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# Mapping Land Cover Changes Using Landsat TM: A Case Study of Yamal Ecosystems, Arctic Russia

## Introduction

This paper details changes in land cover types and vegetation distribution in tundra landscapes during the past two decades. The main method of the work is classification of the Landsat TM scenes for land cover change detection. The new approach of the current work is application of GIS and remote sensing tools for Bovanenkovo region, since there is no previous remote sensing and GIS-based studies performed in the same area focusing research problem of land cover changes.

The research area is geographically located on the Bovanenkovo region, the north-western part of Yamal Peninsula, West Siberia, Russia. The Yamal Peninsula is the world's largest high-latitude wetland system covering in total 900,000 km² of peatlands, since lowland region creates ideal conditions for the development of wetlands, dense lake and river network (Kremenetski et al. 2003). The geomorphology of Yamal Peninsula is flat homogeneous land and low-lying plains with maximal elevations lower than 90 meters (Walker *et al*. 2009). Such environmental settings of Yamal facilitate seasonal flooding, active erosion processing, permafrost distribution and intensive local landslides formation.The dominating vegetation types on Yamal include different types of shrubs and willows, heath, grasses, moss, and lichens.

Changes in land cover types in the Russian North are caused by various reasons. These include multiple ecological and social factors, such as permafrost degradation, reindeer grazing and gas-field development, as well as overall environmental changes, including climate (Walker et al. 2009). One of the factors causing changes in vegetation types in landslide formation. Thus, the early-stage vegetation, such as pioneering mosses or lichens usually follows recent landslide formation, while meadows and willow shrubs with high canopy points indicate later stages of vegetation regeneration after landslide activities. Therefore, distribution of the willow shrubs on bare slopes may indicate that these areas were landslide-affected in the past (Ukraintseva and Leibman, 2007; Leibman and Kizyakov, 2007).

Current research focuses on application of remote sensing data and GIS methods for land cover change detection in Bovanenkovo region. Technically, the data processing was performed in ILWIS GIS, using methods of image interpretation and supervised classification applied for Landsat TM scenes (1988 and 2011). The classification results indicate changes in land cover types in Yamal ecosystems, namely, the overall increase in woody plants, such as willows and shrub tundra (e.g. "short shrub tundra", "sparse short shrub tundra" and "dry short shrub tundra"), and slight decrease in grasses, heath and peatland.

The main detected trend in these changes demonstrates process of greening in Arctic tundra, which indicates structural variations in ecosystems within the Bovanenkovo district. These changes can be explained by the complex ecological processes as well as anthropogenic influence, caused by Bovanenkovo gas field exploration and its consequences.

## Methods

The research methods consist of the application of the remote sensing and geoinformation tools for land cover studies. The technical implementation of the imagery processing, spatial analysis and GIS mapping was performed in ILWIS GIS. The research data include two Landsat TM scenes for the years 1988 and 2011. The Landsat data were selected due to their suitability for land cover mapping they enable recurrent remote sensing observations, interpretation and assessment of temporal changes in land cover types in the high north. The research methodology includes supervised classification of the Landsat scenes, GIS mapping highlighting changes in land cover types. And calculation of the areas of various land cover types in 1988 and in 2011.

The pre-processing of the imagery includes data import and visual settings of colours and contrast. The images were imported to ILWIS from .img into ILWIS raster map format (ASCII) using GDAL

(Geospatial Data Abstraction Library). After converting, each image contained collection of 7 Landsat raster bands and their metadata stored in Map List file, information about geo-reference and coordinate system. The new created imagery was automatically associated with domain type "Image" in ILWIS. The contrast of the images has been enhanced and colour composite of three band selected. Finally, from the whole image of north-western Yamal the research area of interest (AOI) was cropped. The AOI area shows Bovanenkovo region in a large scale.

The methodological approach of the current research is supervised classification (minimal distance method). The basis for this classification is allocation of pixels on the image to the land cover classes, using their different DNs. The classes sampling was performed using Sample Set tool in ILWIS GIS menu. The training pixels, which have spectral values identical to examples from classification key, provided from the University of Joensuu, were selected as representative training samples for each of the land cover classes and stored in Sample Set file. These pixels have contrasting colours, visually visible and distinguishable on the image. The created domain for classification map is "Land classes" included representation colours for each land cover class, which were used for layer mapping. During the classification process the training pixels were extracted in Sample Set Editor, indicating the representative land cover classes, spread over the distribution area. The basis for this classification is allocation of pixels on the image to the land cover classes, using their different DNs. The classification used in the current work is pixel-based and does not include object oriented techniques.

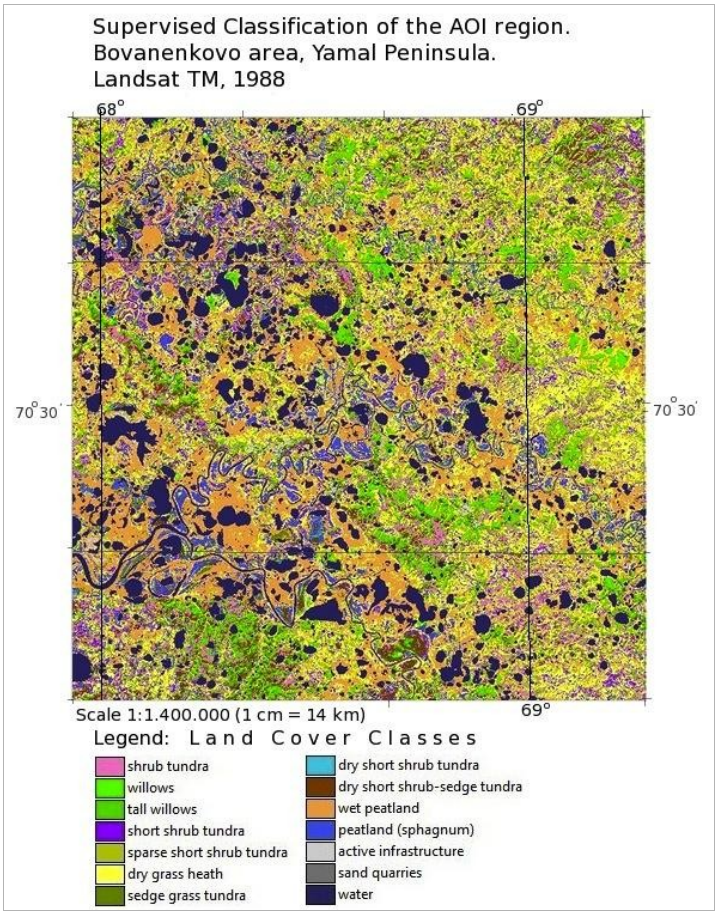


***Figure 1*** *Land cover classes in AOI (Area Of Interest): Bovanenkovo region, Yamal. Results of the supervised classification of the Landsat TM image, 1988 performed in ILWIS GIS.*

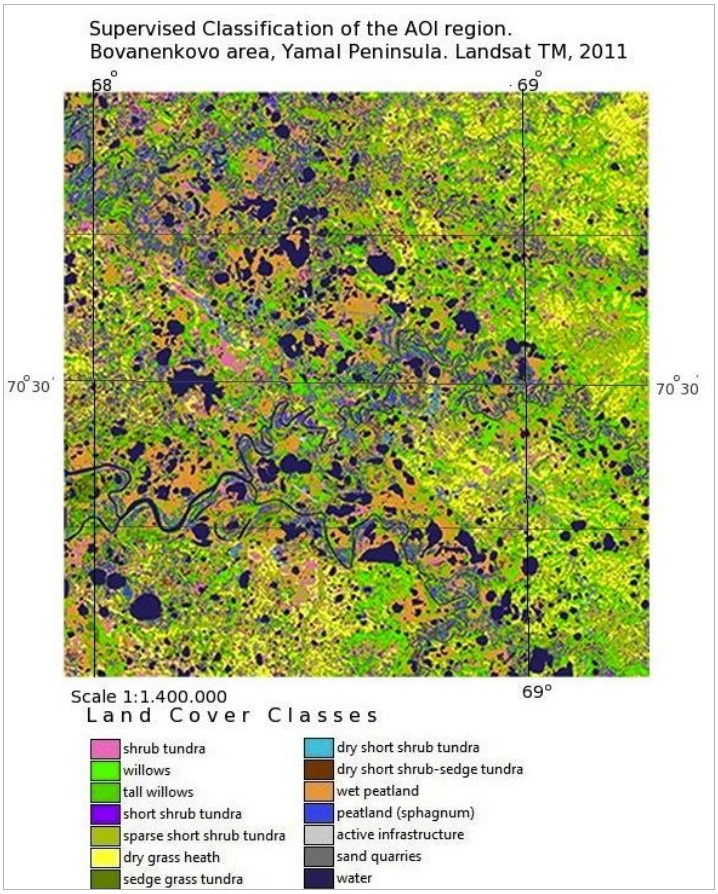


***Figure 1*** *Land cover classes in AOI (Area Of Interest): Bovanenkovo region, Yamal. Results of the supervised classification of the Landsat TM image, 2011 performed in ILWIS GIS*

The final methodological part included calculation of the areas covered by various land cover classes in both years. The calculations were made using information of the pixel size (0º 00´ 01,680´´, or ca 52 m²) and areas covered by each of the classes, computed in ILWIS GIS.

**Results**

The research results include two classified Landsat images and thematic maps presented the main outcomes (Fig.1 and Fig.2) as well as assessment of the areas in km² for various land cover types. The GIS mapping is performed using the results of the image classification, based on the relationship between the spectral signatures and object variables, i.e. vegetation types. The main research results are represented on the thematic maps of the vegetation distribution over the Bovanenkovo area, Yamal (Fig.1 and Fig.2). 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). Also separated classes were created for active infrastructure (buildings and main road network), as well as for sand quarries and water (separated subclasses for lakes and ocean waters). In totally, 14 classes were defined.

The following results were received for measurements of the areas of all land cover classes. For the year 1988 the both classes of willows class covers 2750,57 ha, which is ca 1203 ha more than in 1988, when willows covered 1547,52 ha (also both “tall willows” and “normal willows”). Increase in tundra

vegetation classes is also noticeable. Thus, such tundra classes as "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 against 1823,00 ha twenty years ago. 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 comparing to 488.69 ha by "peatland (sphagnum)" class.

**Discussion**

The research outcomes show changes in the land cover types in Bovanenkovo region in Yamal Peninsula during the past two decades. Analysing the classification results, the most evident trend in the vegetation changes in Yamal ecosystems is the overall increase of woody vegetation (willows) and decrease of peatlands and grasses. The changes in the structure of the Yamal ecosystems come through gradual amendments in species distribution and dominant classes, which now tends to be willows and shrub tundra.

**Conclusions**

The satellite-based monitoring of the northern ecosystems is important tool for the detection of the local environmental changes, caused by various factors. Assessment of land cover types is crucial component of landscape monitoring and management. Use of remote sensing data and GIS improves technical aspects of the landscape studies and mapping, since it enables assessment of spatio-temporal changes in vegetation coverage. The research results presented in the current work demonstrate changes in land cover types and distribution in Bovanenkovo region of the Yamal peninsula. This demonstrates overall increase in various types of shrubs and willows, and decrease in grass, peatland and heath areas. The triggering factors are complex environmental changes in Arctic regions, leading to greening processes, i.e. the unnatural increase of woody plants. Another factor for land cover changes is successive changes in vegetation recovering after landslide processes. Detected variations in land cover types indicate local environmental changes in the northern landscapes in Bovanenkovo district in Yamal Peninsula.

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