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ILWIS GIS for monitoring landscapes in tundra ecosystems: Yamal Peninsula, Russia

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1. Summary

The aim of this research is monitoring changes in tundra landscapes and distribution of various land cover types in Yamal Peninsula, during the past two decades. The technical basis of the work is ILWIS GIS software. The methodology is based on supervised classification applied to Landsat TM images taken in different years. The novelty of the work consists in application of ILWIS GIS spatial analysis tools and Landsat imagery for Bovanenkovo region in Yamal. The data processing was performed in ILWIS GIS software, using methods of image interpretation and supervised classification applied for Landsat TM scenes for 1988 and 2011 years.

Specific climatic-environmental settings of Yamal Peninsula facilitate seasonal flooding, active erosion processing, permafrost distribution and intensive local landslides formation. Landslides affect local ecosystem structure, since they change land cover types due to vegetation recovering after the landslide disaster. As a result of climate and environmental impacts, there are detected changes in the vegetation structure. In this paper we analyzed how the land cover types changed during 20 years.

The results of the performed spatial analysis indicate changes in the land cover types in Yamal ecosystems. Namely, there is detected 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. Such trend demonstrates process of greening in Arctic tundra, which indicates structural variations in ecosystems within the study region (Bovanenkovo district). These changes can be explained by the complex ecological processes including landslides.

2. Introduction

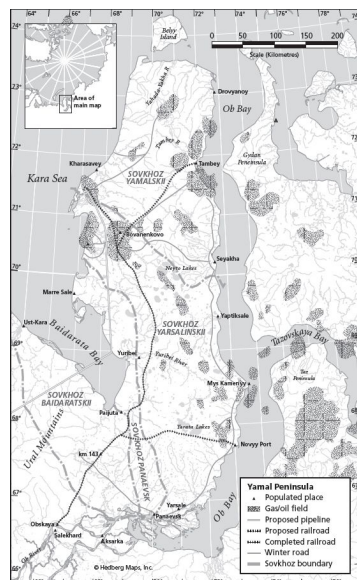


Figure 1. Location of research area: Yamal Peninsula.

Source: B.Forbes

Current research aims at application of the remote sensing data (Landsat satellite images) and ILWIS GIS tools for the detection of land cover changes in the tundra landscapes. The research area is located on the Bovanenkovo region, the north-western part of Yamal Peninsula, West Siberia, Russia (Fig.1).

The region of Yamal is a lowland with flat topography and maximal elevations lower 90 m. The geography of this region supports ideal conditions for the wetlands, dense lake and river network. The Yamal Peninsula is the world's largest high-latitude wetland system with 900.000 km² of peatlands. In the past years there are changes in the landscape vegetation structure on Yamal caused by various reasons. These include multiple ecological factors, such as permafrost degradation, cryogenic landslides, reindeer grazing and gas-field development, as well as general factors, such as climate change.

Cryogenic landslides may cause significant changes in the structure of the landscapes. After the landslide event, vegetation starts complex recovering processes. 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. Generally, the dominating

vegetation types on Yamal include various types of shrubs and willows, heath, grasses, moss, and lichens. However, in the last years, woody plants (e.g. willows) became dominating vegetation type.

3. Method

The research method consists in application of the remote sensing and ILWIS GIS tools for land cover studies. The technical implementation of the imagery processing, spatial analysis and mapping has been done in ILWIS GIS. The research data include Landsat TM scenes for the years 1988 and 2011. The Landsat data were selected due to their suitability for land cover mapping, which enable recurrent remote sensing observations and assessment of changes in land cover types. The research methodology includes supervised classification of the Landsat scenes, GIS mapping and calculation of the areas of various land cover types in 1988 and in 2011.

The technical approach of the research is Minimal Distance method of the supervised classification. The key for the classification is set of training pixels with spectral values identical to examples of land cover classes, their location and representation on the image, provided by T. Kumpula from the University of Joensuu. The used classification methods is pixel-based, i.e. the basis for the classification is allocation of pixels on the image to the land cover classes, using their unique digital numbers (DNs). The classes sampling was performed using Sample Set in ILWIS. The training pixels were selected as core samples for each class, and stored in Sample Set file. Then the training pixels were extracted in Sample Set Editor, indicating the representative land cover classes, spread over the distribution area. Using training set of pixels the classification of the whole image was performed in ILWIS GIS menu in semi-automated regime. Finally, we calculated areas covered by various land cover classes in 1988 and 2011 years. The calculations were based on pixel size (52 m²), multiplied by the size of area covered by each of the classes, respectively. These were computed in ILWIS GIS.

4. Examples

The final research results include following items. First, two classified Landsat images, for 1988 and 2011 years, respectively. Second, two thematic maps of the vegetation distribution over the Bovanenkovo area, Yamal Peninsula, created on their basis (Fig.2 and Fig.3). Third, computed areas for various land cover types in Yamal landscapes (km²).

The classification is based on the relationship between the spectral signatures and object variables, i.e. vegetation types. 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). Auxiliary classes represent active infrastructure (e.g. buildings and main road network), sand quarries and water areas (separated subclasses for lakes and ocean waters). In totally, 14 classes were defined. The thematic layouts were created using results of the image classification (Fig.2 and Fig.3).

The calculated results which illustrated exact areas covered by various land cover types in Yamal landscapes, are summarized in the Table 1. To resume, there are noticeable increase in woody plants, such as willows (both "tall willows" and "normal willows"). The tundra classes: "short shrub tundra", "sparse short shrub tundra" and "dry short shrub tundra", also expanded during the last tow decades and have more areas covered in 2011 comparing to 1988. On the contrary, grass and heath classes, for example such as "dry grass heath", shrank their areas for the same period.

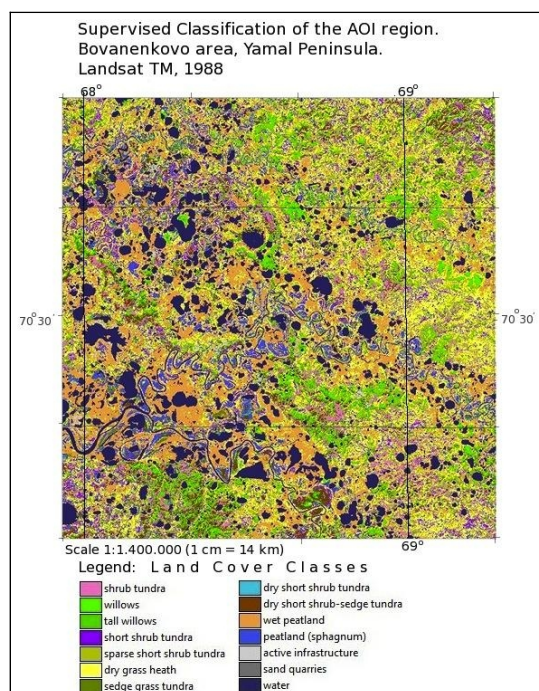


Figure 2. Land cover classes in AOI (Area Of Interest): Bovanenkov region, Yamal. Results of the supervised classification of the Landsat TM image, 1988 performed in ILWIS GIS.

Land Cover Class	1988, no of pixels	2011, no of pixels	Year 1988, ha	Year 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

Table 1. Areas (ha) of various land cover classes in Bovanenkov region, Yamal.

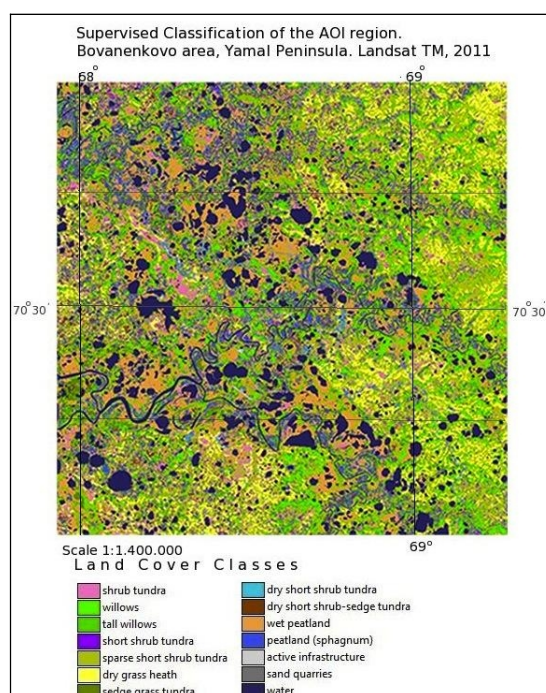


Figure 3. Land cover classes in AOI (Area Of Interest): Bovanenkovo region, Yamal. Results of the supervised classification of the Landsat TM image, 2011 performed in ILWIS GIS.

5. Conclusions

The satellite-based monitoring of the northern ecosystems is crucial tool for the assessment of spatio-temporal environmental changes, monitoring of vegetation coverage within the landscape and decision making in territory management. Remote sensing data, such as Landsat TM scenes and GIS tools (case of ILWIS GIS) are indispensable technical components of landscape studies and mapping.

The final results illustrate structural variations in the Arctic landscapes on Yamal Peninsula in Bovanenkovo region, which is illustrated by gradual amendments in species distribution and changes in dominant classes in land cover types during the past two decades. The two thematic maps illustrate changes in landscape structure and vegetation distribution in Yamal, i.e. the overall increase in shrubs and willows, and decrease in grass, peatland and heath areas.

Therefore, the most evident trend in the vegetation changes in northern ecosystems is the overall increase of woody vegetation and decrease of peatlands and grasses. The dominating vegetation classes now become willows and shrubs. It illustrates the main trend of greening in the landscape dynamics in Arctic, i.e. the unnatural increase of woody plants. The triggering factors for such changes are complex environmental changes in Arctic. Among them important factor is cryogenic landslides, which cause successive changes in vegetation, recovering after disaster. Landscape dynamics indicates local environmental changes in the northern regions in Yamal Peninsula.

6. Acknowledgments

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