land use and development. However, identifying the detailed relationships between the tundra and these disturbances requires some satellite imagery of a high resolution (tens of meters). In this study we used multi-temporal Landsat images to detect land cover and land use changes in the Yamal region.

Research Objectives

1. To evaluate the change detection method;
2. To detect changes along the climatic gradient;
3. To analyze and understand the changes and interpret the effect of these changes on tundra vegetation.

Materials and Methods

In this study, we used multi-temproal Landsat imagery collected in the Nadym region (2007 and 1988) to evaluate the improved methodology based on Fernández et al. (2009).

Study site chosen on the Yamal Peninsula for this study is a region encompasses Nadym city (northern boreal forest, forest-tundra transition), relatively close to oil and gas field facilities. The image pair chosen was mainly associated with the field sites set up in the Yamal Peninsula which can offer certain amount of ground information.

Table 1. imagery collected in the Nadym region

Study site	Date	Mission and Sensor	Path/row
Nadym	1988-6-19	Landsat-4, TM	160/14
	2007-7-7	Landsat-5, TM	160/14

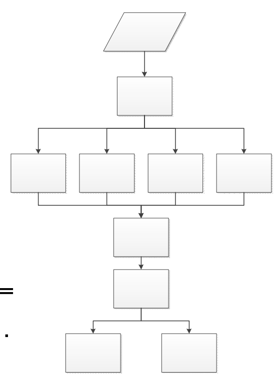

Fig 1. Image Processing Flow chart

$$NDVI = \frac{\rho_{RED}-\rho_{NIR}}{\rho_{RED}+\rho_{NIR}}$$ (Rouse et al. 1974)

$$NDWI = \frac{\rho_{NIR}-\rho_{SWIR}}{\rho_{NIR}+\rho_{SWIR}}$$ (Gao 1996)

$$albedo = -0.0018 + 0.356\rho_1 + 0.130\rho_3 + 0.373\rho_4 + 0.085\rho_5 + 0.072\rho_7$$ (Liang, 2001)

Ts (surface temperature)= f (T6, Ta, e, t) (Qin et al. 2001)

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Difference Maps Based on Four Integrative Indices

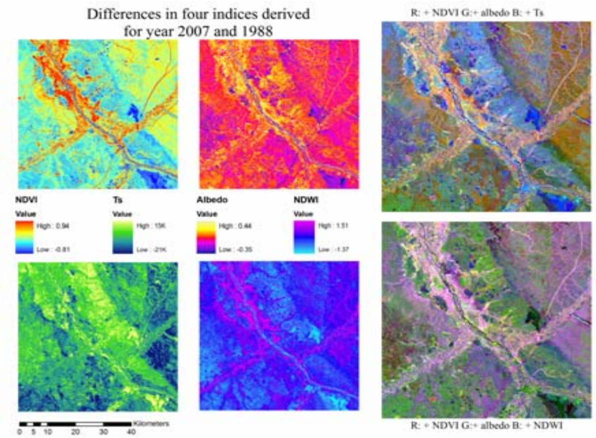

Fig 2. Differences in NDVI, Albedo, Surface temperature and NDWI between 2007 and 1988

From the collected image pair for the Nadym site, we calculated NDVI, albedo, surface temperature and NDWI for year 2007 and year 1988 respectively, four indices indicating vegetation, surface reflectivity, surface temperature and surface moisture content for each image and then calculated the difference between each image pair after a relative normalization procedure. Fig. 2 shows the differences calculated in NDVI, albedo, surface temperature and NDWI between 2007 and 1988. The composite maps show the overall changes in the Nadym region. The greatest changes occur near cities, gas facilities and along the river.

Detected Changes

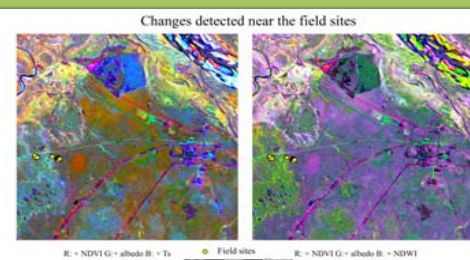

Fig 3. Differences detected close to the field sites between 2007 and 1988

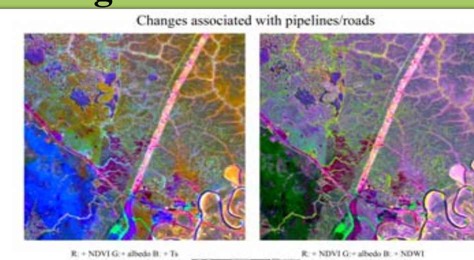

Fig 4. Differences detected associated to pipelines/roads

Fig. 3 shows the changes detected close to the field sites established in 2008 which were close to the gas facilities. Fig. 4 shows changes along pipelines/roads.

Discussion

The methodology provides information beyond surface reflectance and easier for interpretation. For the Nadym site, where the field sites were close to the city, we could easily locate the changes such as new expanded facilities and roads. In addition, newly constructed roads (increase in albedo and decrease in NDVI) and recovery of vegetation (increase in NDVI) were located on the composite difference image, suggesting that multi-temporal Landsat imagery can be very well used to detect land use changes such as road and building constructions indicated by differences in the four indices. This method will be applied to field sites set up in the Yamal region.

While using multi-temporal Landsat images can help detect infrastructure changes in the Yamal region, application of these images to detect other more subtle changes to the vegetation are limited by the phenological and hydrological differences that were caused by the different times during the summer that the images were obtained.