Analysis of Landsat NDVI Time Series for Detecting Degradation of Vegetation

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- GIS and RS application for environmental studies of Yamal
- Calculation of NDVI
- Monitoring vegetation changes in tundra landscapes
- Analysis of the vegetation dynamics in the past two decades (1988-2011).
- Data: Landsat TM scenes for 1988, 2001 and 2011
- Originality: Application of ILWIS
- GIS spatial analysis tools and Landsat imagery
- Area: Bovanenkovo region in Yamal Peninsula, Russian Extreme North

Google Earth Image

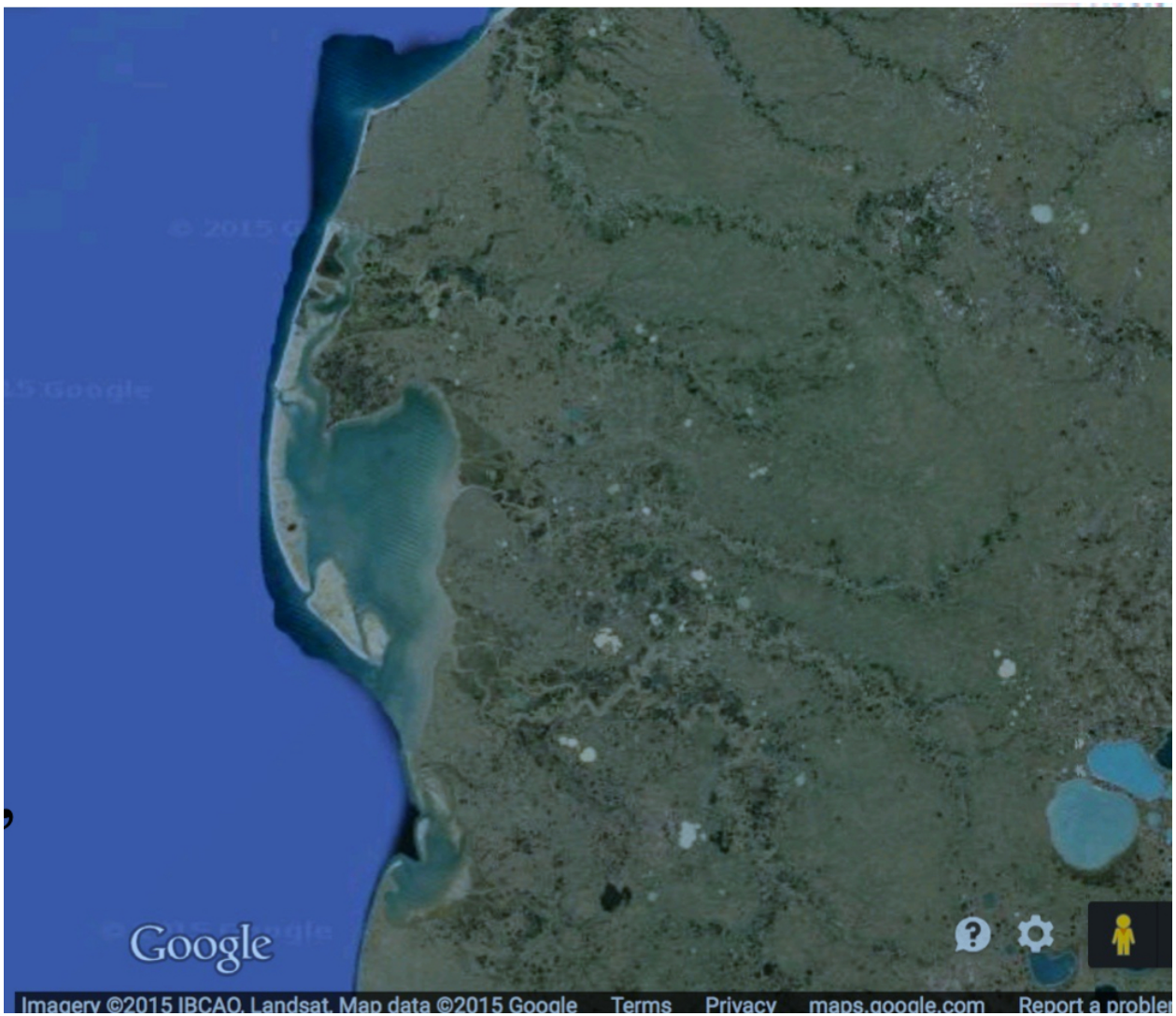
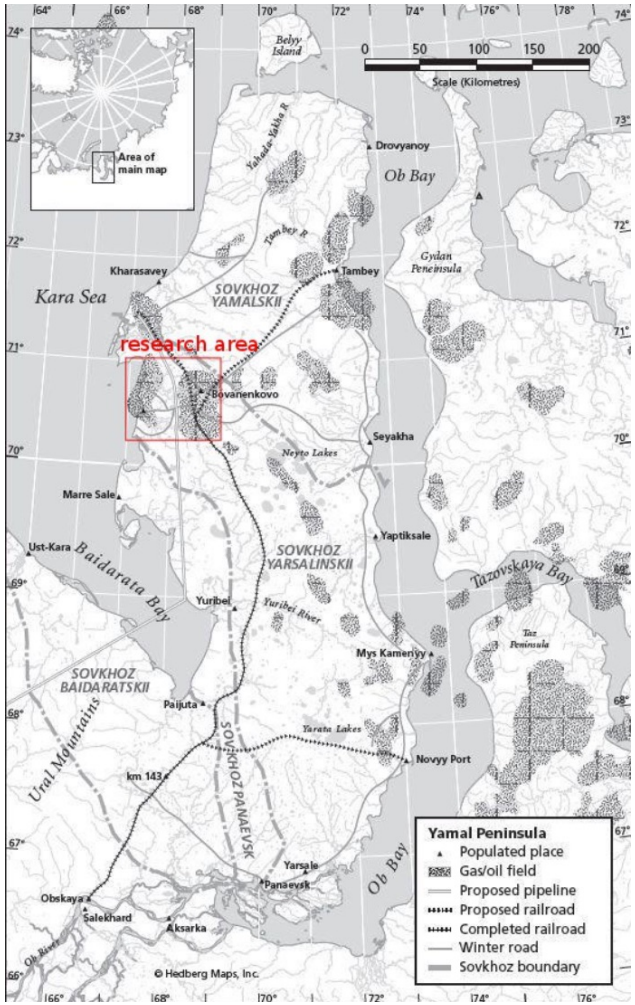


Figure: Study area

Study Area



Geographic location: Yamal Peninsula, north Russia. (a) Geographic location of Yamal (b) Location of the study Peninsula Map source: google.com area on Yamal (western coast).

Source: B. Forbes

Environmental setting

Yamal Peninsula: geomorphology : flat geomorphology, elevations lower than 90 m
Processes:

- seasonal flooding,
- active erosion processing,
- permafrost distribution,
- cryogenic landslides formation

Landslides affect local ecosystem structure.
Landslides change vegetation types recovering after the disaster.

Landscapes of Yamal.

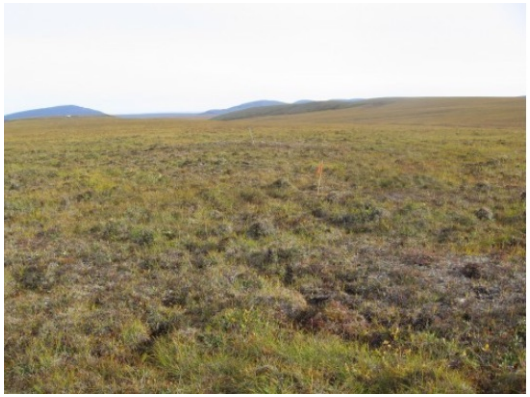
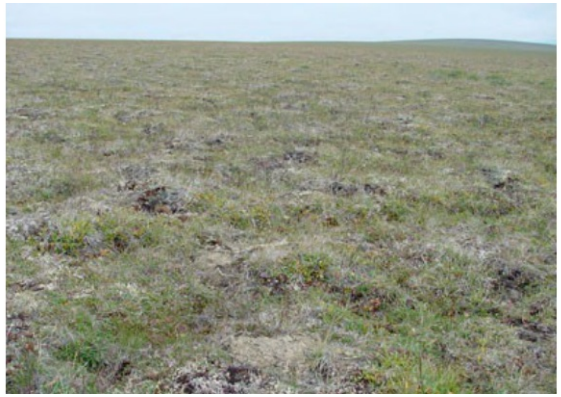
Source: http://pixtale.net/

Landscapes of the Yamal Peninsula - I

Yamal shrub tundra.
Source: www.novaonline.nvcc.edu/

Dwarf willows. Source:
www.travelanguist.com

Landscapes of the Yamal Peninsula - II


Dry grass heath tundra (left). Sedge grass tundra (center). Dry short shrub tundra (right)


Landscapes of Yamal (left). Sphagnum moss (right)

Landscapes of the Yamal Peninsula - III

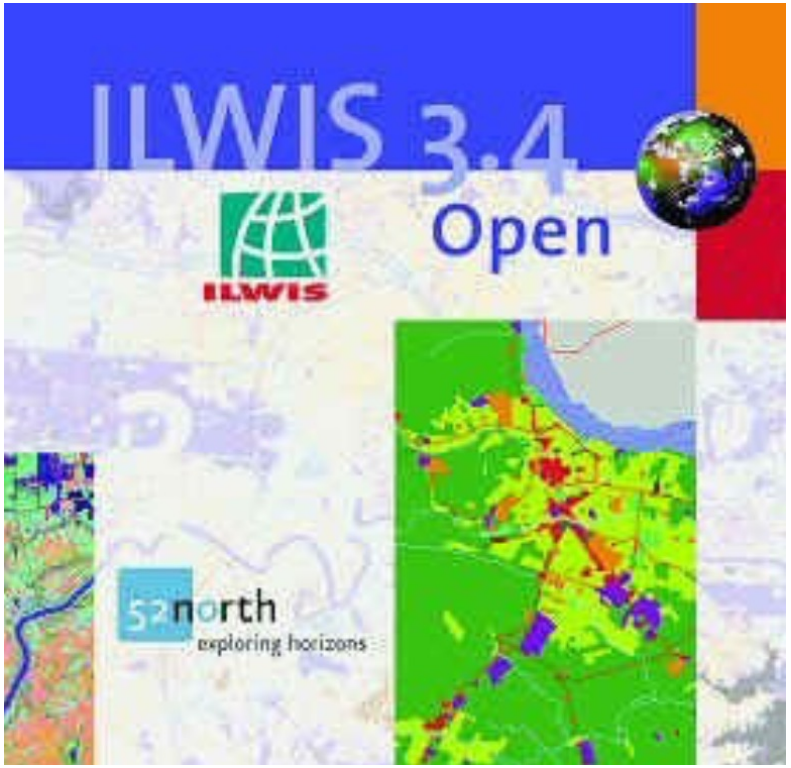
Dry short shrub sedge tundra (left). Wetlands (right)

Short shrub tundra

Methodology: ILWIS GIS

Technical tools: The RS data processing was performed in ILWIS GIS software. Research Methods:

- Image interpretation (Landsat TM scenes).
- NDVI calculation.
- Producing vegetation indices has been done in this research using mathematic calculation of the channels
- The formulae are: (NIR-VIS) / (NIR+VIS), or a ratio for channels: (Band4-Band3) / (Band4 +Band3).
- NDVI values lie in the range of 0 – 1 and never become negative or extend over 1, since NDVI is a linear algebraic function of these bands



ILWIS GIS: https://52north.org/software/software-projects/ilwis/

Advantages of the NDVI

Calculation of vegetation indices, especially and in this case Normalized Difference Vegetation Index (NDVI), has become one of the most successful, popular and traditional attempts in biogeographical research methods.

- NDVI has certain advantages over other vegetation indices or band combinations.
- NDVI is less depending on soil properties of study area
- NDVI is less depending on the daytime illumination comparing to simple red-infrared bands combination
- NDVI is well adjusted specially for the analysis of vegetation properties
- NDVI can be indirectly interpreted from the objects colors, as shown on the raster image

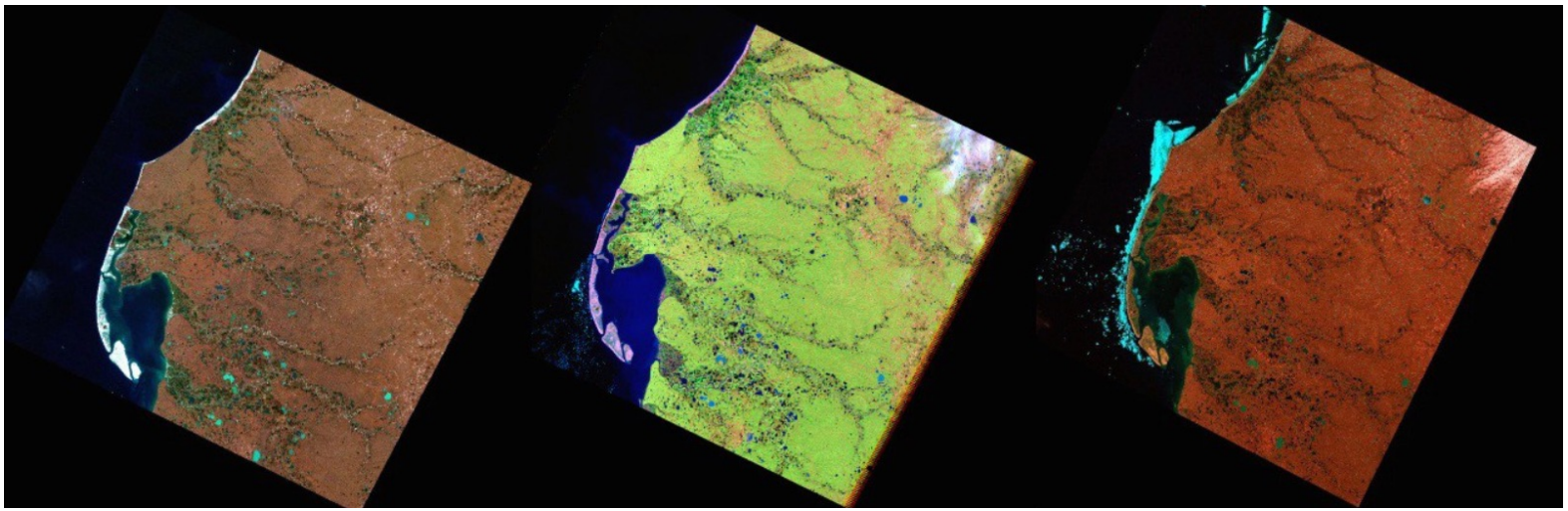
Workflow

Data pre-processing

- Import .img file into ASCII raster format (GDAL).
- After converting, each image contained collection of 7 raster bands
- Pre-processing (visual color and contrast enhancement)
- Geographic referencing of Landsat scenes, initially based on WGS 1984 datum.
- Georeference Corner Editor
- UTM (Universal Transverse Mercator) Projection, Eastern Zone 42, Northern Zone W.
- Crop of study area: the area of interest (AOI) was identified and cropped on the raw images.
- Selected area shows Bovanenkovo region in a large scale
- Environmentally, AOI best represents typical tundra landscapes.
- NDVI Calculation
- GIS visualization and mapping

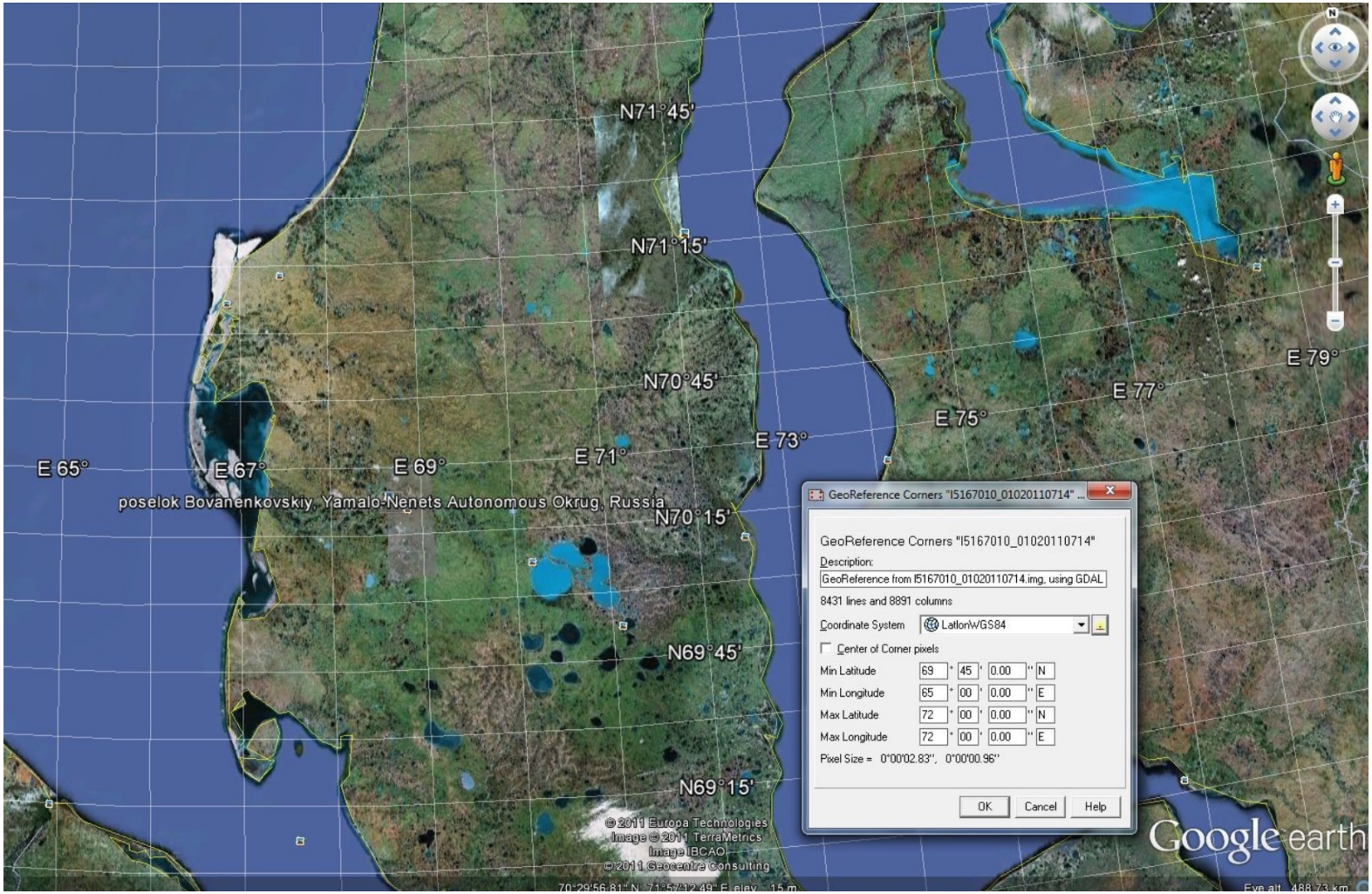
Import and data conversion

- Test area selection (Mask): 67°00' - 72°00' E - 70°00' - 71°00' N.
- 3 selected Landsat TM satellite images show Yamal region in 1988, 2001, 2011.
- Time span: 23 years (1988, 2001, 2011).
- Summer months selected for vegetation assessment.
- Data conversion / original images in format .TIFF converted to Erdas Imagine .img.



Initial remote sensing data, left to right: Landsat TM 1988, bands 7-3-1; Landsat TM 2011, pseudo natural colors composite; Landsat ETM + 2001 bands 6-3-1.

Georeferencing: Google Earth



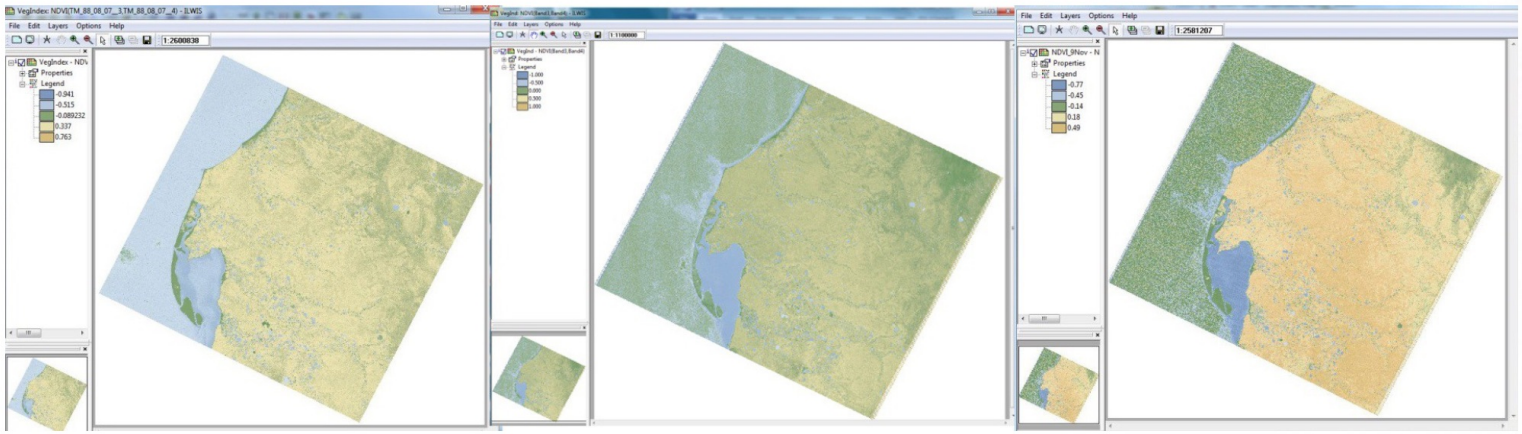
NDVI Calculation

- To model the NDVI I used Map Calculation tool in command line of the Raster Operations menu in ILWIS GIS.
- ILWIS GIS enables to perform spatial analysis and modeling by combination of queries, arithmetic expressions and overlays of selected raster images.
- The NDVI was calculated using following equation: NDVI = (Band4 - Band3) / (Band4 + Band3),
- Band 4 is DN values of spectral reflectance in NIR (near infra-red) and Band 3 is DN values of spectral reflectance in VIS (visual).
- The NDVI was calculated automatically in ILWIS GIS using arguments of images: VegIndex = NDVI (Band3, Band4).
- Two Landsat bands have been used: Band4, containing red reflectance and Band3 with infra-red reflectance: VegIndex=NDVI(TM_3,TM_4).
- Other Landsat scenes were classified individually using the same method scheme in ILWIS GIS in the same way described above.

Results

The resulting images shows distribution of the vegetation over the Bovanenkovo region within three (3) years: 1988, 2001 and 2011.

1988 2001 2011



- The results for 2001 show that vegetation has very moderate overall index, reaching NDVI value 0,50 as a maximal.
- The maximal NDVI values in year 2011 are 0.49,
- The maximal NDVI values in year 1988 was 0.76.

Comparison of these results shows gradual decrease in the biomass values during the past two decades.

Conclusion and Discussion

- This research presented GIS based studies of environmental of Yamal
- The study is technically supported by means of ILWIS GIS which proved to be effective tool for spatial analysis
- Performed analysis demonstrated changes in the NDVI during period of 1988 - 2011, calculated on the on the Landsat TM images
- The results show decrease in overall NDVI values for the study area, which is caused by the environmental and anthropogenic factors
- The results of spatial analysis are presented as 3 GIS maps illustrating changes in vegetation based on the image analysis using NDVI.
- The calculated NDVI indicated biomass and can be also used as indicator of "greenness" of the vegetation.
- Application of RS data is especially important for studies of northern ecosystems, as it enables study of remotely located areas of Arctic
- GIS-based processing of the RS data (Landsat TM) improves technical aspects of the landscape studies and monitoring

Thanks

Thank you for attention !

Bibliography I

[1] S. Gauger, G. Kuhn, K. Gohl, T. Feigl, P. Lemenkova, and C. Hillenbrand, "Swath-bathymetric mapping", The expedition ANTARKTIS-XXIII/4 of the Res. Vessel 'Polarstern' in 2006. Berichte zur Polar- und Meeresforschung // Rep. on Polar and Marine Res. **557**, edited by K. Gohl, 38–45, ISSN: 1618-3193 (2007), https://www.coldregions.org/vufind/Record/288392, In English Ant. Acc. No.: 85104. CRREL Acc. No.: 63000887; illus., incl. sketch maps.

[2] K. Gohl, G. Eagles, G. B. Udintsev, R. D. Larter, G. Uenzelmann-Neben, H. W. Schenke, P. Lemenkova, J. Grobys, N. Parsiegla, P. Schlueter, T. Deen, G. Kuhn, and C. D. Hillenbrand, "Tectonic and Sedimentary Processes of the West Antarctic Margin of the Amundsen Sea Embayment and Pine Island Bay", in 2nd Open Science Conference 29th SCAR on 'Antarctica in the Earth System' (2006), https://www.scar.org/events/.

[3] K. Gohl, G. Uenzelmann-Neben, G. Eagles, A. Fahl, T. Feigl, J. Grobys, J. Just, V. Leinweber, N. Lensch, C. Mayr, N. Parsiegla, N. Rackebrandt, P. Schloter, S. Suckro, K. Zimmermann, S. Gauger, H. Bohlmann, G. L. Netzeband, and P. Lemenkova, *Crustal and Sedimentary Structures and Geodynamic Evolution of the West Antarctic Continental Margin and Pine Island Bay*, (Bremerhaven, Germany, 2006), https://epic.Alfred%20Wegener%20Institute.de/29852/1/PE_75.pdf.

[4] M. Klaučo, B. Gregorová, U. Stankov, V. Marković, and P. Lemenkova, "Landscape metrics as indicator for ecological significance: assessment of Sitno Natura 2000 sites, Slovakia", in Ecology and environmental protection, Proceedings of International Conference (2014), pp. 85–90, http://elib.bsu.by/handle/123456789/103362.

[5] M. Klaučo, B. Gregorová, U. Stankov, V. Marković, and P. Lemenkova, "Determination of ecological significance based on geostatistical assessment: a case study from the Slovak Natura 2000 protected area", Central European Journal of Geosciences **5**, 28–42, ISSN: 1896-1517 (2013), https://www.degruyter.com/view/j/geo.2013.5.issue-1/s13533-012-0120-0/s13533-012-0120-0.xml?format=INT.

[6] G. Kuhn, C. Hass, M. Kober, M. Petitat, T. Feigl, C. D. Hillenbrand, S. Kruger, M. Forwick, S. Gauger, and P. Lemenkova, *The response of quaternary climatic cycles in the South-East Pacific: development of the opal belt and dynamics behavior of the West Antarctic ice sheet*, (Bremerhaven, Germany, 2006), https://epic.Alfred%20Wegener%20Institute.de/29852/1/PE_75.pdf.

[7] P. Lemenkova, "Satellite image based mapping of wetland tundra landscapes using ilwis gis", Russian, in Actual problems of the state and management of water resources, Proceedings of the International Conference, edited by A. V. Kusakin and T. N. Efimova (2015), pp. 110–113, ISBN: 978-5-9903856-9-6, https://elibrary.ru/item.asp?id=24613025.

[8] P. Lemenkova, "Mapping agricultural lands by means of GIS for monitoring use of natural resources", Russian, in Actual problems of the conservation and development of biological resources, Proceedings of the International Conference, edited by I. M. Donnik, B. A. Voronin, I. P. Zorina, and N. V. Roshchina (2015), pp. 226–229, ISBN: 978-5-87203-374-5.

[9] P. Lemenkova, "Spatial Analysis for Environmental Mapping of Šumava National Park", in 6th annual pgs conference, Conference Abstracts (2015), p. 53, https://www.natur.cuni.cz/fakulta/zivotni-prostredi/aktuality/prilohy-a-obrazky/konference/pgs-koference-2015-program.

Bibliography II

[10] P. Lemenkova, "Processing Remote Sensing Data Using Erdas Imagine for Mapping Aegean Sea Region, Turkey", in Informatics, Problems, methodology, technologies, Proceedings of 15th International Conference, Vol. 3 (2015), pp. 11–15, ISBN: 5-9273-0681-0, https://elibrary.ru/item.asp?id=26663916.

[11] P. Lemenkova, "Google Earth web service as a support for GIS mapping in geospatial research at universities", Russian and English, in Web-technologies in the educational space, Problems, approaches, perspectives, Proceedings of the International Conference, edited by S. V. Aryutkina and S. V. Napalkov (Mar. 2015), pp. 460–464, ISBN: 978-5-9906469-1-9, https://elibrary.ru/item.asp?id=23426340.

[12] P. Lemenkova, "Satellite Image Based Mapping of Wetland Tundra Landscapes Using ILWIS GIS", in Actual problems of the state and management of water resources (Mar. 19, 2015).

[13] P. Lemenkova, "Risks of Cryogenic Landslide Hazards and Their Impact on Ecosystems in Cold Environments", in The effects of irrigation and drainage on rural and urban landscapes, Book of Abstracts, 1st International Symposium (2014), p. 27, https://www.irrigation-Management.eu/.

[14] P. Lemenkova, "Detection of Vegetation Coverage in Urban Agglomeration of Brussels by NDVI Indicator Using eCognition Software and Remote Sensing Measurements", in Gis and remote sensing, Gis day, Proceedings of the 3rd International Conference, edited by H. Manandyan (2014), pp. 112–119.

[15] P. Lemenkova, "Cost-Effective Raster Image Processing for Geoecological Analysis using ISOCLUST Classifier: a Case Study of Estonian Landscapes", in Modern problems of geoecology and landscapes studies, Proceedings of the 5th International Conference, edited by A. N. Vitchenko, G. I. Martsinkevich, B. P. Vlasov, N. V. Gagina, and V. M. Yatsukhno (2014), pp. 74–76, ISBN: 978-985-476-629-4, https://www.elib.bsu.by/bitstream/123456789/103641/1/geoconf80.pdf.

[16] P. Lemenkova, "Rural Sustainability and Management of Natural Resources in Tian Shan Region, Central Asia", in International conference 'celebrating pastoral life', Heritage and economic develop. Proceedings International Conference, edited by F. Papageorgiou (2014), pp. 81–89, ISBN: 978-960-6676-22-2.

[17] P. Lemenkova, "Opportunities for Classes of Geography in the High School: the Use of 'CORINE' Project Data, Satellite Images and IDRISI GIS for Geovisualization", in Perspectives for the development of higher education, Proceedings of 7th International Conference, edited by V. Pestis, A. A. Duduk, A. V. Sviridov, and S. I. Yurgel (2014), pp. 284–286, ISBN: 978-985-537-042-1, https://www.ggau.by/downloads/prints/Sbornik_72014_konferencii_perspektivy_razvitija_vysshej_shkoly.pdf.

[18] P. Lemenkova, "Monitoring changes in agricultural landscapes of Central Europe, Hungary: application of ILWIS GIS for image processing", in Geoinformatics: theoretical and applied aspects, Proceedings of 12th International Conference (2013).

[19] P. Lemenkova, "Geospatial Technology for Land Cover Analysis", Middle East and Africa (MEA) Geospatial Digest (2013), https://www.geospatialworld.net/article/geospatial-technology-for-land-cover-analysis/, e-magazine (periodical).

Bibliography III

[20] P. Lemenkova, "Impacts of Climate Change on Landscapes in Central Europe, Hungary", in Current Problems of Ecology, Ecological monitoring and management of natural protection, Proceedings of 8th International Conference, Vol. 2 (2012), pp. 134–136, https://elib.grsu.by/katalog/173327-393652.pdf.

[21] P. Lemenkova, "Water Supply and Usage in Central Asia, Tian Shan Basin", in Civil eng., architecture & environmental protection, Phidac-2012, Proceedings of the 4th International Symposium for Doctoral studies in the Fields of Civil Engineering, Architecture & Environmental Protection, edited by Z. Grdic and G. Toplicic-Curcic (Sept. 2012), pp. 331–338, ISBN: 978-86-88601-05-4.

[22] P. Lemenkova, "Seagrass Mapping and Monitoring Along the Coasts of Crete, Greece", M.Sc. Thesis (University of Twente, Faculty of Earth Observation and Geoinformation (ITC), Enschede, Netherands, Mar. 8, 2011), 158 pp., https://thesiscommons.org/p4h9v.

[23] P. Lemenkova, "Using ArcGIS in Teaching Geosciences", Russian, B.Sc. Thesis (Lomonosov Moscow State University, Faculty of Educational Studies, Moscow, Russia, June 5, 2007), 58 pp., https://thesiscommons.org/nmjgz.

[24] P. Lemenkova, "Geoecological Mapping of the Barents and Pechora Seas", Russian, B.Sc. Thesis (Lomonosov Moscow State University, Faculty of Geography, Deparmnet of Cartography and Geoinformatics, Moscow, Russia, May 18, 2004), 78 pp., https://thesiscommons.org/bvwcr.

[25] P. Lemenkova, *Ecological and Geographical Mapping of the Baltic Sea Region in the Gulf of Finland*, Russian, Moscow, Russia: Lomonosov Moscow State University, Mar. 30, 2002, https://zenodo.org/record/2574447, Term Paper.

[26] P. Lemenkova and I. Elek, "Clustering Algorithm in ILWIS GIS for Classification of Landsat TM Scenes: a Case Study of Mecsek Hills Region, Hungary", in Geosciences and environment, Near-surface geophysics, Proceedings 3rd International Conference, edited by S. Komatina-Petrovic (2012).

[27] P. Lemenkova, B. Forbes, and T. Kumpula, "Mapping Land Cover Changes Using Landsat TM: A Case Study of Yamal Ecosystems, Arctic Russia", in Geoinformatics: theoretical and applied aspects, Proceedings of the 11th International Conference (2012), https://elibrary.ru/item.asp?id=24527736.

[28] H. W. Schenke and P. Lemenkova, "Zur Frage der Meeresboden-Kartographie: Die Nutzung von AutoTrace Digitizer für die Vektorisierung der Bathymetrischen Daten in der Petschora-See", German, Hydrographische Nachrichten **25**, 16–21, ISSN: 0934-7747 (2008).

[29] I. Suetova, L. Ushakova, and P. Lemenkova, "Geoecological Mapping of the Barents Sea Using GIS", in Digital cartography & gis for sustainable development of territories, Proceedings of the International Cartographic Conference (2005), https://icaci.org/icc2005/.

[30] I. Suetova, L. Ushakova, and P. Lemenkova, "Geoinformation mapping of the Barents and Pechora Seas", Geography and Natural Resources **4**, edited by V. A. Snytko, 138–142, ISSN: 1875-3728 (2005), http://www.izdatgeo.ru/journal.php?action=output&id=3&lang_num=2&id_dop=68.