ZAPÁS

Assessment and Monitoring of Forest Resources in the Framework of EU-Russia Space Dialogue

Progress Report III

By

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Content

1 Publishable summary

1.1 Summary description of project context and objectives

Abstract

ZAPÁS (Rus.: Запас) – was chosen as project acronym since this Russian word is used in forest terminology for growing stock volume or forest stock, which is one of the envisaged products of this project. Addressing the important issue of assessing forest resources in the boreal zone, particularly in Siberia, the ZAPÁS project is aiming to actively support the EU-Russian Space Dialogue. ZAPÁS delivers innovative procedures and new products for forest resource assessment and monitoring using jointly ESA and ROSCOSMOS satellite data. In accordance with the FP7 call SPA.2010.3.2-01 EU-Russia Cooperation in GMES (SICA), ZAPÁS focuses on the synergistic exploration of Earth Observation (EO) data provided by ESA and ROSCOSMOS and on the exchange of methodological know-how in processing Earth Observation data.

The geographical focus of research and development within the ZAPÁS project is Central Siberia, which contains two administrative districts of Russia, namely Krasnoyarsk Kray and Irkutsk Oblast. The project team aims at developing Earth observation products at two geographical scales. Improved regional scale land cover and biomass maps will be derived for Central Siberia to (a) improve existing coarse scale land cover databases, (b) link them with biomass information from medium resolution Radar imagery, and (c) use these up-to-date land-cover and forest resource geo-information as input for a full carbon accounting. The results of the terrestrial ecosystem full carbon accounting are addressed to the Federal Forest Agency as federal instance. The high resolution products comprise biomass and change maps for selected local sites. These products are addressed to support the UN FAO Forest Resources Assessment as well as the requirements of the local forest inventories. The team consists of a balanced distribution of leading experts from Europe and Russia. The Russian partners come from two geographically different, federal regions: the city of Moscow and the Krasnoyarsk Kray. An external review board, the ZAPÀS Advisory Board (ZAB) has been installed to involve representatives of the Russian space agency as well as the Federal Forest Agency and connect ZAPÁS to the United Nations Forest Resource Assessment 2010 (FRA 2010) and further international programs.

Forest Monitoring in the Framework of the EU-Russia Space Dialogue

Russia, the European Union's largest neighbor, is considered by the European Parliament as a key player in its efforts to protect the global climate and environment. The strengthening of genuine strategic partnerships founded on common interests and shared values are strongly supported. The ZAPÁS project represents such a strategic partnership between well acknowledged Russian and European scientists in the field of Earth Observation with the support, direct involvement and contribution of the Russian and European Space Agencies.

A further important international agreement is the Kyoto Protocol of the UN Framework Convention on Climate Change, providing mechanisms to reduce greenhouse gases and tackle global warming. The intensification of collaboration between the EU and Russia on environmental issues is a welcome step forward in bringing ecological sustainability and social responsibility more to the forefront in economic dealings. This makes the harmonization of European and Russian environmental policies and legislation particularly important. The collaborative development of advanced methods and the exchange of Earth Observation data fully compliant to the cooperation policy established between the EU and Russia.

The ZAPÁS network is involved in international programs such as GEO FCT (Group on Earth Observation – Forest Carbon Tracking), GOFC-GOLD (Global Observation of Forest Cover and Land Dynamics) and NEESPI (Northern Eurasian Environmental Science Partnership Initiative) through which support to international conventions related to the global environmental issues, such as UNCBD, UNFCCC and its Kyoto Protocol, is ensured.

Multi-scale Assessment and Validation of Central Siberian Forest Maps

Looking at the large-sale distribution of the Siberian Taiga, the systematic monitoring of forest dynamics is still challenging. Satellite earth observation is the only alternative for a frequent monitoring of biomass-decreasing processes such as clear cutting, selective logging, fire, insect infestation, but also afforestation and forest succession processes (White et al., 2005; Yatabe et al., 1995; Kasischke et al., 1992).

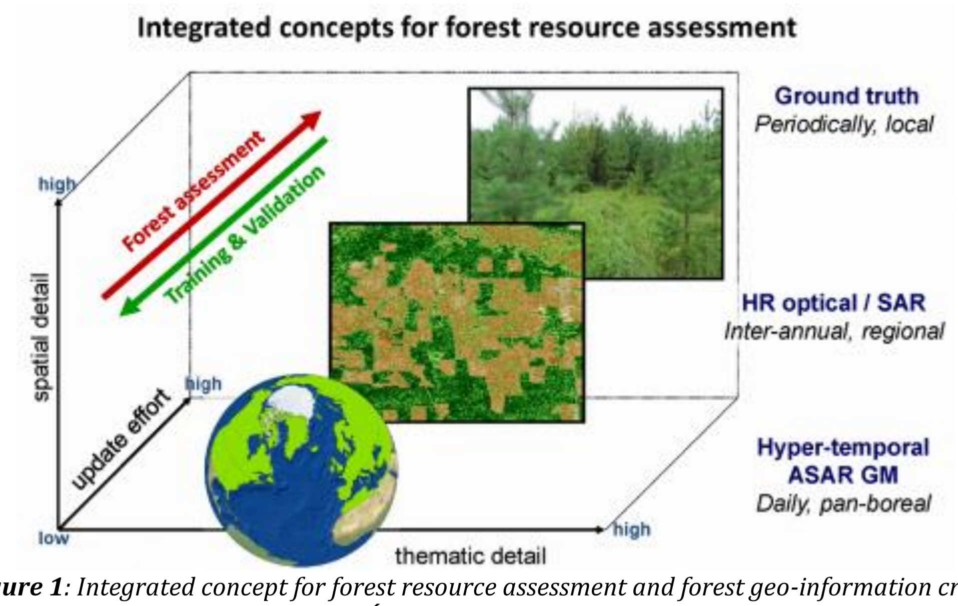

***Figure 1**: Integrated concept for forest resource assessment and forest geo-information cross validation to be implemented by the ZAPÁS project. The graph exemplarily indicates the range of data specifications in terms of spatial and thematic detail in relation to the effort of frequent update.*

ZAPÁS investigates and cross-validates methodologies using both Russian and European Earth observation data to foster the development of a worldwide observation system. The methodologies include state-of-the-art optical and radar retrieval algorithms and their improvement as well as investigation of innovative synergistic approaches (Thiel et al. 2009). Products include biomass maps and biomass change for the years 2007-2010 on a local scale, a biomass and improved land cover map on the regional scale, and a 1 km scale land cover map as input to a carbon accounting model. These products serve the inventory community (e.g. FAO Forest Resource Assessment) as well as the Kyoto Protocol implementation bodies. In specified regions land cover change dynamics, specifically forest regrowth and land abandonment, were investigated.

One of the key perspective goals of the ZAPÁS initiative is to overcome still existing uncertainties in Carbon Accounting. Since the synergistic biomass – land cover product will be one new parameter of the full ecosystem carbon accounting (conducted at IIASA) some general future improvements will be considered for carbon accounting, such as *in-situ* and multi-scale Earth observation synergies and combining regional land cover mapping and biomass products. Integrated concept for forest resource assessment and forest geo-information cross validation to be implemented by the ZAPÁS project (*Figure 1*).

1.2 Work performed during the third year of the project

Wall-to-wall mapping of local test sites in Central Siberia
With the use of four annual SAR backscatter mosaics, provided by JAXA's Kyoto and Carbon Initiative, a systematic matting framework was designed and applied for an area of 2 Mio. Ha in Central Siberia. Based on annual growing stock volume maps (with a spatial resolution of 25 m) for 2007, 2008, 2009, and 2010, further thematic products were generated, such as the Forest cover and disturbance maps for 2007 and 2010 and a reforestation probability map for 2010.

Cross-comparisons and validation of local-scale forest resource maps
The locally relevant information products have undergone a validation and quality assessment by integrating updated forest inventory data. For the first time high resolution growing stock maps (covering an area of 2 Mio. ha) could be validated using up-to-date forest inventory data. The results were comparable with literature values and varied within the relative RMSE range of 30 – 40 %. On the other hand, the biomass maps proved to be useful consistent information sources for detecting inconsistencies in the forest inventory. The validation of change maps was challenging since the availability of temporally fitting land cover change reference data is often problematic. However, the integration of the forest inventory database was successful for proving the spatiotemporal consistency of the forest cover change maps. Synergistic comparisons with Landsat-based land cover information could also state a general agreement of the forest cover change monitoring. Validation activities of an innovative reforestation probability map product with high resolution Resurs-DK-1 data resulted in an overall accuracy of 80 percent for the land cover change type of reforestation processes on abandoned agricultural lands.

Regional scale forest resource assessment
A regional coverage of the Central Siberian investigation area was realized by providing maps of growing stock volume (in cooperation with the ESA BIOMASAR-II

Project), MODIS- based land cover and forest species map, and a hybrid Biomass and forest species map (*Figure 2*).

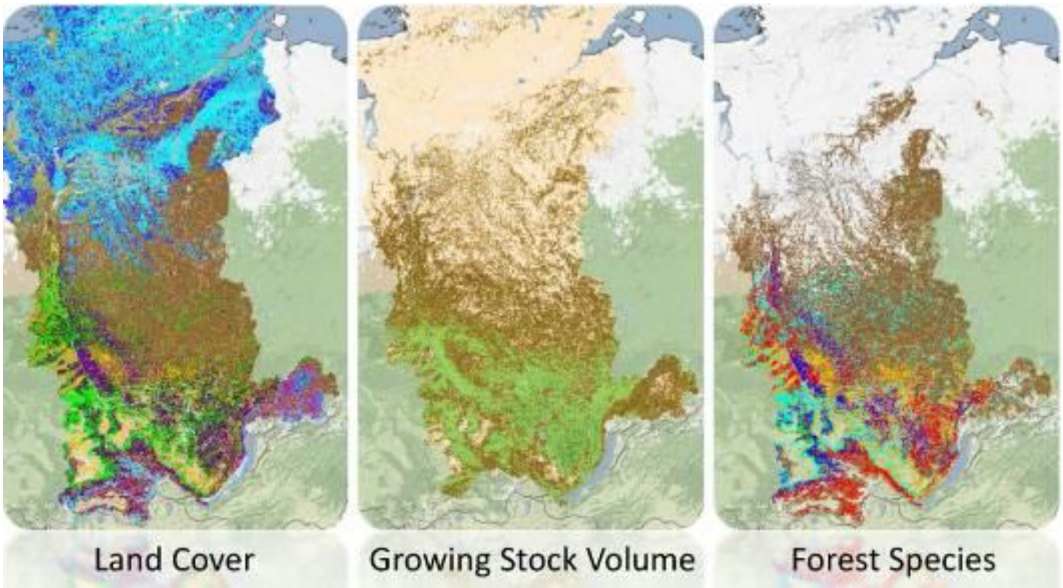

Figure 2: *Regional scale forest resource maps for Central Siberia: MODIS land cover, growing stock volume, and forest species.*

Terrestrial Ecosystems Full Carbon Accounting (FCA) for Central Siberia

A forest Ecosystems full verified carbon account for Central Siberia for 2009 was realized (Figure 3).

Taking into account the fuzzy character of full carbon account of forests for large territories, the methodology used was based on IIASA's landscape-ecosystem approach (LEA) with following comparisons and mutual constraints with results received by independent methods. The LEA is used for designing the account boundaries and assessment of major pools and fluxes. An Integrated Land Information System (ILIS) serves as the information background of the Full Carbon Account (FCA). The ILIS is based on a system integration of all available ground data and multi-sensor remote sensing applications.

Results of calculation show that the region's forests served in 2009 as a net carbon sink of 139.4 ± 35 Tg C yr-1 or 76± 19 g C m-2 yr-1. This result is to some extent anomalous due to unusually small distribution of fire during 2009. Comparisons with other sources supported the results of this study. However, they are to some extent approximate because other studies considered different regions and years of estimation. Overall, the results of the comparisons are satisfactory consistent. The study confirmed the crucial role of multi-sensor remote sensing concept in assessment of the carbon budget of terrestrial ecosystems, particularly forests.

1.3 Project web-site

The results being achieved during the project are presented and disseminated through the bilingual ZAPÁS web portal. Acting as the main communication platform of the EU and Russian scientific and stakeholder community on forest resource assessment the ZAPAS web portal is delivering recent reports and scientific outcomes. The above mentioned geo-information products on forest biomass distribution and dynamics are being disseminated through the ZAPÁS web portal available at http://zapas.uni-jena.de. Further, the ZAPÁS data layers are implemented in the Siberian Earth System Science Cluster (SIB-ESS-C) available at http://sibessc.uni-jena.de. The Siberian Earth System Science Cluster (SIB-ESS-C) is a spatial data infrastructure to facilitate Earth System Science in Siberia and consists of operational tools for multi-source data access and time-series analysis. Therefore data from remote sensing satellites, climate data from meteorological stations, and outcomes of research projects are available. The system comprises interoperable interfaces for data visualization, access, and analysis. A main objective is to provide a wide variety of operational information products free of charge along with a user-friendly web portal for time-series analysis and monitoring.

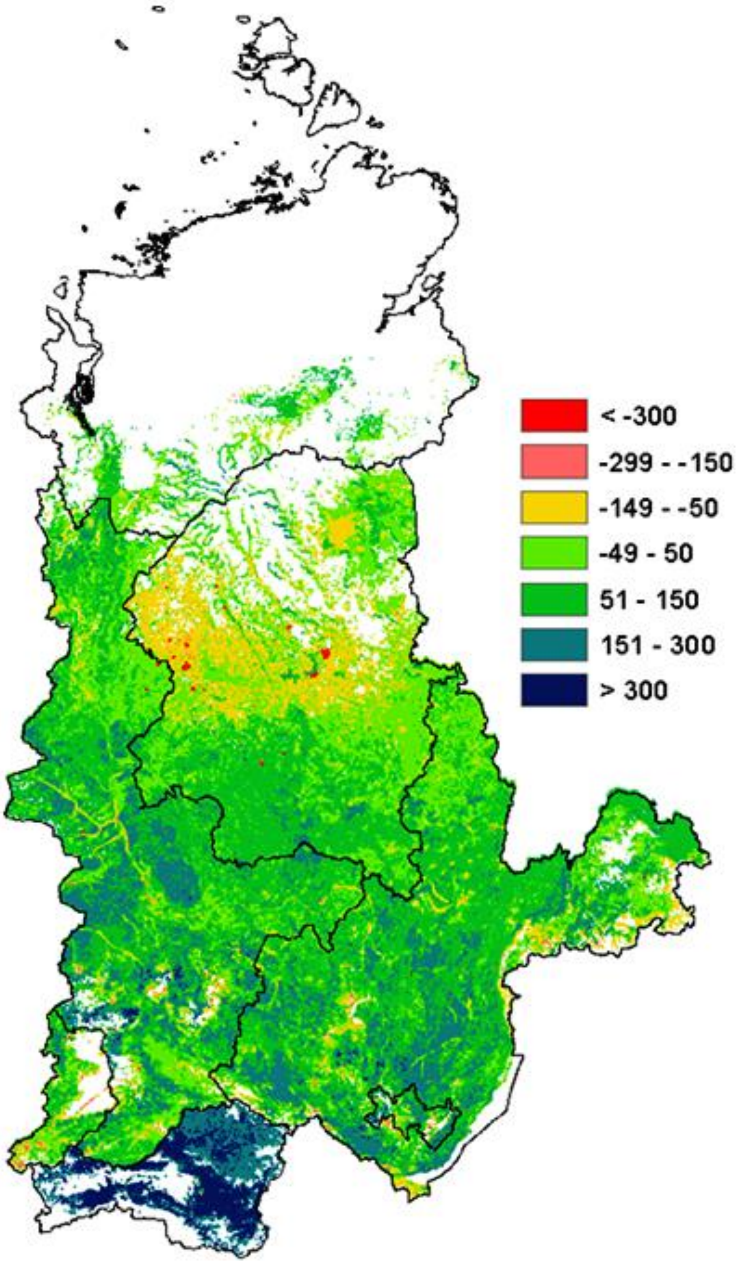

Figure 3: *Carbon balance, g C m^{-2} yr^{-1}. Negative values refer to carbon emission from forest to the atmosphere.*

1.4 Project partners and general contacts for the ZAPÁS project

The consortium consists of a balanced distribution of leading experts from Europe and Russia in the field of Earth observation for forestry applications, involving Russian stakeholders, i.e. the Sukachev Forest Institute of the Russian Academy of Sciences, who themselves apply remote sensing techniques. The Russian partners come from two geographically different federal regions: the city of Moscow and the Krasnoyarsk Kray. An overview of involved organizations is given in Table 1.

An external and informal review board - the **ZAPÀS Advisory Board** (ZAB) - has been installed to involve representatives of the Russian Space Agency as well as the Federal Forest Agency. Further, the ZAB communication connect ZAPÁS to the United Nations Forest Resource Assessment 2010 (FRA 2010) and link international scientific programs, such as the Global Observations of Forest Cover and Land Dynamics and (GOFC-GOLD). The ZAPÁS Advisory Board Members are:

Chris Steenmans	European Environment Agency (EEA) Copenhagen, Denmark
Tony Janetos	Chair of GOFC-GOLD Joint Global Change Research Institute Maryland, United States
Henri Laur	European Space Agency (ESA) Earth Observation Missions Management Office Frascati, Italy
Nina Novikova	Scientific Centre for Earth Operational Monitoring Roscosmos, Moscow, Russia

Table 1: ZAPAS expert consortium.

Institution	Abbrev.	Persons involved	Country
Friedrich-Schiller-University Jena	FSU	C. Schmullius, C. Hüttich, C. Thiel, C. Pathe	Germany
International Institute for Advanced System Analyses	IIASA	A. Shvidenko, D. Schepaschenko	Austria
Space Research Institute of the Russian Academy of Sciences	IKI-RAS	S. Bartalev, V. Egorov, V. Zharko, T. Khovratovich, T. Moskalenko	Russian Federation
V. N. Sukachev Institute of Forest, Siberian Branch of the Russian Academy of Sciences	SIF-RAS	M. Korets, I. Danilova, V. Ryzhkova	Russian Federation
Joint Stock Company "Russian Space Systems"	NTsOMZ	K. Emelyanov	Russian Federation

2 Project objectives, work progress and achievements, and project management

2.1 *Project objectives for the period*

The third year's period aims at the completion of a common forest resource geo-information database comprising the final release of **the Improved Land cover Map for Central Siberia** (WP5). Further on, the *in-situ* database is going to be integrated in the **validation activities** (WP9) of the local and regional scale forest resource maps. Beside the validation process the main milestone for the third year of the project is the implementation of the carbon accounting for Central Siberia. Therefore, the improved land cover database is being **implemented in the IIASA GIS** (WP6). The full terrestrial carbon assessment of Central Siberia's Krasoyarsk Kray and Irkutsk Oblast will be conducted in WP 7. Project dissemination activities will be on-going from the, in particular by updating up the **ZAPAS Web-portal** (WP10) and integrating the ZAPAS results in the web portal of the Siberian Earth System Science Cluster (SIB-ESS-C). The results of the current running work packages were presented in related key conferences and published in peer reviewed journals.

2.2. Work progress and achievements during the period

2.2.1. Project management in the reporting period

2.2.1.1. Consortium management tasks and achievements

During the reporting period FSU was responsible for management activities conducted in WP 1 "Management /Administration". The responsibilities of FSU regarding the management and administration of the project include to:

- implement of a project-specific database for reporting and controlling;
- monitor the project time tables, milestones, and deliverables;
- perform an efficient intra- and extra-consortium communication and cooperation;
- maintain a constructive dialog with the EC project officers;
- lead the communication with the ZAPÁS Advisory Board (ZAB).

2.2.1.2 Summary of progress made

The provision of improved synergetic regional scale joint biomass/ land cover map was realized and a resampled 1 km Forest and Land Cover Map was generated as a preparatory step for the carbon modelling. The terrestrial Ecosystem Full Carbon

Accounting (FCA) was successfully realized for the reference year of 2009 by integrating updated land cover and growing stock information for the modeling area. The Cross-validation and comparisons of all biomass and land cover maps was finished in the third project period. An intensive validation workshop was realized in August 2013 at the Suchachev Institute of Forest with the FSU project members, including a two days validation field trip to the Bolshemurtinsk local test sites.
The validation process was finally discussed and concluded in a third project workshop, held in the Institute for Space Sciences at the Free University Berlin. The results of cross-comparisons between EO products and in-situ data were critically discussed and improved. A synergy paper is close to publication in a scientific journal. Attending mayor science meetings on land and forest monitoring as listed below affected an increased publicity and awareness of the project in the science community. New web-based clients were introduces with the ZAPAS-related Earth Observation monitor. The capabilities of a web-based time series analyses portal was demonstrated using ZAPAS examples leading to an increased visibility of the technology and the project in the scientific an industry-related community.

2.2.1.3. Problems occurred and applied solutions

No major problems occurred during the second phase of the ZAPÁS project.

2.2.1.4. Changes in the consortium

No changes in the consortium occurred.

2.2.1.5. List of project meetings, dates, venues and participants

Table 2: ZAPÁS project meetings in the second reporting period.

Kind of Meeting	Location	Date	Participants
EGU-2014	Vienna	28.4-2.5. 2014	IIASA, SIF-RAS
International conference GEOBIA 2014	Thessaloniki	21-24.05.2014	SIF-RAS
PEEX Meting	St. Petersburg	3.-7.3. 2014	SFU, IIASA
Forest Change Conference	Freising	2.-4- 3. 2014	FSU
National Forum for Remote Sensing and Copernicus	Berlin	8. – 10. 4. 2014	FSU
ZAPAS annual meeting	Berlin	10. – 11. 4. 2014	FSU, IKI, IIASA, SIF-RAS
ZAPAS Review Meeting	Brussels	06.09.2013	FSU, IKI
ESA Living Planet Symposium	Edinburgh	9. – 13. 9. 2013	FSU
Megagrant Permafrost Meeting	Hannover	2.-3. 12. 2013	FSU, SIF-RAS
The V All-Russian Conference on RS applications	Moscow	22-24.4. 2013	IIASA, IKI, SIF-RAS
The 16th Science Conference of IBFRA	Edmonton	7-10.10.2013	IIASA, SIF-RAS
International ZOTTO workshop	Krasnoyarsk	16-22.09.2013	SIF-RAS

2.2.1.6. Project planning and status

Although a delay in the acquisition of EO data and the above-mentioned data gaps were identified in the first period a slight delay of two month of the map production at regional scales occurred. The developed mapping workflow based in the K&C

PALSAR mosaics allowed a faster than planned realization of the local scale maps (GSV, forest cover and disturbance, forest regrowth probability for abandoned land detection). This had no consequences for the carbon modeling task. The carbon modelling as well as the map validation could be realized in time in the third period. No considerable deviations occurred with regard to the GANTT.

2.2.1.7. Impact of deviations from the planned milestones an deliverables

No deviations from the planned milestones occurred.

2.2.1.8. Changes to the legal status of beneficiaries

No changes in the legal status of beneficiaries occurred.

2.2.1.9. Use of the resources

The following table lists the person-months per participant in the second period in WP1.

Table 3: Person-months per participant in the second period in WP1.

FSU	IIASA	IKI-RAS	SIF-RAS	NTsOMZ
1,5	0	2	0	0

2.2.2 Work Package 2 - Satellite and In-situ Data Acquisition and Preprocessing

Lead partner: FSU Jena
Contributing partners: IKI-RAS, SIF-RAS

2.2.2.1. Overview of WP objectives

This WP provides the required database for the project's scientific goals and products under consideration of Earth Observation (EO) data. Data are provided by means of the ESA/ROSCOSMOS data agreement at a level appropriate for further data exploration. Specific tasks are sub-structured in order to:

- procure the required EO data for 2007-2009 (Task 2.1)
- provide pre-processed EO data appropriate for further data exploration (Task 2.1.1).
- provide the required in-situ data (Task 2.2).

2.2.2.2. Summary of progress made

Task 2.1: Data procurement accordant to ESA/ROSCOSMOS data agreement.-Task leader: FSU Jena

All required optical and SAR data SAR data were acquired through a successfully acquired and pre-processed in the first year of the project and implemented in the regional and local scale mapping framework.

Task 2.2: Forest Inventory data acquisition – Task Leader: SIF-RAS

In-situ data were available from three forest management areas in Central Siberia (referred to as test sites) covering an area of over 2 Mio. Hectares. The location and spatial distribution is shown in *Figure 5*. The dataset consists of a digital map of forest stands and several strata of forest variables (land cover type, species composition, tree density, average age, height, diameter, and GSV). A forest stand is defined as an elementary forest inventory unit (EFIU), a forest area relatively homogeneous in vegetation structure and growing conditions. According to the Russian forest inventory regulations, forest stands are delineated and described by a forest inventory expert on 1:10,000 scale by using multispectral airborne images and auxiliary reference field data. The average is 17 ha with a standard deviation of 21.5 ha. The minimum size of all forest stands within the study area was four ha.

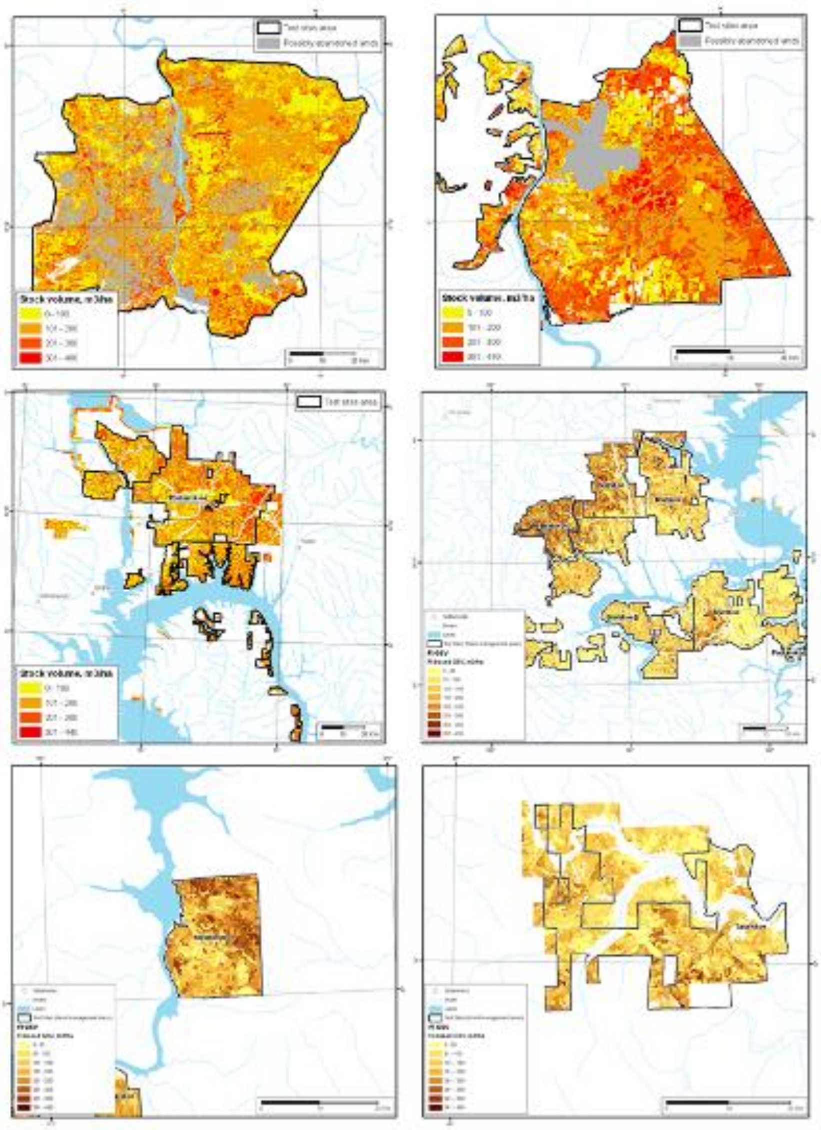

Figure 4: *Location of the forest inventory sites updated during the second period of the ZAPÁS project (Bolshemurtinskoe, Padunskoe, Tulunskoe, Nijneilimskoe, Bratskoe)*

The FI GIS database was assembled considering EO data for consistency, reliability, positional accuracy, and timeliness. Test sites names are the same as those used in FI. Site locations (*Figure 4*) and processing priority were assigned with an account of the most resent local forest inventory dates.

Forest inventory information was updated and vegetation cover changes were detected up to 2011 using recent optical RS imagery (LANDSAT TM, Resource-DK, Monitor-E, RAPIDEYE, QUICKBIRD, WORLDVIEW 1/2).

2.2.2.3. Highlights

All forest inventory data for the local test sites in the Krasnoyarsk and Irkutsk regions were collected within the second phase of the project and were integrated in the validation activities of WP 9. The spatial distribution of the FI sites is shown in *Figure 5*.

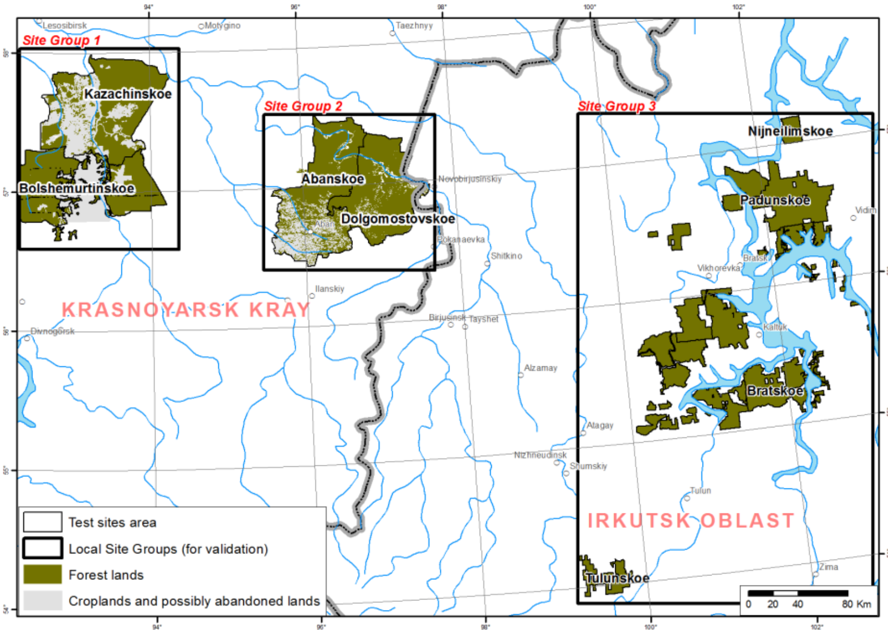

***Figure 5**: Geographic distribution of the Central Siberian local test sited in Krasnoyarsk Kray and Irkutsk Oblast.*

2.2.2.4. Deviations and impact on tasks and resources

No deviations occurred.

2.2.2.5. Use of the resources

The following table lists the person-months per participant in the second period in WP 2.

Table 4: lists the person-months per participant in the second period in WP 2.

FSU	IIASA	IKI-RAS	SIF-RAS	NTsOMZ
3.25	0	0	10	2

2.2.6 Work Package 6 - Derivation of 1 km Forest and Land Cover Map for Implementation in the IIASA-GIS

Lead partner: IIASA
Contributing partners: FSU Jena

2.2.6.1. Overview of WP objectives

The objective of WP6 is to link the improved land cover map for Central Siberia (WP5) with Integrated Land Information System (ILIS) elaborated at IIASA. Moreover, issues 2with increasing space resolution from 1km to 230m and data update need to be solved.
IIASA develops a special algorithm of harmonizing the improved land cover map with existing ground measurements which contain parameters that are required for the terrestrial biota verified full carbon account.
Based on ground measurements derived from State Forest Account, State Land Account, available other source, IIASA develops an algorithm and software for parameterization of vegetative land classes with details required for implementation into the Terrestrial Ecosystems Model for stock of organic carbon in live vegetation, Net Primary Production etc.) and final (Net Ecosystem Carbon Balance) results.

2.2.8.2. Summary of progress made

Resampled 1 km Forest and Land Cover Map

1. Requirements to hybrid land cover and its parameterization within the FCA

An overall goal of WP6.1 and 6.2 is development of information base which would satisfy current requirements to studying the impacts of forests on the global carbon budget. Two terms are crucial in current attempts to understand terrestrial ecosystems carbon cycling: the carbon account should be full and verified. By definition, full carbon account should include all land classes, all ecosystems, all processes etc. in a spatially and temporally explicit way (e.g. Steffen et al., 1998) in opposite to the partial account which was introduced by the Kyoto Protocol during the first commitment period. Only a full account presents a solid background for reliable assessment of uncertainties (Shvidenko et al., 2010). However, the problem of verification of the FCA in not trivial: the FCA is a typical fuzzy system, or in other terminology, a full complexity or wicked problems (Rittel and Webber, 1973; Schellnhuber, 2003). The specifics of such systems require development of a special methodology for assessing the FCA. The landscape-ecosystem approach (LEA) serves an overall system design of the FCA. Information and methodological requirements to the LEA are considered in (Nilsson et al., 2007; Shvidenko et al., 2010). Other methods of studying the ecosystems carbon cycling (process-based models, inverse modeling, and eddy covariance) are used for mutual constraints of the independent results and assessing the final uncertainties (e.g., by the Bayesian approach). The information background of the LEA is presented in form of an Integrated Land Information System (ILIS) that combined available ground and remote sensing information on land, landscapes and ecosystems (Schepaschenko et al., 2011).

Some important information that is needed for providing the acceptable level of uncertainty of the FCA cannot be obtained from remote sensing products of rough resolution. Thus, in order to solve this problem the following way was used: 1) development of a possible accurate land cover based on complimentary use of different RS products including the results of WP 5.0; 2) use of relevant available information from other sources, primarily from on-ground measurements, observations and surveys; and 3) the use of a special optimization downscaling algorithm which would provide biophysical indicators of ecosystems and landscapes with acceptable details and spatial accuracy. Such an approach is particularly important for forests.

The hybrid land cover (HLC) map for the study region was developed based on (1) enhanced forest GSV map for Central Siberia with resolution 230 m that was produced by the Institute of Space Investigation of the Russian Academy of Sciences, Moscow, as a result of WP 5.0 using the synergy of MODIS and ASAR data products (see Deliverable 5); (2) map of burnt area produced by the Institute of Forest of the Siberian Branch of the Russian Academy of Sciences (Krasnoyarsk); (3) time series of MODIS VCF; (4) LANDSAT based forest map of 30m resolution (Sexton et al., 2013); (4) regional data on different inventories and surveys (e.g., State Forest Account, State Land Account, areas of cultivated agriculture lands by region and others).

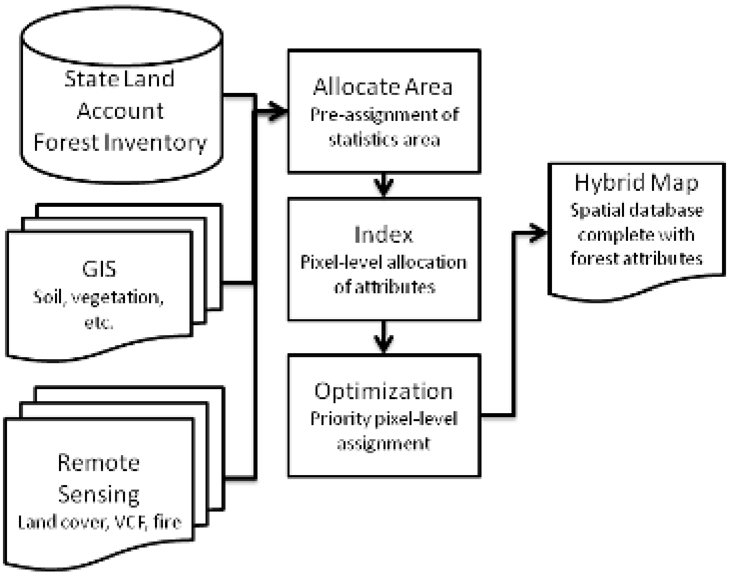

Figure 6: *Flowchart outlining the process of integration of GIS, remote sensing and statistical data to produce a hybrid land cover dataset.*

A need to provide a desirable accuracy of the estimates requires a rather detailed classification of land cover classes. The upper level of the hierarchical classification included (1) unproductive lands (indicated 8 aggregated LC classes within this group); (2) agricultural lands (3 classes); (3) wetlands (19); (4) natural grassland (23) and (5) natural shrubs (12 classes). Forests required a special classification that includes dominant species, age, site index, GSV, many others. However, the remote sensing products that were used in this study do not allowing recognition of some of the above classes. This required implementation of an integrated approach which would combine GIS, remote sensing and regional statistics (xxx).

In the first stage, we allocated the total area presented in the land account by land category (forest, agriculture, wetland, shrubs, grassland, burnt area, water and unproductive land), to the GIS and remote sensing resultant database by administrative units. The purpose of this first step is to ensure that broad classes (i.e. forest, agriculture, etc.) are correctly assigned, before moving to the second stage (pixel-assignment).

2. Optimization algorithm for downscaling of indicators of FCA

The optimization algorithm aims at by-pixel calculation of the quantitative correspondence of statistics (e.g., forest and land account) and spatial (remote sensing, GIS) data within each land cover class. A suitability index (Sts) is calculated for each pixel-pair (grid of territory (t) and statistics record (s)) within the area unit (forest enterprise, administrative region) and land cover class.

$$S_{ts} = \frac{1}{q}\left(\sum_{j=1}^{q}(x_{tj}^{norm} - x_{sj}^{norm})^2\right)^{1/2}$$, where

q - number of parameter;

$x_{tj}^{norm}, x_{sj}^{norm}$ - normalized value of parameter j for territory pixel t and j;

$$x_j^{norm} = \frac{x_j - x_{j\min}}{x_{j\max} - x_{j\min}}$$, where

$x_{j\max}, x_{j\min}$ - Maximum and minimum values of parameter j within the certain area (forest enterprise, administrative unit).

Data on a nominal scale, i.e. land cover classes were ranked with respect to a certain vegetation class in the statistics. For example, the most suitable GLC class for pine forest is "Tree Cover, Needle-leaved, Evergreen", or "Pine dominated forests" of the IKI Forest Map, thus this would receive a high rank. Pine forest could also fit into "Tree Cover, Mixed Leaf Type" or might be found in the "Tree Cover, Broadleaved, Deciduous" GLC class (and would receive a lower rank).

The resultant suitability index S varies from 0 to 1. It can be interpreted as a distance between objects (grid of territory and statistics record) within the space of parameters. The lower the index value, the more suitable is the current piece of territory for the given statistical data. This method corresponds to the methods of land suitability assessment (FAO, 1976).

The next stage involved the optimization of distribution statistics data on the territory based on the suitability index (second stage) results. Each forest and land account record in the statistics was assigned to the most suitable grid within each forest enterprise.

Some specific elements of optimization are introduced for forests. The suitability index allows sufficiently assign dominant species. In order to indicate age, the height of stands (derived from the GLAS system (Simard et al., 2011) is used. The age is calculated based on the height value, introduced in regionally distributed models of growth and productivity of modal stands (Shvidenko et al., 2008). The

growing stock volume is controlled by the ASAR products (Santoro et al., 2011). More details could be found in Schepaschenko et al. (2011).
At the final stage, distribution of forests by dominant species, age and growing stock is controlled by actualized data of forest inventory by forest enterprises (of the total amount of ~1600 across the country). Thus, this product presents the most and updated information staring from an aggregation at the average size of forest enterprises (~15-30 angular seconds).

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The next stage involved the optimization of distribution statistics data on the territory based on the suitability index (second stage) results. Each forest and land account record in the statistics was assigned to the most suitable grid within each forest enterprise.

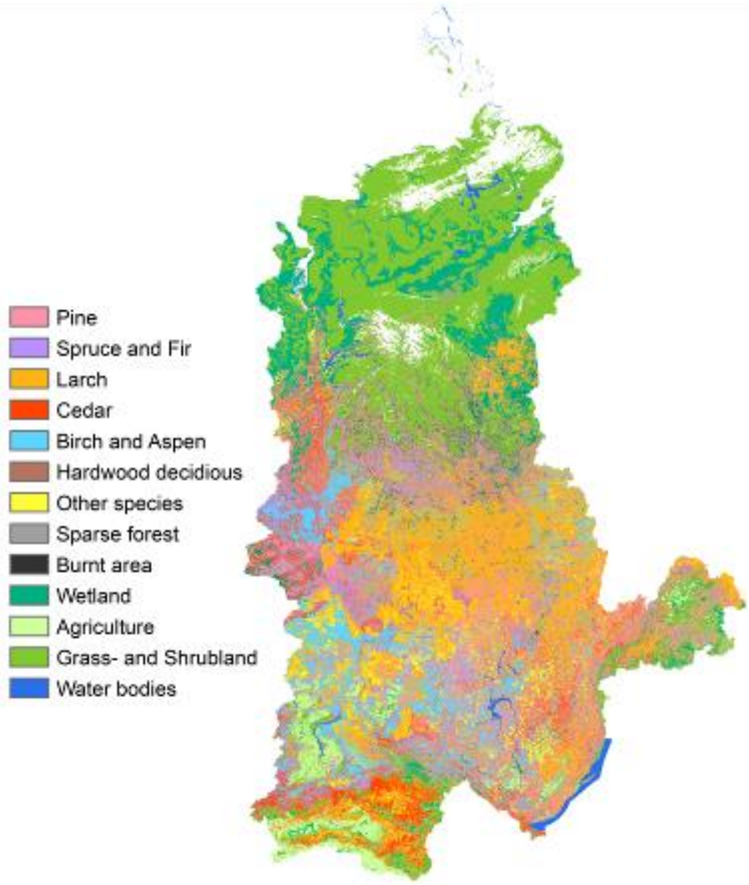


Figure 7: *Forest and Land Cover Map for Central Siberia.*

Some specific elements of optimization are introduced for forests. The suitability index allows sufficiently assign dominant species. In order to indicate age, the height of stands (derived from the GLAS system (Simard et al., 2011) is used. The age is calculated based on the height value, introduced in regionally distributed models of growth and productivity of modal stands (Shvidenko et al., 2008). The growing stock volume is controlled by the ASAR products (Santoro et al., 2011). More details could be found in Schepaschenko et al. (2011).
At the final stage, distribution of forests by dominant species, age and growing stock is controlled by actualized data of forest inventory by forest enterprises (of the total amount of ~1600 across the country). Thus, this product presents the most and updated information staring from an aggregation at the average size of forest enterprises (~15-30 angular seconds).

Summary

The results of WP 6.1 and 6.2 contain the required information base that is sufficient for an application of the methodology of the Terrestrial Ecosystems Full Carbon Account for the region of interest that should be realized in WP 7.0. The information background is represented by the Integrated land Information System (ILIS). The ILIS includes the hybrid land cover (*Figure 7*) at resolution of 230 m (with following aggregation to 1 km) and relevant attributive datasets. The hybrid land cover is presented as a result harmonization of a number of the previously developed RS products and is by-pixel parameterized in a form that is sufficient for assessing the verified full carbon account of forest ecosystems of the study region.

2.2.6.4. Deviations and impact on tasks and resources

No deviations occurred.

2.2.6.5. Use of the resources

The following table lists the person-months per participant in the second period in WP 6.

Table 5: Person-months per participant in the second period in WP 4.

FSU	IIASA	IKI-RAS	SIF-RAS	NTsOMZ
3	**0**	**0**	**0**	**0**

2.2.7 Work Package 7 - Carbon Accounting for Central Siberia

The work package 7 started in August 2013. So far, the parameterization and model calibration with the new EO products derived within the ZAPÁS WP's 3, 4, and 5 are is ongoing.

1. Introduction

According to the DoW of the Project, the objective of WP7.1 is to provide the Forest Ecosystems Full Verified Carbon Account for Central Siberia for 2009. This includes the following working tasks.

Modification of the IIASA model of Terrestrial Ecosystems Full Carbon Accounting (FCA) for the conditions of Central Siberia (1km resolution)

The modification includes updating the empirical models for assessing and partition of major carbon pools (live biomass, dead organic matter, on-ground litter, soil) and C-CO2 fluxes (Net Primary Production, Heterotrophic Respiration, fluxes due to disturbances, lateral fluxes, Net Biome Production). Models and accounting schemes for other carbon contained gases (like CH4 and VOC) are modified and updated as well.

These models and empirical aggregations are applied to the land cover information developed within the Project. This information is gathered based on a "multi" concept of remote sensing application (including imagery from ENVISAT MERIS, ENVISAT ASAR and METEOR-M1 and others) and harmonized with available ground measurements. Major ideas implemented in accounting of carbon cycling of terrestrial ecosystems include

A) providing a verified forest ecosystems full carbon account (FCA), i.e. the account which would present reliable and as comprehensive as possible assessment of uncertainties of the intermediate and final results of the account; and

B) assessing the gain which is provided by implementation of multi-sensor remote sensing concepts in estimation of the FCA.

Verification of the results: Using an integrated methodology developed by IIASA for assessing uncertainties of the FCA taking into account fuzziness of the considered accounting system. Within this methodology, independent estimates (obtained by selected process-based models; inverse modelling; and eddy covariance) will be used for comparisons.

Development of recommendations for policy makers: For introduction of the methodology of the FCA and practical results for Central Siberia into national reporting/ international negotiation process after the first commitment period of the Kyoto Protocol.

Summary and conclusions

Results of calculation show that the region's forests **served in 2009 as a net carbon sink** of 139.4 ± 35 Tg C yr^{-1} or 76± 19 g C m^{-2} yr^{-1}. This result is to some extent anomalous due to unusually small distribution of fire during 2009.

Comparisons with other sources supported the results of this study. However, they are to some extent approximate because other studies considered different regions and years of estimation. Overall, the results of the comparisons are satisfactory consistent.

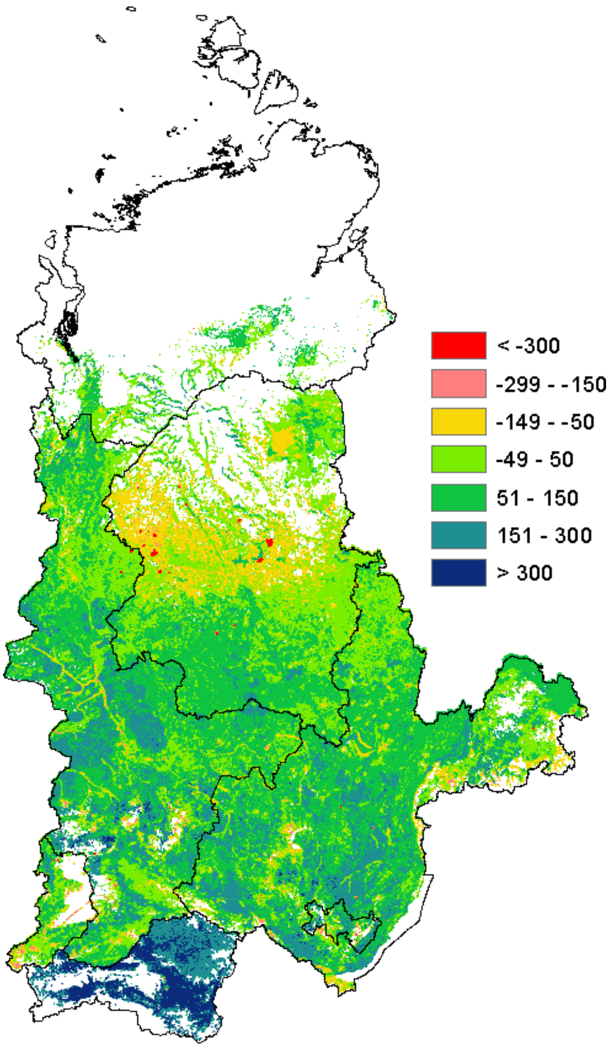


Figure 8: *Carbon balance, g C m^{-2} yr^{-1}. Negative values refer to carbon emission from forest to the atmosphere.*

The study confirmed **the crucial role of multi-sensor remote sensing concept** in assessment of the carbon budget of terrestrial ecosystems, particularly forests. This role is revealed in the following:

- without RS, it is impossible to realize the idea of the Terrestrial Ecosystems Full Verified Carbon (and Full Greenhouse) Account;
- RS tools used in this study were crucial for developing the hierarchical land cover classification with details which would allow obtaining major intermediate (live biomass, NPP, HSR, fluxes due to disturbances etc.) and final (Net Biome Production, Net Ecosystem Carbon Balance) results with uncertainties which would be acceptable for policy making;
- RS presented information for assessment of biophysical indicators that are crucial for understanding of carbon cycling of forests: canopy closure, average height of stands, above ground live biomass etc.; radars with synthetic aperture play a particular role in such assessments;

- RS information served for parameterization of important processes like Net Primary Production; extent, distribution and severity of disturbances; vitality and resilience of ecosystems;
- RS is an only tool for monitoring of land cover change and dynamics of major biometric indicators of forests.

It is necessary to note that evaluation of such dynamic and sophisticated processes like interaction of terrestrial ecosystems (and particularly forests) with the atmosphere, hydrosphere and lithosphere, and, eventually, with the Earth system, requires a systems implementation of a "multiple" remote sensing concept where all diversity of RS sensors could be used. For forests the application of launched and future expected radar instruments are at special significance.

Major **recommendations** for policy makers and managers include:

- taking into account the growing role of terrestrial ecosystems (particularly, forests) in stabilization of the Earth system, it seems relevant development of integrated observing systems which would allow monitor state and changes in land cover with details which would be sufficient for sustainable management of ecosystems including understanding of major global biogeochemical cycles, carbon management, implementation of adaptation and mitigation strategies;
- effective introduction of the remote sensing "multiple" concept requires system development of some directions of ecological science; for instance, there is need in development, on a coordinated scientific base, sets of integrated regional models describing interdependence of biometric characteristics of forest stands; this would allow to assess "hidden components of forest ecosystems" (e.g. below ground live biomass);
- current capacities of radar instruments which are in orbits provide possibility of obtaining satisfactory information at scales which are relevant for ecological modeling of coarse resolution; there are urgent needs in system research of possibilities provided by such instruments launched at Sentinel 1 and planned *Biomass* mission;
- further effective implementation of remote sensing for solution of environmental and ecological problems requires system improvements of the situation with availability of ground truth data; the idea on development of a unified permanent network of ground test areas in hotspot regions (e.g., Northern Eurasia) could be discussed;
- the results of this study has a particular meaning for Russia, which has substantial problems with knowledge about the current state of forests because of more than 50% of the country's forests have been inventoried more than 25 years ago. On-going development of both National Forest Inventory and Management Forest Inventory and Planning might substantially benefit from the results of this study;
- this study showed particular importance of such projects as ZAPAS for future development of the Space Dialog between the European Union and Russia.

2.2.7.4. Deviations and impact on tasks and resources

No deviations occurred.

2.2.7.5. Use of the resources

The following table lists the person-months per participant in the second period in WP 6.

Table 6: Person-months per participant in the second period in WP 7.

FSU	IIASA	IKI-RAS	SIF-RAS	NTsOMZ
0	3	0	0	0

2.2.8 Work Package 8 - Local Sites: Biomass and Change Mapping

Lead partner: SIF-RAS
Contributing partners: FSU Jena

2.2.8.1. Overview of WP objectives

The objectives of WP 8 are to provide maps for local sites within Krasnoyarsk Kray and Irkutsk Oblast. Biomass maps refer to forest biomass maps based on PALSAR data (data availability through JAXA Kyoto & Carbon Panel membership of FSU), change maps refer to forest disturbance mapping as well as detection of potential new forest land (abandoned agricultural land). I particular, the following thematic goals are defined:

1) Adapt and apply forest biomass estimation approach based on PALSAR data. Provide recent forest biomass maps for at least 10 local sites (5 for Krasnoyarsk Kray plus 5 for Irkutsk Oblast). Local site refers to forest enterprise subdivisions or its smaller fragments with average area of 100000 ha each.
2) Provide forest disturbance maps (clear-cut & fire damage) for the same sites from above. Timeframe of change to be detected: 2000-recent.
3) Provide maps of recent abandoned land which corresponds to potential new forest land for 5 local sites within Krasnoyarsk Kray (same sites as selected above). Recent refers to the year 2005.

2.2.8.2. Summary of progress made

Recent fine scale forest biomass maps

One key objective of WP 8 is the generation of recent fine scale maps for **biomass**, **forest cover and disturbance**, and **forest regrowth and afforestation**. The maps were planned for 10 local sites within Krasnoyarsk Kray and Irkutsk Oblast (5 for Krasnoyarsk Kray plus 5 for Irkutsk Oblast). The 10 local sites Local site refer to forest enterprise subdivisions or its smaller fragments with a maximum area of 100.000 ha each. As mentioned above, all maps were generated on the JAXA K&C ALOS PALSAR backscatter HH / HV mosaic based on summer acquisitions between

2007 – 2010 with a 25 m spatial resolution. As shown in *Figure 9* the data cover an area of 569.400 km² in Central Siberia. All maps are available online available under:

http://zapas.uni-jena.de/

http://www.sibessc.uni-jena.de/

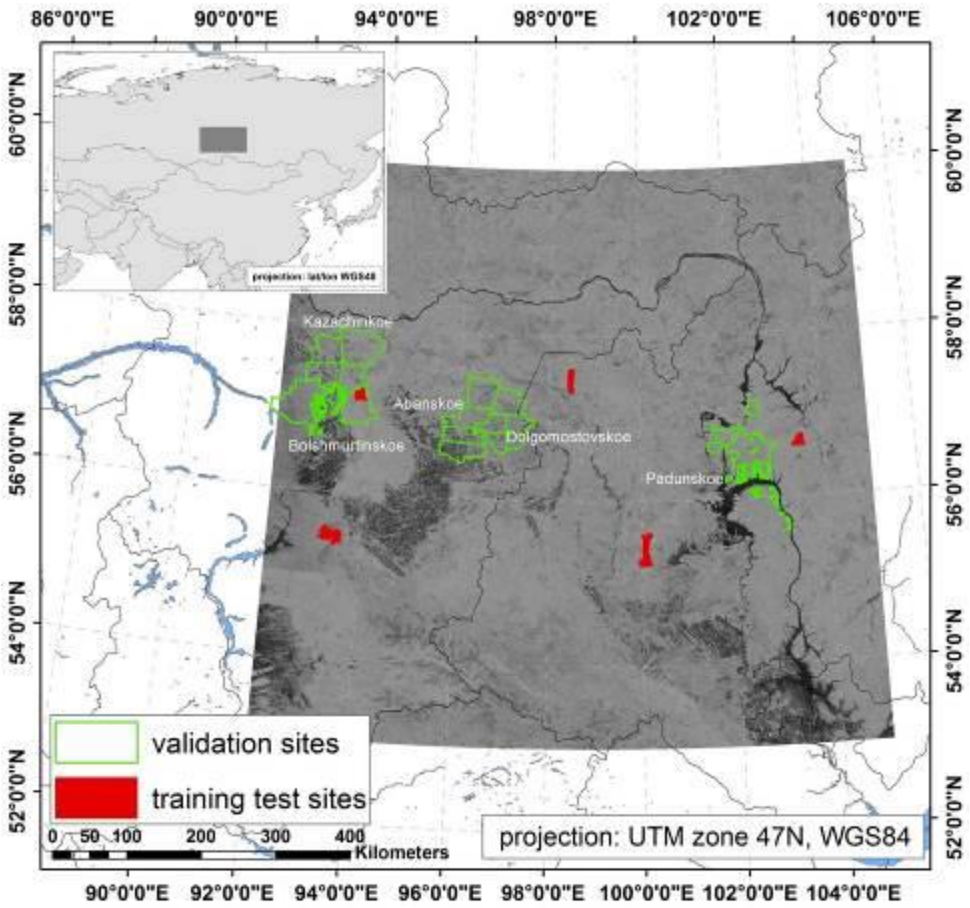


Figure 9: *Coverage of the JAXA K&C ALOS PALSAR backscatter mosaics. The ZAPAS local test sites are shown in green.*

2.2.8.3. Highlights

Validated Wall-to-wall maps of biomass, forest, cover and disturbance, and re-/afforestation

Full coverage of the local scale mapping could be achieved for all test sites in Central Siberia. Based on multi-temporal ALOS-PALSAR SAR imagery the following forest resource maps were generated at a 25 m spatial resolution. The maps were **validated or cross-compared** within WP9.

- **Biomass:** Growing Stock Volume Maps (2007, 2008, 2009, 2010)
- **Disturbances:** Biomass Disturbances (2007-2010)

Forest Cover and Disturbance Maps (2007, 2010)

- **Land Abandonment and Reforestation:** Re-/afforestation Probability Map

All maps are delivered to the consortium and integrated in further validation and modelling activities. The maps are online accessible at the SIB-ESS-C Geoportal (http://sibessc.uni-jena.de) in and the web map portal of the ZAPÁS web page.

A detailed description of the map resourced has been created including the classification systems and legend descriptions of the forest resource maps. The document is in a final editing phase and will be added to the final version of this report.

Local scale mapping product description

Introduction

The ZAPAS project aims to provide forest resource maps at regional and local scales using multi-source Earth Observation data. Locals scale geo-information products such as growing stock volume maps, forest cover and disturbance maps, and reforestation probability maps will support a temporally and spatially consistent forest monitoring on forest management area level. Regional scale land cover and forest species maps support an improved full terrestrial carbon assessment and provide forest resource distribution information for Central Siberia. The following product description provides detailed information on the legends and classification systems used.

Forest definition of Russian Forest Inventory

Forest Inventory data for 10 forest management areas were used for the calibration and validation of the local scale maps. In total, an area of over 2 Mio. Hectares were covered by forest inventory data. The following forest definition was used or the delineation of forested and non-forested areas:

Forest Fund (or Reserve) lands - all lands managed by forest authorities including Forest land and Non-forest land - territories "which are not designated, or which are not suitable for cultivation of tree stands or shrubs without preliminary amelioration or re-cultivation" (5.1.2, page 53, ref below). All other land is considered as forest land. Forest land is divided in the following categories:

- Forested area
- Unstocked planted forests;
- Forest plantations and nurseries;
- Natural sparse forest;
- Land that is not covered by forests [5.1.2, page 53]

The definition of forest in Russia is as follows:

- Land covered by young tree stands with relative stocking 0.4 and more and by stands of other age groups with relative stocking 0.3 and more.

- clear cuts, burns and other plots of naturally regenerated forest lands, if quantity and state of the natural regeneration at these lands
- plots that are covered by shrubs, where, due to natural and geographical conditions, trees cannot grow, or plots, on which a special shrubbery management is organized [page 53]
- Natural sparse forests - stands with relative stocking 0.1-0.2
- Land not covered by forests (burned stands, dead forests - after insect outbreaks, destroyed by wind, air pollution etc., clear cuts, and grassy glades).

Reference: Federal Forest Service of Russia. 1995. Manual on Forest Inventory and Planning in Forest Fund of Russia. Part 1. Moscow, 174 pp.

Local scale growing stock volume maps

The growing stock volume (GSV) maps were generated according to the GSV estimated included in the forest inventory database. The legend is defined as a continuous scale in m^3/ha.

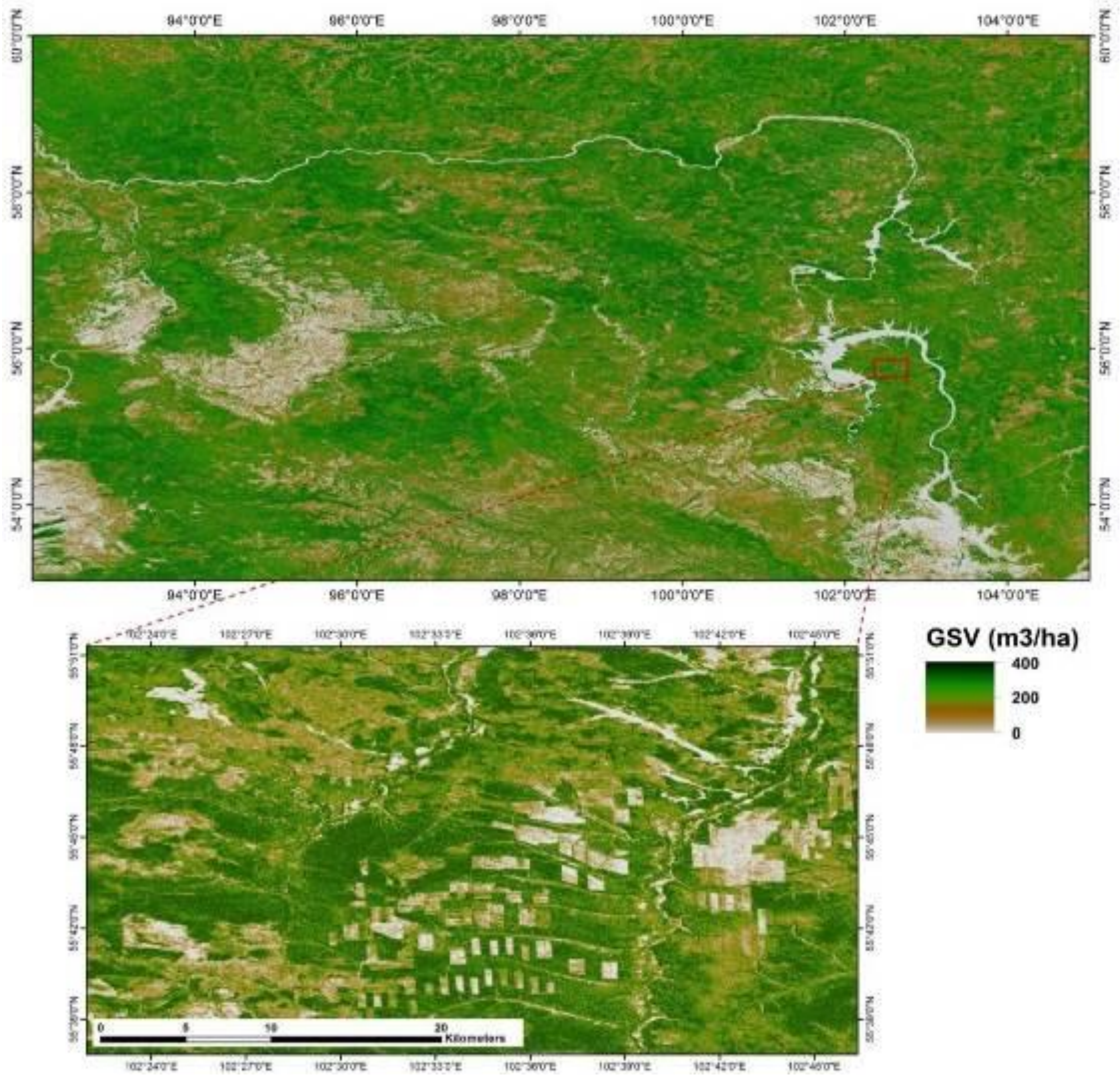


Figure 10: *ALOS-PALSAR-based growing stock volume map for the local test sites in Central Siberia.*

Forest cover and disturbance maps (2007, 2010)

Class	Description
Undisturbed Forest	Areas with open to closed tree cover and growing stock volume higher than 50 m^3/ha
Disturbed Forest and non-forest	Areas with no tree cover to open tree cover and growing stock volume below 3 m^3/ha
Forest Regrowth	Areas with sparse to closed tree cover and growing stock volume between 3 m^3/ha and 50 m^3/ha, referring to reforestation areas on clear cuts or burnt areas.

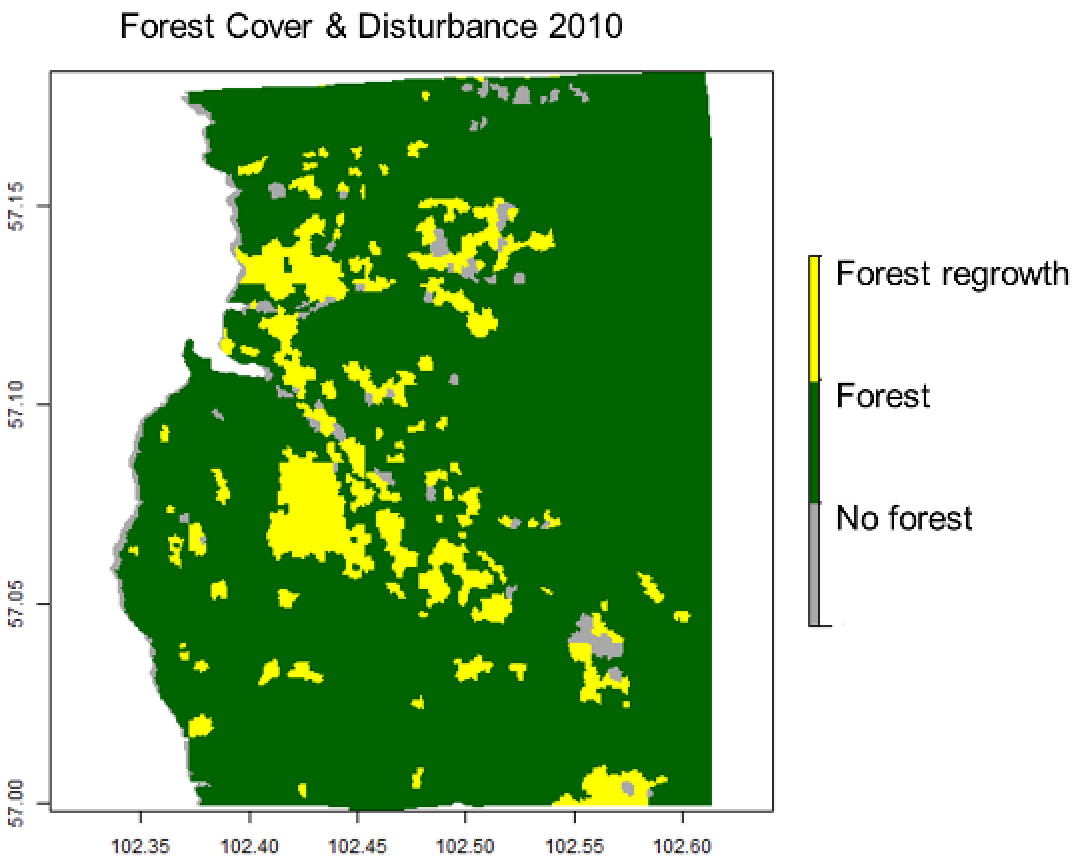


Figure 11: *forest cover and disturbance map example for one local test site in Central Siberia.*

Biomass Disturbances (2007-2010)

The map of biomass disturbances was generated using the annual growing stock volume maps from 2007 to 2010 by applying simple image differencing and threshold application. The resulting image mask represents areas with a significant loss of biomass in terms of growing stock. Forest cover disturbances such as logging, forest fires, and conversions from forests to other land uses were detected with this approach.

Re-/Afforestation probability map

The reforestation and Afforestation map was developed to detect forest succession processes by gradually increasing growing stock volume rates. Originally designed to detect afforestation processes on abandoned agricultural lands, it was found that the specific land cover modification processes cannot be statistically separated without historic knowledge of the land cover distribution. Changes from arable land to forest could not be distinguished between reforestation processes on clear cuts or afforestation processes on newly developed forest plantations. The classification scheme of the presented map involves forest growth processes detected by gradually forest vegetation succession, such as:

- **Reforestation** on logging areas, clear cuts, and burnt areas
- **Afforestation** on abandoned agricultural land, newly developed forest plantations, or land cower transformation and modification from other land cover to forested land

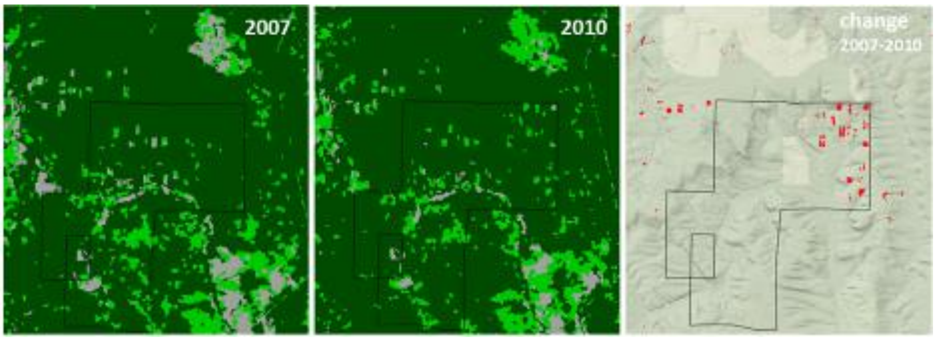


Figure 12: *Forest cover and disturbance maps for one local test site in Irkutsk Oblast. Left and middle: Forest cover and disturbance maps for 2007 and 2010 (dark green – undisturbed forest, light green – Forest regrowth, grey - Disturbed Forest and non-forest). Right: Biomass Disturbance Map (2007-2010).*

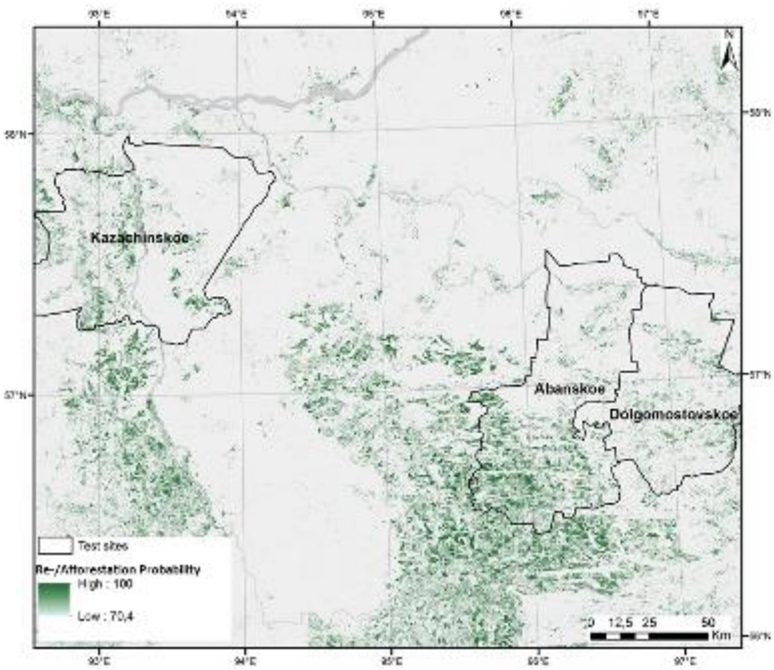


Figure 13: *Forest growth probability map capturing re- and afforestation processes on abandoned arable land, degraded forests and other land cover types.*

2.2.8.4. Deviations and impact on tasks and resources

No deviations occurred.

2.2.8.5. Use of the resources

The following table lists the person-months per participant in the second period in WP 8.

Table 7: Person-months per participant in the second period in WP 8.

FSU	IIASA	IKI-RAS	SIF-RAS	NTsOMZ
3	0	0	6	0

2.2.9 Work Package 9 - Validation and cross-comparison of products

Lead partner: SIF-RAS
Contributing partners: FSU Jena, IIASA, IKI-RAS, NTsOMZ

2.2.9.1. Overview of WP objectives

All products based on EO data foreseen for delivery were validated to assess the quality and usability for further implementation into forestry related services. These are the forest biomass maps for Central Siberia, the improved land cover map for Central Siberia, the updated IIASA GIS land cover layer, the results of carbon accounting for Central Siberia, the recent forest biomass maps, the forest disturbance maps, and the maps of recent abandoned land. Cross-comparison of maps generated within the project: Forest biomass map for Central Siberia against recent forest biomass maps and improved land cover map for Central Siberia against maps of recent abandoned land and forest disturbance.

2.2.9.2. Summary of progress made

A GIS-based approach was used to check the consistency of the forest inventory (FI) data with respect to the optical EO data. To minimize the impact of geolocation errors between the forest stand map and the EO data, a 30 m buffer was removed along the perimeter of each stand. A spatial homogeneity analysis based on mean and standard deviation (SD) of spectral band brightness values of 2010–2011 Landsat TM scenes was calculated for each EFIU. Forest stands with SD greater than two SD were assigned as change area and removed from the FI dataset.

Validation and cross-comparisons of local scale biomass maps

The generated GSV maps have been validated by the Sukachev Institute of Forest located Krasnoyarsk, Russia, Siberia. SAR-derived GSV estimates were compared to elementary forest inventory polygons (FIP), which contain information about land cover type, stand species composition, density, age, height, tree diameter and GSV per species in m^3/ha. The total GSV for all species in the FIP has been used for validating the SAR-based GSV. Statistical parameters (mean and standard deviation) were calculated for each FIP based on the SAR pixel values and FIP's with a negative GSV have been removed from the initial polygons dataset. The comparison statistics were evaluated for four annual maps and the multi-temporal GSV map using total averaging. The local validation sites were grouped into three areas (*Figure 5*).

The overall statistics of the validation results are gathered in Table 8. While the results of the first three maps are well consistent in comparison to each other, the map of 2010 shows weaker results. In comparison to the other maps, the 2010-map contains a stronger underestimation of the GSV. The greatest underestimated GSV (Emin) of this map is dropped to -285.8 m^3/ha, which is 20.9 less than in the worst case of the other images. Also the mean difference between FIP and SAR pixel values (ME) shows the weakest result in the 2010-map (-14.6 m^3/ha). The accuracy of the generated GSV-maps was measured by the root-mean-square error (RMSE). In case of the maps for the years 2007, 2008 and 2009, an RMSE between 55.2 and 57.9 m^3/ha could be obtained, while the result of 2010 showed a higher error of 63.3 m^3/ha. The multi-temporal approach, where we used the datasets of all 4 years, led to a lower RMSE of 54.4 m^3/ha.

Table 8. Validation results, overall statistics of SAR and FI-based GSV comparison (m^3/ha).

Label	Characteristics	2007	2008	2009	2010	multi-temporal
Emin	ΔGSV_{min}	-259.1	-249.6	-264.9	-285.8	-247.9
Emax	ΔGSV_{max}	202.5	216.5	217.6	208	221.2
ME	Mean ΔGSV (SAR-FI)	-1.3	1.4	6.3	-14.6	3.7
SD	ΔGSV Standard Dev.	55.3	55.2	57.6	61.6	54.3
MAE	Mean Absolute Error	43.5	43.5	46.0	49.7	42.9
RMSE	Root-Mean-Square Error	55.3	55.2	57.9	63.3	54.4

Assessment of retrieved forest GSV from ALOS and PALSAR data with respect to forest inventory data

Comparisons of the 1-km ASAR and the 25-m PALSAR GSV estimates with forest inventory showed positive correlations for all test sites, but different congruency levels occurred among the test sites (Table 9). The congruency was weak in Bolshemurtinsk/Kasachinsk and Padunsk with R values between 0.3 and 0.45. Moderate correlations were achieved for the Abansk/Dolgomostowsk test site (0.6 and 0.55, respectively). The RMSE between ASAR-based GSV and FI GSV was between 47.7 and 64.9 m^3/ha. The RMSE between the PALSAR-based GSV and the FI GSV was between 58.9 and 71.3 m^3/ha. For a better comparability between test sites the relative RMSE was included related to the average stocking (167.1 m^3/ha) in the FI data. At test site level the ASAR-based map achieves a deviation from FI estimates of 28.39 % - 38.63 % (total mean for all test sites = 34.01 %). Slightly higher RMSE show the GSV maps derived from the PALSAR mosaics (35.06 % - 42.44 %, total mean for all test sites = 39.44 %).

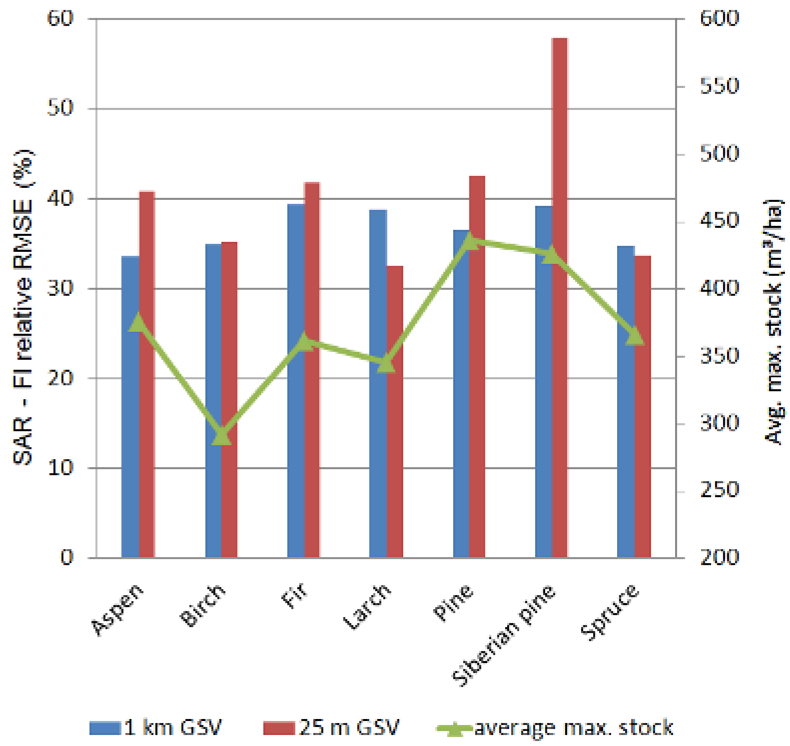
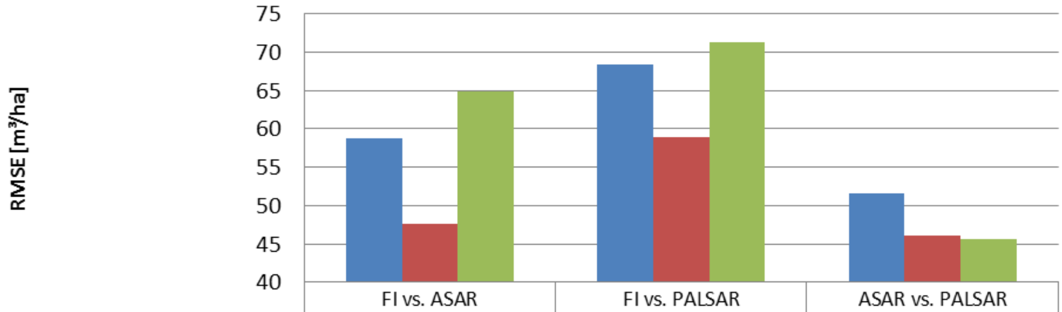


Figure 14: *Relative RMSE of SAR – forest inventory comparisons of dominant forest species (mean values of all test sites). The 1 km GSV map better matches with FI in the high biomass levels and vice versa.*

When stratifying the FI-SAR comparisons according to dominant species, the strongest congruency for both SAR products was achieved for the classes Spruce (1 km GSV: 34.76 %, 25 m GSV: 33.96 %) and Birch (1 km GSV: 34.96 %, 25 m GSV: 35.18 %) followed by Larch and Aspen (Figure 4). Species with higher maximum average stocking rates like Pine (1 km GSV: 36.51 %, 25 m GSV: 42.86 %) and Siberian Pine (1 km GSV: 39.23 %, 25 m GSV: 57.96 %) indicate better map congruities for the ASAR-based map. Comparisons of the Siberian Pine stands show high incongruities in the Padunsk region. The Siberian Pine error distributions of the other two test sites are comparable with those of the Pine stands. Except for the Padunsk test site the best FI-SAR GSV congruencies were measured in the higher biomass stands of the ASAR-based GSV maps. But the high stocking stands indicate higher incongruities between the ASAR and the PALSAR- based maps. Generally, Kazachinsk (site group 1) and Abansk/Dolgomostowsk (site group 2) have similar results in terms of species-wise GSV deviations. Padunsk (site group 3) shows higher errors, particularly for Fir and Siberian Pine. Here, the difference between the ASAR-based and the PALSAR-based GSV products has the highest RMSE at 1 km scale. The FI statistics report most extensive disturbances for the Padunsk test site (5,416 ha clear cuts and 1,608 ha burned area), causing higher small-scale fragmentation of forest. This may introduce errors at 1 km scale GSV estimates.
Cross-comparisons of the GSV retrievals from FI, ASAR, and PALSAR show distinct differences of the GSV congruency between the three test sites. In order to depict the most consistent dataset between the test sites, the RMSE of the three combinations (FI vs. ASAR, FI vs. PALSAR, ASAR vs. PALSAR) are presented in *Figure 15*. The ASAR and PALSAR GSV estimates comparisons indicate the best map matching among the test sites. As discussed, Bolshemurtinsk/Kazachinsk achieved

significantly higher errors than the remaining test regions. Variance in the error distribution is visible within the FI-SAR comparisons for both, between test sites and SAR products. As discussed, the ASAR-based map represents closer results to the FI reference than PALAR. However, the FI-SAR comparisons show substantial inconsistencies between the test sites. The highest errors are observed for Padunsk (which is in contrast to the ASAR-PALSAR comparisons), followed by Bolshemurtinsk / Kazachinsk and Abansk / Dolgomostowsk. The latter test site comes out as most consistent for all comparisons.



	FI vs. ASAR	FI vs. PALSAR	ASAR vs. PALSAR
Bolshemurtinsk & Kazachinsk	58,8	68,4	51,6
Abansk & Dolgomostowsk	47,7	58,9	46,1
Padunsk	64,9	71,3	45,7

Figure 15: *Cross-comparisons of the GSV retrievals from forest inventory, ASAR-based mapping and PALSAR- based mapping.*

Validation and cross-comparisons of local scale Forest Cover and Disturbance Maps

Cross Comparison of 25 m Disturbance Map vs. Forest Inventory Data
Input Data

Data for cross comparison included SAR-based 25m disturbance maps for 2007 and 2010 (with classes: non-forest, forest, and regrowth), and forest inventory polygons for the local sites of Krasnoyarsk kray.

The Forest inventory polygons (FIP) were grouped by FI land cover type. The FIP layer was overlaid on 25 m raster maps of disturbances (2007 and 2010) and cross-tabulated areas between FI land cover types and SAR-based land cover types were calculated. The SAR-based land cover type distribution inside FI land cover type was estimated as % of overlapping areas.

Results were spatial statistics for the mapping dates of 2007 and 2010 showing the class distribution of the forest cover maps compared to the FI layers. Examples (Krasnoyaksk local test sites) are shown in Fig. 15b (detailed statistics in Deliverable 9.9). Differencing the SAR-based forest cover maps provided information about the direction of change and the corresponding class (*Figure*). In general, the SAR-based maps agree with the change classes of the FI statistics (*Figure* 7). Krasnoyarsk shows a better SAR-FI agreement than the Irkutsk test sites.

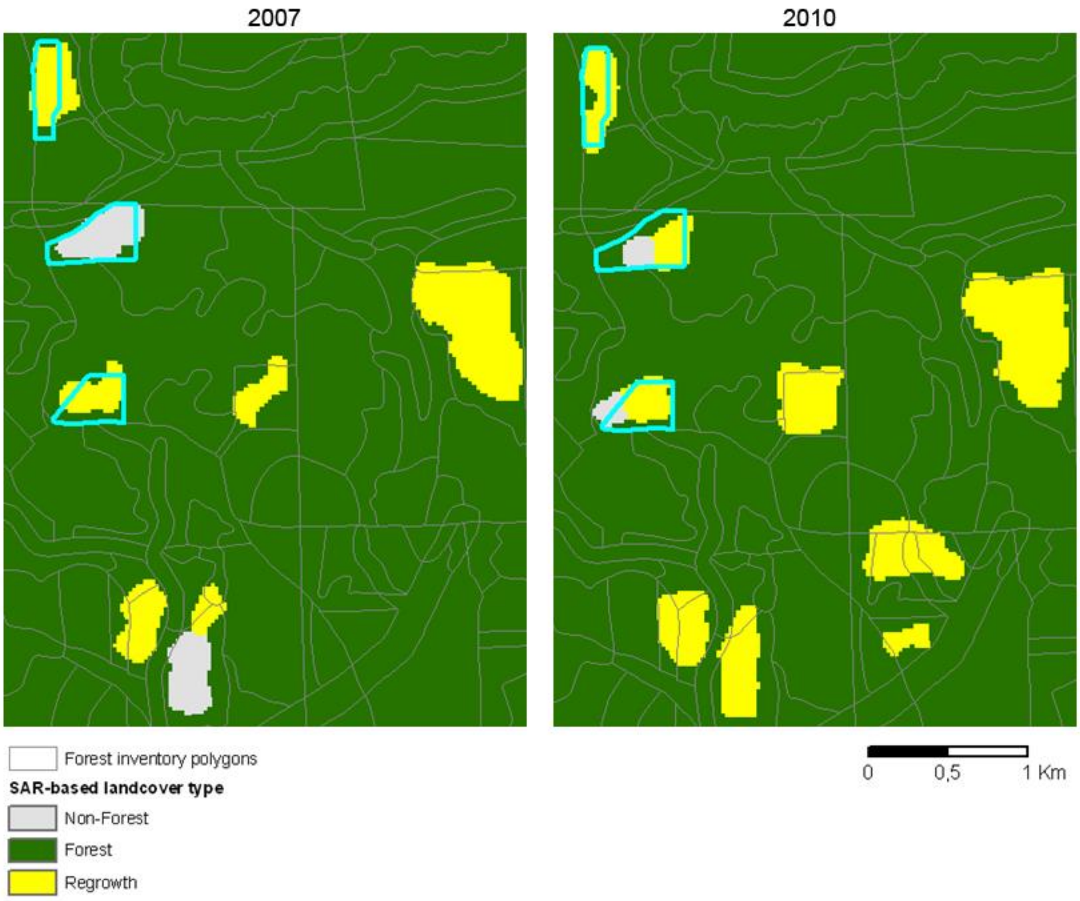


Figure 15b: *SAR-based land cover types (2007 - 2010) and forest inventory polygons (cuttings are highlighted). Bolshemurtinsk local site*

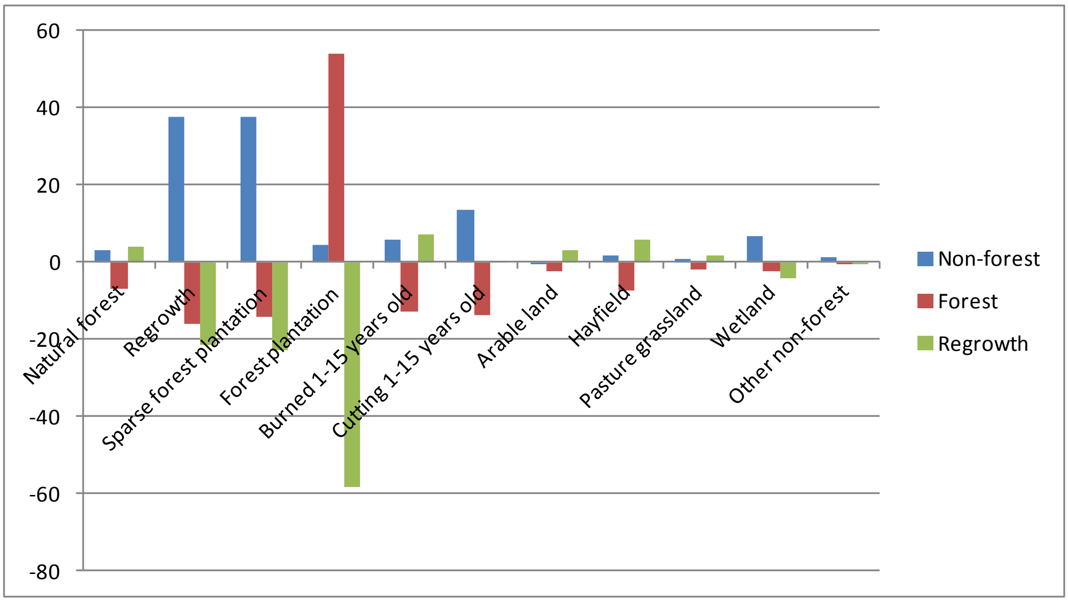


Figure 166: *SAR-based land cover type area difference (2007 - 2010) inside FI land cover types.*

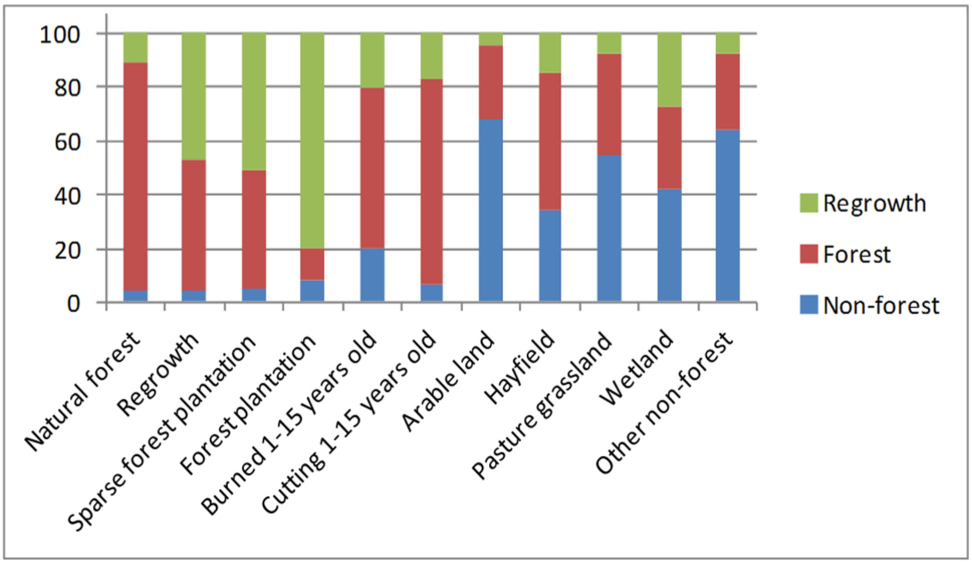


Figure 177: *SAR-based land cover type area distribution (2007) inside FI land cover types.*

Cross-comparisons of SAR-based Forest cover and disturbance maps with forest cover maps based on multi-temporal Landsat classifications

The forest cover and disturbance maps were compared to the updated forest inventory data where information of the change history and land cover change transitions and modifications are included. However, in order to get information on the product quality for the two mapping years of 2007 and 2010, the SAR-based classifications were cross-compared with forest / non-forest classifications derived from Landsat TM imagery for the years 2007 and 2010.

The classifications for the years 2007 and 2010 were compared to the ALOS PALSAR based forest disturbance classifications for the overlapping map regions of the test sites Kazachinsk and Padunsk. Therefore, the legends of the SAR-based maps were converted to the forest / non-forest classification scheme by assigning the forest regrowth class to the forest class. The results of the annual comparisons indicate a general agreement of the two datasets over time and between the test sites. As shown in Figure 18, Padunsk achieved map agreements of 85 % for 2007 and 87 % for 2010. Kazachinsk achieves an overall agreement of 81 % for 2007 and 88 % for 2010. The SAR- based forest cover product seems to overestimate the forest class. This is indicated by varying class matches of Landsat Non-forest – PALSAR Forest for 2007 and 2010. The overestimation of the forest class of the PALSAR products might be explained by the integration of the class forest regrowth that includes areas with a growing stock volume higher than 100 m^3/ ha.

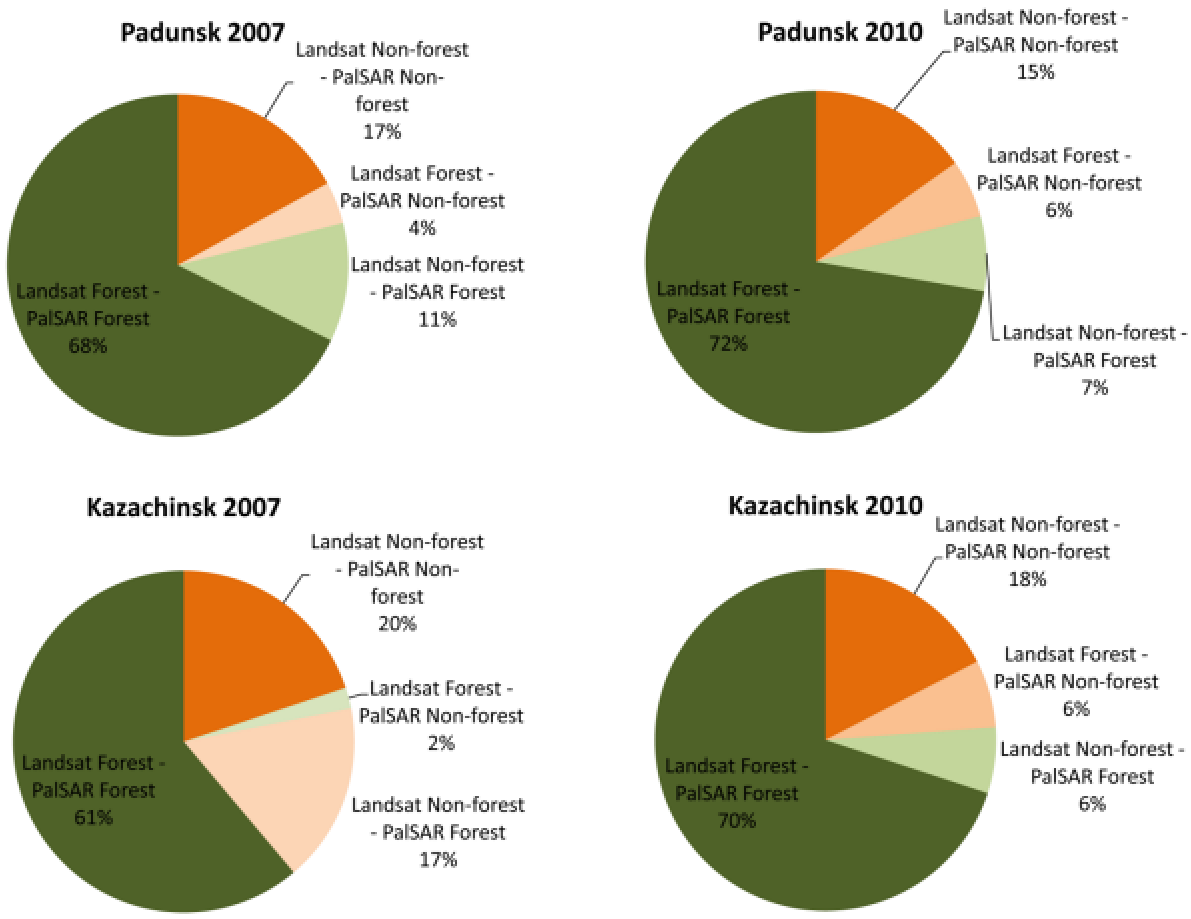


Figure 18: *comparisons of Landsat- abs PALSAR-based forest / Non-forest classifications for 2007 and 2010 for overlapping areas of the test sites Kazachinsk and Padunsk.*

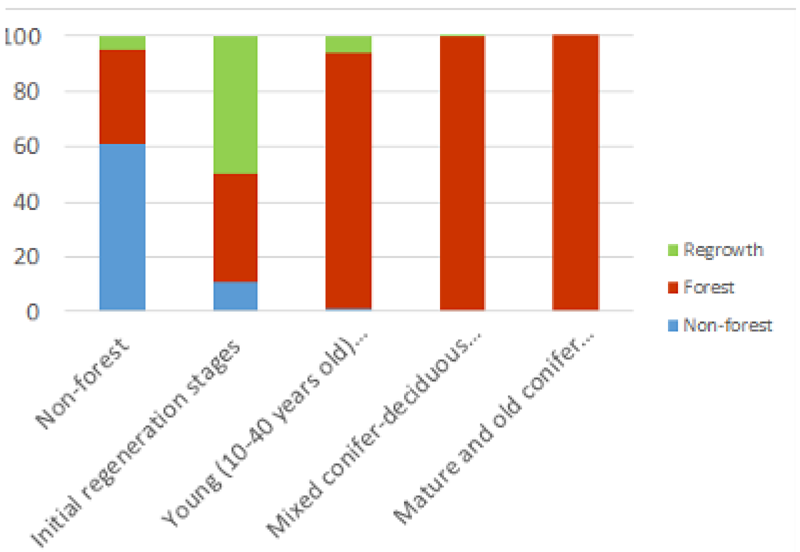


Figure 19: *Class distribution of Landsat- and SAR- based forest cover maps in the Krasnoyarsk Test sites.*

Further on, Landsat based classifications were generated with class descriptions consisting of forest type and age class. These maps indicate the time of change and the regeneration state of the forest. Comparisons with the SAR-based forest cover maps show a general consistency of the class distributions (*Figure 18*9). Comparisons with VHR data of Resurs-DK-1 and Monitor-E data also prove the applicability of the SAR-based GSV maps for forest cover change tracking (*Figure 19*20).

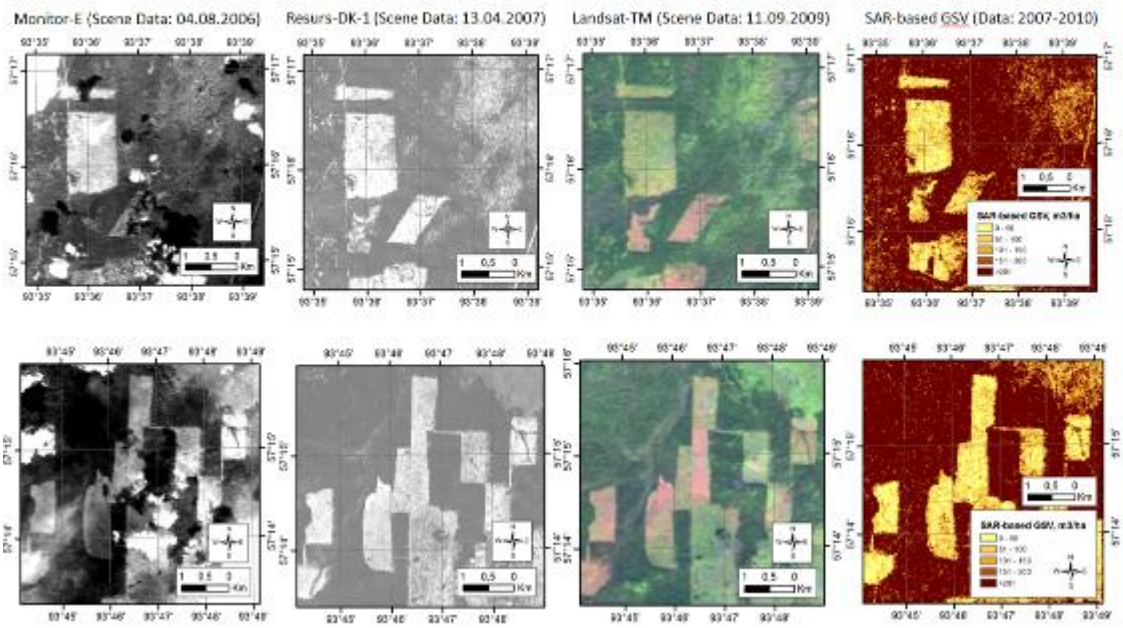


Figure 20: *Comparison of Monitor-E, Resurs-DK-1, Landsat and PALSAR- based GSV maps for forest cover and change monitoring in Siberia.*

Validation and cross-comparisons of local scale Reforestation probability Maps

Extended validation and re-calibration of the forest regrowth probability map

Based on the results of the cross-comparisons of the reforestation probability map with forest inventory, an extended validation was performed in order to confirm and recalibrate the previously selected threshold of 69.3 %. Input data for collection of forest regrowth plots comprised the SAR-based regrowth probability map, RESURS-DK imagery for the regions Krasnoyarsk and Irkutsk for 2006 – 2011, ESRI World Imagery Base maps, Landsat TM-based land cover map of 1989, MODIS-based land cover map of Central Siberia for 2010, and Landsat TM-based abandoned land layer. Regrowth plots were collected for the five land cover types: abandoned land, arable land, natural forest, cutting, and burned areas in form of point and polygon information. In total, 282 regrowth plots were collected (abandoned land: 81, arable land: 72, natural forest: 55, cutting: 55, burned: 19). A polygon was created for each regrowth plot. The zonal statistics tool in ArcGIS was used to calculate the mean pixel-values of the SAR-based forest regrowth probability map for each polygon.

The probability threshold for the SAR-based forest regrowth probability map of 69.3 % was replaced by the new mean regrowth probability value of the land cover type abandoned land of **70.4 %.**

An accuracy rate of **80.5 %** was achieved. As shown in Table 9, the main commission error occurred in the class of arable land. This can be explained by similar vegetation structure (low biomass levels) and potentially similar inter-annual dynamics of the GSV values, e.g. bare land in 2007 and cultivated land in 2010 could lead to high reforestation probabilities. The Non-regrowth related land cover classes did not show any commission errors.

Table 9: Confusion matric for the Regrowth / Non-regrowth versus the main land cover types (by applying the threshold of 70.4 %).

	Abandoned land	Arable land	Natural forest	Cutting	Burned
Regrowth	81	52	0	0	3
Non-regrowth	0	20	55	55	16

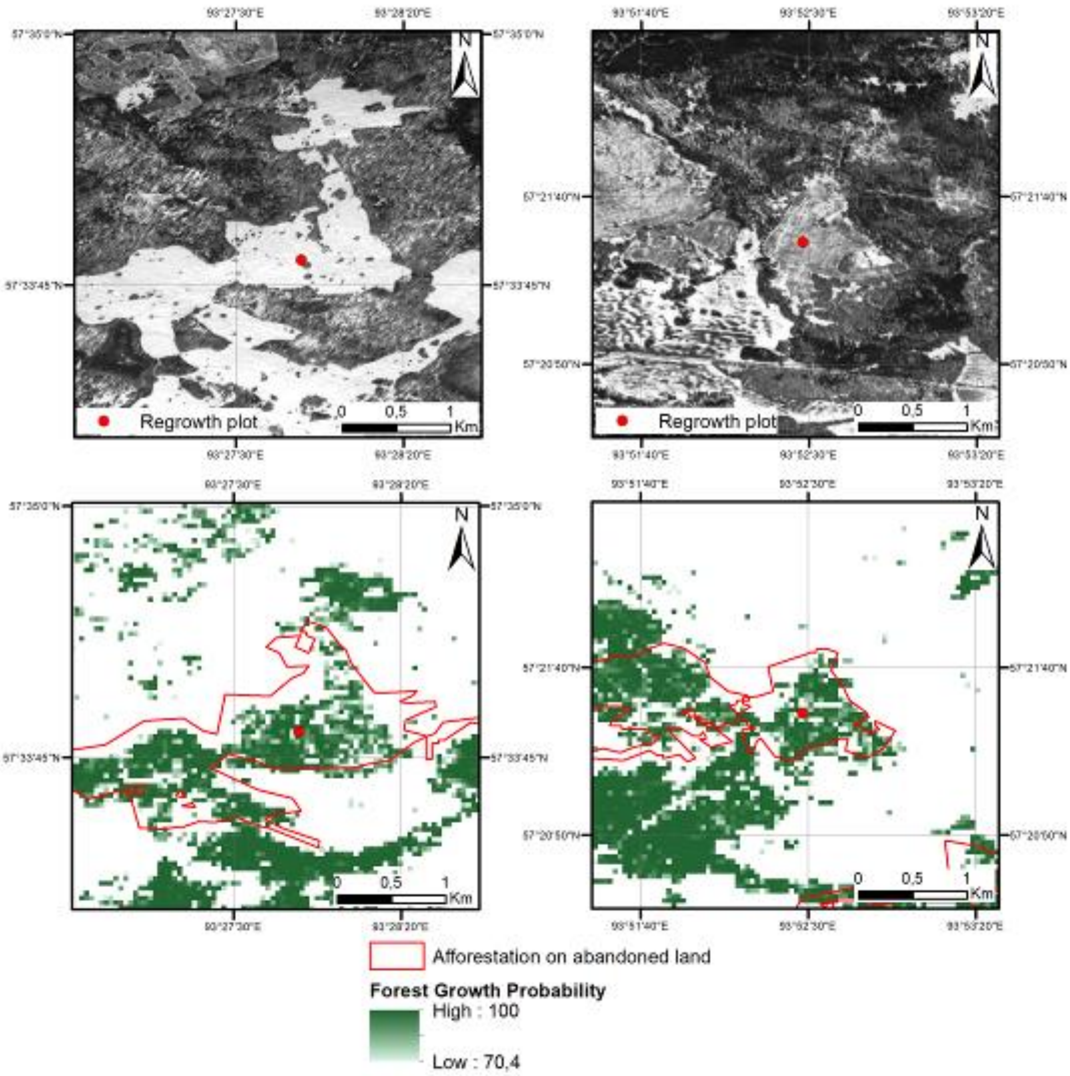


Figure 21*: Two examples of collected regrowth plots of abandoned lands on Resurs-DK-1 (Scene Date: 13.04.2007) imagery and on SAR-based Reforestation Map with regrowth probability.*

Each plot was selected using Landsat- based land cover classifications, VHR RESURS-DK1 Imagery, and temporally high resolution MODIS time series imagers (2000 - 2014) as information source. Figure 21 shows two examples of the spatial information content provided by the RESURS-DK-1 panchromatic images, provided by ROSCOSMOS. Validation points were selected in abandoned land sites. The red line indicates an abandoned land polygon, which was retrieved by Landsat classification.

Validation and cross-comparisons of regional scale land cover maps

Data for cross comparison included the MODIS-based 250 m Land cover Map and Forest Species Map, and Forest inventory polygons for the local sites of Krasnoyarsk and Irkutsk regions.

The land cover class comparison was based on elementary forest inventory polygons (FIP). The FIP attributive database contains land cover type, stand species composition, density, age, height, tree diameter, and growing wood stock volume (GSV) per specie (m3/ha). Comparison statistics were provided to estimate the class distributions for MODIS and the FI data. Examples are given below (Table 10, *Figure 22*) for the comparisons of the FI dominant species database with the MODIS- derived forest species map. For all classes large error rated and inter-class confusions were detected. The integration of the regional scale maps within locally relevant forest management activities is thus not recommended. Sources of error can be scale differences, coarse scale pixel location errors or outdated land cover information in the forest inventory data.

Table 10: MODIS Forest map classes area distribution (% of total area) per FI dominant specie classes.

	MODIS Forest Species map classes								
FI Class	**Non-forest**	**Spruce**	**Fir**	**S. pine**	**Pine**	**Larch**	**Birch**	**Aspen**	Total
Non-forest	-	-	-	-	-	-	-	-	100
Spruce	4	**42**	26	3	14	7	3	1	100
Fir	1	27	**53**	7	7	1	3	1	100
S. pine	3	30	2	**37**	21	6	0	0	100
Pine	6	28	0	3	**43**	2	17	0	100
Larch	3	**59**	0	10	15	4	8	1	100
Birch	10	10	2	2	23	1	**46**	5	100
Aspen	9	12	1	1	23	0	**49**	4	100

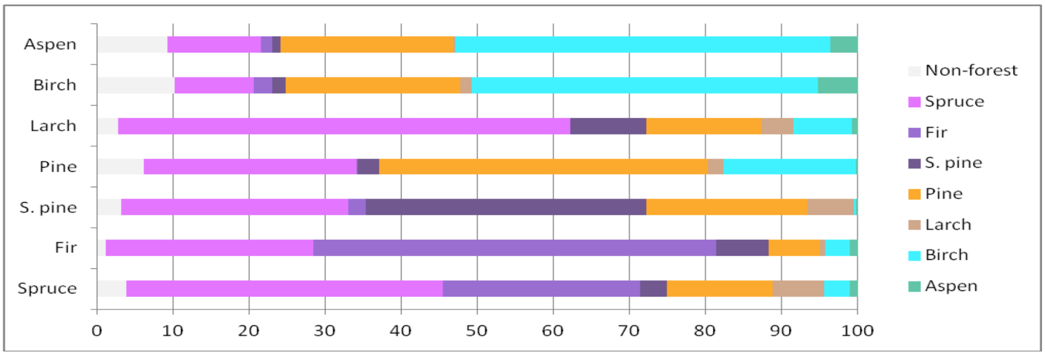


Figure 22: Class distribution of forest species maps derived from MODIS and FI.

Comparison of results of the Verified Full Carbon Account of forest ecosystems with GOSAT Level 4 products

A full Carbon Account (FCA) of forest ecosystems of Central Siberia was estimated within the project and presented in deliverable D7.1. Our method is based on the Land Ecosystem Approach (LEA). The comparison with other methods, especially remote sensing is considered as a very important. One of such independent method is inverse modelling based on direct measurements of CO_2 in atmosphere. Any solid assessment of the uncertainties in studying complex ecological systems requires mandatory compliance with background rules of applied systems analysis (Dolman et al., 2012). With respect to the current comparison we used by pixel values of the Net Ecosystem Carbon Balance (NECB), limited to forest land and components accounted for GOSAT Level 4 products and aggregated the product to a spatial resolution of 1˚.

The carbon accounting products derived using the LEA approach was compared to the GOSAT Level 4 products in order to estimate the level of agreement between both datasets.

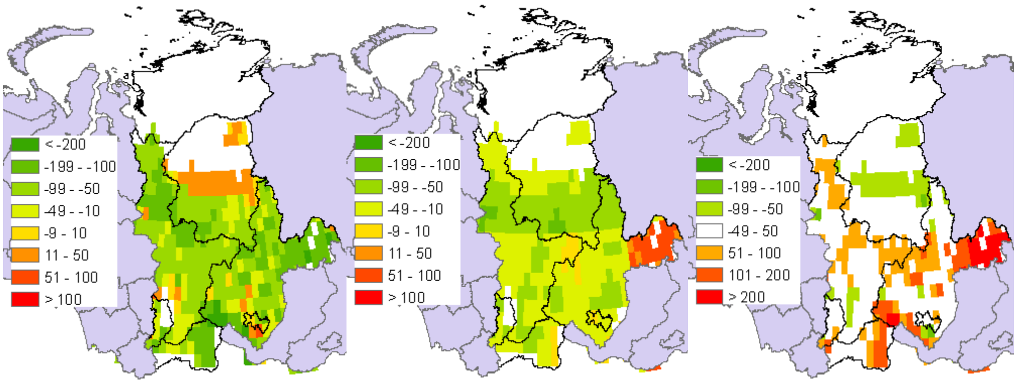


Figure 23: *Left: LEA carbon balance of forest land, g C m^{-2} yr^{-1}. Negative value means sink and positive – emission. Other than forest vegetation classes were assigned to zero, Middle: GOSAT carbon flux (Biosphere and biomass burning), g C m-2 yr-1, Right: Difference in carbon balance estimation, g C m-2 yr-1. Negative value (green color) means LEA has higher estimation and positive (red color) – GOSAT is higher.*

Table 11: Comparison of GOSAT (vegetation) and LEA (forest) estimation of NCEB.

Region	Pixels	NECB, g C m^{-2} yr^{-1}			
		GOSAT	LEA	Difference	Std. dev.
Krasnoyarsk kray	194	-54	-51	3	51
incl. Taimyr	2	-46	-38	8	1
incl. Nenetsky	82	-61	-28	33	44
incl. without autonomies	110	-48	-76	-29	39
Irkutsk	107	-27	-97	-70	87
Khakasiya	5	-42	-11	31	36
Tyva	17	-32	-100	-68	61
Average	321	-44	-73	29	73

In general, the carbon fluxes demonstrate rather consistent results. The following conclusions could be done based on the above comparisons:

- There is an overall consistency between regional estimates of GOSAT Level 4 Products and Landscape-Ecosystem approach.
- Aggregated data demonstrate no significant difference for the administrative regions, however substantial spatial disagreement is taking place.
- The inconsistency can be explain partly by:
    - different subject – forest in case of LEA and all land cover classes in case of GOSAT;
    - contrast NECB estimation by GOSAT for different regions. The most visible difference in the Eastern part of Irkutsk oblast related to GOSAT region 26, which almost entire emits carbon and has clear border with the neighbors.

2.2.9.3. Highlights

Validation meeting at Suchachev Institute of Forest in Krasnoyarsk

A 10 day working meeting between FSU and SIF-RAS was realized in August 2013. The purpose of this meeting was the validation of the high resolution forest resource maps on biomass and forest cover and disturbances with forest inventory data. Data harmonization, comparisons and statistical analyses were conducted at the Suchachev Forest Institute in Krasnoyarsk. Within the two days field trip to one of the local test sites in the Bolshemutinsk area parts of the local scale maps were validated and additional field plots were collected. The German-Russian team exchanged important knowledge on forest ecology and mapping with optical and SAR- based observation systems.

Figure 24: *Recent clear cut in the Bolshemurtinsk region.*

Figure 25: *Forest tracks as part of the logistic infrastructure within the clear cut sites.*

Figure 26: Forest ecology lessons in the field provided by SIF-RAS scientists.

Figure 27: *Regrowing forest on abandoned agricultural land.*

Figure 28: *Regrowing forest on former clear cuts.*

Figure 29: *Forest ecology lessons in the field provided by SIF-RAS scientists.*

Third annual project meeting in Berlin

The finalization of the validation and cross-comparison activities in WP 9 was the main topic during the two days project meeting, held on April 1 and 11 at the Institute for Space Sciences at the Free University in Berlin. The project team was updated on the recent validation developments. Methodological improvements were discussed and a final action plan was released for the remaining project life time. Further on, recent results on the carbon assessment were discussed and possible integration options of the ZAPÁS Earth Observation products were discussed.

2.2.9.4. Deviations and impact on tasks and resources

No deviations occurred.

2.2.9.5. Use of the resources

The following table lists the person-months per participant in the second period in WP 9.

Table 12: Person-months per participant in the second period in WP 9.

FSU	IIASA	IKI-RAS	SIF-RAS	NTsOMZ
0	1	2	5	1

2.2.10 Work Package 10 - Development of Web-Portal and Product Dissemination

Lead partner: IKI-RAS
Contributing partners: NTsOMZ, FSU Jena

2.2.10.1. Overview of WP objectives

The goal of the Web-Portal is to provide a platform for intra-project communication and data dissemination as well as external product provision. Moreover, the web portal will be used for data dissemination when products are finalized and the dissemination of scientific publications.

2.2.10.2. Summary of progress made

Web-Portal

A bi-lingual web portal was established and hosted by the FSU team. The ZAPÁS web portal is available under http://zapas.uni-jena.de. The web portal is the main tool for the dissemination of project information and background, documents (scientific publications, reports, and presentations) and the communication within the project team. All activities will be communicated and published in a web blog style. The data distribution service within the project is provided by the Siberian Earth System Science Cluster (SIB-ESS-C). The web portal is also hosted by FSU, available under http://www.sibessc.uni-jena.de and linked in the ZAPAS web portal.

The other pages are of formal character aiming at (a) describing the background and objectives of the ZAPÁS project, (b) showing and describing the geographic location of the study areas. Local test site locations are depicted on a web-map viewer. The project consortium and contact information is presented on a single site describing participant names and institutions. As the web portal is aiming to fulfill key dissemination purposes documents and presentations of the project team are presented and frequently updated.
The ZAPAS web-portal also include two links to a map-service hosted by IKI (http://zapas.smislab.ru), which provides access to the satellite data sets and thematic products developed within the project framework along with various tools for data analysis.

The second Geoportal hosting and visualizing ZAPAS geo-information products are the SIB-ESS-C portal hosted by the FSU's Department for Earth Observation. The mission of the Siberian Earth System Science Cluster (Sib-ESS-C) is to provide a web-based infrastructure and comprehensive information products derived from Earth Observation that support environmental and earth system research in Siberia. The ZAPÁS project is closely linked to the SIB-ESS-C developments and uses its capabilities by integrating local and regional scale forest resource maps and using the SIB-ESS-C land dynamics analyses tools (*Figure 30*).
After developing regional and local scale forest resource maps based on optical and SAR satellite data, all geo-information products are now integrated in the SIB-ESS-C

geoportal. The portal can be used to apply the so-called multi-resolution concept in earth observation. In the case of the ZAPÁS initiative, state and dynamics of forest resources can be assessed for the Central Siberian test region. The complete set of EO-based forest resource maps related to biomass and forest cover tracking is accessible via the SIB-ESS-C Geoportal. The basic functions are explained in a tutorial.

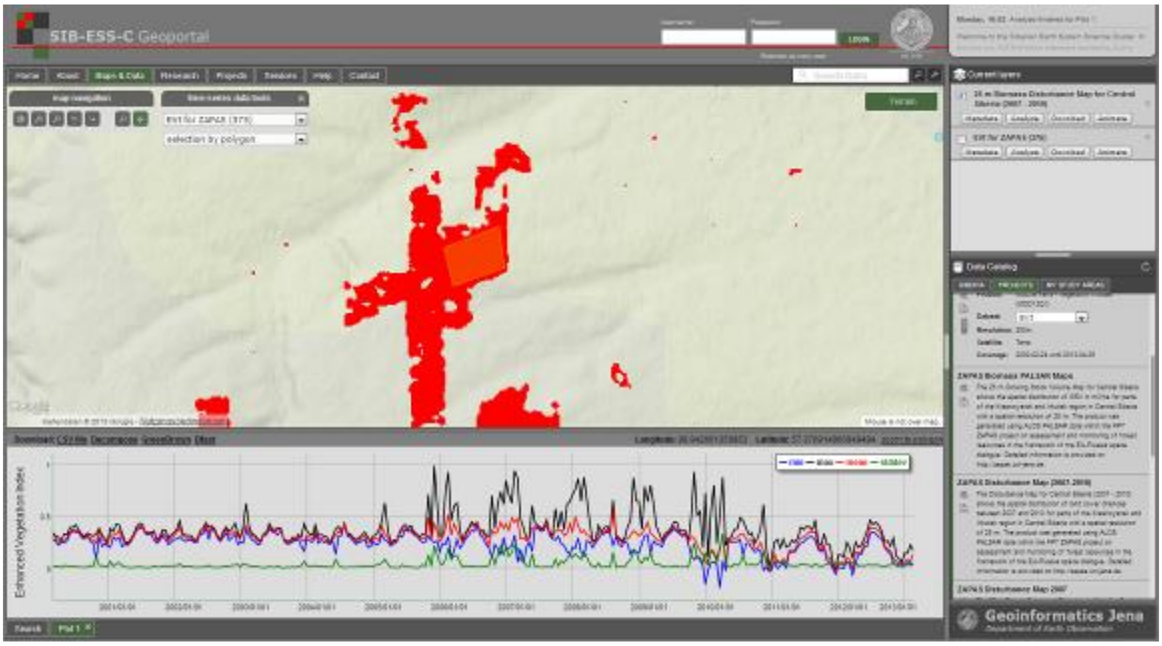


Figure 30: *Visualization of deforestation (red) patterns based on annual biomass maps derived from ALOS PALSAR (25 m mosaics provided by JAXA's Kyoto and Carbon Science Initiative).*

Figure 31: *Visualization of the growing stock volume map for Central Siberia in the ZAPÁS web map portal.*

Further SIB-ESS-C online tools include: Operational Time-Series Data Integration, Visualization and Analysis, data Web Services provided with standards compliant to the Open Geospatial Consortium (OGC), web-based Data Visualization, and online Time-Series Analysis functions with R backend. Further information is provided in a project flyer where forest change dynamics in terms of re- and deforestation monitoring in the ZAPÁS project are presented.

The following dissemination activities were conducted to further inform and educate the stakeholder community:

- A webinar explaining the handling of the geoportal is currently under development and will be released by the end of the project.
- Tutorials on the use of the products were given at conferences (Forest Change Conference Freising, ESA Living Planet Symposium)
- Poster Presentations were provided on the data catalogue and access on science meetings and conferences

- Flyer were produced and distributed to the community network in Europe and Russia
- Case studies and data demonstrations are being conducted within the operational work of the organizations of the project partners to reach an implementation of the main functions for operational forest management purposes
- A number of research papers have been submitted

2.2.10.3. Highlights

Maintaining of the informational part of the web portal is ongoing. Recent activities comprise the frequent update of the information portal to provide information on latest publications, meetings and reports. Web site summary statistics indicate a permanent increase of the project website visits (*Figure 32*). All ZAPÁS products are online available for further exploration and visualization. Online tools are applicable using the IKI and FSU geoportals to assess forest resources (Growing stock volume) and forest dynamics. A user tutorial accessible on the website is in production to assist the stakeholders on data use and data access.

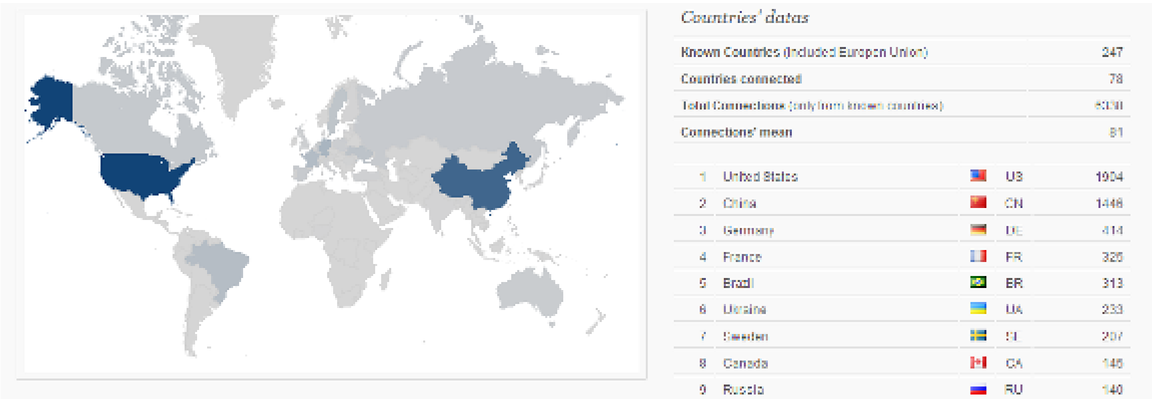


Figure 32: *Map of web portal visits since January 2013 acquired from http://zapas.uni-jena.de.*

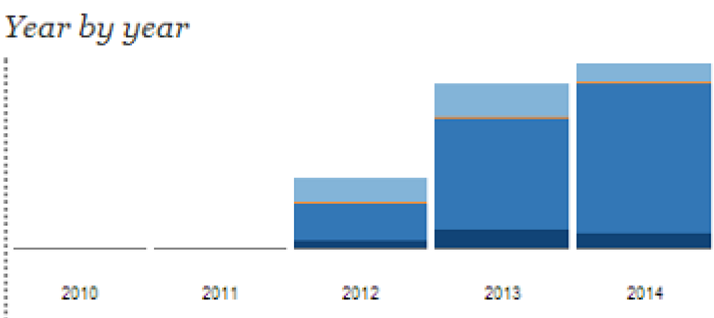


Figure 33: *Page views during the project live time. In 2014 38,000 page views were recorded.*

A new project on web-based EO data processing and time series access was established at FSU Jena. The Earth Observation Monitor (EOM) is a product based on the Siberian Earth System Science Cluster established at the Department of Earth Observation at the Friedrich-Schiller University Jena. Time-series data from NASA

MODIS sensor is provided for an easy access and analysis with web-based technologies. The analysis of time-series data is focused on the detection of breakpoints, trends and phenological parameters. With an automated data access and analysis process the user does not need to process the data.

Features:

- Individual time-series filtering based on quality flags and user-defined date range
- Time-series analysis for breakpoints, trends, and phenological parameters with individual parameterization
- Export of processed data for offline usage
- Sharing of analyses with other users

Figure xxx shows the main time series analyses tools accessible via the EOPM portal. The ZAPÁS project is an important use case for this project. Capabilities of near real-time forest monitoring are being proposed and elaborated in the ZAPÁS scientific network.

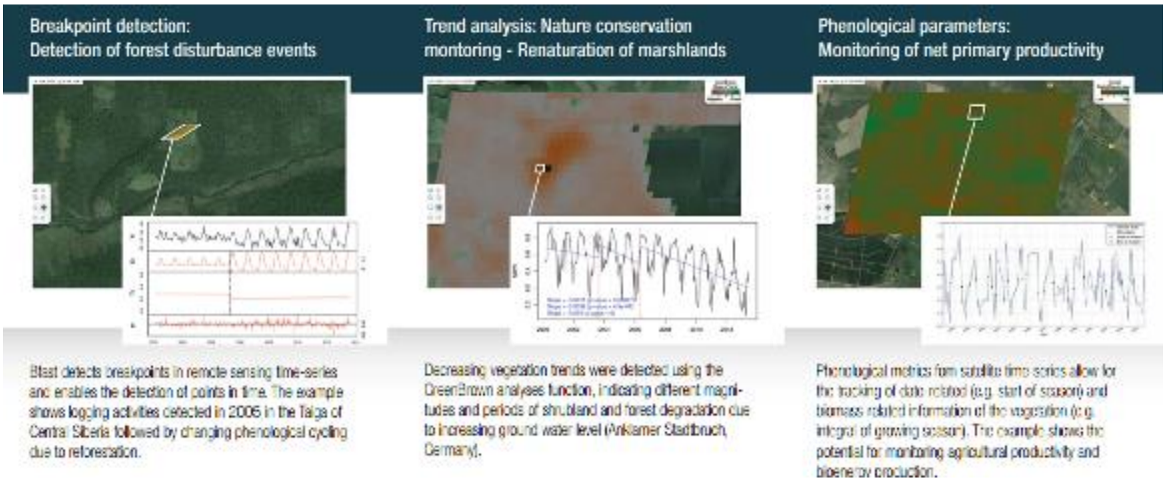


Figure 34: *Time series analyses tools available via the Earth Observation Monitor.*

Dissemination activities

The dissemination activities during the third year focused on the strengthening of important existing networks and collaborations but also the dissemination of project results to a broad user-orientated public audience.

The ZAPÁS map products and validation results were presented at several scientific conferences. Capabilities and limitations of EU-derived forest resource maps and forest inventory were presented and discussed. These findings are being published in key scientific journals. The full list of dissemination activities is shown in Table 13.

Table 13: Dissemination activities during the second reporting period.

Title	Location	Date	Participants	Type of activity
EGU-2014	Vienna	28.4-2.5. 2014	IIASA, SIF-RAS	Conference
International conference GEOBIA 2014	Thessaloniki	21-24.05.2014	SIF-RAS	Conference
PEEX Meting	St. Petersburg	3.-7.3. 2014	SFU, IIASA	Conference
Forest Change Conference	Freising	2.-4- 3. 2014	FSU	Conference
National Forum for Remote Sensing and Copernicus	Berlin	8. – 10. 4. 2014	FSU	Conference
ZAPAS annual meeting	Berlin	10. – 11. 4. 2014	FSU, IKI, IIASA, SIF-RAS	Workshop
ZAPAS Review Meeting	Brussels	06.09.2013	FSU, IKI	Workshop
ESA Living Planet Symposium	Edinburgh	9. – 13. 9. 2013	FSU	Conference
Mega grant Permafrost Meeting	Hannover	2.-3. 12. 2013	FSU, SIF-RAS	Workshop
The V All-Russian Conference on RS applications	Moscow	22-24.4. 2013	IIASA, IKI, SIF-RAS	Conference
The 16th Science Conference of IBFRA	Edmonton	7-10.10.2013	IIASA, SIF-RAS	Conference
International ZOTTO workshop	Krasnoyarsk	16-22.09.2013	SIF-RAS, Max Planck Institute	Conference
Hüttich et al. 2014. Supporting a Forest Observation System for Siberia: Earth Observation for monitoring, assessing and providing forest resource information. Earthzine, (in press).	Jena		all	Publication
Hüttich et al. 2014. Exploiting growing stock volume maps for large scale forest resource assessment: Cross-comparisons of ASAR- and PALSAR-based GSV estimates with forest inventory in Central Siberia. Forests. (in press).	Jena		all	Publication
Sokolov V.A., Shvidenko A.Z., Vedrova E.F. Forests of Krasnoyarsk Kray in the Kyoto Process. Saarbrueken, Germany, Lambert Academic Publisher, 2013. 154 pp. [has not been indicated earlier]	Laxenburg		IIASA	Publication
Shvidenko A.Z., Schepaschenko D.G. 2014. Carbon budget of Russian forests. Siberian Journal of Forest Science, No 1, 69-92 [in Russian].	Laxenburg		IIASA	Publication
Shvidenko A., Lakyda P., Schepaschenko D., Vasylyshyn R., Marchuk Yu. 2014. Carbon, climate and land-use in Ukraine: Forest sector. IIASA and National	Laxenburg		IIASA	Publication

University of Life Sciences and Environment of Ukraine, Kiev, Ukraine, 283 pp. [in Ukrainian]			
Thurner M., Beer Ch., Santoro M., Carvalhais N., Wutzler T., Schepaschenko D., Shvidenko A., Kompter E., Ahrens B., Levick S.R., Schmullius C. 2014. Carbon stock and density of northern boreal and temperate forests. Global Ecology and Biogeography, 23, 297-310, doi: 10.111/geb.12125	Jena	FSU, IIASA	Publication
Shvidenko A., Schepaschenko D., Baklanov A. 2014. Integrated Land Information System – a relevant step for development of information background for PEEX? EGU Abstracts EGU, Vol.16, EGU 2014-4143-2, 2014 (Session AS4.4/BG5.5/CL4.7/ SSS/0/14).	Laxenburg	IIASA	Publication
T. A. Chowdhury, C. Thiel & C. Schmullius (2014): Growing stock volume estimation from L-band ALOS PALSAR polarimetric coherence in Siberian forest.-In: Remote Sensing of Environment, in press.	Jena	FSU	Publication
Üreyen, S., Hüttich, C., & Schmullius, C. (2014): Modeling Growing Stock Volume Using SAR Data and OBIA : Effects of Scale Parameter and Textural and Geometrical Features, Journal of Remote Sensing Technology, 2 (2014), 108–117.	Jena	FSU	Publication
Bartalev S.A., Egorov V.A., Loupian E.A., Khvostikov S.A. A new locally-adaptive classification method LAGMA for large-scale land cover mapping using remote-sensing data, Remote Sensing Letters, 2014, 5(1), pp. 55-64.	Moscow	IKI	Publication
C. THIEL & C. SCHMULLIUS (2013): Investigation of the impact of freezing on the scattering phase center in Siberia using ALOS PALSAR FBS and FBD data.-In: Proceedings CD of ESA Living Planet Symposium, 09 – 13 September, Edinburgh, UK.	Jena	SFU	Publication
Khovratovich T.S., Bartalev S.A., Zharko V.O. Growing stock volume evaluation method based on joint use of ASAR and MODIS data based products [in Russian] // Eleventh annual All Russian open conference “Actual problems in remote sensing of the Earth from space” 11-15	Moscow	IKI	Publication

November, Moscow, Space research institute, 2013. p. 331.			
Egorov V.A., Bartalev S.A., Loupian E.A. Optimization possibilities for test sites network design for statistical forest inventory using satellite growing stock volume map [in Russian] // Eleventh annual All Russian open conference "Actual problems in remote sensing of the Earth from space" 11-15 November, Moscow, Space research institute, 2013. p. 329.	Moscow	IKI	Publication
Urban, M., Forkel, M., Schmullius, C., Hese, S., Hüttich, C., & Herold, M. (2013). Identification of land surface temperature and albedo trends in AVHRR Pathfinder data from 1982 to 2005 for northern Siberia. International Journal of Remote Sensing, 34(12), 4491–4507.	Jena	FSU	Publication
Urban, M., Eberle, J., Hüttich, C., Schmullius, C., & Herold, M. (2013). Comparison of Satellite-Derived Land Surface Temperature and Air Temperature from Meteorological Stations on the Pan-Arctic Scale. Remote Sensing, 5(5), 2348–2367. doi:10.3390/rs5052348	Jena	FSU	Publication
Eberle, J., Clausnitzer, S., Hüttich, C., & Schmullius, C. (2013). Multi-Source Data Processing Middleware for Land Monitoring within a Web-Based Spatial Data Infrastructure for Siberia. ISPRS International Journal of Geo-Information, 2(3), 553–576. doi:10.3390/ijgi2030553	Jena	FSU	Publication
Zharko V.O., Bartalev S.A., Egorov V.A. Production of the dominant forest species map based on the analysis of their spectral reflectance dynamic using satellite observation data [in Russian] // X Conference of young scientists "Fundamental and applied space research" [in Russian]. 3-5 April, Moscow, Space research institute, 2013. p.38-39.	Moscow	IKI	Publication
Zharko V.O., Bartalev S.A., Egorov V.A. Russian forest species mapping based on MODIS satellite data // Aerospace methods and GIS technologies in forestry and forest management: Proceedings of the V All Russian Conference, dedicated to the memory of Vasily Iv. Sukhikh	Moscow	IKI	Publication

and Georgy N. Korovin. Moscow, Russia, April 22-24, 2013. M. CEPF RAS, 2013. p.144-145.			
Egorov V.A., Bartalev S.A. Analysis of Russian forest cover dynamics based on multi-year MODIS satellite data [in Russian] // Tenth annual All Russian open conference "Actual problems in remote sensing of the Earth from space" 12-16 November, Moscow, Space research institute, 2012. p.383.	Moscow	IKI	Publication
Zharko V.O., Bartalev S.A., Egorov V.A. Evaluation of forest tree species composition based on the analysis of their seasonal reflectance dynamic using satellite data [in Russian] // Tenth annual All Russian open conference "Actual problems in remote sensing of the Earth from space" 12-16 November, Moscow, Space research institute, 2012. p.386.	Mowcow	IKI	Publication
C. THIEL & C. SCHMULLIUS (2013): Investigating the impact of freezing on the ALOS PALSAR InSAR phase over Siberian forests.-In: Remote Sensing Letters 4 (9), pp. 900-909.	Jena	FSU	Publication
C. THIEL & C. SCHMULLIUS (2013): Investigating ALOS PALSAR interferometric coherence in central Siberia at unfrozen and frozen conditions: implications for forest growing stock volume estimation.-In: Canadian Journal of Remote Sensing 39 (3), pp. 232-250.	Jena	FSU	Publication
T. A. CHOWDHURY, C. THIEL, C. SCHMULLIUS & M. STELMASZCZUK-GORSKA (2013): Polarimetric Parameters for Growing Stock Volume Estimation Using ALOS PALSAR L-Band Data over Siberian Forests.-In: Remote Sensing 4, pp. 5725-5756.	Jena	FSU	Publication
C. THIEL & C. SCHMULLIUS (2014): Impact of Tree Species on Magnitude of PALSAR Interferometric Coherence over Siberian Forest at Frozen and Unfrozen Conditions.-In: Remote Sensing 6(2), pp. 1124-1136.	Jena	FSU	Publication
Multi-Source Data for Land Monitoring: Automated Access and Analysis from Open Image Archives with web-based Technologies	Jena	FSU	Flyer

Links to other projects

ZAPÁS is linked to several projects and initiatives related to land monitoring and earth observation. Concerning the central task of validation and inter-comparison of multi-scale biomass map products a strong link exists to the **GeoWiki Project** hosted at the consortium partner IIASA. Within the biomass branch of the web portal – the Biomass-GeoWiki (http://biomass.geo-wiki.org) – biomass mas produced within the ZAPAS team will be implemented. A multi user validation process is possible based on a voluntary basis. Read more: http://geo-wiki.org.

A further strong link exists to the **Kyoto & Carbon Science Initiative** (K&C) by the Japanese Space Agency (JAXA). Within K&C JAXA deliverers ALOS PALSAR satellite data free of charge to a global science community working on different environmental monitoring themes (e.g. biomass estimation, forest and wetland monitoring). The role of ZAPAS is to provide new and innovative methods for forest biomass modeling and forest cover change detection. Read More: http://www.eorc.jaxa.jp/ALOS/en/kyoto/kyoto_index.htm.

Moreover, the project is inter-linked to the ESA funded BIOMASAR-II Project. Both projects use the same methodology for regional scale biomass estimation by applying the BIOMASAR algorithm. After producing maps at different spatial resolutions (250 m and 1000 m) cross-validation approaches will be applied on the biomass maps derived from both projects. Read more: http://www.biomasar.org/.

The ZAPÁS project is strongly inter-connected to the FSU-hosted **Siberian Earth System Science Cluster** (SIB-ESS-C), a project building the umbrella framework for environmental studies in Siberia. ZAPAS contributes with data and product sharing and providing results from the product validation assessments. Read more: http://www.sibessc.uni-jena.de.

The **Global Observation of Forest Cover and Land Dynamics** (GOFC-GOLD) aims to improve the quality and availability of observations of forests and land cover at regional and global scales and to produce useful, timely and validated information products from these data for a wide variety of users. ZAPÁS is one of the first projects building confidence to biomass geo-information at different scales and provides the results on biomass validation and biomass-land-cover harmonization to the GOFC-GOLD community. Read more: http://www.fao.org/gtos/gofc-gold/land.html.

The **Group on Earth Observation** (GEO) is coordinating efforts to build a Global Earth Observation System of Systems, or GEOSS. GEO is a voluntary partnership of governments and international organizations. It provides a framework within which these partners can develop new projects and coordinate their strategies and investments. The ZAPÁS project represents the European and Russian activities in EO based forest monitoring in Siberia and represents a platform for exchanging scientific know how in the forest remote sensing theme in GEO.

The **Global Forest Observations Initiative** (GFOI) is an initiative of the inter-governmental Group on Earth Observations (GEO) that aims to foster the sustained availability of observations for national forest monitoring systems; support governments that are establishing national systems by providing a platform for coordinating observations, providing assistance and guidance on utilizing observations, developing accepted methods and protocols, and promoting ongoing research and development; and work with national governments that report into international forest assessments. The ZAPÁS project represents and provides input for the methodological knowledge pool and is involved in the methodological guidance preparations.

The **PEEX 'Pan-Eurasian Experiment'** study is a multidisciplinary climate change, air quality, environment and research infrastructure program focused on the Northern Eurasian particularly arctic and boreal regions. The PEEX research agenda is reinforced by the services, adaptation and mitigation plans for the northern societies to cope with the global change. It is a bottom up initiative by several European, Russian and Chinese research organizations and institutes. ZAPÁS is involved and provides methods and results of biomass and forest dynamics mapping. More information: https://www.atm.helsinki.fi/peex/.

In the third phase of the project intensive contacts were generated with the **Global Earth Observation Biodiversity Observation Network (GEO-BON)**. For instance, the web-based forest observation capabilities were highly appreciated by the GEO BON secretariat. Future collaboration is envisaged integrating the web-based forest monitoring techniques for biodiversity protection and tracking activities. More information: https://www.earthobservations.org/geobon.shtml.

The project is further linked to the **Future Earth Initiative**. One of the goals is to make the research more useful and accessible for decision makers, making research accessible to all parties. The ZAPÀS related web portals will contribute these requirements. Results, software, and recommendations will be published and distributed within this network. More information: http://www.futureearth.info/impact.

2.2.10.4. Deviations and impact on tasks and resources

No deviations occurred.

2.2.10.5. Use of the resources

The following table lists the person-months per participant in the second period in WP 10.

Table 14: Person-months per participant in the second period in WP 10.

FSU	IIASA	IKI-RAS	SIF-RAS	NTsOMZ
3	0	5	0	1

3 Deliverables and Milestones

The third project year includes the realization of milestones 7 to 11. Milestones 3 to 10 could be finished, as listed below.

Table 15: ZAPÁS milestones in the third year.

MS No.	Milestone Name	WP Number	Lead beneficiary	Delivery (month)
MS7	Provision of improved synergetic regional scale (300 m and 500 m) joint biomass/land cover map	WP5	3	22
MS8	Resampled 1 km Forest and Land Cover Map	WP6	2	25
MS9	Terrestrial Ecosystem Full Carbon Accounting (1 km raster)	WP7	2	31
M10	Cross-validation of all maps	WP9	4	33

After the first reporting period all required deliverables were submitted. The list of the finalized deliverables is shown below.

Table 16: ZAPÁS deliverables in the second year.

No.	Title	Lead	Delivery date (from annex I)/ Actual delivery date	Description & Comments
9.12	Report on results of validation of local scale maps of recent abandoned agriculture land	SIF-RAS	01.07.2014	
9.9	Report on results of validation of recent local scale forest disturbance maps	SIF-RAS	01.07.2014	
9.4	Report on results of validation of results of carbon accounting for Central Siberia	SIF-RAS	27.06.2014	
9.6	Report on results of validation of recent local scale forest biomass maps	SIF-RAS	25.06.2014	
7.1	Report on results of carbon accounting	IIASA	14.04.2014	
2.6	Report on forest inventory data	SIF-RAS	01.03.2014	
9.3	Report on results of validation of updated IIASA GIS land cover layer 1:500,000 and 1 : 1 Mio.	SIF-RAS	01.03.2014	
9.8	Report on results of validation of recent local scale forest disturbance maps	SIF-RAS	15.02.2014	
9.11	Report on results of validation of local scale maps of recent abandoned agriculture land	SIF-RAS	15.02.2014	

9.2	Report on results of validation of improved regional land cover map for Central Siberia	SIF-RAS	15.02.2014
9.1	Report on results of validation of regional forest biomass map for Central Siberia	SIF-RAS	15.02.2014
6.2	Resampled 1 km Forest and Land Cover Map	IIASA	10.02.2014
9.7	Report on results of validation of recent local scale forest disturbance maps	SIF-RAS	30.01.2014
9.10	Report on results of validation of local scale maps of recent abandoned agriculture land	SIF-RAS	30.01.2014
1.1	Progress Report 1	FSU	21.10.2013
1.2	Progress Report 2	FSU	21.10.2013
4.1	Draft forest biomass map for Central Siberia	FSU	19.09.2013
5.2	Final improved biomass and land cover map for Central	IKI	19.09.2013
2.7	Report on forest inventory data	SIF-RAS	13.08.2013
8.4	Fine scale forest disturbance maps for 10 local sites. Delivery at PM09: 3 sites, PM22: 3 sites, PM3	SIF-RAS	09.08.2013
8.2	Recent fine scale forest biomass maps for 10 local sites. Delivery at PM09: 3 sites, PM32: 7 sites.	SIF-RAS	09.08.2013
8.5	Fine scale forest disturbance maps for 10 local sites. Delivery at PM09: 3 sites, PM22: 3 sites, PM3	SIF-RAS	09.08.2013
8.7	Fine scale maps of recent abandoned land for 5 local sites. Delivery at PM09: 1 site, PM22: 2 sites,	SIF-RAS	09.08.2013
2.5	forest inventory data	SIF-RAS	09.08.2013
8.8	Fine scale maps of recent abandoned land for 5 local sites. Delivery at PM09: 1 site, PM22: 2 sites,	SIF-RAS	09.08.2013