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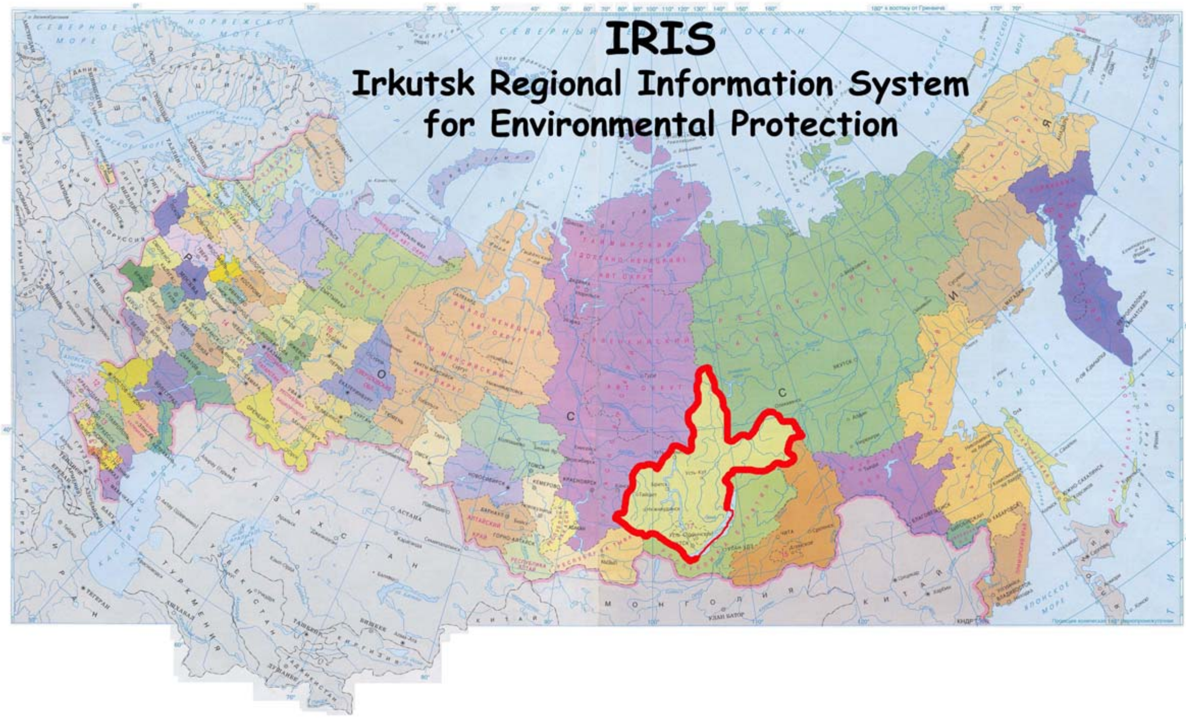

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Dissemination Level		
PU	Public	PU
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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List of Abbreviations:

AP	Alternating Polarisations
APR	Annual Progress Report
ARIMA	AutoRegressive Integrated Moving Average
ASAR	Advanced SAR
CESBIO	Centre d'Etudes Spatiales de la BIOsphère
CMG	Climate Modelling Grid
DB	Database
DEM	Digital Elevation Model
DMSP	Defense Meteorological Satellites Program
DVD	Digital Versatile Disc
EC	European Commission
ENVI	The Environment for Visualizing Images
ENVISAT	Environmental Satellite
EO	Earth Observation
ESA	European Space Agency
ETM	Enhanced Thematic Mapper
FSU	Friedrich-Schiller-University
FTP	File Transfer Protocol
GAMMA	Gamma Remote Sensing
GEO	Group on Earth Observations
GeoTIFF	Geo Tagged Image File Format
GHG	Greenhouse Gases
GIS	Geographic Information System
GMES	Global Monitoring of Environment and Security
GOFC	Global Observation of Forest Cover
GOLD	Global Observation of Land Dynamics
GPP	Gross Primary Production
GRP	Gross Regional Product
GSE	GMES Service Element
GTOPO30	Global Topography 30 (DEM with 30 arc-secs spacing from USGS)
HH, HV	Horizontal Horizontal, Horizontal Vertical (polarisation)
IDL	Interactive Data Language
IGBP	International Geosphere-Biosphere Programme
IIASA	International Institute for Applied Systems Analysis
IRIS	Irkutsk Regional Information System for environmental protection
ISC	Irkutsk Science Center
LIC	Lumber Industry Complex
LPDAAC	Land Processes Data Distributed Active Archive Centre
LST	Land Surface Temperature
MODIS	MODerate-resolution Imaging Spectroradiometer
MOD11C3	Land Surface Temperature/Emissivity Monthly L3 Global 0.05Deg CMG
MOD12C1	Land Cover Type Yearly L3 Global 0.05Deg CMG
MOD17A3	Gross Primary Productivity Yearly L4 Global 1km
MOD44B	Vegetation Continuous Fields Yearly L3 Global 500m
NASA	National Aeronautics and Space Adminstration
NDVI	Normalised Difference Vegetation Index
NDWI	Normalised Difference Water Index
NEESPI	Northern Eurasia Earth Science Partnership Initiative
NIERSC	Nansen International Environmental and Remote Sensing Center
NIR	Near infrared
NPP	Net Primary Production
NTsOMZ	Research Center for Earth Operative Monitoring, now Federal State Unitare Enterprise "Russian Institute of Space Device Engineering” (FSUE "RISDE")
OGC	Open Geospatial Consortium
OMI	Ozone Monitoring Instrument

RS	Remote Sensing
SAR	Synthetic Aperture Radar
SeaWiFS	Sea Wind Fields Satellite
SIBERIA-II	Multi-Sensor Concepts for Greenhouse Gas Accounting of Northern Eurasia
SIB-ESSC	Siberian Earth System Science Cluster
SibFORD	Earth Observation for Assessment of Forest Disturbances induced Carbon Emissions in Central Siberia
SPOT VGT	SPOT Vegetation satellite
SRTM	Shuttle Radar Topography Mission
S10	10 day composite of surface reflectance compensated for atmospheric effects
TOMS	Total Ozone Mapping Spectrometer
UNFCC	United Nations Framework Convention on Climate Change
VCF	Vegetation Continuous Fields
WP	Work Package

Project Execution

1. Project Objectives

The overall project goal is the development of the Irkutsk Regional Information System for Environmental Protection - 'IRIS', which assesses the current status and dynamics of the Irkutsk region's forestry environment influenced by man-made changes and anthropogenic impact arising from pollution sources and other negative anthropogenic drivers located in the region and in adjacent areas. The project investigates the responsiveness and vulnerability of forestry environment within the region under different scenarios of industrial development and nature-preserving measures.

The summarized scientific and technological objectives of IRIS are

1. to efficiently share Earth Observation (EO) data and domain-specific environmental and economic information within the Earth science community and the regional governance bodies,
2. to identify environmental impact from man-made changes(industry and tourism),
3. to assess the impact from man-made changes to the forest environment,
4. to exploit IRIS for simplified risk scenarios, and
5. to prepare (research) initiatives for the practical use of IRIS by the regional governance and nature protection services.

The fifth objective refers to integrated environmental management designs mirroring the complexity of the natural resource to be managed and the difficulty to predict the driving forces influencing them. Following the principle of interoperability, IRIS is planned to become part of a distributed network of similar systems where not only data is being distributed and shared, but also applications are being offered and used throughout the network. IRIS is thus using standards published by the World Wide Web Consortium (W3C®), the Open Geospatial Consortium (OGC™) or the International Organization for Standardization (ISO). On the long-term, decision makers and Earth science communities will highly profit with applications where domain-specific knowledge and information has been rigorously categorized.

In March 2009, a public meeting will be held in Irkutsk for local authorities, nature-protection services and other organizations potentially interested in the IRIS Environmental Information System since the major objective and overall goal of this project, the foundation for implementation of a powerful tool for risk assessment and environmental protection, has been successfully concluded.

The project webpage is www.iris.uni-jena.de.

1.1. The Irkutsk Region

The Irkutsk region is rich: rich of natural resources and rich of historical human impact. The Irkutsk region is environmentally important due to its central, indicatory location in the Eurasian boreal zone with pronounced indicators of climate change. The Irkutsk region is politically important since its development represents the economic and sustainable growth in the vast rural territories of Siberia. The Irkutsk region needs an environmental protection system since

1. it encompasses more than 0,5 Mio square kilometres of high value forest,
2. it forms the Western boarder of the Earth's largest freshwater reserve Lake Baikal,
3. it is rich of mineral resources (gold, diamonds, graphite, gems) and gas,
4. its large areas are under intensive anthropogenic pressure which are substantially increasing,
5. it has a very diverse, touristically attractive landscape similar to alpine environments, and, last but not least,
6. its ecosystem vulnerability is very high and recovery rate very slow due to the extreme continental climate.

Located in the heart of Siberia, Irkutsk has a long history of exploration that started three centuries ago with fur merchandising. Strategically located on the route to the Russian Far East as well as to Mongolia and China, two major railroads were constructed in the last century that crosses the Irkutsk region: the Transsiberian in the South and the Baikal-Amur-Magistral (BAM) in the North. The many years of human impact culminated in heavy industrial development during Soviet times – causing electricity demands which are supplied by one of the largest hydro-power plants of the country: the Angara dam near the city of Bratsk. Recently, i.e. for the last five years, national and international tourism is strongly increasing due to Irkutsk's airport convenient location about 50 km from Lake Baikal, the Pearl of Russia and Sacred Sea of the locals. Atmospheric pollution by large industrial zones, contamination by untreated waste water effluents and higher run-off loads of nutrients caused by intensified land use and timber logging are pointed out as today's most apparent risks for this UNESCO World Heritage Site. Very recently, in 2003, plans were published to build a gas pipeline through the Irkutsk region and along the shore of Baikal to explore resources in the Russian Far East and for selling gas to China and other Asian countries.

The Russian Federation possesses the largest forestry resources in the world, containing about 22% of the world's forest. One of the most wooded regions of Russian Federation is the Irkutsk Province compromising 4.5% of Russian territory. The Irkutsk Province is dominated by typical taiga forest. 81% of the territory is covered by forest, which corresponds to an area of 66.8 million hectares or 9.9% of Russian forested areas. The annual gain is estimated to 80 million m3 timber. The proportion of wood processing and pulp and paper industries is about 20% of the industrial production of the region. Thus, the resource potential determines the leading role of the forest complex in industry structure alongside with fuel and energy, chemical, petrochemical and the nonferrous metallurgy complex. Lumber industry enterprises thereby are the major ones in many administrative districts.

The controlling of forest resources and their active involvement into the economic cycle do not provide the region with proper sustainability and qualitatively high economic growth. Irkutsk Province, as a large typical resource-rich Russian administrative region, suffers much from this resource exploration and material inputs and accordingly reaches only low levels of added value and low labour productivity in comparison to more sustainably oriented countries. Moreover, the big number of industrial facilities in the territory has produced serious ecological consequences: high and very high levels of pollution of the natural environments are verifiable in 42 % of Irkutsk Provinces and frequently exceed the average of Russian pollution indicators. Under these conditions, the formation of a sustainable economic growth is not ensured and economic, ecologic and social risks can arise. Considering the above mentioned remarks, the issue of an adequate measurement system about the region's economical functioning by taking into account a proven number of factors describing the public welfare is obvious and needs implementation. To develop such an environmental information system towards sustainable land use management for the Irkutsk Province is the task of the IRIS project.

2. The Consortium

The consortium consists of five multi-disciplinary partners from Germany, Austria and Russia: one university (FSU), two international research centres (IIASA, NIERSC), one institute of the Russian Space Agency (NTSOMZ), and one regional research centre (ISC). IRIS is coordinated by the Department for Earth Observation of the *Friedrich-Schiller-University Jena (FSU)*, Germany. The Department has established well-known experience over many years since the 4th Framework Programme through coordination of large and complex EC projects (SIBERIA, SIBERIA-II, GMES RUSSIA), ESA projects (DRAGON, DRAGON-II, ESA Land Cover Project Office, RadarCover, BIOMASAR) and EO missions (involvement in the Shuttle Radar Topography Mission (SRTM) and airborne campaigns, e.g. TerraDew and AGRISAR). Website: www.eo.uni-jena.de.

Founded in 1972, the *International Institute for Applied Systems Analysis (IIASA)* in Laxenburg, Austria, is a non-governmental research organisation located near Vienna, Austria. The institute conducts inter-disciplinary scientific studies on environmental, economic, technological and social issues in the context of human dimensions of global change. The work is based on original state-of-the-art methodology and analytical approaches and links a variety of natural and social science disciplines. IIASA is independent and can provide apolitical and unbiased perspectives. For the last 15 years, IIASA's Forestry Project (FOR), in cooperation with the Russian Academy of Sciences, several Ministries of the Russian Federal Government and European institutions, has been involved in a number of large projects devoted to the Russian forest sector, including the generation of the Integrated Land Information System at the national level, application of multi-sensor remote sensing concept for forest monitoring and terrestrial biota full greenhouse gas account. The FOR has a well developed Russian collaborative network (of about 25 institutions) in different regions of the country. Website: www.iiasa.ac.at/Research/FOR/index.html?sb=1.

The participation of Russian institutions was critical for the successful implementation of the IRIS Project and is hence in conformity with the interest of the Community policies. The Russian participants are well recognized in their fields as top-level specialists. Their institutions add substantial value to the implementation of the EC´s INCO programme and have been essential for achieving the objectives of the project.

The *Nansen International Environmental and Remote Sensing Centre in St.Petersburg, Russia (NIERSC)* was founded in 1992 as a non-profit environmental and climate change research centre. Its activity is focused on northern high latitude environment and climate change research. One of the main directions of NIERSC activities is the development of techniques and algorithms for studying and monitoring boreal forests making combined use of different remote sensing and field observation data. In this respect NIERSC staff has expertise in application of satellite data for boreal forests monitoring and in the development of geographical information systems, databases for remote sensing, and in-situ data acquisition and analysis. In the IRIS project, NIERSC also performed a coordination function with regard to the Russian partners. Website: www.niersc.spb.ru.

The: *Research Centre for Operational Space Monitoring of the Russian Space Agency (NTSOMZ)* in Moscow, Russia, is a leading organisation of Roskosmos in acquiring, processing, archiving and promoting remote sensing data and using it for environmental monitoring. The scientific research fields encompass: Research & Development of air-space techniques and facilities for EO, creation and maintenance of the Russian satellite data archives and catalogues, Research & Development of inspection methods and monitoring of spacecraft instrumental payload information and data quality, advancement and upgrading of on-ground facilities, environmental stress monitoring, vegetation monitoring, ecological monitoring, ocean research. Website: eng.ntsomz.ru.

The *Irkutsk Science Centre (ISC)* in Irkutsk, Russia, is subordinated to the Presidium of the Siberian Branch of Russian Academy of Sciences (SB RAS) and is a prominent scientific foundation. The Department of Regional Economic and Social Problems participated in the IRIS project. The scientific directions and fields of expertise of this department are regional socio-economic policy, economic federalism, and territorial systems stability. The Department investigates the mechanisms of regional development and the linkages of the system "Economy and Environment". Currently, the Department is working on the creation of a regional branch model to analyse and forecast strategies for local regional management. Other projects include the methodological propositions of economic zoning, formation of Territorial Production Complexes, complex development for the Angara-Yennisey region, and the economical development of the Baikal-Amur Railway (BAM) zone based on mathematical modelling. Upon the analysis of institutional changes of the economy in transition, the Department improved directions of the Irkutsk region's production structure and foreign economic activity influence on the region's socio-economic development. International contacts related to regional research exist to Birmingham and Bonn Universities. The particular value of this partner to the IRIS project is not only due to the participation of regional scientists, but also to the fact that the Department leader, Dr. Dumova, is simultaneously a member of the regional administration. The latter was of extreme importance for the success of the proposed project tasks as it allowed the whole team access to the majority of the regional input geo data and to plan a regional meeting in March 2009 when the IRIS information system will be presented to stake holders from industry, government, scientific institutions and NGOs. Website: www.isc.irk.ru/Eng/oresp_e.htm.

The following Table 1 shows the consortium leads per Work Package. The even share of responsibilities was successfully implemented.

Table 1: Workplan List.

Work-Package	Workplan List	Lead contractor	Deliverable
WP 1000	Project coordination	**FSU**	D.1.1-D.1.5
WP 2000	Collection of additional in situ and remote sensing data for Irkutsk region for further update of IRIS GIS	**NTSOMZ**	D.2.1-D.2.4
WP 3000	Assessment of current and historical man-made changes arising from pollution sources and other anthropogenic drivers located in Irkutsk region	**ISC**	D.3.1-D.3.3
WP 4000	Update of existing GIS for Irkutsk region and transfer it into operative testing and trial exploitation	**IIASA**	D.4.1-D.4.3
WP 5000	Assessment of environmental risks for forestry and agriculture due to man-made changes, industrial, agricultural and tourism pollution	**ISC**	D.5.1-D.5.4
WP 6000	Creation of new research initiatives and prospective studies regarding the development of the sophisticated information system for Irkutsk region	**NIERSC**	D.6.1-D.6.3

3. Work Performance

3.1. State-of-the-Art

The evaluation of the influence of specific industrial branches onto the economic well-being of the society takes a centre stage by economists for more than a decade. Special attention is paid to the system problems, such as the reduction of negative impacts of specific productions and industries on the environment or the provision of ecologically sustainable or acceptable functioning of economic systems. There are a lot of disputes on how to better determine and compare levels of public welfare of various regions, areas, or countries. In 1946 and for the first time, it was offered by Hicks to solve this problem with the help of the net national product parameter. The researches in this direction were continued by the authors RM Sollow in 1956 or ML Weitzman in 1976. Criticism came up since the net national product does not take into account the negative aspects of the economy functioning from a society’s point of view. It was offered to correct the net national product indicator by values characterizing depletion of natural resources and environmental degradation. New approaches, such as the estimation of an environmentally-adjusted net domestic product were proposed by P. Bartelmus in 2001 dealing with the social costs of environmental impacts.

One of the major challenges for an integrative environmental development is the integrated management of natural resources and socio-economic developments in order to secure a sufficient availability of timber. Thus, for an integrated management methodical designs are necessary which refer to the complexity of the resources to be managed and the difficulty to monitor them. A recent, sophisticated approach is to understand landscapes consists in modelling their structures as a fuzzy system composed of complicated, dynamic, stochastic processes. This methodology supports specifically landscape-ecosystem based approaches in which ecosystems of different scales are regarded as primary units for quantification and modelling. Satellite-based Earth Observation (EO) platforms are herein the primary data source from which the above mentioned landscape patterns can be assessed.

Satellite images are one of the fundamental sources of information to study and monitor forest state and land cover. This technical and scientific field is called Earth Observation (EO). The multiband and hyperspectral images from the satellites Landsat TM/ETM, SPOT-4, SPOT-Vegetation, NOAA/AVHRR, TERRA/MODIS and TERRA/ASTER, as well as archived ERS-1/-2 SAR radar data and the new generation of ALOS/PALSAR and ENVISAT/ASAR data deliver a wealth of environmental information.

The application of EO images for ecological monitoring and identification of the impacts of pollution to forest vegetation, soils, surface water bodies etc. is constantly being developed during recent years to also evaluate the impact of emissions from different industrial enterprises on the environment. The information content of EO scenes is furthermore used as input parameters to energy-mass exchange models of the upper hydrodynamic zone of the Earth’s crust. In particular, space images allow carrying out an estimation of the boundary conditions of models using results of landscape classifications. EO data increasingly specify the definition of the following parameters in water-soil-vegetation models: infiltration recharge, evaporation from a surface of the soil, soil moisture and evapotranspiration.

The analysis of lineaments using EO images allows allocating sites of zones of high permeability, on which intensive infiltration recharge to the underground water occurs. Here, the probability of migration of pollution to deep underground water horizons is high.

In studies of the anthropogenic impact on the environment, an important aspect is the spatial and temporal variability of gaseous pollutants and aerosols in the atmosphere. The numerical simulation will allow to reduce the volume of costly and time consuming experimental studies as well as to assess the contribution of local and remote emission sources to the secondary pollution of the regional forestry and soil conditions. It is important here to conduct a risk assessment and determine the potential anthropogenic “signal” among a great variety of photochemical air pollutants and aerosol particles. It should be noted that combining the experiments with theoretical studies within the framework of prognostic simulations of various scenarios in the given region allows us both to reduce the overall costs and to validate the results for possible transfers.

Many experimental studies have been performed in the Irkutsk region (and in the Baikal region as a whole) both by Russian and foreign researchers aiming at studying the chemical and aerosol composition of the atmosphere. As a result, huge databases on different environmental aspects of the project area were collected. However, so far these measurement data have not been used in their full scale and there has been a lack in the efficiency of their use in modelling studies on the basis of complex three-dimensional numerical models accounting for both direct and feedback relationships. In particular, there have been no comprehensive investigations on the assessment of the pollution impact on local forestry and soil conditions as well as calculation of the characteristics of the environmental damage. Other different anthropogenic drivers may impact forests of the region in a negative way: development of infrastructure (pipelines, dams, and large artificial water reservoirs, catastrophic vegetation fires).

3.2. Methodological Approaches

The IRIS environmental information system builds on results of finalised Framework Programme 4 and 5 projects of the coordinator (SIBERIA, SIBERIA-II, GMES-RUSSIA) and adopts some of their findings to the specific needs of the involved governmental agency of the Irkutsk county. That implements that the scientific results from former EC-funded scientific co-operations are being collected and transformed to tools for regional management by the administration. Therefore, the first project year focused on the following two questions and two technical implementation considerations.

What is available from finished and ongoing projects?
IRIS is a follow-on activity to the SIBERIA-II project (www.siberia2.uni-jena.de). The SIBERIA-II products included regional maps of land cover, fire induced disturbances, phenology, snow depth, snow melt date, onset and duration of freeze and thaw, LAI and others. Most of these products are available for several years and cover the entire Irkutsk region. The GIS database already developed for the Irkutsk region by Partner 2, the Institute for Applied Systems Analysis **(**IIASA), together with a number of Russian institutions includes a number of layers (landscape, soil, vegetation, forests, utilities) which were effectively used for the anthropogenically-driven risk assessment in the IRIS regional information system. The GMES-RUSSIA (www.gmes-russia.uni-jena.de) project provided the necessary background material and know-how about the technical-scientific assessment of the Russian infrastructure, socio-economic aspects and institutional/organisational/policy issues. Four of the five IRIS partners collaborated in the GMES (Global Monitoring for Environment and Security) project which was dedicated to implement GMES topics in Russia. This was the first project to establish contact between this important European programme and the Russian federation. The relevant ongoing projects are SibFORD (www.sibford.uni-jena.de) and GSE Forest Monitoring 2 (www.gsefm2.uni-jena.de), both dealing with forest monitoring in central Siberia.

What is the natural and anthropogenic impact on the local environment?
The Irkutsk region is politically important since its development is representative for the economic and sustainable growth in the vast rural territories of Siberia. The many years of human impact culminated in heavy industrial development during Soviet times – causing electricity demands which are supplied by world's largest hydro-power plant system along the Angara River. Large areas are under intensive anthropogenic pressure. Atmospheric pollution from large industrial zones, contamination by untreated waste water effluents and higher run-off loads of nutrients caused by intensified land use and timber logging represent today's most apparent man-made environmental risks to the Irkutsk region's environment. Another development is the growing demand of wood products from China. The high value timber in the Irkutsk region is strongly affected by this development. Due to an additionally increasing number of forest fires in the last decade intensive large area changes of forest cover are being observed.

Satellite-based EO is crucial
Satellite-based Earth Observation (EO) platforms are the primary data source from which the above mentioned environmental impacts can be assessed in an independent and unbiased framework at multiple temporal and geometric scales. IRIS' strategy follows an approach that considers spatial, spectral and temporal resolution demands by combining a variety of EO products, specifically multi-band and multi-temporal images from SPOT-Vegetation, TERRA/MODIS, the Russian Monitor-E, Aura/OMI,

ALOS/PALSAR and ENVISAT/ASAR data deliver a wealth of environmental information. The derived EO products serve either as the core or additional information to create the multipurpose IRIS GIS.

Using web service technology

IRIS profits from recent technological developments like universal connectivity (internet), comprehensive analysis environments (GIS, Spatial Data Infrastructures), standards for data, metadata and web services (like OGC), or communication platforms for computer-supported cooperative work (Wikis). One of the essential components of IRIS is the implementation of an Open Source GIS system. Open Source technology is a growing field that encourages free sharing of software, codes and services. The goal of the Open Geospatial Consortium (OGC) is to promote standard open software interfaces. These interfaces enable geoprocessing so that different geospatial systems are able to communicate with each other. The IRIS spatial data base is implemented as a 3-tier architecture with a database server (PostgreSQL), an application server (Geoserver or Mapbender Client Suite) and an internet browser. PostgreSQL with the PostGIS extension follows the simple features of SQL specifications from the Open Geospatial Consortium. The application server acts as an OpenGIS-compliant web service layer on top of existing data sources. The main technical goal of IRIS is to bring GIS functionalities into web browsers by using recent developments of web map services (WMS), web feature services (WFS) or web coverage services (WCS).

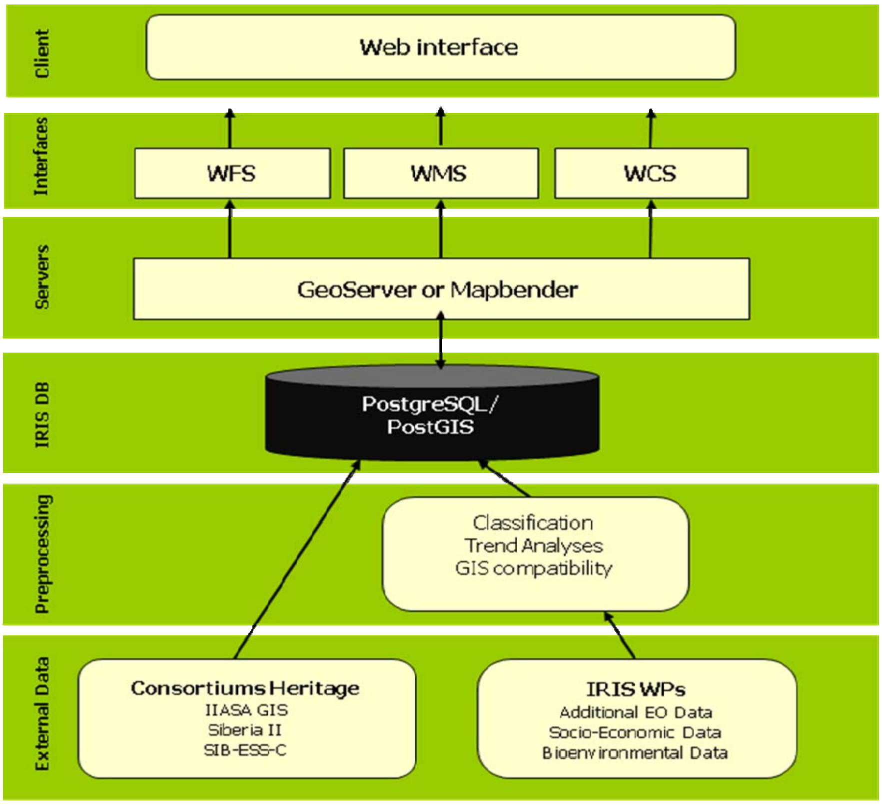


Figure 1: Concept of bringing data and GIS functionalities to the web. WFS: Web Feature Service, WMS: Web Map Service, WCS: Web Coverage Service.

The methodological approaches concern the following milestones:

- the technical description of the GIS structure and organization of interfaces,
- the creation of the initial prototype of the IRIS GIS and its interface as well as an internet based version,
- the synergistic assessment of human impact on the Irkutsk Province environment;
- the discussion on the relevance of forecasts of the economical development of the region under study.

The realisation and the results of these technical approaches is further discussed in the next chapter.

Main result of the coordination of the consortium activities was the successful cooperation between the Russian and European partners despite the very diverse disciplines and geographically very long distances. Delays in the delivery of project deliverables were a problem but did not jeopardize the project performance. All deliverables were eventually produced by all partners. The meeting schedule could be kept and participation in meetings of international programmes (such as NASA's NEESPI Initiative) was performed with great resonance to the project presentations. Partner 3, NIERSC, was also performing coordination functions with regard to the Russian participants which turned out to be a very efficient management tool.

As a result of the IRIS project, the preliminary work necessary for implementation of a powerful tool for risk assessment and environmental protection of the Irkutsk region (IRIS) is performed, the detailed plan of research initiatives aimed at future IRIS development (including technical requirements) is elaborated, and a proposal on a new initiative for IRIS full implementation is being prepared to the German Ministry of Science and Education (BMBF).

4. Results and Conclusions

4.1. Remote Sensing Information (WP 2000)

Through close links with other large projects of the coordinator, a very extensive set of diverse satellite data could be used for the IRIS Information System from different sensors over the last 20 years time period as well as newly obtained radar images (see Table 2). Also, additional information from the forest sector and corresponding attributes for newly inventoried forest enterprises and for transformed territories were integrated. Finally, IRIS contains data in three spatial scales: global, regional and local.

Table 2: List of data contained in the deliverables for WP2000.

Deliverable	Description/Purpose	Main EO source	Lead
D.2.2.NTL	area-wide lighting including gas flaring estimates (1992 - 2003) to point on increasing/ decreasing human activities	DMSP	FSU
D.2.2.AI	area-wide Aerosol Index (AI) (1980 - 2007); mapped to distinguish between human-induced or natural and local or regional sources of aerosol particles and the long-term impact on the Irkutsk region	TOMS/OMI	FSU
D.2.2.OZ	area-wide Ozone distribution (2004 - 2007); mapped to distinguish between human-induced or natural and local or regional sources of total ozone;	OMI	FSU
D.2.2.LST	area-wide Land Surface Temperature data to detect and to link significant temperature variations with the rate of growth of vegetation, to determine risk potentials for infrastructures such as slope failures in permafrost regions and to map temperatures as major stress factor on human health;	MODIS/Terra (MOD11C3)	FSU
D.2.2.LCC	area-wide Land Cover Classification product containing multiple classification schemes and percentage of each pixel covered by a given Land Cover type to map land cover properties during 12 months of input data (one year)	MODIS/Terra (MOD12C1)	FSU
D.2.2.SRTM	area-wide digital height data and 1st order derivates (slope, aspect) from GTOPO30 and SRTM to include into image processing and terrain analyses; SRTM Water Bodies	SRTM-3, GTOPO30,	FSU
D.2.3.VCF	area-wide Vegetation Continuous Fields product contains proportional estimates for vegetative cover types: woody vegetation, herbaceous vegetation, and bare ground;	MODIS/Terra	FSU
D.2.3.GPP	area-wide Gross Primary Productivity (GPP) and annual Net Primary Productivity (NPP), describing the rate at which light energy is converted to plant biomass	MODIS/Terra (MOD17A3)	FSU
D.2.3.VGT	area-wide seasonal NDVI mosaics (1998 - 2005) to point on photosynthetic trends under the influence of climate and human impact	SPOT-VGT	FSU
D.2.3.Fire	area-wide Forest Fire data (2000 - 2005) to link fire distribution with climate and human impact	MODIS/Terra	FSU
D.2.3.FAC	SAR imagery (2006) for selected areas to map clear cutting, burnt areas and re-forestation for an up-to-date forest area change map to point on the human impact on forests	ENVISAT-ASAR SAR	FSU
D.2.3.CCD	High-res data (2002 and 2006) for up-to-date information on clear cutting for selected areas	Resurs-DK	NTsOMZ
D.2.3.FAC2	Optical imagery (2006) for selected areas to map clear cutting, burnt areas and re-forestation for an up-to-date forest area change map to point on the human impact on forests	Monitor-E, Resurs-DK, Meteor-3M	NTsOMZ

4.1.1. Global Scale – Addressing Climate Change

The international dimension of the project implementation is strongly connected with problems of climate change. The Intergovernmental Panel on Climate Change has concluded that human activities in forests can have significant effects on the atmospheric concentration of carbon dioxide. IRIS aims to monitor parameters that are directly linked with this phenomenon. Two important aspects are the spatial and temporal variability of gaseous pollutants and aerosols in the atmosphere and land surface (canopy) temperature variations. IRIS is exploring data sets on a global scale due to the regions´ central, indicatory location in the Eurasian boreal zone. For the last centuries a strong Atlantic control has been shown to affect the timing of the ice break-up in Lake Baikal. This observation supports a strong teleconnection between the Central Asian and European weather systems that cause a well-defined atmospheric pattern in the region. These links to the global atmospheric system as well as the necessities of estimating the current carbon balance of Northern Eurasia make the region highly attractive to climate research on a global scale. Thus IRIS has implemented data sets with global coverage such as TOMS/OMI Aerosol Indices or MODIS 5-km Climate Modeling Grid (CMG) products (MOD11C3).

4.1.1.1. Aerosol Index, Ozone

TOMS/OMI data represent the primary long-term, continuous record of satellite-based observations available for use in monitoring global and regional trends in total ozone and aerosols over the past 25 years.
Aerosols occur either naturally, generated from dust storms (Fig. 3, left), volcanoes or forest fires (Fig. 2, right) or human-induced, such as by burning of fossils or land cover alteration. Exploring pollutant sources is thus an important task of the data analysis to better understand its impact on public health, climate and forests. IRIS uses data from Nimbus-7, Earth Probe and Aura satellites. Their instruments (TOMS, OMI) were designed to measure the distribution of ozone and aerosols globally. The processing chain (IDL-code) is designed to map and query daily TOMS-like data of absorbing aerosols (dust, smoke, industry) from 1980 onwards. TOMS7OMI instruments have been flown on Nimbus-7, EarthProbe and at this time on Aura. TOMS/OMI-Aerosol Index (AI) (1980 – 2007) mapping can be used to distinguish between human-induced or natural and local or regional sources of aerosol particles and the impact on the Irkutsk region.

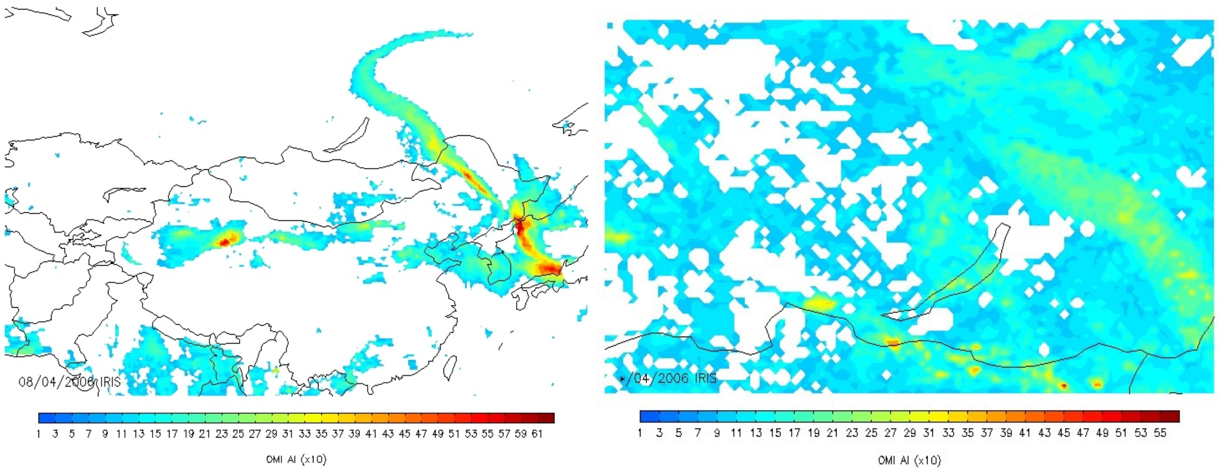


Figure 2: Left - Daily Aerosol Index (AI) over Asia on 08th of April 2006. The days before, a major dust storm crossed China from West to East with sand from Taklamakan and Gobi deserts. The sand also picked up heavy metals and carcinogens as the clouds passed industrial areas. The pollutants are transported by prevailing winds to Korea, Japan and in a longsome plume to Eastern and Central Siberia. Right - Monthly averaged AI over Irkutsk region for April 2006. With better spatial resolution of OMI (compared to TOMS), isolated high AI values along the Russian-Mongolian border can be observed, which results from smoke from forest fires. The phenomenon described left has generated the smoke plume to the East of Lake Baikal.

4.1.1.2. Land Surface Temperature

Canopy temperature is among the main determinants of the growth rate of vegetation. Increasing temperatures are a major stress factor on the composition of vegetative ecotypes and plant (forest) physiology and can force the outbreak of insect calamities and forest fires. Moreover, permafrost is influenced with rising risk potential for infrastructures (slope failures). Time series analyses of 7-year records of monthly Terra-MODIS Land Surface Temperature Climate Modelling Grid data (MOD11C3) for the Irkutsk region was carried out and trends in daytime Land Surface Temperatures were assessed.

MOD11C3 is simply composited and averaged from the global 8-day CMG product (MOD11C2) over a period of 32 days. MOD11C2 again is composited and averaged from the global daily CMG product (MOD11C1) over a period of 8 days. MOD11C3 time coverage is 2000-2006 on a monthly (Fig. 2, top right) and seasonal base with a ground resolution of 5 km. Surface Temperature analysis data (GISTEMP) from NASA Goddard Institute for Space Studies (GISS) is additionally included. GISTEMP gives information about the surface temperature change in a global monthly resolution from 1880 to 2005.

4.1.2. Regional Scale – Monitoring using MODIS and SPOT-VGT Products

To ensure a continuous, detailed but area-wide approach, IRIS enables exploration at the regional scale using data sets from the MODIS product suite. Different MODIS 1-km Land Products have been obtained and processed. In addition, SPOT-VGT data were transformed into seasonally NDVI composites (1km) and DMSP Nighttime Lights and Gas Flaring Estimates are used as monthly composites. MODIS is designed to provide comprehensive series of global land and atmosphere observations in the visible and infrared regions of the spectrum. Four daily MODIS observations are available to contribute to monitoring, the Terra instrument acquires 10:30 am and 10:30 pm, the Aqua instrument 2:30 pm and 2:30 am. The MODIS products used in here are gridded (500 m, 1km, 5km) composites over an 8-day, monthly or yearly interval. The product uncertainties are well defined and are thus ready for use in scientific publications.

4.1.2.1. Land Cover Types

The MODIS-MOD12C1 product contains multiple classification schemes and percentage of each pixel covered by a given Land Cover type. The classification schemes are multi-temporal classes describing land cover properties as observed during the year. The primary land cover scheme (Fig. 3, top left) developed by the International Geosphere-Biosphere Programme (IGBP), includes 11 natural vegetation classes and 3 developed land classes.

4.1.2.2. Forest Fire

Fire locations are detected using daily 4- and 11-micrometer brightness temperatures (data: courtesy of S. Bartalev, IKI-RAS Moscow). For the Irkutsk region, forest fire distribution for the years 2000 - 2005 is displayed in Figure 3 (middle left).

4.1.2.3. Vegetation Continuous Fields

MODIS Vegetation Continuous Fields product MOD44B (Fig. 3, down left) contains proportional estimates for vegetative cover types: woody vegetation, herbaceous vegetation, and bare ground and shows how much of a land cover exists.

4.1.2.4. Gross Primary Productivity

MODIS Gross Primary Productivity (GPP) and annual Net Primary Productivity (NPP) (MOD17A3) are describing the rate at which light energy is converted to plant biomass. This is termed primary productivity. The sum total of the converted energy is called gross primary productivity (GPP). Net primary productivity (NPP) is the difference between GPP and energy lost during plant respiration. MOD17A3 data are available for the years 2000 – 2005. Enhanced NPP for 2006 over Irkutsk region is presented in Figure 3 (middle right).

4.1.2.5. NDVI (SPOT-VGT)

The data source of this time series analysis is based on S-10 standard products from the SPOT-4 Vegetation sensor. The Vegetation sensor was especially designed for vegetation mapping and monitoring and was launched in 1998 onboard the French SPOT-4 satellite. The data has been provided by the TerraNorte Information System (Russian Academy of Science's Space Research Institute, IKI-RAS). Time series analyses of a 6-year record of seasonal SPOT-VGT mosaics for Northern Eurasia were carried out and trends in vegetation photosynthetic activity were assessed. SPOT-VGT time coverage is 1998-2005 for summer and fall, 1999-2005 for spring season with a ground resolution of 1km. Mosaics were derived for spring (March-May), summer (June-August) and fall (September-November). Trends are the increase/decrease of NDVI per year. Tundra or disturbed areas show an increase or "greening" of vegetation (Fig. 3, down right). In contrast, and after excluding impacts like clear cuts, fires or insect calamities, there are areas with decreasing photosynthetic activity, also called "browning" of vegetation.

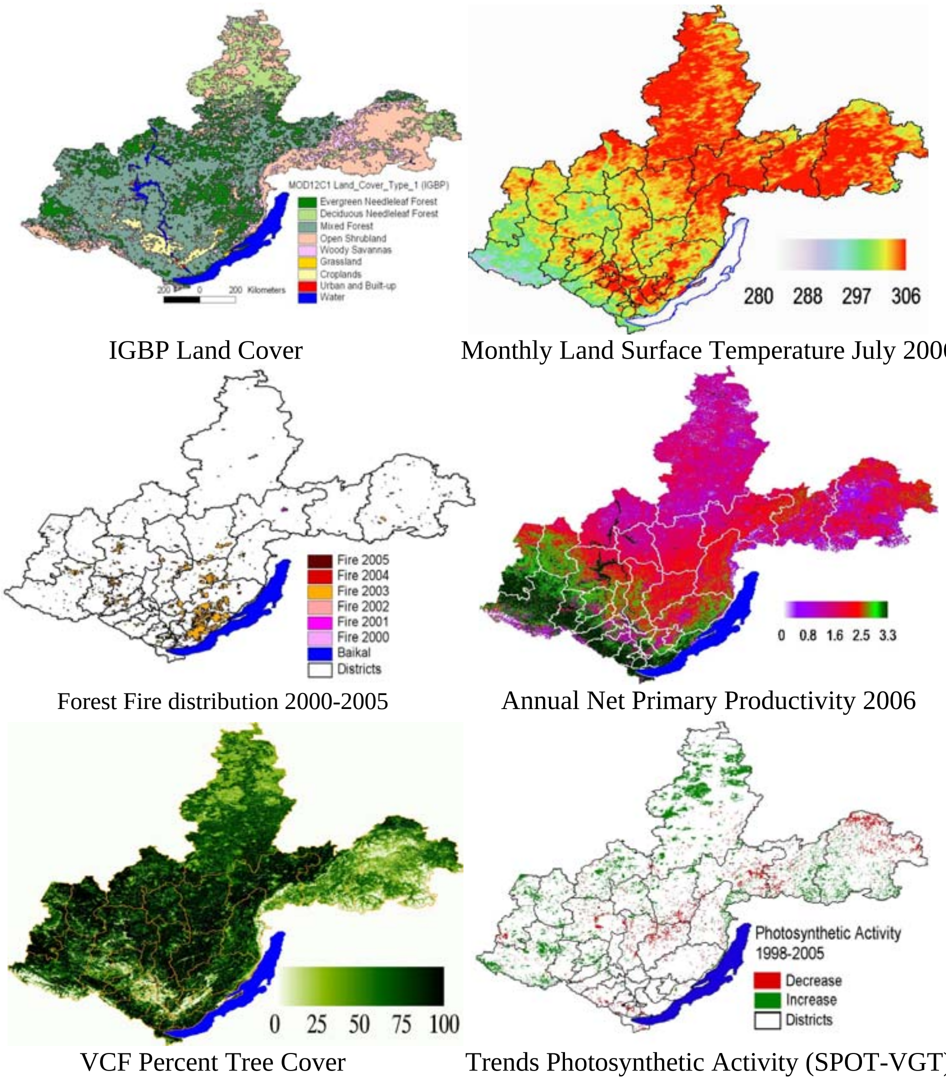


Figure 3: Land surface parameter monitoring on the regional scale: the MODIS Product Suite.

4.1.3.Local Scale – Mapping Areas of High Dynamics

Reliable and up-to-date information on forest characteristics and changes are required by governmental authorities to fulfil international and national treaties as well as for own state forest policies. Specific information needs arise for continuous forest inventories of forest land as a basis for operative planning and assessment of changes.The local scale is covered by spatially high-resolution C-band SAR data from ENVISAT-ASAR (25-50 meters), Monitor-E (8 meter) and Resurs-DK (1 meter), which are used for reliable and up-to-date information on forest extent and changes in specific areas with high dynamics. Forest Area Classification has been performed using object-based classification. Monitor-E data from 2006 serve as additional high-value information layer concerning forest area change.

4.1.3.1. Forest Area Change with ENVISAT-ASAR

Radiometric and geometric corrections are crucial steps towards operational radar data analysis. Prerequisite is the availability of precise elevation data. For forestry, the use of large incidence angles enhances the sensitivity to biomass, whereas the use of steep incidence angles enhances the discrimination of forest types through interaction with the forest structure. The availability of cross-polarisation improves the discrimination between volume scattering (vegetation) and surface scattering (soil), in the Irkutsk region the forest/non-forest discrimination and retrieval of low biomass values (forest regeneration, re-growth).

Forest area maps for the Irkutsk Province were generated using cross-polarized ENVISAT-ASAR precision images acquired at large incidence angles (swath 7). Main processing steps include image preprocessing Sigma Nought calculation, orthorectification, topographic normalization, transformation to dB-values, segmentation, image classification and accuracy assessment. Figure 4 shows examples of the retrieved Forest Area Change Maps. Freely available Landsat TM5 and Landsat ETM 7 as well as ground reference data have been used for validation. The accuracy threshold of the thematic mapping accuracy is 90% for forest areas and 85% for forest area changes, respectively.

The remote sensing and thematic input layers to the IRIS information system are described in the following list:

- 13 cross-polarised C-Band ENVISAT ASAR APP IS7 scenes were used. The data have been delivered as precision images with a pixel spacing of 12.5 m x 12.5 m. The scenes have been pre-processed and georeferenced with GAMMA RS Software to a resampled resolution of 25 m. This was done to reduce speckle and data storage and to avoid oversampling. By applying a Multi-Looking Filter (MLI) of 2 x 2 the data storage is reduced to one-forth of the original storage.
- A Landsat ETM 7 Mosaic has been classified and used as basis for the Forest Change Map.
- The SRTM C-Band DEM was used as input to the rtho-rectification of SAR data with GAMMA RS Software. After a raw registration via orbit parameters, a synthetic SAR image generated from the DEM, is cross-correlated with the scene to be ortho-rectified. The accuracy is in the order of 1 pixel (compared to the DEM).
- Forest inventory data from the years between 1995 and 2001 have been used as training areas for an object based classification using the eCognition software. The inventory is available on analogue maps in the scale 1:200.000 of three forest enterprises with corresponding analogue disturbance data.

Forest Area Classification has been performed using a supervised nearest neighbour algorithm to produce a Forest/ Non-forest map. Ground collected training data and in-situ data were used as reference as well as visual quality control using Google Earth. The classification accuracy assessment is based on forest inventory data. Along the forest borders differences occurred that are due to the spatial resolution of the satellite data and due to segmentation results. Some errors occur, where object edges cannot be detected completely accurate. Inaccurate segmentation is based on the speckle effect and on a low contrast between forest and non-forest. No severe errors on large forest areas were detected.

4.1.3.2. Forest mapping with Monitor-E, Resurs-DK, Meteor-3M

The Monitor-E remote Earth-probing satellite is the first Russian satellite in a family of small spacecrafts, which are designed to serve as an EO constellation for environmental monitoring in regional scale. Monitor-E, launched on 26. August 2005, operates on sun-synchronous circular orbit with the orbit inclination 97.5° at an altitude of about 550 km. The payload includes two imagers, a panchromatic imager (spectral band 0.58 – 0.8 µm, spatial resolution in nadir 8 m over a 93.8-km wide swath) and a multi-channel imager (spectral bands 0.54 – 0.59; 0.63 – 0.68; 0.79 – 0.9 µm, spatial resolution in nadir 20 m over a 160-km wide swath). An up-to-date (2006) and multi-scale remote sensing data set from Russian sensors has been generated for IRIS (Tab. 3). Pre-processing tasks such as atmospheric and geometric correction have been performed in order to provide the data with the highest feasible quality. Meteor-3M and Resurs-DK (1 meter) data has been used to generate information on clear-cuts (Fig. 5). The Monitor-E-PSA data (8 meters) was used to investigate selected forest areas in terms of disturbances (fire, insects) or logging practices. Moreover, this spatially high-resolution data will be used to describe industrial facilities with focus on the Lumber Industry Complex. Monitor-E-RDSA data with ground resolution of 25 meters are quite comparable to Landsat ETM and were incorporated in the time-series analysis of the MODIS products.

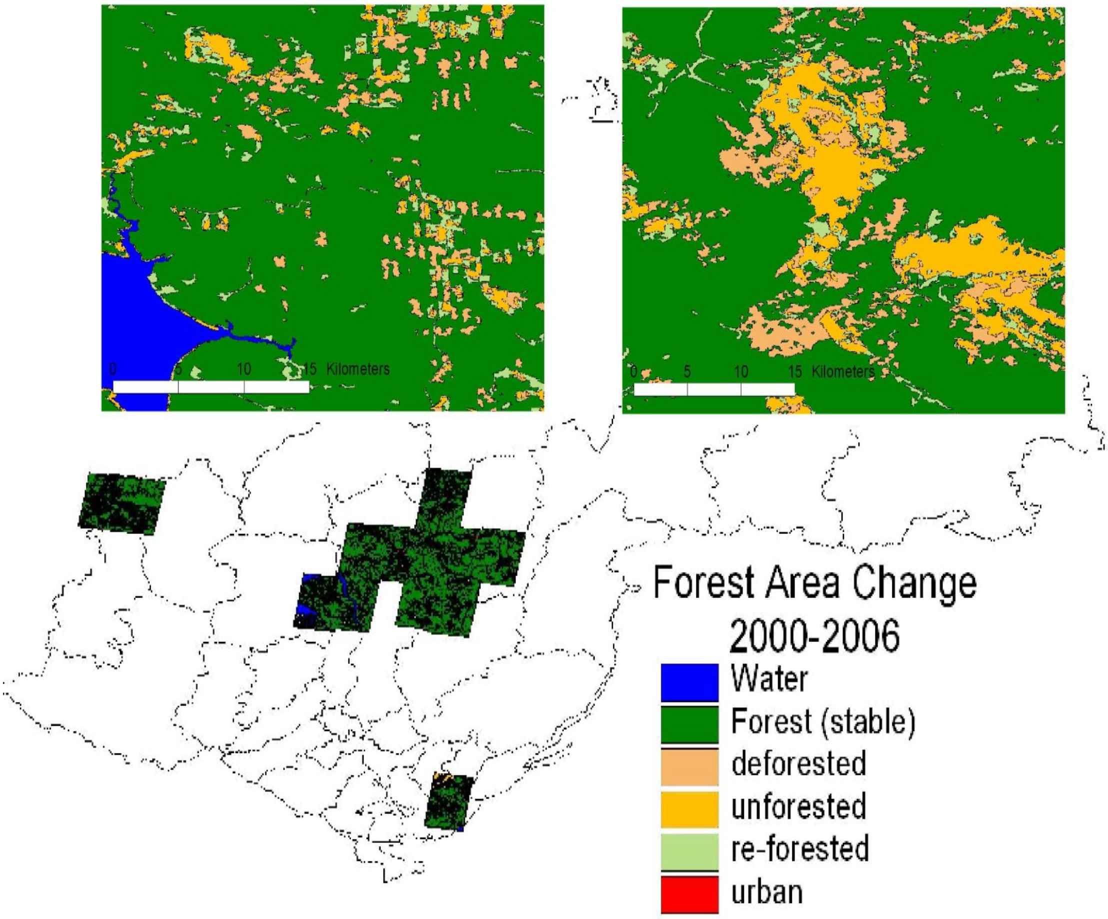
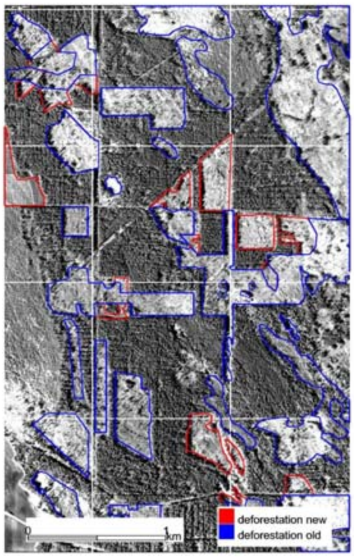
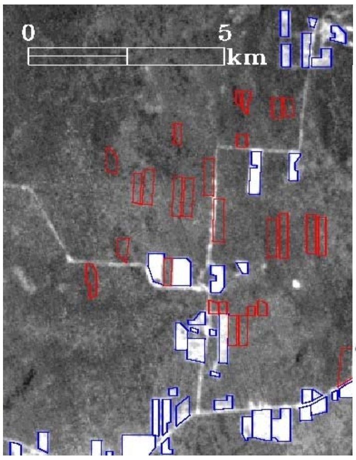


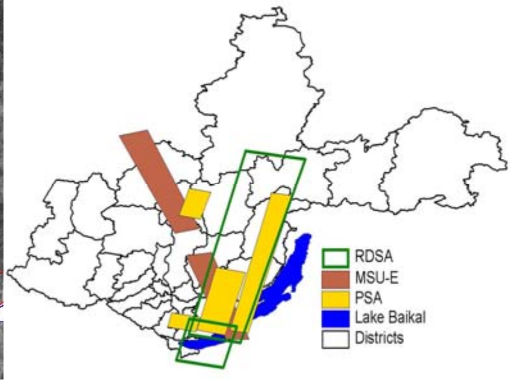
Figure 4: Forest Area Change Map 2000-2006. Top left: clearcut pattern, top right: burnt areas.

Table 3: Russian satellite data characteristics

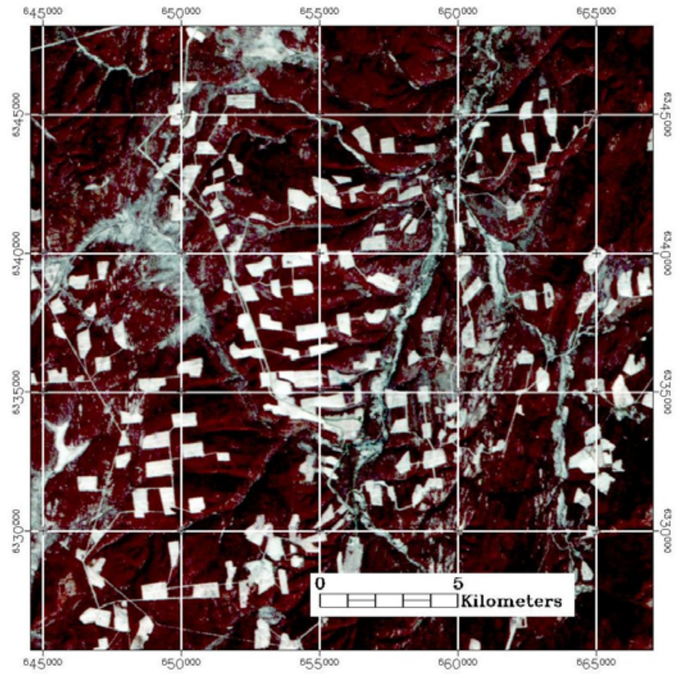
satellite	device	date	ground resolution
Monitor-E '1	RDSA	27.04.2006	25; 50
Monitor-E '1	RDSA	25.05.2006	25
Monitor-E '1	PSA	21.06.2006	8
Monitor-E '1	PSA	22.06.2006	8
Monitor-E '1	PSA	23.06.2006	8
Monitor-E '1	PSA	24.06.2006	8
Meteor-3M '1	MSU-E	10.07.2002	30







Resurs-DK Meteor-3M Russian EO data coverage



Monitor-RDSA Monitor-PSA

Figure 5: Forest Area Change using Russian satellites Resurs-DK, Meteor-3M (MSU-E device) and Monitor-E (RDSA and PSA devices). Clear-cut delineation has been performed on Resurs-DK and Meteor-3M. Monitor-RDSA data (down left) show very good discrimination of forest/non-forest areas. Map grid represents MODIS CMG ground resolution. In contrast, Monitor-PSA data (down right) show significant striping artefacts that make an automated classification difficult.

4.1.4. Additional data

4.1.4.1. DMSP Nightlights for Human Activity Monitoring

Version 2 DMSP (Defense Meteorological Satellites Program)- Night-Time-Lights Time Series from 1992 to 2003 contain the lights from cities, towns, and other sites with persistent lighting, including gas flares. These data were used for the estimation of increasing/decreasing human activities in the Irkutsk region. Global Gas Flaring Estimates based on DMSP observations are available from 1992 through 2005. Gas flaring is a practice for the disposal of natural gas in mineral oil producing areas where there is no infrastructure to make use of the gas. The Night-Time-Lights files are cloud-free composites produced from all available archived DMSP smooth resolution data. The products are 30 arc second grids, spanning -180 to 180 degrees longitude and -65 to 65 degrees latitude. Gas Flaring Estimates are polygon vectors in shape format.

4.1.4.2. Terrain and Water Bodies

SRTM data are distributed in two levels: SRTM3 sampled at three arc-seconds (3 arc-second data corresponding to approx. 90 meters) are generated by 3x3 averaging of the 1 arc-second SRTM1 samples (~30 meters). Data are divided into one by one degree latitude and longitude tiles in geographic projection. The SRTM Water Body data is a by-product since ocean, lakes and river shorelines were identified and delineated. First order derivates such as slope and aspect have been calculated. The original SRTM3 data tiles for Irkutsk region are listed and are available on the IRIS FTP-site. Data comprise 93 files (623 MB zipped). The analysis of SRTM elevation and slope data gives further evidence for a strong influence of terrain relief to the trends.

4.1.5. Summary

The necessary EO data has been acquired and the methodology to retrieve products for the Irkutsk Province have been developed or refined. Most products are freely available and can be used also in future applications of the IRIS information system. For new EO data, such as MODIS CMG, unexpected products have been additionally obtained, such as Land Surface Temperature and from ENVISAT ASAR biomass, which shows great potential for large-scale mapping.

Cross analysis of the different EO products has shown strong merits. For ecological time switches for example, the joint use of the land cover, temperature and biomass products appears crucial to improve the knowledge of economic and environmental processes. IRIS has successfully established the first step to interdisciplinary modelling by introducing the use of EO products in the econometrics approach (WP3000) and in the IRIS-GIS framework (WP4000)

Climatic conditions and human impact are the main influencing factors on the Irkutsk region's ecosystem fluxes. To detect significant trends in the EO data, time series of SPOT-VGT NDVI mosaics (1998 – 2005) and MODIS LST products (2000 – 2006) were analyzed using a temporal trend analysis based on the ordinary least squares (OLS) regression technique of a linear regression model (*Y = a +bX + å*). Every pixel value is plotted over time and the linear model fit is calculated by minimizing the sum of the vertical deviations (least squares) from each data point. By applying the linear regression model on satellite time series data it is possible to detect linear changes of the pixel values over time. These changes can be detected either with positive or negative slope values. The slope value thus gives information about the annual increase or decrease of the respective pixel representation (here temperature and NDVI). Another parameter taken into account is the coefficient of determination (R^2), which describes how strong the linear relationship is between LST or NDVI change and time. The trends were analyzed on a confidence level of 95% using the standard t-test to avoid interpretation ambiguities. The SPOT-VGT NDVI and the MOD11C3 LST datasets were regressed over six respective seven years for the same seasonal time interval.

4.2. Assessment of Current Man-Made Changes and Stress Sources (WP3000)

The Irkutsk Province is one of the most important industrial regions in the eastern part of Russia. The economic complex domain is characterized by a sharply pronounced industrial incline. The specific weight of industry on the gross regional product (VRP) is almost 1.5 times higher than on the average in the country. Formation and prospects for the development of the economy of the Irkutsk Province are determined by the presence of the richest natural-resource potential in Russia. The presence of cheap energy supply (cascade of Angara power plant) stimulated the development of powerful energy- and capital-intensive productions: aluminium, chemical, petrochemical, lumber, woodworking and pulp and paper industry. Irkutsk holds the 4^{th} to 5^{th} place in gold mining and is of high importance for machine construction. A special feature of the specialization of Irkutsk's industry is the orientation towards a removal of products in the form of raw materials and half-finished products to other Russian regions or for the export. The export in 2004 composed 69% of the industrial production, 80% of aluminium, more than 75% cellulose, 90% of lumber, about third of diesel fuel. Most important foreign economic partners are China and Japan.

Inertia of the economic increase however is observed in recent years. In 2000-2004 according to the index of the fixed asset investment per capita of population, the region was on place 8 of 10 of the Russian Federation, next to the depressive Ivanovo and Kurgan provinces.[1] The wear of the fixed capital for the industry of Irkutsk region is of about 55%, and for some branches (petroleum refining, petroleum chemistry) it already reaches 80%. The resource potential of the region caused the leading part of forest complex in the structure of its industry. In the timber value, Irkutsk occupies the first place in Russia. Lumber, woodworking and pulp and paper industry produce about 20% of the industrial production of the region, forest enterprises are shaping many districts.

The overall objectives of this project task are therefore

- to assess the current and historical man-made changes and negative impacts arising from pollution sources and other anthropogenic drivers located in the Irkutsk region and in adjacent areas and
- to gather information on actual and potential sources of pollution in the region under study and in the proximity of its border.

The key problem are adequate measurements of the region's economical functioning. This should be done not only by taking into account so-called environmental costs but also a certain number of factors describing the public welfare. Partner 5 (ISC) therefore developed:

- a model of regional and branch systems analysis and forecasting,

and along with this model a multitude of environmental-related data such as:

- the territory, source and amount of environmental pollution and
- public well being (measured as the state of human health) according to the territory.

Substantial parameter data sets are a prerequisite to assess both, the environmental impacts and the social costs of these impacts. The main goal thus was the consideration of 'environmental and social costs' in estimating and forecasting the Gross Regional Product (GRP).

4.2.1. The Lumber Industry Complex (LIC)

The Irkutsk Province is dominated by typical taiga forest. 81% of the territory is covered by forest, which corresponds to an area of 66.8 million hectares or 9.9% of Russia's forested area, taking the first place of all provinces. The annual gain is estimated to 80 million m^3 timber. The proportion of wood processing and pulp and paper industries is about 20% of the industrial production of the region. Thus, this resource potential determines the leading role of the forest complex in the industry structures alongside with fuel

[1] Data of the ministry of economic development and trade www.economy.gov.ru

and energy, chemical, petrochemical and the nonferrous metallurgy complex. Lumber industry enterprises thereby are the major features in many administrative districts.

However, the controlling of forest resources and their active involvement into the economic cycle do not provide the region with proper sustainability and qualitative economic growth. Moreover, the big number of industrial facilities in the territory has resulted in serious ecological consequences: high and very high levels of pollution of the natural environments are verifiable in 42% of Irkutsk Provinces' settlements, which frequently exceed average values of the Russian Federation indicators.

The formation of a qualitative economic growth is not ensured and economic, ecologic and social risks arise. The issue of an adequate measurement system for the region's economical functioning by taking into account a certain number of factors describing the public welfare is necessary and sought in ecomometrical models.

4.2.2. Econometrics

IRIS integrates methods of econometrics, a framework to estimate quantitatively the contribution of specific industrial branches, here the Lumber Industry Complex (LIC) into the economy of the Irkutsk Province. Econometrics is concerned with the tasks of developing and applying quantitative methods to study economical principles. One of the fundamental statistical methods used in econometrics is regression analysis. Regression methods are important because economists typically cannot use controlled experiments. Partner 5 (ISC) has developed a regression model for estimating and forecasting the Gross Regional Product.

4.2.2.1. Social costs of environmental impacts

The evaluation of the influence of specific industrial branches onto the economic well being of the society takes a center stage by economists for more than a decade. Special attention is paid to the system problems, such as the reduction of negative impacts of specific productions and industries on the environment or the provision of ecologically sustainable or acceptable functioning of economic systems. There are a lot of disputes on how to better determine and compare levels of public welfare of various regions, areas or countries. In 1946 and for the first time, it was offered by Hicks to solve this problem with the help of the net national product parameter. Criticism came up since the net national product does not take into account the negative aspects of the economy functioning from a society's point of view. It was offered to correct the net national product indicator by values characterizing depletion of natural resources and environmental degradation. New approaches - such as the estimation of an environmentally adjusted net domestic product - deal with the social costs of environmental impacts. The ISC model follows this direction.

4.2.2.2. Estimation of the Gross Regional Product (GRP)

The main mathematical equation of the dependency of the Lumber Industry Complex (LIC) net product from the various factors was determined to estimate the contribution of the LIC into the net regional product of Irkutsk province with the consideration of the volumes of environmental contaminations. The possible changes in the GRP indicator, related to the inclusion of ecological pollution characteristics into the calculations had been determined; the forecasted LIC's GRP values had been constructed. The calculations were carried out on the basis of the methods of the econometric analysis with the use of EVRISTA and SPSS programs. The data of the territorial agency of the Federal Service of the State Statistics of the Irkutsk Province and the materials of researchers of the Irkutsk Science Center (Partner 5's Department of Regional Economic and Social Problems) had been used as source information.

GRP is the major indicator characterizing the efficiency of the economy functioning. The following have been considered in the equation for the calculation of a society's well being in the region with regard to pollutions:

$$GRP= u_cC+u_pP+ \lambda_1S+\lambda_2F(K(t),R(t),t)+ \lambda_2\mu(t)*P'(t)+\lambda_3[r*(H-K)+ +X_e(t)+X_0(T)],$$

where,

- ***C*** is the purchasing power in the LIC (salaries, dividends, allowances and other payments in all the enterprises in the province, savings);
- ***P*** : the harm made to the environment while LIC operates;
- ***H*** : major LIC's funds (fixed capital);
- ***S*** : total number of the forest cuttings (obtaining of the major resource for the LIC);
- ***F(K(t),R(t),t)*** : production of goods made from the forest resource;
- ***P'(t):*** allowable pollution level, established by the State, the excess of this level results in fines and penalties;
- ***r :*** rate of return used in the capitals market (LIBOR rate);
- ***K*** : volumes of the retiring assets in the LIC;
- ***Xe(t)* :** round woods export;
- ***X0(t)*** : LIC products export;
- ***$\lambda_1, \lambda_2, \lambda_3$–:*** shadow coefficients of the influence of the indicators presented on the GRP (national income in terms of the benefit should reflect the well being, and should be definitely corrected for the values of the resources depletion, increase of the pollution and increase of the national non-resource wealth, all these is evaluated as the shadows prices);
- ***μ*** – the dependency ratio of the pollution from the permissions granted.

The following assumptions were made during the analysis:

- the value of the province's GRP according to the direct calculation provides the true estimation of the product produced by the society and the transition from the net national product indicator to the gross regional product in this case is justified due to the consideration of the GRP only, which is produced in the LIC of the Irkutsk province;
- only the LIC input was considered in the econometric analysis;
- volume of pollution of the natural environment only takes the lumber industry complex into account;
- the P indicator takes into consideration the sum of the penalties paid to the state and the fines for the harm made to the environment;
- the P' indicator is considered as the actually "legalized" non-paid level of pollution (the divergence of the pollution estimations among ecologists and administrative bodies results in the underpayment of amends for pollution);
- the following is derived from the equation of an estimation of pollution of the current year:

$$P(t) = \varphi F(K(t), R(t), t) – \mu(A(t))P(t), P(0) = P_0$$

Further reasoning relate to the question of the determination of shadow coefficients with the help of tools of econometric analysis. As a result the equation was evaluated and the following shadow coefficients were received:

$$GRP=0,466*C+768,238*P+0,071*S-2,026*F-7\ 27,115*P\ '\ +0,314\ *\ [r\ (H-K)]$$

4.2.2.3. Forecast of GRP

The next step of research was to obtain and evaluate the forecast values of the GRP using several methods. The following variants of the calculating the development of the Province's economy for the next several years had been considered:

- the forecast under the factorial analysis (the simple forecast on the cost structure);
- the forecast with the use of expert estimations;
- the forecast under the factorial analysis (with the use of prices);
- the forecast and the volumes on the ARIMA (p, d, q) model;
- the technical forecast.

The expert estimations received from the Irkutsk Federal Statistical Agencies were used for the forecasts. The regression equation, which allows evaluating the forecast values of the province's GRP change in the LIC for the next 10 years, were obtained based on the factorial analysis.

4.2.3.Datasets on Pollution Sources

Partner 5 (ISC) undertook the collection of data on current major pollution sources. The following deliverables are now part of the IRIS information system:

- Dataset on pollution of atmosphere,
- Dataset on pollution of surface waters,
- Dataset on pollution of soils,
- Maps of Complex Impact (atmosphere, hydrosphere, bioenvironment, complex impact).

4.2.3.1. Dataset on pollution of atmosphere

The tables reflect the dynamics of the gross emissions of the polluting substances which have been emitted from industry and exhaust gas pollution into the atmosphere in 2003, 2004 and 2005.

Parameters: Territory,
Polluting substances,
MAC - Maximum Allowable Concentration (maximum single & daily average),
Class of hazard,
Excess above MAC (average, minimum, maximum),
Excess above all-Russia level (number of times),
Source of pollution (industry).

4.2.3.2. Dataset on pollution of surface waters

The tables reflect the dynamics of the gross emissions of the polluting substances which have been emitted with the sewage waters into the water bodies in 2003 and 2005. Surface waters are: Irkutsk water-storage reservoir, Angara river near the Irkutsk-Angarsk city, Bratskoe water storage reservoir (Angara river), Ust'-Ilimskoe water storage reservoir (Angara river), Irkut river, Olkha river, Kaya river, Ushakovka river, Kuda river, Kitoy river, Belaya river, Oka river, Vikhorevka river, Lena river.

Parameters: Territory,
Polluting substances,
Place of Location,
Amount (excess),
Criterion of the Level of the water pollution,
Pollution index,
SCIPW: Specific Combined Index of the Pollution of the Water.

4.2.3.3. Dataset on pollution of soils

The tables reflect the dynamics of the gross emissions of the polluting substances which have been emitted from industry and exhaust gas pollution into the soils in 2003, 2004 and 2005. The tables represent information on disturbed lands by branches of the national economy and soils remediation 2005.

Parameters: Territory,
Enterprise,
Land damage,
Grounds complained for the reporting year (ha),
Place of Location; Amount (excess),
Polluting substances (pesticides),
Decrease of the pollution's level in comparison to 1996 and number of times,
Disturbed, abandoned, remediated lands (ha).

4.2.3.4. Maps of Complex Impact

The information on complex impact, pollution of atmosphere, hydrosphere and bioenvironment only exists as scanned maps. Reference and map notations are in Russian. To supplement the IRIS-GIS by this new and relevant layers, information content of selected maps were made GIS-compatible and are now synergistically available.

4.2.4. Datasets on Other Stress Factors

4.2.4.1. Sanitary-epidemiological conditions

Sanitary-epidemiological conditions in cities of the province and impacts of ecological factors on health of the population in 2002 and 2003.

Parameters: Territory and group of territories,
Disease,
Group of the Population,
reason (source),

- Impact of chlorine, chlorine by-products, tetraethyl lead,
- Severe climatic conditions,
- Unsatisfactory quality of potable water,
- Significant presence in the bowels of the rare elements, including gold, which create the increased radiation background;
- Closeness of the industrial enterprises,
- Deficiency of the quality of the potable water,
- Aggravation of problems of social character due to the agricultural economy,
- Negative development of conditions of life in the Northern areas,
- anthropogenous load, which results is significant deterioration of ecological state due to the harmful emissions in the atmosphere and polluted drains into the water reservoirs, and soils' saturation with toxic substances, which fall down with atmospheric sediments and thawed snow,
- The aluminium and chemical industries,
- Thermal power stations,
- The consumption of drugs intravenously, a sexual way, a vertical way,
- Influence of cultural and natural factors, high fluoric load. Ways of its entry: respiratory, foodstuffs and water,
- Indicator of the disease per 100 thousand of the population (scale of the distribution, number of people, changes in comparison with 2001/2002, units).
-

4.2.4.2. Birth and Death Rates, Migration, Poverty

- Indicators of Birth and Death Rates in the Irkutsk Province Territories for 2001-2005 (Number of born and dead per 1000 persons and territory);
- Indicators of the dynamics of the natural migration of the population in the Irkutsk Province and of the Russian Federation since 2000 till 2004;
- Indicators of the infantile death rate in the Irkutsk Province territories since 2001 till 2005;
- Indicators of diseases of the population of Irkutsk province for years 2003-2005 (per 100 thousand people);
- Comparison of diseases indicators of all the population of Irkutsk province and of the Russian Federation for year 2004;
- Groups of the municipal Entities by the level of poverty based on the complex index of the territory's development (see also Table 4 and Figure 6).

4.2.5. The Main Sources of Pollution

The enterprises of fuel-energy complex, forestry and woodworking industry, housing and communal services remain the main sources of environmental pollution. Due to the insufficient economic interest of enterprises, low technical level of the technologies used, lack of facilities and contemporary equipment, only some of the waste products are processed and used in the territory of the region. The major pollution sources are:

- heat-power engineering,
- fuel industry,
- chemical and petrochemical industry,
- nonferrous metallurgy,
- forestry, woodworking and pulp and paper industry,
- housing and communal services of the region,
- waste products of production and consumption.

Table 4: Groups of the municipal Entities by the level of poverty based on the complex index of the territory's development

Good standing municipalities and districts (Group I)	Relatively good standing municipalities and districts (Group II)	Relatively bad standing municipalities and districts (Group III)	Bad standing municipalities and districts (Group IV)
 Angarsk Bratsk Shelekhov Sayansk	Irkutsk Taishet Tulun Usolye-Sibirskoye Ust'-Ilimsk Ust'-Kut Cheremkhovo Ziminsky district Kazachinsko-Lensky district Nizhneilimsky district Sludyansky district Taishetsky district	Bodaibo Zima Nigneudinsk Bratsky district Balagansky district Zhigalovsky district Tulunsky district Kirensky district Kuitunsky district Mamsko-Chuisky district Nizhneudinsky district Ust'-Ilimsky district Cheremkhovsky district Chunsky district Zalarinsky district Irkutsky district Usolsky district	Katangsky district Olkhonsky district Ust'-Udinsky district Kachugsky district

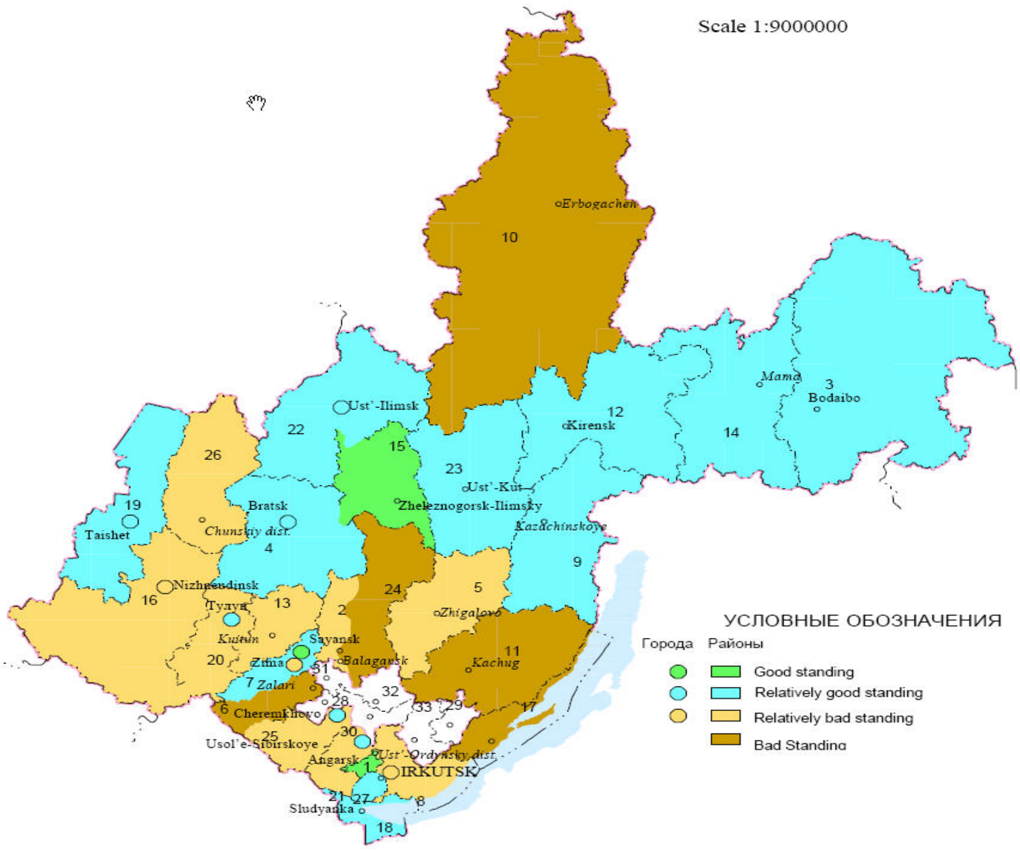


Figure 6: Groups of the municipal entities by the level of poverty based on the complex index of the territory's development.

4.2.6. Summary

The main injurious effect on the forest resources and the living environment of biota renders the pollution of the air. In the Irkutsk Province the enterprises of fuel-energy, chemical, petrochemical complexes and nonferrous metallurgy are the basic sources of pollutants entering the atmosphere. A second large contribution is introduced by truck transport. The large number of industrial objects in the cities consistently causes high and very high levels of pollution to the environment, often exceeding Russian average indices. The high load of pollutants to the environment is aggravated by the climatic special features of the territory - the anti-cyclone weather type in winter – which produces stable climatic conditions facilitating stagnation leading to the accumulation of harmful impurities in the atmosphere above the industrial objects[2].

For a period of already several decades there are regions with unhappy ecological situation of very high levels of pollution in the near-ground air: Angarsk, Bratsk, Zima, Irkutsk; Usolye- Sibirskoe, Shelekhov, Cheremkhovo, Ust-Ilimsk.. Bratsk and Irkutsk for many years have been included in the priority list of the Russian cities with the highest level of air pollution. Zima is included into priority list since 2001, Angarsk - since 2004. During five years Shelekhov was included (2000-2004), and Usolye - Sibirskoe - in 2001, 2002.
The data about level and sources of the pollution of atmospheric air in the populated areas of Irkutsk region yearly are published in the state report "About the state and protection of the environment in the

[2] Analysis, estimation and risk control at the level of the region: man-caused, natural and social aspects /Proceedings of the reports reg. scientifically - practical conference. Irkutsk: ISEM SO RAN, 2001. - 371 p. - "Problems and the prospect for the development of the territorial system of monitoring and predicting Extraordinary Events of the natural and man-caused nature in Irkutsk region". Author: Yakhno A.N., p.93

Irkutsk region", the documents of the state committee of RF statistics.[3] In the appendices 1-4 on the basis of the sources enumerated above is generalized the information for the years 2002-2005 about the pollutants, whose content it exceeds the maximum permissible concentrations.

The econometric analysis conducted allowed the following conclusions:

- the statistical dependency of the GRP produced by the LIC from the solvent demand created in the LIC, the pollutions made by the LIC, the cost estimation of the LIC's products, and fixed assets used in the LIC, turned out to be significant under all the factors, thus:
    - the solvent demand results in the growth of the province's regional product and is the most significant factor of the growth of the society's wealth;

- the pollutions paid for - enterprises are obliged to pay for the environmental contaminations which exceed the state limited values as penalties - are a factor positively influencing the well being of the society, which is explained by the fact, that with an increase of pollutions also the deductions into the budget grow and the production grows;

- the process of the deforestation is organized inefficiently: there is a high share of unaccounted cuttings, a smaller output of the wood products per square meter in comparison to the developed countries, a resource oriented export, a smaller margin profit from the functioning of the production;
- the increase of the quantity of pollution permissions results in the decrease of well being of the society because of the growth of the unpaid pollutions and the growth of uncompensated harm to the environment;

- the GRP values were obtained considering the harm causing environmental degradation, an inefficiency penalty for the resource and a fixed assets usage.

Intensive effort has been spent to produce up to date and accurate datasets on anthropogenic drivers of pollution. All datasets are checked for errors and every effort has been made to ensure that the datasets function properly in the IRIS information system. The econometrics approach has highlighted a number of problems in data availability, e.g. for regionalization. Even if model input data were collected and archived for the entire province, they are not available on a more discrete district basis. Many individual assessments were limited by this constraining factor. Despite these problems, a comprehensive assessment of a large multi-parameter database was performed. The statistics show that the models do provide very useful information on the future development of the LIC and thus on sustainable forest resource development and man-made land cover change.

Partner 5 (ISC) developed an initial draft of a regional branch systems analysis and forecasting approach for operating LICs including various sets of auxiliary data and information of negative anthropogenic impacts on the environment as well as of indicators for social costs of these impacts. The econometrics approach has met its initial objectives and is available in the IRIS-GIS. Thus, the central theme of this project task, the development of regions, inter-budget relations in the region, and links in the system "Economy and Environment" has successfully been performed.

[3] State report on the state and protection of the environment of the Irkutsk region in 2002, 2003, 2004, 2005. - Irkutsk: Oblmashinform; The protection of the atmospheric air in the cities and the regions of Irkutsk region/Statistical bulletin, 2004-2005.

4.3. The IRIS GIS (WP 4000)

The technical core of the IRIS project is the creation of the prototype of the IRIS GIS and its interface as well as an Internet based version, which shall handle three major components:

- to assemble available open data sources for the IRIS GIS,
- to provide regular, comprehensive, easily accessible information on key indicators of the potential risks for the region's forestry environments arising from man-made changes and anthropogenic forcing, and
- to develop an easy-to-use IRIS GIS interface for policy makers, interested scientists and the public.

The GIS serves as a repository for all datasets acquired over the course of the project that contain the necessary parameters for use in the information system framework. In addition, interim datasets and cartographic datasets are included.

4.3.1. Geospatial data/information

According to ISO 19110, Geographic Information can be represented in a couple of general models, such as the boundary model or the Coverage model. The boundary model is widely used in the Land Management Community. To this Geographic Information community (usually GIS users) the world is a collection of features (e.g., roads, lakes, clear cuts) with geographic footprints on the Earth surface. The features are discrete objects described by a set of characteristics such as a shape/geometry. The Coverage model is widely used in the Earth Sciences realm. To the Earth and Space Science community, the world is a set of event observations & measurements described by parameters (e.g., temperature, biomass) that vary as continuous functions in 3-dimensional space and time. The behavior of the parameters in space and time is governed by a set of equations. It is a methodical challenge to conceive and implement earth science info communities' interoperability.

4.3.1.1. Requirements analysis

Requirements analysis is an important part of the GIS system design process, whereby GIS developers identify the needs or requirements of the users/clients. Once user requirements have been identified, the system designer is then in a position to design a solution. In the context of IRIS, the Irkutsk administration and the Irkutsk Science Center define the exact requirements, so that a system that meets the needs is produced.

4.3.1.2. Contributions to standards

One of essential components of IRIS is the Open Source GIS system. Open Source technology is a growing field that encourages the free sharing of software, codes and services. The goal of the Open Geospatial Consortium (OGC) is to promote standard open software interfaces called OpenGIS. These interfaces will enable geoprocessing so that different geospatial systems are able to communicate with each other. The use of common languages such as XML or GML enables easy integration between systems. OpenGIS supports the easy retrieval of geospatial information in a distributed environment, regardless of physical location of the data. These distributed datasets can then be combined and rendered for display. The spatial data of the IRIS information system meet internationally recognized data standards. Associated high quality metadata increase the value of the system by allowing the user to determine the value of the datasets used in the GIS as well as reliability of the output generated. By conforming to international metadata standards, the user has access to standardised information about each dataset such as data origin, age, resolution and source. Thus IRIS contributes to a common European standard for satellite data products, model variables and other data.

4.3.1.3. Computer supported cooperative work

The IRIS Communication Platform (http://www.iris.uni-jena.de/iriswiki/) serves as the basis for computer supported cooperative work. – ‘The more people use the platform, the more valuable it becomes.’ - We implemented MediaWiki, a free and open source software that is used to organize and facilitate collaborative work. Due to the strong emphasis on multi-linguality in the Wikimedia projects, internationalization has received significant attention by developers. The user interface has been fully or partially translated into more than 70 languages (http://www.mediawiki.org).

4.3.2. Sib-ESS-C GIS

Only a comprehensive and well-designed GIS system is capable of managing large and varied datasets as required for a complex environmental information system. Due to the large geographical extent of the project and the level of detail required for the environmental analysis along with the large variety of spatially dependent input parameters required for the monitoring efforts, the system must be reliable and able to provide future usage. The IIASA GIS on Russian Land Resources employs the coverage data model (for compatibility) and the object-oriented geodatabase data model (www.iiasa.ac.at/Research/FOR/russia_cd). All data (vector, raster, address, measures, etc.) is stored together in Microsoft’s Jet engine DBMS. This allows for an integrated data management policy covering all data. In addition, the coordinator runs the Siberian Earth System Science cluster at her Department, containing relevant EO products from former EC-projects (www.sibessc.uni-jena.de). Table 5 gives an overview of the available data.

4.3.3. Estimation of the Dynamics of the Irkutsk Forest Territories 1963-2003

Due to the tremendous importance of the forest sector for the Irkutsk economy, one special project task focussed on the forest cover dynamics. Based on data of the first complete forest inventory of the region, a forest map has been prepared in 1963 and published in 1965. The central and southern part of the region has been presented at scale of 1: 300 000 and the northern part at a scale of 1:600 000. The forest map of 2003 was produced in two stages. First, initial classes of land cover (forested areas; unforested areas; agricultural lands; natural grasslands; shrublands; non-vegetated lands) have been delineated based on low-resolution satellite imagery (mainly using MODIS at 500 m). 30% of the area was then validated with imagery from LANDSAT 7 ETM (resolution 30-40 m). Further details (dominant species, age, site index, relative stocking, growing stock, some others) were implemented based on forest inventory data. This map has been produced at a scale 1:1 million. Both maps have been digitized and presented in the GIS environment using the same projection and topographic basis (Figures 7 and 8). The maps were matched using the boundaries of the region of 2003.

Major conclusions which could be drawn based on this 40-year analysis are the following:

- Areas covered by stands of major forest forming species increased for the analyzed period by 0.51 million ha (+1.0%). Area of soft wood deciduous species decreased more than 2 fold – from 7.71 to 3.56 million ha. Areas of light coniferous species increased (+6%) due to substantial increases in the area of pine forests (+18%). The area of dark coniferous forest also increased (+23%) due to the increase of the area of cedar forests.
- The areas of shrubs increased by 2.7 times although they cover a relatively small territory (0.97 million ha in 1963 and 2.06 million ha in 2003). Probably it is explained by uncertainties of data received from air taxation before 1960s.
- Age structure of forests substantially changed during the period: the area of young and middleaged stands substantially increased at the expense of immature, mature and overmature stands. Increased areas of young coniferous forests is larger than decreasing areas of older stands. It is a sign of restoration of coniferous species on areas that have been accounted before as deciduous forests.

•

Table 5: Detailed description of datasets included in IIASA's SIBERIA-II GIS and FSU's Sib-ESS-C.

Feature Datasets	Objects	Source	Scale/Resolution	Type	Description
Administrative	SibII Boundary	IIASA, 2003	1:1 Mio	Vector	Outer boundary of study area
	Administrative Oblasts	IIASA, 2003	1:1 Mio	Vector	Six administrative units with names
	Forest Enterprises	IIASA, 1993	1:1 Mio	Vector	Individual forest enterprise units
Climate	Avg. Temperature	CRU, 1961/90	50 km	Raster	Monthly average temperature
	Avg. Precipitation	CRU, 1961/90	50 km	Raster	Monthly average precipitation
Anthropogenic	Urban	Russia, 1990	1:1 Mio	Vector	Area of larger settlements
	Cities	Russia, 1990	1:1 Mio	Point	Cities, towns and settlements
	Landmarks	DCW, 1993	1:1 Mio	Point	Major landmarks
	Mines	DCW, 1993	1:1 Mio	Point	Existing mines
Hydrography	Watersheds	USGS, 1996	1:1 Mio	Vector	Watershed boundaries taken from the global HYDRO1K dataset
	Water bodies	Russia, 1990	1:1 Mio	Vector	Freshwater lakes and major rivers
	Small_lakes	DCW, 1993	1:1 Mio	Point	Lakes to small to be represented as polygons
	Watercourses	Russia, 1990	1:1 Mio	Line	Rivers, streams and creeks
Hypsography	DEM_GTOPO30	USGS, 1996	1 km2	Raster	Digital Elevation Model – 1km
	DEM_SRTM	NASA, 2000	100 m	Raster	Digital Elevation Model – 100m
	Slope_SRTM	NASA, 2000	100 m	Raster	Slope measure in degrees
Terrestrial Themes	Landscapes	IIASA, 2003	1:1 Mio	Vector	Derived based on similarities in topography, climate, soil etc.
	Soil	IIASA, 2003	1:1 Mio	Vector	Major groupings of soil
	Vegetation	IIASA, 2004	1:1 Mio	Vector	Major vegetation classes grouped based on GHG calculations
	Permafrost	IIASA, 2002	1:4 Mio	Vector	Permafrost boundaries
Test Areas	Forest Inventory	IIASA, 2003	1:50,000 - 1:200,000	Vector	Forest inventory data spread across study area for EO verification
Transportation	Roads	Russia, 1990	1:1 Mio	Line	Major road networks
	Railroads	Russia, 1990	1:1 Mio	Line	Major railroad networks
	Utilities	DCW, 1993	1:1 Mio	Line	Major utilizes
	Airports	DCW, 1993	1:1 Mio	Points	Airports of various sizes
EO Products	Land cover	UWS, 2003	500 m	Raster	Level2 land cover derived from raw MODIS data
	Disturbance	CEH, 2003	1 km	Vector	SPOT derived fire scar data
	FPAR/LAI	DLR, 2002	1 km	Raster	MODIS FPAR/LAI
	Budburst	CESBIO	5 km	Raster	Initiation of budburst
	Senescence	CESBIO	5 km	Raster	Initiation of senescence
	Snow depth	CESBIO	12 km	Raster	Snow depth based on SSM/I data
	Start of snowmelt	IPF	10 km	Raster	Date of first snowmelt based on QuikSCAT data
	Duration of snowmelt	IPF	10 km	Raster	Duration of the snowmelt period derived from QuikSCAT data

- The most evident negative change of forest cover dynamics reveals a substantial increase (more than by 1.5 million ha) in the area of burns and dead stands. It can be explained by the large fires of 1998 and 2003 that have not been included in SFA-2003 (due to the latter, the burnt areas comprise only 0.87 ha). However, we cannot exclude the impact of probable underestimation of the burnt area on the map of 1963).
- Age structure of forests substantially changed during the period: the area of young and middleaged stands substantially increased at the expense of immature, mature and overmature stands. Increased areas of young coniferous forests is larger than decreasing areas of older stands. It is a sign of restoration of coniferous species on areas that have been accounted before as deciduous forests.
- The structure of lands outside of forest funds (that have not been indicated on the map of 1963) is estimated based on the map of 2003. Of the total area of 5.686 million ha, 1.748 million ha is covered by agricultural lands, 0.556 million ha by grassland. However, a major part of this territory – 3.209 million ha - is estimated as forested area. The latter (69%) is represented by young and middleaged forests with a dominance of pine (76% of younger forests), birch (11%) and larch (10%). These data correspond well to official statistics of land cover in this region.
- Forested areas estimated by both maps do not substantially differ from the corresponding data of the SFAs. So, the forested areas due to the map of 2003 differs from SFA-2003 by +1.2%.
- As an overall conclusion of this comparison, it could be stated that two major drivers defined major features of forest dynamics in the region during the last 42 years. The first is presented by evolutionary stipulated regularities of succession dynamics of forest ecosystems. The second one deals with increasing anthropogenic pressure on forests of the region, mostly fire and logging, particularly in central and southern parts of the region.

While the total area of lands accounted for forest purposes has decreased according to the official statistics, the forested area has increased from 58 to 63 million ha or at 8.5% in 1961-2003. This resulted in increasing the forest cover percentage from 76.1 to 81.3%. This significant increase is explained by:

- low accuracy of air-visual taxation data and untimely surveys of restored unforested area by forest managers. At least 2.83 million ha of young forests have been omitted in the SFA 1961;
- imperfection of the account for forests which belong to the Ministry of Defense and some other agencies; for this reason, 1.27 million ha of forested area has not been accounted for in 1961;
- changing approaches to forest inventory; the increase of 0.9 million ha of areas of *ernics* and shrubs of dwarf pine has been caused by accounting for these land categories, identified by air-visual survey as bogs, rocks and stony fields.
- Thus, the officially reported increase of the forested area is explained by imperfection of forest inventory methods previously used, or by insufficient applications of these methods in practice. It has not been a result of natural reforestation or forest management activities. In reality, the forested area within the oblast remained rather stable (the decrease was only 0.1%).

Legend for Figures 7 and 8:
1,Pine_young; 2,Pine_mature; 3,Spruce_young; 4,Spruce_mature; 5,Fir_young; 6,Fir_mature; 7,Larch_young; 8,Larch_mature; 9,Cedar_young; 10,Cedar_mature; 11,Dwarf_pine; 12,Birch_young; 13,Birch_mature; 14,Aspen_young; 15,Aspen_mature; 16,Birch_shrub; 17,Sparse_forests; 18,Harvested_areas; 19,Burnt_areas; 20,Grassland_tundra; 21,Bogs; 22,Water; 23,Meadows/Agr_Land; 24,Rocks; 25,Settlements; 26,No data.

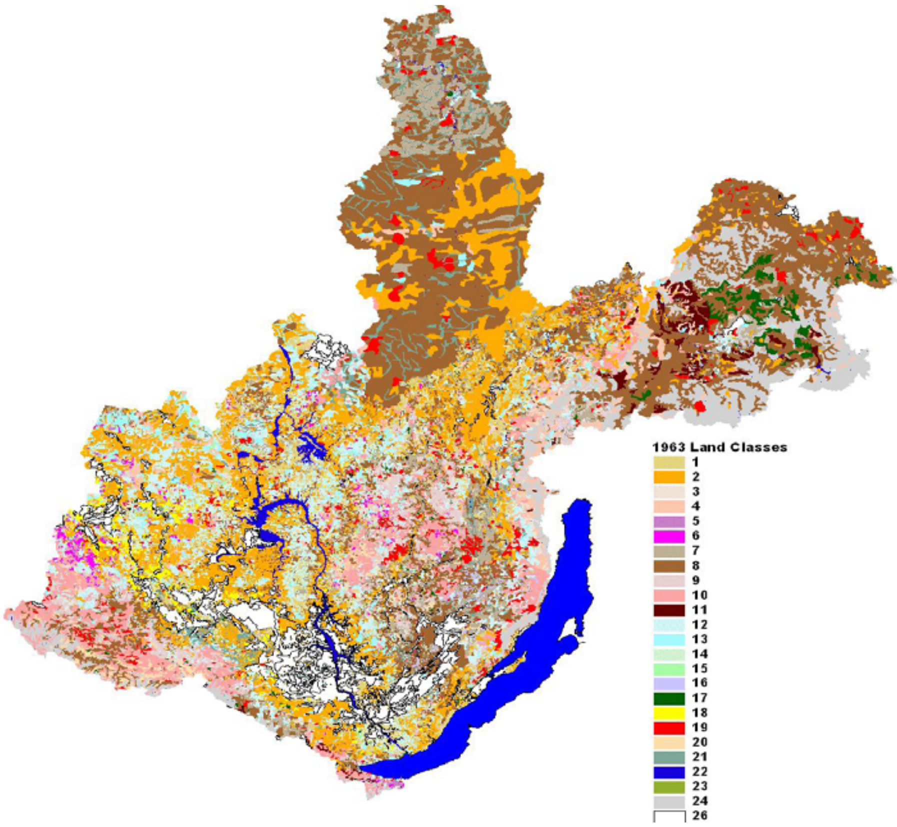


Figure 7: Land classes in Irkutsk oblast according to forest inventory of 1963 (see legend below).

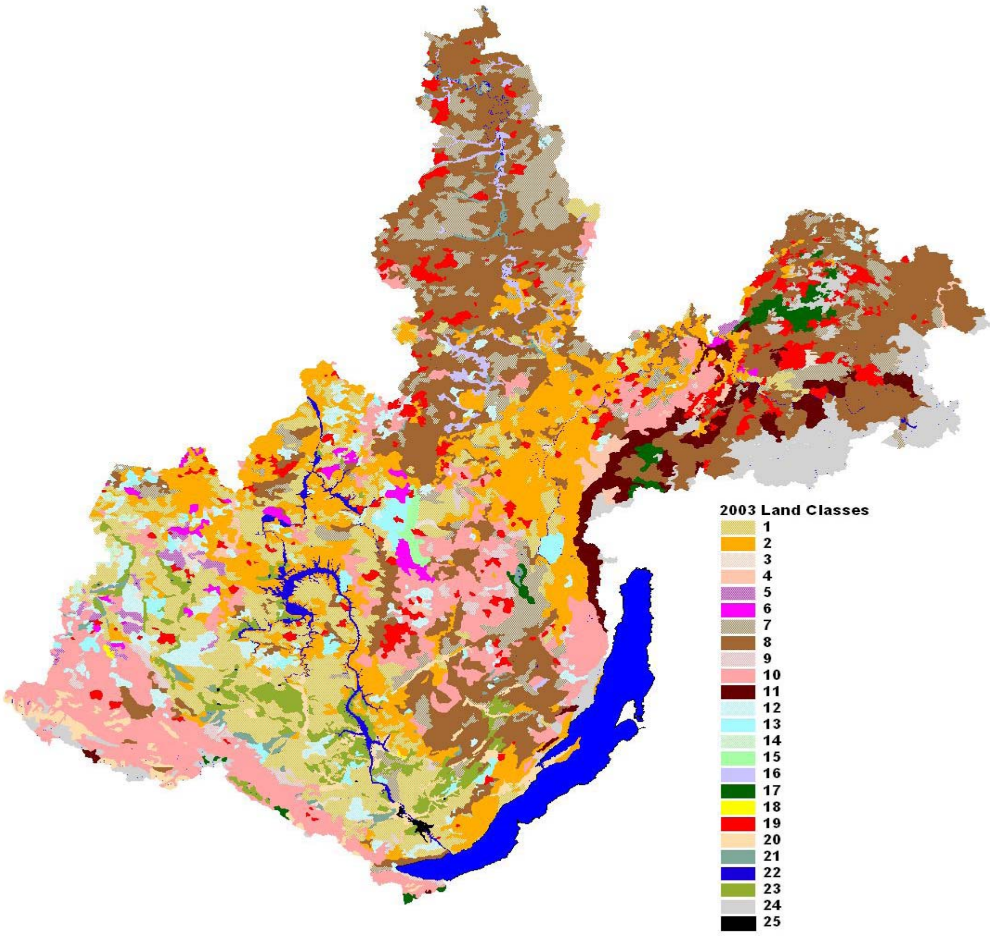


Figure 8: Land classes in Irkutsk oblast according to forest inventory of 2003 (see legend below).

4.3.4. Internet-based Version of the IRIS GIS

The goal of the Open Geospatial Consortium (OGC) is to promote standard open software interfaces. These interfaces will enable geoprocessing so that different geospatial systems are able to communicate with each other. Consequently, the IRIS spatial database is implemented as a 3-tier architecture with a database server, a web server and a client application. The application server acts as an OpenGIS-compliant web services layer on top of existing data sources. The main technical goal of IRIS was to bring GIS functionalities into web browsers by using recent developments of WMS, WFS or WCS standards.

The client-server model is used, where an IRIS user can connect to IRIS web services operating on a remote system through the internet protocol suite. IRIS GIS data are hosted on the University Jena Geodatainfrastructure filesystem (server) and are assessable as

- OpenLayers based WebViewer Client on
  Url = www.iris.uni-jena.de/maps

OpenLayers based WebViewer Client was chosen to view all important data which have been integrated in the IRIS OGC Web Service infrastructure (see Figure 9). IRIS maps web page is thus able to load map data from its core services such as:

- NEESPI Giovanni
  - http://gdata1.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance_id=neespi
- NASA Web Fire Mapper
  - http://maps.geog.umd.edu/firms/default.asp
- SIBESS-C GeoServer
  - http://argon.geogr.uni-jena.de/geoserver/wms?
- NTsOMZ Web-Portal
  - Ntsomz.ru
- OpenStreetMap
  - http://www.openstreetmap.org/openlayers/OpenStreetMap.js

Additional services (selection):

- JPL GlobalLandsat Mosaic
  - http://t1.hypercube.telascience.org/cgi-bin/landsat7
- Google Maps
  - http://maps.google.com/maps?file=api&v=2&key= (key site-specific)
- Virtual Earth
  - http://dev.virtualearth.net/mapcontrol/mapcontrol.ashx?v=6.1
- Yahoo! Maps
  - http://api.maps.yahoo.com/ajaxymap?v=3.0&appid=euzuro-openlayers
- Metacarta
  - http://labs.metacarta.com/wms-c/Basic.py?

The GIS database already developed for the Irkutsk region by the Institute for Applied Systems Analysis (IIASA) together with a number of Russian institutions includes a number of layers (landscape, soil, vegetation, forests, utilities), which are effectively used for the goals of the regional information system on environmental protection and anthropogenic-driven risk assessment. In order to serve as a basis of IRIS, the GIS require adapting to recent technological standards such as Web Map Services (WMS), Web Coverage Services (WCS) and Web Feature Services (WFS).

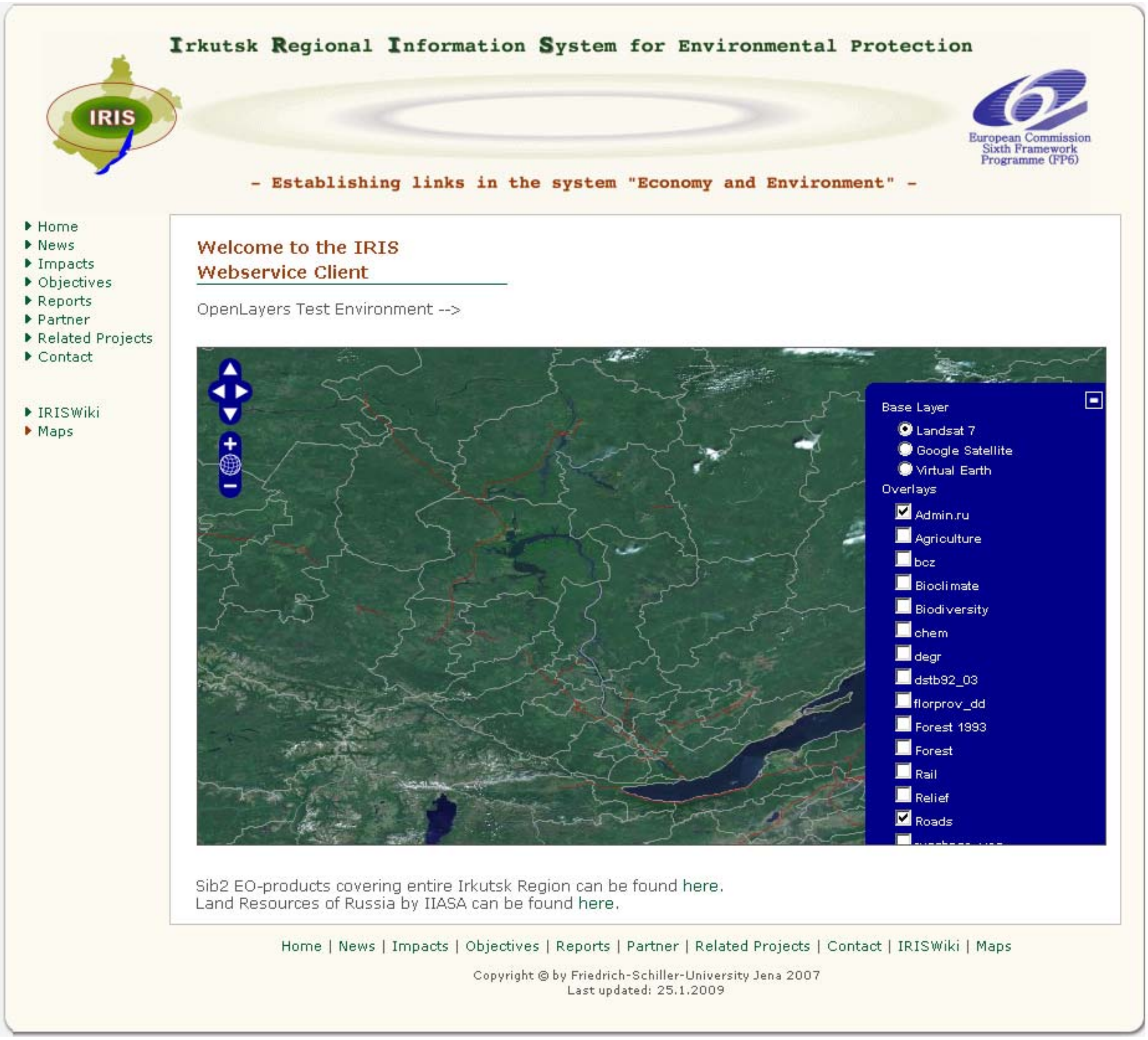


Figure 9: IRIS Web Service: Browser-based client OpenLayers allows to assess multiple Web Services www.iris.uni-jena.de/maps

- GeoServer - Mini-map preview of the enabled FeatureTypes (FSU Jena)
  Preview maps as OpenLayers, KML, GeoRSS, PDF, SVG:
  Url = http://argon.geogr.uni-jena.de/geoserver/mapPreview.do

- Web Map Service or Web Feature Service (FSU Jena)
  wmsUrl = http://argon.geogr.uni-jena.de/geoserver/wms?
  using any OGC compliant GIS client.

A secure ftp system has been adopted in February 2007:

- Secure FTP (SFTP via SSH2)
  Url = ftp://angara.geogr.uni-jena.de

4.3.5. NTsOMZ Catalog

The created Irkutsk Regional Information System (IRIS) should assure for regional users (for regional authorities, ecology commissions and forest regulation organizations) searching and receiving space information of different processing levels. NTsOMZ is providing a wide dissemination of information

among users through their active information system. The system provides a remote sensing data catalogue, a data set archive and dissemination tools. This information system provides user interfaces with the General Catalogue on the base of the NTsOMZ WEB-portal (www.ntsomz.ru). Users can realize data selection, booking and receiving archived space data.
The General Catalogue includes several NTsOMZ own catalogues of Russian and foreign satellites (“Resurs-01”, “Meteor-3M”, “Ocean”, “Monitor-E”, “Resurs-DK1”, “TERRA”/ “AQUA”) and other organization catalogues (“Resurs-Ph” of State Center “PRIRODA”, “ERS-2” and “TERRA”/ “AQUA” of Kyanty-Mancy Center UNIIT). NTsOMZ archive (a robot library) incorporates raw images and standard level of processing (L1B) images. The General Catalogue incorporates image metadata in agreed formats. Thus the General Catalogue presents content descriptions of different archives. The information supplemental system is a user guide for data selection, booking and receiving archive space data including thematic products of high processing level.

Regional users can receive results of stream processing of MODIS/TERRA/AQUA (in HDF-format), transforms and products of operative thematic processing. These thematic products could be used as GIS products for regional monitoring systems and for regional projects. It can respond with NDVI-maps, RGB-composites, FIRE-products and etc. These products could be used for operative fire discovery and fire monitoring, for assessment of burnt areas, for snow, agricultural and forest monitoring.

Now regional users have access to satellite “Resurs-DK1” catalogue and can book data with 2-3 m resolution. The General Catalogue NTsOMZ has power of dynamic integration with data of different services and regional monitoring systems. It extends users provision ability with environment state information via dynamic interface. Example of Resurs-DK1 catalogue dynamic integration with FIRE database of Russian Forestry department is shown in Figure 9.

So the future research activities and initiatives for the development of the efficient simulation and IRIS management tool can be application-specific. NTsOMZ General Catalogue is ready for space data applications for practical use by Irkutsk governance and nature-protection services and for the management of risks associated with man-made changes and anthropogenic forcing of the forestry.

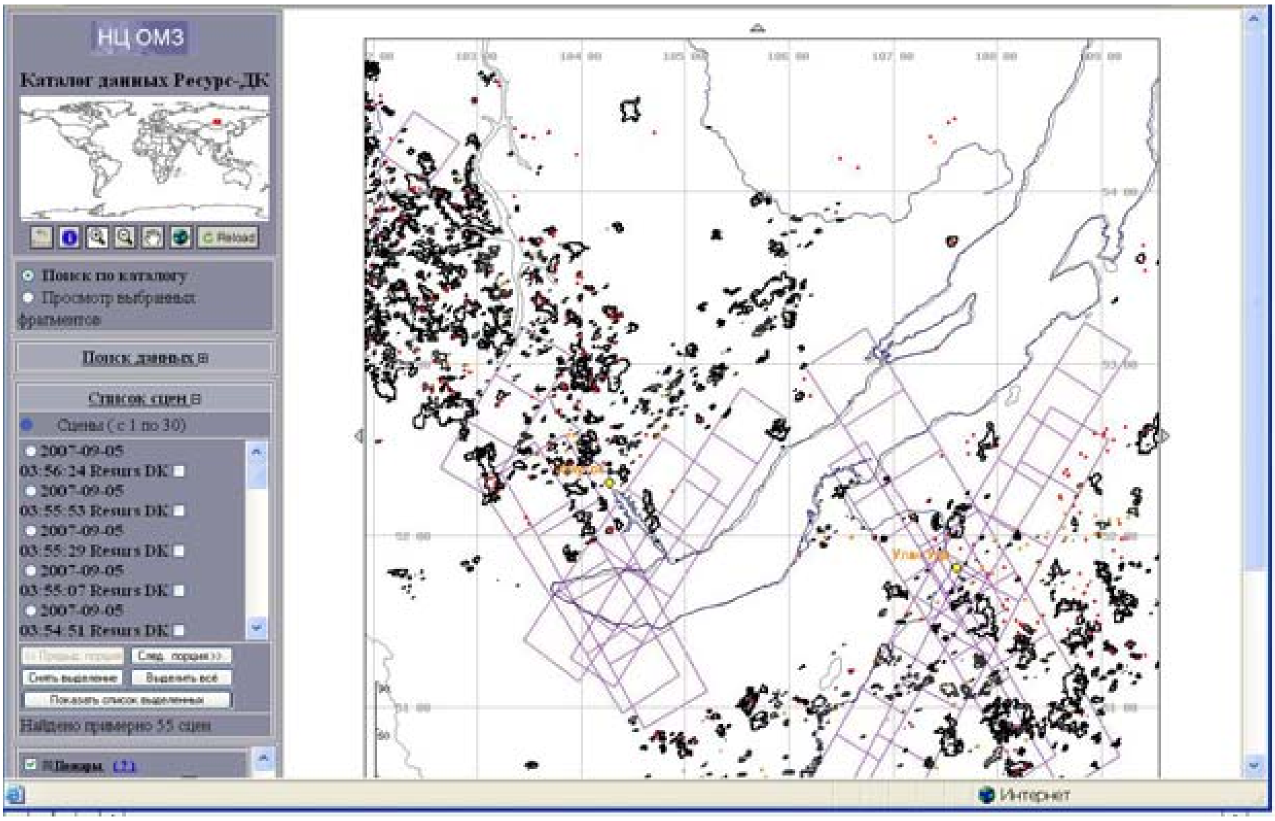


Figure 10: Design of Resurs-DK1 catalogue combined with FIRE data from Russian Forestry department database. www.ntsomz.ru

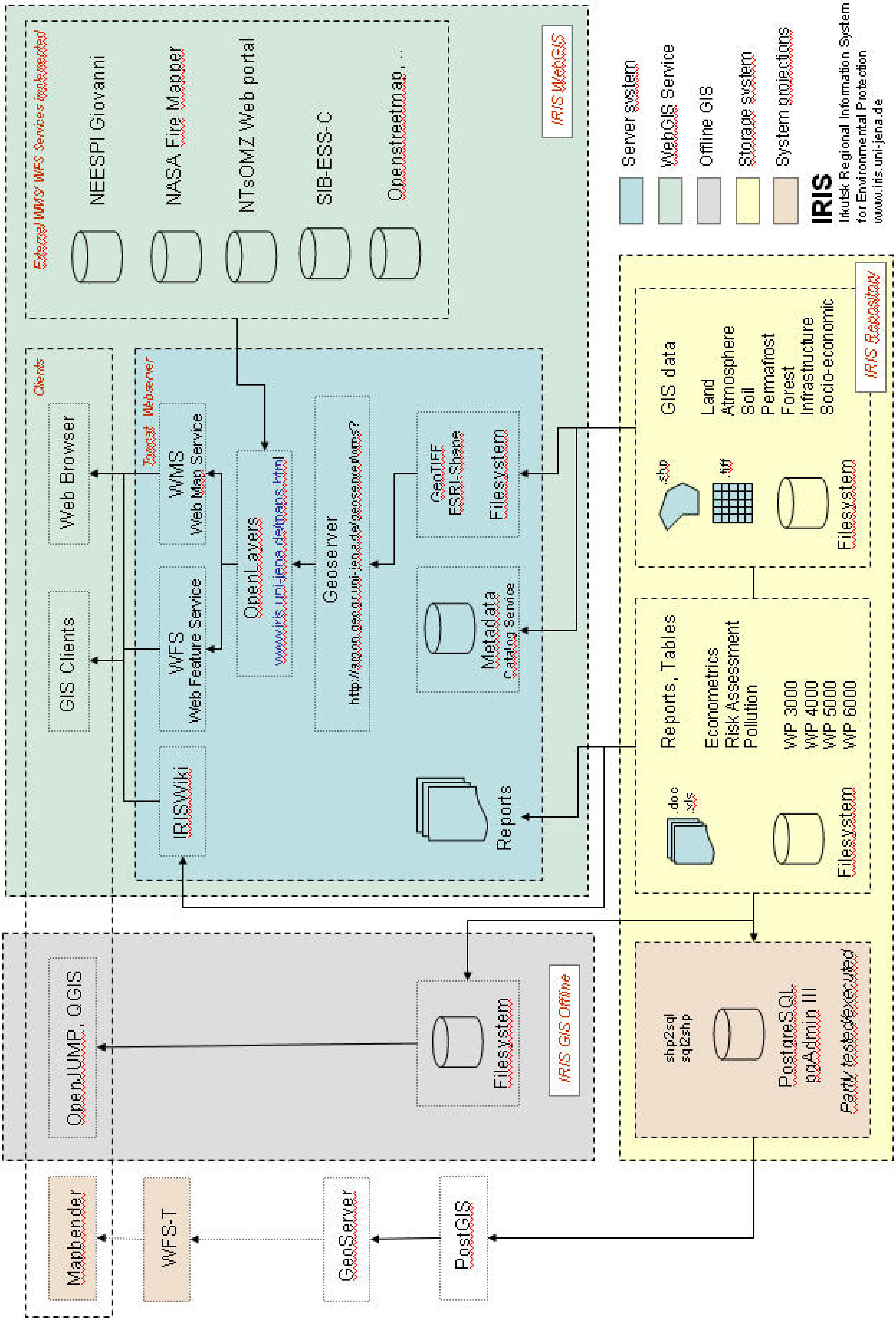


Figure 11: Overview of the IRIS technical concept and implementation.

4.3.6. Standalone version of the IRIS GIS

4.3.6.1. Desktop applications

More sophisticated in terms of spatial analysis are GIS Clients as desktop applications. Several open-source software packages have been evaluated (for example gVSig, Ilwis, Spring, SAGA ore uDig). Mostly all of the named tools are based in common open source libraries.

OpenJUMP (http://openjump.org) is an open source GIS software written in Java. It is based on JUMP GIS by Vivid Solutions:

- it is a vector GIS that can read raster as well,
- OpenJUMP is known to work on Windows, Linux and Mac platforms, but should work on any operating system that runs Java 1.5 or later,
- it is not just another free demo viewer, but you can edit, save, analyze etc.,
- it provides a GIS API with a flexible plug-in structure, so that new features are relatively easy to develop around the sound mapping platform,
- it utilizes standards like GML, WMS and WFS,
- it is free (under the GPL license).

Advantages: OpenJUMP has a good Graphical User Interface (GUI) and is very simple and intuitive. The Add-Ins functionality allows keeping the software updated and increasing their capabilities by means of using 3rd party plug-ins. It reads almost all the known file formats and allows the connection with Geoservers and Web Services.

Disadvantages: Sometimes stability is not ideal.

4.3.7. Implementation and Recommendations

4.3.7.1. Solution for the IRIS Online-GIS

The client-server model is used where an IRIS user can connect to IRIS web services operating on a remote system through the internet protocol suite. IRIS GIS data are hosted on the University Jena Geodatainfrastructure filesystem (server) and are assessable as

- OpenLayers based WebViewer Client on
  Url = www.iris.uni-jena.de/maps

- Web Map Service or Web Feature Service on
  wmsUrl = http://argon.geogr.uni-jena.de/geoserver/wms?
  using any OGC compliant GIS client.

4.3.7.2. Solution for the IRIS Offline-GIS

Assessing the entire IRIS Repository (filesystem) using a GIS Client which is both, compliant to connect with web-based spatial resources and which reads all of the vector files, allows the use of raster files, with a very well improved functionality. Recommend **OpenJump** for vectorial processes, enhanced with plug-in to customize it to the current user needs.

4.4. Environmental Risks to Forestry Due to Man-Made Changes (WP5000)

The main objective of this WP is an assessment of the risks for forestry due to man-made changes, industrial, agricultural and tourism pollution. The tasks comprised a risk assessment through account of the pollution-induced damage to the forest ecosystems. The identification of pollution sources in WP3000 along with the integrated land cover information generated in WP2000 and WP4000 allowed a systematic analysis of source-cause interactions of pollution-induced environmental impact. Using the geoinformation capabilities of GIS, a geographical optimization approach was accomplished which integrated pollution source location, strength and impact. Sources are industry, logging and agricultural practices as well as locations of attracting large tourist activity. Thus recommendations become possible to minimize environmental hazard.
All the information has been acquired, implemented and used within concepts of econometrics (see D.6.1), a statistical framework for the estimation of region's economic outcome under consideration of so-called 'environmental and social costs'. Parameter collection and model formulation have been the main tasks within this WP.

4.4.1.Report on risk assessment due to man-made changes

Major drivers which substantially impact dynamics of forest territories, state and functioning of forests are forest fire, and following processes of post disturbance reforestation of the damaged areas. Fire is an inherent factor of dynamics of taiga forest cover and occurs here periodically from prehistory time. Industrial harvest of forests started in the region about two hundred years ago, with substantially increased areas for the period from 1950s. From 1956 to 2003, burnt areas exceeded the clearcut areas at about 3 times, and, in some periods, the ratio between burnt and harvested areas reached 8. Dead stands generate the third major driver land category of damaged forests. Reasons for the death of forests are outbreaks of dangerous pests; air pollution; and hurricanes that cause windfall (Vaschuk and Shvidenko, 2006). This Section contains information and short analysis of the impact of major anthropogenic and natural drivers on the region's forests.

The main work in WP5000 has been done within the framework of econometrics, where ISC undertook an attempt to estimate quantitatively the contribution of the Lumber Industry Complex (LIC) into the economy of Irkutsk Province, to determine how essential the factor of ecological pollutions is while estimating and forecasting the Gross Regional Product (GRP) of the region (see D.6.1).

The key problem is the issue of an adequate measurement of the region's economy functioning. This should be done not only by taking into account so-called environmental costs but also a certain number of factors describing the public welfare. ISC therefore developed:

- A model of regional and branch systems analysis and forecasting (see D.6.1)

Along with this model ISC delivered a multitude of environmental-related data such as:

- The territory, source and amount of environmental pollution and
- Public well being (measured as the state of human health) according to the territory.

Substantial parameter data sets are a prerequisite to assess both, the environmental impacts and the social costs of these impacts while such a LIC operates. The main goal thus was the consideration of 'environmental and social costs' in estimating and forecasting the Gross Regional Product (GRP).

Please note that the deliverable ⇒ *D.5.1 Report on risk assessment of man-made changest* has mainly been developed in table format for database integration. Issues adressed:

  - District
  - Number of sources of influence
  - Major factors of ecological risk
  - Industries which are major pollutants
  - Ecological risk: conventional areas of industrial influence onto the environment

4.4.2. Report on risk assessment due to industrial impact

The *Report on risk assessment due to industrial impact* (Project Deliverable 5.2) has been developed in table format for database integration. Issues adressed:

Presence of old, unsuitable and/or forbidden pesticides in Irkutsk region's facilities in 2002:

- District,
- Chemicals name,
- Class of chemical substances,
- Class of toxicity (WHO),
- Kind of packaging (container),
- State of packaging (of containers),
- Weight, kg.

Erosion of soils due to agricultural activities for:

- District,
- Kind of erosion,
- Degree of erosion of the soil cover, percent.

4.4.3. Report on risk assessment due to agricultural pollution

The agricultural complex in the Irkutsk Province plays a significant role in provision of the population with food (milk, eggs and potato for 100%, meat for 60.8%, vegetables for 97.4%) and acts as the basic work activity in the countryside where about 20% of the population live. The total area of the lands used for the agricultural production comprises about 4% of the regional land fund. Most of it relates to the agricultural purpose lands, a significant amount to the settlement land, and a part is of the industrial and mixed purposes, and forest fund lands.

The Ust'-Orda Buryat Autonomous County (UOBAC) has been the most developed in terms of Agriculture: 40% of its area comprises agricultural lands. Only Alarsky and Nukutsky districts, which are part of UOBAC, relate to the agricultural type in the land fund structure (a share of agricultural lands is 65 % and 58 % correspondingly), a share of lands used for agricultural activity in other districts of the province does not exceed 10-18 %. The production of agricultural products within the borders of Irkutsk province in the central ecological zone, which is directly close to the lake Baikal, is rather insignificant.

The Irkutsk province's Agriculture is not one of the branches of high ecological danger according to the level of impact onto the environment. At the same time this kind of economic activities negatively influence the environment: Agriculture's influence results in a degradation of the fertile soil layer, erosive processes develop, natural environments get polluted by harmful substances, including highly toxic, vegetation and fauna changes, and the conditions of evolution of many kinds of organisms change too.

The estimation of influence of agricultural production onto the environment of Irkutsk province has been carried out through the determination of ecologically dangerous lands. Those include housing, eroded and plowed lands, and the lands in a zone of impact of cattle-breeding complexes.

The Agro-industrial Potential of Irkutsk province is presented in Figure 12.

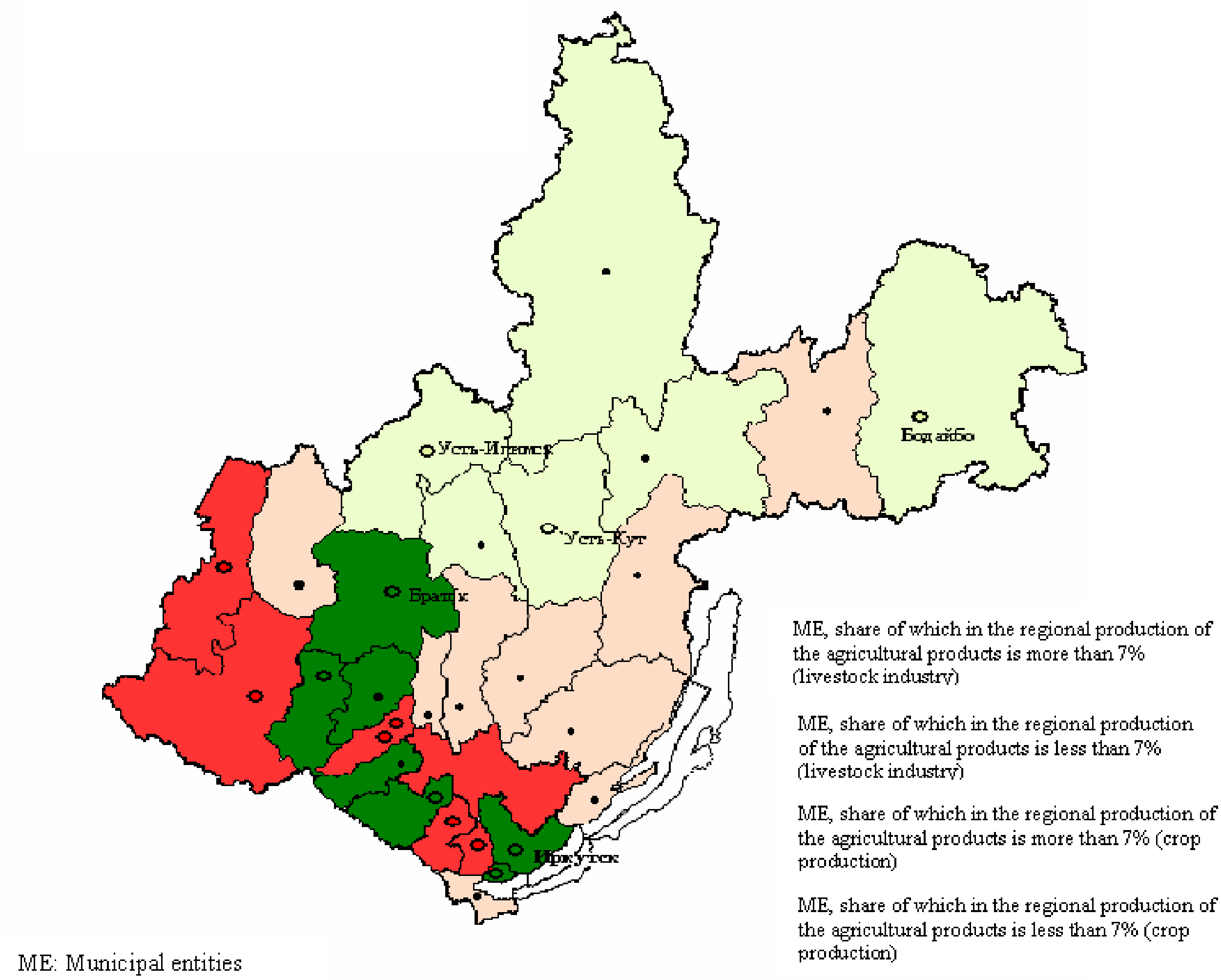


Figure 12: Agro-industrial potential of Irkutsk Province

4.4.3.1. Erosion and deflationary processes

There is a strengthened development of erosive processes observed in Irkutsk province: about 42 % (in Osinsky district up to 64 %) of the agricultural land is impacted by erosion in the most developed agricultural regions Ust'Ordynsky Byryatsky Autonomous County (UOBAC). As a whole, there are 25 % of eroded agricultural lands in the province, developed water and wind erosions, which are quite common together (5.5 % of the area of agricultural lands in UOBAC, 2.4 % on average in the province).

The water erosion especially widely occur s within the borders of UOBAC, Ust'-Udinsky and Kuytunsky districts and in lands located on the Irkutsko-Cheremkhovskaya plain also. The total area of the land impacted by water erosion is 10.6% of agricultural land area of the province and about 14% of arable land. The deflationary processes in the province influence about 11% of agricultural lands and 15% of arable land. These values vary significantly in different parts of the territory, the greatest amount of the wind erosion is observed in UOBAC (22% of agricultural lands and 29% of arable are damaged). Besides that, there is a process of humus horizon of soils washout observed in agricultural land of the autonomous region: a share of medium and strongly eroded soils in average in the county comprises 5.2% of the area impacted by the erosion. In the rest of the territory of the county those processes rarely appear.

There are 23 and 31 % of agricultural land impacted by the erosion in Cheremkhovsky and Usol'sky districts accordingly, the deflationary processes dominate (58% and 87% of agricultural lands damaged by the erosion in Cheremkhovsky and Usol'sky district accordingly). A degree of erosion feature of agricultural lands in Kuytunsky district comprise about 14%, the processes of plane washout prevail (about 87%). There are 47% of the agricultural lands damaged in Olkhonsky district, mostly due to the development of deflationary processes (up to 70 or even 80 %, including sites with a combined occurrence of water and wind erosions, of the area of eroded lands of the district). There are active erosive processes present in approximately 40% of agricultural lands in Ust'-Udinsky and Balagansky districts, and with planar washout dominating.

A quarter of agricultural land has been impacted by the erosion in Kachugsky district, here, besides the dominating processes of the washout (about 73% of the area of the eroded lands), the wind erosion quite intensively occurs (up to 25%). About 20% of the lands in Zalarinsky district are impacted by the erosion, a third of these are damaged as a result of deflationary processes occurred, the remaining part is subject to water erosion. 12.4% of agricultural lands in Irkutsk district are impacted by erosion, the deflationary processes prevail above water-erosive ones, and 12.2% are in Zhigalovsky district. 6.9% are damaged with the water erosion in Nizhneilimsky district, about 9% of the agricultural lands - in Ust'-Kutsky district. 4.2-5.3% of the area of the agricultural lands in Tulunsky and Ziminsky districts is eroded mostly due to the washout of the humus horizon of soils (71-97%).

The erosion processes are poorly developed within the borders of Bratsky, Tayshetsky and Nizhneudinsky districts (a share of the damaged agricultural lands does not exceed 1-3 %). The soil management is practically not developed in Katangsky, Bodaybinsky, Mamsko-Chuisky and Slyudyansky districts due to the adverse soil-bioclimatic conditions, the erosive processes in the agricultural lands are not studied yet.

The report *Risk assessment due to agricultural pollution* (Project Deliverable 5.3) has been developed in table format for database integration. Issues adressed:

- District,
- Share of agricultural lands in total area, percent,
- Agricultural potential specialization,
- Existing and potential kinds of the negative influence onto the natural environments,
- Level of the ecological risk resulted from agricultural activity, a share of lands in ecological danger,
- Level of ecological risk resulted from summer cottage and gardenning complex.

4.4.4. Report on risk assessment due to tourist activities

4.4.4.1. Role of tourism in social and economical development of Irkutsk Region

Nowadays tourism contribution to regional economical indicators is insufficient (the contribution of tourist sector to Irkutsk region GRP was only 0,5% with a potential of no less than 10% in 2006), tourism did not get a respectable place in Irkutsk region economy and is not one of the leading sectors of the region.

Nevertheless, existing tourist potential of Irkutsk region, its geographic location, economical and political situation, forecasted incoming and internal tourist flows are prerequisites for a noticeable rise of tourism role in the economy of Irkutsk region. In all regional strategies of socioeconomic development (official and alternative) [3-5] tourism is being discussed as one of important directions which can provide significant improvement of living standards and leadership of Irkutsk region in dynamics of economic development of the Russian Federation constituent entities. For several territories of the region tourism is almost the only kind of economic activity which is able to provide positive economic and social effects and compensate for economic losses related to rough ecological economic activities restrictions caused by implementation of "About preservation of Baikal lake" federal law.

4.4.4.2. Tourist potential of Irkutsk region

The Irkutsk Province has significant set of recreational resources primarily due to happy blend of vast little-developed territories with different and unique natural landscapes. Total area of protected territories is about 2.4% of Irkutsk region area; those territories include Pribaikal'sky National Park, two nature reserves (Baikalo-Lensky and Vitimsky), and 13 wild life sanctuaries of regional importance. Natural monuments are 78 natural objects having scientific, historical, aesthetic and cultural role.

There are rich supplies of unique hydromineral resources (the largest in the world Angaro-Lensky artesian basin of mineral waters with estimated supplies of 2700 km^3; moreover, about 300 of mineral springs are proved along with 6 mud lakes) and special recreation object - Baikal Lake and its coast.

Rich natural and recreational potential of the region makes it possible to develop different types and forms of natural tourism such as recreational, informative, adventurous, sports and extreme, hunting and fishing, religious, ethnical and ethnographic tourism.

Recreational tourism includes beach rest, cruise and treatment tourism. At the moment it’s a prevailing form of tourism which is actively developing on the following territories: south shore of Maloe more and island Olkhon; settlement Bolshoe Goloustnoe; Peschanaya bay; coast of Bratskoe More; coast of Irkutskoe More; coastal line of Slyudyanka region, settlement Listvyanka, Severobaikal’sk. Possibility of “cruise tourism” development in the region is defined by existence of such water objects as Baikal Lake, Bratskoe More, Irkutskoe More, and Angara river.

Informative tourism is tourist visits of historical and cultural monuments, tourist territories and objects of cultural heritage. Except Irkutsk, one of the cultural and historical centers of East-Siberia, tourist resources are Olkhonsky, Kachugsky and other districts. There are interesting industrial objects in Irkutsk region territory including Krugobaikal’skaya railroad, Irkutsk and Bratsk hydro electric power stations, Baikal-Amur Mainline zone. From the position of the best accessibility of Baikal coast ad developing tourism infrastructure settlement Listvyanka stands out greatly.

Adventurous and extreme tourism includes alpinism, mountain climbing, mountain hiking, backpacking, and cycle touring develop on the vast territories of mountain taiga territories (Hamar-Daban, Primorsky, Sayan Mountains, Olhinskoe plato). Cataracted rivers Utulik, Irkut and others are interesting for rafting.

Hunting and fishing tourism is a kind of adventurous tourism. Its potential is based on a variety of areas, mostly located far from the center of Irkutsk region (Kachugsky, Jigalovsky, Chunsky, etc).

Sports tourism includes different types of tourism competitions (ski-, water-, mountain-, and cave tourism). This kind of tourism potential is in areas with more or less developed sports infrastructure: Irkutsk, Angarsk, Shelekhovo, Bratsk, and other big cities with fixed-site large sports objects of multipurpose use: Sludyansky district, Sayansk, Listvyanka, Shelekhov district – mountain skiing complexes.

Religious, ethnic and ethnographic tourism is travelling to do some kind of religious procedures, missions, vows and an acquaintance with religious, cultural and everyday way of life of local residents. Irkutsk region has relevant potential presented by Russian orthodox heritage, buryat shamanism and Lamaism (Irkutsk, Olkhon, and Ust-Ordinsky districts).

Tourist activity impacts the environment incoherently, and this influence has complex character, which makes the task of estimation of its kinds and a degree complicated enough. Practically, any kind of recreational activity finally takes all components of landscapes in a time, and division of problems, related to the tourism development, is rather conditional.

The spectrum of possible influences can be presented as follows:

- triggering of erosive and deflationary soil processes, condensation of the soil cover;
- pollution of surface and subsoil waters;
- fires;
- not regulated forest cuttings;
- reduction of species and of the biological variety population;
- deterioration of sanitary conditions of territories,
- influence onto the landscapes and landscape structure of territories;
- influence onto the aesthetic (landscape, "specific") properties of a landscape.

The impact of the tourism onto the environment depends on scales and a type of recreational-tourist activity, and on a sustainability of nature complexes and environments to the type of impact. In Figure recreational development of the most tourist attractive areas of Irkutsk province is presented.

The modern situation in Irkutsk province is that, the tourism development, especially of the unorganized tourism, contradicts to the issue of the territory protection and rational usage, first of all, of the coasts of the lake Baikal. Scales of the harm, produced by amateur tourists to the nature complexes and territories adjoining to the lake Baikal, constantly increase[4]. The areas, which are the most perspective for the tourism development (Pribaykalsky national park and coast to the east from Baikalsk city, Maloe Morie and Olkhon island), can be considered as the zones of complex infringement and pollutions now, and Malomorskaya zone especially due to the degradation of nature landscapes under the influence of a mass uncontrollable tourism. The Federal law regulating economic activities in Baikal area[5], encourages transition to the recreational wildlife management, to the country-wide development of tourism, rest and resort business (article 12). The law does not consider tourism as a powerful anthropogenous factor, capable to harm the lake Baikal's ecosystem. At the same time, the quantity of negative anthropogenous impacts onto the environment increases every year, the scales of the harm made to the nature complexes by tourist activities increase. It is related to the limitation of recreational capacity of specific territories, and to the uniqueness and originality of some natural communities, and to an increase of tourism intensity.

Conflicts of recreational wildlife management are present in the acute way in outskirts of cities and rural settlements, as a consequence of urbanization, and in territories directly adjoining to nature sanctuaries also, which are object of the raised tourist interest.

The factors generating ecological risks while developing tourism:

- a low level of ecological culture, characterizing a society, which is reflected directly, on one side, in aspiration for a momentary profit instead of long-term ecologically sustainable aims when organizing tourist business, and, alternatively, in the approach of tourists to the organization of their own rest;
- the effective indicators of recreational capacity of territories are not stated legally and in norms in the Irkutsk province, as well as, norms of alienation of the areas of natural complexes for recreational usage and norm of recreational load; a stream of organized and unorganized tourists, regulated by no one flows in aesthetically attractive places, the development of settlements and recreational objects in the lake Baikal area is chaotic, in many cases facilities are constructed without corresponding sanctions right on the water's edge;
- the state of the tourist and household infrastructure in territories of Irkutsk province mostly does not meet the modern world standards;
- the solution of the issue of collecting, utilization and processing of the household wastes, resulted from small-sized fleet, tourist stationary bases and amateur tourists is in embryo state; there are no equipped effectively coastal facilities for its utilization and processing

4.4.5. Summary

An overall initial approach to assessing the theoretical background of risk assessments has been undertaken and presented. A detailled risk assessments depends on the availability of validation data of high quality. Within the IRIS project and according to the project's workforce, no mathematical assessment according to risk theory was performed. This would be the task of a follow-on research project. Main focus was therefore on an assessment of the risks for forestry due to man-made changes. Moreover, industrial, agricultural and tourism pollution have been explained. Good progress was achieved for an agreed approach to conceptual documents on risk assessment and satellite-based EO information and a very extensive EO database has been set up. A synergistic assessment of the human impact on the Irkutsk region environment is the main outcome. Impact maps (also in digital format) have been included in the IRIS Information System.

[4] V.M. Hromeshkin. Imperatives of the Baikal tourism. Irkutsk, 2008

[5] Federal Law # 94-FZ dated May 1, 1998)

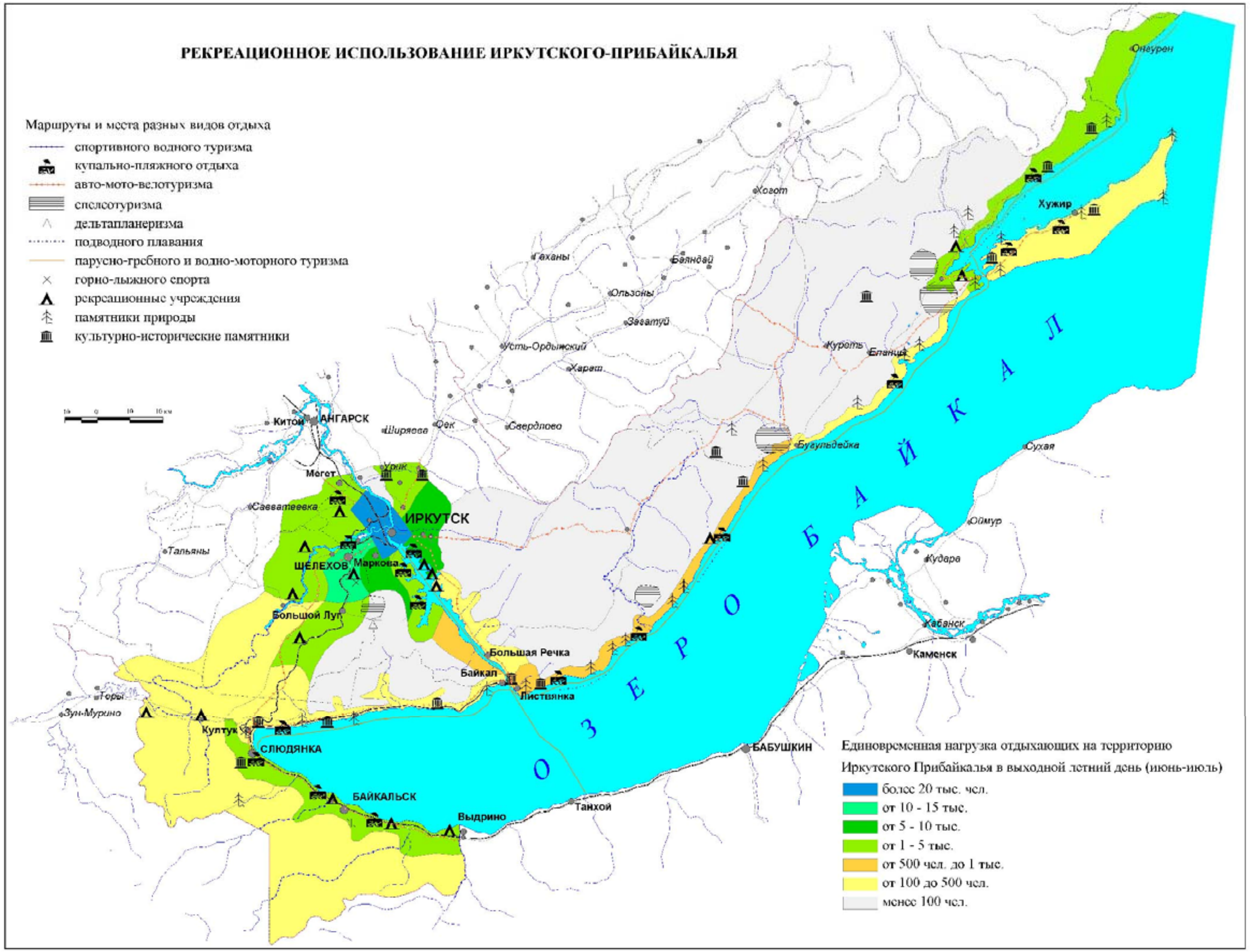


Figure 13: Recreational use of Irkutsk's Pribaykalye Area

4.5. Prospective Studies and New Research Initiatives (WP 6000)

The prospective studies for the IRIS Information System have three main aspects:

- to outline a set of scenarios of the possible economic development of the Irkutsk region from the viewpoint of environmental protection (for future input into the development of IRIS system);
- to prepare detailed research activities and initiatives for the development of the regional information system as an efficient simulation and management tool (IRIS) for practical use by regional governance and nature-protection service(s),
- to disseminate information about current status and planned development of the IRIS Information System among potential end-users and other interested entities, and to analyze feedback for future improvement of the system characteristics.

4.5.1. Technical Report on the Characteristics of the Economic Structure of the Region

The main work has been done within the framework of econometrics, where Partner 5 (ISC) undertook an attempt to estimate quantitatively the contribution of the Lumber Industry Complex (LIC) into the economy of Irkutsk Province and to determine how essential the factor of ecological pollution is while estimating and forecasting the Gross Regional Product (GRP) of the region.

The key problem is the issue of an adequate measurement of the region's economical functioning. This should be done not only by taking into account so-called environmental costs but also a certain number of factors describing the public welfare. ISC therefore developed:

- A model of regional and branch systems analysis and forecasting.

Along with this model ISC delivered a multitude of environmental-related data such as:

- the territory, source and amount of environmental pollution and
- public well-being (measured as the state of human health) according to the territory.

Substantial parameter data sets are a prerequisite to assess both, the environmental impacts and the social costs of these impacts, while such a LIC operates. The main goal thus was the consideration of 'environmental and social costs' in estimating and forecasting the Gross Regional Product (GRP).

As above-mentioned, IRIS is integrating methods of econometrics, a framework to estimate quantitatively the contribution of specific industrial branches, here the Lumber Industry Complex (LIC) into the economy of Irkutsk Province. Econometrics is concerned with the tasks of developing and applying quantitative methods to study Economics principles. One of the fundamental statistical methods used in econometrics is regression analysis. Regression methods are important because economists typically cannot use controlled experiments. The ISC has developed a regression model for estimating and forecasting the Gross Regional Product.

4.5.1.1. Econometric analysis - Conclusions

The econometric analysis conducted in the framework of the IRIS project allows the following conclusions:

- The statistical dependency of the GRP produced by the LIC from the solvent demand created in the LIC, the pollutions made by the LIC, the cost estimation of the LIC's products, and fixed assets used in the LIC, turned out to be significant under all the factors, thus:
- the solvent demand results in the growth of the province's regional product and is the most significant factor of the growth of the society's wealth;
- the pollutions paid for (enterprises are obliged to pay for the environmental contaminations, which exceed the limited by the state values, as penalties) are the factor positively influencing the well

being of the society. It is explained by the fact, that with an increase of pollutions, the deductions into the budget grow the production grows;

- the process of the deforestation is organized inefficiently: there is a high share of unaccounted cuttings, a smaller output of the wood products per square meter in comparison to the developed countries, a resource oriented export, a smaller margin profit from the functioning of the production;
- the increase of the quantity of the permissions to pollute results in the fall of the well being of the society: the growth of the unpaid pollutions, the growth of the uncompensated harm to the environment;
- the GRP values were obtained with consideration of the harm made to the environmental degradation, an inefficiency use of the resource and a fixed assets usage.

Using the geoinformation capabilities of the IRIS GIS, a geographical optimization approach can be accomplished which integrates pollution source location, strength and impact. Sources are industry, logging and agricultural practices as well as locations of attracting large touristic activity. Thus recommendations become possible to minimize environmental hazard.

Within priorities set by the expected impact on the forest resource, effective use of econometrics in forecasting forest resource development has been demonstrated and some assessment of uncertainties in the calculations have been performed. Underlying this activity has been a substantial amount of development in both the assessment of negative impacts from pollution sources and the environmentally adjusted, LIC-oriented econometrics approach by Partner 5 (ISC).

4.5.2. Concept and Strategy for Future Development of the IRIS Information System

The future development of IRIS system aims at the creation of the efficient simulation and management tool for practical use by regional governance and nature-protection services for the management of risks associated with man-made and climate changes and anthropogenic stress affecting the forestry environment of the target region through the atmosphere and land runoff.

The general strategy of IRIS' further development consists of the application of the models of the pollution transport to the data sets, characterizing the Irkutsk region with the subsequent risk assessment for Irkutsk environment.

These models should be upgraded and tuned for this specific region, and working both under elaborated, actual scenarios of possible industrial and socio-economic development of the Irkutsk region, and under anticipated climate changes in the region, taking into account the pollution from the adjacent areas. Such a system should be facilitated both by simulation tools including pollution transport models, climate change projections, digitized scenarios of socio-economic and industrial development of the region, risk assessment instruments, and by actual data on the pollution sources in the region and the adjacent areas. Integrating all the tools and data into a joint consolidated system with developed user-friendly interface should give a flexible instrument for risk investigation, running various scenarios of the climate change in the considered area and Irkutsk Region development.

This powerful system should allow decision makers from the regional governance and nature-protection services to estimate potential risks arising from anthropogenic forcing according to chosen scenarios, taking into account projected climate changes, and to initiate nature-preservation measures.

The general concept of such a system development consists of dedicated interconnection and integration of the following major blocks:

1) Initial Geo Information Systems as the result of the IRIS project containing a Forest Environment GIS for the Irkutsk Province; a Pollution Sources and Other Anthropogenic Factor GIS; and Stress Factor Layers;

2) sets of tools ensuring consistency and actuality of the IRIS GIS data;

3) comprehensive models of the pollution transport in the system air – vegetation – soil – water, derived from upgraded models that are tuned for Irkutsk region separate pollution transport systems;

4) sets of scenarios for the possible industrial and agricultural development of the Irkutsk region and adjacent areas;

5) climate change projections for the region;

6) risk management tools.

The interconnection and interaction of these blocks can be presented schematically as follows in Figure14.

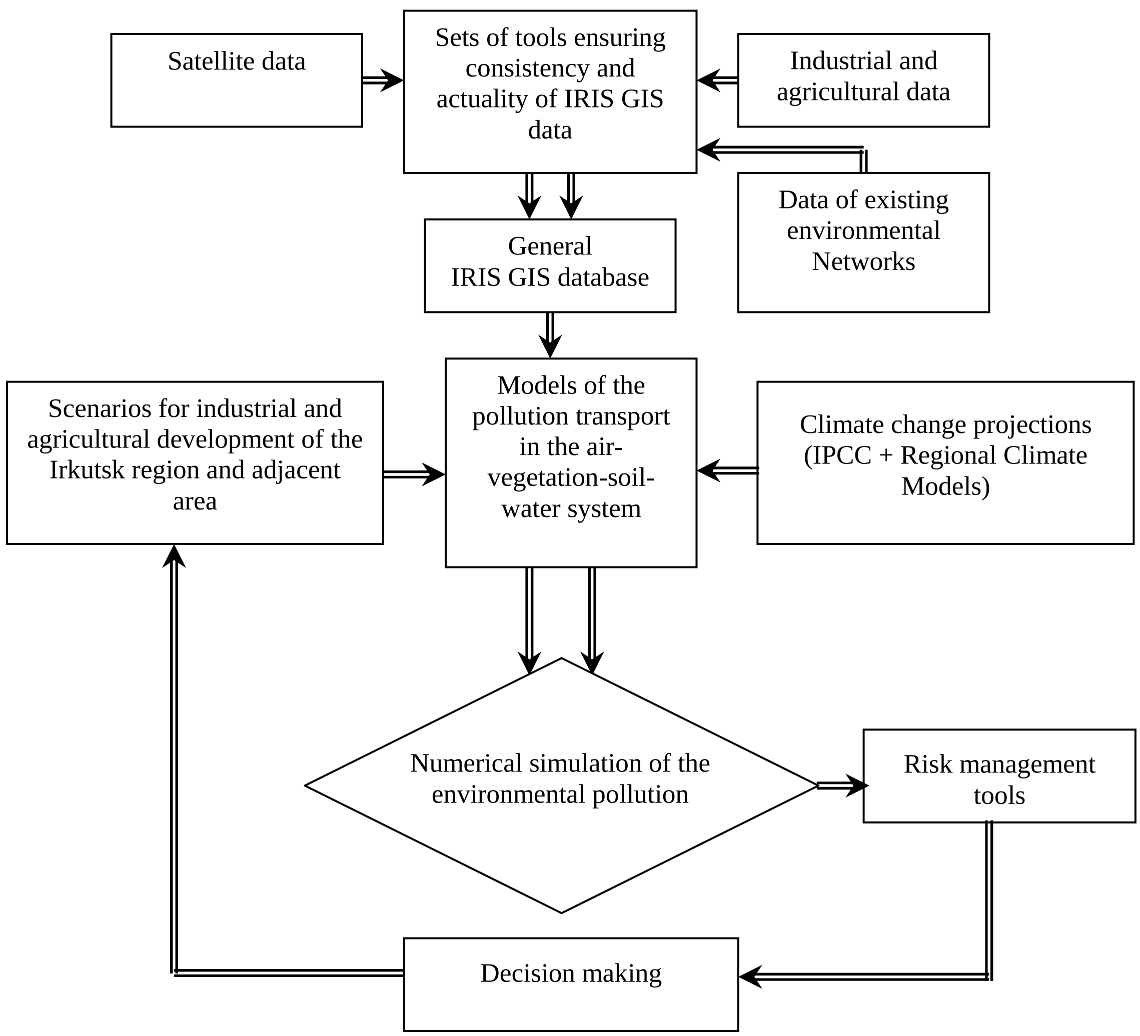


Figure 14: The general strategy of IRIS further development

4.5.3. Objectives of the Proposed IRIMS Development

General objective of the proposed work can be defined as:

Development and implementation of the powerful Irkutsk Region Information and Management System (IRIMS) as an administration and operation tool for decision makers from regional governance and nature-protection services exploitation for the management of risks associated with man-made and climate changes in the Irkutsk region.

Specific objectives can be distinguished as:

1) to develop a system of up-to-date scenarios for a possible sustainable industrial and agricultural development for Irkutsk region and for adjacent areas, possessing a function of its periodically upgrading;
2) to calculate, using IPCC scenarios, Irkutsk Region climate model projections and create the database of significant to IRIS climate changes;
3) to construct the comprehensive model of the pollution transport in the system air – vegetation- soil – water, combining upgraded and tuned for the Irkutsk region existing pollution transport models for separate systems
4) to simulate the pollution transport from natural, industrial, forestry and agricultural sources through the air – vegetation- soil – water system, using this new consolidated powerful pollution transport model, IRIS GIS, scenarios for Irkutsk region development and calculated climate change projections;
5) to assess and investigate the risks for the Irkutsk Region associated both with anthropogenic changes and with climate changes;
6) to integrate IRIS GIS, developed in the frame of the current project, with all newly developed blocks of numerical modeling, system of upgraded scenarios, climate change database and risk assessment tools into new powerful Irkutsk Region Information and Management System (IRIMS) with developed user-friendly interface;
7) to ensure IRIS GIS permanent upgrading;
8) to handover and implement IRIMS to the Irkutsk Region Governmental Authorities.

4.5.4. Future IRIMS Work Tasks

The **main work tasks** which need to be fulfilled to reach the objectives are seen as the following issues:

1. elaboration of the analytical model system for the sets of scenarios for the possible industrial and agricultural development of the Irkutsk region;
2. working out the configuration of the system facilitating IRIS GIS with up-to-date data support and renewal;
3. creation of the database of the main atmospheric pollutants from the adjacent to Irkutsk regions (Krasnoyarsk Territory, Yakutia, the Chita Region, Buryatia, the Republic of Tuva);
4. elaboration of the comprehensive model of the pollution transport in the system air – vegetation-soil – water, combining upgraded and tuned for the Irkutsk region existing pollution transport models for separate systems;

5. analysis of runs of IPCC models and Regional Climate Models for the Irkutsk Region to construct the database of possible climate change projections;
6. determination of the risk assessment tools to be included into IRIMS;
7. elaboration of the unified format and program language for all program modules (PM) for the defined elements of IRIMS;
8. programming IRIMS program modules;
9. integration of all PMs into the whole IRIMS with the development of user-friendly interface for data upgrading and display, supporting scenarios actual, running them and estimating risks aiming at the effective Irkutsk region management and final decision making.

Task 1. <u>Elaboration of the analytical model system for the sets of scenarios for the possible industrial and agricultural development of the Irkutsk region</u>

In the frame of the current project it was supposed to outline a set of scenarios of the possible economical development of the Irkutsk region from the point of view of environmental problems. In the proposed research the set of scenarios should be transferred into an economic-mathematical analytical model which can be used in the Irkutsk Region Information and Management System. The general content of work will be the transfer from the qualitative description of socio-economic scenarios to their quantitative realization applying the theory of mathematical modeling and analysis of socio-economic scenarios of development. This will require both determination of the social and economic characteristics of the region (key variables) which are mostly influencing the environment, especially Irkutsk Region forests, and formulation of the suggestions of ways by which industry, agriculture, social factors, technology, economic forces, politics and other factors may go and shaped by the chosen scenario theme.

Specific requirements: the institution which is supposed to conduct this work should have an expertise and experience in economical modeling and work in close connection with Irkutsk Region authorities.

Task 2. <u>Working out the configuration of the system facilitating IRIS GIS with up-to-date data support and renewal</u>

This work relates to the creation of the Data Network, feeding IRIS GIS with up-to date data on forest environment. This Network should be composed from:
1) open source satellite data of high resolution;
2) existing environmental Networks of in-situ data.

The web site at special Irkutsk region forest server will be organized for data keeping, archiving and browsing after receiving. The data format and the way of their managing will be defined in the process of this work fulfillment. One of the new elements comparatively to existing GIS will be the data from new instruments which are being launched regularly. Also a lot of data are becoming available from year to year. Special investigations will be needed aiming at revealing the new sources of data.

Technical requirements: powerful computer server for data keeping

Task 3. <u>Creation of the database of the main atmospheric pollutants from the adjacent to Irkutsk regions (Krasnoyarsk Territory, Yakutia, the Chita Region, Buryatia, the Republic of Tuva)</u>

As in the frame of the current project, this work will consists of the collection of the information on actual and potential sources of atmospheric pollution in the adjacent to Irkutsk region areas - Krasnoyarsk

Territory, Yakutia, the Chita Region, Buryatia, the Republic of Tuva - and standardization of collected information to be put into additional layers of developed IRIS GIS. Besides, special investigation should be conducted aiming at the revealing dominant winds over the territory and estimation of the distance needed to be considered when searching the sources of the main atmospheric pollutants, affecting trees and forests. The forest pollutants will be further specified. Beside nitrate, sulfate, ozone, carbon and ammonium, other additional aspects of air pollution that affect trees and forests are other oxidants (nitrogen dioxide, sulfur dioxide), heavy metals, chlorofluorocarbons through stratospheric ozone depletion and increased UV-B radiation and aerosols that reduce photosynthetically active radiation should also be included into consideration.

Task 4. Elaboration of the comprehensive model of the pollution transport in the system air – vegetation- soil – water, combining upgraded and tuned for the Irkutsk region existing pollution transport models for separate systems

One of the central components of the proposed activity aimed at IRIS development is the mathematical modeling of the processes of pollution transport in various media with the following analysis of their movement and transformation in dependence on the determined and random factors. The specific features of all the environments are their multi-component structure, non-linearity, anisotropy and significantly changing in space and time physical and chemical characterizing parameters. Besides, to fulfill such modeling it is necessary to solve the problem of hydro-meteorological field retrieval due to the absence of regular observations over the whole territory. Therefore, hydro-meteorological processes modeling and pollution transport simulation refer to the tasks requiring development of effective numerical algorithms.
To elaborate the comprehensive model of the pollution transport in the system air – vegetation- soil – water it will be necessary to interconnect all the models for the transport of multi-component gaseous pollutants and aerosols in various environment from the pollution sources up to their suppression in the forests and transmission through soils into ground waters and then into rivers and Lake Baikal. The following activities are foreseen:

- Realization of the numerical modeling of the anthropogenic pollutants probability distribution for the main pollution sources for the Irkutsk region and adjacent territories;
- Regional processes modeling using: quasi-static three dimensional model of the regional atmospheric processes, baroclinic model of storm katabatic winds and the model of local winds over Baikal;
- Numerical modeling of gaseous pollutant and aerosol transport and transformation basing on regional models;
- Modeling of atmospheric pollution forcing on the forest ecosystems in the Irkutsk region;
- Mathematical modeling of the surface drainage and pollution transport in soils;
- Simulation of the pollution transport in the rivers;
- Numerical modeling of the hydro thermo dynamical processes and pollution transport in Lake Baikal;

Task 5. Analysis of the results of IPCC AR4 models and Regional Climate Models for the Irkutsk Region to construct the database of possible climate change projections

- Creation of a model-data archive based on multi-member super-ensemble GSM simulations which can be directly used for the further analysis. A set of the IPCC AR4 GCM simulations, including simulations of the climate of the 20th century, and projections for the 21st century under the three SRES scenarios: A2, A1B and B1.

- Extraction of the information concerning Irkutsk region from the model outputs
- Evaluation of the output from the model experiments for targeted area by assessing how well they simulate the present climate and select the models reasonable reproduce climate of the targeted area.
- Analysis of future changes in climate parameters over Irkutsk region projected by a selected GCM for the 21st century under the three SRES scenarios.

Task 6. Determination of the risk assessment tools to be included into IRIMS

There is a number of risk assessment techniques, methods and tools developed. The choose of the more appropriate one to be included into IRIMS will need a comprehensive analysis of these tools aiming at answering the following questions:

- What is it? – to give a basic description of the method;
- How does it work? - to understand how to complete the method;
- What are the pollution risk estimation indicators? - to get the summary of risk indicators used in the method;
- How to interpret the results? – to grasp an explanation of how the results can help decision makers;
- What are the limitations of the method?
- Can the method be programmed and integrated into IRIMS?

Task 7. Elaboration of the unified format and program language for all program modules (PM) for the defined elements of IRIMS

Task 8.. Programming IRIMS program modules

Task 9. Integration of all PMs into the whole IRIMS with the development of user-friendly interface for data upgrading and display, supporting scenarios actual, running them and estimating risks aiming at the effective Irkutsk region management and final decision making

5. Impact

In March 2009, a public meeting will be held in Irkutsk for local authorities, nature-protection services and other organizations potentially interested in the IRIS Environmental Information System since the major objective and overall goal of this project, the foundation for implementation of a powerful tool for risk assessment and environmental protection, has been successfully concluded.

The IRIS Information System can help to assess the impact of pollution on the forest environment of the Irkutsk province and foster sustainable management of the land resources. It is useful for officials of the Russian Federation at different levels of state hierarchy, i.e. at regional level (Irkutsk), inter-regional level (since neighbouring areas are also included in the IRIS GIS as present and potential sources of pollution) and federal level (e.g. management of federally controlled nature resources and stress on the environment by enterprises held in federal property).

The IRIS Information System can also serve as a prototype of a Regional Information Systems for other territories of the Russian Federation. Indeed, adaptation of the developed components of IRIS to local conditions of other regions is a straightforward task because of the modular structure of the GIS and the rational organisation of connections between the system modules.

5.1. Impact of the IRIS Earth Observation Data Base

The technical nature of the results from the EO database has substantial socio-economic meaning and practical implications outside of the project. The collected satellite data of the IRIS Project represents comprehensive characteristics of vegetation, land-use and land-cover, anthropogenic impact and disturbances, generating unique information for managers of this vast and insufficiently monitored region.

The ability to derive biosphere surface parameters from EO at a regional scale has been recently demonstrated by a number of organisations (e.g. LPDAAC). The products which are already derived from the MODIS team, such as Land Cover Type and Dynamics (MOD12C1), Land Surface Temperature (MOD11C3) or Gross and Net Primary Productivity (MOD17A3) can be assessed, adapted and used in the IRIS Information System. Other products (e.g. the forest change map) needed to be generated from EO data to meet the project requirements. The ability to independently derive land surface information from EO data is of great importance to the sustainable land use management.

The accuracy assessment of all data products is critical to policy makers to get an informed opinion on the real value of Earth Observation derived information. In the context of environmental security, knowledge of the accuracy values will provide guidance of the potential improvements that might be achievable by incorporating the data products. For instance, judgements on the transition to sustainable forest management are impossible without such information. Some results, which were received, can be used in various climatic change national and international studies and in Russian forest/land management.

5.2. Impact of the IRIS Econometric Analysis

In the framework of econometrics, the collection and use of data on negative environmental impacts is irreplaceable in at least three aspects:

(1) to identify current pollution sources and natural and human-induced disturbances,
(2) to estimate an environmentally-adjusted GRP, particularly in vast, remote LIC-dominated areas,
(3) to estimate social costs in terms of public welfare while LIC operates.

Coupled with results from the regression model, this allows the development of forecast models of welfare consequences to technological and environmental externalities that will be relevant for post-Kyoto international negotiation processes. Simultaneously, the approach presents operative and reliable information for integrated land management (with regards to associated environmental and economic risks) in particular for organizing a system of forecasting under acceleration of both lumber markets and disturbance regimes in the project area.

Finally, the approach provides unique data for estimating possible synergy in the use of diverse information sources. Comparison of the ISC results for example with EO measurements is important for testing the credibility of the model calculations and increasing confidence in the use of such predictions by policy-makers. In addition, using EO data to constrain econometrics calculations increases confidence in their outputs and hence relevance to policy.

Intensive effort has been spent to produce up to date and accurate datasets on anthropogenic drivers of pollution. All datasets are checked for errors and every effort has been made to ensure that the datasets function properly in the IRIS information system. The econometrics approach has highlighted a number of problems in data availability, e.g. for regionalization. Even if model input data were collected and archived for the entire province, they are not available on a more discrete district basis. Many individual assessments were limited by this constraining factor. Despite these problems, a comprehensive assessment of a large multi-parameter database was performed. The statistics show that the models do provide very useful information on the future development of the LIC and thus on sustainable forest resource development and man-made land cover change. It would have been valuable to have a time-series of EO data (either NDVI or GPP) to assess the spatial-temporal aspects of the results of econometrics.

Partner 5 (ISC) developed an initial draft of a regional branch systems analysis and forecasting approach for operating LICs including various sets of auxiliary data and information of negative anthropogenic impacts on the environment as well as of indicators for social costs of these impacts. The econometrics approach has met its initial objectives and is available in the IRIS-GIS.

Within priorities set by the expected impact on the forest resource, effective use of econometrics in forecasting forest resource development has been demonstrated and some assessment of uncertainties in the calculations was performed. Underlying this activity has been a substantial amount of development in both the assessment of negative impacts from pollution sources and the environmentally adjusted, LIC-oriented econometrics approach by ISC.

5.3. Impact of IRIS in the Context of the Open Geospatial Consortium

One of essential components of the IRIS Information System is an Open Source GIS system. Open Source technology is a growing field that encourages the free sharing of software, codes and services. The goal of the Open Geospatial Consortium (OGC) is to promote standard open software interfaces called OpenGIS. These interfaces will enable geoprocessing so that different geospatial systems are able to communicate with each other. The use of common languages such as XML or GML enables easy integration between systems. OpenGIS supports the easy retrieval of geospatial information in a distributed environment, regardless of physical location of the data. These distributed datasets can then be combined and rendered for display. The spatial data that will be utilized in the IRIS project will strive to meet internationally recognized data standards. Associated high quality metadata increase the value of the system by allowing the user to determine the value of the datasets used in the GIS as well as reliability of the output generated. By conforming to international metadata standards, the IRIS user has access to standardized information about each dataset such as data origin, age, resolution and source. Thus IRIS contributes to a common European standard for satellite data products, model variables and other data.

5.4. Impact of the IRIS Environmental Risk Assessment to Forestry

By the end of 2004, 280 plots in the Irkutsk Province forests were transferred into lease agreements. The leasers harvested 88% of the total amount of wood which was harvested by final felling. The annual amount of wood that was allowed for harvest by the leasers constituted 24.4 million m3 in 2004 (comprising only 46% of the annual allowable cut) and 61% has been used.

The annual number of fires varies greatly – from about 300 to 3500 – and mostly depends upon weather conditions during the fire season. The annual average number of fires during the last 63 years amounts to 1430, but the number of fires is gradually increasing. According to official statistics, 6.85 million ha of forested area have been enveloped by fire during the above period, the annual average burnt area is estimated to be 109 thousand ha, and the average area of an individual fire is 76 ha. However, the statistical fire data does not reflect reality. Sometimes, there are underestimated burnt areas up to 10 times. Remote sensing data for 1996-2003 indicated fires on 4.63 million ha (the annual average burnt area is 0.6 million ha) of forest land. During extreme years, burnt areas amount to about 2 million ha (e.g., in 2003). For the entire period after the first complete State Forest Account in the oblast, the burnt areas exceeded the harvested areas by about 6 times. An overwhelming majority of fires (78%) are caused by humans, “dry thunderstorms” are the cause of 18% of fires, and the reasons for the remainder are not known.

IRIS is designed to meet also the needs of long-term monitoring and will establish therefore a basis for future cooperation in the field of environmental risk assessment and environmental protection. The prototype of the IRIS Information System allows an assessment of state and functioning of the regional forests, to identify areas of rapid changes, which require operative monitoring, and to estimate environmental risk in different aspects.

The research performed will be relevant for environmental security and climate protection. Its wider significance lies in the fact that the boreal forest region is especially vulnerable to climate change and that numerous indications show that this change is already beginning to occur. The implications of these changes for resource management of this large region are fundamental. Risk assessments provide the link between accounting methods and a deeper process understanding.

The IRIS Information System works as an expert system for assessing the impacts of negative anthropogenic drivers on forests to serve as a basis for preparing of programs of new advance studies and research initiatives.

5.5. International and Immediate Impact

The international dimension of the successful project implementation is strongly connected with problems of climate change and sustainable land use management. The Intergovernmental Panel on Climate Change has concluded that human activities in forests can have significant effects on the atmospheric concentration of carbon dioxide. The United Nations Framework Convention on Climate Change of 1992 has the objective to stabilise the greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. The Kyoto Protocol to the UNFCCC is a key policy tool to be used to achieve this and Russia had – as the last and crucial country – ratified the protocol.

Forests act as carbon reservoirs by storing large amounts of carbon in trees, under story vegetation, the forest floor, and soil. In addition, changes in forests, such as the growth of trees, can remove carbon dioxide from the atmosphere. Forests thus can act as a sink for absorbing emissions from human or other natural sources. Conversely, when human activities degrade a forest, both the reservoir and the sink potential are damaged, and the forest can become a substantial source of carbon dioxide emissions. There is no doubt today that the role of the boreal forests is essential. In this context the Siberian taiga, which is the largest forest region in the world, and Irkutsk region as a part of taiga is of vital importance.

The IRIS Information System contributes to ensuring a sustainable ecological, economic and social future of one of the key forest areas of Russia – the Irkutsk Region. It should be stressed here that the IRIS Information System is a lot more than a mere compilation of its parts (GIS, models, scenarios etc.). Matching these parts together allows reaching a qualitatively new level of understanding of response of forest environments to man-made changes and sources of pollution.

The results of the IRIS project, if implemented by the local bodies, may in the longer term contribute:
(i) to maintain the optimal scheme of economic development of the region as a compromise of industrial demands and nature-protection decisions and actions; and
(ii) to foster sustainable forest environment management.

As a result of this public meeting in March 2009, prospective research initiatives for the continuation of the IRIS GIS and databases, the further development of pollution transport models, industrial development scenarios and risk assessments will be formulated since it is the expressed wish of the consortium to continue cooperation.

6. Dissemination and Use

For new EO data sources such as MODIS CMG data, unexpected products have been obtained, such as LST and GPP – both with great potential for large-scale mapping and time-series analyses. EO products have started to be used in the regional and branch systems analysis (econometrics approach) and risk assessment. With these applications, IRIS is proceeding to frontier science results about implementing EO with econometrics and global change tools for an integrated Earth System Science analysis towards environmental security and public welfare.

IRIS results have gained increasing interest due to Russia's recent commitment to the Kyoto Protocol. IRIS results have also been promoted through the coordinator's role in the international GOFC-GOLD and NASA's NEESPI programmes, as well as through ESA's Land Cover Project Office at the coordinator's organisation.

The information accumulated by the project as well as methodological and modelling findings of IRIS can be substantially used by the European Commission e.g. in GEO and GMES plans, and by the European Union e.g. for the Kyoto Protocol. Overall, the IRIS project's international recognition is beyond expectations due to a dedicated partnership, a good project timeline, and a challenging and innovative project goal.

The official project web page (Figure 15) was put online in January 2006 with first information about project objectives, project structure and the project team. With the major layout change a new section provided links to partner institutions and related projects. Close communication links to international programmes exist by means of email communication and participation in meetings.

In order to disseminate the project results the following actions have been performed:

- the IRIS Website (http://www.iris.uni-jena.de) was installed and had been updated bi-monthly with meeting presentation, news, publications and new links (Figure 15);
- a secure IRIS ftp site (ftp://angara.geogr.uni-jena.de) at FSU was implemented and used for project-related documents, data storage and the distribution of project-internal data;
- in addition, IRISWiki (http://www.iris.uni-jena.de/iriswiki/) (Figure 16) now serves as a powerful tool for communication within the project team and for potential IRIS-GIS users;
- we implemented MediaWiki 1.9.3, a free and open source software that is used to organize and facilitate collaborative work;
- due to the strong emphasis on multilinguality in the Wikimedia projects, the user interface has been fully translated into the Russian language.

Figure 15: IRIS Web page (http://www.iris.uni-jena.de)

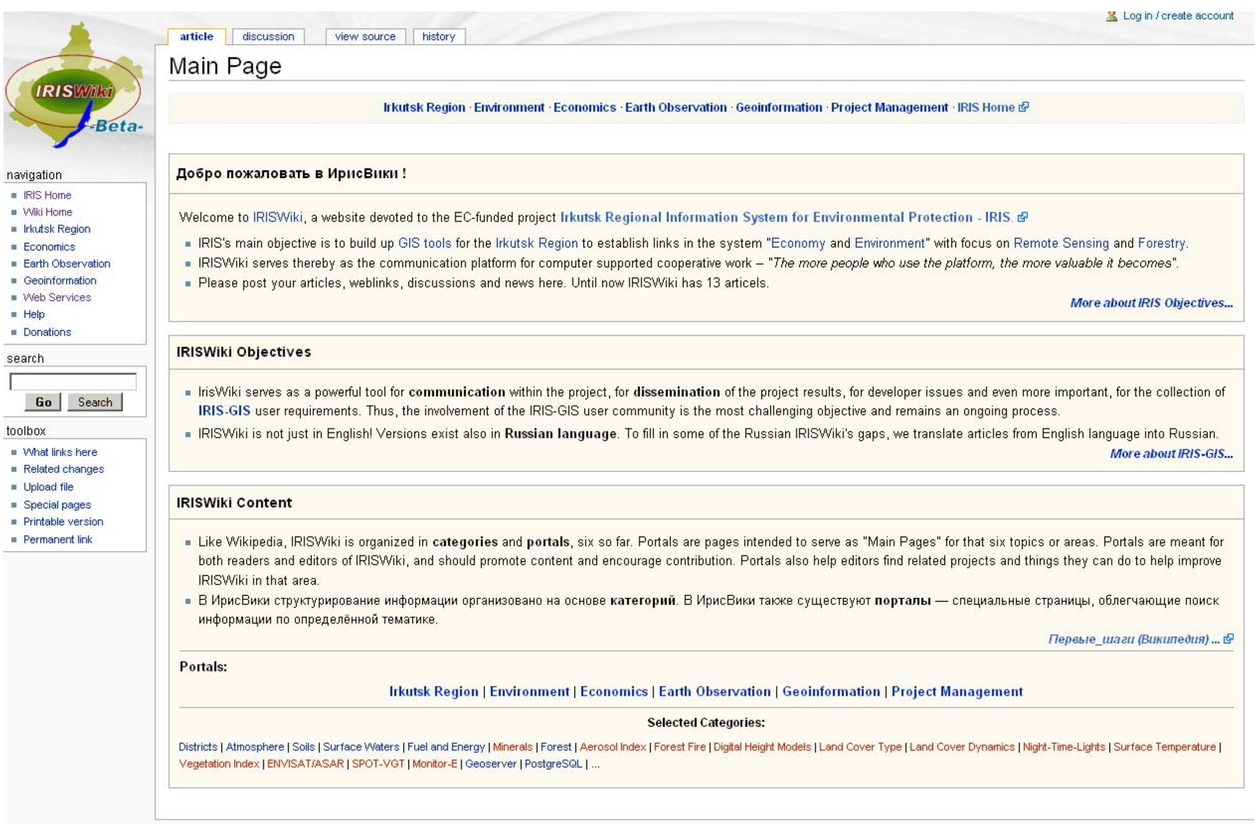


Figure 16: IRISWiki Web page (http://www.iris.uni-jena.de/iriswiki)

Links to External World, other Organizations and Projects

- The link to the Siberian Earth System Science Cluster Programme (SIB-ESSC) was held by attending the SIB-ESSC meeting in September at University of Leicester, UK.
- Contacts to the SibFORD-Team (Earth Observation for Assessment of Forest Disturbances induced Carbon Emissions in Central Siberia) for links with IRIS have been established by attending the SibFORD-Kick-off meeting in February 2007, Potsdam, Germany
- Contacts to the ESA GOFC-GOLD Land Cover Implementation Team for links with IRIS have been established. Participation on the GOFC/GOLD Land Cover Workshops in Ulaanbaatar and Jena.
- Establishment of cooperation between GSE Forest Monitoring and IRIS through joint student work.
- The IRIS project was presented at ENVISAT Symposium 2007 and recommended as a small project out of SIBERIA-II project heritage.
- A shortlist of established links to related projects can be found at: http://www.iris.uni-jena.de/sites/relprojects.html

Project dissemination

IRIS science presentations:

- 2nd International Conference on Land cover/Land use study using Remote Sensing and Geographic Information System, Ulaanbaatar, Mongolia, 8-9 June 2006.

Frotscher, K. & C.C. Schmullius (2006):
Projects and Initiatives addressing Environmental Impact Studies in Northern Mongolia and the Lake Baikal Region. 2nd International Conference on Land cover/Land use study using Remote Sensing and Geographic Information System, Ulaanbaatar, Mongolia, 8-9 June 2006.
http://www.iris.uni-jena.de/reports/iris-ub06.pdf

- ENVIROMIS Conference, Tomsk, Russia, 1-8 July 2006.

Frotscher, K. & C. Thiel (2006):
Forest Monitoring in the Framework of a Regional Information System for Environmental Protection. ENVIROMIS Conference, Tomsk, Russia, 1-8 July 2006.
http://www.iris.uni-jena.de/reports/abst-enviromes06.pdf

- SIB-ESS-C Symposium, 18th-20th September 2006, University of Leicester, UK

Environmental change in Siberia - Insights from Earth Observation and modelling.

- SibFORD Kick-Off, 09-10 February 2007, Potsdam, Germany

The SibFORD (Siberian Forest Disturbance) consortium is meeting for the official opening event under the lead of Prof. C.C. Schmullius.

- ENVISAT SYMPOSIUM, Montreux, Switzerland 23-27 April 2007.

Frotscher, K, Thiel, C. & C.C Schmullius (2007):
The Irkutsk Regional Information System for Environmental Protection (IRIS). ENVISAT SYMPOSIUM, Montreux, Switzerland 23-27 April 2007.
http://www.iris.uni-jena.de/reports/iris-env07.pdf

- IPY GeoNorth 2007 First International Circumpolar Conference on Geospatial Sciences and Applications Yellowknife, Northwest Territories, Canada 19-24 August 2007.

Frotscher, K., Dumov, V, Lipnyagova, R.R., Dayneko, D., Gerlach, R. & Schmullius, C.C (2007):

The Irkutsk Regional Information System for Environmental Protection (IRIS). IPY GeoNorth 2007 First International Circumpolar Conference on Geospatial Sciences and Applications Yellowknife, Northwest Territories, Canada 19-24 August 2007. (Paper submitted.)
http://www.iris.uni-jena.de/reports/iris-north2007.pdf

- European Geophysical Union 2008

K.Frotscher and Ch.Huettig (2008): Mapping gradual changes in boreal forests using MODIS time series. Geophysical Research Abstracts, Vol. 10, EGU2008-A-10568, 2008.

- NEESPI Science Team Meeting, 2-6 June 2008, Helsinki, Finland

K.Frotscher and R. Lipnyagova (2008): The Irkutsk Regional Information System for Environmental Protection (IRIS).iLEAPS

Long-term solution for the IRIS Information System

- Hosting the IRIS repository as tables in an object-relational database (**PostgeSQL**) using spatial SQL to provide high performance queries for mixed spatial/non-spatial as well as raster/feature queries.

- Making such **high-performance queries** assessable by using geo data server. (Besides GeoServer the 'deegree' framework with its WMS, WFS and WCS components is supposed to be running.)

- **MapBender** (http://www.mapbender.org) based WebGIS Client instead of GeoServer would allow feature-based modifications such as boundary digitization via WFS-T. IRIS would become a comprehensive project to create a free editable map on the base of reliable satellite-based, multi-product and area-wide information.

- A Communication Platform (**IRISWiki**) has already been designed to enable anyone who accesses IRIS to contribute or modify content and to promote meaningful topic associations in terms of science, economy and society.

Follow-on proposal activities

Due to the pronounced wish of the project partners to continue cooperation, two follow on proposals have been/are being submitted:

1)"ECV-Lab: Establishing an ECV Data Archive of a Climate Hot Spot", Call Title: FP7-SPACE-2009-1,
2) "IRIMS: Irkutsk Information and Management System", Call of the German Ministry for Education and Science (BMBF) for Sustainable Land Use Management.

CD with the offline version of the project website for public use:

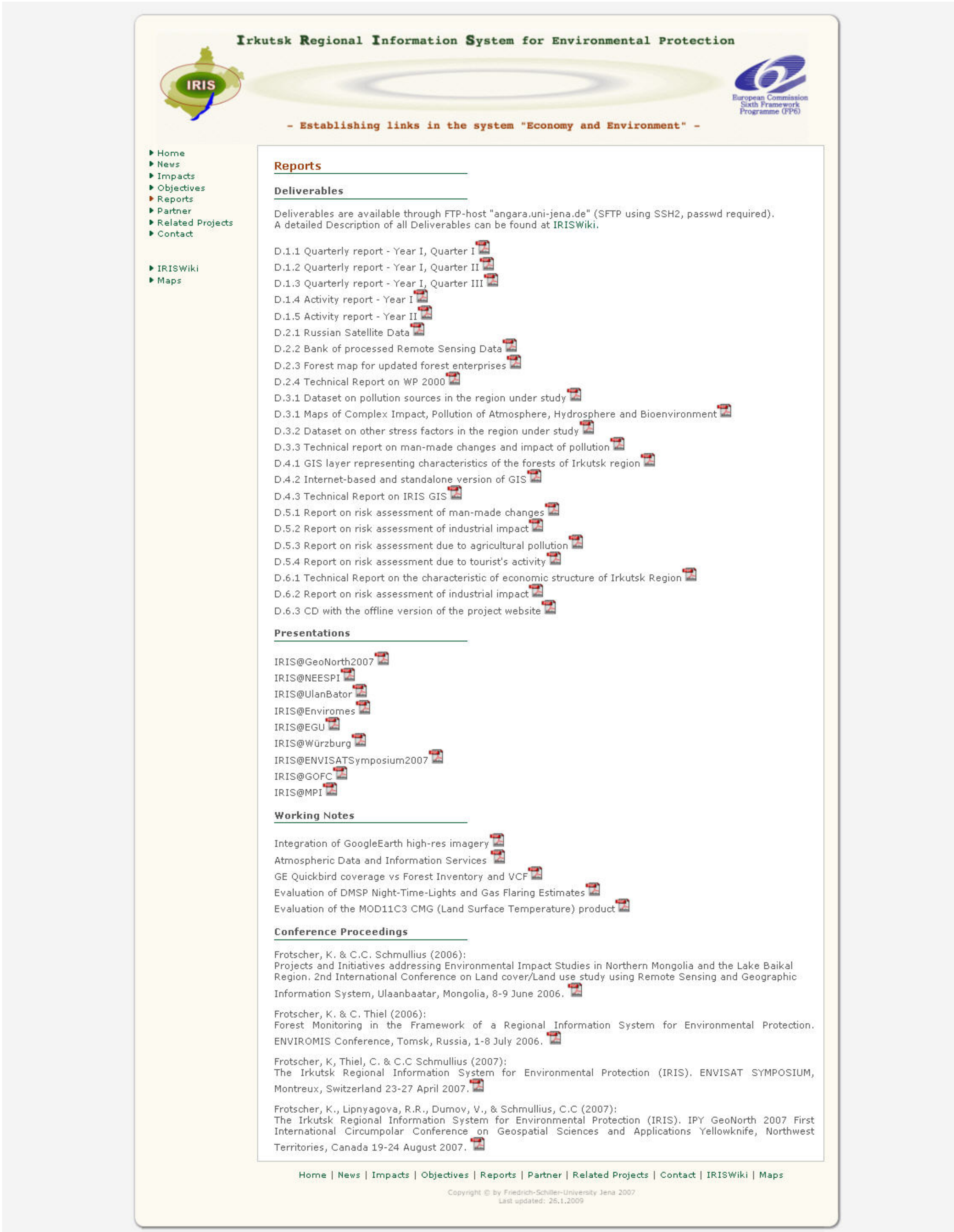


Figure 17: Part of the offline version of the project website with all reports available in PDF-format.