Mapping land cover changes using Landsat TM: a case study of Yamal ecosystems, Arctic Russia

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Summary

This paper details changes in land cover types in tundra landscapes (Yamal) during since 1988. The research method is supervised classification (Minimal Distance) of the Landsat TM scenes. The new approach of the current work is application of ILWIS GIS and RS tools for Bovanenkovo region.

Research area: location & environmental settings

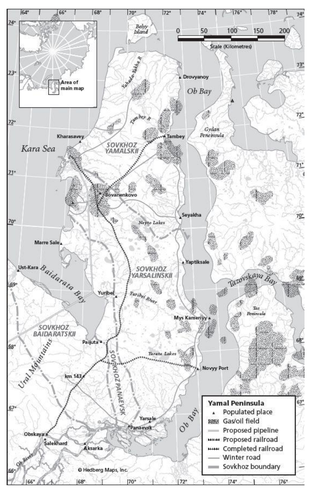

Figure: 1. Yamal Peninsula

The research area is geographically located on the Bovanenkovo region, the north-western part of Yamal Peninsula, West Siberia, Russia (Fig.1). The Yamal Peninsula is a flat homogeneous lowland region with low-lying plains of heights <90m. Such geographic settings create specific local environmental conditions in the region. Thus, Yamal is the worlds largest high-latitude wetland system covering in total 900,000 km^2 of peatlands, complex system of wetlands, dense lake and river network. Typical for this region are seasonal flooding, active erosion processing, permafrost distribution and intensive local landslides. Dominating vegetation types are typical tundra species (heath, grasses, moss, and lichens), and woody plants (shrubs and willows).

Research data

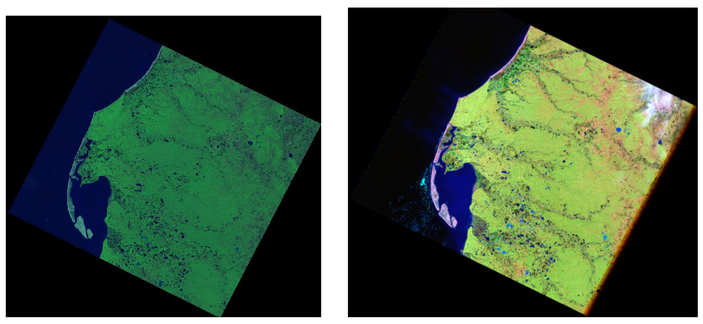

Figure: 2. Landsat TM images: 1988 (left) and 2011 (right)

The research data are orthorectified Landsat TM scenes covering north-west of Yamal. The images have a time span of 23 years: 1988-08-07 and 2011-07-14, taken in growing season when vegetation coverage is clearly visible.

Methods

The research methods consist of image classification, spatial analysis and thematic mapping, technically performed in ILIWIS GIS. Research steps:

1. Data pre-processing: **a)** import .img into ASCII raster format (GDAL). After converting, each image contained collection of 7 Landsat raster bands **b)** visual color and contrast enhancement **c)** geographic referencing of Landsat scenes: UTM (Universal Transverse Mercator), Eastern Zone 42, Northern Zone W, WGS 1984 datum (Georeference Corner Editor, ILWIS).

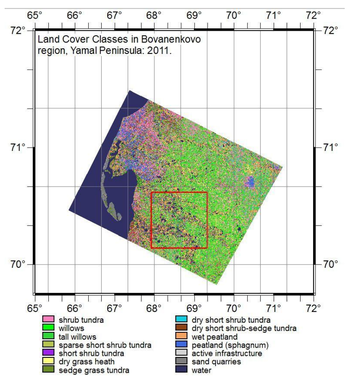

Figure: 3. Selecting AOI (study area)

2. Research area selection. The area of interest (AOI) was identified and cropped on the raw images (Fig.3). This area shows Bovanenkovo region in a large scale. The AOI area best represents typical tundra landscapes.

3. Image classification method is supervised classification (Minimal Distance), which is based on the spatial analysis of spectral signatures of object variables, i.e. vegetation types. The classes sampling was performed using Sample Set tool in ILWIS GIS. The training pixels for each land cover type were selected as representative samples and stored as classification key. They have contrasting colors, visually visible and distinguishable on the image. The defined classes include *shrub tundra, willows, tall willows, short shrub tundra, sparse short shrub tundra, dry grass heath, sedge grass tundra, dry short shrub tundra, dry short shrub sedge tundra, wet peatland, peatland (sphagnum)*. The pixels were associated with land cover classes, using their DNs, similar to the key samples.

4. Thematic mapping: layout of main research results, represented as maps of the land cover classes. The created domain Land classes includes legend with representation colors visualizing each category.

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Results

The research output includes following results:

1) two thematic maps of land cover types in Bovanenkovo area, Yamal (Fig.4)

2) calculation of the areas in *ha* of land cover types (Tab.1).

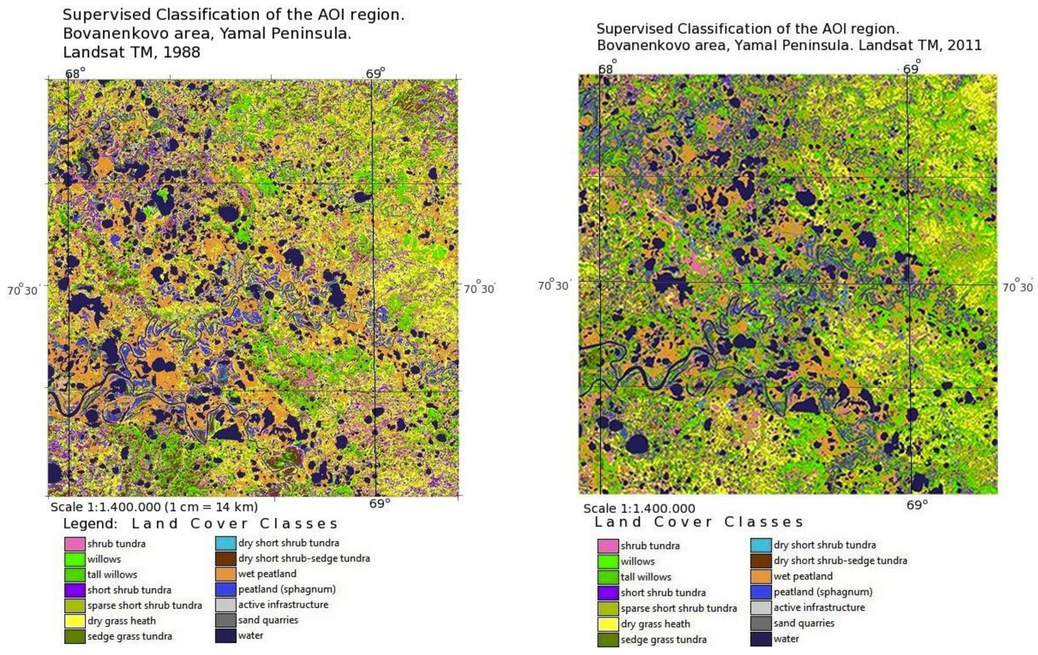

Figure: 4. Land Cover Classes in Bovanenkovo area, Yamal Peninsula: 1988 (left) and 2011 (right)

The assessment of the areas of all land cover classes shows following results. Willows covers 2750,57 ha in 2011, which is more than in 1988, when it covered 1547,52 ha (both *'tall willows'* & *'willows'* classes). Noticeable is increase in tundra vegetation: *'short shrub tundra'*, *'sparse short shrub tundra'* and *'dry short shrub tundra'* have more areas covered in 2011 comparing to 1988: almost 5442,00 ha vs 1823,00 ha.

Table: 1. Statistics on the land cover classes, Bovanenkovo region, Yamal Pennsula.

Land Cover Class	1988, # pixels	2011, # pixels	1988, ha	2011, ha
Shrub tundra	220447	168226	1146.3244	874.7752
Short shrub tundra	165079	270158	858.4108	1404.8216
Willows	193645	457004	1006.954	2376.4208
Tall willows	103954	71952	540.5608	374.1504
Sparse short shrub tundra	176511	759380	917.8572	3948.776
Dry grass heath	641420	231719	3335.384	1204.9388
Sedge grass tundra	27545	57052	143.234	296.6704
Dry short shrub tundra	8984	16993	46.7168	88.3636
Wet peatland	761231	531809	3958.4012	2765.4068
Peatland (sphagnum)	120328	93979	625.7056	488.6908
Dry short shrub-sedge tundra	173693	92242	903.2036	479.6584

Increase of wooden vegetation class goes along with shrunk of grass and heath areas: *'dry grass heath'* occupied area of 3335.39 ha in 1988, while currently it covers 1204.94 ha. Slight decrease can be noticed in the *'peatlands'* and *'wet peatlands'* classes: 3958.40 ha against 2765.41 ha in 2011 by *'wet peatlands'*, and 625.71 ha in 1988 versus 488.69 ha by *'peatland (sphagnum)'* class.

Conclusion

The GIS-based mapping of the northern ecosystems is important tool for the landscape monitoring and management. Processing of remote sensing data (*e.g.* Landsat TM scenes) by means of GIS (*e.g.* ILWIS) improves technical aspects of the landscape studies, since it enables assessment of spatio-temporal changes in vegetation coverage. Spatial analysis of land cover types in northern landscapes can help to detect local environmental changes in Arctic regions.

Current research details changes in the land cover types in Bovanenkovo region, Yamal Peninsula, during the past 2 decades. These results are received as a result of the spatial analysis of classified images. The GIS mapping is based on the results of the image classification. The research results presented in the current work illustrate spatial distribution of land cover types in the selected area.

Analysis of the results shows noticeable overall increase of woody vegetation (willows and shrubs) and decrease of peatlands, grass and heath areas. This illustrates environmental process of greening in Arctic, i.e. the unnatural increase of woody plants. The gradual changes in plant species patterns and distribution affect landscape structure in Yamal ecosystems. The triggering factors for these processes could be complex environmental changes in Arctic, as well as local cryogenic processes (*e.g.* successive change in vegetation recovering after cryogenic landslides).

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