FINAL REPORT for APN PROJECT

Project Reference Number: ARCP2009-02CMY

Human Impact on Land-cover Changes in the Heart of Asia

The following collaborators worked on this project:

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Human Impact on Land-cover Changes in the Heart of Asia

Project Reference Number: ARCP2009-02CMY-Okladnikov
Final Report submitted to APN

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OVERVIEW OF PROJECT WORK AND OUTCOMES

Non-technical summary

Understanding human impact on land-cover and capacity to monitor change is fundamental to sound research and informed decision-making to address Global Change and ensure sustainable development. While remote sensing technology is evolving rapidly and multiple land-cover products have been developed, the lack of reliable information on land-cover remains a major problem. There is significant disagreement among the available land-cover products, particularly in the proposed study region in the heart of Asia where validation sites are sparse, the impact of climate change is severe, and processes of land-cover change are widespread and strongly influenced by humans. Analysis of vegetation changes in the selected region includes a variety of vegetation types and provides a broad-scale evaluation of available land-cover products, human impact assessment, along with synthesis and documentation of results by research groups actively involved in supporting land-use policy decisions in the region. Tools, methods, data, and collaborations needed to characterize land-cover dynamics and contribute to broader regional and global efforts to study land-cover and its change were developed. These data are available on dedicated web sites. The project also contributes to the ongoing effort of GOFC-GOLD and START International to develop a regional network of collaborators involved in observations of land-cover.

Objectives

The main objectives of the project were:

1. To set up four test sites (2 in West Siberia and 2 in Mongolia).
2. To select, collect and preprocess satellite imagery for the selected sites.
3. To collect and analyze ground data and satellite observations, prepare land-cover maps.
4. To elaborate and validate change detection methods.
5. To perform detected land-cover change analysis and classification.
6. To summarize project findings.

Amount received and number years supported

The Grant awarded to this project was:
US$ 40,000 for Year 1: 2008-2009.
US$ 18,000 for Year 2: 2009-2010.
Total: US$ 58,000 for two years.

Activity undertaken

(1) Initial meeting, Tomsk, Russia. Siberian test sites selection.

According to the timeline the project started in July 2008 with the Initial Planning Meeting in Tomsk at SCERT/IMCES (within ENVIROMIS-2008 International conference). The three days Meeting gathered two of three key project's collaborators as well as young scientists from the Russian team. Two test sites in Siberia were selected for field work: "Vasyugan'e" and "Tomsk". They are easily accessible for ground data collection, quite representative both by vegetation diversity and anthropogenic influence, and complement each other. Dr. Olga Krankina has visited them on July, 6 and later discussed two test sites in Mongolia with Dr. Tsolmon Renchin.

(2) Training sessions in OSU, Corvallis, Oregon, USA.

Russian and Mongolian team visited Oregon State University in the framework of a dedicated training session devoted to satellite images processing techniques. Knowledge required for land-cover maps creation and its change detection using Landsat satellite images was obtained. Two teleconferences with leading American specialists in land-cover detection and typification were conducted. Short presentations were made and current progress and results obtained were discussed with Mongolian and American teams.

(3) Mongolian test sites selection, Ulaanbaatar, Mongolia.
In order to visit Mongolian test sites and participate in the 3rd International and National Workshop "Applications of geo-informatics for Mongolian natural resource and environment" Dr. Igor Okladnikov went to Ulaanbaatar, Mongolia. There he discussed current progress with Dr. Tsolmon Renchin and Mongolian team, visit area designated for test sites and met with local authorities to organize relationships needed for better understanding regional human activities and their impact on land-cover.
(4) Satellite images selection, processing and analysis.
For the four test sites corresponding Landsat and MODIS images were selected and preprocessed. The cutting edge technologies of remote sensing data analysis obtained by Project partners during the training session in OSU allowed a subsequent relevant satellite images analysis as well as a possibility to ensure sustainability of regional teams in their decision-support work. During this work in close co-operation with OSU team the change detection methods were elaborated and validated.
(5) Land-cover change maps and socio-economical analysis.
Using provided by OSU team change detection methods Russian and Mongolian teams created land-cover change maps and performed socio-economical analysis. Results obtained allowed to start a work on elaborating recommendations in nature management policy-making activities for regional decision-makers and local authorities.
(6) Joint Workshop, Tomsk, Russia.
During the Joint Workshop conducted in Tomsk in the framework of International Conference ENVIROMIS-2010 project partners gathered to discuss, summarize and compare their findings, both scientific and applied. This Conference gathered many specialists and young scientists from different areas as well as local authorities and representatives of Central Asia research community thus working as a dissemination tool giving regional research community and decision makers a vision of remote sensing methods potential and indicating major spots of environment degradation. The partners presented results obtained and discussed plans of possible future cooperation.

Results

Results indicate that increased human activity negatively impacts vegetation cover. We also found that economic growth resulted in the expansion of urbanization, recreation, mining, timber cutting and agriculture. This resulted in increased spatial uniformity of landscapes. Results demonstrate also the influence of climate and socio-economical factors on vegetation. Population has a negative relationship to EVI and vegetation. This means that the vegetation is highest in areas with the lowest levels of population because the overall study area's vegetation is affected by human activities. Unauthorized mining as well as nomadic herders, which are moving their herd frequently to find land for their livestock to graze on due to the reduced amount of pasture, have a negative effect on pastureland. Livestock has shown positive relationships with vegetation. This means that livestock strategy is to increase total stocking rates in relation to increasing levels of vegetation. Also intense forest cutting for timber industry and local use led to decrease of forest area in West Siberia in 1990-1999. Forest cuttings areas have specific shape and were recognized easily on the space images. All disturbed forest areas were separated into areas clearly eliminated by human activity and areas damaged by all other reasons. Results indicate that some increase of forest cutting occurs in 1999-2007 due to intensification of economical processes in Tomskii rajon administrative unit. For this time interval we observed some small new cuts for the local purposes appeared in the basic dark coniferous forests near villages and in old cuttings where roads exist.

We have found that decrease of forest area is not affected significantly by human activity. The primary natural reason of forest damage at the studied test sites is tree falling/breaking at strong winds (local hurricanes). A strong wind have damaged forests between 1990 and 1999 in stripes up to 15x1 km oriented from south-west to north-east in the prevailing wind direction. Such stripes are clearly detected at space images. Strong winds were registered in Tomsk region at the beginning of the 21st century. They made different wind throw areas. The strongest hurricane has destroyed and damaged forest in area 5 by 50 km.

Some invasion of young tree into abandoned agricultural lands also can be found at comparison of 1999 and 2007 images. The high sustainability of the studied region to anthropogenic and natural impact is explained by high overall moisture of the territory (about a half of the area occupied by mires), weak population density, the prevailing of broadleaved forests with rich vegetation cover.

This project focused only on four (though quite typical) regions in Western Siberia and Mongolia in the light of investigation of human impact on land-cover change. It also developed land-cover change and disturbance indices maps for the selected regions to assess. However, it is not enough to cover the whole Asia and obtain comprehensive results. Further research is needed to characterize land patterns and classify vegetation types remotely in Mongolia and Russia to understand more deeply interrelations between land-cover changes and socio-economical processes. Improved data collection, methodologies, and national collaboration are necessary to answer more complex questions. This could be achieved by establishing a consolidated network of test sites and researchers, dedicated to monitoring land use and land-cover change processes in Mongolia and Russia. These activities will ensure obtaining new knowledge within APN Agenda and regional capacity building, outreach through the connections of collaborators to several regional networks, and development of methodologies for operational land-cover monitoring.

Project results were disseminated at such international conferences as CITES-2009, ENVIROMIS-2010, European Geoscience Union General Assembly 2010 and American Geophysical Union Fall Meeting 2010. Besides this, results and data (collected and obtained) are disseminated through a special web site deployed on a dedicated web-server supplied with a high-performance storage system for storing of a large archive of Landsat images and processing results. This web site is available at the following URL: http://apn.scert.ru/.

Relevance to the APN Goals, Science Agenda and to Policy Processes

The project will provide valuable input to all APN's three Agendas as progress in virtually all aspects of global change research and policy development requires consistent, reliable and transparent measurements of land cover and its change and understanding the role of humans in this process. Remote sensing is the principal source of data, however the discrepancies among the available land-cover products hamper the use of this new remote sensing technology. All project participants are engaged in providing scientific input to policy decision-making by their local, provincial, and national governments and at international fora and the project will strengthen the regional linkages and develop new knowledge of the role of humans in changing land-cover. The proposed synthesis builds on past and ongoing work of partners supported by IPCC, START, IGBP, and NEESPI. This project led to cooperation of teams based in three APN countries, capitalize on their past research investments, and ensure consistency of land-cover mapping across the region.

Self evaluation

The collaborating teams completed all the project tasks, finished the development of land-cover maps and land-cover change maps, and obtained a series of scientific results that were published and disseminated both to scientific community and to regional decision makers. The research project delivered results and produced outcomes, which will be actively used for the analysis of human actions affecting on land-cover during forming the regional policy. To support results dissemination a dedicated web site was launched and its stable operation beyond the project lifetime is ensured. However, the project has stretched longer than expected, partially due to the problems in conducting socio-economic analysis of results obtained.

Potential for further work

Gained experience of satellite images processing and analysis as well as established cooperation links between US, Mongolian and Russian researchers clearly show good potential for further cooperative activity in study of complex interrelations of land cover changes and economic situation/activity using remote sensing approaches.

Publications

Okladnikov I.G., Krankina O.N., Tsolmon R., Gordov E.P. **Anthropogenic Impact on Land-cover Changes in the Heart of Asia** // *International Conference and Young Scientists School "CITES-2009"*, Krasnoyarsk, Russia, July 5-15, 2009, p. 82. (Oral).

Peder Nelson, Olga N. Krankina, Robert E. Kennedy, Warren B. Cohen. **Analyzing the 1972-2008 Landsat satellite imagery archive to detect land cover and land use change in Mongolia** // *Proc. of The 3rd International and National workshop "Applications of Geoinformatics for Mongolian Natural Resource and Environment"*, Ulaanbaatar, Mongolia, 30 June – 2 July, 2009, p. 48.

Dyukarev E.A., Pologova N.N., Golovatskaya E.A., Dyukarev A.G., Gordov E.P., Okladnikov I.G., Titov A.G. **Vegetation structure changes in the south part of Western Siberia at the end of XX century** // *AGU 2010 Fall Meeting*, 13–17 December 2010, San Francisco, California, USA. GC33A-0915. (Poster)

Dyukarev E.A., Pologova N.N., Golovatskaya E.A. **Technologies of remote sensing for study of spatial structure of forest-mire complexes at the key site "Bakcharskiy"** // *Journal of Siberian Federal University. Engineering & Technologies 2008*. v.4. P. 334-345. (in Russian).

Dyukarev E.A., Pologova N.N., Golovatskaya E.A. **Human impact on vegetation in the South and Sub-Taiga of Western Siberia** // *International Conference on Environmental Observations, Modeling and Information Systems "ENVIROMIS-2010"*, July 5-11, 2010, Tomsk, Russia, p. 120. (Oral)

Dyukarev E.A., Pologova N.N., Golovatskaya E.A. **Analyses of changes in vegetation cover in the South and Sub-Taiga of Western Siberia using Landsat data** // *Geophysical Research Abstracts, Vol. 12, EGU General Assembly 2010*. EGU2010 - 5714. (Oral)

Acknowledgments

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TECHNICAL REPORT

Preface

This project was intended to investigate the dynamics of land use and land-cover change related to the impact of humans on environment. Firstly, in situ land-cover data were collected during field surveys, and temporal changes in land use and land-cover were assessed using multiple methodologies for spatial analysis. Then relationship between land use change and socioeconomic factors were investigated. Landsat, MODIS EVI, climatic, and social data were integrated in the socio-economic analysis.

Results indicate that increased human activity negatively impacts vegetation cover. We found that economic growth resulted in the expansion of urbanization, recreation, mining, timber cutting and agriculture. This, particularly, resulted in increased spatial uniformity of Mongolian landscapes. We also found that natural factors (such as strong winds) have a great impact on Russian forests as well.

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1.0 Introduction

In this project Land Change Science (LCS) has emerged as a foundational element of sustainability science. LCS methods employ satellite remote sensing and geographic information system (GIS) technologies to monitor interactions and relationships between environment and society. Changes in land-cover and its implications for global environmental change and sustainability are a major challenge for the human- environmental sciences (Turner et al. 2007; Millennium Ecosystem Assessment, 2005). The assessment of land-cover within Land Change Science (LCS) can be generally subdivided into four categories: deforestation, desertification, agriculture and urbanization. Global land use change associated with these four categories can affect, amongst other things, food production, forest resources, regional climate and air quality, habitats and biodiversity, water flow and quality, and carbon sequestration (Foley et al. 2005).

Thus understanding human impact on land-cover and capacity to monitor its change over time is fundamental to sound research and informed decision-making to address LCS and ensure sustainable development. While remote sensing technology is evolving rapidly and multiple land-cover products have been developed, the lack of reliable information on land-cover remains a major obstacle for developing sound land use policies. There is significant disagreement among the available land-cover products, particularly in the proposed study region in the heart of Asia where validation sites are sparse, the impact of climate change is severe, and processes of land-cover change are widespread and strongly influenced by humans (Figure 1).

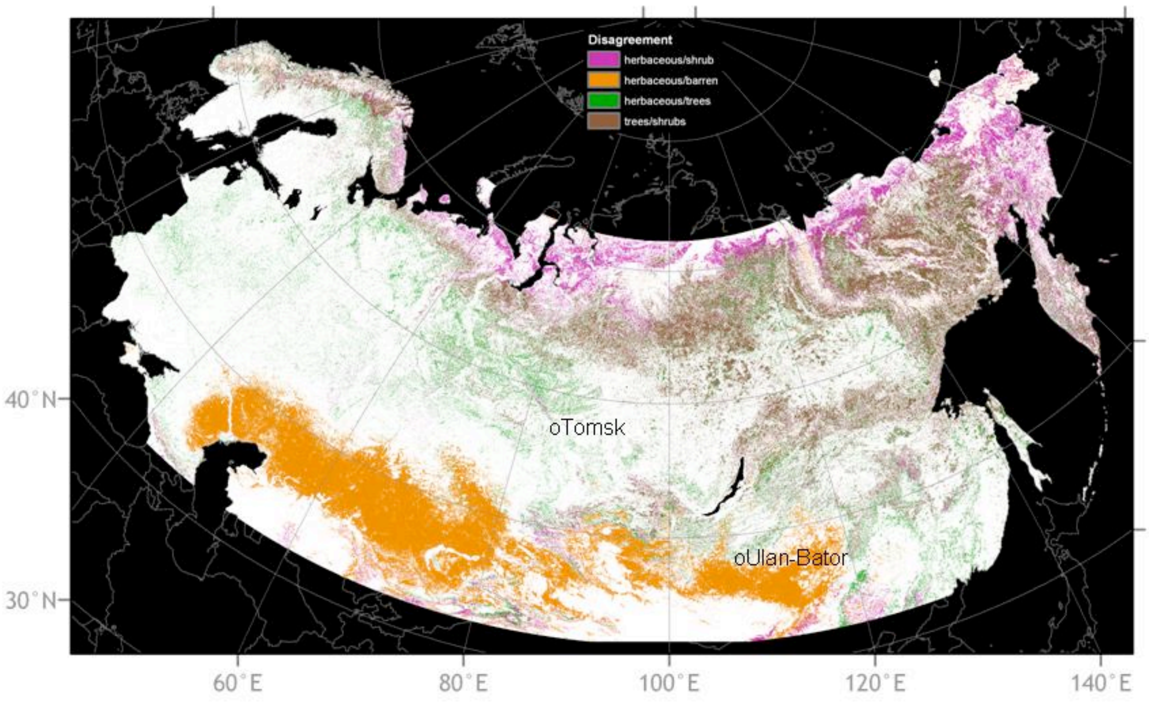


Figure 1 Map of disagreement in major vegetation types (tree-dominated, shrub-dominates, herbaceous, bare land) between 2 recent land-cover products: MODIS IGBP 2001 and GLC 2000

Particularly, there is a significant concentration of disagreements in the distribution of tree cover immediately north of Tomsk and a major area of confusion between herbaceous cover and bare land south of Ulaanbaatar. It is well known that Mongolia and Russia have undergone an economic and political transition into a market economy since the 1990s and have suffered great socio-economic changes including those resulting in land-cover changes. In particular in Mongolia little attention has been paid to problems of land degradation in most areas occurring after the collapse of the communist system due to economic difficulties. Similar situation took place in Russia. Nowadays environmental scientists in Mongolia, Russia and abroad are coming to understand the importance of the study of land-cover and land use analysis and particularly in the regions where human activity strongly impacts to environment. However, few research projects have been undertaken so far on detailed study of land-cover changes and their interrelations with on-going socio-economical processes.

We briefly review LCS linkages to desertification in this report because desertification extended in Mongolia and in neighboring regions of Russia. Lepers et al. (2005) mapped global desertification or dry land degradation for the period 1980-2000. They used pre-existing remote sensing data on vegetation degradation, water and wind erosion, and chemical and physical deterioration processes to identify areas influenced by desertification. The largest area afflicted with desertification was in Mongolia and this was due to wind and water erosion. Geist and Lambin (2004) reviewed 132 peer-reviewed articles to identify common land use change factors associated with desertification. Geist and Lambin found six common human and biophysical factors associated with the proximate causes of desertification. These factors include demographic factors, economic factors, technological factors, policy and institutional factors, climate factors and cultural factors. Each of these factors was associated with four common proximate causes of desertification, which were: agricultural activities, infrastructure extension, wood extraction, and increased aridity. One of the primary drivers of desertification in rural areas is land-cover change associated with pasture or rangelands. Pasture is defined as land used permanently for herbaceous forage crops, either cultivated or growing wild (Lambin et al. 2003). Lambin et al. (2001, p. 263) defined rangelands by “the presence of grass and trees used by grazers or browsers, and encompassing vegetation types ranging from complete grass cover, through woodlands with as much as 80% canopy cover, to pastures within dense forests.”

For analyzing land-cover and its change captured with time series of Landsat space imagery four test sites were established. Two sites in Mongolia are used as a study area since most of the area’s land surface is managed as pasture land, which means that coupled human-environment systems are mainly limited to land degradation in the context of one land use system. And two sites in Russia are used as a study area since most of the area’s land surface is covered by forest. The analysis is focused on the effects of changes in land use in the region during 1989-2007 and understanding the observed changes in historic context. The test sites provide data for evaluation of existing coarse-resolution land-cover products and regional assessment of novel remote sensing methods. Analysis of the actual land-cover in these locations helps to evaluate available land-cover products. For each of the test sites all available socio-economic studies and government statistics including land inventories, population census, GDP, agricultural and forest sector production, and other economic indicators are used to assess observed land use changes. It is very important to understand the regional variation in the extent and types of human impact on land-cover change, and to assess the capacity of evolving Earth Observation System to monitor these changes, and build regional collaborations in support of consistent policy decisions. The analysis of results and synthesis across the study region focused on understanding the human impact on land-cover, assessment of the response of land-cover to changes in climate and land use, evaluation of available coarse-resolution land-cover products (based on MODIS data), and development of summary of findings for regional decision makers.

This project is related to LCS because it focuses on interactions between environment and society with an emphasis on desertification and land degradation of pastureland as well as on man-made deforestation. The project allowed for the opportunity to use Remote Sensing/GIS and its application for land cover analysis in the study area in order to assist in the region’s sustainable development initiatives. The project further provides an opportunity for the NERIN and scientists working in

Northern Eurasian environments to share research results and to expand the participation of international partners and collaborators. That's why all project's results were made available on web sites of SCERT and NEESPI. The project also contributes to the ongoing effort of GOFC-GOLD and START International to develop a regional network of collaborators involved in observations of land-cover and its change.

2.0 Methodology

2.1 Siberian study area

The Siberian study area is located in the south part of Western Siberia in three different bioclimatic zones including South Taiga, Sub-Taiga and Forest-Steppe zones. Two test sites were selected for the detailed analysis. Test site "Bakchar" and test site "Tomsk" were named accordingly the largest settlement located at the test site (Figure 2).

Figure 2 Study area: 1 – "Bakchar" and 2 – "Tomsk" test sites

2.1.1 Test site "Bakchar"

The test site "Bakchar" is located on the territory of Bakchrskii rajon administrative unit. It is located at the south-west part of the West-Siberian Plain in the South Taiga zone with elevations from 110 to 130 m a.s.l. The studied area is drained by Chaya River and its feeders: Iksa, Bakchar, Teterenka, Andarma and Parbig rivers. Watersheds are occupied by bogs. Left-side river terraces are usually paludificated. Bog massifs formation started 4.5 – 5 thousand years ago and since that time the peat deposits cover the initial relief roughness. Watershed bogs have peat depth about 3–4 m.

Underlying soils are mostly carbonate loams and clays with lake-alluvial genesis. Soils are sod-podzol and sod-gley type with relict humus horizons, remained from intense humus accumulation epoch in the Holocene climatic optimum. The natural vegetation is very various. The large part of the area is occupied by wet of paludificated broad-leaved forests (Betula pendula Roth. and Polulus tremula L.). Dark coniferous forests with herbaceous-moss layer typical for the South Taiga zone cover very small areas. Mires occupy about 50% of the West Siberia area. Mire types at the test site are presented by open sphagnum and sedge fen, ridge-hollow and ridge-lake complex, pine-shrub-sphagnum community (or “ryam”). Ryams with different tree height (Pinus sylvestris L.) and tree layer density are located at bogs periphery and in the central parts of bog massifs.

The area is weakly populated due to high wetland contents. Settlements and agricultural lands (plowed fields, grasslands and hayfields) are located on well-drained areas along rivers. The largest village (Bakchar – district center) with adjoined agricultural lands is located in the place of four rivers junction. Reduction of areas of use of plowed fields and hayfields in 1990s results in formation of secondary meadows and partial overgrowing by young birch.

Dark coniferous forests occupy a part of the area, but clear-cuts are relatively small (up to 50 ha per year) due to the fact that fires considerably disturbed forests in the beginning of XX century. Clear-cuts are located in the north part of the test site. Clear-cuts near the settlements are quite rare. Some forest areas were disturbed at roads and power lines construction.

During the XX century the vegetation cover was exposed to natural and anthropogenic changes. Fires at the beginning of the century during intense area exploration have significant influence on formation of the present forests. Tall grasses preventing coniferous trees restoration occupy fired areas and clear-cuts. It brings to wide distribution of spare small-leaved forests. Dark coniferous forests with spruce, fir and Siberian pine are pushed to more damp habitats. Fires with periodicity from 12 to 20 years happen both in forests and bogs periphery during the dry years when burns out the top layers of peat.

The natural process changing shape of vegetation is active paludification as at the periphery of bogs and the surface depressions. The specific indicator of the paludification process is presence of pine forest with sedge-sphagnum layer on peat.

Drainage of the part of the Bakcharskoe bog located in a southern part of the test site by the open channels method was done in 1965-1970. Drained area is 22 000 ha. Drainage was done without peat excavation and the subsequent channels swallowing occurred. Now areas along the channels are covered by deciduous species (birch, willow), and adjoining ryams increase in growth of a pine.

2.1.2 Test site “Tomsk”

The test site **“**Tomsk” is located on the territory of Tomskii rajon administrative unit. It has a great variety of landscapes of Western Siberia and located on a joint of ridges of Altai-Sayan mountain area and Western Siberian lowland. The river Tom' divides the test area into rather raised right-bank part and lowered left-bank one. The highest altitude is 290 m a.s.l. located at the east part. Four basic geomorphological surfaces which natural borders are the large rivers Ob’ and Tom' are allocated.

1) Central part of the test site (Ob’-Tom’ interfluve) is a dennudation-accumulative plain of Mid-Quaternary age. Surfaces of the ancient plain are combined with loess loams soils and sands of ancient river valleys. The territory has active anthropogenic activity more than 300 years. The 80 % of areas of grey loamy sols are under cultivated lands. Small patches of pine-birch grassy woods of park type and secondary birch, aspen-birch, high-grass, and Siberian Pine forests are kept. Dark coniferous forests are located on low terraces Tom' and Ob’ rivers. Pinewoods are widespread by continuous fields in hollows of ancient river valleys. More than 40 % of the areas of hollows are occupied by oligotrophic bogs eutrophic fens.

2) South part of the test site is the south of Ob’-Tom’ interfluve. The area concerns to the northern forest-steppe bioclimatic zone. The area relief is hilly with dense network of river valleys and gullies.

Small rivers are rather narrow and superficial. Cultivated lands occupy more than 50 % of the area. The typical landscape represented by patches of aspen-birch forests in the broad gullies, alternating arable lands and meadows. There are mixed forests containing birch, aspen and pine. Small steppe sites can be found at southern slopes and at the most raised banks near the Tom' river. Wetland are presented by boggy meadows, bogs and ponds. River floodplains are occupied by bird cherries, willow, dogrose, caragana and small patches of mixed forests.

3) East part of the test site is located at the area of Tom'-Jaja interfluve within low ridges of Altai-Sayan mountain system. Soil basement is loess-like loams lying from 3-4 up to 6-8 m, they characterized by rather loose compaction. High variability of forms of slopes and local watersheds exists from narrow convex up to flat poorly sloping surfaces. Almost near each settlement there are artificial reservoirs (ponds). Largest of them are near villages Luchanovo, Aksenovo and Belousovo. The area of Tom'-Jaja interfluve is located at Sub-Taiga bioclimatic zone. The native vegetation has been strongly transformed by cuttings down and fires to the beginning of XX centaury. Now about 80 % of watersheds and gentle slopes of Ushaika and Basandaika rivers are occupied by arable lands.

4) West part of the test site is located at the left side of Ob' river. The relief is flat with low depressions up to 20-100 m diameter and 2-4 m depth. River terraces are well drained and covered by carbonate loams and clays. The most part of the area is covered by Sub Taiga vegetation only near the Ob' river exist anthropogenic forest-steppe landscapes. The natural vegetation has kept only within the limits of numerous closed depressions, gullies and the river valleys. The vegetation is presented by aspen, birch-aspen and birch forest patches with shrubs and various grassy cover. The meadow vegetation develops rather narrow strips around of forest patches, on sparse forested slopes and bottoms of broad gullies.

2.1.3 Local climate and its ongoing change

The climate of the studied areas is continental with cool wet summers and long cold winters. The long-term average annual temperature is 0.53 ± 0.56 ^{o}C. The annual temperature varied from -0.35^{o}C in 2006 to +1.74^{o}C in 2007. The average total annual precipitation was 488 ± 117 mm. According to the 20 years average snow cover lasts from 2 November till 22 April. The length of snow free period was 192 ± 10 days. The average May - September air temperature was 13.6 ±0.7^{o}C. About 58% of total precipitation (or 285 ±91 mm) occurred during these months.

In spite of the fact that regional global change manifestations are well pronounced in Siberia [Gordov and Vaganov, 2010], till now those have not affect forestry significantly. Really [Gordov et.al., 2011a], trends of annual mean temperature based on ERA-40 Reanalysis data and station observations have shown increase of air temperature on the most part of Siberian territory, equal to 0.4 - 0.6 ^{o}C/10 years and 0.8 ^{o}C/ 10 years - for some regions. However analysis of seasonal and monthly air temperatures has shown that temperature changes in winter (0.7 - 0.9 ^{o}C/ 10 years) and spring (0.5 - 0.6 ^{o}C/ 10 years) seasons make the main contribution, while contribution of temperature changes in summer and autumn are much less. Analysis of important for biological processes, especially to vegetation productivity climatic characteristics such as duration of warm and growing season, numbers of thaw days has shown an increase of number of days with daily mean temperature exceeding 0 ^{o}C and 5 ^{o}C, respectively, by 2-3 days/10 years in average. An increase of number of thaw (daily mean temperature > -2 ^{o}C) days by 2-4 days/10 years for the Western Siberia territory was also revealed. Precipitations dynamics analysis [Gordov et.al., 2011b] shows that their amount grows mainly during winter (November – April, up to 27.3 mm/10 years) and during the second part of warm season (August – October, up to 15 mm/10 years). Due timescale of forest growing processes the observed change of temperature and precipitation regimes has not effect on the test sites characteristics.

2.1.4 Dynamics of socio-economical situation

Before 1995 timber cutting was one of the major activities in Tomskaya oblast'. However the whole situation changed together with disappearance of large state owned timber-processing industry in the region. The first version of the Forestry Codex determining new regulations for timber cutting was adopted in 1997. It opened to business possibility to rent officially some areas of forest on competitive basis. It has a number of drawbacks, which led to growing illegal cuttings, and was replaced by completely new one adopted in 2006. Till now it is in process of permanent improvement (10 significant changes during period 2008-2010). It should be noted that now it is possible to rent a part of forest via an auction only.

The Bakchrskii rajon administrative unit is located in more then 200 km from the city Tomsk, administrative capital of the Tomskaya oblast'. According to statistical data its population decreases from 17,6 thousands in 1990 to 16,9 thousands in 1999 and to 14,4 thousands in 2007. The whole situation with timber cutting in the Bakcharskii rajon had started to change only in 2008, when new RF Forestry Codex was adopted. It allows to rent some parts of forest and to organize timber cutting there. It should be noted that significant amount of timber is officially cut by local population for their local usage (during 2008 near 20 thousands of cubic meters).

The Tomskii rajon administrative unit is located nearby the city Tomsk, administrative capital of the Tomskaya oblast'. According statistical data its population decreases from 94 thousands in 1990 to 85,6 thousands in 1999 and to 65,7 thousands in 2007. It should be noted that industrial cutting here formerly was quite active. However, currently it is rather low due near lack of proper forestry. For example, amount of timber officially cut by local population for their local usage during 2008 in near 5 thousands of cubic meters only.

2.2 Mongolian study area

The Mongolian study area covers different vegetation types. Regions corresponding to Tuv and Darkhan provinces were selected for critical study (Figure 3). The Darkhan province is located in the northern part of the country, between 47^{o}-49^{o}N and 104^{o}-107^{o}E. Tuv province is in steppe zone of Mongolia, between 46^{o}-48^{o}N and 105^{o}-108^{o}E.

Human activity negatively impacts vegetation cover in two provinces. The big expansion of urbanization in Darkan province and hand made mining in Tuv province resulted in increased land degradation of landscapes. Some parts of the study areas where after mining finishes are undergoing rehabilitation. Landfills are covered with topsoil and vegetation is planted.

2.2.1 Climate and socio-economical situation

Several studies have dealt with climate controls on primary vegetation production in Mongolia. These studies focused on the water component as the major climate constraint as identified by Nemani et al. (2003). For example, Ni (2003) and Li et al. (2007) showed that relationships existed between vegetation production and both precipitation and evapotranspiration in Mongolia. Both Miyazaki et al. (2004) and Munkhtetseg et al. (2007) demonstrated the influence of climate on vegetation production in the growing- season. They both showed that precipitation in July had the greatest influence on vegetation production. Furthermore, other studies (Zhang et al. 2005; Munkhtetseg et al. 2007) concluded that air temperature had a negative influence on vegetation production, especially in drier regions and in dry years. "In the desert-steppe, biomass, functional group cover, richness and diversity did not vary along grazing pressure gradients, but all vegetation variables except the cover of weedy annuals and unpalatable forbs varied significantly between years in the desert steppe. Vegetation dynamics in this zone largely conformed to the NEP of rangeland dynamics."

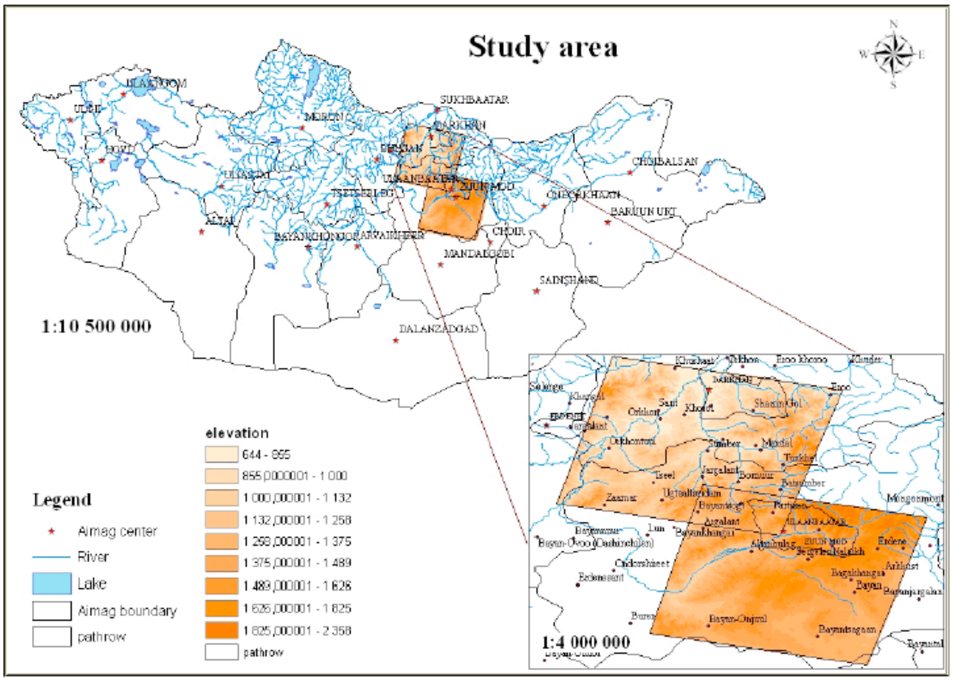


Figure 3 Study area: Darkhan and Tuv provinces

“In the mountain-steppe, grass and total biomass, total vegetative cover, the cover of grasses, weedy annuals and unpalatable forbs, and richness and diversity varied along grazing pressure gradients. With increasing grazing pressure, grasses decreased and forbs and weedy annuals increased, as the conventional range condition model predicts. Inter-annual variation in precipitation influenced total vegetative cover, species and functional group cover, and richness and diversity.” “In the steppe, forb biomass, grass, forb, unpalatable forb and weedy annual cover, and diversity varied along grazing pressure gradients. Grass biomass and total vegetative cover responded interactively to precipitation and grazing”.

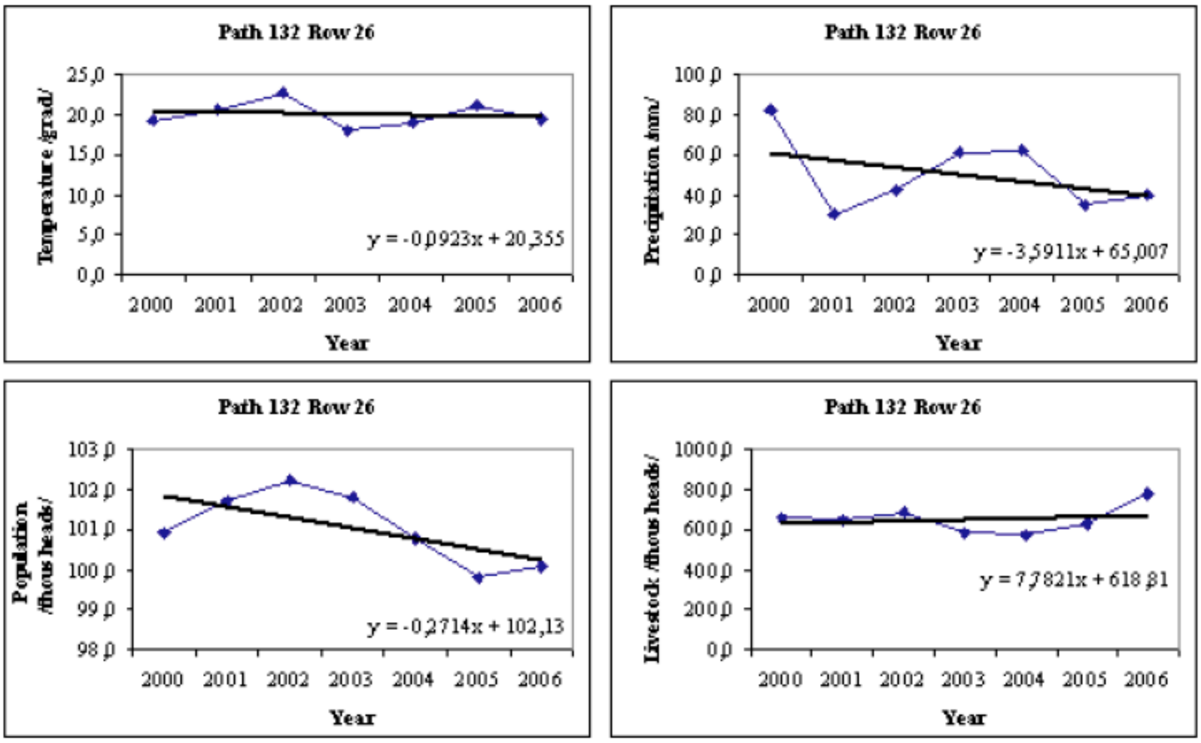


Figure 4 Change of climate and socio-economic data in Darkhan province

According above research works temperature and precipitation influenced on vegetation type for the study areas. We collected climate and socio-economic data from the two sites for population, livestock and climate data; precipitation and temperature. Figure 4 and Figure 5 show annual change of socio economic and climate data in the Darkhan and Tuv provinces respectively for August between 2001-2006. The Darkhan province's mean temperature, precipitation and population number decreases while livestock steadily increases (Figure 4). Temperature and precipitation decreases and population and livestock increases in Tuv province (Figure 5).

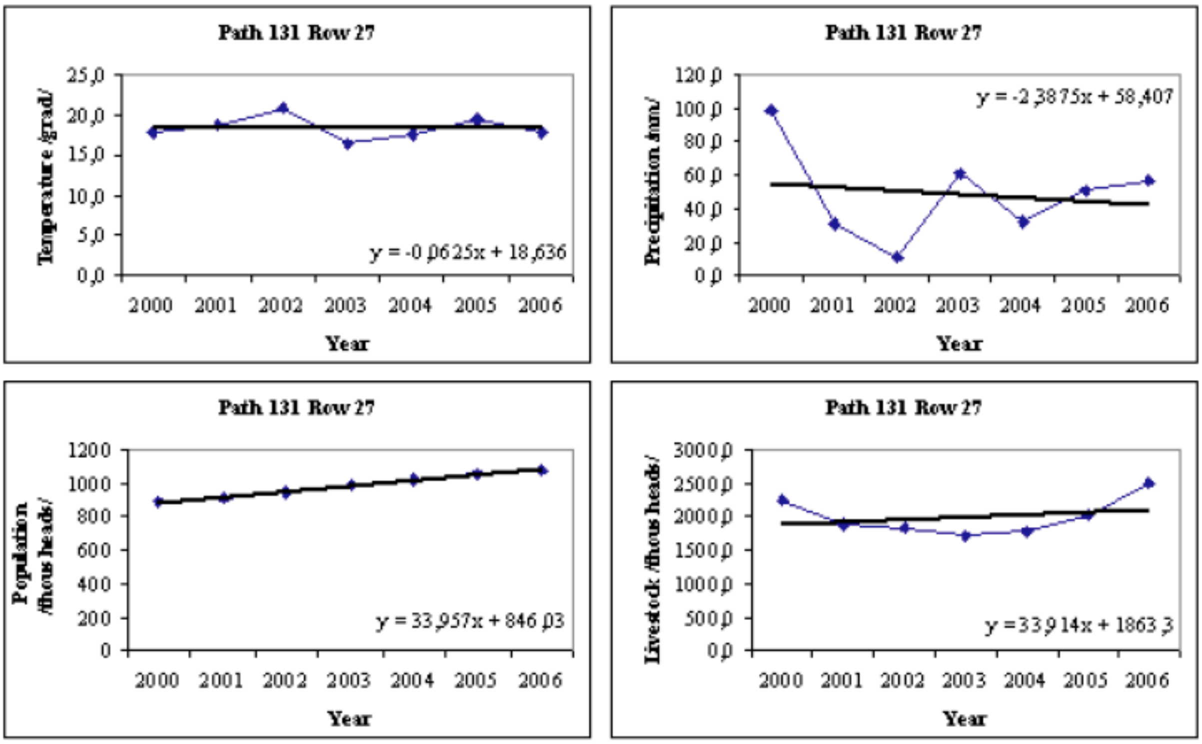


Figure 5 Change of climate and socio-economic data in Tuv province

2.3 Data

2.3.1 LANDSAT data

The Landsat TM, ETM+ images present the primary source of data for land-cover/use mapping and change detection of the two study areas. The Landsat images between years 1989 and 2007 were used in this project (Table 1).

Table 1: Landsat imagery

Instrument	Date	Path Row	Site
TM	Aug. 21, 1989	P132 R26	Darkhan
ETM+	Sep. 21, 2000	P132 R26	Darkhan
ETM+	Sep. 10, 2002	P132 R26	Darkhan
ETM+	Aug. 31, 2001	P131 R27	Tuv
ETM+	Aug. 26, 2005	P131 R27	Tuv
TM	Aug. 5, 2006	P131 R27	Tuv
TM	Aug. 30, 1990	P150 R20	Bakchar
ETM+	Sep. 16, 1999	P150 R20	Bakchar
TM	Jul. 20, 2007	P150 R20	Bakchar
TM	Jun. 16, 1990	P148 R21	Tomsk
ETM+	Sep. 18, 1999	P148 R21	Tomsk
TM	Jul. 14, 2007	P148 R21	Tomsk

2.3.2 MODIS data

Moderate Resolution Imaging Spectroradiometer (MODIS) 250 m Enhanced Vegetation Index (EVI) products were used for the analysis vegetation over years 2001-2006 (Figure 15). The MODIS EVI products have several advantages suitable for regional land cover mapping. The newly launched sensors of MODIS offer a unique combination of spectral, temporal, and spatial resolution in comparison to other global sensors.

2.3.3 Ground data

Collection of good ground truth data is a key issue for reliable land cover mapping. Ground data were collected from field trips to the test sites. We used ground data collected to find classes of unsupervised classification corresponding to known classes. For each item from the map legend we pick out a number of points at the satellite image. The ground points with the known vegetation type were selected using data of field works (stationary and track observations, botanical descriptions, landscape-typological maps), Google Earth images, and expert knowledges on the landscape types. Also existing thematic maps for soil and vegetation of Mongolia and Joint Russian-Mongolian complex biological expedition map “Ecosystems of Mongolia”, (Moscow 2005, Soil Mapping of Mongolia) were used. The total number of sampling points is 414 for “Bakchar”, 277 for “Tomsk” and 1188 for both Mongolian sites were selected. Some example photos are in Appendix 5. Detail locations of sampling points are shown in the Figures 6 and 7**.**

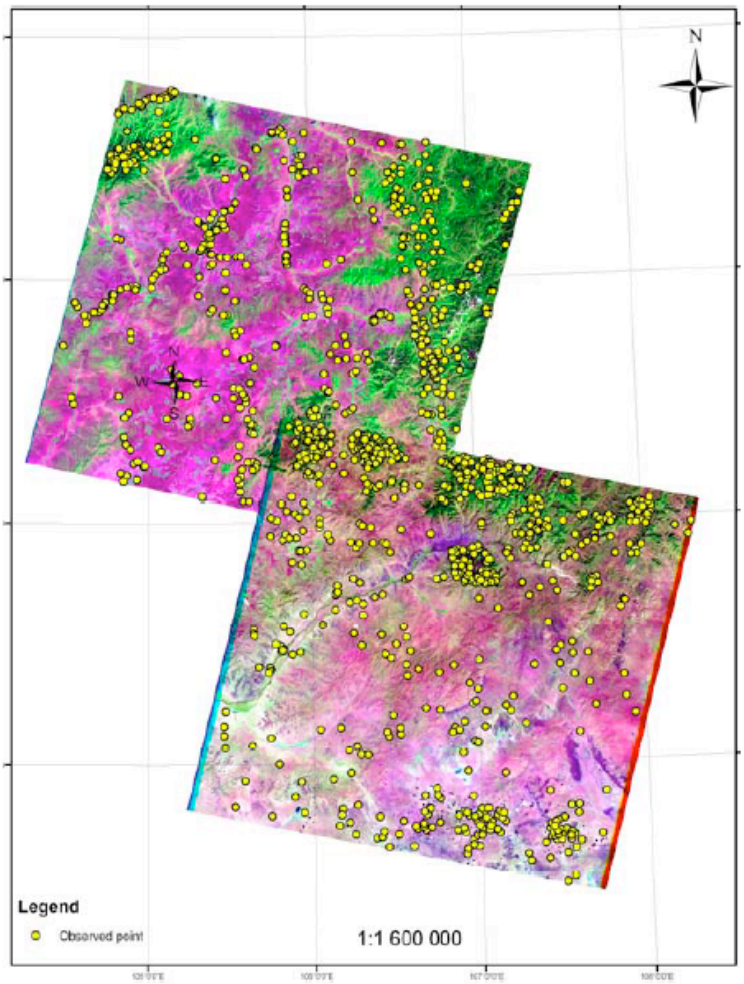


Figure 6 Locations of sampling points in Mongolia

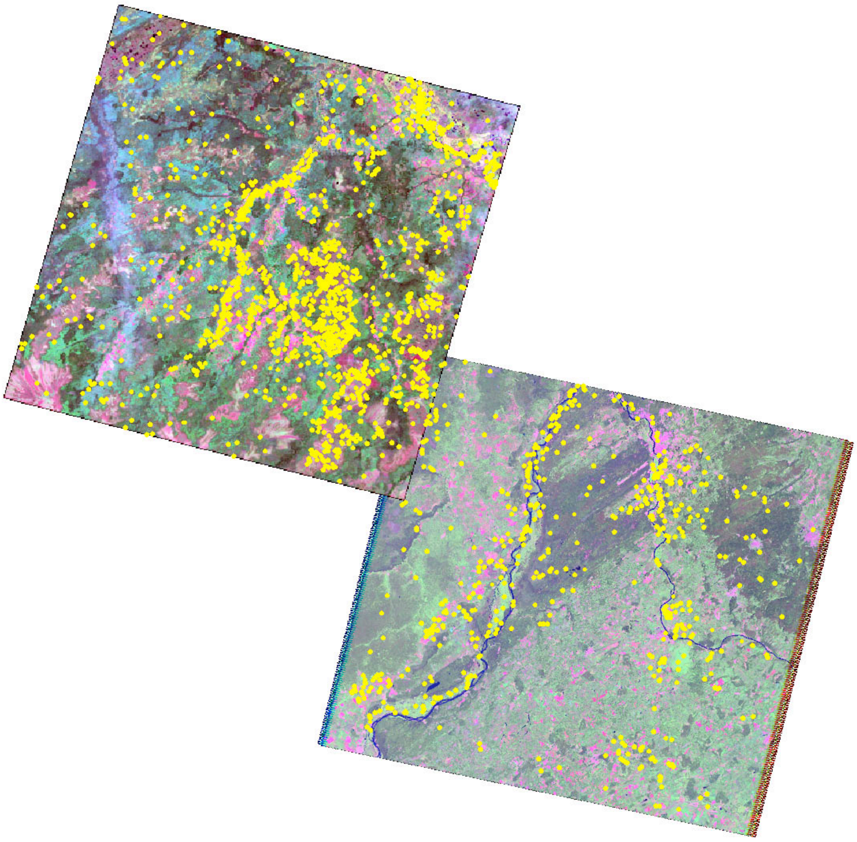


Figure 7 Locations of sampling points in Siberia

3.0 Results & Discussion

Land cover is the observed (bio) physical cover on the earth's surface. On the other hand, land use is characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it (FAO, 2000). Another definition of land use is that land use is a series of operations on land, carried out by humans, with the intention to obtain products and/or benefits through using land resources (de Bie, 2000). Land cover is a part of the information about real land surface from the view point of mainly vegetation. Therefore there are several organizations/groups such as IGBP, UNEP/FAO, CORINE which are trying to develop land cover data set of global or continental area. The Land Cover Working Group (LCWG) of the Asian Association on Remote Sensing (AARS) has also developed land cover data set to meet both scientific needs (global change studies) and social needs (global/continental scale land use planning). The classification maps taken from LCWG in 1999 AARS Asia 30 second Land Cover Data Set with Ground truth information from CEReS, Chiba University, Japan were used as the reference maps for the mapping of the study area.

3.1 Mongolian land-cover classification

We used land-cover class code from NELDA definitions (See Appendix 6). The atmospheric correction was applied for image processing of satellite data (Appendix 7). For the land cover classification map we used Landsat TM/ETM data (Figures 8-13). The land cover classification approach is developed by following interpretation:

- Geocoding of satellite data
- Preparation of material for ground survey
- Develop land-cover classification and interpretation keys

- Supervised classification using existing information and ground survey results
- Post-processing and filtering of systematic errors
- Interpretation and refinement of classification results
- Generalize land cover classes into big classes
- Generate land cover change map

3.1.1 Vegetation classes definition

In order to make land cover legends we used the baseline legends and took 15 classes from class definitions from NELDA project. Tree dominated, Shrub Dominated Herbaceous Dominated, Bare Land and Sparse Vegetation, Water were main classes for our imagery:

1. Tree Dominated

Needleleaved Deciduous Closed

The main layer consists of needleleaved deciduous closed trees. The crown cover is more than (70-60)%. The height is in the range of >30 - 3m.

Needleleaved Deciduous Open

The main layer consists of needleleaved deciduous woodland. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified. The height is in the range of >30 - 3m.

Broadleaved Deciduous Closed

The main layer consists of broadleaved deciduous closed trees. The crown cover is more than (70-60)%. The height is in the range of >30 - 3m.

Broadleaved Deciduous Open

The main layer consists of broadleaved deciduous woodland. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified. The height is in the range of >30 - 3m.

Mix (not able to be defined according to LCCS)

Areas dominated by trees where neither deciduous (broadleaved or needleleaved) nor evergreen (broadleaved or needleleaved) species represent > 75% of the cover present.

2. Shrub Dominated

Mix

Areas dominated by shrubs where neither deciduous (broadleaved or needleleaved) nor evergreen (broadleaved or needleleavead) species represent > 75% of the cover present.

3. Herbaceous Dominated

Herbaceous Vegetation Closed

The main layer consists of closed herbaceous vegetation. The crown cover is more than (70-60)%. The height is in the range of 3 - 0.03m but may be further defined into a smaller range.

Herbaceous Vegetation Open

The main layer consists of open herbaceous vegetation. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified

4. Bare Land and Sparse Vegetation

Primarily non-vegetated areas containing less than 15% vegetation cover during at least 10 months a year. A further distinction is possible in Bare, for areas with less than 5% of vegetation, and Sparse Vegetated for areas with vegetation cover more than 5% and less than 15%.

5. Water

The land cover consists of perennial natural water bodies where water is present > 11 months.

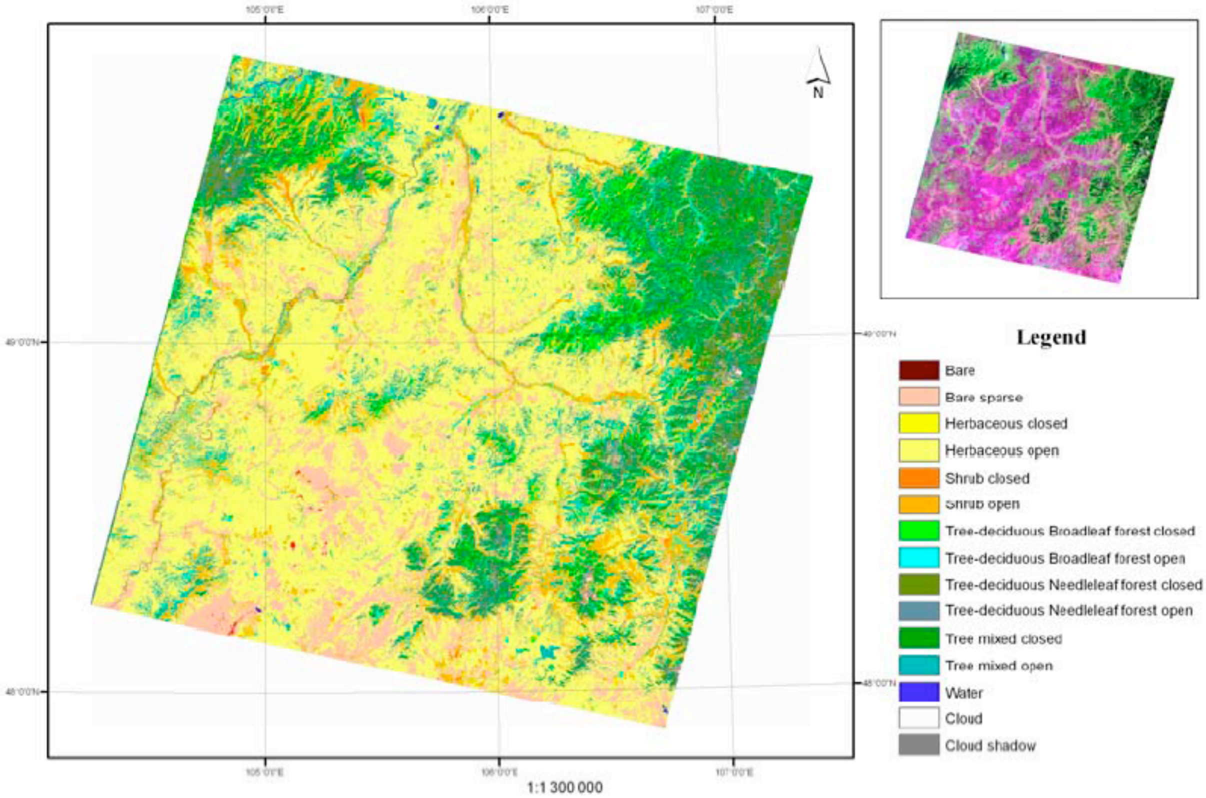


Figure 8 Land-cover classification of Darkhan province (Landsat image, path 132, row 26, Aug. 21, 1989)

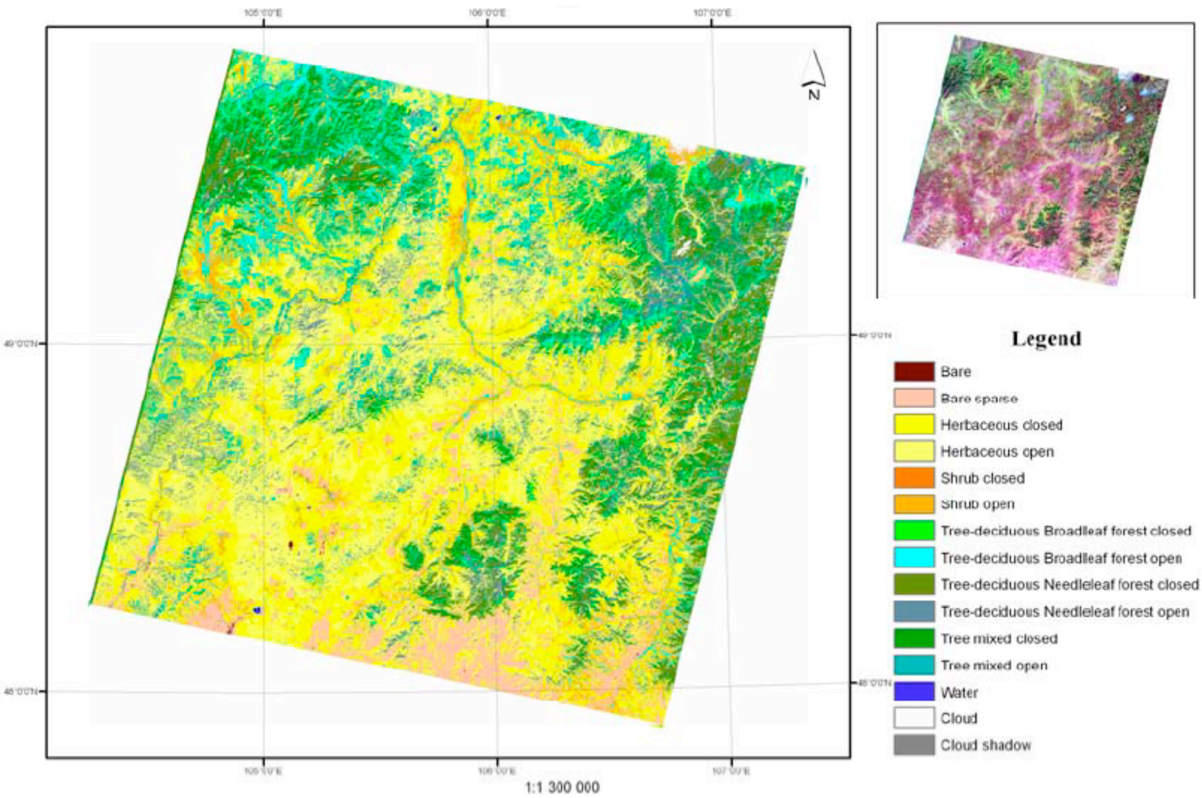


Figure 9 Land-cover classification of Darkhan province (Landsat image, path 132, row 26, Sep. 21, 2000)

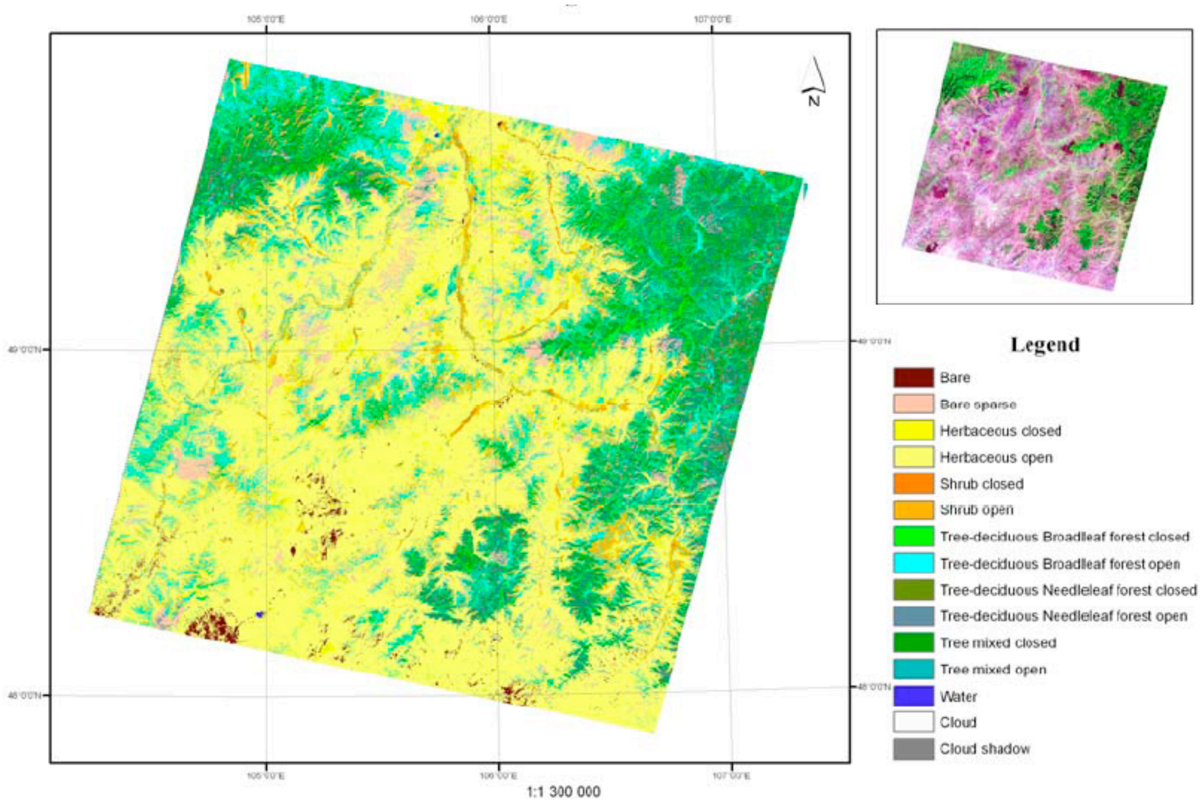


Figure 10 Land-cover classification of Darkhan province with mining area (Landsat image, path 132, row 26, Sep. 10, 2002)

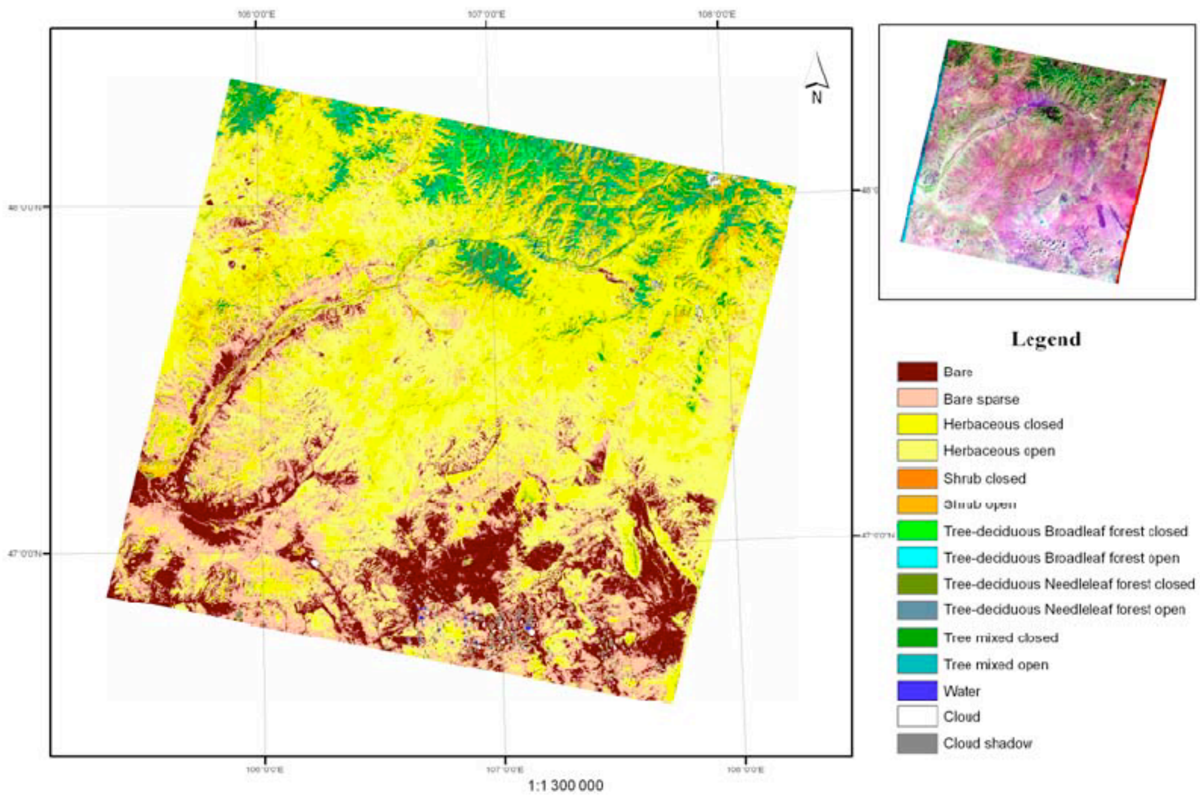


Figure 11 Land-cover classification of Tuv province (Landsat image, path 131, row 27, Aug. 31, 2001)

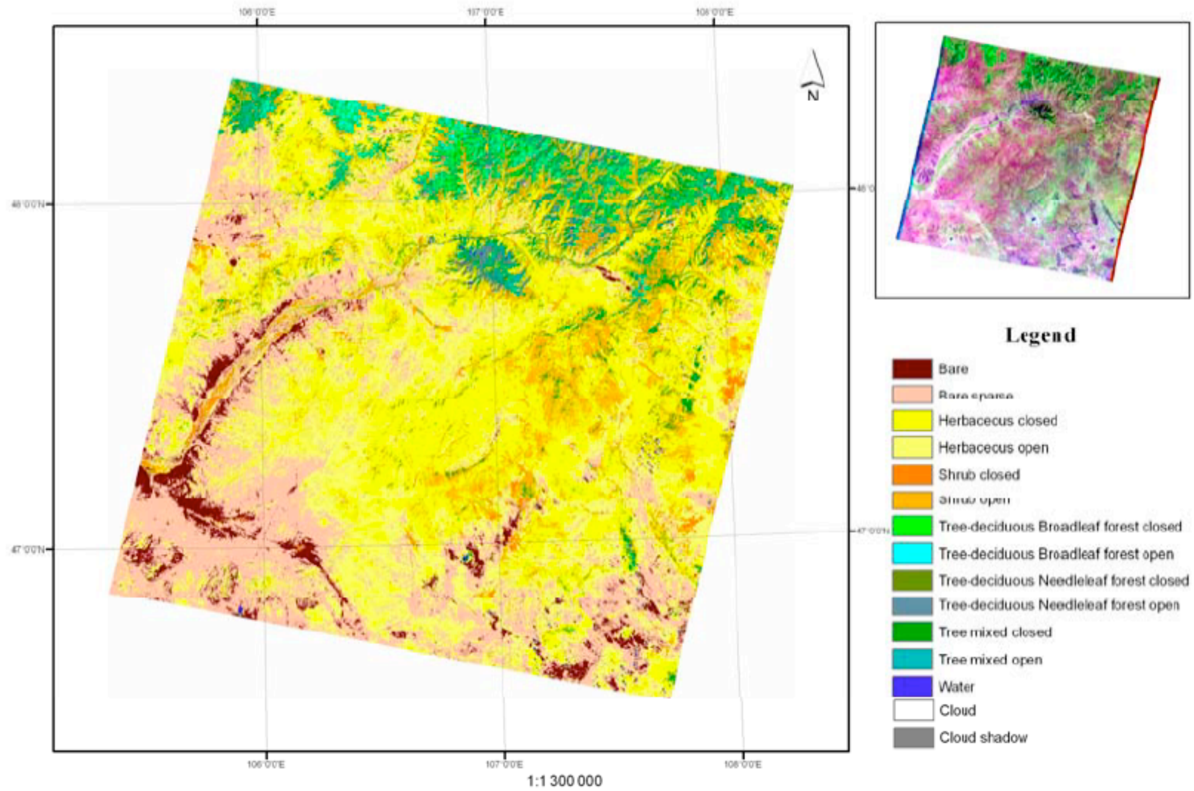


Figure 12 Land-cover classification of Tuv province (Landsat image, path 131, row 27, Aug. 26, 2005)

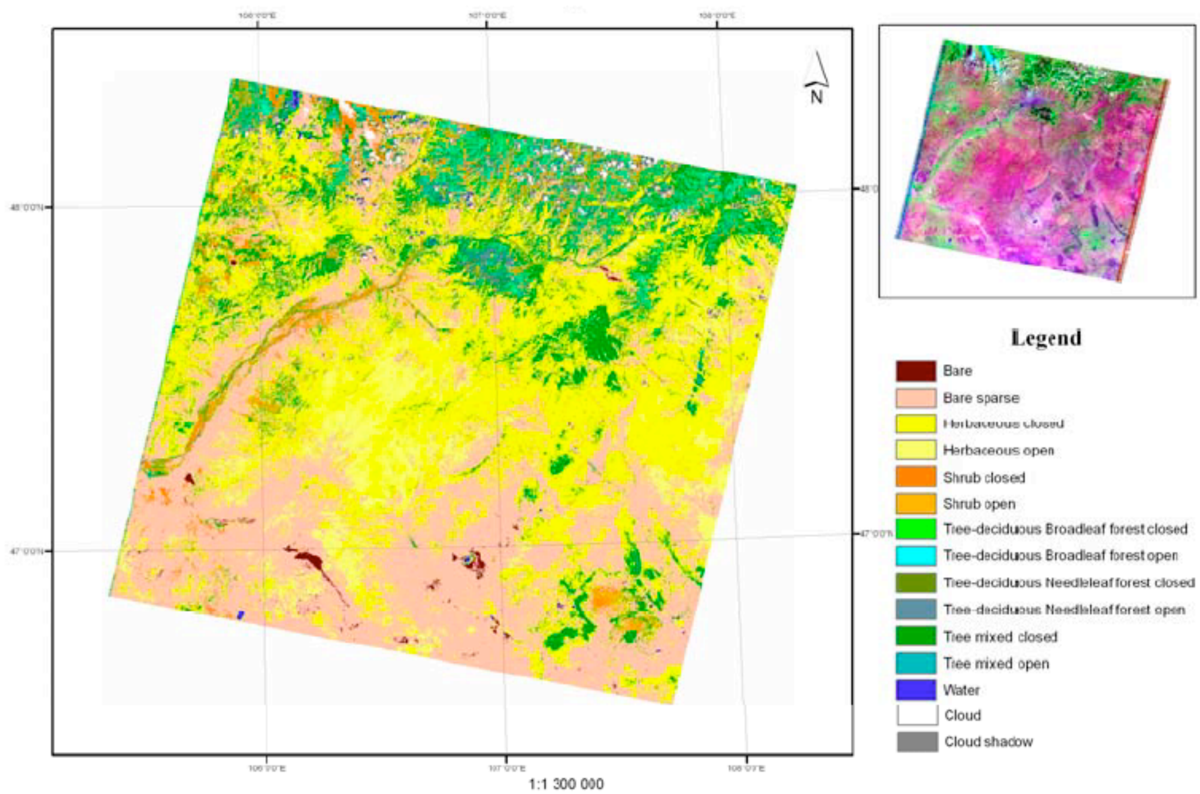


Figure 13 Land-cover classification of Tuv province (Landsat image, path 131, row 27, Aug. 5, 2006)

3.1.2 Accuracy assessment

The distribution of the accuracy assessment points for each scene is 561 and 627 respectively for Darkhan province and Tuv province. The accuracy assessment are presented in Table 2 and Table 3. The results show that the overall accuracy of land cover classification is 78% and 88 % respectively for the two scenes. The assessment for 13 aggregated land cover classes including:

B	Bare
BS	Bare sparse
HC	Herbaceous closed
HO	Herbaceous open
SC	Shrub closed
SO	Shrub open
TDBC	Tree Deciduous Broadleaf Closed
TDBO	Tree Deciduous Broadleaf Open
TDNC	Tree Deciduous Needleleaf Closed
TDNO	Tree Deciduous Needlelead Open
TMC	Tree Mixed Closed
TMO	Tree Mixed Open
W	Water

were selected for the land cover mapping in this research project.

Table 2: Full classification Accuracy Assessment (Darkhan province, path 132, row 26)

		Classes derived from satellite														
		B	**BS**	**HC**	**HO**	**SC**	**SO**	**TDBC**	**TDBO**	**TDNC**	**TDNO**	**TMC**	**TMO**	**W**	**Sum**	**Comission, %**
Grand observed class	**B**	19	10	0	1	0	0	0	0	0	0	0	0	0	**30**	36.67
	BS	1	37	0	1	0	1	0	0	0	0	0	0	0	**40**	7.50
	HC	0	0	45	5	2	2	1	0	0	0	0	0	0	**55**	18.18
	HO	0	1	0	41	0	6	0	0	0	1	0	1	0	**50**	18.00
	SC	0	0	8	0	39	1	0	1	0	0	0	0	0	**49**	20.41
	SO	0	0	1	3	0	30	1	7	0	0	0	1	0	**43**	30.23
	TDBC	0	0	0	0	0	0	19	2	0	2	5	2	0	**30**	36.67
	TDBO	0	0	0	0	0	0	5	45	0	2	1	0	0	**53**	15.09
	TDNC	0	0	1	0	0	0	1	0	30	7	2	0	0	**41**	26.83
	TDNO	0	0	0	0	0	0	0	0	6	26	0	0	0	**32**	18.75
	TMC	0	0	0	0	0	0	0	3	2	1	35	2	0	**43**	18.60
	TMO	0	0	0	0	0	0	0	1	1	4	3	42	0	**51**	17.65
	W	0	0	0	0	0	0	0	0	6	2	1	0	35	**44**	20.45
	Sum	**20**	**48**	**55**	**51**	**41**	**40**	**27**	**59**	**45**	**45**	**47**	**48**	**35**	**561**	
	Omission, %	5.00	22.92	18.18	19.61	4.88	25.00	29.63	23.73	33.33	42.22	25.53	12.50	0.00		

Table 3: Full classification Accuracy Assessment (Tuv province, path 131, row 27)

		Classes derived from satellite														
		B	**BS**	**HC**	**HO**	**SC**	**SO**	**TDBC**	**TDBO**	**TDNC**	**TDNO**	**TMC**	**TMO**	**W**	**Sum**	**Comission, %**
Grand observed class	**B**	41	5	0	0	0	0	0	0	0	0	0	0	0	**46**	10.87
	BS	0	45	5	0	0	0	0	0	0	0	0	0	0	**50**	10.00
	HC	0	0	60	3	0	0	0	0	0	0	0	0	0	**63**	4.76
	HO	0	4	8	30	0	0	0	0	0	0	0	0	0	**42**	28.57
	SC	0	0	0	0	40	17	0	0	0	0	0	0	0	**57**	29.82
	SO	0	0	0	0	0	66	0	0	0	0	0	0	0	**66**	0.00
	TDBC	0	0	0	0	0	0	29	10	7	0	0	0	0	**46**	36.96
	TDBO	0	0	0	0	0	0	0	44	0	0	0	0	0	**44**	0.00
	TDNC	0	0	0	0	0	0	0	0	48	0	0	0	0	**48**	0.00
	TDNO	0	0	0	0	0	0	0	0	0	43	0	1	0	**44**	2.27
	TMC	0	0	0	0	0	0	0	0	0	0	46	0	0	**46**	0.00
	TMO	0	0	0	0	0	0	0	0	0	15	0	40	0	**55**	27.27
	W	0	0	0	0	0	0	0	0	0	0	0	0	20	**20**	0.00
	Sum	**41**	**45**	**68**	**33**	**40**	**83**	**29**	**44**	**48**	**43**	**46**	**41**	**20**	**627**	
	Omission, %	0.00	18.75	23.64	5.882	4.878	25.00	0.00	16.95	15.56	25.86	0.00	2.439	0.00		

3.1.3 Land cover change

The Landsat TM and ETM+ images for years:

a) August 1989, b) Sep, 2000; c) Sep 2002 for Darkhan and a) August 2001, b) August 2005, August 2006 for Tuv province were selected for change detection analysis. We combined 13 classes into 5 classes; bare, herbaceous, shrubs, trees and water. From Table 4 and 5 it is shown that land-cover for 5 classes are changing over years. Herbaceous is the most dominant class in both areas. Bare class was dominated due to mining by 1989. Herbaceous class is increasing in both areas. There is rehabilitation process is going on in some places. Shrubs are decreasing due to expansion urban and transportation (Table 4 and Table 5).

Table 4: Land-cover change in Tuv province

Path 131 Row 27	Aug., 2001 (area, km^2)	Aug., 2005 (area, km^2)	Aug., 2006 (area, km^2)
Barren	3810	2840	1887
Herbaceous	17075	17434	18596
Shrubs	3802	2653	2903
Trees	9566	11336	10885
Water	48	38	29
Sum	**34301**		

Table 5: Land-cover change in Darkhan province

Path 132 Row 26	Aug., 1989 (area, km^2)	Sep., 2000 (area, km^2)	Sep., 2002 (area, km^2)
Barren	10669	8229	347
Herbaceous	19486	19195	27820
Shrubs	1441	3872	1308
Trees	2648	2948	4802
Water	56	57	23
Sum	**34301**		

Figure 14 illustrates the changes of bare sparse in both study areas Tuv and Darkhan provinces respectively. Bare sparse increase in Tuv province while it decreases in Darkhan. It argues that there is decrease greenness in Darkhan due to urban.

Figure 14 Change detection for bare sparse land in the study areas a) Darkhan province, b) Tuv province

3.1.4 MODIS EVI vegetation change

Vegetation indices (VI's) have emerged as an important tool in the monitoring, mapping, and resource management of the Earth's terrestrial vegetation. Vegetation indices (VI) have been used since the late 1960s, with a continual evolution of new types of VIs and their uses. VI's serve as useful indicators for seasonal and inter-annual variations of vegetation and resultant climatic and anthropogenic influences on the environment.

Enhanced vegetation index (EVI) was developed to optimize the vegetation signal with improved sensitivity for high biomass regions and improved monitoring through de- coupling of the canopy background signal and reduction of atmospheric influences. The EVI is represented by the following equation:

$$EVI = G\frac{NIR - \mathrm{Re}d}{NIR + C_1 \mathrm{Re}d - C_2 Blue + L}$$

where L is the canopy background adjustment that addresses nonlinear, differential NIR and red radiant transfer through a canopy, and C_1, C_2 are the coefficients of the aerosol resistance term, which uses the blue band to correct the aerosol influences of the red band. The coefficients adopted in the EVI algorithm are, L=1, C_1=6, C_2=7.5, and G (gain factor)=2.5 (Huete, 1997).

MODIS Enhanced Vegetation Index time series data over years August, 2001-2006 were used for the analysis of vegetation (Figure 15).

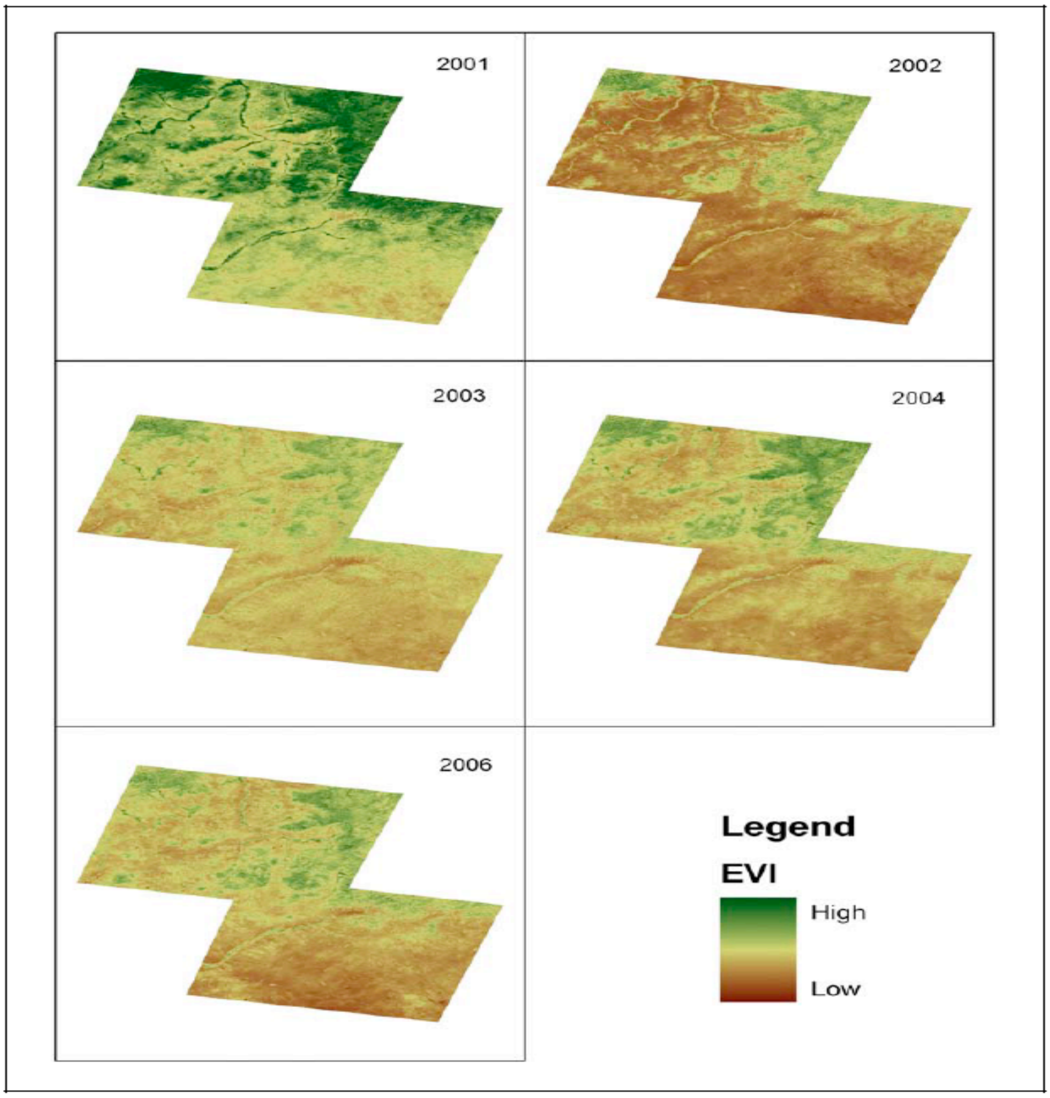


Figure 15 Enhanced Vegetation Index change over years 2001-2006

3.1.5 Analysis

We look the relationship between EVI and temperature (r^2=0.13), precipitation (r^2= 0.36), population (r^2=0.29) and livestock (r^2=0.09) in Tuv province (Figure 16); and relationships between EVI and temperature (r^2=0.38), precipitation (r^2=0.0001), population (r^2=0.47), and livestock (r^2=0.05) in Darkhan province (Figure 17) in order to demonstrate the influence of climate and socioeconomic factors on vegetation. Population has a negative relationship to EVI in both areas. This means that the vegetation is highest in areas with the lowest levels of population.

Livestock has positive relationships with vegetation in both scenes. This means that livestock strategy is to increase total stocking rates in relation to increasing levels of vegetation.

Furthermore, temperature availability influence negatively on vegetation in both areas. In general, population has negative relationship with vegetation. This means that the overall study area's vegetation affected by human activities (ninja). Population number was selected as the ninja's number for this research. Ninja is a person who digs small, unauthorized mines for gold in Mongolia. Ninja mining have a negative effect on pastureland, as well as nomadic herders have to move more frequently to find land for their livestock to graze on due to the reduced amount of pasture.

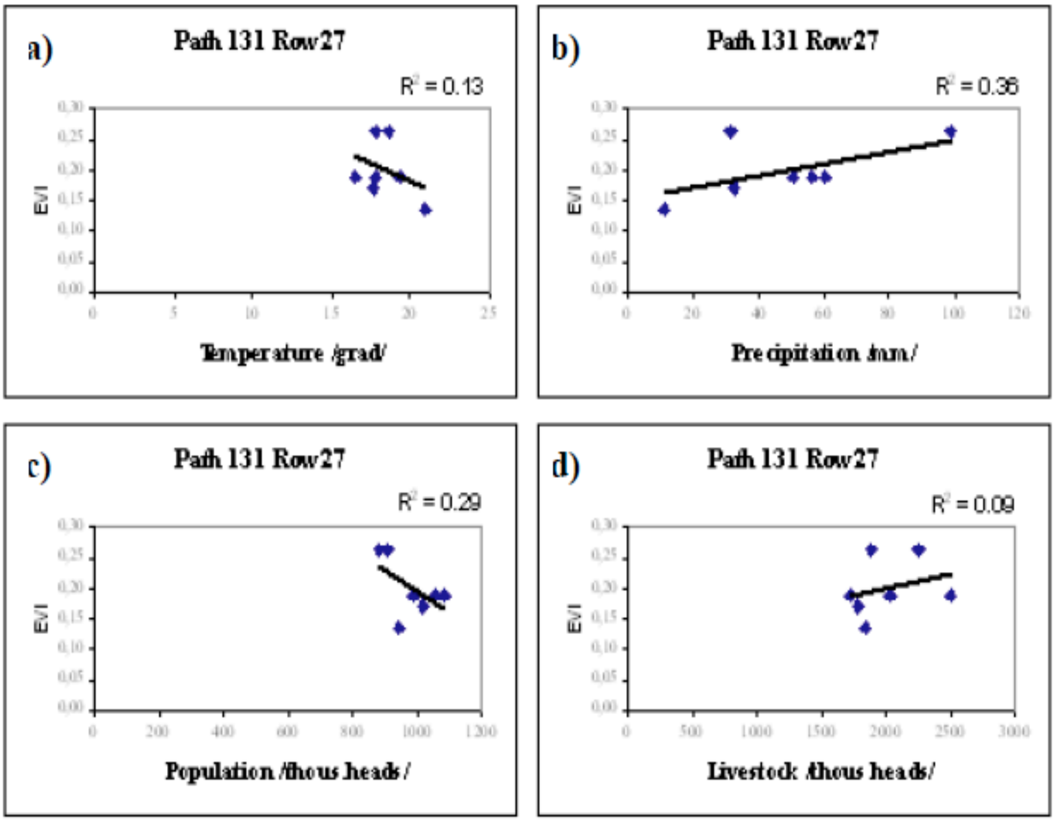


Figure 16 The relationships between vegetation, climate and socio-economic data, where a) temperature, b) precipitation, c) population, d) livestock (Tuv province)

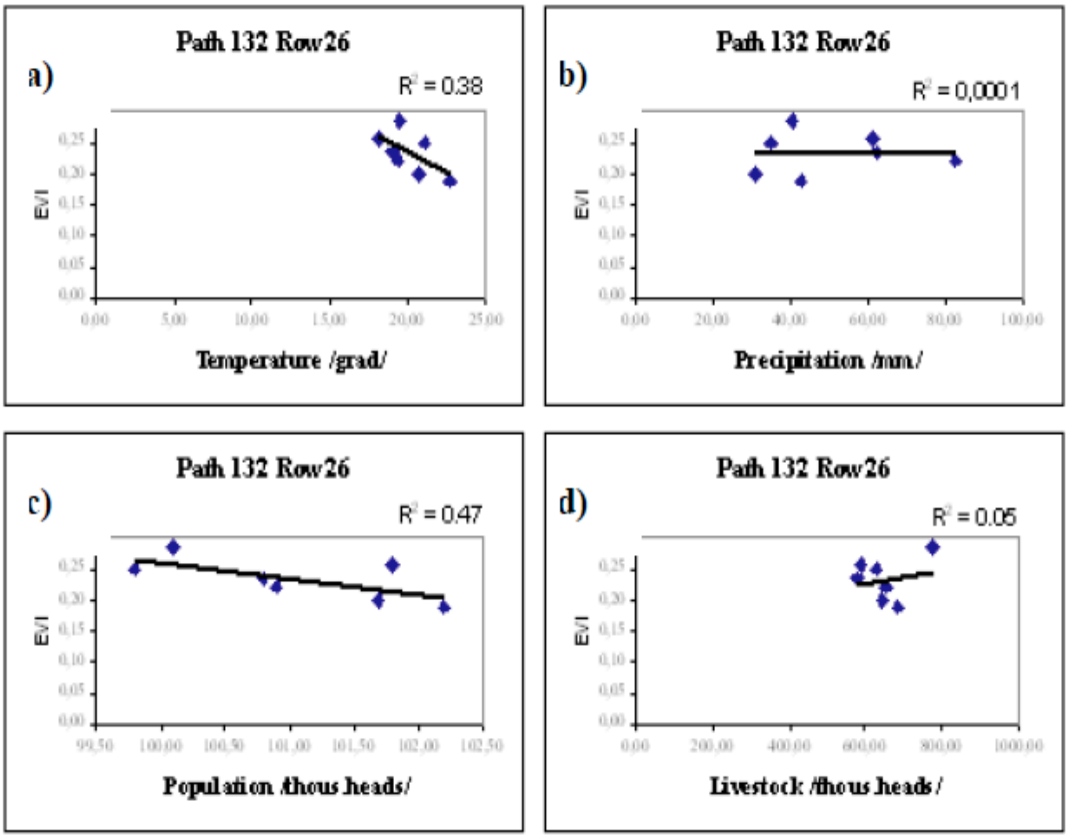


Figure 17 The relationships between vegetation, climate and socio-economic data, where a) temperature, b) precipitation, c) population, d) livestock (Darkhan province)

3.2 Siberian land-cover classification

In order to make land-cover legends we used the baseline legends and took 13 classes from class definitions by NELDA (See Appendix 6).

3.2.1 Vegetation classes definition

Class	Code	Definition
Settlements	Set	Areas of permanent community in which people live, without being specific as to size, population or importance. Settlement areas were defined manually.
Water	W	Perennial natural water bodies where water is present over 11 months per year.
Bare Land	B	Primarily non-vegetated areas containing less than 15% vegetation cover during at least 10 months per year.
Herbaceous	H	Main layer consists of herbaceous vegetation with less than 15% tree crown cover. Usually cultivated lands with grasslands or fields at a different stage of agriculture processing (mowed grass, fallen grass)
Herbaceous. Wetland	HW	Herbaceous and moss vegetation with less than 15% trees on land with water table near/at/above soil surface for enough time to promote wetland or aquatic processes (bogs).
Shrub	S	Vegetation height 0.5-3m with main layer of shrub species with less than 15% tree crown cover.

Shrub.Wetland	SW	Vegetation height 0.5-3m with main layer of shrub species with less than 15% trees on land with water table near/at/above soil surface for enough time to promote wetland or aquatic processes (bogs).
Tree.Broadleaved. Deciduous. Closed	TBDC	Vegetation height greater than 3m with the main layer consisting of broadleaved deciduous woodland with a crown cover greater than 65%.
Tree.Mixed.Closed	TMC	Vegetation height greater than 3m without dominating woodland type and crown cover greater than 65%.
Tree.Mixed.Closed. Wetland	TMCW	Vegetation height greater than 3m with no dominant woodland type and crown cover greater than 65% on land with water table near/at/above soil surface for enough time to promote wetland or aquatic processes (bogs).
Tree.Mixed.Open. Wetland	TMOW	Vegetation height greater than 3m with no dominant woodland type and crown cover 15-65% on land with water table near/at/above soil surface for enough time to promote wetland or aquatic processes (bogs).
Tree.Needleleaved. Evergreen.Closed	TNEC	Vegetation height greater than 3m with the main layer consisting of needleleaved evergreen woodland with a crown cover greater than 65%.
Tree.Needleleaved. Evergreen.Closed. Wetland	TNECW	Vegetation height greater than 3m with the main layer consisting of needleleaved evergreen woodland with a crown cover greater than 65% on land with water table near/at/above soil surface for enough time to promote wetland or aquatic processes (bogs).
Tree.Needleleaved. Evergreen.Open. Wetland	TNEOW	Vegetation height greater than 3m with the main layer consisting of needleleaved evergreen woodland with a crown cover 15-65% on land with water table near/at/above soil surface for enough time to promote wetland or aquatic processes (bogs).

The bare lands usually are represented by riverbank sands, plugged fields or burned areas on wetlands. Bare build up was not detected on the image, because settlements on the studied area are small and have more grass cover than buildings.

Imagery pre-processing

The Landsat ETM+ scenes obtained in 2007 was used for land cover mapping was acquired at level 1G processing with a 30 m spatial resolution and UTM projection (zone 44N, WGS84) (Figure 18-19).

The image-based COST method for atmospheric correction (see Appendix 7, Chavez Jr., 1996) combined with radiometric calibration (Skirvin, 2000) was applied for image processing. Finally, the six ETM+ reflectance bands were transformed into Tasseled Cap indices of brightness, greenness, and wetness (Crist, 1985) (Figure 20-21).

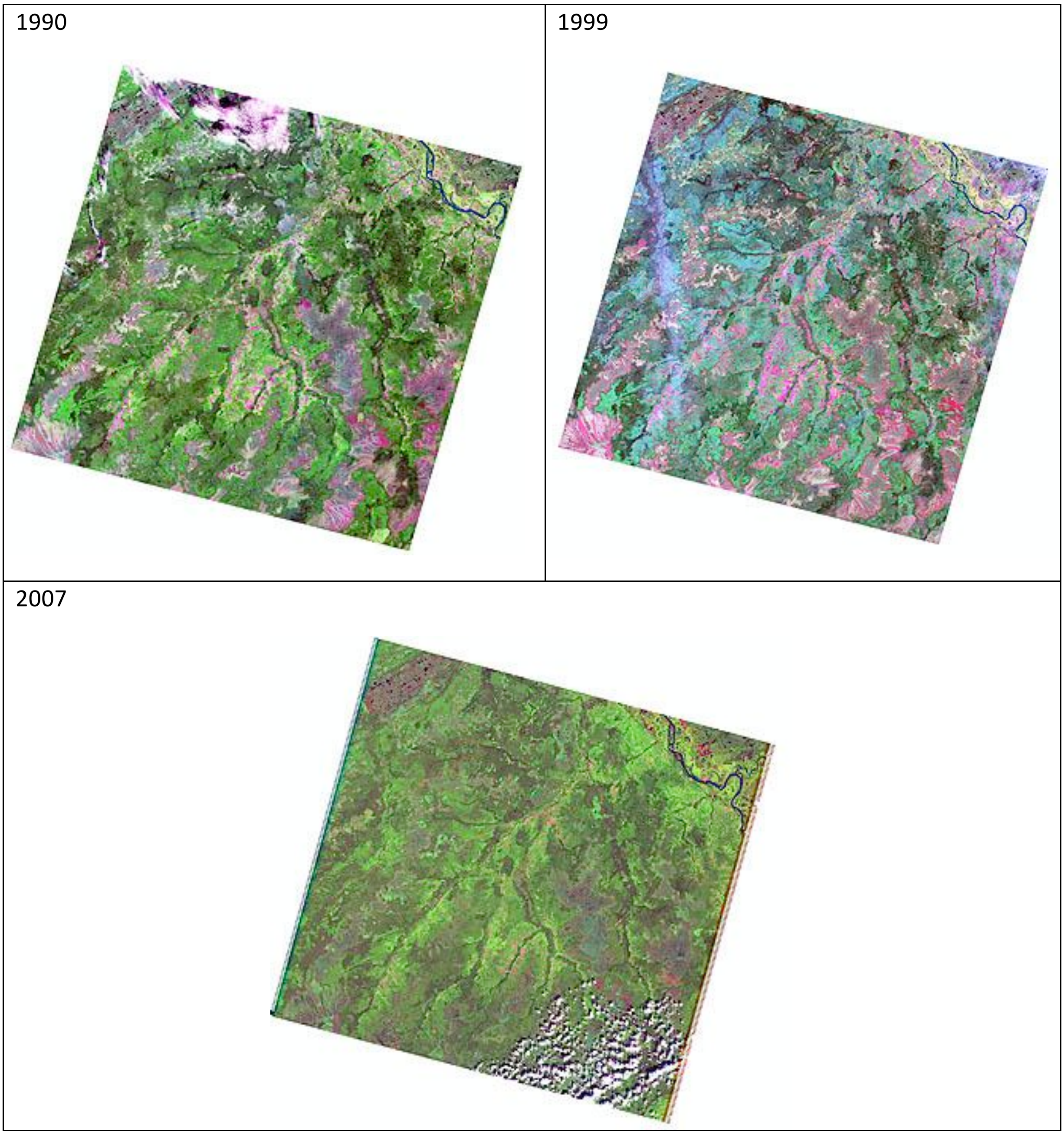


Figure 18 Landsat images, Path 150 Row 20, test site "Bakchar"

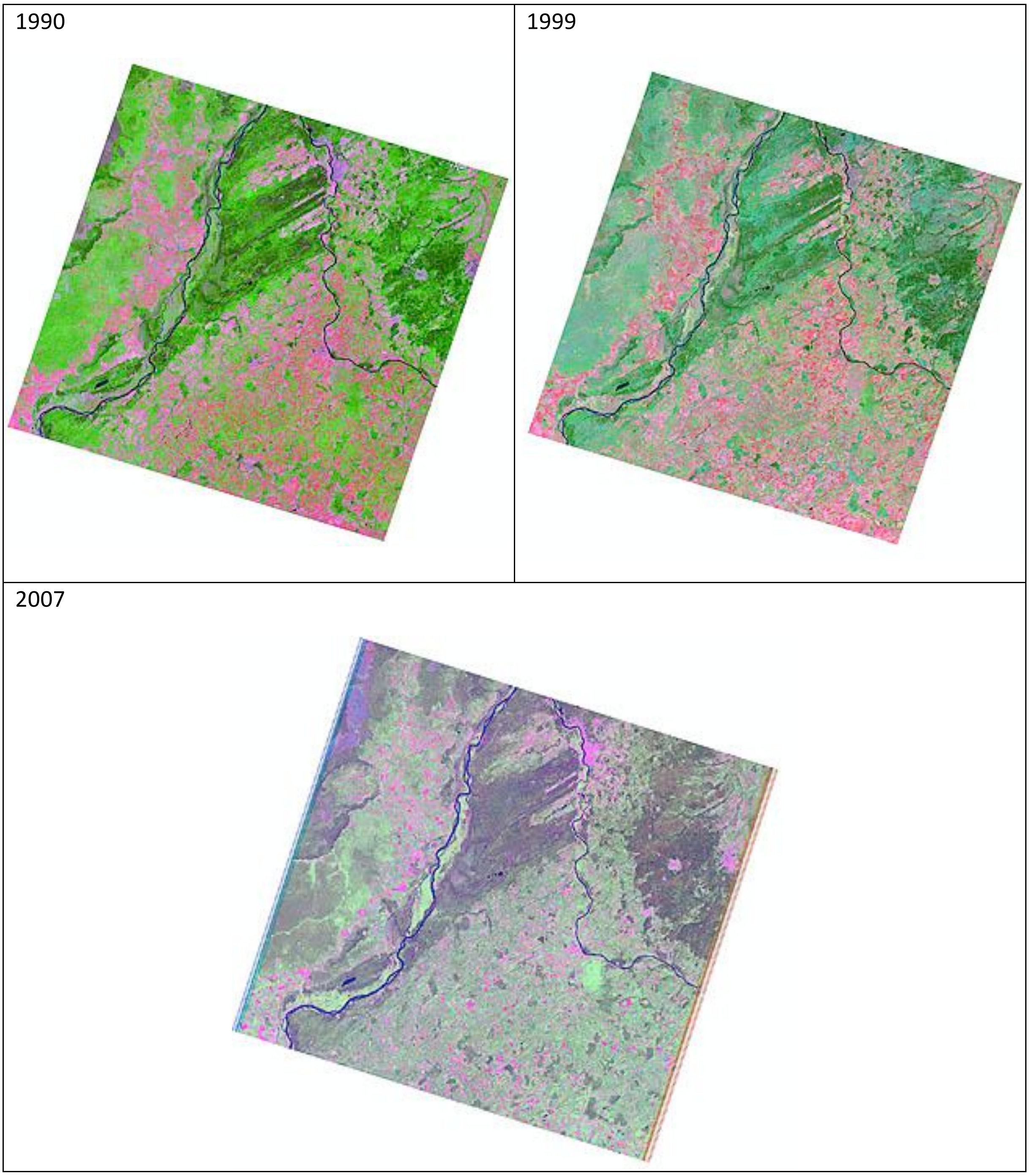


Figure 19 Landsat images, Path 148 Row 21, test site "Tomsk"

Clouds/Shadows/Haze mask

Mask was constructed basing on unsupervised classification of the image. The image was constructed from 6 bands, including thermal infrared band. Thermal infrared band (#6.1 10.4-12.5 µm TIR) allows recognize partially clouded areas and atmospheric haze. A standard procedure of automatic cloud cover assesement [Irish 2000] does can't solve this problem. The composite image was classified into 30 classes. Three classes were referred to cloudy/haze areas where natural mosaic spatial structures replaced by uniform areas with a single class. These areas were combined to the clouds mask.

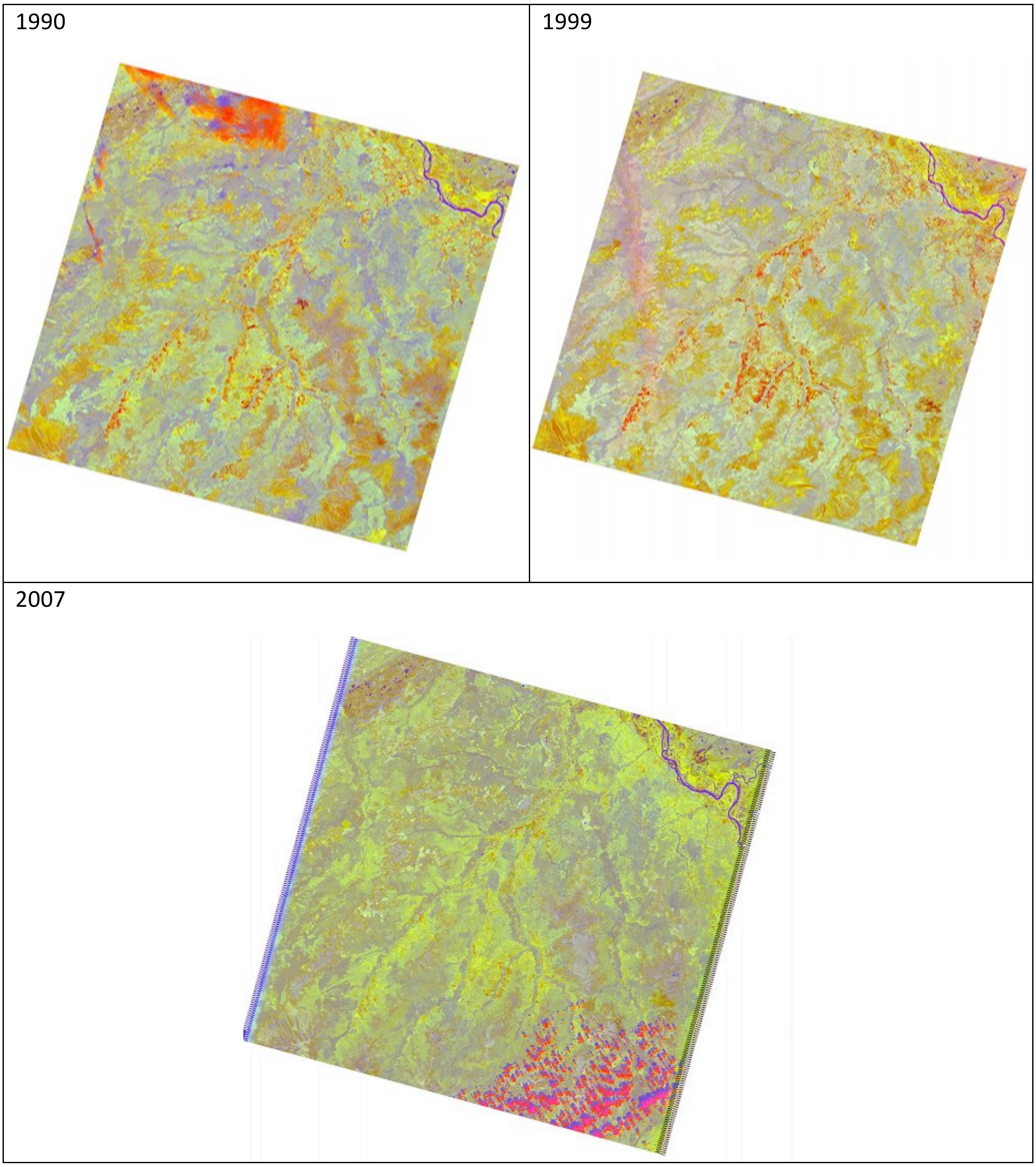
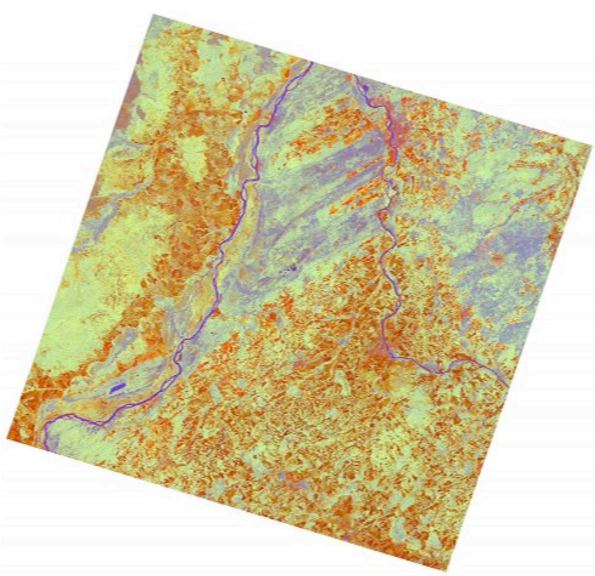


Figure 20 Tasseled cap processing stage, Path 150 Row 20, test site “Bakchar”

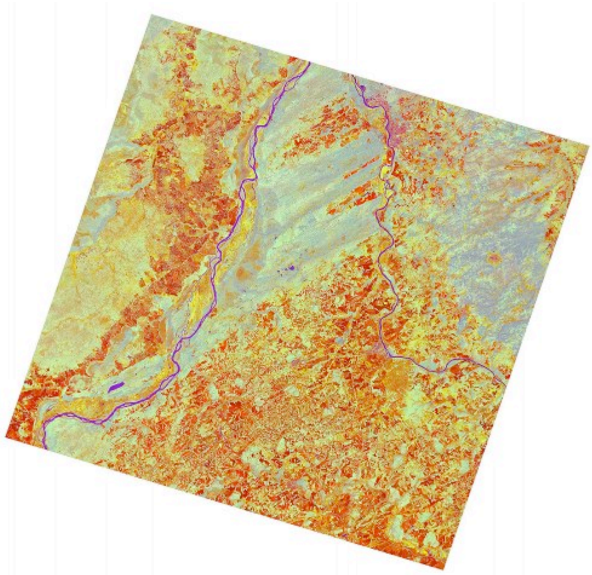
Unsupervised classification

The Tasseled Cap image was classified into 62 land cover classes using multiple iterations of ISODATA unsupervised classification after applying clouds mask. The classified image was filtered to minimum mapping unit ~0.7 ha (3x3 pixels) with the use of “clump” and “eliminate” procedures.
1 pixel = (28.5m*28.5m) = 812.25 m^2. Thus, 9 pixels = 7310.25 m^2.

1990



1999



2007

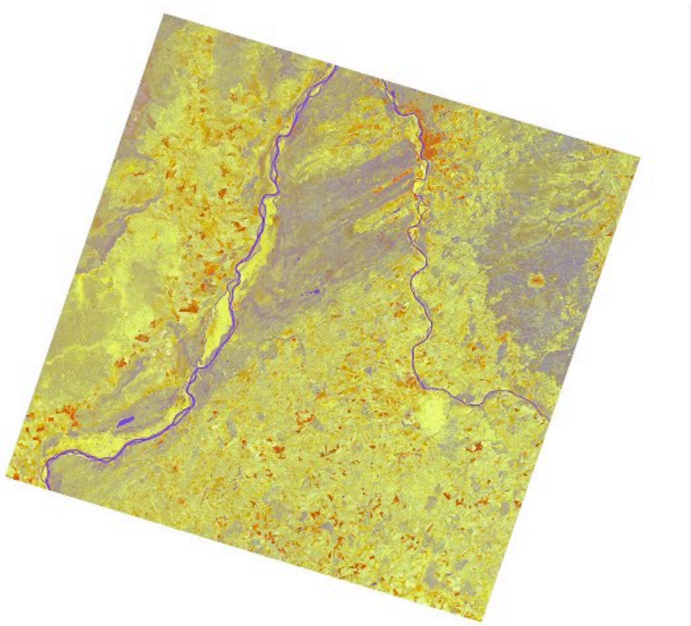


Figure 21 Tasseled cap processing stage, Path 148 Row 21, test site "Tomsk"

Class assessments

For each class from 30 to 180 points were selected as training data basing on the ground data. The compliance matrix was created to find classes of unsupervised classification corresponding to known classes at ground data. Some unsupervised classes clearly correspond to a single class from map legend (Bare, Water). Spectral characteristics of some classes are very close. For example, we can not exactly separate grassland (herbaceous vegetation) from sedge-sphagnum fens (wetland herbaceous vegetation). Wetlands contain specific objects (water flow lines, forested islands) and can be easily recognized by eye. After classes assessments we manually process the image to correct the classification results. Wrongly determined upland classes (H, S, TNC) located on wetlands were marked as the consequent wetland classes (HW, SW, TNCW). Wrongly determined wetland classes

(HW, SW) located in well-drained areas were marked as the consequent upland classes (H, S) (See Figure 22-23).

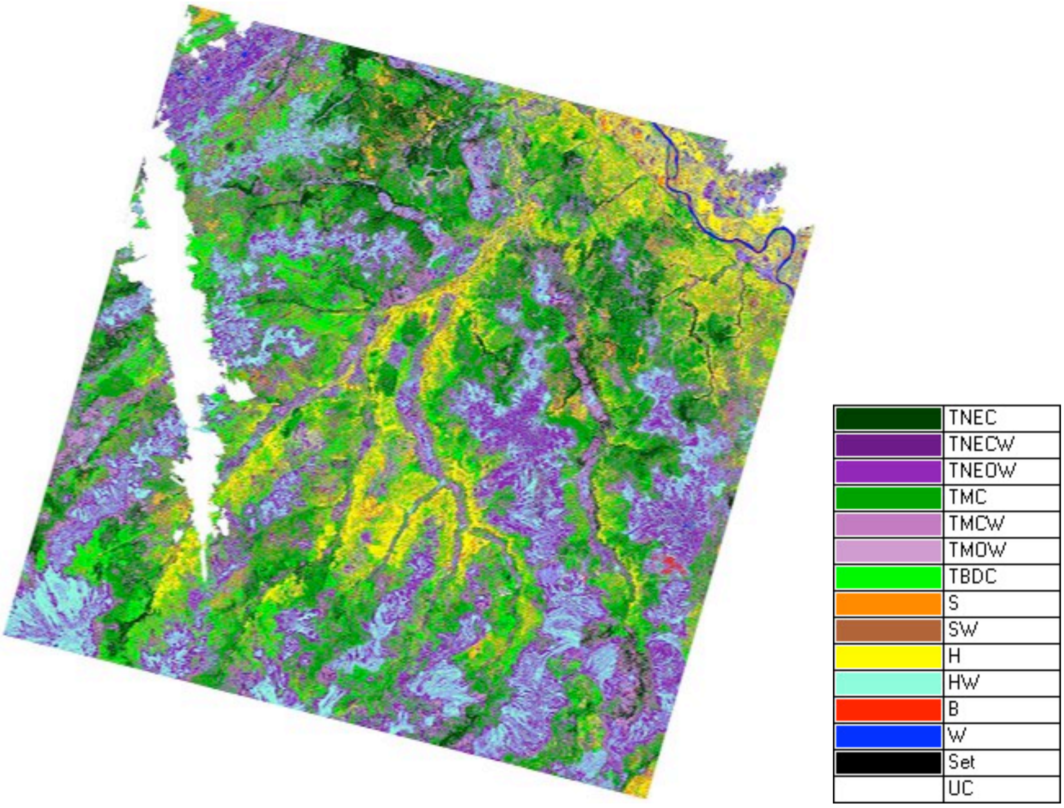


Figure 22 Classified image, Path 150 Row 20, test site "Bakchar"

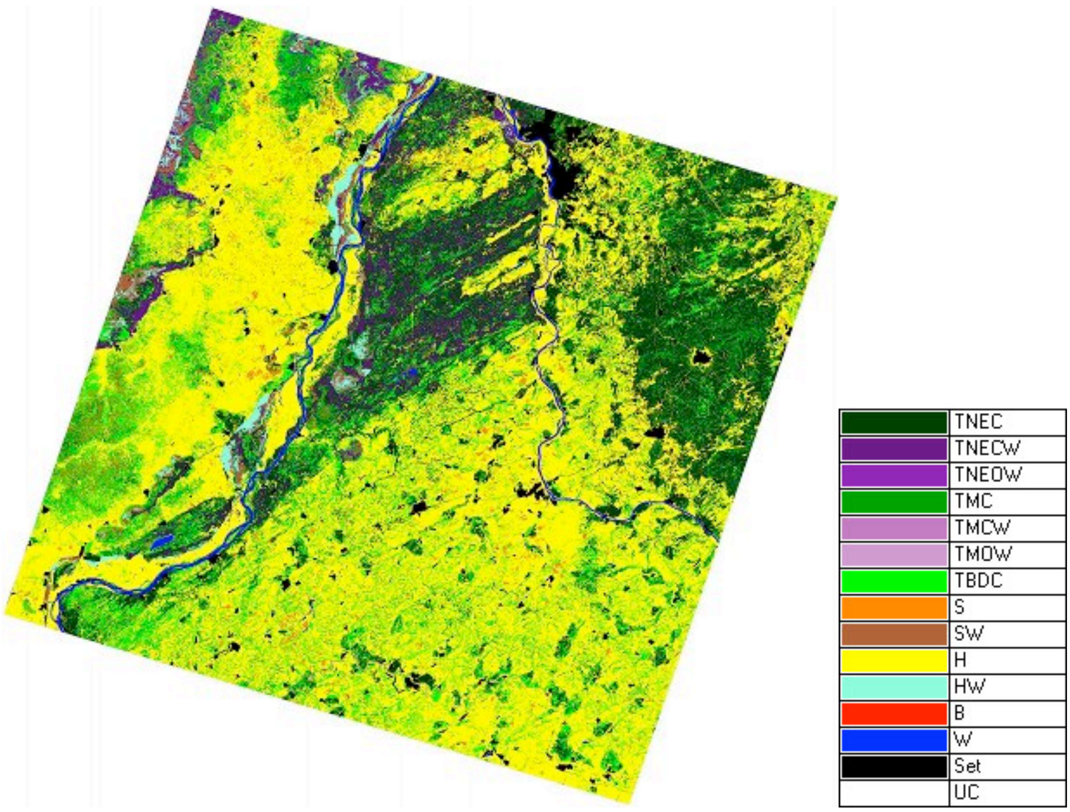


Figure 23 Classified image, Path 148 Row 21, test site "Tomsk"

3.2.2 Accuracy assessments

We have selected 414 and 277 accuracy assessment points for each scene. The results of accuracy assessment are presented in Table 6 and Table 7. The results show that the overall accuracy of land cover classification is 84% and 74 % respectively for the two scenes.

Table 6: Accuracy assessment for test site "Bakchar"

Classified Data	TNEC	TNECW	TNEOW	TMC	TMCW	TMOW	TBDC	S	SW	H	HW	W	B	Set	Totals
TNEC	**27**	1	0	2	0	0	0	0	0	0	0	0	0	0	**30**
TNECW	1	**24**	2	0	3	2	0	0	0	0	0	0	0	0	**32**
TNEOW	0	3	**20**	0	0	0	0	0	0	0	0	0	0	0	**23**
TMC	0	2	0	**31**	6	3	0	1	0	0	0	0	0	0	**43**
TMCW	0	2	0	0	**22**	6	0	0	0	0	2	0	0	0	**32**
TMOW	0	3	1	0	1	**21**	0	0	0	0	0	0	0	0	**26**
TBDC	0	0	0	1	0	0	**34**	2	0	0	0	0	0	0	**37**
S	0	0	0	0	0	0	2	**24**	0	1	0	0	0	0	**27**
SW	0	0	4	1	0	0	0	0	**21**	0	2	0	0	0	**28**
H	0	0	0	1	0	0	0	2	0	**30**	0	0	1	0	**34**
HW	0	0	0	0	0	0	0	1	7	0	**22**	0	0	0	**30**
W	0	0	0	0	0	0	0	0	0	0	0	**24**	0	0	**24**
B	0	0	0	0	0	0	0	0	0	0	0	0	**32**	0	**32**
Set	0	0	0	0	0	0	0	0	0	0	0	0	0	**16**	**16**
Total	**28**	**35**	**27**	**36**	**32**	**32**	**36**	**30**	**28**	**31**	**26**	**24**	**33**	**16**	**414**
Correct	**27**	**24**	**20**	**31**	**22**	**21**	**34**	**24**	**21**	**30**	**22**	**24**	**32**	**16**	**348**
Accuracy	96.4	68.6	74.1	86.1	68.8	65.6	94.4	80	75	96.8	84.6	100	97.0	100	**84.1**

Table 7: Accuracy assessment for test site "Tomsk"

Classified Data	TNEC	TNECW	TMC	TBDC	S	SW	H	HW	W	B	Set	Total
TNEC	**19**	4	7	4	1	2	0	0	0	0	0	**37**
TNECW	1	**17**	2	0	1	0	0	1	0	1	0	**23**
TMC	9	0	**12**	2	1	2	0	1	0	0	0	**27**
TBDC	0	0	3	**15**	3	0	1	0	0	0	0	**22**
S	0	0	2	0	**12**	0	0	1	0	1	0	**16**
SW	0	0	0	0	0	**13**	0	2	0	0	0	**15**
H	0	0	0	4	1	0	**49**	1	1	4	4	**64**
HW	0	1	0	0	0	1	0	**12**	0	2	0	**16**
W	0	0	0	0	0	0	0	0	**19**	2	0	**21**
B	0	0	0	0	0	0	0	0	0	**16**	0	**16**
S	0	0	0	0	0	0	0	0	0	0	**20**	**20**
Total	**29**	**22**	**26**	**25**	**19**	**18**	**50**	**18**	**20**	**26**	**24**	**277**
Correct	**19**	**17**	**12**	**15**	**12**	**13**	**49**	**12**	**19**	**16**	**20**	**204**
Accuracy	66.5	77.3	46.2	60	63.2	72.2	98	67.7	95	61.5	83.3	**74.6**

Class distribution

Table 8 and Figure 24 show distribution of land cover classes at the studied test sites. The main part of the test site "Bakchar" is occupied by tree dominated classes (66%). Wetlands occupy about 43% of the area. Part of herbaceous vegetation is rather low (9%). The test site "Tomsk" has completely different structure of classes. More than one-half of the area (52%) is covered by cultivated lands with herbaceous vegetation. Forests cover only 42% of the area. Wetlands (9%) exist in the Ob'-Tom interfluve and left bank of the Ob' river. Wetlands are the specific landscape type. It is strongly differs from the other types by the structure of vegetation and ecosystem functioning.

Table 8: Distribution of land-cover classes

	Tomsk		**Bakchar**	
	area, ha	**area, %**	**area, ha**	**area, %**
TNEC	500711	15.6	251358	7.8
TNECW	103818	3.2	184654	5.7
TNEOW			326156	10.1

TMC	315840	9.8	685926	21.3
TMCW			75484	2.3
TMOW			148080	4.6
TBDC	428682	13.3	441090	13.7
S	56562	1.8	151382	4.7
SW	31721	1.0	370784	11.5
H	1629569	50.6	301474	9.4
HW	31650	1.0	243496	7.6
B	1662	0.1	11629	0.4
W	40951	1.3	19277	0.6
Set	76760	2.4	4736	0.1
Total	3217925	100.0	3215527	100.0

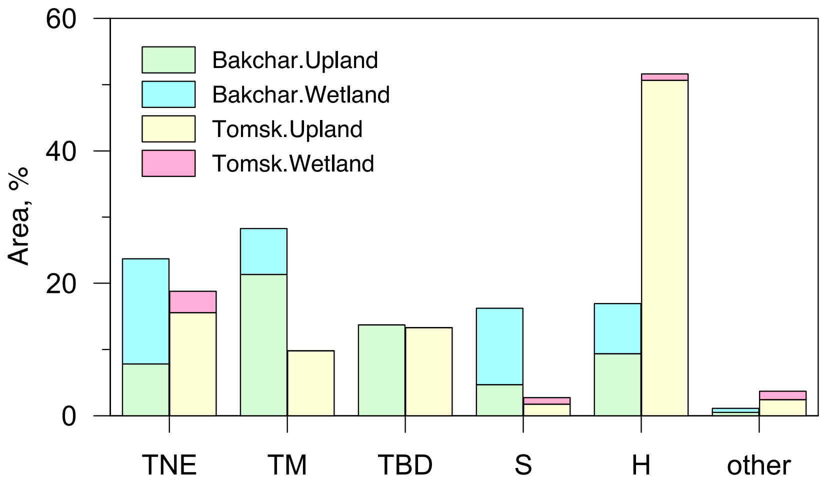


Figure 24 Distribution of land-cover classes

3.2.3 Land Cover Change

Two additional images 1990 and 1999 were processed as described above. Cloud masks were constructed for each image. Tasseled caps processing was performed. Disturbance index (DI) was calculated for each tasseled cap image normalized, as described in [Healey et.al., 2005] for forested areas. All disturbance index images were stacked into a one DI image (see Figure 25-26).

Unsupervised classification of the DI image was made and 32 classes were revealed. 350 points were randomly generated for accuracy assessment analysis: 200 points of undisturbed classes and 75 points for each class related to disturbed at different time periods. The visual comparison of different time images was done for detection of changes at all reference points. The areas with significant changes in forest cover are clearly identified by changes in color, texture and sharp boundaries of cut sites. Accuracy assessments analysis has shown that the overall accuracy of disturbed forest determination is about 75%.

The image with forest areas eliminated in 1990-1999 and 1999-2007 is shown at Figure 27 and 28. The area of forests disturbed in 1990-1999 is equal to 12711 ha at “Bakchar” test site and 3213 ha at “Tomsk” test site. The total forest area has reduced by 8148 ha in 1999-2007.

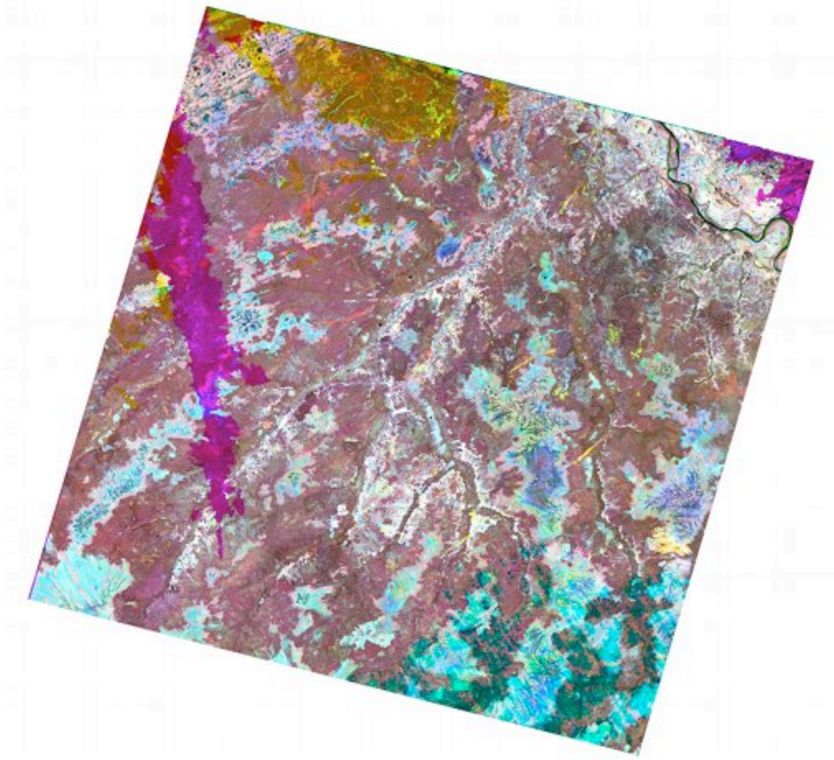


Figure 25 RGB image of disturbance index map, Path 150 Row 20, test site "Bakchar" Disturbance index: red channel – 2007, green channel – 1999, blue channel – 1990.

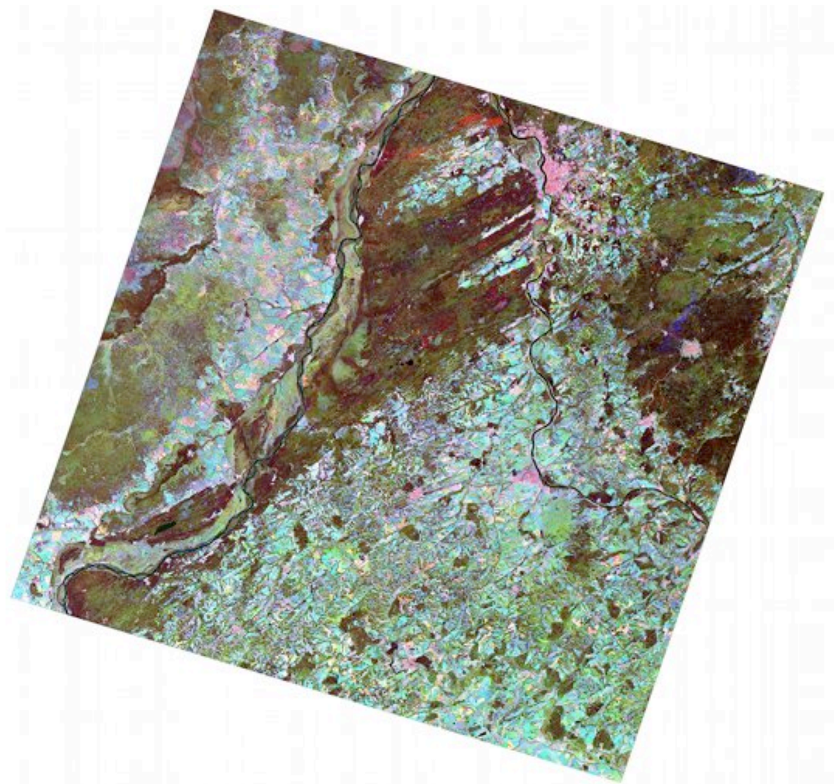


Figure 26 RGB image of disturbance index map, Path 148 Row 21, test site "Tomsk" Disturbance index: red channel – 2007, green channel – 1999, blue channel – 1990.

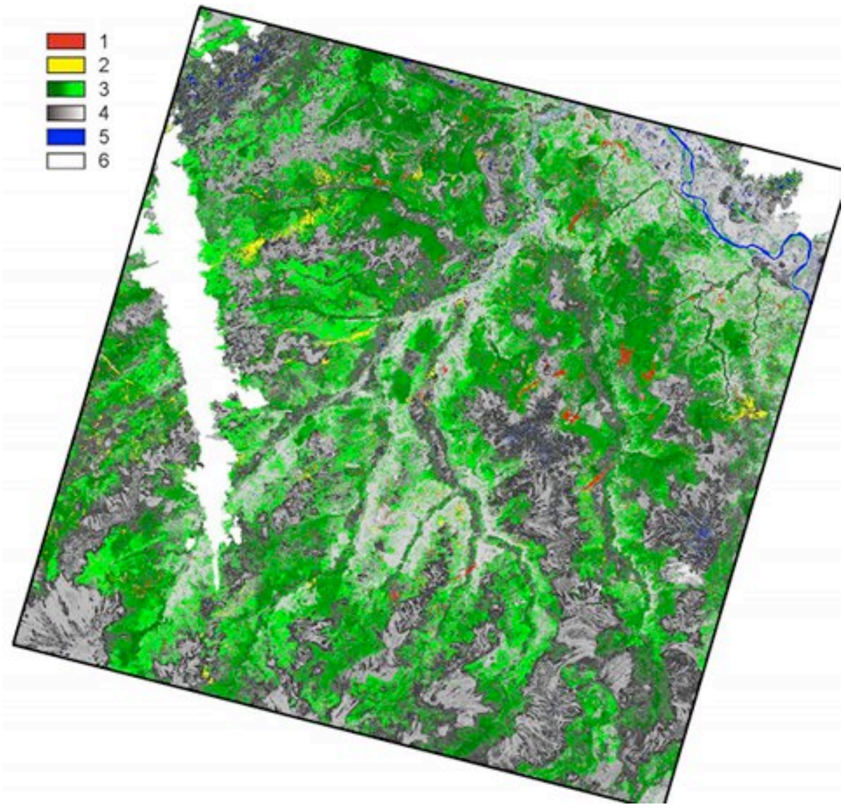


Figure 27 Forest disturbance map. Here: 1 – disturbed in 1990-1999, 2 – disturbed in 1999-2007, 3 – undisturbed forests, 4 – non-forested areas, 5 – water, 6 - clouds

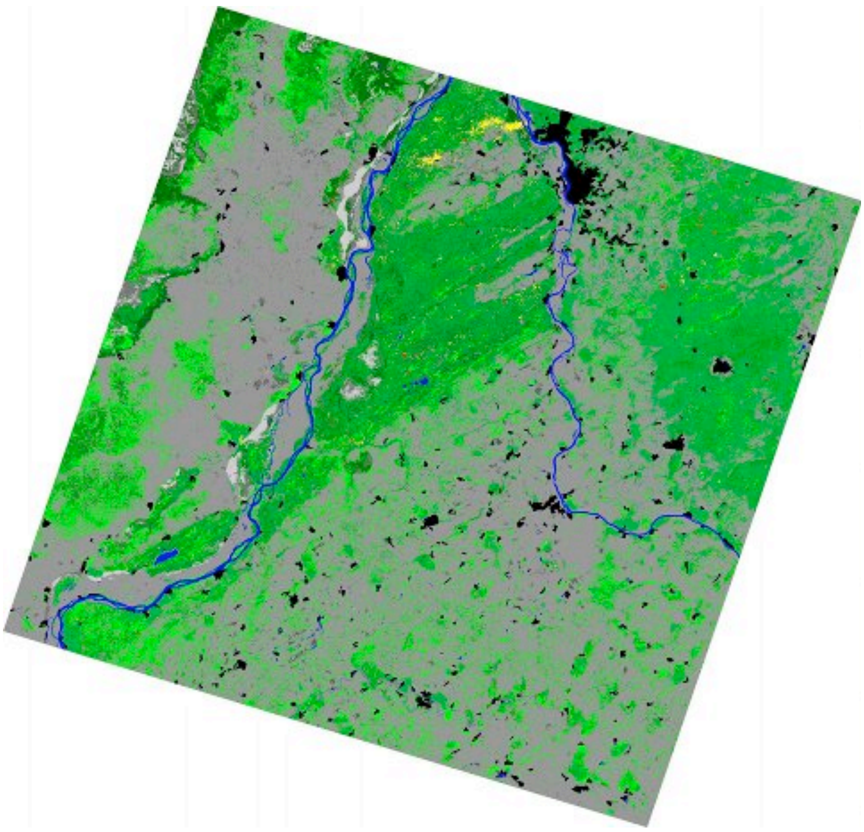


Figure 28 Forest disturbance map. Here: 1 – disturbed in 1990-1999, 2 – disturbed in 1999-2007, 3 – undisturbed forests, 4 – non-forested areas, 5 – water, 6 - clouds

3.2.4 Analysis

Decrease of forest area in 1990-1999 at both test sites occurs primary due to intense forest cutting for timber industry and local use (for house, road, etc. construction). Forest cuttings areas have specific shape and can be recognized manually at the space images. We have separated all disturbed forest areas into areas clearly eliminated by human activity and areas damaged by all other reasons. We have found that for both test sites and both studied time intervals the areas of forest decreased due to human activity do not change significantly. Cut forest area at the test site “Bakchar” is a bit higher than at the test site “Tomsk” due to large total forest area at the test site “Bakchar”. Some increase of forest cutting occurs in 1999-2007 at the test site “Tomsk” due to intensification of economical processes. For this time interval we observe some small new cuts for the local purposes appeared in the basic dark coniferous forests near villages and in old cuttings where roads exist.

The primary natural reason of forest damage at the studied test sites is tree falling/breaking at strong winds (local hurricanes). A strong wind have damaged forests between 1990 and 1999 in stripes up to 15x1 km oriented from south-west to north-east in the prevailing wind direction. Such stripes are clearly detected at space images at the test site “Bakchar”. Strong winds were registered in Tomsk region at begin of the century (in 2003, 2005, and 2007). They made different wind throw areas. The strongest hurricane has destroyed and damaged forest in area 5 by 50 km.

Some invasion of young tree in to abandoned agricultural lands also can be found at comparison of 1999 and 2007 images. After 1999 many agricultural lands stopped to plug, transformed to unmanaged meadows (grassland) and now occupying by young birch. Small burned areas are exists on the studied territory primary at drainage peatlands but fires does not affect forests significantly. The high sustainability of the studied region to anthropogenic and natural impact are explained by high overall moisture of the territory (about a half of the area occupied by mires), weak population density, the prevailing of broadleaved forests with rich vegetation cover.

	Disturbed forest area, ha	
Period	Site 1 - Bakchar	Site2 -Tomsk
1990 - 1999	12711	3213
1999 - 2007	8148	8149

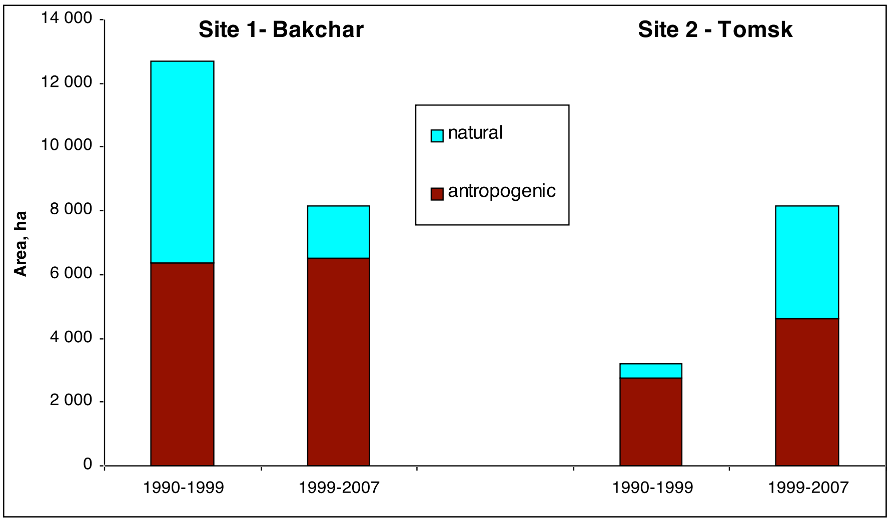


Figure 29 Decrease of forest area stipulated by anthropogenic activity and natural processes

4.0 Conclusions

The report aims to contribute to the decision makers in government organizations both in Russia and Mongolia, and international research groups for the developing land cover/change mapping. The objective also directly addresses the goals of the Northern Eurasia Regional Information Network (NERIN). The project provides datasets of ground data in association with Remote Sensing/GIS data for the analyses of land cover change in two areas in Western Siberia and two areas in Mongolia. Land cover classification and local data sampling results are combined: different vegetation zones in the region; identified areas affected by desertification pressures, such as land degradation linked to mining and pasture overgrazing, and by deforestation linked to timber cutting activities. Land cover change assessment found that changes were largely attributed to urban expansion and bare land. However, natural factors have also a great impact on land-cover in Western Siberia. The approach of the research combined thematic collection land-cover data as well as continuous topographic and multitemporal- multisensor-satelite data. The land-cover data collected from ground validation and land cover maps derived from satellite will be added to the GOFC-GOLD NERIN Regional Network Database to be shared with project members. Land degradation affected by climate change and human activity has become one of significant risk in the study area. One of the most prevalent human activity in the Mongolian study areas is animal husbandry, characterized be livestock grazing, mining and urban expansion. Timber cutting is a typical human activity in the Russian study areas. The produced land-cover maps contribute in managing to develop pastoral animal husbandry, agriculture, urban and regulation of timber cutting and mining activities.

5.0 Future Directions

This project focused only on four (though quite typical) regions in Western Siberia and Mongolia in the light of investigation of human impact on land-cover change. It also developed land-cover change and disturbance indices maps for the selected regions to assess. However, it is not enough to cover the whole Asia and obtain comprehensive results. Further research is needed to characterize land patterns and classify vegetation types remotely in Mongolia and Russia to understand more deeply interrelations between land-cover changes and socio-economical processes. Improved data collection, methodologies, and national collaboration are necessary to answer more complex questions. This could be achieved by establishing of a consolidated network of test sites and researchers, dedicated to monitoring land use and land cover change processes in Mongolia and Russia. These activities ensure obtaining new knowledge within APN Agenda and regional capacity building, outreach through the connections of collaborators to several regional networks, and development of methodologies for operational land-cover monitoring.

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Appendix 1: Conferences/Symposia/Workshops

1. Inception workshop

Organized by: SCERT, Tomsk, Russia.
Dates: June 30 – July 6, 2008
Agenda: According to the timeline the project started in July 2008 with the Initial Planning Meeting in Tomsk at SCERT/IMCES (within ENVIROMIS-2008 International conference). The three days Meeting gathered two of three key project's collaborators as well as young scientists from the Russian team. Two test sites in Siberia were selected for fieldwork: "Vasyugan'e" and "Tomsk". They are easily accessible for ground data collection, quite representative both by vegetation diversity and anthropogenic influence, and complement each other. Dr. Olga Krankina has visited them and later discussed two test sites in Mongolia with Dr. Tsolmon Renchin.
Participants: Dr. Igor Okladnikov, Dr. Olga Krankina, Prof. Evgeny Gordov, Prof. Anatoliy Dyukarev, Dr. Egor Dyukarev, Mr. Alex Titov

2. Final joint workshop

Organized by: SCERT, Tomsk, Russia.
Dates: July 5 – 10, 2010
Agenda: During the Joint Workshop conducted in Tomsk in the framework of International Conference ENVIROMIS-2010 project partners gathered to discuss, summarize and compare their findings, both scientific and applied. This Conference gathered many specialists and young scientists from different areas as well as local authorities and representatives of Central Asia research community thus working as a dissemination tool giving regional research community and decision makers a vision of remote sensing methods potential and indicating major spots of environment degradation. The partners presented results obtained and discussed plans of possible future cooperation.
Participants: Dr. Igor Okladnikov, Dr. Tsolmon Renchin, Prof. Evgeny Gordov, Prof. Anatoliy Dyukarev, Dr. Egor Dyukarev, Mr. Alex Titov, Ms. Tungalag Amar

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Appendix 2: Funding sources outside the APN

(1) SCERT and IMCES SB RAS in-kind support (soft, premisies, expertise, data)

(2) IT-infrastructure used in process of the project carrying out was developed under RFBR and SB RAS grants support.

(3) Used for analysis of Siberia sites dynamics satellite images were provided by USGS EROS data center in course of START project.

Appendix 3: List of Young Scientists

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Appendix 4: Glossary of Terms

AARS	Asian Association on Remote Sensing
CEReS	Center for Environmental Remote sensing
EVI	Enhanced Vegetation Index
GIS	Geographical Information System
GOFC-GOLD	Global Observation of Forest and Land Cover Dynamics
ICWG VII/IV	Inter-Commission Working group
IGBP	International Geosphere-Biosphere Programme
ISPRS	International Society for Photogrammetry and Remote Sensing
ITC	International Institute for Geo-Information Science and Earth Observation
LCS	Land Change Science
LCWG	The Land Cover Working Group
MODIS	Moderate Resolution Imaging Spectroradiometer
NEESPI	Northern Eurasian Earth Science Partnership Initiative
NERIN	Northern Eurasia Regional Information Network)
NUM	National University of Mongolia
VI	Vegetation Indices

Appendix 5: Land-cover photos

 Herbaceous closed	 Herbaceous open
 Reclaimed area	 Mining area (Bare)
 Cultivated land	 Shrubs

 Tree mixed forest	 Tree deciduous broadleaf forest
 Tree deciduous needleleaf forest	 Water

Appendix 6: NELDA project land-cover legend

Baseline Legend — ***Possible Additional Distinctions***

Tree Dominated

Needleleaved
- Evergreen
  - Closed[1]
  - Open[2]
- Deciduous
  - Closed
  - Open

Broadleaved
- Evergreen
  - Closed
  - Open
- Deciduous
  - Closed
  - Open

Mixed
- Closed
- Open

Possible additional distinctions:

Cover Detail
Mortality (yes/no, if yes what %)
Species
Wetland (yes/no)
Understory Characteristics (Shrubs or Herbaceous > 15%)
Managed Plantation (Tree Farm/Orchard)
Presence of Build up > 15% (yes/no)

Shrub Dominated

Broadleaved
- Closed
- Open

Needleleaved
- Closed
- Open

Closed

Mixed
- Open

Possible additional distinctions:

Cover Detail
Mortality (yes/no, if yes what %)
Species
Wetland (yes/no)
Leaf Longevity – Deciduous or Evergreen
Tundra (yes/no)
Trees < 15 % and >5% Present/not Present
Managed Plantations (Vineyard, for example)
Tree Regeneration (yes/no)
Presence of Build up > 15% (yes/no)

Baseline Legend — ***Possible Additional Distinctions***

Herbaceous Dominated
- Closed
- Open

Possible additional distinctions:

Species (grasses, lichens, mosses, etc)
Mortality (yes/no)
Wetland (yes/no)
Tundra (yes/no)
Pasture (yes/no)
Cultivated Lands
Trees or shrubs < 15 % and >5% Present/not Present
Presence of Build up > 15% (yes/no)

Bare Land and Sparse Vegetation

Possible additional distinctions:

Bare (Vegetation < 5%)
Sparse Vegetated (Vegetation < 15% and > 5%)
Presence of Build up > 15% (yes/no)
Cultivated Lands
Wetlands (yes/no)

Permanent Snow and Ice

Water

Appendix 7: Conversion to reflectance and COST atmospheric correction

Radiance conversion:

TM Radiance:
Lsat = bias + gain * DN
ETM+ Radiance:
$Lsat = ((LMAX\lambda - LMIN\lambda)/(QCALMAX-QCALMIN)) * (QCAL-QCALMIN) + LMIN\lambda$

Input data are contained in the metadata files of the Landsat TM (gain and bias for each band) or ETM+ (LMAXλ, LMINλ, QCALMAX,QCALMIN) images

Reflectance conversion without atmospheric correction:

$\rho = (PI * Lsat\lambda * d2)/(ESUN\lambda * \cos\theta)$
ρ – planetary reflectance
Lsatλ – radiance at sensor
d – Earth-Sun distance in astronomical units
θ – solar zenith angle (90 – solar elevation)
ESUNλ mean (by band) solar exoatmospheric irradiance

Reflectance conversion + atmospheric correction (COST):

$$REF = \frac{(PI*(Lsat-Lhaze))}{(TAUv*(Eo*Cos(TZ)*TAUz+Edown))}$$

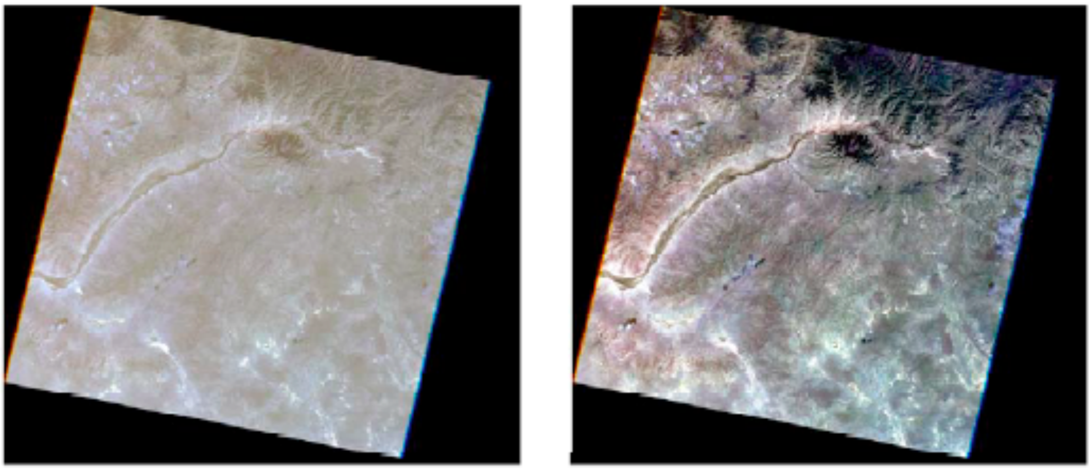
Lhaze: upwelling spectral radiance (path radiance), value derived from image using dark-object criteria; Calculated by using the dark object criteria (lowest value at the base of the slope of the histogram from either the blue or green band)
TAUv: atmospheric transmittance along the path from ground to sensor, assumed to be 1 because of nadir look angle

- Eo: solar spectral irradiance
- TZ: solar zenith angle, ThetaZ

TAUz: atmospheric transmittance along the path from the sun to the ground surface, =1-TZ2/2!+TZ4/4!-TZ6/6!
Edown: downwelling spectral irradiance at the atmosphere (Chavez, P.S. Jr (1996). Image-based atmospheric corrections – revisited and improved. *Photogrammetric Engineering and Remote Sensing 62, 1025-1036.*)

1. Calculate radiance (Lsat)
2. d = 1 + 0.0167 * sin[2* PI * (JD – 93.5) / 365]
3. Lλ1% = (0.01 * d2 * cos2θ) / (PI * ESUNλ)
4. Lλhaze = Lλmin - Lλ1%
5. ρ = (PI * d2 * (Lsat - Lλhaze)) / (ESUNλ * cos2θ)

where JD is the Julian Date (or day of the year , ranges 1- 365),
θ is the solar zenith angle (calculated as 90 – solar elevation angle)
ESUN – incoming solar radiation by wavelength



Atmospheric correction of the study area (Path 131 Row 27)

Appendix 8: Special web site for dissemination or project's results.

In order to disseminate project results a special web site was deployed on a dedicated web-server accompanied by high-performance storage system for storing Landsat imagery. The web site can be found at URL: http://apn.scert.ru (Figure 1).

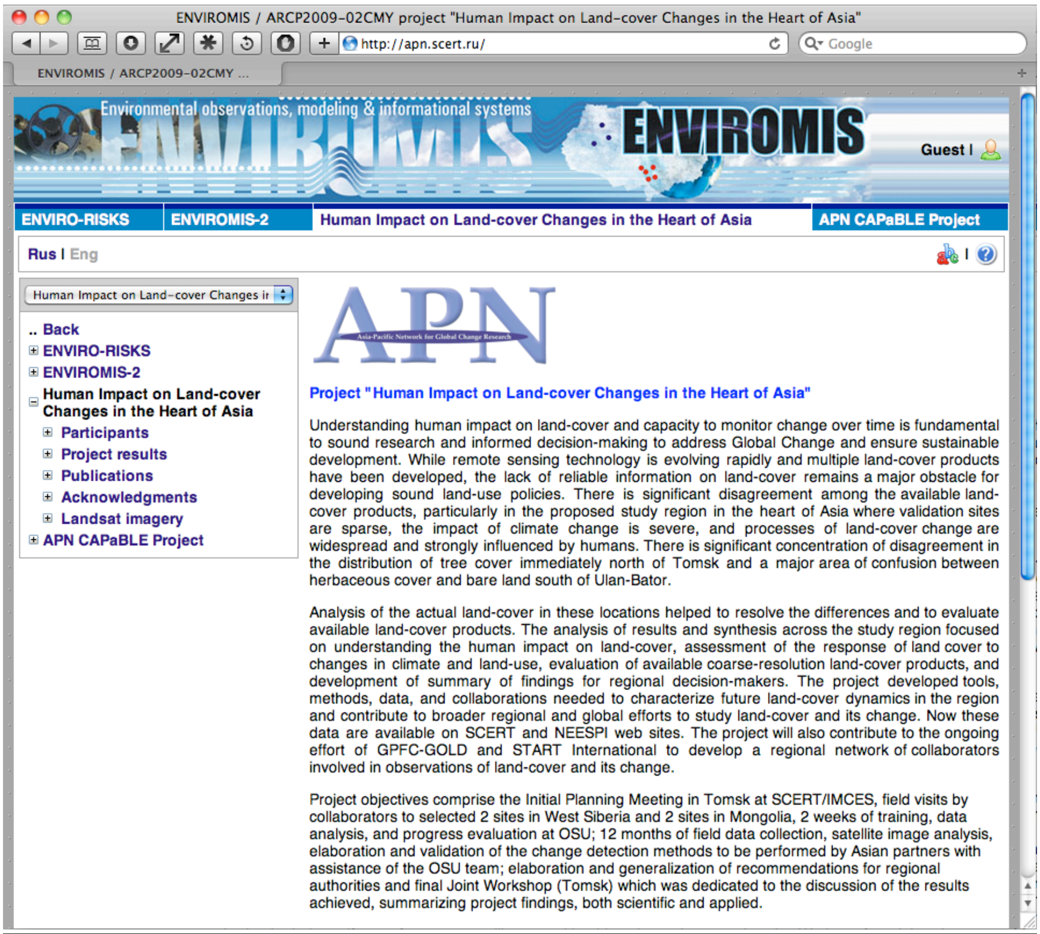


Figure 1 Project's web site

This site allows a wide scientific and social community to obtain necessary information about the project, to get results and to download Landsat images used during the project execution. Landsat, GLS and MODIS data in total amount of more than 3 Tb are stored on a dedicated high-performance storage system (see Figure 2) and can be accessed through a special web software GLOVIS provided by USGS EROS Data Center (Figure 3).

Figure 2 Dedicated web-server and storage system

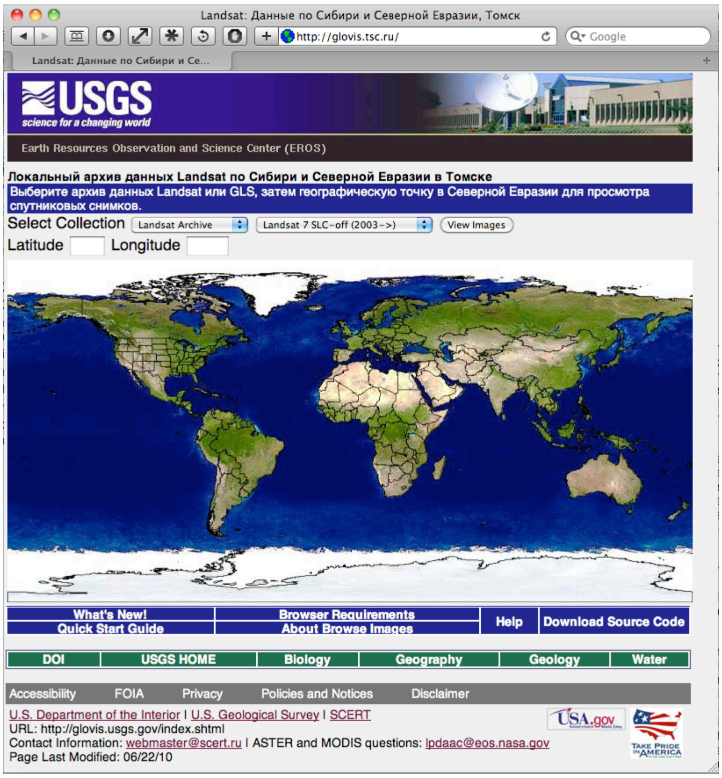


Figure 3 Web site for accessing Landsat imagery