Linking GIS and Remote Sensing Data to Study Vegetation Patterns

Polina Lemenkova

УДК 004.942

КОМБИНИРОВАНИЕ ДАННЫХ ДИСТАНЦИОННОГО ЗОНДИРОВАНИЯ И ГИС ДЛЯ ИЗУЧЕНИЯ ЛАНДШАФТНЫХ ПАТТЕРНОВ В РАСТИТЕЛЬНОМ ПОКРОВЕ

П.А. Леменкова
Карлов университет в Праге, Институт экологических исследований

LINKING GIS AND REMOTE SENSING DATA TO STUDY VEGETATION PATTERNS

P.A. Lemenkova
Charles University in Prague, Institute for Environmental Studies

В статье рассматривается использование геоинформационных технологий (ГИС) для обработки спутниковых снимков для мониторинга изменения ландшафтов в течение двух десятилетий. Методология работы направлена на техническое применение инструментов дистанционного зондирования и ГИС для изучения растительного покрова в тундре экосистем методом классификации снимков. Схема обработки снимков включает составление цветных композитов, георефенцирование, управляемая классификация по эталонным пикселям. Данные включают в себя сцены Ландсат (Landsat TM).

The paper studies changes in land cover types in tundra landscapes during the past two decades. The study area is located in the Yamal Peninsula, north-central Russia. The main objective of this research is to analyze changes in vegetation distribution and land cover types over the area of Yamal Peninsula. Methodology of the work aims at technical application of the remote sensing and GIS tools for studies and includes georeferencing, creation of color composites, supervised classification. The research data includes Landsat scenes.

Ключевые слова: ландшафты, Ландсат, классификация, ИЛВИС ГИС
Keywords: landscapes, Landsat, classification, ILWIS GIS

Remote sensing plays important role for the land use studies. Traditional methods for vegetation monitoring include fieldwork and ground survey, usually performed in a large-scale areas. The use of the remote sensing techniques enables to monitor extended areas in a small scale which is indispensable for monitoring vegetation changes in high latitudes. Therefore, satellite imagery serves as a valuable source of geoinformation for time series analysis providing accurate and low-cost data source. The 30m resolution Landsat scenes are useful for landscape monitoring, recurrent remote sensing observations, interpretation and assessment of temporal changes in land cover types in a high north. Arctic tundra is very specific ecoregion, highly important for the world environmental heritage.1 Lots of tundra species have only circumpolar spread. Arctic ecosystems have complex structure with functional linkages between soil and plant communities, highly adapted to the polar climatic and environmental conditions. Thus, the biodiversity in Yamal is in general low, with limited taxonomic diversity of plant communities [7, p.115]. There are only 26 mammal species, 32 species of valuable fishes (with up to 70% of Russian salmon) and 186 species of Arctic spread birds [1, p.4]. Major role in functioning of ecosystems plays reindeer, lemmings and arctic fox. The western natural border of the region is Kara Sea, and the eastern is the Ob River bay. The major part of the study region is treeless low Arctic tundra with dominated shrub tundra vegetation type, located on low plains, which characterizes the environmental conditions of the northernmost continental climatic area. The dominating landscape on Yamal is low Arctic tundra mostly occupied by moss, lichens, different types of shrubs, willows. Besides natural factors, the Yamal Peninsula is susceptible to the impacts of industrial activities, mostly caused by gas exploration. The continental shelf of Kara Sea is the largest Russian national reserve of hydrocarbons [2, p.981] where the gas-field Bovanenkovo, located in the western part of Yamal Peninsula, is being currently explored [9, p.553]. Negative impacts from such activities for the environment include pressure on the vegetation coverage caused by construction of new infrastructure and expansion of existing one, pipelines, expanded road and rail network and residential facilities [8, p.167]. Besides direct destruction of the lands, the nearby vegetation coveragelocated in the immediate vicinity of roads and vehicle trails can be affected [10, p.16].

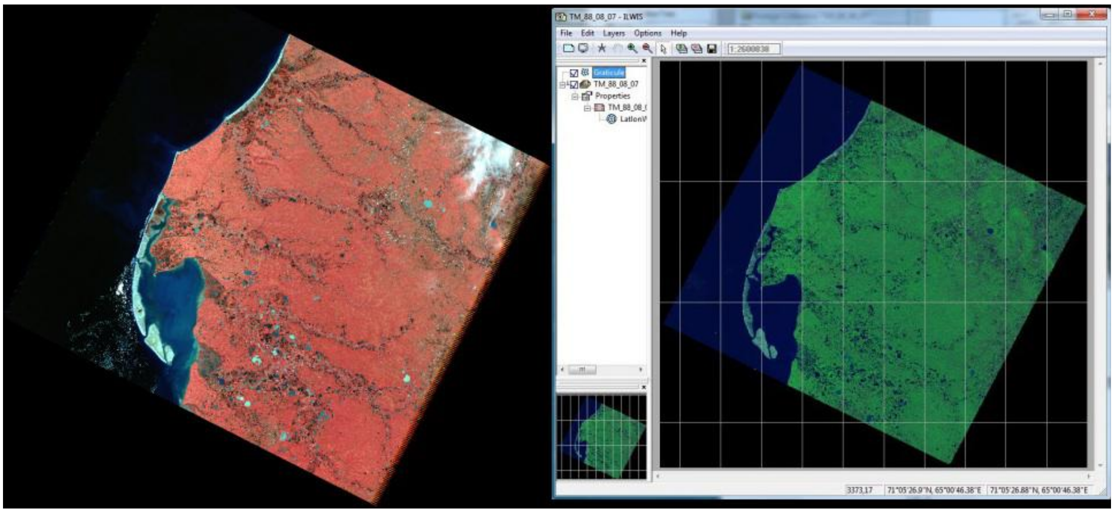

Fig.5. Georeferencing and creating nature color composite (right) from the raw Landsat TM image (left). ILWIS GIS menu.

Another example of the anthropogenic impact on ecosystems is overgrazing and pressure on the tundra vegetation caused by reindeers. Yamal Peninsula is a homeland for about 5000 nomadic Nenets tribes migrating with their herds up to 1200 km annually [10, p.1]. The steady increase of reindeer and humans cause pressure on tundra vegetation. Thus, reindeer overgrazing causes desertification and thawing of permafrost [8, p.171]. Sandy soils, widely distributed on the Yamal Peninsula, are especially sensitive to degradation by reindeer trampling since they are difficult to recover. The consequences of the human activities, can lead to the changes in tundra local landscapes and be a major potential source of changes in land cover types in the future.

The research method consists in Landsat image processing (Fig.1), georeferencing via the Google Earth (Fig.2) and spatial analysis performed in ILIWIS GIS. The choice of Landsat scenes for land cover mapping is explained by their well-known advantages of application in geosciences and cartography, almost 40 year old history of the image record, and free availability [4, p.537]. The Landsat scenes are a series of imagery received from the Earth-observing satellites jointly managed by NASA and the U.S. Geological Survey which provide free of charge and regular updates of satellite imagery with 30-m resolution. In the current work we used orthorectified Landsat Thematic Mapper (TM) data files in Geographic Tagged Image-File Format (GeoTIFF) acquired over the part of the Yamal Peninsula. The images have a time span of 23 years: 1988 and 2011, taken in growing season, i.e. summer to early autumn, with clearly visible vegetation coverage.

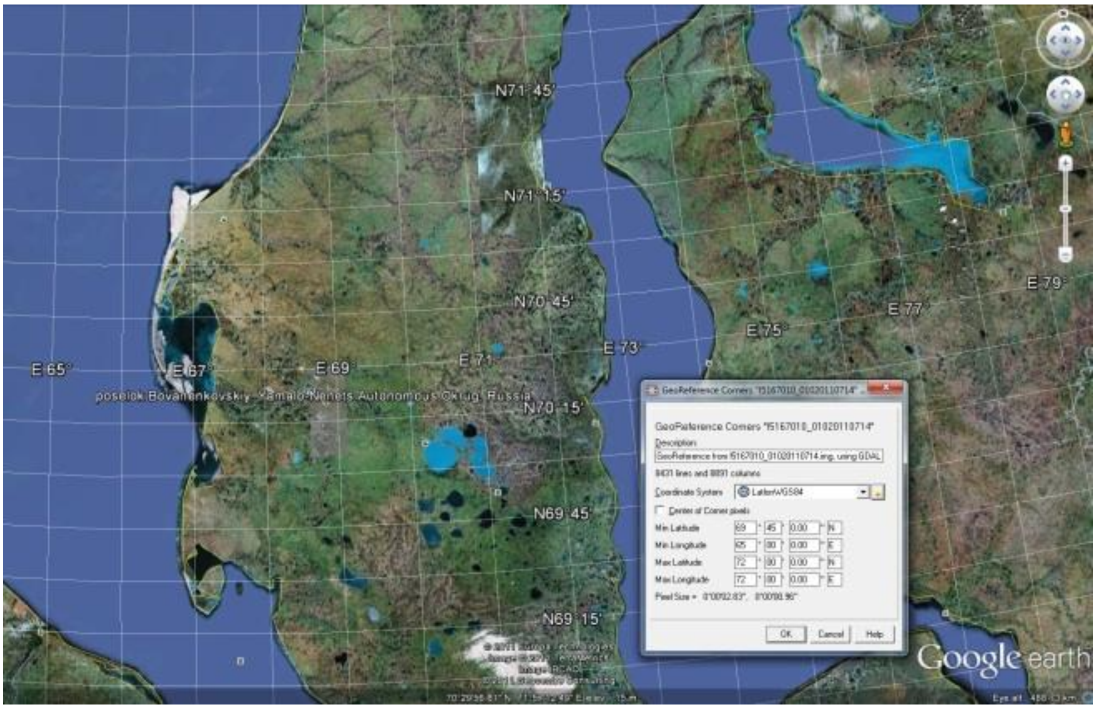

Fig.6. Verifying Georeferencing of study area via the Google Earth

The ILWIS GIS classification menu enables to choose several possible classifiers, from which I have chosen Maximal Likelihood. During the supervised classification process the training pixels were extracted in Sample Set Editor, indicating the representative land cover classes. The main difficulty during the classification process is similarity of spatial characteristics of pixels, which caused some miss-classification errors and mixed up pixels during the process. Some regions in the north-eastern part of the area were covered by clouds. Therefore, the upper-right part of the images was cut off, to avoid mistakes and uncertainties in image processing. The classification has been completed in interactive way, using several attempts of creating training samples, selecting various sample sets and repeating the classification until the final results were achieved. The domain for classification is “Landclasses”. The classification was performed using supervised classification with training pixels, represented various land object classes, homogeneously spread over their distribution area. The main principle for recognition objects is similarity in spectral signatures of pixel DNs. A lot of classes in the test areas are self-evident, e.g. such as ocean water, sand, shelf areas. However, in practice, there could be distinguished more sub-classes for water areas, as they had different color shadows changing with depth and water salinity. The recognition of the vegetation types is more complex: they vary in response to the local conditions and differences in regional settings due to changed geochemical soil content and through different geomorphic and elevation ranges. The classification used in the current work is pixel-based.

Tab. 3. Results of the calculations: numbers of pixels in both images converted to area (ha).

Land Cover Class	Nr. of pixels, 1988	Pixels 2011	Area, ha, 1988	Area, ha, 2011
Shrub tundra	220447	168226	1146,3	874,7
Short shrub tundra	165079	270158	858,4	1404,8
Willows	192645	457004	1006,9	2376,4
Tall willows	103954	71952	540,5	374,1

Sparse short shrub tundra	176511	759380	917,8	3948,7
Dry grass heath	641420	231719	3335,3	1204,9
Sedge grass tundra	27545	57052	143,2	296,6
Dry short shrub tundra	8984	16993	46,7	88,3
Wet peatland	761231	531809	3958,4	2765,4
Peatland (sphagnum)	120328	93979	625,7	488,6
Dry shrub-sedge tundra	173693	92242	903,2	479,6

The complexity of the surface includes such properties as shapes, texture, area, size of selected fields, geographic context (location of the object within the area), was not studied in this research. While object-oriented methods use these attributes for image analyzing, pixel-based approach does not take them into account. Therefore, this may cause uncertainties in the final outcome of current work. The main classification goal was to allocate and categorize each pixel from the image to land cover classes (14 in total) and to calculate changes in land cover classes (if they increased or decreased during the past two decades). The basis for this classification is DN of pixels, i.e. spectral information, which differ by each of these classes. The classes sampling was performed using Sample Set tool in ILWIS GIS. 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 following landscapes types: 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), Tab.1. The pixels were associated with land cover classes, using their digital numbers (DNs), similar to the key samples. The created domain Land classes includes legend with representation colors visualizing each category. Finally, thematic mapping was performed, which included layout of main research results, represented as maps of the land cover classes. The landscapes of the same territory in selected study area have been changed. There are various reasons for such changes. The results show that there are changes vegetation classes: e.g. increase in willow and shrubland and decrease in grass and heath dry grass areas, which have shrunk during the same time period. The final outcomes show changes in the vegetation coverage and land cover classes in Bovanenkovo region of the Yamal Peninsula, which happened during the past two decades. The results are received by comparing and analyzing of two classified maps covering the same geographic region with time span of 23 years: in 1988 and 2011. The changes mostly concern types of land covers and overall increase of shrubland and willows (Tab.1). It can be explained by the complex environmental changes in Arctic regions, which leads to “greenness” processes, or unnatural increase of willows. Finally, it may result in serious alterations in the structure of tundra ecosystems. The environment in Arctic is mostly influenced by the climate conditions, which had several changes since past time. Nowadays, the processes of global climate warming have severe threats to the tundra environment. As summarized by [5,p.2], since early 1980s the processes of Arctic warming activated and included meteorological changes (precipitation level, permafrost and snow cover depth) and increase of content of greenhouse gases in the atmosphere. This has naturally triggered changes in vegetation coverage. Namely, climate change in Arctic, i.e. unnatural increase in vegetation growth, primarily of willow. The significant increase in willow growth, height, cover, abundance and shrub ring width is detected in the last 60 years, which perfectly correlates to the overall increase in summer temperatures for the same period in the research area [6, p.1549]. Growth of the willow shrubs and climate change are closely connected, so that the first one serves as a good indicator of the second [3, p.12].

The satellite-based monitoring of the northern ecosystems is important tool for the detection of the environmental changes. Assessment of the changes in land cover types, caused by various factors, is crucial component of landscape monitoring and management. Use of remote sensing data and GIS software improves technical aspects of the land cover mapping and landscape studies, because it enables assessment of temporal and spatial changes in vegetation coverage. This paper presented ILWIS GIS based image processing of Landsat scenes of Yamal area. This work demonstrated how GIS spatial analysis can be applied to studies of the environmental changes, monitoring and mapping landscapes by the GIS tools.

Literature:

1. Данилов Н.Н. Роль животных в биогеоценозах Субарктики. / Н.Н. Данилов // Биоценотическая роль животных в лесотундрах Ямала. — Свердловск, 1977.
2. Каминский В.Д., Супруненко О.И., Суслова В.В. Континентальный шельф российской Арктики: состояние изучения и освоения нефтегазовых ресурсов. Геология и геофизика, 2011, т. 52, No 8, с. 977—985.
3. Николаев А.Н., Самсонова В.В. Влияние склоновых процессов на произрастание ивы на Ямале. Вестник ТГУ, №12. — Томск, 2012.
4. Cohen W.B. and Goward S.N., 2004. Landsat's role in ecological applications of remote sensing. Bioscience, 54, 535−545.
5. Forbes B.C. and Stammler F., 2009. Arctic climate change discourse: the contrasting politics of research agendas in the West and Russia. Polar Research. Available from: doi:10.1111/j.1751-8369.2009.00100.x
6. Forbes B.C., Fauria M.M. and Zetterberg P., 2010. Russian Arctic warming and “greening” are closely tracked by tundra shrub willows. Global Change Biology, 16 (5), 1542–1554.
7. Hodkinson I.D., Wookey P.A., (1999), Functional ecology of soil organisms in tundra ecosystems: towards the future. Applied Soil Ecology 11, 111-126.
8. Kumpula T., Forbes B.C. and Stammler F. 2010, Remote Sensing and Local Knowledge of Hydrocarbon Exploitation: The Case of Bovanenkovo, Yamal Peninsula, West Siberia, Russia. Arctic, 63 (2), 165-178.
9. Kumpula T., Pajunen A., Kaarlejärvi E. and Forbes B.C., 2011. Land use and land cover change in Arctic Russia: Ecological and social implications of industrial development. Global Environmental Change 21, 550–562.
10. Walker D.A., Leibman M.O., Epstein H.E., Forbes B.C., Bhatt U.S., Raynolds M.K., Comiso J.C., Gubarkov A.A., Khomutov A.V., Jia. G.J., Kaarlejärvi E., Kaplan J.O., Kumpula T., Kuss P., Matyshak G., Moskalenko N.G., Orekhov P., Romanovsky V.E., Ukraintseva N.G., and Yi Q., (2009), Spatial and temporal patterns of greenness on the Yamal Peninsula, Russia: interactions of ecological and social factors affecting the Arctic normalized difference vegetation index. Environmental Research Letters 4, 045004 (16).