INTERNATIONAL SOCIETY FOR PHOTOGRAMMETRY AND REMOTE SENSING (ISPRS)
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ISPRS WG IV/2 Workshop

Global Geospatial Information and High Resolution Global Land Cover/Land Use Mapping

21 April 2015
Novosibirsk, Russian Federation

Proceedings

2015

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The workshop confirmed growing interest in the issues of mapping which have gained importance for the national and global management of resources and for sustainable development with increasing emphasis on environmental issues. The current status of topographic mapping, data base updating and high resolution global land cover/land use mapping in the world were discussed.

The proceedings are meant for professionals, surveying and mapping agencies, services, other institutions, and the private sector, including both the status of technological and legal issues pertaining to geospatial data.

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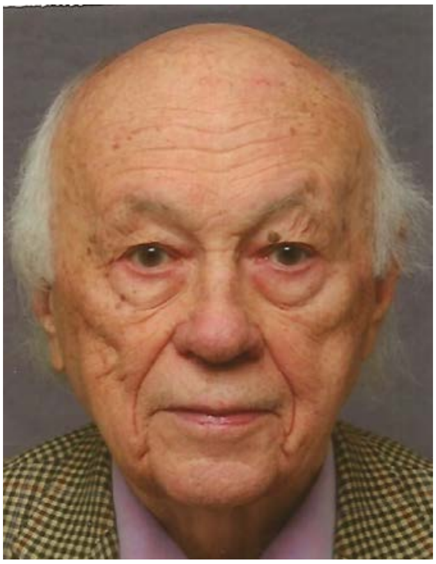
INTRODUCTION TO THE WORKSHOP OF ISPRS WG IV/2: "GLOBAL GEOSPATIAL INFORMATION AND HIGH RESOLUTION GLOBAL LAND COVER/LAND USE MAPPING"



ISPRS Working Group IV-2, chaired by Prof. Vladimir Seredovich conducted a successful workshop during the 80th Anniversary of the Siberian State Academy of Geodesy and the Interexpo GEO-Siberia-2013. At that time the joint UNGGIM-ISPRS Project, which was trying to carry on with the activities of the United Nations Secretariat in New York of the 1960´s and 1970´s was by no means complete. Due to excellent international cooperation from all parts of the globe, including that from the Russian Federation, we can now present a result. It is a start for a monitoring process for what our professional activities are producing.

It is an honour again to hold a workshop in Novosibirsk at a time, when the Siberian Academy of Geodesy has been officially recognized with University Status.

ISPRS has at this time identified a new goal. Satellite imagery data sources not only provide a basis to compile and to update topographic base data, but they also permit to monitor land cover of ehe globe and to set it into relation with land management and land use for a sustainable development. The workshop promises to become a platform for these crucial efforts for the years to come.

Em. Prof. Gottfried Konecny
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ISPRS WG IV-2 Vice Chair

THE GLOBAL STATUS OF TOPOGRAPHIC MAPPING

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Commission IV, WG IV-2

KEY WORDS: Mapping Status, Topographic Mapping, Map Updating

ABSTRACT
This paper is a preliminary version of a detailed publication, which is being prepared to the UNGGIM5 Conference in New York by G. Konecny, U. Breitkopf, A. Radtke of Leibniz University Hannover and K. Lee of Eastview Geospatial, Minneapolis, MN. This publication is the result of a project initiated by ISPRS and UNGGIM to assess the current status of topographic information in the world, an activity of the United Nations Secretariat, which was not continued since the 1980´s and now has been revitalized. The basis was a questionnaire sent to UN Member countries. The information was supplemented by other sources to result up-to-date information.

1. Origins of the Project

In 1986, the Department of Technical Cooperation for Development of the United Nations Secretariat completed the last survey on the “Status of World Topographic and Cadastral Mapping”. The results of the survey were published by the United Nations, in New York, 1990 in World Cartography, Vol. XIX. The text was submitted by the UN Secretariat as document E/CONF 78/BP7 in 1986, prepared by A.J. Brandenberger and S.K. Ghosh of the Faculty of Forestry and Geodesy at Laval University, Quebec, Canada. It referred to previous surveys submitted by the Department of Technical Cooperation for Development of the United Nations Secretariat in 1968, published in World Cartography XIV, and in 1974 and 1980, published in World Cartography XVII.

The paper published in World Cartography XIX in 1990 summarized the progress made in topographic mapping across the globe between 1968 and 1980 in 4 scale categories:

range I	scales between 1:1000 and 1: 31 680
range II	scales between 1:40 000 and 1:75 000
range III	scales between 1:100 000 and 1:126 720
range IV	scales between 1:140 000 and 1:253 440

These ranges represent the more recently standardized scales:

range I	scale 1:25 000
range II	scale 1:50 000
range III	scale 1:100 000
range IV	scale 1:250 000

While scale in the age of digital cartography has changed the meaning, the scale ranges nevertheless maintain their significance with respect to the resolution of mappable details.

The 1986 survey covered the following number of countries or territories:

Africa	53 countries	4 territories
North America	24 countries	13 territories
South America	12 countries	3 territories
Europe	39 countries	4 territories
Asia	40 countries	3 territories
USSR	1 country	0 territories
Oceania	countries	17 territories

Source of the data obtained by the surveys were completed questionnaires, sent by the UN Secretariat to the UN member countries, plus additional surveys made directly by Laval University for UN member countries not having answered the questionnaires, for non-UN member countries and for territories under foreign administration. The result of the survey was for each region and for the different scale ranges:

Country	range I	range II	range III	range IV
Africa	2.3%	29.7%	20.6%	86.8%
North America	41.3%	68.2%	8.0%	92.8%
South America	9.7%	29.0%	44.2%	50.4%
Europe	92.5%	93.8%	81.3%	95.0%
Asia	16.0%	62.7%	65.4%	92.0%
USSR	>5%	>60%	100%	100%
Oceania	13.3%	15.6%	36.1%	99.8%

The areas covered by the survey were:

Country	range I	range II	range III	range IV
Africa	75.8%	100%	100%	100%
North America	90.7%	100%	100%	99.5%
South America	100%	100%	100%	100%
Europe	98.0%	90.2%	97.25%	96.7%
Asia	87.8%	90.9%	87.6%	90.2%
USSR	100%	100%	100%	100%
Oceania	94.1%	94.5%	94.3%	99.9%

World summary:

	range I	range II	range III	range IV
area of survey	90.1%	97.4%	97.0%	97.75%
1986 map coverage	17.9%	49.3%	46.4%	87.5%
1980 map coverage	13.3%	42.2%	42.2%	80.0%
1974 map coverage	11.6%	35.0%	40.5%	80.5%
1968 map coverage	7.7%	23.4%	38.2%	81.0%

While the surveys presented in 1986 did not concentrate on map revision on a global basis, they nevertheless derived an update rate for the four scale ranges:

	range I	range II	range III	range IV
update rate	3.2%	1.8%	2.7%	3.6%

This points to the fact, that in 1986 the maps at the scale relevant to national planning operations 1:50 000 were hopelessly out of date.

Other aspects of the surveys conducted in 1980 were directed toward the existence of geodetic networks and their density. In 1980, there existed 3.67 M horizontal and 3.16M vertical control monuments on the globe, but again their density varied from 2.66 km^2 per horizontal control monument and 3.61km^2 per vertical control monument in Europe to 232km^2 in Africa with an average of 42.5km^2 per horizontal control monument to 46.4km^2 per vertical control monument.

In 1980, the national mapping agencies possessed 12 120 theodolites, 5790 precise leveling instruments and 1914 EDM devices, 162 airplanes for aerial photography, 267 aerial survey cameras and 3120 photogrammetric stereo plotting instruments. Disregarded in that survey are instruments owned by companies mapping for governments under contract.

The attempts of 1980 to determine the existing manpower of the national mapping agencies for each region were based on few countries only (e.g. Algeria and Nigeria for Africa, the USGS in the USA, the Surveys and Mapping Branch in Canada, the IGN France in Europe). These data were used to extrapolate the requirements in other countries with the attempt to develop a budget of global expenditures, yielding a global sum of US$ 868 million, at that time 0.010% of the gross national product, while the global surveying and mapping activities at that time were estimated to be between 8 to 9 billion US$ per year. A program for increasing the expenditures to 0.02% of the GNP was recommended in the report, to meet the need for lacking mapping coverage and lacking map updates.

These rather inaccurate and inconclusive results may have discouraged the UN Secretariat in continuing the surveys due to lack of a budget for this purpose.

2. The UNGGIM-ISPRS Project

The United Nations Regional Cartographic Conferences (UNRCC) for the Americas and for Asia and the Pacific nevertheless continued to recommend to the Secretariat to continue the studies on the global status of mapping. One of these resolutions of the UNRCC for the Americas in 2009 gave the mandate to the Secretariat for a new survey.

This happened at the time, when UNGGIM (United Nations Global Geospatial Information Management) was created as a new structure.

ISPRS approached the director of UNGGIM in 2011 to start a joint project on the survey of the status of topographic geospatial information:

- because the issue is of global interest
- because new technologies, such as GNSS (GPS, GLONASS), digital aerial mapping, high resolution satellites for mapping, digital photogrammetry and GIS have taken over as new mapping methodologies
- because large private organizations such as the navigation industry (Here, Tomtom),
  Google Earth and Microsoft Bingmaps have entered the mapping effort, which was previously the domain of the national mapping agencies.

The project was approved in December 2011 by Dr. Pau Cheung, director of UNGGIM at that time, who nominated Dr. Amor Laaribi as UNGGIM contact, and by Chen Jun, President of ISPRS, who nominated Prof. Gottfried Konecny, of Leibniz University Hannover, as ISPRS contact.

In January 2012, a questionnaire to the UN member states was designed, mutually discussed, translated to French, Russian and Spanish and mailed to the contacts of the UNGGIM Secretariat in the UN member states. Ms. Vilma Frani of the UNGGIM Secretariat sent the replies to Leibniz University Hannover, where Ms. Annette Radtke placed them into a database designed by Uwe Breitkopf for further analysis.

3. The Questionnaire

The jointly designed questionnaire contained 27 questions, the most relevant 12 of these had the following content:

1. National data coverage at various scale ranges
2. Age of the data and update cycles
3. Availability of data to the public without restrictions
4. Sale of the data or free distribution

5. Methodology of updating
6. Orthophoto mapping use as map substitute
7. Use of satellite imagery for updating
8. Mapping operations inhouse or by outsourcing
9. Use of lidar for DEM´s and use of radar
10. Use of 3D products
11. National cadastral map coverage
12. Web distribution of geospatial products

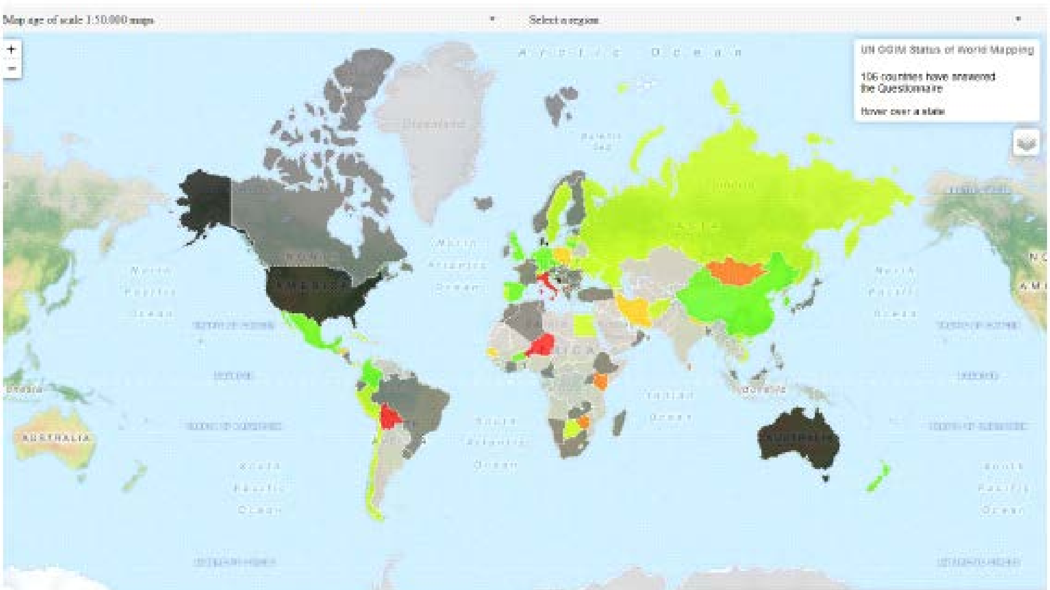
Until February 2015, altogether 113 responses have been received from 193 UN member states. In addition, there are 44 non-UN member countries or territories, which are also covered by map data. These map data were generated in UN member states, but these have in general no direct responsibility for mapping these territories.

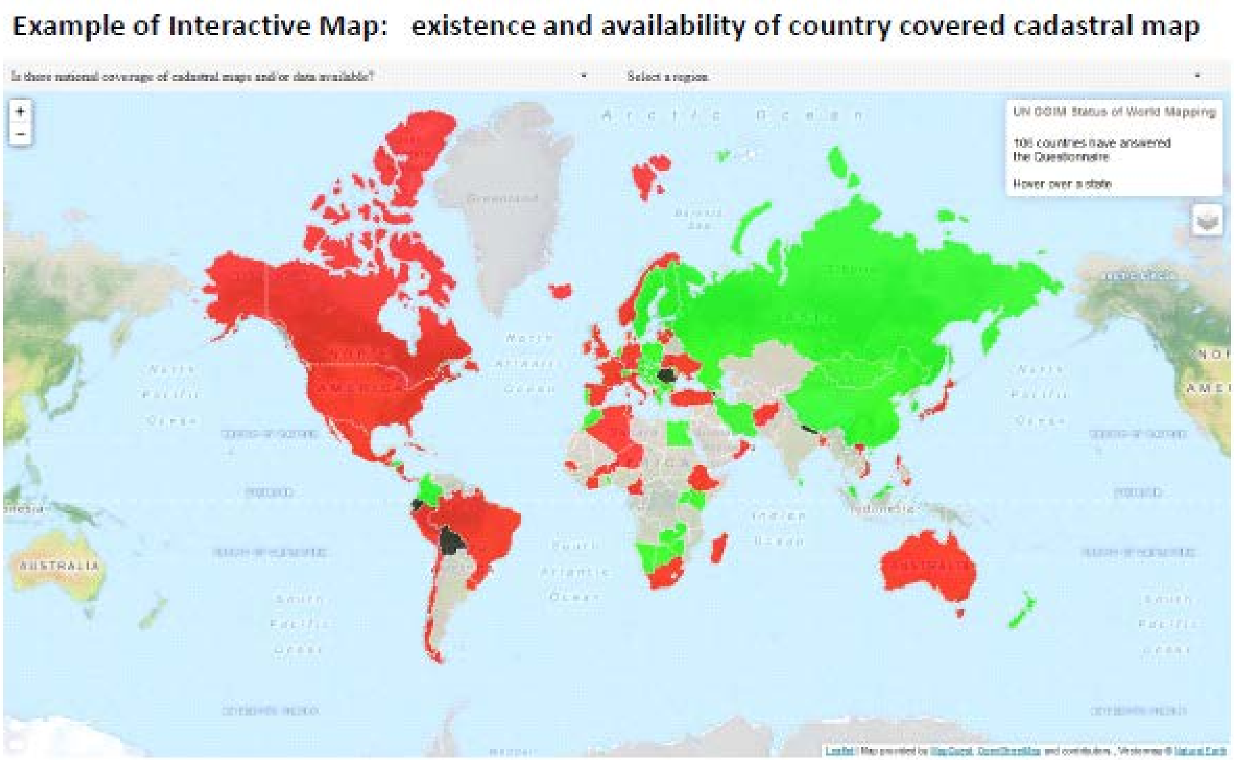
4. Content of the Excel Database

While not all of the 27 questions need to be answered globally, this is, however, important for questions 1 and 2, that characterize the global coverage of data at the different scale ranges and the age of the data. To assess the global status, the Eastview database is a fundamental component to answer these questions. Dr. Kent Lee, CEO of Eastview, has kindly agreed to make the missing data available from their database.

An Excel database has been developed, which can analyze the results or the 27 questions by an interactive viewer. A number of examples are shown here:

Example of Interactive Map: display of map age 1:50 000 for each country





5. Mapping Contributions by Private Industry

As has been demonstrated, official and authoritative mapping by government provides a geospatial infrastructure, which is used for many public and private applications, but which is costly, difficult and slow to maintain. For that reason private enterprises have succeeded to launch several initiatives to provide faster update solutions in areas, which require fast update solutions. These are based on different cost and accuracy models for specific applications, which require fast updates. These applications do not replace official authoritative cartography, but they supplement it, as all such efforts utilize official cartographic products as a base to start their value added operations.

5.1. Google

Google´s prime aim is to provide a location based information system for uses of the public. What the general user wants is quick orientation about how to locate a specific object, such as a landmark, a store, a restaurant or a service provider and how to drive to it.

Geometric accuracy within the context of the neighborhood topography is of lesser importance than the addressability and the access by roads or pathways. In general, business advertising provides the revenue to establish and to maintain the system.
Google Inc. operates by different projects, of which the following are the most important from the cartographic point of view.

5.1.1 Google Earth

Existing orthophotography coverages with ground sample distances between 0.1m and 0.5m as well as high resolution satellite imagery coverages with ground sample distances (GSD) between 0.5m to 2m and beyond provide the geometric background image information which can be interpreted by the user with respect to the searched objects, such as buildings, roads, vegetation, water surfaces. While ortho images have a high geometric accuracy related to ground features commensurate with the GSD, this is not so for building tops and tree tops. Geometric accuracy even deteriorates more for high resolution satellite imagery, since most of these images have been acquired with inclinations with respect to the vertical, unless stereo imaging permitted the generation of ortho imagery.

Nevertheless, despite some of these shortcomings with respect to official cartography, Google Earth can easily satisfy the geolocation demands for the uses Google Earth has been designed for.

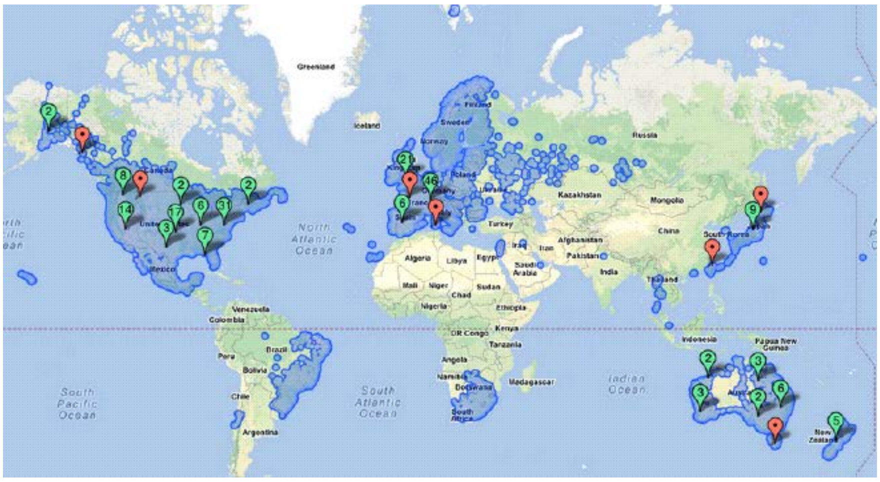
5.1.2 Google Maps

Google Maps is a product usually derived from authoritative cartography. It has been designed to supplement Google Earth with a cartographic output containing place names, road names and building addresses. It serves the ideal function of superimposing images with line graphics. Even though Google Maps may be derived from authoritative cartography, the feature content is much less elaborate and reduced to the intended geolocation function.

5.1.3 Google Street Map

Google Street Map has been developed as a tool to image buildings and street furniture along urban roadways. This is done by vehicle based cameras, located by GNSS signals. In some communities the imaging of building facades has net resistance by some of the population, which did not wish to show them to the public on the web. Nevertheless, Google has pursued street mapping for the sole reason to update the Google Map content as an internal operation.

In this manner, Google Street Map has proved to be an effective tool to quickly update the Google Map content for buildings and roads.



5.1.4 Google Ground Truth

In the attempt not only to update the map content, but also to maintain a high level of geometric accuracy, the Google Ground Truth project has been launched for a number of countries in North America, Europe, Australia and South Africa, in which authoritative cartography has been merged with the results of high tech operations, such as Google Street Map.

As Google regards the progress of these projects as a confidential matter, it is not possible to make a more detailed account of the progress made.

WHERE Is Ground Truth?

43 countries and regions,
launched over past 5 years!

HOW Does Ground Truth work?

Authoritative data + Internal data + Algorithms & Elbow Grease

Algorithms and Elbow Grease

Atlas

- Internal tool
- Home-brewed

... used by ...

Operators

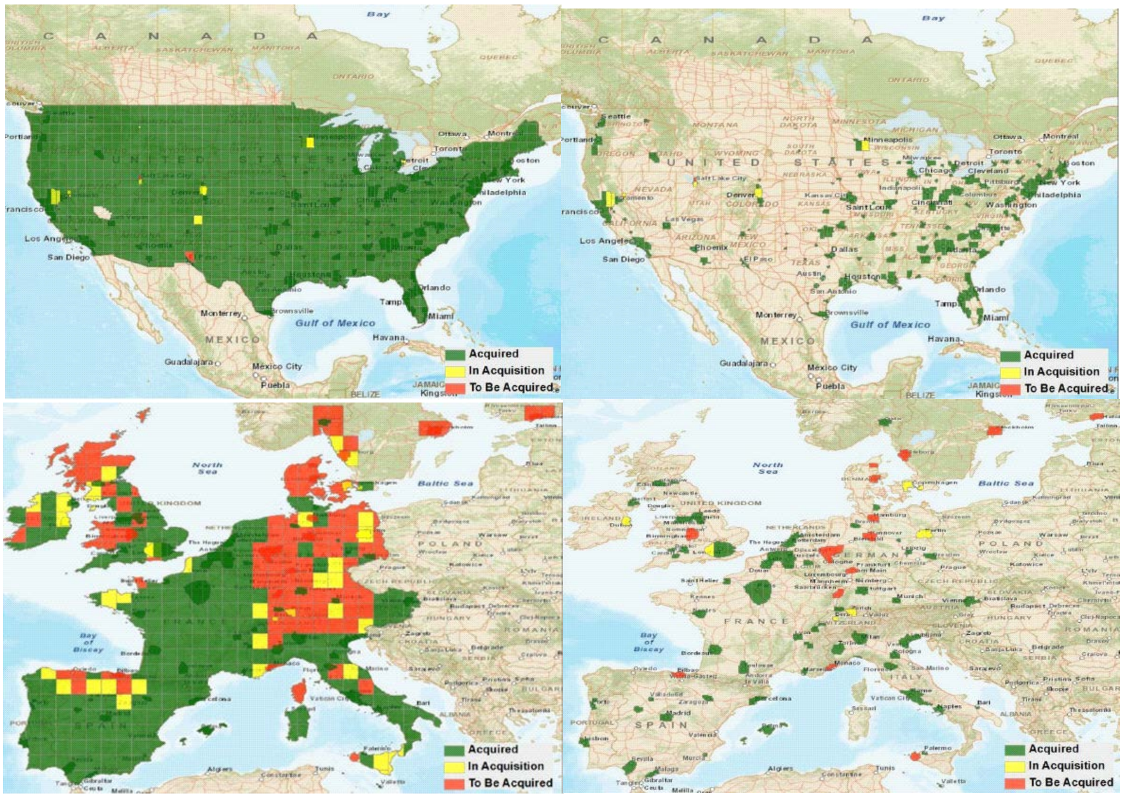
- Internal workforce
- Heavily trained

5.2 Microsoft Bingmaps

Microsoft considered Google to be their strongest competitor, while Bingmaps has the same objectives as the Google efforts. Therefore, care has been taken to achieve a higher resolution and a more accurate geometry than Google Earth.

This was possible by limiting the area of interest to the continental USA and to Western Europe, where there were no flight restrictions. Furthermore, the imagery used for Bingmaps consisted solely of digital aerial imagery flown by the company owned Vexcel Ultracam cameras.

The coverage of the countryside for the USA and for Western Europe was completed at 30cm GSD, and the urban areas were imaged at 15cm GSD.



5.3 Yandex

Another approach has been undertaken by Yandex in the Russian Federation, which was also applied in Turkey by the company Yandex.

Yandex has procured high resolution satellite imagery from Digital Globe for the entire territory of the Russian Federation at 0.5m GSD and at 1m GSD. The objects of interest were building blocks, single buildings, roads, creeks. They could be identified and mapped from the images. The geocoding of the mapped information was done by accuracy augmented GNSS code receivers with 2 to 3m accuracy on the ground. In this way, Yandex succeeded to generate digital maps for about 300 urban conglomerations in Russia and Turkey.

Yandex, like international car navigation system suppliers, was also interested in car traffic routing, providing real time traffic congestion options for the agglomeration of Moscow.

5.4 HERE

When the Finish company Nokia bought Navteq, the global car navigation system efforts were continued by the subsidiary HERE.

HERE makes car navigation systems based on their own maps for 196 countries of the world, 116 countries of which have voice guided navigation and 44 countries of which with live traffic services.

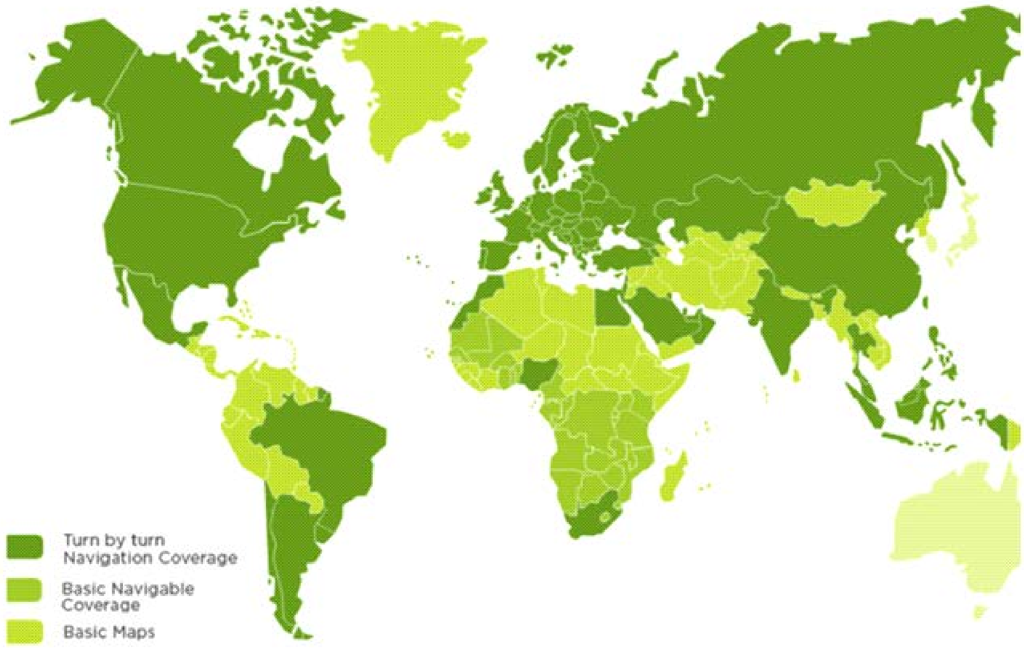
Of interest are roads and points of interest.

In Europe 15% of the map´s content is updated every year, modifying or adding 1.1M km of roads, creating 700 000 new points of interest and adding 600 000 speed cameras.

In the Russian Federation, 800 000 km of roads change after 6 months, and so do 120 000 street names, 22 000 turn restrictions, 3400 one way streets, 38 000 speed limits and 8700 directional street signs.

5.5 TomTom

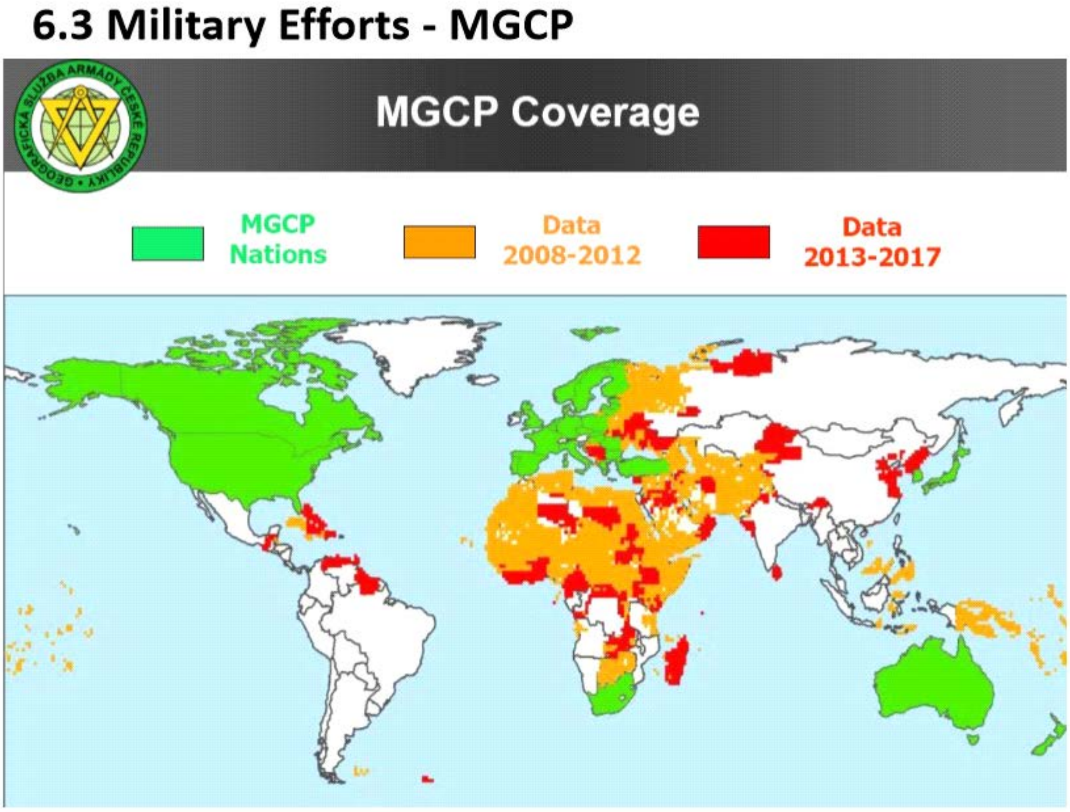
TomTom has road navigation coverage for 118 countries extending over North America, Brazil, Argentina, Europe, the Russian Federation, India, Indonesia, Thailand, Australia, New Zealand, West and South Africa.



6. Mapping by Military Organizations

As happened during the cold war period, when the US and the USSR military organizations considered it their goal to conduct mapping operations in what they considered to be crisis areas, this practice was recently revived by about 30 nations from Europe, North America, Australia, New Zealand, Japan, Rep. of Korea and South Africa, when they launched the Multinational Geospatial Co-Production

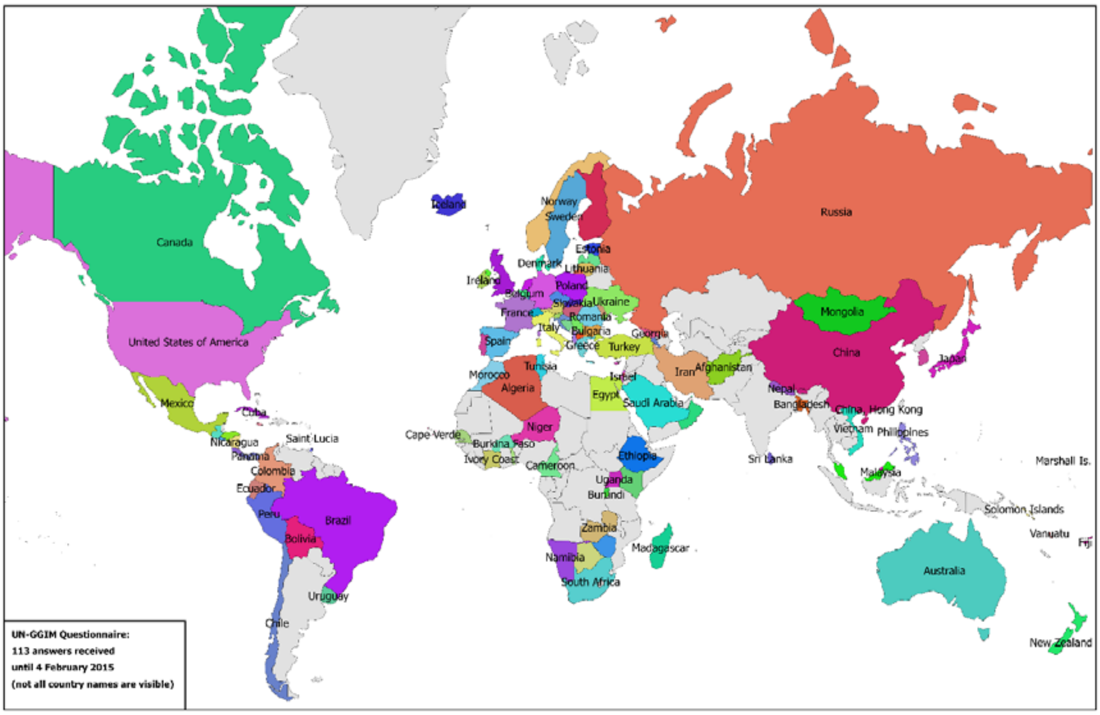
Program MGCP. The goal of this program is to generate up-to-date 1:50 000 digital maps for potential crisis areas of the globe in Asia, Africa, the Middle East, the West Indies and the Pacific Ocean. Benefitting from this activity is the UN cartographic section, which utilizes these maps to create information for crisis mitigation.



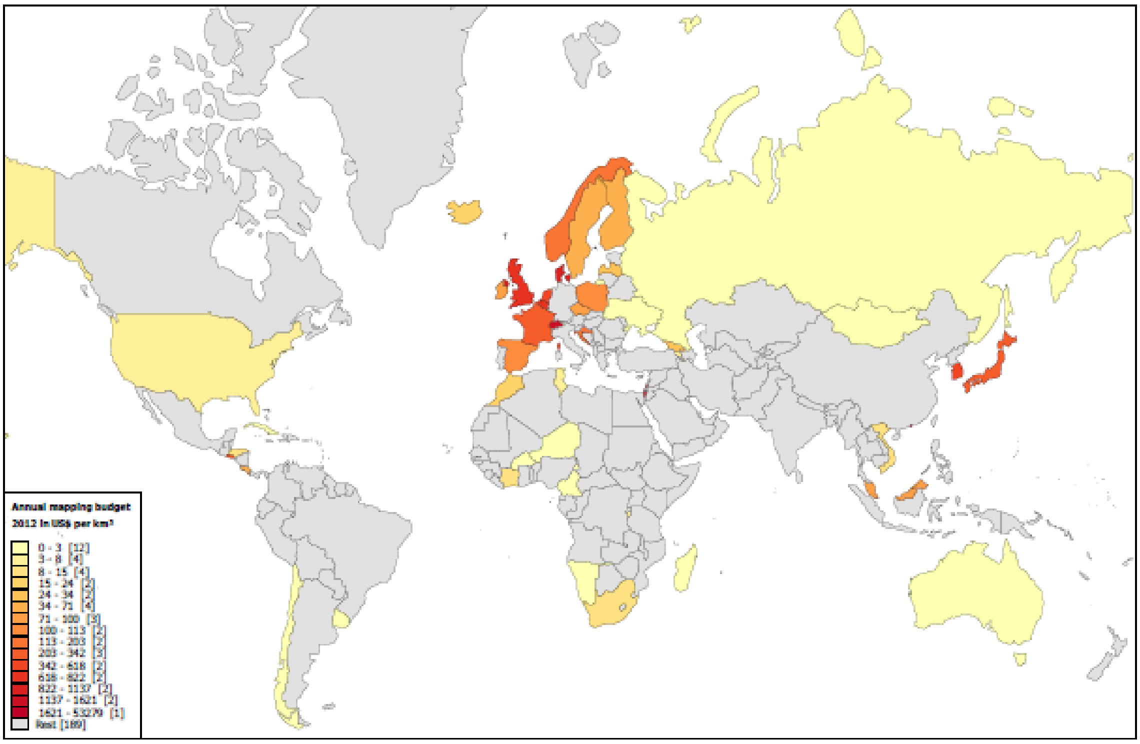
7. Summary of Results

- 113 UN Member countries have responded to the 2012-2014 UNGGIM-ISPRS Survey. It has been shown, that nearly all reporting countries have modernized their facilities to adopt modern GNSS, digital imaging and GIS technology in their operations, which are still handicapped by lack of funding and staff shortages.
- While in 1986 the world was basically covered by 1:250 000 maps, progress in technology has now made it possible to state that topographic mapping of the globe at 1:50 000 scale, relevant to sustainable development, has been reached.
- There are still gaps in providing updated information in developing countries. These need to be closed with a goal of no data to be older than 5 years.
- New technologies, such as those used by Google and by Yandex could help to reach this goal in priority areas.
- Attached are a number of summary maps showing results of the survey:
  1) 113 countries, which have participated in the survey
  2) 46 countries which have reported on their mapping budget
  3) 1:25 000 data coverage or larger from all sources
  4) 1:50 000 data coverage or larger from all sources

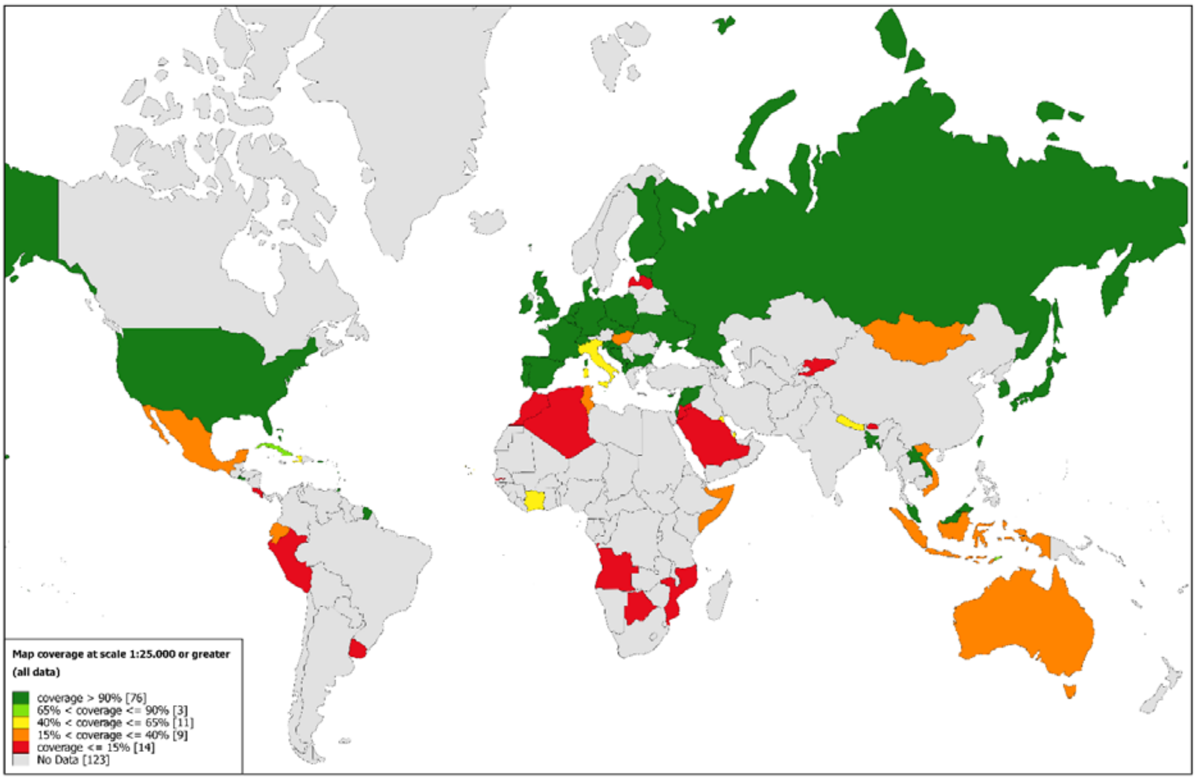
5) 1:100 000 data coverage or larger from all sources
6) 1:250 000 data coverage or larger from all sources



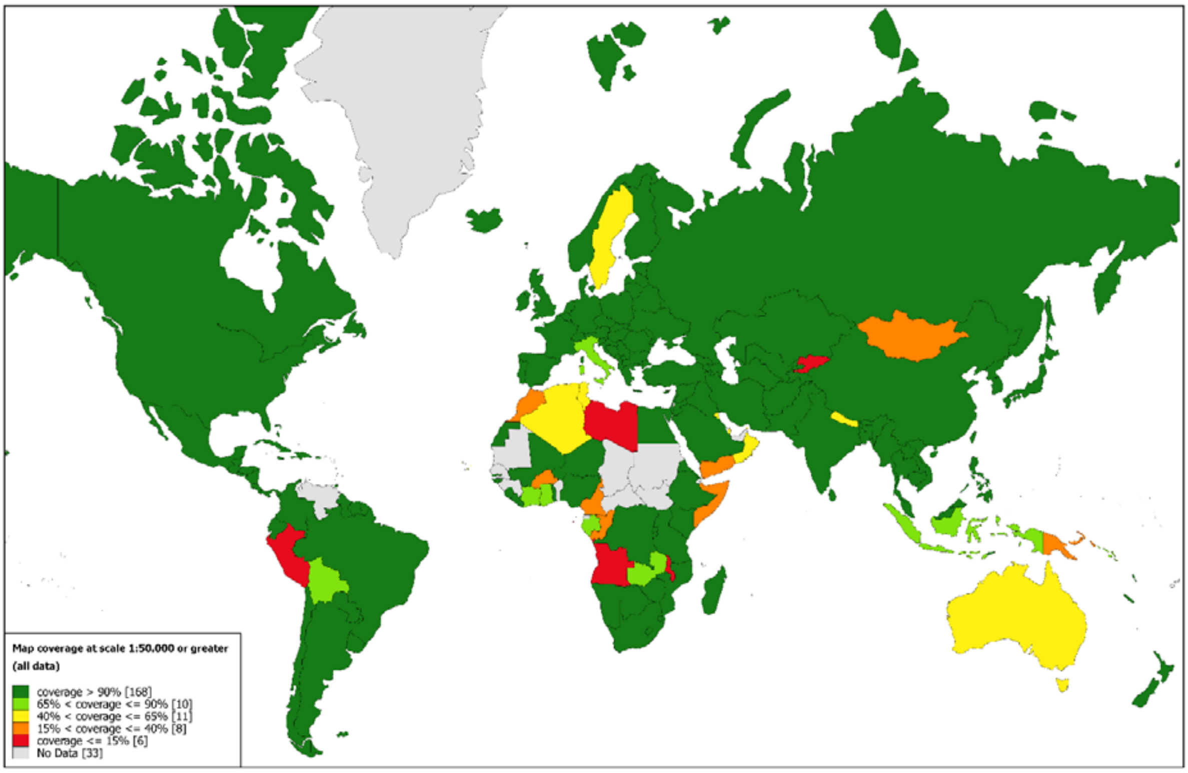
1) 113 countries participating in the survey



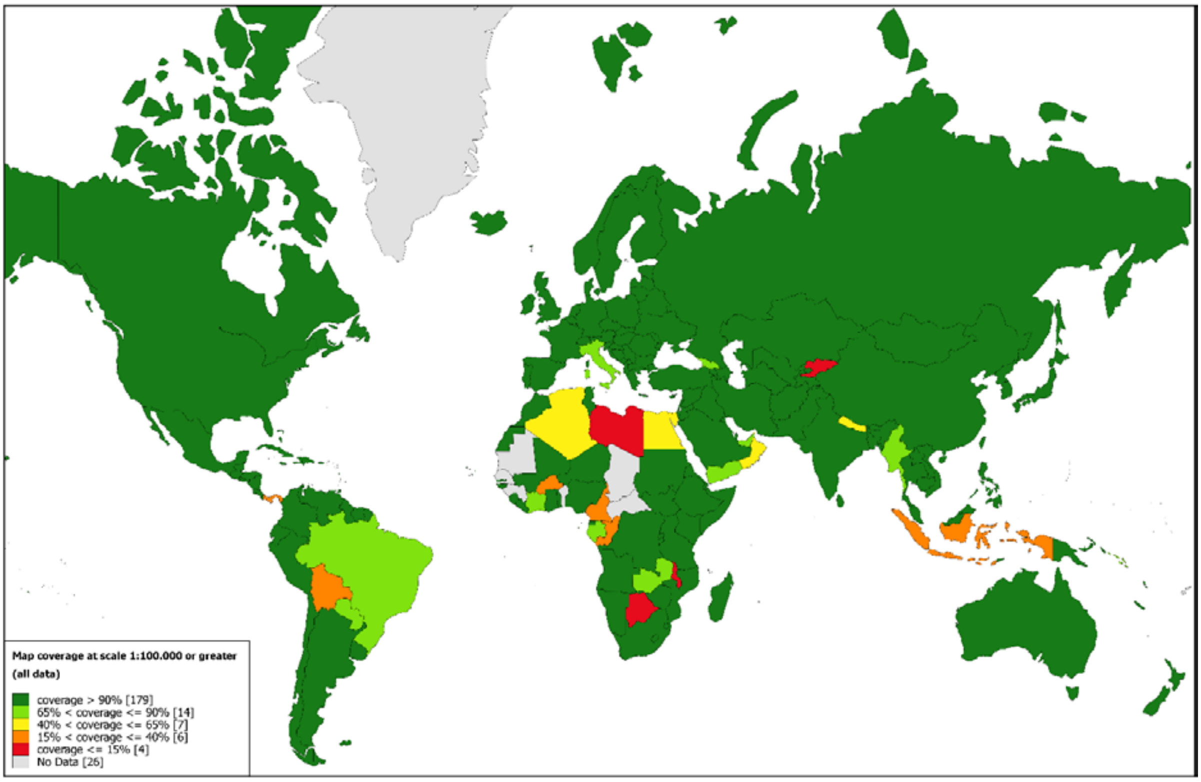
2) budget for national geospatial data



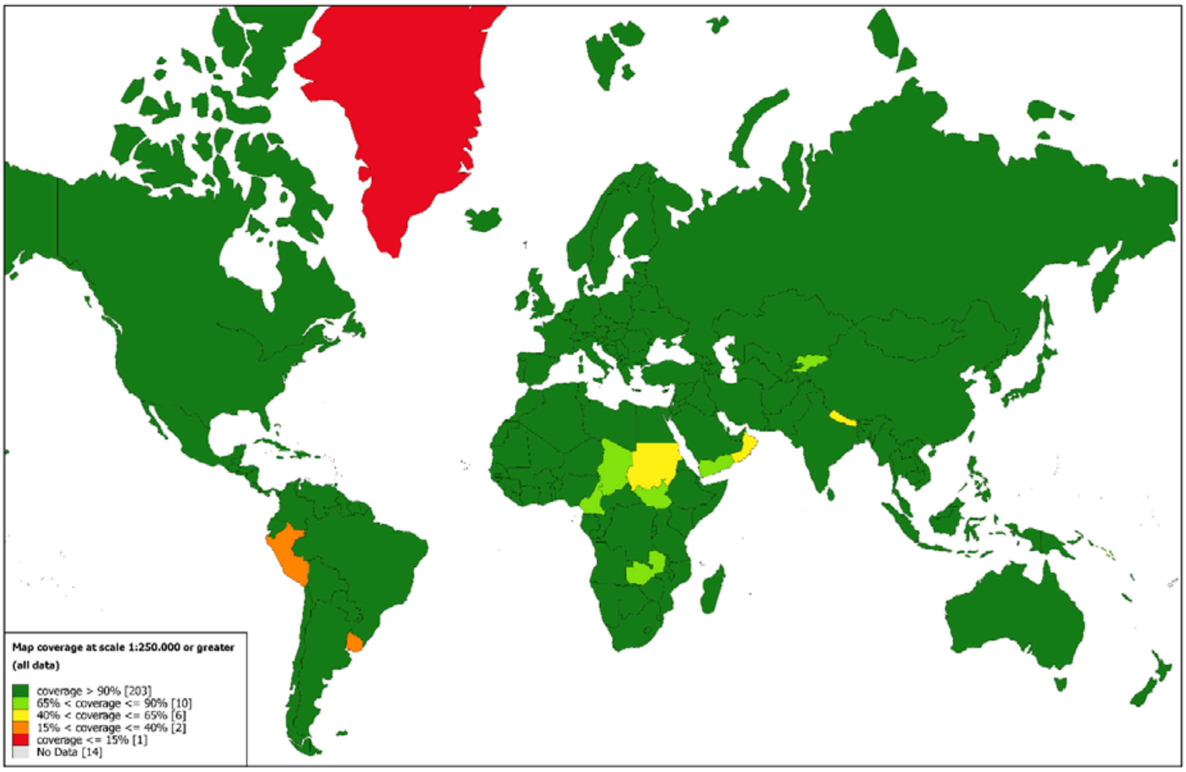
3) 1:25 000 geodata available from all sources



4) 1:50 000 geodata available from all sources



5) 1:100 000 geodata available from all sources



6) 1:250 000 geodata available from all sources

8. Future Activities

- ISPRS has created Working group IV-2 to accompany the UNGGIM-ISPRS project.
- This working group has successfully provided the needed discussion forum for the task.
- It will be the future goal of this group to assure that the data collection and analysis will be sustainable by cooperating with UNGGIM and UN-GEO
- A near goal will be the expansion of the work to include global land cover mapping as a task.

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THE GLOBAL STATUS OF TOPOGRAPHICAL MAPPING: TECHNICAL BACKGROUNDS OF THE PROJECT

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Commission IV, WG IV-2

ABSTRACT

This presentation will give some insights on the technical backgrounds of the project on the current status of topographic mapping in the world which was initiated by ISPRS and UNGGIM. The project is carried out by G. Konecny, A. Radtke and U. Breitkopf of Leibniz University Hanover. The main source of information is a questionnaire that was sent out to UN member countries by the UNGGIM secretariat in 2012. The questionnaire contained 27 questions in four different categories namely *National Topographic Mapping Coverage*, *National Imagery Acquisition*, *National Surveying and Cadastral Coverage* and *Organization*. The questionnaires were sent to 193 UN countries. Until now 113 answers have been received. The results of the questionnaires were assembled in an MS-Access database. Out of the 27 questions 26 have been analyzed.

One goal of the project is to assess the global coverage of topographic mapping in different scale ranges. Due to missing information in many of the questionnaires and a big number of countries that did not answer at all, other sources had to be used to get a more complete estimation on the global coverage of maps in different scales. Those sources include data like the cartographic database of the German state library of Berlin (Staatsbibliothek zu Berlin) as well as the East View Geospatial web store which offers map series for most countries of the earth.

The online database of the state library of Berlin has been inspected and coverages of the available map series overviews have been determined by visual evaluation. For the East View Geospatial online store a method has been developed to estimate national coverage map series by converting the overview image as shown in the web store into vector format and intersecting the resulting polygon with the country boundary. After that it was possible to calculate percentage values for the country area that is covered by the map series. The method makes use of geospatial libraries like GDAL and was programmed in Python-script. The script runs inside the free and open source GIS tool QGIS.

Besides the overview on the data that as used for the analysis, the talk will cover how the project results are visualised by the use of coloured maps. Those maps will be included in the final publication along with diagrams illustrating the results of the questionnaires. Another way to present the results is an interactive world map that was programmed in JavaScript/HTML and is powered by the open-source JavaScript library Leaflet. For that a world map in vector format and the results from the MS-Access database were converted to JSON format again by the use of a Python script. Then functions were programmed in JavaScript to display the map in different colours based on the results from the study. The interactive map is viewable in modern web browsers. A preliminary version will be demonstrated during the talk.

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THE CURRENT STATUS OF MAPPING IN THE WORLD - SPOTLIGHT ON PACIFIC ISLANDS

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Commission IV, WG IV-2

KEYWORDS: Global Mapping, Digital, Scale, Pacific Islands

ABSTRACT

This paper comprises a summary of the results of a questionnaire sent to mapping agencies in Pacific Island countries to investigate the status of mapping in those countries.

1. INTRODUCTION

Konecny (2013) stated that surveys of the status of mapping around the world were carried out in 1968, 1974, 1980 and 1987, the last survey revealing the status of mapping in 1986 nearly 30 years ago. Further surveys are urgently needed to document whether there has been an improvement in the map coverage. The most recent survey of mapping in Oceania, of which Australia covers the vast majority of area, revealed that 27.8% had been mapped at a scale of 1:25,000, 46.3% at 1:50,000, 100% at 1:100,000 and 100% at 1:250,000. This paper will demonstrate the current extent of map coverage in six sets of Pacific Islands. While the paper will reveal the types of mapping undertaken by each country, there is little information available on the actual percentage of coverage in each of the scales.

In order to undertake this survey, government departments responsible for mapping namely in each of the island states were approached to complete the questionnaire and responses have been received from six of them.

Table 1 Status of Topographic Mapping in Pacific Island States

Jurisdiction – area of landmass/ Population	1:10,000 & larger % coverage Approx. age	1:25,000 % coverage Approx. age	1:50,000 % coverage Approx. age	1:100,000 % coverage Approx. age	1:250,000 % coverage Approx. age	1:500,000 & smaller % coverage Approx. age
Cook Is - 237 km² Pop 10,900		100%				

	N/A	N/A	N/A	N/A	N/A	N/A
Solomon Is 28,450 km², Pop 560,000	x		x			x
	N/A	N/A	N/A	N/A	N/A	N/A
Tonga - 747 km²' Pop 105,000			x			
			10 yr			
Republic of Marshall Islands (RMI) 181 km² Pop 68,000	x	x	x	x	x	
	15 yrs or more	15 yrs or more	15 yrs or more	15 yrs or more	15 yrs or more	
Vanuatu 12,200 km² Pop.250,000	x		x			x
	N/A		N/A			N/A
Fiji - 18 274 km² Pop 880,000			x		x	x
			N/A		N/A	N/A

2. RESPONSES TO QUESTIONNAIRE

Question 1: Scales of topographic digital data and/or map products (or series) produced and maintained & Question 2: Current Age of Existing Geodata

Summary: Most of the Island states are small in area and population as revealed by the figures for each of the countries in Table 1. There is a variety of scales of maps provided by each country. There is little information available on the actual coverage of the scales or the age of the maps.

Question 3) Restrictions on Map Data Distribution

Cook Is – No
Solomon Is – No
Tonga – Yes
RMI - No
Vanuatu – No
Fiji – No

Summary: Generally there are no restrictions on the distribution of maps in the island states.

Question 4) Sale of Maps: Are maps sold to the public free of charge and free to Government departments?

Cook Is: Sold to the public, not free, not freely available to Government departments. Users need to be registered to enable them to use the data for free.
Solomon Is – Maps sold to the public, not freely available and free of charge to stakeholders. A similar pricing is used as in Australia, but in local currency.
Tonga – Sold to public, not free and not free to stakeholders, pricing being trialled.
RMI – Free of charge to public and stakeholders.
Vanuatu – Sold to public, free to stakeholders, not available online.
Fiji – Sold to public, free to stakeholders. Price in accordance to scales and file sizes.

Summary: In most cases maps are sold to the public and provided free to stakeholders. There is no indication on the price of sale of data.

Question 5) Updating Strategy

Cook Is - mapping update program available.
Solomon Is –revision program across all scales
Tonga – mapping program available across scales, every 5 years depending on funding
RMI – N/A
Vanuatu – complete revision of whole series
Fiji – revision program across all scales

Summary: Some island states have a revision program, although only Tonga indicated that it aimed for a 5 year revision cycle

Question 6) Updating Methodology

Cook Is – Field surveys, satellite images and crowd sourcing.
Solomon Is – aerial photography for 1:5000 and larger, satellite images and for smaller of scales; 3rd party data sources also used.
Tonga – field surveys
RMI – field surveys
Vanuatu – field surveys
Fiji – field surveys, aerial survey, photogrammetric

Summary: the majority of countries updated their maps by field surveys, although subsequent questions indicate that satellite imagery is also available and presumably used for updating their smaller scale maps.

Question 7) In-house Capabilities of NMAs

Cook Is – in-house and outsourcing from LINZ for updating 1:25,000.
Solomon Is – in-house
Tonga – in-house
RMI – N/A
Vanuatu – in-house
Fiji – in-house

Summary: Most states undertake the mapping in-house

A) National Imagery Acquisition

Question 8) National Aerial Imagery Program

Cook Is. No national imagery capability.
Solomon Is – No national imagery capability, satellite images acquired from international programs, digital imagery used
Tonga – No national imagery capability, acquired internationally, no regular program
RMI – No national imagery capability, acquired internationally, no regular program, analogue
Vanuatu – No national imagery capability, acquired internationally, no regular program, digital imagery used.
Fiji – A national imagery program exists, flown internationally on a regular basis and currently analogue.

Summary: With the exception of Fiji, none of the states has a regular imagery program. Imagery is collected for all states by international contractors.

Question 9) Satellite Imagery Used by NMA

Cook Is – satellite imagery acquired internationally systematically and as needed.
Solomon Is – satellite imagery acquired internationally systematically and as needed
Tonga – satellite imagery acquired internationally systematically and as needed
RMI – satellite imagery acquired internationally systematically and as needed
Vanuatu - satellite imagery acquired internationally systematically and as needed
Fiji – satellite imagery acquired internationally systematically and as needed

Summary – all states acquire satellite imagery from international satellites systematically on an as needed basis.

Question 10) Use of Radar or Lidar

Cook Is - No other imagery acquired
Solomon Is – No other imagery acquired
Tonga – Yes, the main islands of Tongatapu & Pangai – Haápi Island Resolution with 0.2m
RMI – No
Vanuatu – Yes, lidar coverage only of some parts of main islands like Efate, Malekula and Santo for climate change
Fiji – No

Summary: generally the only other imagery acquired is for specific locations in the island states.

Question 11) Lidar DEM

Cook Is – No
Solomon Is – No
Tonga – Yes as in Q10
RMI – No
Vanuatu – No
Fiji – No

Summary: Lidar DEMs are derived for some countries in specific limited areas

Question 12) Orthophoto Program

Cook Is – No
Solomon Is – 1:5000 and 1:7500
Tonga – Yes, digital
RMI – No
Vanuatu – 1:5000 for 6 Provincial centres and the 2 main town
Fiji – 1:20,000

Summary: There is some evidence of the production of orthophotos in some states but not across all islands and there is no consistency in scales.

Question 13) National DEM

Cook Is – No

Solomon Is – No
Tonga – Yes
RMI – No
Vanuatu - Yes
Fiji – No

Summary: Only some countries have a program for national DEM coverage.

Question 14) Interest in 3D technology by NMA

Cook Is – No
Solomon Is – Yes
Tonga – No
RMI – No
Vanuatu – No
Fiji – Yes
Summary: varies with country

B) National surveying and cadastral coverage

Question 15) Licensed Surveyors

Cook Is – Yes
Solomon Is – Yes
Tonga – No
RMI – No
Vanuatu – Yes
Fiji – Yes

Summary – varies with country

Question 16) Responsibility for Cadastral Mapping and Cadastral Map Coverage

Cook Is – There is a national program undertaken by the private sector.
Solomon Is – Undertaken by NMA
Tonga – Undertaken by other Government department.
RMI – Undertaken by NMA
Vanuatu – Undertaken by NMA
Fiji – Undertaken by NMA, except for Registrar of Titles in the Attorney General's Office.

Summary: NMAs in most countries are responsible for the cadastral mapping.

Question 17) Use of Cadastral Maps

Cook Is – Land registration, Titles, Conveyancing
Solomon Is – Land registration, Titles, Conveyancing, Taxation
Tonga – Land registration, Titles, Conveyancing, Other
RMI – Land registration, Conveyancing, Other
Vanuatu – Land registration, Titles, Conveyancing, Taxation, Other
Fiji – Land registration, Titles, Conveyancing, Taxation and for localities and Land Acquisition Diagrams

Summary – Cadastral maps are used for the normally expected purposes.

Question 18) Cadastral Maps and Geodetic Control

Cook Is – WGS84
Solomon Is – International, GUX1 Astro
Tonga – Tonga Cadastral
RMI – A local coordinates system based on UTM zone 59 on false origin
Vanuatu - Local systems but wish to change to a global system
Fiji – WGS 72 Spheroid

Summary – There is no consistency in the projection systems adopted by the various countries with several basing their mapping on local systems.

Question 19) Monumentation of Property Boundaries

Cook Is – Yes
Solomon Is – Yes.
Tonga – Yes
RMI – Yes
Vanuatu – Yes
Fiji – Yes

Summary – all countries use monumentation for boundaries.

Question 20) Updating of Cadastral Maps

Cook Is – A court order from the Ministry of Justice for changes to the original boundaries will lead to updating.
Solomon Is – When surveys for new boundaries, subdivisions, extensions or combinations is been effected
Tonga – maintenance of the cadastral master plan
RMI – Field survey

Vanuatu – A cadastral database exists for all surveys throughout the country which is updated on a daily basis.
Fiji – Each new survey results in new plans which will be reflected in the cadastral maps

Summary – Generally the cadastral data is maintained and updated regularly, in some countries on a daily basis.

Question 21) Number of Cadastral Employees

Cook Is – 7 surveyors in private sector and government.
Solomon Is – 13 in private sector and government
Tonga – 3 surveyors
RMI – 4 surveyors
Vanuatu – 14 government and private
Fiji – about 200

Summary – the number of surveyors tends to reflect the populations in the different countries, but apart from Fiji there appears to be serious shortage of surveyors to undertake cadastral surveys in these countries resulting in the cadastral system being poorly served.

C) Organisation

Question 22) National Funding for Mapping

Cook Is – funded by Government
Solomon Is – No
Tonga – Yes
RMI – No
Vanuatu - Surveying and cadastral program – Government; Mapping – Funding Agency
Fiji – Yes

Summary – most countries provide funding for mapping programs but some countries depend on funding agencies.

Question 23) Mapping Budget

Cook Is – N/A
Solomon Is – N/A
Tonga – N/A
RMI – N/A

Vanuatu – National Government gives very little emphasis on funding for national mapping
Fiji – N/A

Summary – no country is able to provide details of budget for mapping. It seems that the level of funding is low.

Question 24) NMA staff

Cook Is – 4 staff
Solomon Is – 5 mapping staff. Tonga – About 14 drafting staff
RMI – 4
Vanuatu – 2
Fiji – about 90

Summary – as stated in Q21, apart from Fiji there are inadequate staff to undertake and revise mapping programs in most countries.

Question 25) Legal Status of Mapping

Cook Is – No
Solomon Is – Yes, stipulated in the Ministry Corporate Plan. Strategic Plan, Annual Plans and Individual work plans
Tonga – Under the Land Acts, the Minister for Lands has the authority for cadastral maps
RMI – Surveys are governed by the Land Surveying Act which states that there must be a Board of Land Surveyor Examiners which shall consist of five (5) members and each must have qualification or background in surveying or other related fields such as civil engineer, architect and geography. The Surveyor General who shall be appointed by the Minister is charged with the general administration of the act. In ten years or so there has been no such Board, nor a register land surveyor. However, the Office has been operated by unqualified persons.
Vanuatu – The Land Surveyor's Act mandates the Director of Lands, Survey and Registry to undertake the production of topographic mapping of Vanuatu. Since independence in 1980, there has been assistance from the Australian defence for the production of mapping for all the islands of Vanuatu.
Fiji – The Ministry of Lands and Mineral Resources is mandated by the government to capture, verify, approve and authorize the use of all data pertaining to mapping and surveying in Fiji.

Summary – There is legislation in all countries mandating mapping and the management of the data, although some countries depend on aid programs to compete their mapping while the program RMI for instance in not operational.

Question 26) Form of Map Products Supplied

Cook Is – 60% hardcopy, 20% digital, 10% downloaded and 10% by web services
Solomon Is – 85% hardcopy, 10% digital, 5% downloaded
Tonga – 100% hardcopy
RMI – N/A
Vanuatu – N/A
Fiji – 70% hardcopy, 25% digital, 10% downloaded

Summary – generally hardcopy maps are used, but there is a trend to downloading digital data

Question 27) Archival of Geodata

Cook Is – Hardcopy and digital
Solomon Is - Ministerial Server centralised under government ICT networking system
Tonga – Hard copies in storage, Digital topographic & GIS maps in server
RMI – N/A
Vanuatu - Digital archival for digital data and an archival for hard copy maps
Fiji – Hardcopies stored n the ministry and also in the National Archives and Soft Copies backed up in servers

Summary – hardcopy data is the major source of data

3. CONCLUSIONS

The paper gives a brief description of the extent of map coverage in some Pacific Island states. Overall the availability of modern technology especially satellite images, digital aerial photography and lidar should enable the island countries to provide better map products in future, but this would depend on many occasions on foreign aid. There appear to be insufficient professionals in most countries to maintain the mapping programs. Given that many Pacific Island states will be impacted by rising sea level in the future, better mapping of these countries is essential.

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HIGH RESOLUTION GLOBAL LAND COVER/LAND USE MAPPING CURRENT STATUS AND UPCOMING TRENDS

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KEYWORDS: Land Use, Land Cover, Monitoring, Advanced Methodologies, Validation

ABSTRACT

Land use, land cover and their dynamics are of high interest not only for geographic research but also of growing interest to many administrative, economic and environmental institutions. For four decades, Remote Sensing from satellite images has been a technology allowing the observation of regions even in remote parts of the world. Starting from the global meteorological and climatic dynamics, the observation of vegetation and more specific of food production became a field of great interest for research and environmental and economic applications. The paper highlights the methodological dichotomy between land use and land cover, the technological progress since the 1970s and recent applications on European and global levels.

The paper introduces different global land cover mapping and land cover monitoring data sets of public availability and reports on their significance of class division, spatial resolution and thematic focus if applicable. Recent results for high resolution global data sets are evaluated according to their methodological progress and their potential for further applications. Finally the upcoming trends in high resolution global mapping and monitoring are presented. The focus is not only on scientific progress but also on changing information demand because demands from different fields of application will help to generate the necessary funds for improvement of methods. The overall benefit will be a better knowledge of the actual dynamic of the world regarding food resources and environment.

INTRODUCTION

Since the first Earth Resource Satellite missions in the early 1970s, there have been attempts of obtaining global overviews of land use and land cover, vegetation, settlements and natural resources. While the first available satellite capacities could not easily provide a real global cover in short periods due to revisit limitations, today there are several high resolution satellite systems offering combined or multi date coverage around the world. The easy availability of image data now gives way to evaluate more precisely the limits and potentials of derivative products like land use mapping, land cover mapping or vegetation mapping.

There is a very strong demand for knowing and monitoring the land use on all scales. Remote sensing was seen as a solution to overcome the unbalanced updating of cartographic mapping (Konecny 2013). From local land parcels to regional or national land use dynamics, there is much interest not only for scientific but especially for environmental and economic reasons. The actual land use and the potential for land use development together with crucial questions of land ownership are the main reasons for investments and socio-economic decisions. There is a high demand for knowledge about land use and its dynamics, but the satellite images offer predominantly information on land cover. In the first global or continental remote sensing products of low and medium resolution, this dichotomy was not really obvious; the new potential of remote mapping was just amazing. With better image resolution and a greater differentiation in land use classes, the problem of ambiguities between land cover and land use arose. For instance, the land cover grassland may result from different land uses, like a meadow within the land use "agriculture", like a lawn within the land use "public recreation", like a soccer turf within the land use "sport field" or like a grass field within the land use "airport". Such problems can be tackled either by local validation or by automatic attempts of semantic and geometric interoperability.

METHODOLOGICAL CHALLENGE FROM LAND COVER TOWARDS LAND USE

Spatial patterns on the surface of the earth are of special socio-economic interest in terms of their actual use or the potential to change the actual use by different actors. The value of usable parts of the earth's surface is determined by natural properties of the land, by the access to land and often by the competition of human interests. Land offers potential for food production, cattle husbandry, settlement, economic production, circulation, recreation and extraction of earth resources. Therefore, the knowledge of the land use is an important parameter of decision for most human activities, especially with regard to a growing world population on a limited surface of the Earth. This also applies to the militant usurpations of foreign land as well as the actual globalisation of trade and exchange. Many stakeholders, regional planners and investors need to know the land use not only in their home region but also more or less worldwide.

The Gap

The principal gap between required land use and observed land cover appears in different parameter values. Generally spoken, the size of the gap grows with reduced pixel size and with increasing number of land use classes. In the initial ERTS-1 pixel size of 80 m x 80 m most natural or urban surfaces appeared rather interpolated and therefore appropriate to pixel based classification techniques of that time. Today's high resolution satellite data in the range of 10 m to 5 m are more difficult to classify due to many small differentiations, height differences, shadows and variations in illumination. In high resolution images there are less areas of homogeneous appearance than in image data of medium resolution.

The second reason for the gap between required land use and observed land cover is the number of land use classes. The CORINE Land Cover describes land cover and land use according to a nomenclature of 44 classes organised hierarchically in three levels. The first level comprises four classes, the second level 15 classes and finally the third level 44 classes.

Approaches to Bridge the Gap

There have been a series of different approaches tested during the last decades to refine automatic land cover classification by introducing algorithms for calibration, interpretation keys gained from field observation, libraries of spectral characteristics (reference signatures), knowledge based training parcels and object based class similarities.

LARGE AREA LAND COVER

To understand the different approaches it is interesting to look at large scale land cover mapping projects such as study areas covering whole countries or continents where remote sensing has to be performed without or with only reduced access to ground truth calibration or to ground based validation.

Historic Prototype: LACIE

From 1974 until 1977, the United States Department of Agriculture (USDA), NASA and NOAA conducted the first phase of the Large Area Crop Inventory Experiment (LACIE). The experiment was designed to develop a monitoring method targeted on wheat production in important regions throughout the world (U.S., Canada, USSR, and Brazil). The technological basis was the image data received since 1972 by the Earth Resource Technology Satellite (ERTS), later renamed as LANDSAT-1. The project proved successfully the usefulness of multispectral image data to extract timely crop information, mostly for wheat (Erb & Moore, 1979).

In retrospect, this project has been driven predominantly by political targets. It has also been successful because it concentrated at first on a single-class classification of multispectral data. So it became possible for the United States to predict the wheat harvest for large regions in Russia several weeks prior to harvest within a relatively small error margin. The background is that yield predictions mostly rely on the determination of crop extend and acreage and additionally on crop condition exposed to timely and geometric variables of temperature and precipitation. This explains why the researchers from the LACIE project used additional meteorological data to refine their results (NASA 1978).

Pan-European approach of CORINE

In 1985, the European Commission initiated the project "Coordination of Information on Environment" (CORINE), a very ambitious programme to monitor a great number of environmental features and their spatial distribution and development. Finally, the first feature, which came into realisation, was in fact the land cover, because of the available methods by remote sensing from orbital platforms. Most of the other important environmental features could not be taken into account due to scientific and administrative discussions about definitions and unsolved observation techniques on a European scale. So when the first CORINE Land Cover (CLC) started, it was based on the reference year 1990 and on Landsat 7 image data. Initially the inventory was set up with a minimum mapping unit of 25 ha and 44 land cover classes. For the follow-up mapping, the minimum mapping unit was reduced for changes to 5 ha.

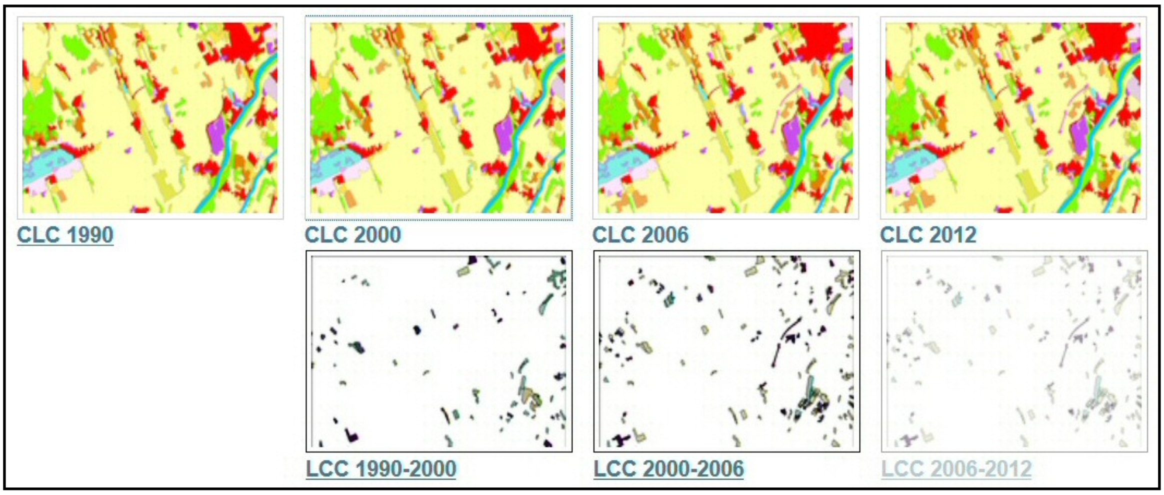

Figure 1: Monitoring stages of CORINE Land Cover (Copernicus 2014)

After the European Environment Agency (EEA) started to become operational 1994 in Copenhagen, tasks within the Directorate General Environment became assigned step by step to EEA, including the CLC 2000 update. Since 2012, the CLC time series became embedded in the structural context of the Copernicus programme. As far as member states are using national digital landscape models, updated with satellite image data, the CLC updates are no longer performed separately, but derived from these landscape models.

Figure 2: CORINE Land Cover 2006 main classes (Copernicus 2014)

LUCAS – the European Sample Monitoring Approach

Since 2001, there have been surveys approximately every three years throughout the European member states. In 2015, there will be another 270.000 points observed in a sample survey according to land cover classes, actual land use and soil conditions, ecological features including a photo documentation of about 1.5 million terrain witness photos per survey year. Based on a stratified sampling strategy on a 2 km by 2 km grid base, the data base of EUROSTAT offers a unique fund of land use/land cover information. Fig. 3 shows an overview of the main land cover classes depicting the 2012 survey results.

The right part of the figure shows an online extract from the terrain photos, one of the sample point itself and additional views in the four cardinal directions. Over the last 15 years, the LUCAS database has been a unique source of information on the spatial development of land cover change throughout Europe, a big data set showing the relation between land cover and land use and an on-site view collection which could provide a valuable calibration source for further refinement of remote sensing classification.

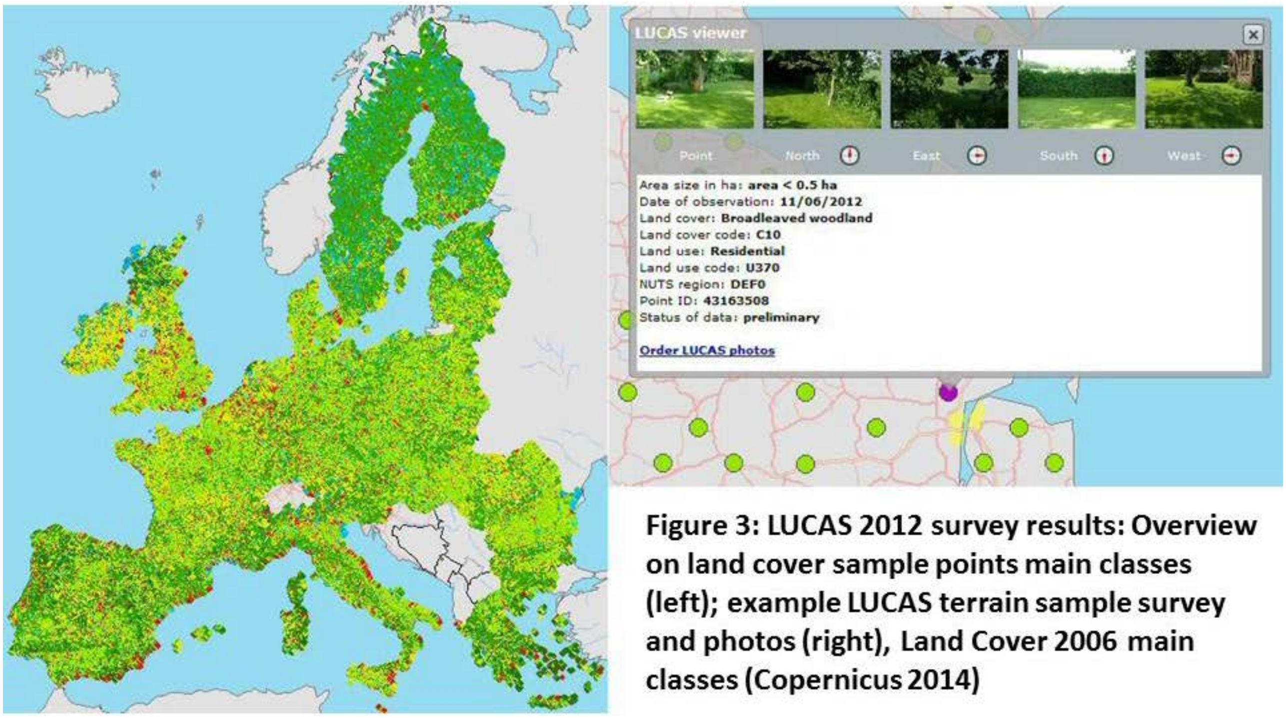

Figure 3: LUCAS 2012 survey results: Overview on land cover sample points main classes (left); example LUCAS terrain sample survey and photos (right), Land Cover 2006 main classes (Copernicus 2014)

GLOBAL APPROACHES

The early approaches for a global coverage were often limited by capacity constraints of the few satellites and by frequent cloud cover in many parts of the world. Therefore, the first global satellite maps often needed more than five years to achieve a complete coverage. More recently several satellite constellations are providing image data with GSD between 30 m and 5 m at short repeat cycles.

Copernicus Global

In 1988, the European Commission, together with the European Space Agency (ESA), initiated a joint programme called Global Monitoring of Environment and Security, better known under its acronym GMES. Under this umbrella a great number of initiatives, projects and service elements were developed. Some examples out of this programme have been the service elements of “Global Monitoring for Food Security” (GMFS) with regional components directed towards Africa (Brockmann et al. 2011, Komp & Haub 2012, Haub et al. 2013). Under the Frame Programme FP7 of the European Commission within the GMES initiative, the Fast Track Service Land was initiated. A bundle of Geoland 2 projects were started, like the Area Frame Sampling Africa. Parallel to those R&D projects the European Commission also initiated direct global monitoring themes, predominantly focussing on biophysical parameters like climate and vegetation. The following figure shows a snapshot from the dynamic development of the seasonal vegetation cover as observed by the PROBA V satellite from May/June 2014, originally with a coarse ground resolution between 100 m (nadir) and 350 m.

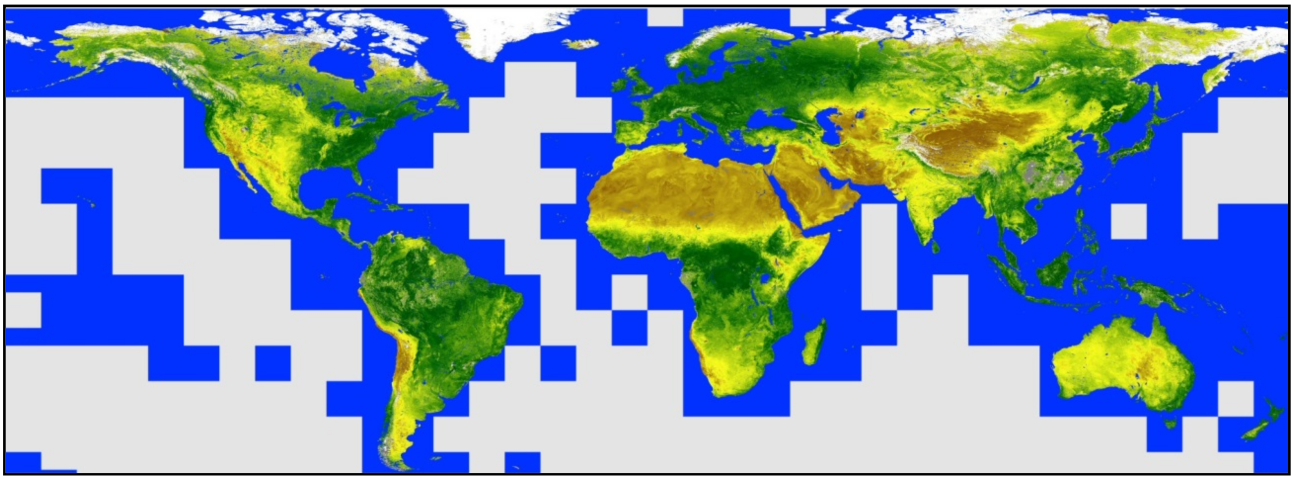

Figure 3: Global Land Cover of Vegetation of 2014 May/June (Copernicus 2014-2)

Another attempt was the Global Land Cover project initiated by the Joint Research Centre (JRC) of the European Commission starting under the frame of a project entitled as Global Environment Information System (GEIS). The task was to “provide information on changes in the world’s vegetation cover for EU policy in the area of environment, development and external affairs” (Bartholomé 2002). The vegetation instrument on board of the SPOT 4 satellite offered a quick but coarse coverage. The cooperation of about 30 research groups developed for the GLC 2000 product a common legend using the LCCS terminology concerted between JRC and FAO.

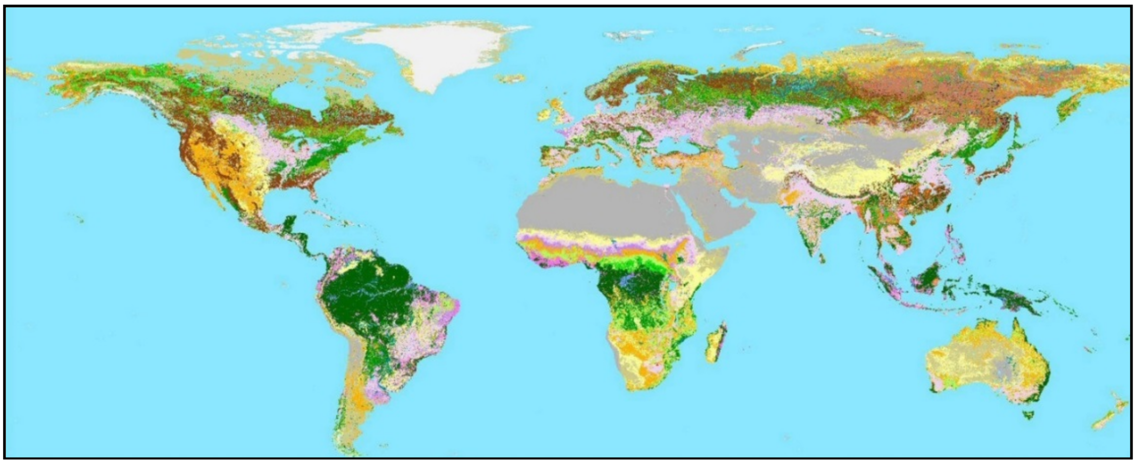

Figure 4: Global Land Cover2000 Product (Bartholomé 2002)

At the same time, similar attempts were conducted by the Food and Agriculture Organisation (FAO) of the United Nations. The new product is called “Global Land Cover – SHARE” (GLC-SHARE) and has been launched in a beta release in March 2014. The database utilizes the ISO standard “Land Cover Classification System” (LCCS) to harmonize various land cover databases from land cover products all over the world. The improved LCCS served to derive the “Land Cover Meta Language” (LCML), which is able to specify any land cover type around the world according to detailedness and scale. By using LCML, the researchers could create eleven land cover classes according to the System of Environmental Economic Accounting (SEEA).
Fig. 6 shows the global extend of ten of these classes with major proportion. The eleventh class comprises all artificial surfaces with only 0,6 % of the world’s land area including inland water bodies.

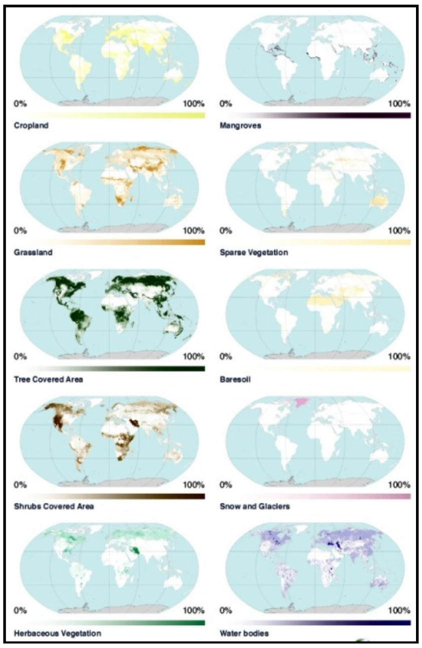

Figure 5: GLC SHARE Land Cover Data Base – single classes (Latham 2014)

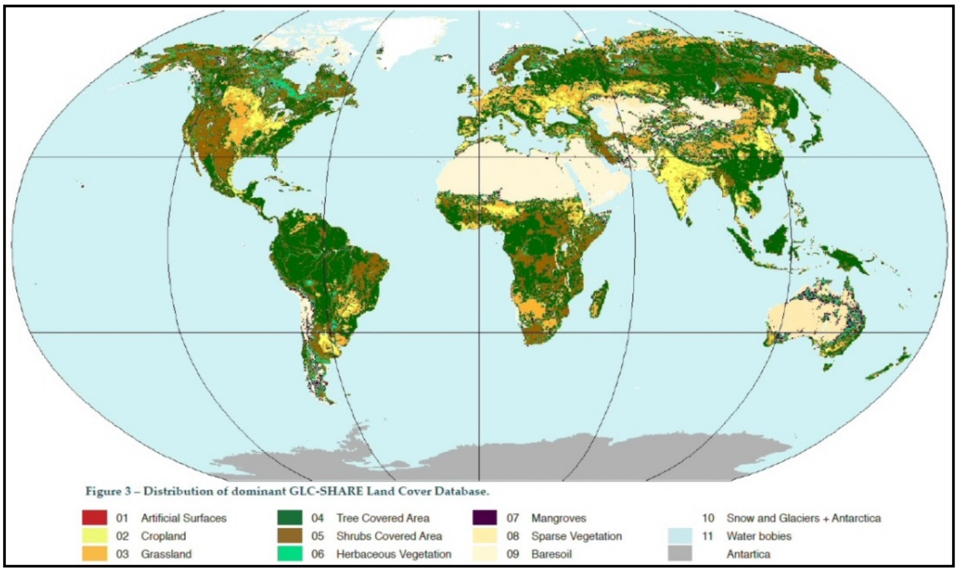

Figure 6: GLC SHARE Land Cover Data Base Map (Latham 2014)

The database is geometrically compiled within a pixel resolution of 30 arc-second, corresponding to ~1 km x ~1 km. The area south of latitude 60° S was not included in the data base. While Northern America, Europe, the Eastern half of Africa, Russia, China, some Southern Asian states and Australia were covered by high resolution data sets, Southern America, the Western half of Africa, the Arabian Peninsula, India and the Indonesian Archipelago were only covered by global data sets of coarse resolution.

Around 1000 stratified random sampling sites were used to perform a quality validation, of which the result is shown in Table 1. The overall class accuracy has been computed with 80,2 %. FAO is expecting that the reliability will increase with updates using improved databases.

Table 1: CLC-SHARE 2014 Quality Assessment
(own compilation from Latham 2014)

GLC-SHARE Land Cover types	Label	Global fraction	User's accuracy	Producer's accuracy
Artificial Surfaces	01	0,6 %	70,0 %	100,0 %
Cropland	02	12,6 %	94,9 %	88,8 %
Grassland	03	13,0 %	75,4 %	65,6 %
Tree covered Areas	04	27,7 %	94,9 %	91,8 %
Shrub Covered Areas	05	9,5 %	50,0 %	67,9 %
Herbaceous vegetation	06	1,3 %	56,0 %	53,8 %
Mangroves	07	0,1 %	80,0 %	100,0 %
Sparse vegetation	08	7,7 %	50,0 %	44,3 %
Baresoil	09	15,2 %	57,3 %	89,6%
Snow and glaciers	10	9,7 %	96,3 &	72,2 %
Water bodies	11	2,6 %	100,0 %	66,7 %
Total		100,0 %		

GLC Global Land 30

Between 2010 and 2013, the Chinese National Geomatics Center (NASG) prepared two global land cover maps of high resolution of 30 meters for the reference years 2000 and 2010 from freely available Landsat scenes. This has been launched as a national 30 m GLC mapping project and was listed as a GEO sub-task SB-02 C1 (Chen 2014).

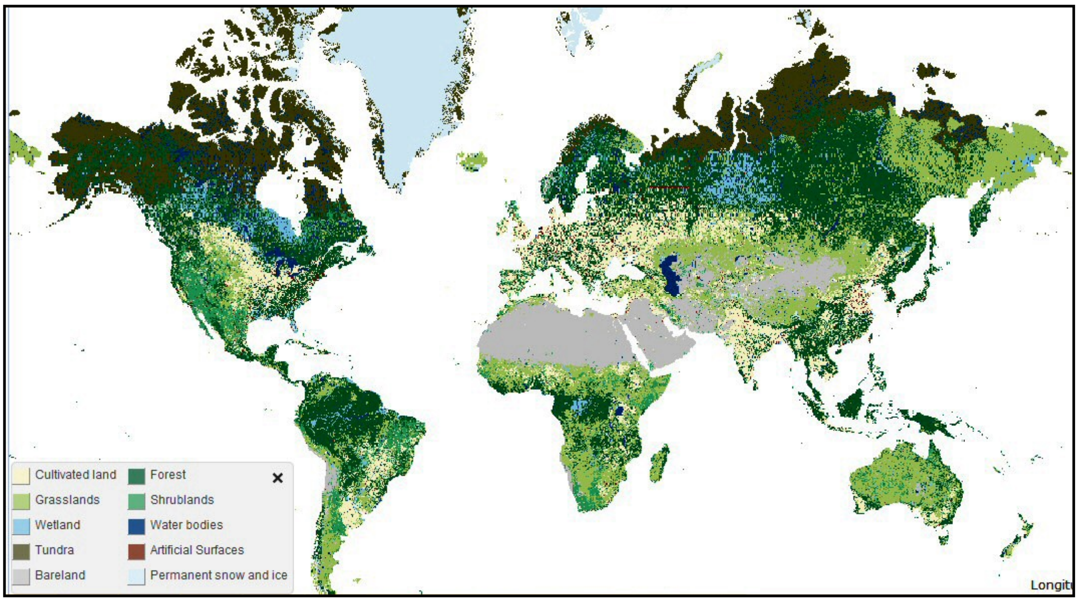

Figure 7: GLC Global Land 30 result for 2010 (Chen 2014)

To obtain a dataset for the reference year 2000, the National Geomatics Center of China in Beijing processed 10270 Landsat TM scenes. For the update 2010 though they could already use 2640 scenes from the Chinese HJ-1 satellite together with 9907 Landsat TM scenes. For four years around 500 scientists worked on the geo-coding and thematic processing of these data and developed a bundle of sampling techniques, classification and change detection procedures, e.g. the spectral gradient difference (SGD) based approach for land cover change detection (Chen 2013). The GLC 30 product comprises 11 land cover classes (see Fig. 8).

For the scientific user community it is very important that the complete data base for both reference years including sample areas and reference data like CORINE are available as a web service: www.globallandcover.com/GLC30Download/index.aspx. About 139 map sheets have been independently validated in sample areas by five international research groups, confirming a disagreement generally lower than 5 %.

Needs for Validation

All the explained land cover products basically have to face the same problem: The lower the number of well-known ground samples is, the more the automatic classification approaches have to extrapolate land cover characteristics into other regions, but with the consequences of raising risks of misclassification. On the other hand world coverage will hardly be completed without a certain margin of uncertainty related with time saving automation.

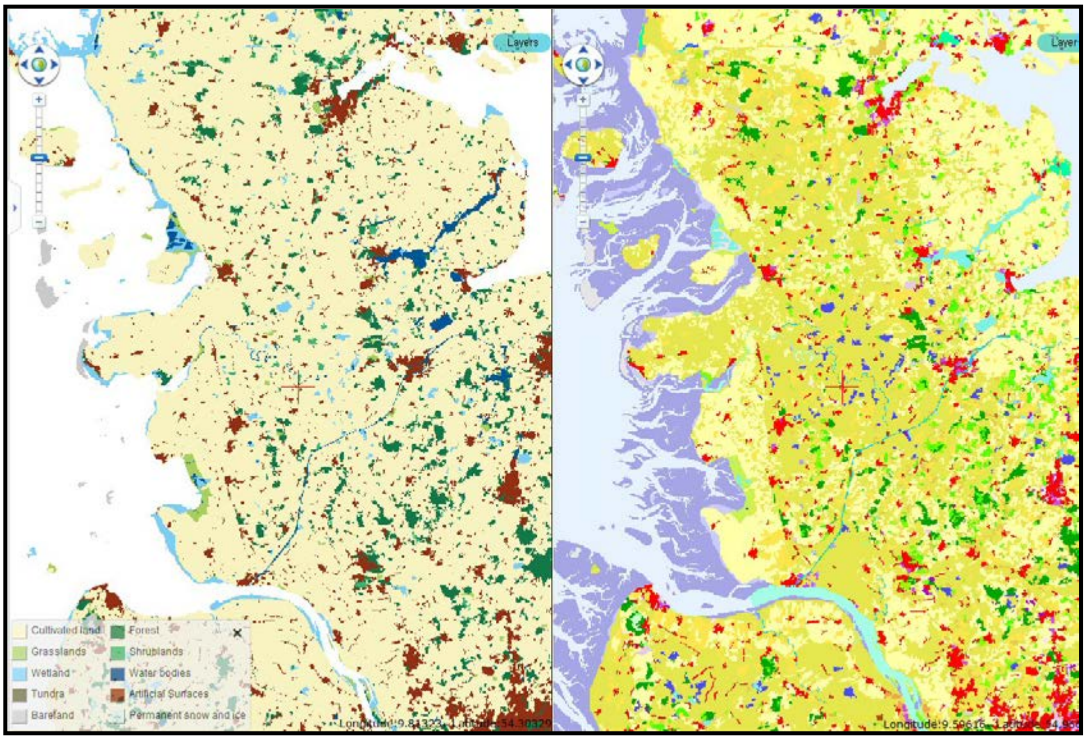

Figure 8: Validation example of GLC Global Land 30 (2010) against CORINE (CLC) for Schleswig-Holstein in Northern Germany (Chen 2014; www.globallandcover.com/GLC30Download/index.aspx)

Fig. 9 shows the comparative view of an extract from the GLC 30 and the corresponding CLC 2006 of a small part of Northern Germany between the city of Hamburg in the lower right corner and the German-Danish border of about 16.500 km², just separating the North Sea (left) from the Baltic Sea (right). Artificial surfaces, water bodies and forest show a very good concordance. But there is a well-known land cover differentiation of a strip of 40 km width and 120 km length parallel to the Western coast of predominantly grassland (CLC code 231), which is missing in the GLC 30 results. At least in this area, this will result to an underestimation of grassland cover to the benefit of the cultivated land ratio. Some other differences in the tidal flats along the North Sea coast are not of importance because in the global view these tidal amphibious lands are in the range of mangrove coasts extensions which also are not subject of GLC 30.

This example may underline the potentials for further improvements of the reference database, which will be performed certainly in the next update of GLC 30, as was already announced in Chen 2014.

MONITORING LAND COVER / LAND USE CHANGES

Methodological Advances in DeCOVER

In the frame of project for space-based services for German land cover, the DLR co-funded the development of approaches to overcome the gap between land cover and land use. The project DeCOVER focussed on the existing international and national land cover models like CORINE land cover, ATKIS Basis-DLM and DLM-DE with the aim to also support in future the setup of the European land service components within the Copernicus land serving components. Methodologically, there were different services to be addressed: the automatic detection and classification of land cover changes, the agricultural monitoring, the environmental monitoring and the crucial question of overcoming the partial discrepancies between the different existing national and international land cover models.

This special research needs to be explained in detail. Satellite based land cover data are supposed to have an area fully covered by a number of land cover classes, without overlaps and without any unclassified gaps between adjacent areas. Contrary to this, the ATKIS Basis DLM model provides information on land cover and land use, normally with several information layers (cadastre, legal requirements, land use, built-up structures, public limitations on real estate use, economic zoning, etc). The project has improved approaches of semantic and geometric interoperability to derive object classes from different cadastre comparable based on a common vocabulary (Christ & Lessing 2012, DeCOVER 2013).

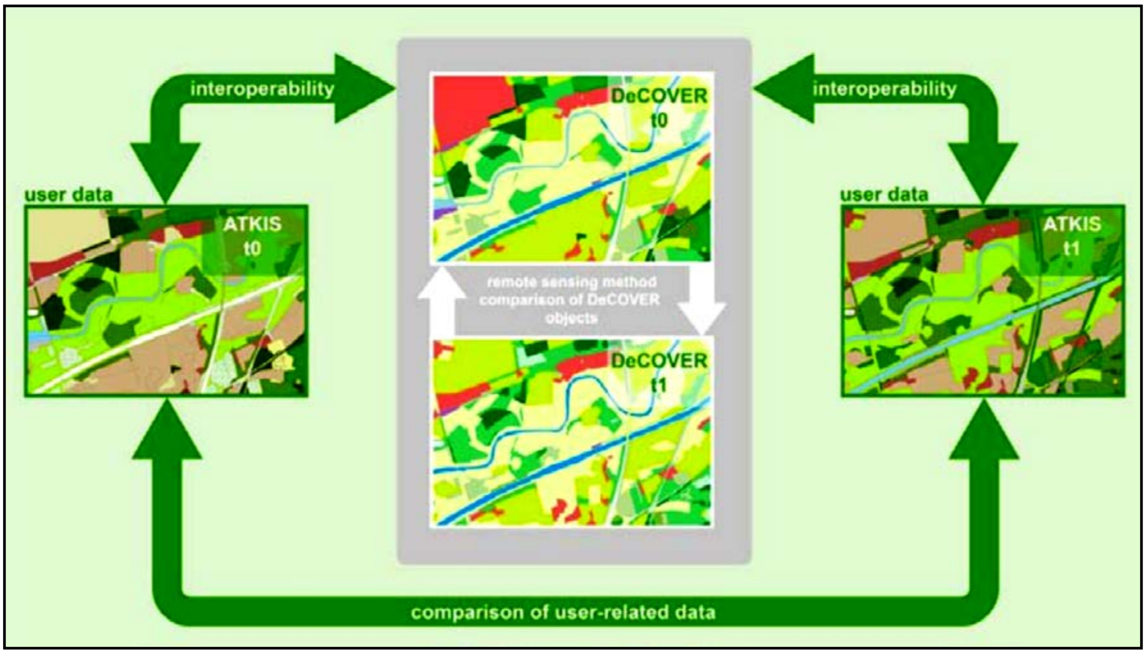

Figure 9: Knowledge based semantic and geometric interoperability (DeCOVER 2013)

The method allows for many suitable classes a semantic translation and for some classes even a geometric translation between the remote sensing derived land cover and the administrative and legal land use. These are for now R&D results in the frame of knowledge based regional context. To develop this method into a reliable service element there is still the need for more experience based case applications. Especially the local and regional knowledge bases according to the same standards will be a bottleneck for fast global spread of satellite based monitoring of high resolution. Perhaps the 15 years of recurrent LUCAS surveys will help to extend the knowledge base of land use and land cover at least in Europe.

These recent developments of methodological advances combined with repeatedly updated sample surveys give a very good perspective to improve the possibilities for global land cover / land use monitoring based on worldwide high-resolution satellite data.

Upcoming Trends in Global Monitoring

Several trends that can be observed lately will support further advances in high-resolution global land cover products. One important core issue is the continuation of high-resolution satellite programmes, even as a combination of satellite resources from different providers. Therefore, it is very promising that there is not only the Landsat continuity but also the upcoming Sentinel series, the RapidEye constellation, Spot 7, ResourceSat-2 from India and the Chinese HJ-1 that have enlarged the observation capacity already. Further follow-up satellites are under construction and planned. A second support field comes from various projects and international initiatives: Originally started as a project, there has been for several years one initiative working actively to promote and improve global earth observation, the "Global Observation of Forest Cover – Global Observation of Land Dynamics" (GOFC_GOLD) initiative. The Committee on Earth Observation Satellites (CEOS), the Group of Earth Observation (GEO), the United Nations (often through FAO) and many regional or national governmental institutions are pushing earth observation into a confluence of methodological and technical progress (Mora 2014).

Fortunately, there is other support, sometimes not in the focus of the scientific communities, but with growing and driving force. This support comes from an emerging group of users of global land cover information, not only from the public, but also from the private sector. The first global information of coarse resolution has created rising interest for information of better geometric and temporal resolution. The traditional user group has different administrative interests, like disaster mitigation, support to regional planning and zoning, monitoring of water resource regions, desertification, climate, biodiversity, ecosystem conservation and vegetation characteristics and change (cf. Mora 2014). Additionally, there is a special demand among the governmental user group to support earth observation in relation to developing countries and less-favoured regions (Komp 2010, Voelker 2011). The ongoing globalization of all social and economic relations has created a third important support group: the private sector, meaning the society as a whole. Besides the scientific interest of all earth-related disciplines, there is increasing interest in free access to global land cover information from private persons for travel, foreign investments, social engagement of NGOs and various economic activities. Initially, the main sectors that are profiting are the agriculture, forestry, mineral resources extraction and the energy sector, because all of them depend on knowing the spatial pattern in actual and accurate characteristics. The third group often benefits significantly from land cover information and will then be ready to finance projects that go beyond the free access information and generate information that is more specific. Such growing demand driven by globalisation will provide funding for scientific progress in earth observation, even in times of declining budget resources.

Those driving trends will be the basis for the scientific-technical trends in high-resolution global land cover mapping. Upcoming changes are visible in user oriented differentiation of monitoring cycles, monitoring scales and monitoring subjects. There are regions like the upper Amazonas forest or the north Siberian tundra where large scale mapping will happen only on demand in the absence of governmental programmes. On the other hand there will be extended online access to all geographic data. It is a very promising example that the Chinese GLC30 data base already offers an online validation tool which may serve in future to broaden the sources for local input of knowledge ("crowd sourcing validation"). Furthermore, the number of people travelling for private or work related reasons will increase further and require more specific information on their destination via online access. This will certainly bring new forms to display land cover mapping in user-adapted peculiarity.

CONCLUSION

Since the first satellite images were available, global land cover mapping data have been the key source for researchers, governments and private users. The paper demonstrated the scientific developments and technological progress since the Large Area Crop Inventory Experiment where the United States predicted the Soviet wheat yield. Furthermore, this paper discussed different land cover data sets to highlight the regional and global developments. In terms of high resolution, accuracy and actuality the Chinese Global Land Cover change detection data set presently appears to have the highest standard The GLC30 product fascinates with its information content and the web based functionalities, but also shows potential for local improvement.

The demand for ongoing global land cover observation is expressed by different user communities. Upcoming trends are more continuity of data with higher resolution, harmonization and standardization of mapping procedures, but also emerging user demands and new user communities related to web services. Finally, these prospects will broaden the user community who sees the Societal Benefit Areas (SBA) of earth observation. This will be the common mandate for all researchers and experts involved to support the advancement of earth observation. Their engagement in earth observation and high-resolution land cover monitoring will contribute to a responsible and sustainable development of our planet Earth.

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VEGETATION COVER STATE EVALUATION WITHIN THE FUKUSHIMA-1 AREA BY MULTISPECTRAL AND RADAR SATELLITE DATA ANALYSIS

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KEYWORDS: vegetation cover state, multispectral satellite imagery, radar satellite imagery, data cube classification, Fukushima-1, land cover classification accuracy

ABSTRACT

The map of land cover classification for evaluation of vegetation state within the Fukushima-1 area on the base of RapidEye multispectral satellite data and ALOS-2 radar satellite data is provided. Radar data engagement significantly improves the classification accuracy for some types of land covers, especially for ones, which related to humidity. The classification results will be valuable for further investigation of ecological state of different forest vegetation species within radionuclide contaminated area.

1 INTRODUCTION

Reliable and accurate estimation of vegetation condition is an important task for monitoring of territory affected by nuclear accident. Vegetation cover state parameters are indicators of the overall environment condition of study area, as well as ones are the source data for many natural resource applications. Practicability of vegetation multispectral remote sensing to assess the radioactivity impact on the phytosanitary condition is determined, on the one hand, by high information capacity and, on the other hand, by efficient data acquisition capabilities. Also the radiation safety of research personnel is very important.

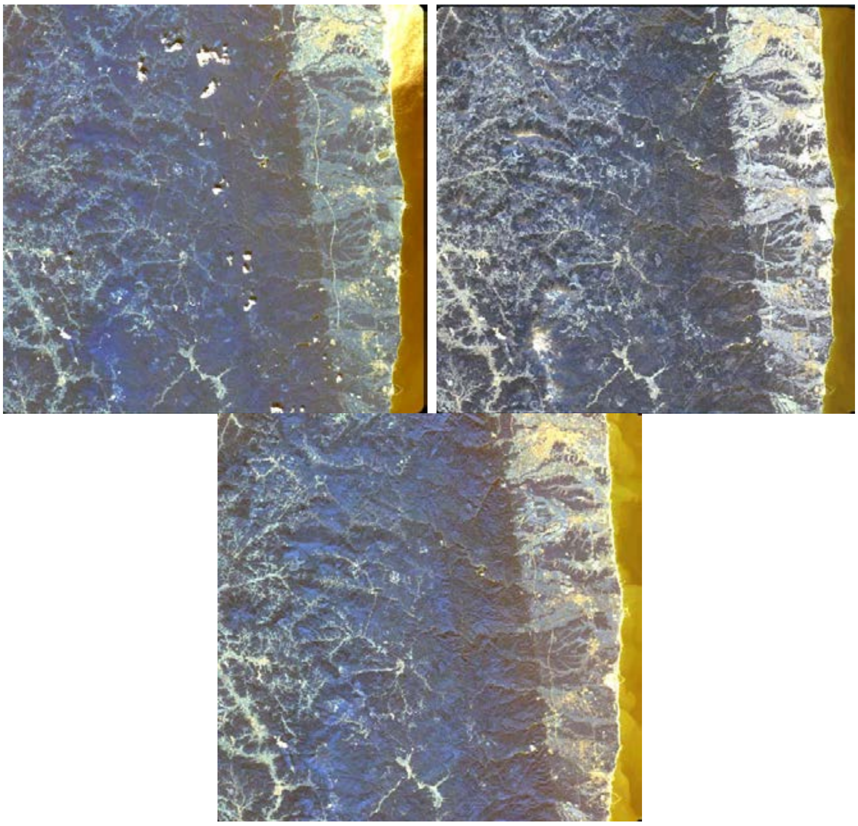
2 RESEARCH TASK

Research tasks include pre-processing of satellite and ground truth data and environmental condition analysis of vegetation inside radionuclide contamination area using different vegetation indices (Lyalko et al., 2011). The main research goal is to provide the land cover classification for evaluation of vegetation state within Fukushima-1 area on the base of multispectral satellite data analysis. Also another objective of the study is the evaluation of microwave radar imagery suitability to improve the classification accuracy.

3 SOURCE DATA

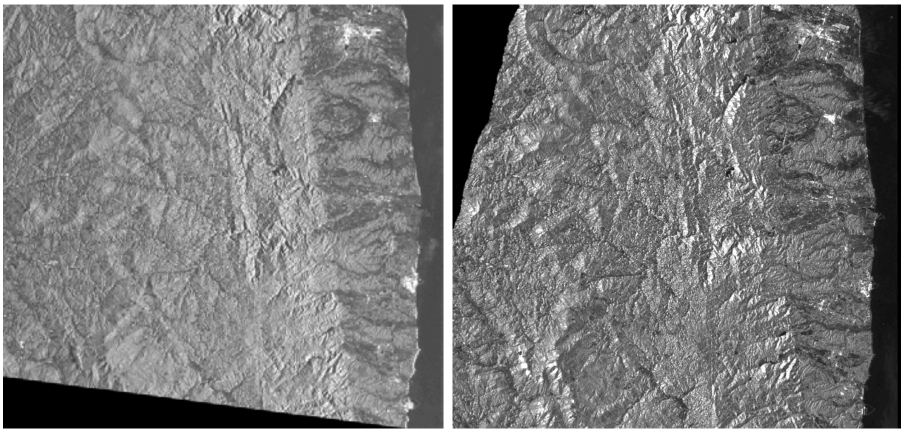
To conduct the research, the following source data were used: multispectral satellite data – three sets of RapidEye/JSS-56 satellite images (http://blackbridge.com/rapideye/) of Fukushima-1 area for different period of time

(**Fig. 1**) and conformed Landsat-8/OLI satellite images (http://landsat.usgs.gov/landsat8.php); L-band radar satellite data – two sets of ALOS-2/PALSAR-2 satellite images (http://global.jaxa.jp/projects/sat/alos2/) of Fukushima-1 area of different period of time (**Fig. 2**); ground-truth forest inventory data for Iwaki, Aizu, Okukuji and Abukumagawa districts (**Fig. 3**); descriptions of landscapes, vegetation and soils of the eastern part of central Honshu (Nagaike, 2012); monthly average long-term climatic characteristics of the study area (http://www.jma.go.jp/jma/indexe.html); digital terrain elevation data of study area as ASTER GDEM v2 (http://gdem.ersdac.jspacesystems.or.jp/) mosaic (**Fig. 4**); plant biotopes and other land covers classes of study area as interpretation result of previously multispectral satellite imagery.



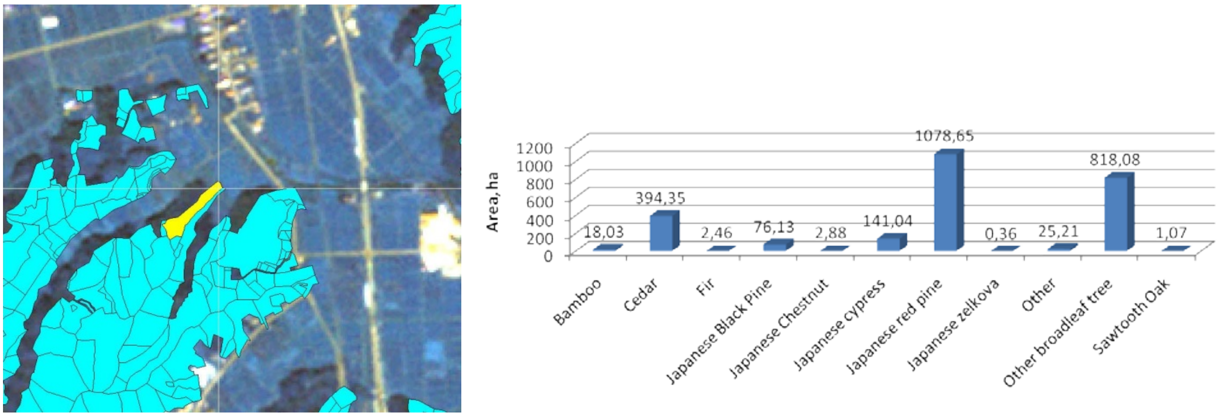
a *b* *c*

Figure 1: RapidEye multispectral satellite image mosaics of Fukushima-1 area:
a – August 22, 2012; *b* – March 15, 2013; *c* – October 25, 2014



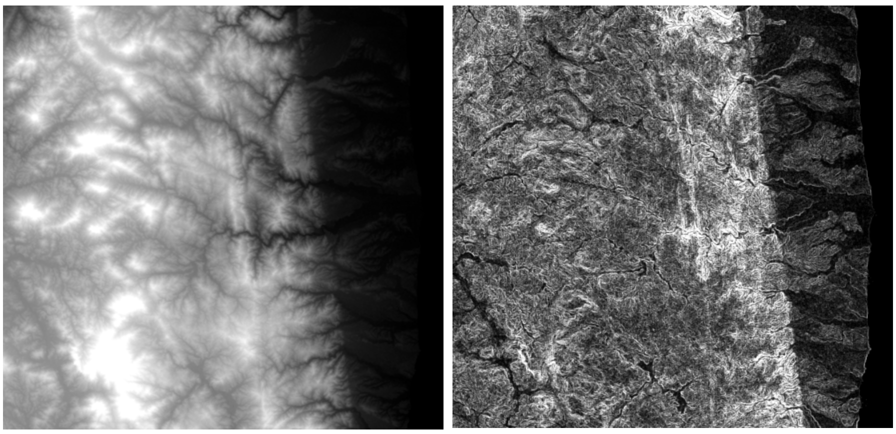
a *b*

Figure 2: ALOS-2 microwave radar satellite images of Fukushima-1 area:
a – August 27, 2014 (VV); *b* – November 17, 2014 (HH)



a *b*

Figure 3: Forest inventory geospatial database of Fukushima-1 area:
a – vector map layer; *b* – forest species statistics



a *b*

Figure 4: Digital terrain elevations data of Fukushima-1 area:
a – ASTER GDEM v2 mosaic; *b* – terrain slope tangents

4 METHOD USED

To perform land cover classification the multispectral image mosaic was constructed. Before thematic processing all multilayer mosaic images were georeferenced to each other as well as to forest inventory database. The land cover supervised classification has been done using ground truth data by minimum distance and maximum likelihood algorithms (Mather and Tso, 2009). The comparative analysis of multi-temporal mosaics was performed to improve the classification accuracy. Two modes of classifications were done: 1) using only RapidEye multispectral imagery and 2) using combination of RapidEye imagery and AlOS-2 radar imagery. Different polarization modes (VV and HH) of satellite radar images were used. Digital terrain elevations were taken into account in the form of interpolated surface slopes when performing classification (Popov et al., 2008). The RapidEye multitemporal mosaics were used to produce multilayer datacube for joint land cover classification in the first case and RapidEye multitemporal mosaics in conjunction with radar images – in another case.

5 RESULTS AND DISCUSSION

As a result of classification of multilayer datacube based on RapidEye 5 m spatial resolution mosaics on August 22, 2012, March 03, 2013 and October 25, 2014 the map of forest vegetation species and other land covers was obtained. This map is shown in Fig.5.

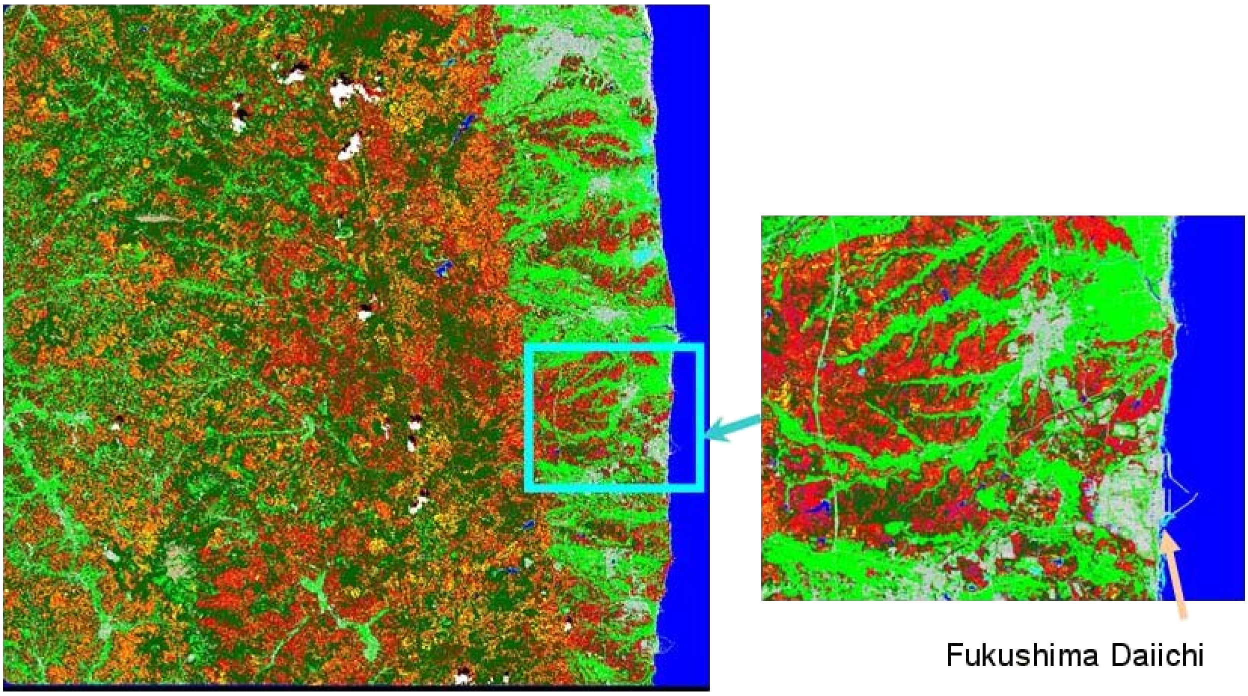


Figure 5: Land cover classification map of Fukushima-1 area by RapidEye mosaics processing

Thirteen land cover classes of including main forest vegetation species were found, as listed in Table 1.

Table 1. Land cover classes of Fukushima-1 area (multispectral only)

Code	Class [Color]	Percentage
	Japanese red pine [Red]	19.10
	Japanese black pine [Purple]	0.76
	cedar [Orange]	11.53
	Japanese cypress [Yellow]	2.64
	other broadleaf trees, oaks [Dark Green]	38.85
	meadows, former rice fields [Green]	13.78
	settlements, rare vegetation [Grey]	1.15
	man-made surfaces, roads, sea damps, etc. [Light Grey]	3.53
	bare soil, sparce vegetation [Tan]	1.15
	wetlands, shallow water, river valleys [Cyan]	0.37
	open water [Blue]	7.12
	clouds [White], shade from clouds [Black]	0.02

Average accuracy of classification is about 79%.
The classification on the base of one RapidEye mosaic image (on one date) has worse accuracy then if we use three RapidEye mosaics on different date. For example, the classification on RapidEye mosaic image on October 25, 2014 has the insufficient accuracy concerning identification of other broad leaves trees, wetlands and some other classes (average accuracy is about 62%).
The second mode of classification was performed using combination of RapidEye and ALOS-2 PALSAR-2 (L-Band) data. It was used two PALSAR-2 registrations at VV and HH polarizations for the study area for the dates of August 21, 2014 (VV) and November 17, 2014 (HH) with 2.5 m spatial resolution. For classification the multilayer datacube on RapidEye data and two PALSAR-2 radar images had been constructed. Before construction of datacube the PALSAR-2 data had been processed using Lee-Sigma filter for radar speckle suppression. The result of classification is shown on **Fig. 6**.

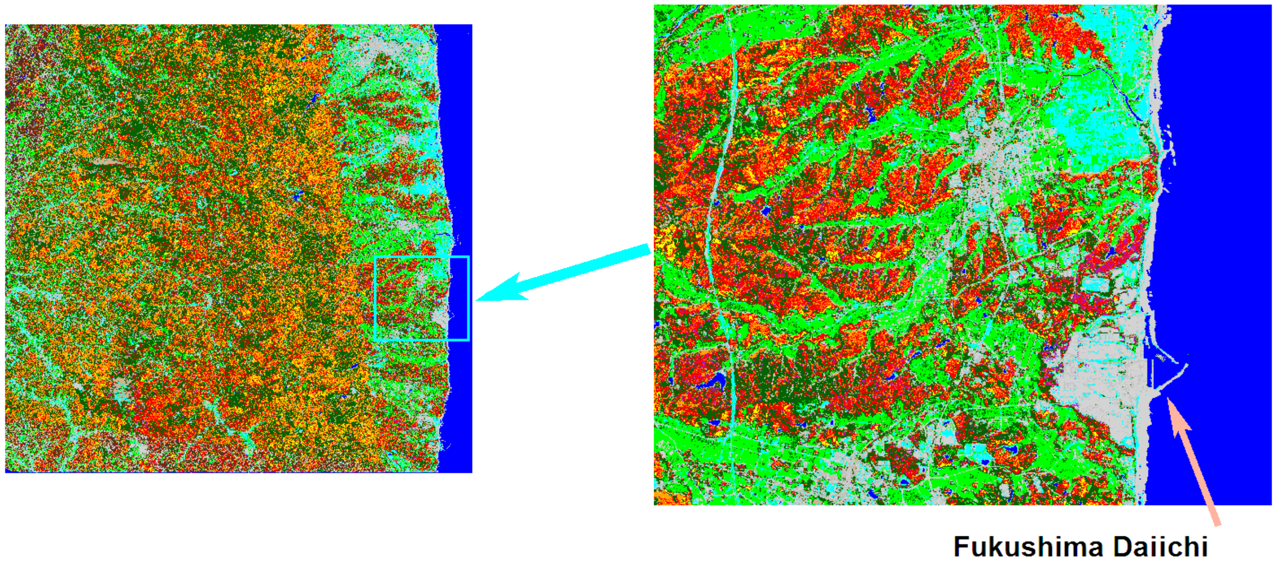


Figure 6: Land cover classification map of Fukushima-1 area by RapidEye and ALOS-2 data processing

Percentiles of the same land cover classes have somewhat changed, as noted in Table 2.

Table 2. Land cover classes of Fukushima-1 area (multispectral and radar)

Code	Class [Color]	Percentage
	Japanese red pine [Red]	14.40
	Japanese black pine [Purple]	0.60
	cedar [Orange]	14.87
	Japanese cypress [Yellow]	3.49
	other broadleaf trees, oaks [Dark Green]	33.67
	meadows, former rice fields [Green]	8.50
	settlements, rare vegetation [Grey]	0.82
	man-made surfaces, roads, sea damps, etc. [Light Grey]	9.66
	bare soil, sparce vegetation [Tan]	2.77
	wetlands, shallow water, river valleys [Cyan]	4.20
	open water [Blue]	7.02
	clouds [White], shade from clouds [Black]	0.00

As a result of classification it was found the significant improving of accuracy for identification of wetlands, water bodies as well as for bare soil, sparse vegetation and meadows. For example, for wetland the accuracy improving is about 9%. It was confirmed that the classification of wetlands using only optical satellite data is difficult because of the spectral confusion between land cover classes especially among different types of wetlands (Dabrowska-Zielinska et al., 2014). Therefore in this case the ALOS-2/PALSAR-2 data engagement is rather useful. But in general the average accuracy of land cover classification was improved imperceptibly – from about 79% up to about 81% using combination of RapidEye and ALOS-2 data. For some forest vegetation species (e.g. broad leaves trees) it is observed even a little bit decrease of classification accuracy. This phenomenon can be explained by weak reflectance of plants in the long-wave radar L-band (22.9 cm wavelength).

6 CONCLUSIONS

The classification results will be valuable for further investigation of ecological state of different forest vegetation species using, for example, analysis of red edge vegetation indexes changes for different kind of vegetation cover. Besides, the classification output is the base data for the numerical simulation and risk assessment of adsorbed radionuclide emission by wildfire within Fukushina-1 area (Stankevich et al., 2013). Also the microwave radar data involvement eliminates the cloudiness influence, which is a serious problem for the optical remote sensing.

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MAPPING TECHNIQUES FOR SPATIO-TEMPORAL SIBERIAN VEGETATION CHANGES

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KEYWORDS: vegetation mapping, map, mapping techniques, GIS-layers, forest inventory, vegetation changes rate

ABSTRACT
The paper shows mapping techniques for spatio-temporal vegetation changes in Siberia. As an example a part of Forest Fund of Russian Federation near Samotlor lake (Khanty-Mansi Autonomus Area, RF) is taken into account. Map-making was based on topographic maps or forestation plans as GIS layers formed in process of forest management. Paper includes the following maps: track map, temporal series map, map showing value difference between two dates. Rate of vegetation changes at the testing site has been determined.

Siberia occupies more than a half of Russian territory. It is subdivided into the West and the East parts. Almost all natural zones (from tundra to mountainous forest-steppe) are presented here. The relief is also inhomogeneous: alongside with lowlands there are many mountain systems. This determines complex structure of vegetation cover as well as species and biocenosis diversity.

When making vegetation maps we set the task to represent the plant community distribution pattern throughout the earth surface. By its content, the map may be floristic, representing distribution of certain species (areals) or geobotanical. Geobotanical maps represent areas occupied by certain types of plant communities (associations, formations, etc.).

At present most of the geobotanists consider vegetation cover as a spatial object, whereas it is a process, and plant diversity regularity cannot be understood out of time. Floristic method of vegetation classification has become a common interest for many of geobotanists, this resulted in formalized approach to the plant communities differentiation to a degree that made this classification unsuitable for both vegetation dynamics study and its mapping (Galanin, Galanina, 2012).

The object of geobotanical mapping is either current vegetation cover or the vegetation, which had existed on the territory before the latter was developed by man. At present, there are three types of maps: revegetation species maps which give an idea of native vegetation (forest and steppe); maps of current (actual) plant cover taking into account the degree of lands development; dynamic maps, representing mature plant communities replacement due to anthropogenic impacts or environmental effects of current waters, fires, deforestation, etc. To our opinion, we should also differentiate forecasting maps, which show the trends of future vegetation changes.

Geobotanical map is fairly considered as a model for vegetation cover of any size, and the larger is the map scale the more detailed is the model, with all smaller units of taxonomic classification being represented. Thus, the units of topological level are represented in large-scale maps, those of regional level – in medium- and small-scale maps, and global – in general-purpose maps of the world or continents.

Plant cover classification is significant for geobotanical mapping. The most common principles applied in geobotanics are those of ecological-and-morphological classification developed as early as 30-s in works of V. N. Sukachev, A.P. Shennikov, E.M. Lavrenko and A.V. Prozorovsky. They were used for different scales geobotanical maps making. Also important for cartography is a geographic-and-genetic classification, developed by V.B. Sochava. It is based on phytocenological, ecological-and-geographical and genetic principles. The classification presents two series of plant cover subdominants. The first series corresponds to the topological maps, the second one refers to geobotanical zoning problems.

There exist several techniques for electronic mapping of changes: application of temporal series of maps, track-map making (several positions of the object in the same map), or demonstration of the values difference between the two or several dates or instants of time. In other words, three types of time dependencies may be shown in the map:

- Tendencies – changes taking place between two or more dates or instants of time;
- Situation before and after – conditions preceding and following the event;
- Cycle – changes taking place in repetitive time intervals, such as day, month or year.

Three testing sites were chosen in the north, medium and south taiga of West Siberia for mapping spatio-temporal vegetation changes. As a result of mapping, the greatest spatio-temporal vegetation change has been revealed in the vicinity of Lake Samotlor (Khanty-Mansi Autonomous Area, R.F.) in medium taiga. The change is a result of the strong anthropogenic impact of the fuel-energy complex enterprises in the given area. The maps of the other two sites in north and south taiga of West Siberia are not presented, as the rate of vegetation changes over the relatively short period of time is insignificant. The plant cover was mapped completely as a single object without taking into account taxonomic units, in accordance with the requirements of forest management instruction.

When comparing forest sub-compartment boundaries (within the boundaries of forest resources) by the materials of forest management (inventory) and vegetation cover (table 1), correlations to be used for map-making were obtained. These maps represent current and restored vegetation superposition. To designate objects in the map hatching and colouring were applied separately or in combination.

As a result of mapping four maps were made to demonstrate techniques for spatio-temporal vegetation changes were made.

Temporal series of maps (maps 1 and 2): green areas show vegetation cover, yellow areas are non-vegetation areas, white areas show other lands not belonging to Forest Fund (as a rule these are industry lands). Map 1 shows the situation in 2000, map 2 shows the situation in 2008.

Track map (map 3). Green areas show the vegetation cover conditions in 2000 (top) and in 2008 (bottom).

Map showing value difference between 2000 and 2008 (map 4). Yellow are vegetation cover area with no changes (39,6 square kilometers, 69,7% of total area), Green areas show decreasing of vegetation cover area (14,9 square kilometers, 26,2% of total area), red areas show increasing of vegetation cover area (2,3 square kilometers, 4,1% of total area).

Map-making was based on topographic maps or forestation plans as GIS layers formed in process of forest management. Vegetation maps contours either reproduce the forest sub-compartment boundaries or unite some of them. In 2000 forest management materials (inventories) were based on the aerial survey data. In 2008 forest management materials were formed by interpreting multispectral satellite images produced by artificial Earth satellites with spatial resolution of 1 – 2.5 m. In both cases images were rectified and projected for geographic coordinate system.

Mapping is a final stage of natural objects geographical study. For quantitative estimation of the plant cover, various characteristics may be used including average contour area, maximum contour area, contours density, contours boundaries density, and average entropy of contours (M. Yu. Gafarov). In addition to the above mentioned, nonnormalized rate of vegetation cover changes was determined at the characteristic testing site near Lake Samotlor (Khanty-Mansi Autonomous Area, R.F.). This rate amounted to 0.33 km^2/year with negative sign (Table 2).

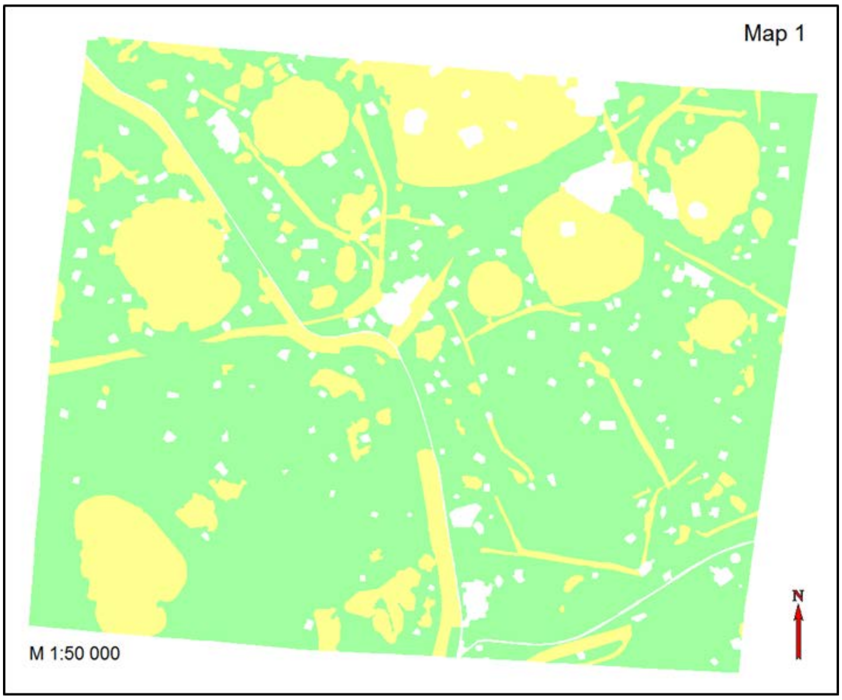
Table 1. Forest sub-compartment boundaries and vegetation cover characteristics correlation

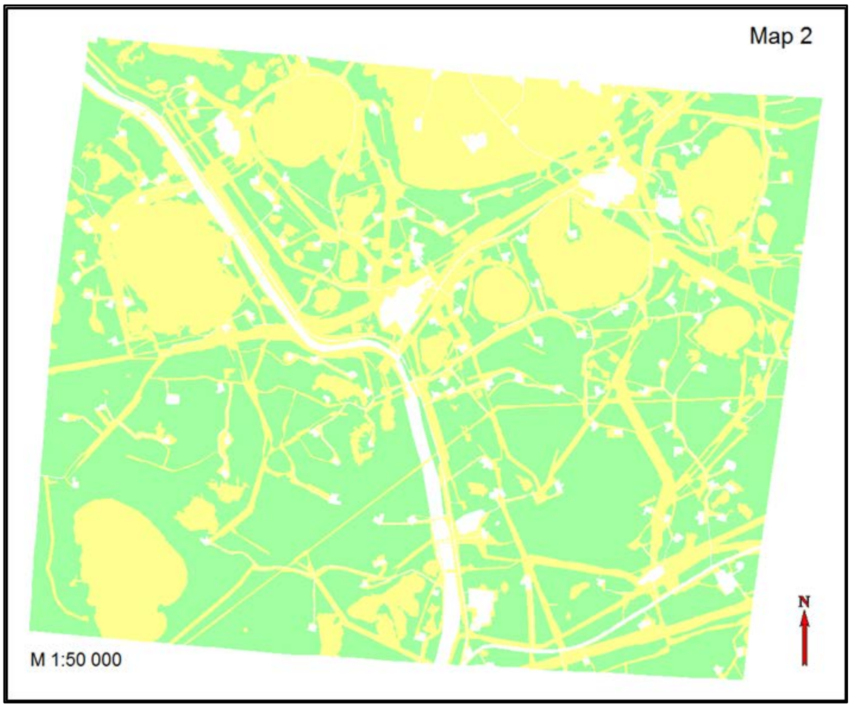
<table>
<tr><th colspan="5">Forest sub-compartment boundaries characteristics group</th><th>№</th><th>Vegetation cover</th></tr>
<tr><td rowspan="11">Forest lands/ha</td><td colspan="3" rowspan="2">with forest vegetation cover</td><td>Total</td><td>1</td><td>W</td></tr>
<tr><td>including sylvula</td><td>2</td><td>W</td></tr>
<tr><td rowspan="8">without forest vegetation cover</td><td colspan="3">open forest plantations</td><td>3</td><td>W</td></tr>
<tr><td colspan="3">forest nurseries and plantations</td><td>4</td><td>W</td></tr>
<tr><td colspan="3">Natural forest thinnings</td><td>5</td><td>W</td></tr>
<tr><td rowspan="5">reafforestation resource</td><td colspan="2">burned-out forests</td><td>6</td><td>W</td></tr>
<tr><td colspan="2">perished forest plants</td><td>7</td><td>W</td></tr>
<tr><td colspan="2">clearings</td><td>8</td><td>W</td></tr>
<tr><td colspan="2">glades, barrens</td><td>9</td><td>W</td></tr>
<tr><td colspan="2">total</td><td>10</td><td>W</td></tr>
<tr><td colspan="4">forest lands, total,</td><td>11</td><td>W</td></tr>
<tr><td rowspan="12">Non-forest lands/ha</td><td colspan="4">arable lands</td><td>12</td><td>W</td></tr>
<tr><td colspan="4">hayfields</td><td>13</td><td>W</td></tr>
<tr><td colspan="4">pastures</td><td>14</td><td>W</td></tr>
<tr><td colspan="4">water</td><td>15</td><td>O</td></tr>
<tr><td colspan="4">gardens, mulberry groves, berry fields</td><td>16</td><td>W</td></tr>
<tr><td colspan="4">roads, glades</td><td>17</td><td>O</td></tr>
<tr><td colspan="4">farmsteads and other</td><td>18</td><td>O</td></tr>
<tr><td colspan="4">swamps</td><td>19</td><td>W</td></tr>
<tr><td colspan="4">sand</td><td>20</td><td>O</td></tr>
<tr><td colspan="4">glaciers</td><td>21</td><td>O</td></tr>
<tr><td colspan="4">other lands</td><td>22</td><td>O</td></tr>
<tr><td colspan="4">non-forest lands, total</td><td>23</td><td>O</td></tr>
</table>

W	- with vegetation cover
O	- without (or with scarce) vegetation cover

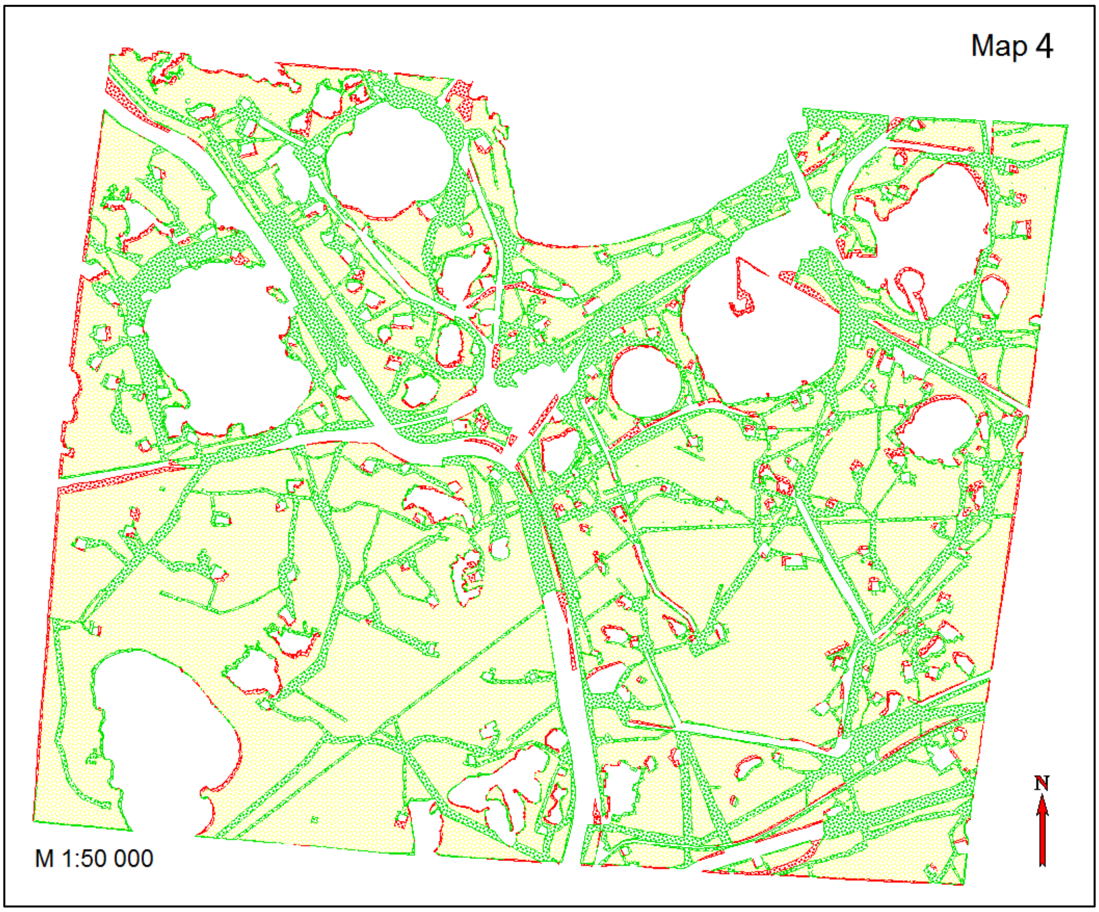
Table 2. Determination of nonnormalized rate of vegetation cover changes in the testing site near Lake Samotlor (Khanty-Mansi Autonomous Area, R.F.)

Forest management/years	Area, m^2	Rate, km^2/a year
2000	44,5284	-
2008	41,9249	-
8	2,6035	- 0,33






Map 3
2000 year
2008 year
M 1:50 000
N



CONCLUSIONS

The main purpose of the map is to show spatial location of the objects. On the whole, the maps of vegetation spatio-temporal changes based on GIS layers of forest management materials (inventories) show spatial location of the vegetation and temporal tendencies of vegetation changes. The disadvantages of this kind of mapping include, for one thing, a considerable error (inaccuracy) of forest sub-compartment boundaries determination (at the stage of lands remote monitoring data interpretation by different operators (afforestation inspectors) in different years); for another, the necessity of taking into account not only actual state of vegetation, but also limitations of the conferred right of use of forest estate plots. Taking into account relatively short period of comparison (8 years) we can guess that vegetation cover area is in fact increased by the mentioned inaccuracy (4,1% of total area).

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BELLIGERENT LANDSCAPE CHANGE ANALYSIS USING REMOTE MAPPING OF VEGETATION COVER

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KEYWORDS: belligerent landscape, Donbass, remote mapping, vegetation cover, satellite imagery

ABSTRACT
Analysis of indirect belligerent landscape changes using multitemporal high resolution satellite imagery is performed over the vicinity of the Popasna town, Ligansk region of Ukraine. Intensive forest cutting is detected, presumably due to proxy influence of warfare. The primary tool for landscape changes detection is the remote mapping of vegetation cover over study area.

1 INTRODUCTION

There is a growing interest in how geospatial processes and patterns affect ecosystems within zones of warfare impact. Many other questions about the interaction of features in landscapes and the effects of the warfare impact on the processes in ecosystems are best answered with satellite images and remote mapping.
Methods for vegetation change assessment using remotely sensed data allow for fast and spatial overview, quantitative vegetation assessment, land degradation mapping, etc. Evaluation of the static attributes of land cover on satellite image data may allow the types of change to be regionalized and the approximate sources of change to be identified.
Moreover, multispectral bands can provide increased spectral resolution that can be used to further analyze and classify environmental conditions, land cover and change detection, and how belligerent actions and associated transportation development impact these conditions. Landscapes of Donbass region (Ukraine) are under warfare impact now.

2 BACKGROUND

The Donbass landscapes are unique because of their nature diversity and contrasts. Here one can meet different types of the steppe landscape complexes: from cretaceous cleavage over the large river terraces to pure almost untouched ravine forests (Fig. 1). And what is more unique – all that is possible to meet within relatively small areas. In spite of the common stereotype there are more “wild nature” corners here than in the other Ukrainian regions.

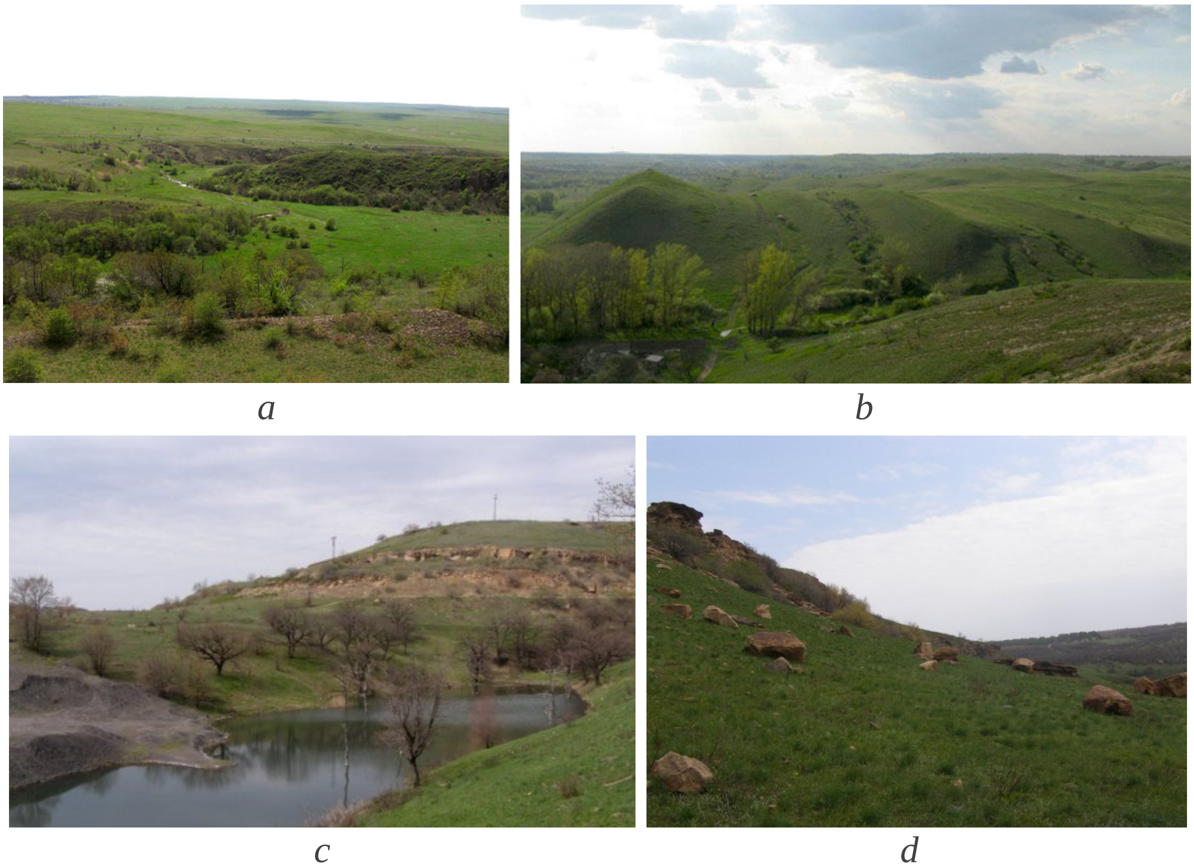


Figure 1: Unique Donbass landscapes in the vicinity of the Popasna town (http://www.ostrovok.lg.ua):
a, *b* – Donetsk mountain range; *c*, *d* – stony remnants

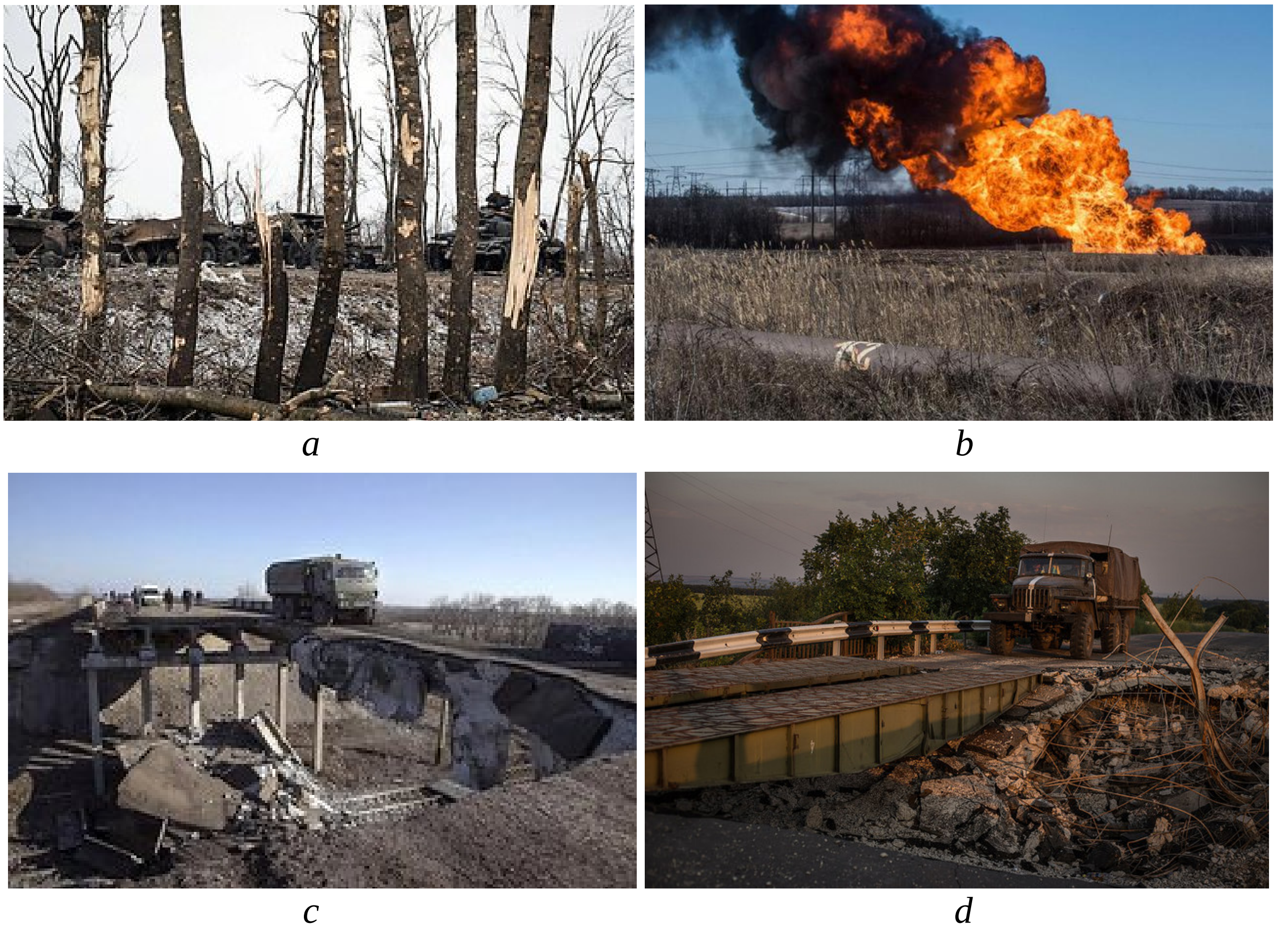
In the Soviet times the landscapes of Donbass were severely overused. The increasingly tensions rising between society's need for resources and space on the one hand, and the capacity of the land to support these needs on the other hand resulted in unprecedented changes in landscape configuration and hence in the environment. The high yield of crops and high rate of coal production had been achieved by any means available at those times leading to the demolishment of natural steppe landscapes. After the deforestation of natural oak-alder woods the territories were used for agricultural activities and later were replaced by homogeneous forests. The existing landscapes – pastures, hayfields and urban terrains – represent heavily transformed ecosystems that are under continuous anthropogenic-load. As a result, the majority of fauna and flora steppe species had disappeared and ruderals appeared instead.

The virgin landscapes can be only found on the gullies, ravines and steppe reserves because these territories are not suitable for farming. Nonetheless, these slopes are being used for grazing which leads to degradation and wind and water erosion. The adjacent steppes are used for agriculture, vegetable and livestock farming and viticulture. The lack of water resources in the area resulted in intensive irrigation practices. The main environmental spatial effect has always been associated with degradation of arable lands because of water and wind erosion and due to high mineralization (salinization) caused by intensive irrigation.

The steppe territory is highly degraded in terms of the depth of transformation and the level of anthropogenic transformation is considered to be *highly significant*. All-in-all the landscapes are threatened by fragmentation of habitats, agricultural pressure and infrastructure development and subjected to the conflicting interests of environmental preservation and agricultural and forestry activities (Dudar, 2014).

3 STUDY AREA

Under belligerent landscapes we consider those formed owing to warfare impact. Belligerent complexes create specific group of anthropogenic landscapes. Their spatial location does not depend on natural conditions but on belligerent actions (Denysyk and Timets, 2010). There are directly and indirectly belligerent landscapes. Directly belligerent complexes are those created directly as a result of the war factor. These are road-belligerent complexes, defensive earthworks, belligerent badlands, destroyed irrigation complexes, belligerent calderas, ruined constructions, etc. (Fig. 2).



a *b*

c *d*

Figure 2: Belligerent landscapes of the Donbass region, February 2014 (http://www.wordpress.com)

All complexes formed in the vicinity of the warfare area are referred to indirectly belligerent landscapes. Indirect impacts are often longer-lasting than direct ones. In our case we can observe both but consider at a spatial level indirectly belligerent landscapes around and south-east the Popasna town of the Lugansk region (around 13.6 km west-east and 8.7 km north-south).

The region is located in the northern steppe landscape zone described above and characterized with uniqueness and diversity of landscape complexes on the one hand and with high level of anthropogenic impact on the other hand. The soil cover is mottled and heterogeneous and stony on the slopes. The topsoil layer is predominantly presented with ordinary chernozem of average humus content and fragmented vegetation of motley-feather grass content and ravine forests. At a relatively small area we can observe diverse complexes from large areas of crops and arable lands, and vineyards to cretaceous cleavage over the river terraces and remnants of ravine forests (Fig. 3).

4 DATA AND METHODS

As an input data, the satellite imagery of different time periods were used – high (submeter) spatial resolution QuickBird-2 (2010, Fig. 3*a*) and Worldview-2 (2014, Fig. 3*b*) of the Popasna town, Luhansk Region. The imagery was chosen from the times when vegetation was at its maximum.

a

b

Figure 3: Color-synthetic satellite images of study area:
a – QuickBird-2 (2010), *b* – WorldView-2 (2014)

The images were calibrated and converted into the land surface reflectance (Stankevich, Vasko and Gubkina, 2011). According to in-situ observations, the reference points with peculiar landscapes were chosen. Based on the latter, scene classification was performed (Stankevich, Levashenko and Zaitseva, 2014). The results of the classification are shown on the Fig. 4.

a

b

Figure 4: Land covers classifications of study area:
a – by QuickBird-2 (2010), *b* – by WorldView-2 (2014)

The list of the main land cover classes is given in Table 1.

Table 1. Land covers classes of study area

Code	Class [Color]	Percentage (2010)	Percentage (2014)
	Forest [Fern Green]	15.51	19.92
	Crops [Tea Green]	35.78	46.55
	Arable [Apricot]	21.11	15.38
	Barren [Pale Pink]	26.95	17.35
	Water [Air Blue]	0.65	0.80

The use of imageries of different dimensions enabled to detect the changes in indirect belligerent landscape near the Popasna town, covering the period from 2010 (peaceful times) to 2014 (active warfare time). The results of change detection are shown on the Fig. 5.

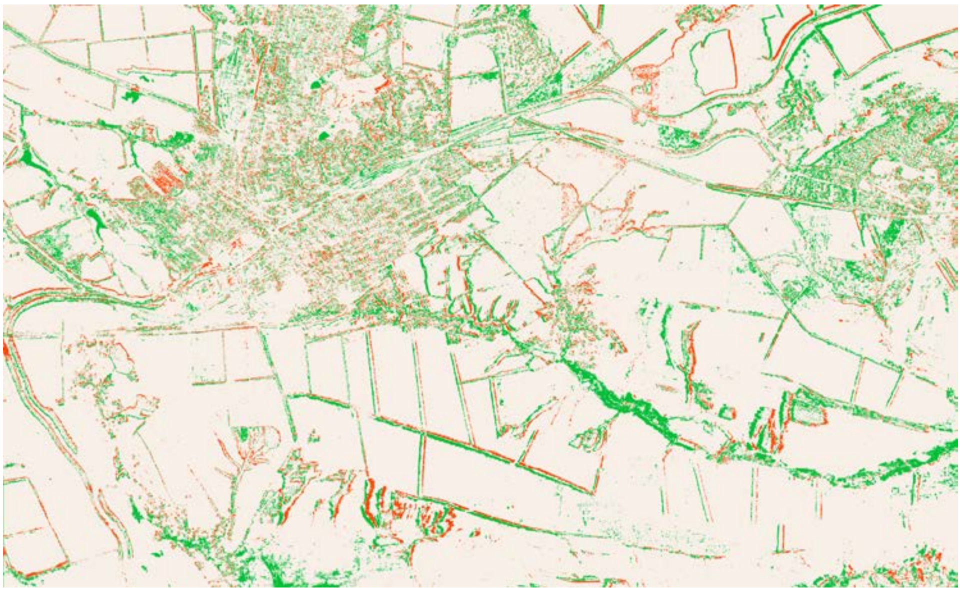


Figure 5: Land cover classes change (from 2010 till 2014)

The forest vegetation communities were mapped. The statistics of detected changes can be found in Table 2.

5 RESULTS AND DISCUSSION

The orange color signified disturbance with forest cover is made up of 4,77% which is quite high value for a relatively small area (Fig. 5). The forest cutting abruptly intensified after the warfare operations had started (in order to provide wood for building shelters and creating cooking fires, etc.) is a significant contributor to this factor. It is notable in the northern part of the town where wood clearance is observed around the large park pond. In the north-west part of the town the broken forest is reflected with dense orange spot. Deforestation and a high level of eutrophication are fixed in the vicinity of the Annenskiy pond (around 3 km north-west of the town). Alarm orange repeats the contours of the wooden massive south-east of the town, the railway and highways all over (right-of-way clearing), and also the vineyards south-west of the town. So, on the hand the wood clearance provoked vegetation change rate. And on the other hand, we can suggest deforestation as a result of natural processes within the ravine forests on the south behind the arable lands and also down the river Lugan valley.

Table 2. Forest change classes of study area

Code	Class [Color]	Percentage
	Rehabilitation [Pastel Green]	19.92
	Indifferent [Sea Shell]	46.55
	Deforestation [Alarm Orange]	0.80

6 CONCLUSIONS

Belligerent landscapes created due to warfare operations on the east of Ukraine are considered in this paper. The high resolution satellite imagery sets of the Popasna town, Luhansk Region were used to estimate the landscape changes during four year time period. Satellite imagery enabled to detect the changes in indirect belligerative landscapes, covering the period from 2010 (peaceful times) till 2014 (active warfare time). On the one hand, one can notice a direct correlation between woods clearance (intensified because of the warfare) and the forest change rate. On the other hand, long-term vegetation cover change is also observed within the remnants of virgin landscapes presumably as a result of natural processes.
The existing methods of warfare caused far greater devastation on the ecosystems which is yet to be investigated and overcome for many years after the war finishes. Remote methods introducing new dimensions into the study and understanding of long-term ecosystem processes will be of high priority then.

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AUTOMATED THEMATIC CONTOURS BORDER REGISTRATION AS AN EXAMPLE OF DIGITAL SOIL MAP FOR NOVOSIBIRSK REGION AND CREATION OF ANALYTICAL INFORMATION RETRIEVAL SYSTEM FOR THE DEVELOPEMENT OF AGRO-INDUSTRIAL CLUSTERS IN SIBERIA

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Commission IV, WG IV-2

KEYWORDS: soil contour, digital soil map, automated border registration, Novosibirsk Region, GIS, information system, agro-industrial cluster, Siberia.

ABSTRACT

Some questions of research programs in soil science and agrochemistry on the modern stage of developing for information resources and means of analysis are discussed. Automatic way of border registration for thematic contours as an example of digital map of soils in Novosibirsk Region was introduced as a new instrument for catching and analyzing information in GIS, with the next export of gridding data in information retrieval system. Circus method is recommended here to fix researching targets as territories of the same form and fixed size. It is necessary to provide unified approaches to analyse soil spectra and calculate percentages of soil units in structure of soils cover, according to the program of fundamental scientific researches of Russian Academy of Sciences in 2015–2017 years.

INTRODUCTION

Development of agro-industrial clusters in the southern part of Western Siberia in coming years will depend on prompt and effective management of relevant information on the current state of agricultural lands. Relevant data collection concerning the state of Siberian soils was done twice in the recent past: during the activity of Resettlement Department of Russian Empire and during the development of virgin and fallow lands of the USSR (Giprozem service). In the last thirty years Western Siberia soils study mostly had fragmented character and had been performing within the separate researches in Institute of Soil Science and Agrochemistry, Siberian Branch of the Russian Academy of Sciences (ISSA SB RAS), Tomsk State University, and several other scientific and educational institutions, in the absence of national program for soil monitoring in Russian Federation. Cumulative information on the current state of Novosibirsk Region soils was summarized in the map «The soils of Novosibirsk Region» (2007) as well as in the atlas "Natural zonation and recent state of soils in Novosibirsk Region" (2010).

Because of specificity of the information provided by these sources, they can't be directly included in analytical information retrieval systems and taken into account under elaboration of scenarios for economic development of Siberian Federal District. It was necessary to make maps digital, to create additional tools for targeted queries, parametric calculations, etc.

HISTORY

The present research was begun in 2006 on the basis of previously created cartographic materials, and currently its aim is to identify and describe regional regularities of soils distribution with specific agricultural characteristics caused by temperature gradients and hydrological regime features, i.e. by soil-physical processes. The creation of a high-precision digital temperature models (Shergunova et al., 2014), according to the data of 46 meteorological stations in the southern part of West-Siberian Plain for more than 30 years, implemented by software ArcGIS made possible to ascertain the detailed correlation of soils distribution with an average annual temperature of the surface air layer and relief. Just a few years ago such opportunities for solving research issues in the field of soil science and agrochemistry were unavailable. Recently published «National atlas of soils in Russian Federation» (2011) and «Unified state register of soil resources in Russia» (2014) have become an important additional information support.

The research work was started in 2010 by ISSA SB RAS with the aim to create database «Soils in Siberia»; at the modern stage of IT development it can be significantly modified and extended by geographic information (Baykov et al., 2014), taking into account the new possibilities of computer design. Digital soil maps and soil contours, creation of temperature and moisture gradient models in the study area of southern part of Western Siberia allow to detail and quantify the most of local features in soils distribution, previously unknown or defined only in general. This is fundamentally new tool capabilities in the development of soil databases and analytical information systems, as applied to the needs in agricultural sector of business, actively developing in Western Siberia.

TECHNOLOGY

Technologies and standards in the information system “Soil-geographical database of Russia” (Golozubov et al., 2015) should be the subject for careful study and for the subsequent conversion of information fields in Siberian geographical module of the soil data. This should be done during interactive operation, soil scientists can make an important contribution here by finding technological solutions in their research, such as SITES standard (Jacquier et al., 2012).

The need to create compatible formats of regional soil data banks and information retrieval systems with those of the global level, including World Reference Base

(WRB) and FAO database, makes developing of unified approaches to global soil classification especially urgent (Ivanov, 2012).

Cartographic method is widely used in soil science as a way to represent soils distribution and its combinations and complexes as objectively existing, commonly manifested stable structures (Friedland, 1980; Friedland, 1984).

Soil maps are also the basis for agro-industrial evaluation of soil fertility and for development of specific measures for raising the level of their productivity, long-term conservation and more effective usage (Khmelev, Tanasienko, 2009; Khmelev, Tanasienko, 2013).

We propose to get soil geographic information data by circus method, choosing research targets of fixed shape and size (Baykov et al., 2014). This is necessary to ensure the unified approach to the analysis of soil spectra composition and percentage of soil variants in spectrum. This approach allows taking into account temperature and precipitation variation, as there is a strong binding to the cardinal points. Recorder step (radially oriented sensor) can be different: to calculate the percentage of soil variants in forest-steppe zone of Western Siberia it is assumed to be 45 degrees.

To automate the capture of thematic data about soil variants composition and their percentage in soil cover of key (model) territories, original technology of geo-information analysis based on digital soil maps and geo-processing methods was developed, which has no analogues in the world practice. To perform automated capturing of such data and the subsequent generation of thematic tables with the structure of the soil cover the following requirements to the original digital map should be met:

1) Correct spatial binding of soil contours;
2) Full semantic description of all soil variants and its combinations;
3) Topological correctness of soil contours.

Screenshot of digital soil map for Novosibirsk Region is shown in Fig. 1. Yellow targets show circus borders and their centres, located in longitudinal and latitudinal directions.

The algorithm for calculating the composition of soil spectrum of circus and total share of each soil variant consists of the following steps: 1) the selection of model area – research target (in our experiment it is a circus of 20 km in diameter) – by fixing the centre and borders; 2) the determination of number of recorders for thematic contours borders (in our experiment we have eight: zeroth one is directed along the radius from the centre of circus to the north; the other seven are shifted to 45 degrees clockwise each; any other values of the angle rotation of recorder are possible); 3) the construction of buffer zones – bands, where recorders cross with thematic contours of digital soil map along the each radius (Fig. 2); 4) the finding of resulting buffer zones intersections with soil contours, the calculation of parameters of resulting fragments: square and distance from the middle of fragment to the centre point of circus; 5) the sorting of resulting fragments data according to the direction of the recorder and the distance between the centre of circus and the middle of fragment; 6) the calculation of the total share of soil variant along all recorders.

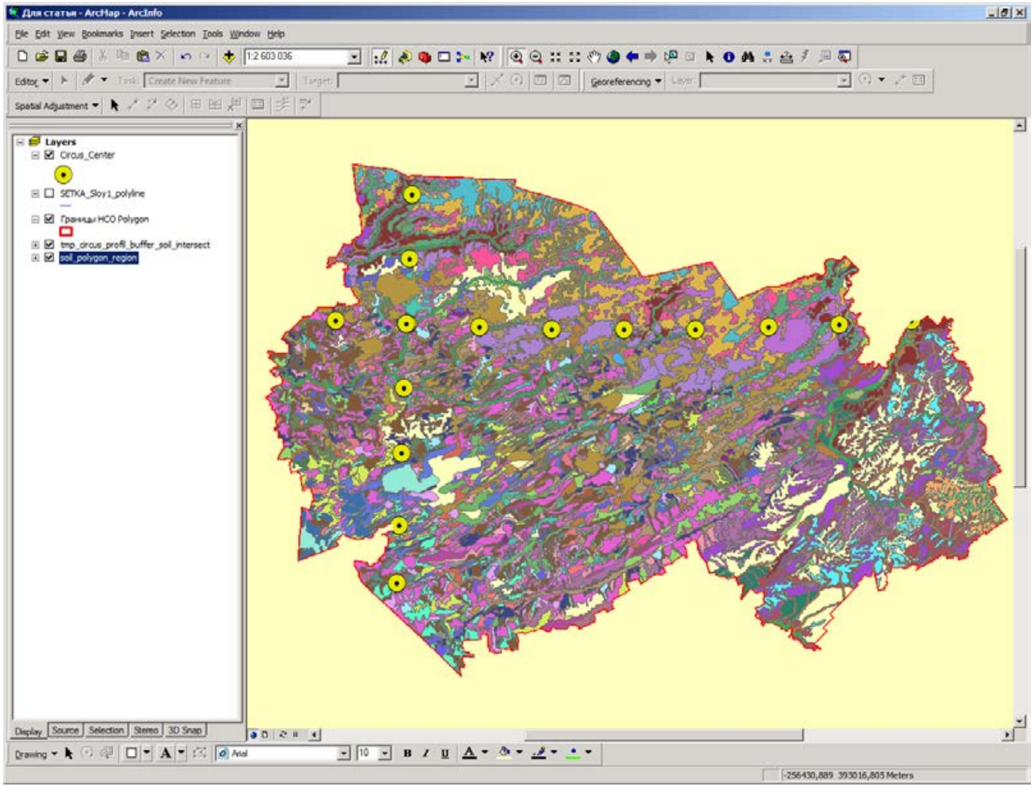

Figure 1: Screenshot of digital soil map for Novosibirsk Region

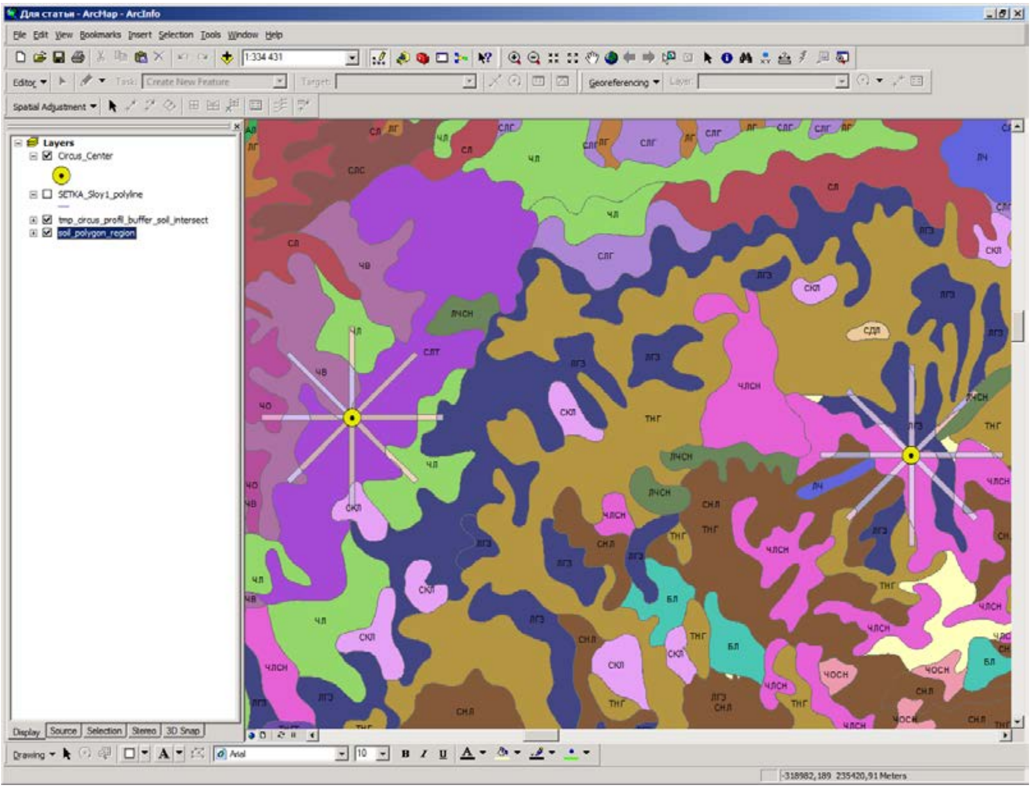

Figure 2: Digital soil map fragment with profiles-recorders

Then summary table is generated for calculated data for every research target, with export function of thematic data in analytical information retrieval system. To automate the calculation of soil spectra, specialized tool for data handling was developed, using built-in ArcGIS tools. Technology process model was created using the interface ModelBuilder, its visualization is shown in Fig. 3. The basis for this model is standard ArcGIS tools; however, a number of key algorithms were implemented using the script language Python.

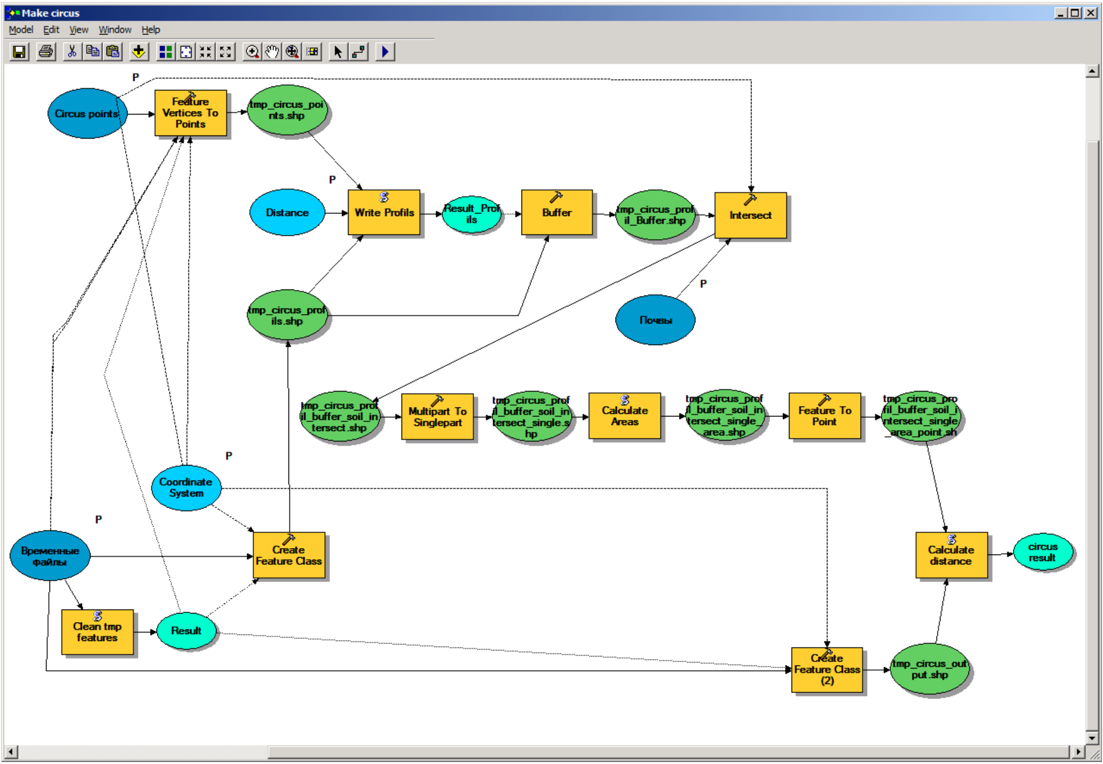

Figure 3: Visualized scheme of automated soils contours border registration and formation of soil spectrum of model area

In ModelBuilder service functional groups of elements are usually denoted by different symbols. Thus, dark blue ovals indicate the elements of input data of the project. In our case it is the initial data of soil contours, coordinates of circus centers and their parameters. Yellow rectangles show operations performed with the usage of input data, for example, the construction of buffer zone, the search of buffer intersection with soil contours, etc. Green ovals show elements of derivative data (intermediate values of operations within the process). Light blue ovals have references to non-geographic data, such as circus diameter.

The accuracy of proposed method will depend on both geographic basis and thematic content. Geographic basis corresponds to the accuracy of common geographic map of scale 1: 1000 000, that in this scale is equal to 400 meters for clear contours (roads, area borders) and 800 meters for fuzzy contours (for example, hydrographical objects). Thematic content of the soil contours is created by the prevailing soil variant, its correspondence with the real soil combination of soil variants will depend on the topography, hydrological regime, and other factors determining the number of contiguous soil variants generalized in the contour.

FUTURE CHALENGES

To predict the soils behavior as a result of changes in their agricultural usage, it is necessary to create special training sample having a regional binding. To develop a network of agro-industrial clusters, there is a need to combine information on the main consumers of agricultural products, transport routes, and soil fertility. Analytical information retrieval system for soils of the southern part of Western Siberia should become an important tool for optimizing of agribusiness network in Siberia.

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A3 EDGE MAPS VAST RUSSIAN AREAS

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Commission IV, WG IV-2

KEYWORDS
A3 Edge, LightSpeed, AT, mapping, orthophoto, vertical image, oblique image, aerial camera

ABSTRACT
This paper summarizes the characteristics, features, and unique capture technology of the A3 Edge Digital Mapping System. The paper analyzes two large-scale mapping projects – urban and forestry - executed in Russia using the A3 Edge System, and summarizes the performance of the system in each case.

1. Introduction

A3 Edge [2,3], VisionMap’s newest digital mapping system, has gained attention for the high productivity, resolution, and accuracy it provides. The camera is based on a unique technology of two “sweeping” telescopes. The telescopes capture single frames while sweeping perpendicular to the flight direction. By doing so, they generate a wide field of view.

Coupled with the A3 LightSpeed automatic processing suite, A3 Edge provides a complete end-to-end mapping solution. A3 LightSpeed automatically performs aerial triangulation and produces orthophotos, stereo pairs and DSM from A3 camera images. As VisionMap customers take on larger and larger projects, A3 LightSpeed has to deal with an incredibly large amount of imagery. It does so successfully, with the complete A3 Digital Mapping System meeting all industry standards.

Mathias Lemmens [1] highlighted the system’s unique capture and processing methods in his 2014 article “Digital Oblique Aerial Cameras” published in GIM International. Lemmens describes A3 Edge’s high productivity and efficiency compared to other large format systems on the market.

2. The challenge

Baltaeroservice, a Russian aerial survey and mapping company, specializes in aerial survey and mapping of linear infrastructure objects and large forest areas for the Russian Forest Agency. Over the years, the company has used various aerial survey and mapping technologies. They own Cessna P210 aircraft and have access to other aerial survey planes in the area.

With an increase in demand for constantly updated mapping products, for higher resolution, for vertical and oblique images of urban areas, and for regular mapping of very large areas of Russia, the company decided to purchase the A3 Edge Digital Mapping System, due to its meeting all of these requirements in a single system.

In 2014 the company used A3 Edge for two projects – mapping of very large forest areas and mapping of St. Petersburg.

The forest mapping project was commissioned by the Russian Forest Agency to cover large forest areas by aerial survey and produce color (RGB) and color infrared (CIR) orthophoto.

The urban project presented several challenges: minimal flight altitude restrictions, the need to use vertical and oblique images for orthophoto and 3D City model creation, and year-round scarcity of good flying weather in this part of the world. This project required a system that would be able to fly at high altitudes while meeting large scale mapping resolution and accuracy requirements, and being able to capture the area quickly and efficiently.

3. Aerial survey of vast forest

Russia contains over 8 million square kilometers of forest. The inventory of the forest area and forestry taxation is taken place every year. Typically, the inventory is taken by use of satellite images, and the taxation – by ground survey. A3 Edge technology, due to its extremely high aerial survey and processing productivity, successfully competes with satellite technologies. The high ground resolution and image quality of its RGB and NIR images enables replacing a labor-intensive ground survey for taxation with a simple and highly efficient aerial survey.

Image 1. Forest area. CIR orthophoto and RGB image.

In this project, A3 Edge collected RGB and NIR images of a 33,490 km^2 area at 14 cm GSD. The aerial survey of these vast areas was completed in less than 48 hours.

Region (Oblast)	Area (km^2)	Distance from the base (km)	Aerial survey time (hour)	Total flight time (hour)
Novgorodskaya (two areas)	10,780	250/330	16.0	36.1
Pskovskaya 1	1,290	200	2.4	3.8
Leningradskaya	4,660	170	6.4	10.9
Karelia	8,750	550	11.9	25.7
Pskovskaya 2 (two areas)	1,110	340/320	2.1	5.8
Archangelskaya	6,900	530	8.9	20.6
Total	**33,490**		**47.7**	**102.9**

The flights were executed with the following aerial survey parameters:

- Flight altitude – 17,700 feet
- Ground speed – 150 knot
- Forward and side overlap – 55% - 70%
- Distance between flight lines – 3,000 m

4. Processing of the forest imagery

Automatic processing of the imagery consisted of two main photogrammetric processes – aerial triangulation (AT) and orthophoto creation. An existing DTM was used for the orthophoto creation. The orthophoto was produced as 4-band (RGB and NIR) orthophoto at 30 cm GSD. The A3 LightSpeed photogrammetric software was used for the automatic processing. The processing was completed in 52 days.

A3 LightSpeed software features several powerful capabilities. LightSpeed’s latest version supports up to 250,000 single images in a single block. The significance is that for GSD = 30 cm with a forward overlap of 55% and a side overlap of 60%, the area of the block can reach 55,000 sq. km. This efficiency enables the processing of very large areas as a single block, providing high homogeneous accuracy in the block and eliminating manual processes of connecting single blocks between them. Needless to mention is automatic tie point creation even in dense forest area and automatic creation of cut lines. Without these powerful features, the automatic photogrammetric workflow simply would not have been possible. Very high accuracy of the aerial triangulation has been ensured by multiple overlaps between images and by large amount of tie points. Such processes as automatic brightness, color and contrast adjustment, and haze removal provide the high visual quality of the final products.

The following table demonstrates processing productivity in each area of the project:

Regions (Oblast)	Area (km^2)	Processing time (day)
Novgorodskaya (two areas)	10,780	14
Pskovskaya 1	1,290	5
Leningradskaya	4,660	8
Karelia	8,750	12
Pskovskaya 2 (two areas)	1,110	5
Archangelskaya	6,900	8
Total	**33,490**	**52**

As a result of the project, the following final products were delivered to the Russian Forrest Agency:

- RGB and CIR Super Large Frames (SLF) which are used mainly for stereo taxation and stereo vectorization,
- RGB and CIR orthophoto of the entire forest areas for various purposes including forest inventory.

Image 2. Forest area. CIR orthophoto

5. Aerial survey of Saint Petersburg

Due to its long focal length, A3 Edge can be flown at high altitudes while providing very high ground resolution and aerial survey productivity. Furthermore, the camera's simultaneous collection of vertical and oblique imagery makes it ideal for 3D city modeling.

The purpose of the project was to provide an orthophoto of the entire city, and prepare vertical and oblique accurately oriented images for the visual investigation of the area and for further 3D City modeling. During the course of the project, RGB vertical and oblique images were captured of the city, spanning a total area of 2007 sq.km.

Image 3. Peter and Paul Fortress, Saint-Petersburg, A3 Edge vertical and oblique images.

The aerial survey flight was executed at an average altitude of 13,300 feet, providing a ground sample distance (GSD) of 10 cm. The ground speed of the aircraft was about 140 - 150 knots. The city was covered by means of crisscross flight lines, providing further capability for 3D City modeling. The flight was executed with the following aerial survey parameters:

- Forward overlap – 60%
- Side overlap – 80%
- Side oblique overlap – 30%

- Distance between flight lines – 1,500 m
- Maximal oblique angle – 55°

The aerial survey flight took 11 hours and the total flight time was 14 hours. During the flight, 450,000 vertical and oblique images were captured.

6. Processing of the St.-Petersburg imagery

The A3 LightSpeed photogrammetric software enables automatic processing of aerial triangulation (AT), DSM creation and orthophoto production. In this project, a previously created DTM was used for the orthophoto creation.
In the first stage, all images, vertical and oblique, were simultaneously adjusted in AT receiving very accurate orientation parameters. In the second stage, only the vertical images were used for the orthophoto creation.

The total processing, AT and orthophoto, was done automatically over 15 days. All of the mapping products met the accuracy requirements of a 1:2,000 mapping scale.

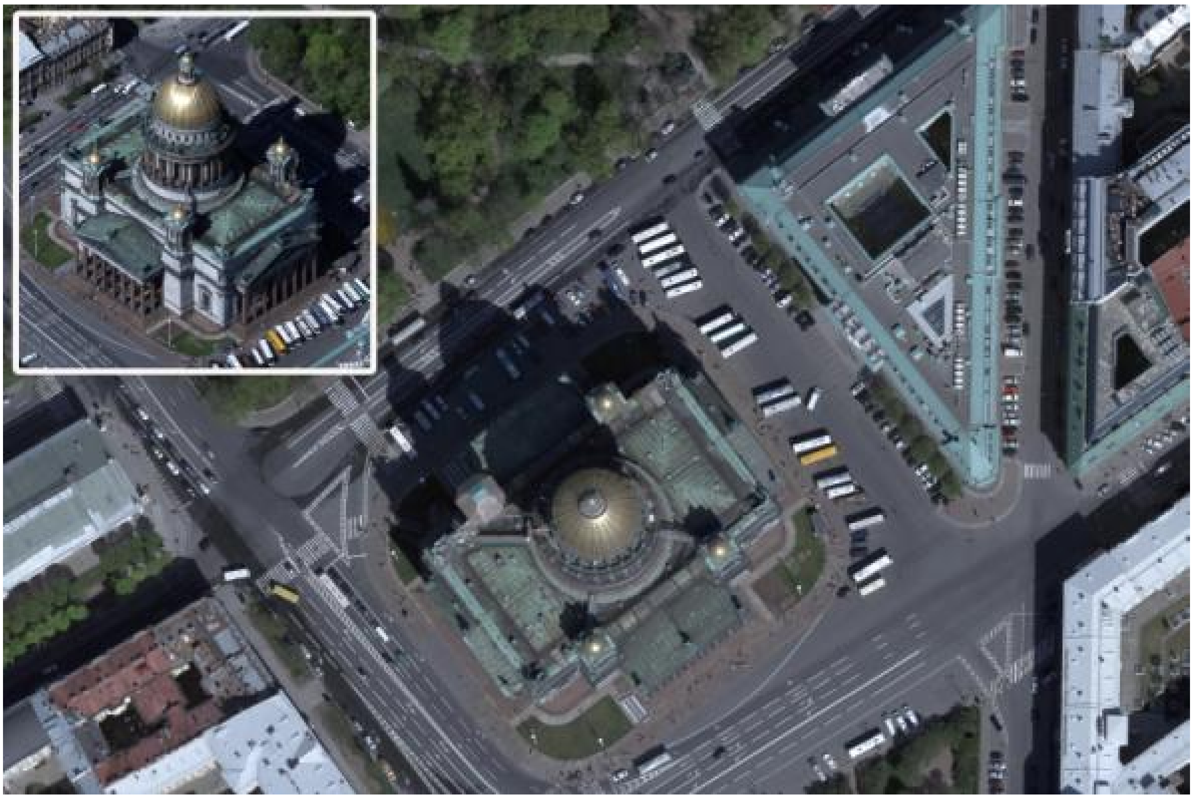

Image 4. Saint Isaac's Cathedral, Saint Petersburg, A3 Edge vertical and oblique images.

For comparison, in 2011 the same company was contracted to survey the exact same urban area. The camera used at the time was PhaseOne, and processing was performed by Talca 4.0 photogrammetric software. It took five operators six months

to do the job. This time, with A3 Edge, the entire project took only 15 days with one operator.
As a result of the aerial survey and processing, accurately oriented vertical and oblique RGB images, and orthophoto from the vertical images were obtained. All of the images will be used for the creation of a 3D model of St. Petersburg.

7. Conclusion

After selecting the A3 Edge Digital Mapping System for their recent projects, Baltaeroservis successfully completed the mapping of St. Petersburg as well as vast forest areas across Russia. The aerial survey of St. Petersburg took 11 hours, and automatic processing took 15 days, while the forest survey took less than 48 hours, and automatic processing was completed in 52 days. The mapping company was pleased with the system's high productivity, resolution and image quality. The final products met and even exceeded all of their client's requirements.

After completing these two projects, the mapping company noted that they were very pleased with the performance of the A3 Edge system, which has already performed a significant amount of work for them in the short time since they acquired the system.

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SUMMING UP THE ABILITIES OF MODERN AIRBORNE LIDARs FOR FOREST MAPPING

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KEY WORDS: laser scanning, forest mapping, inventorying

ABSTRACT

Currently, the primary data collection method for the study of forests is multispectral satellite survey. Digital aerial images are mainly used for forest inventory. However, now the widely used air laser scanning has not found the application for forest research. The main reasons: high cost, lack of methodology, low awareness of the method by researchers.

Progress in laser scanning field allowed greatly increase productivity of systems, among which are a number of devices that are comparable with aerial systems in capability. The cost of obtaining data in these systems can also be compared with space segment data.

The use of this survey type in common with aerial images allowed quickly and accurately obtains a number of vegetation characteristics which inaccessible to obtain with space images or classical aerial photography. For using these possibilities, it takes to develop of calculation methods for the new information. Such an experience is already available: in 2012-2013 was conducted research for "Roslesinforg" dedicated to exploring the possibilities of forest inventory by laser scanning data.

Taking into account the hardware equipment features and additional sensors are invited to intensify efforts to implement this method in practice of geographical forest research along with practical problems solution.

1. Current situation on the market of remote sensing data

At present the multispectral satellite imagery and digital aerial photography are the main sources of the data for forest mapping. Digital aerial photography is generally used for forest inventorying. But the airborne laser scanning using LIDARs (further we will use just the term "LIDAR") is not very widespread for this purposes in Russia. The main reasons of this were: the high price, the lack of methodology, proved on Russian types of landscapes, lack of the people who know something about LIDARs.

But is this method really expensive?

Let us compare the price of the new satellite imagery with 0.5 m pixel (or GSD – ground sample distance), made according to our own order, with the price of RGB digital aerial photography. We can see, that satellite imagery will cost us about 20 \$ per 1 km^2, and aerial survey with 0.1-0.2 m GSD (including operations of photo-triangulation and photogrammetric network adjustments) will cost us about 42-65 \$

per 1 km^2. The final price of aerial imagery varies from the actual place of surveying, while satellite imagery prices are independent. It is easy to see, that aerial photography is 2-3 times more expensive, but offers 2.5-5 times more detailed data.

From the end of 2014 it is also possible to purchase 0.3 m GSD satellite imagery, and in March 2015 the final price for this type of data in Russia is about 60 $ (prices for WorldView3 data). But the big demand for this type of data and the lack of satellites with comparable characteristics will not allow the common users to use this data very widely next 1-2 years, though 0.3 m GSD space imagery can be very concurrent with aerial imagery with the same GSD in terms of prices and operability.

In conclusion, it is obvious that any type of remote sensing data with GSD greater than 30 cm costs 42-60 $, and allows us to produce GIS data equal to 1:2000-1:5000 scale. This data is suitable for production digital elevation models with normally 0.3-0.6 elevation error (1 sigma) in open spaces and it is not suitable for production of any elevation model in forest regions.

2. Current satiation in airborne laser scanning: productivity, speed, and precision.

The progress in airborne laser scanning during last 15 years is impressive. In 2000 the swath width was about 300 meters and the average point distance (analog of GSD in imagery) from 1.5-3 m, in 2015 the swath width is up to 3000-5000 m while average point distance now is up to 0.2-0.4 m. (Schwarz, 2010; Medvedev, 2007).

For example, top level aerial system like Riegl Q1560 allows working from the altitude 2800 m, making 800 000 laser measurements per second. If we use the aerial vehicle with the cruise speed about 90 knots (like Antonov-2, or Mi8, or Cessna), than we can achieve the density of 4 points per 1 m^2, or average point distance about 0.5 m and average elevation error about 0.1-0.12 m. This is enough for 1:1000 scale mapping. This data allows us to produce DEM (digital elevation model) in open spaces, in forest, and to measure the relative altitude of the vegetation. With such conditions it is possible to survey about 450 km^2 per hour.

In case of use faster vehicle it is possible to achieve following volumes:

- Speed 140 knots, altitude 4000 meters, area per hour – about 1000 km^2, density – 2 points/m^2, average point distance – 0.7 m, suitable for 1:2000 mapping in any kind of terrain;
- Speed 200 knots, altitude 4000 meters, area per hour – about 1000 km^2, density – 0.7 points/m^2, average point distance – 1.2 m, suitable for 1:5000 mapping in any kind of terrain.

So far, in Russia the average cost of 1:1000-1:5000 LIDAR data acquisition (including flight costs and additional costs of any kinds) can be about 30-60 $ per km2, depending of time, region and level of detail.

In addition it must be figured, that during the laser scanning, the normal aerial imagery using mid-size cameras is collected (NIR or RGB modes are available).

From altitudes mentioned before the GSD of these images can vary from 0.25 to 0.35 m. Normally, the big-frame aerial cameras are not strictly needed to be used during the laser survey flight.

It is quite obvious, that efficiency of these systems is equal or greater than the efficiency of normal aerial imagery, because it allows us to collect real 3D data about relief and vegetation, without any problems with forests or grass, and the prices are equal or lower than prices of aerial or satellite imagery. The precision of the data (and elevation errors) are also several times better.

3. **What for the LIDAR data can be used**

LIDAR data with the density of 4 points/m^2 (suitable for 1:1000) allow us to detect directly in 3D (using information about the form of the canopy without spectral information) the type of the tree and its height over the relief. Data with density of 2 points per m^2 (is suitable for 1:2000) are also enough for forest inventory and monitoring of the vegetation (Kumar, 2014). Data, equal to 1:5000 (0.5-1.0 points/m^2) is suitable for proving the results of forest growth models (Pinto, 2014; Blashke, 2004).

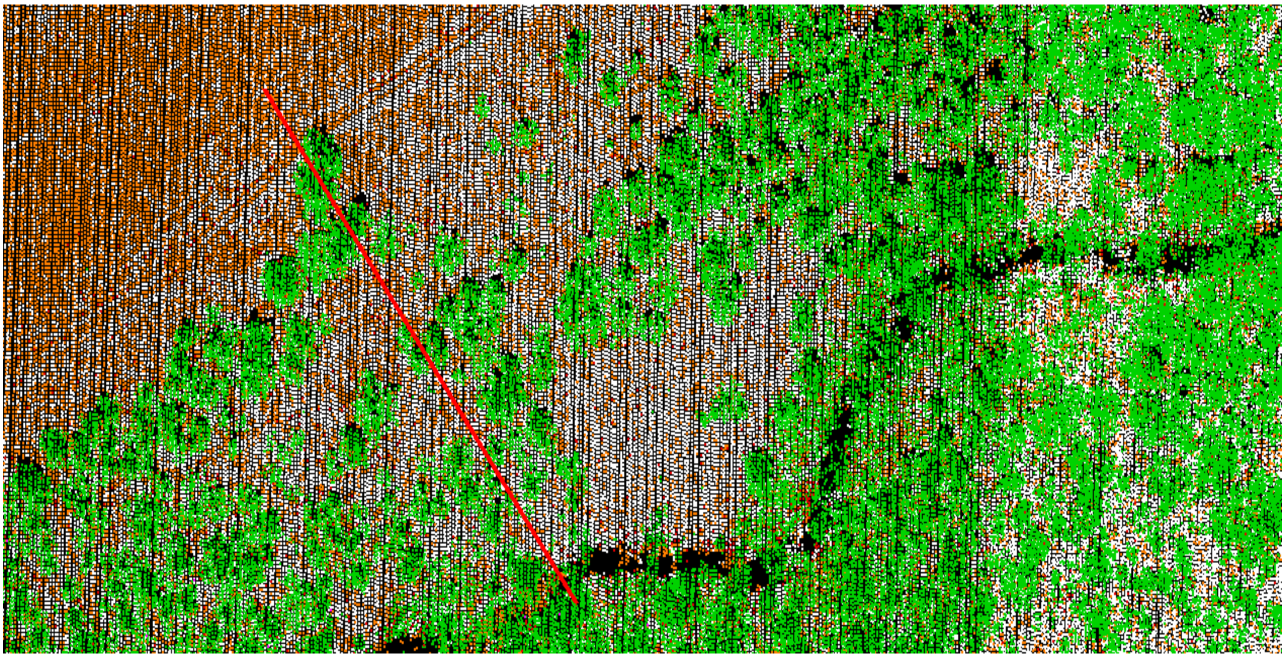

Figure 1. Example of airborne LIDAR data, density is about 4 points/m^2.
Red line is the axis of profile (see Fig. 2, below)

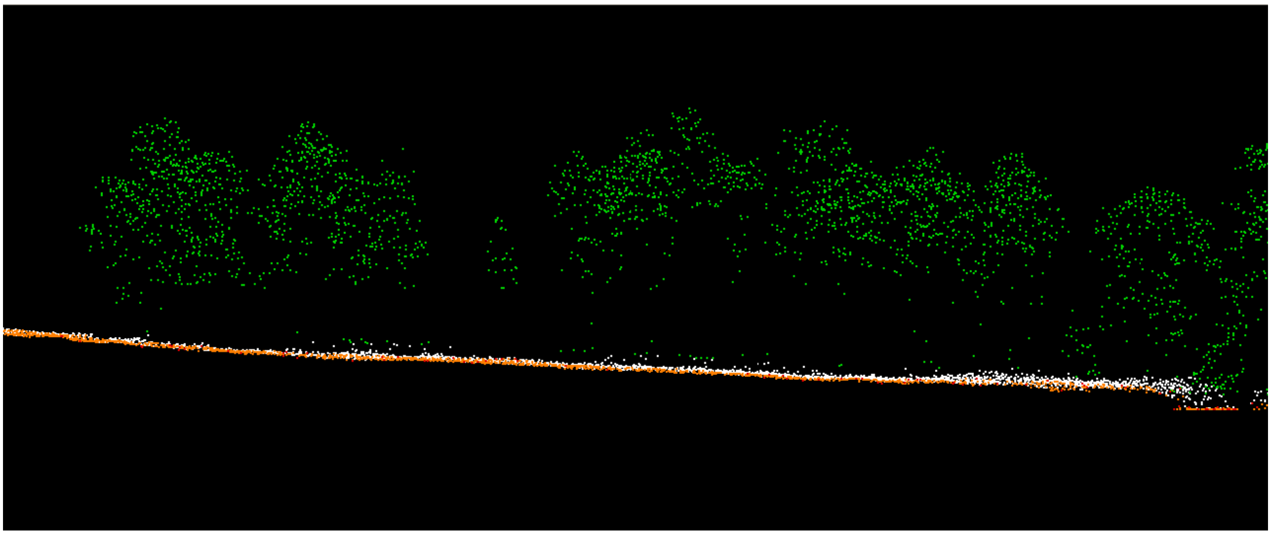

Figure 2. Profile along the red line through the LIDAR data.
Green points – the upper parts of canopies, yellow and white – the surface of the relief – even under the canopies.

In modern remote sensing there are no any other methods except airborne laser scanning, that allow us to detect in 3D the visible surface of canopies and mostly invisible surface of the relief simultaneously (Lang, Tiede, 2006). It is obvious, that optical sensors are suitable only for detection of objects, which are open to see. The radars, using longer wavelength, can give us the information of the relief under the trees, but the trees become transparent. Also the radars of these wavelengths do not provide very precise 3D data (up to several meters of elevation error). As compared with mentioned above, the airborne LIDAR provide 3D data of both surfaces simultaneously, and the precision of the data is much better - about 10 cm.

These features allow us to use this method for achieving the geometric parameters of EACH tree of the main story of the forest (Tiede, 2006). The most important parameters are the diameter and relative height of the canopy; this information, aggregated together with the information about the type of vegetation and local factors of growth, allow us to solve definite tasks. There can be building the model of growth for the whole region, searching for intra-zonal landscapes or specific conditions of vegetation, search of extra old or extra high trees, ecological research and so on. Also very important task of calculation of the actual lumber volume can be successfully solved. This approach is widespread in Scandinavian countries, well known by their careful attitude to the environment (Holmgren, 2004).

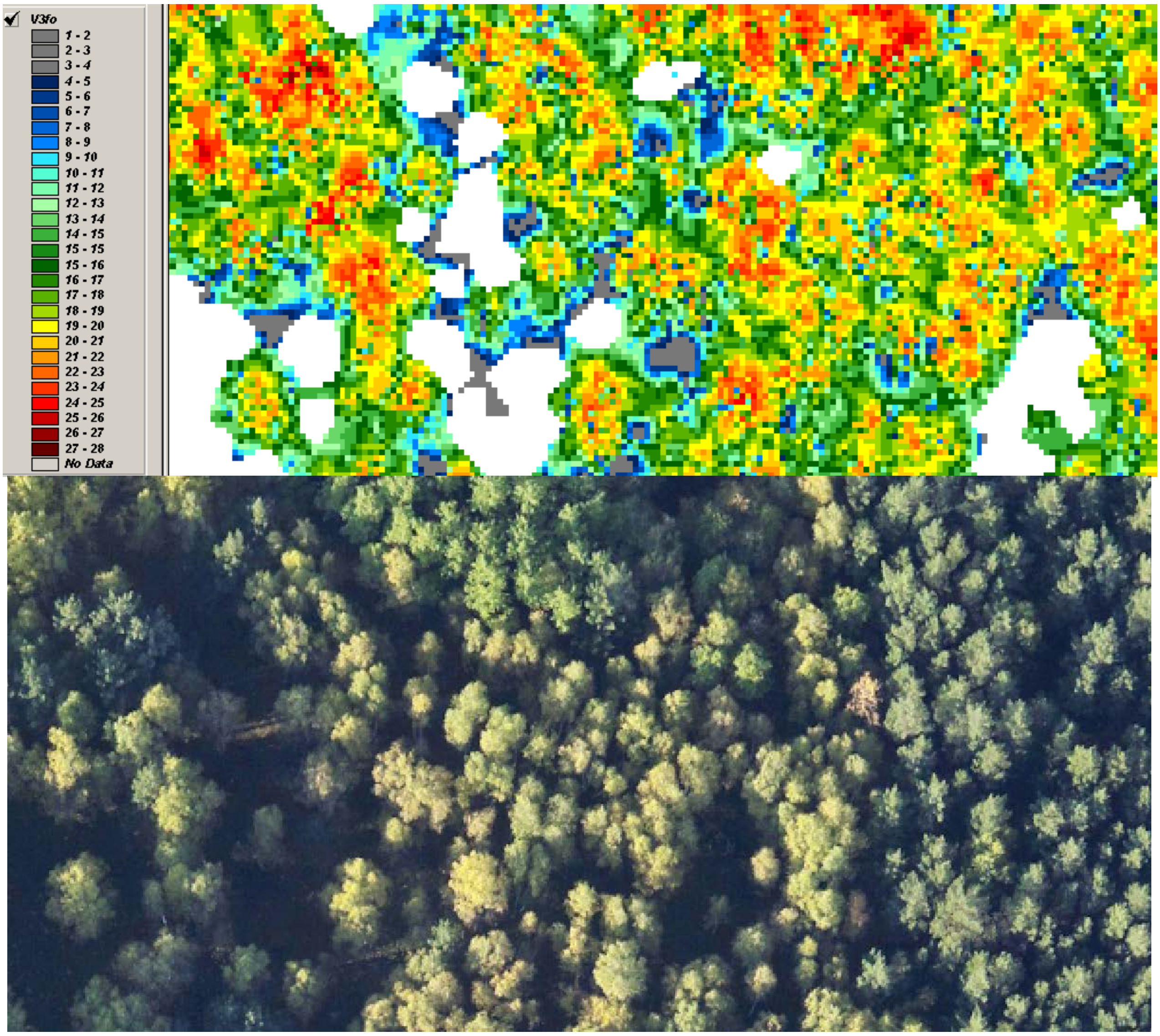

Figure 3. Digital elevation model of relative heights of canopies (upper picture) and common digital imagery (below).

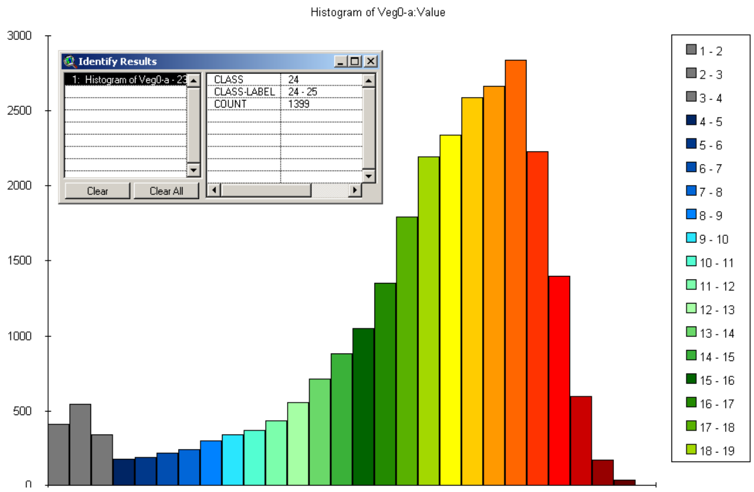

Figure 4. Histogram of distribution of the single trees according to their heights within previously mapped contour of the forest, defined by the experts as “homogenious”. Done using 4 point/m^2 airborne laser scanning.

But the most interesting scientific results can be achieved using the airborne LIDAR simultaneously with the multiband high-resolution space imagery. The most valuable spectral range is between 630 and 2300 nanometer wavelength. (Burnett, 2003; TIEDE, 2004). Here are several examples:

1. For precise datasets and detailed research and mapping: (1:5000-1:25000) – 0.5 m GSD data from WorldView2 with 8 spectral channels (including 3 infrared channels); or 0.3 m GSD data from WorldView3 with 10 spectral channels (including 8 infrared channels)
2. For big territories and mid-scale mapping (1:50 000-1:100 000) – 15m GSD Landsat 8 (4 infrared channels), or 30 m Hyperion (220 channels).

Figure 5. Example of usage WorldView2 infrared data for correction of zonal borders during forest inventorying according to the type of forest. This data is to be used later (together with the airborne LIDAR data) to renew statistics.

Multispectral satellite imagery, used together with the LIDAR, can be very important for depicting the slight, but sometimes critical changes in the forest structure (detection of pathological sickness). But the direct application of high resolution multispectral data (and its spectral analysis) needs to solve several problems. These problems can be solved easily using the airborne LIDAR data:

- Texture and shadow analysis using 3D LIDAR data (Tiede, 2004);
- Correct topographic normalization of spectral data (to eliminate the influence of the relief over the spectral data) including the micro-relief of the visible surface of the forest;
- Collection of 3D characteristics of trees and other objects using LIDAR data for supervised classification of satellite data (Wehr, 2003);
- Application of extremely detailed and precise DEM or DTM and relative vegetation height information in automated mapping systems and/or knowledge bases, based upon Euclidian or Neural logics (Tiede, 2005; Dorren, 2004)

3D laser data can be especially valuable in regions, which are under the impact of climate change, which can dramatically change the speed of forest growth or even the whole landscape structure -especially in northern, semi-arid and intra-zonal regions (Tiede, 2006; Kuemmerle, 2010).

4. Implementation of the method and current experience

In Russia the method of airborne laser scanning became very common in map-making and precise geodetic projects during last 10 years. The biggest national corporations – like TransNeft, Gazprom and Russian Railroads produced in 2007-2010 their own corporate standards of surveying using LIDAR. But in Russian forest industry and ecological researches the method is not widespread at all.

First attempts to investigate the abilities of the airborne laser scanning method in forest inventorying were made under the authority of Geokosmos company (Medvedev, 2007) in collaboration with the V.N. Sukachev Institute of Forest of the Siberian Branch of Russian Academy of Sciences (Krasnoyarsk). Due to the deterioration of the economic situation in the country and financial crisis of 2008-2009, there were now researches till 2012. In 2012-2013, on behalf of Russian Forest Information Organization (RosLesInforg) and together with such companies like Arkon (Moscow) and Proektstroy (Omsk), several researches were performed. The researches were focused on the definition of equations, which allow us to estimate the volume of lumber without any field activity. Also the methodology of airborne laser scanning and data processing was improved, according to the task mentioned above (Rylskiy, 2013).

Tree specie	Growth class	Equation	η	F	S	σ
Cedar	III	$Dmean=3.270+1.772Hmean-0.003Hmean^2-12.485P+1.157P^2$	0.96	16.96	6.38	2.52
	IV	$Dmean= 1.335+1.982Hmean-0.011Hmean^2-7.299P-1.031P^2$	0.96	16.23	6.85	2.62
Pine	II	$Dmean=4.791+0.749Hmean+0.022Hmean^2-4.616P-1.353P^2$	0.97	17.14	4.33	2.08
	III	$Dmean= 6.843+0.556Hmean+0.026Hmean^2 – 7.475P+1.169P^2$	0.97	18.46	4.64	2.15
	IV	$Dmean=5.419+0.744Hcp+0.025Hcp^2-5.050P+0.086P^2$	0.98	12.15	3.72	1.93
Larix	III	$Dmean=8.799+0.109Hmean+0.049Hmean^2-10.685P+1.062P^2$	0.97	16.94	5.91	2.43
	IV	$Dmean=9.917+0.219Hmean+0.046Hmean^2-13.338P+3.270P^2$	0.97	16.80	6.24	2.50
Spruce	III	$Dmean=1.789+1.574Hmean-0.013Hmean^2-4.167P+2.160P^2$	0.96	15.63	7.40	2.72
	IV	$Dmean=4.137+1.346Hmean-3.432P-2.167P^2$	0.96	16.19	7.08	2.65
Silver fir	III	$Dmean=5.388+0.899Hmean+0.008Hcp^2-0.803P-5.091P^2$	0.96	16.28	6.93	2.63
	IV	$Dmean=8.187+0.688Hmean+0.015Hmean^2-2.008P-3.709P^2$	0.97	16.18	6.80	2.61
Birch	I-III	$Dmean=3.949+0.546Hmean+0.022Hmean^2-2.674P-0.903P^2$	0.96	16.23	6.89	2.62
Aspen	I-III	$Dmean=15.464-0.811Hmean+0.054Hmean^2+9.000P-10.272P^2$	0.98	21.87	3.83	1.96

Tablet 1. Equations, describing dependency of diameter, height and relative tree coverage for different species of trees in southern parts of Krasnoyarsk Region, calculated for usage of the airborne LIDAR data together with satellite imagery data. Equations calculation is based upon comparison of the laser data measurements and field approval. Dmean – mean log diameter; Hmean – mean height of the tree; P – relative coverage (from 0 to 1); η - correlation; F – Fisher criteria; S - dispersion; σ - mean square error

The test region covered by surveys has the area of approximately 17 000 hectares. The results of lumber volume estimation, produced using the laser and satellite data were compared with the field researches and results, that can be achieved using previous methods (based upon growth models (Herold, 2001). The final result included a kind of prototype of methodology, suitable (with corrections according to the local peculiarities) for the national forest industry.

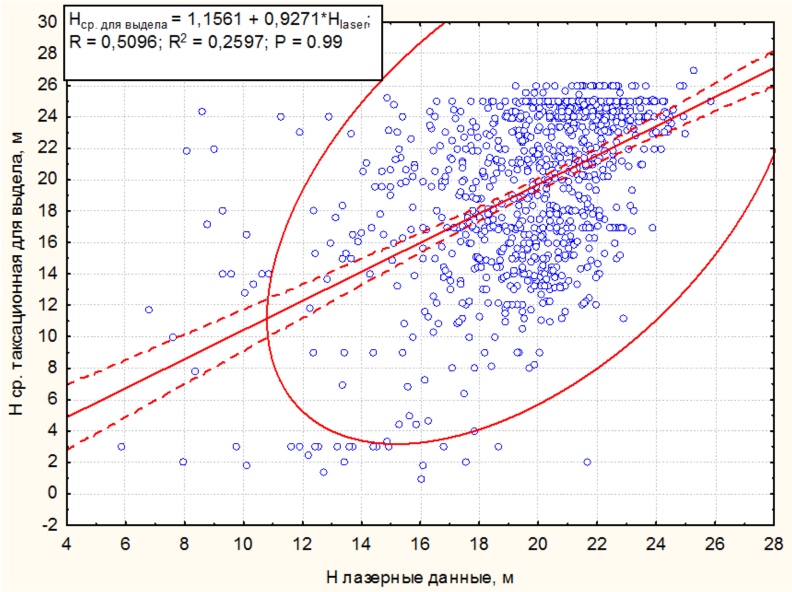

Figure 6. Dependency between mean heights of the trees, defined manually in the field (Y axis) and using the LIDAR data (X axis). Diagram belt using 978 semi-homogeneous regions.

During the research mentioned above, the airborne laser systems (like Riegl Q1560 mentioned above) were not produced yet, so the price of the survey shown during the LIDAR survey was comparably high. Now the development of the technology allows us to continue the implementation of the LIDARs if forest researches with greater efficiency and several times lower prices.

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ECOLOGICAL AND GEOGRAPHICAL MAPPING OF ALTAI KRAI LAND COVER: APPROACHES AND EXPERIENCE

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KEYWORDS: ecological and geographical mapping, map of land cover, map of land community types; map of vegetation degradation; map of plant community dynamics; map of disturbances (destruction) of plant communities, Altai Krai.

ABSTRACT
Mapping is one of the major methods in ecological and geographical studies, particularly in biodiversity assessment and vegetation analysis. Ecological and geographical mapping of land cover or eco-phytogeographic mapping is developing as one of the current trends on the basis of geobotanical, biogeographical, phyto-ecological mapping. In order to develop geoinformation eco-geographical mapping of vegetation was performed an analysis of 50 geobotanical cartographic works, were justified classification features of the main types of maps of the subjects of research, and considered the prospects for the development of this area of mapping of Altai krai land cover in modern conditions.

The vegetation cover is the most dynamic component of geosystems, a vulnerable indicator of growing conditions, i.e., the ecological condition of the territory. Ecological and geographical maps of vegetation (ecological and phytogeographic maps) are distinct from classical geobotanical and phyto-ecological maps, primarily in scientific approaches to their creation: they reflect characteristics of the geographical environment, consider vegetation as one of the components of geosystems (landscapes), reflect vegetation changes associated with anthropogenic impacts, are aimed at solving ecological and geographical problems of environmental quality management. Typically, creating eco-maps is based on the two-pronged approach: the classical environmental (bioecological) and eco-geographical [2].

Geobotanical maps occupy an important place among human environment maps, showing not only vegetation in its modern structurally coenotic manifestations, but also ecological and geographical factors, their determinants, as well as basic spontaneous and anthropogenic dynamic processes taking place in it. They are, by definition of V.B. Sochava, universal or inventory vegetation maps [2]. The ideas of V.B. Sochava in environmental-geobotanical mapping were further developed in the works of A.V. Belov, I.P. Zarutsky, G.I. Ogureeva, A.G. Isachenko.

A.G. Isachenko identified the main types of ecological and geographical maps of vegetation. He subdivided them into the following maps: types (kinds) of communities, degradation of the vegetation cover, biological contamination (introduction of weeds and poisonous plants), changes in resource and environment protective (security) functions of vegetation, disturbances (destruction) of vegetation, flora habitats, etc. [4]. Following A.G. Isachenko, during private scientific analysis of an array of geobotanical maps, ecological and geographical maps of vegetation and other similar maps in content or subject, was performed a division into groups of maps:

- Plant community types;
- Vegetation degradation;
- Plant community dynamics;
- Disturbances (destruction) of plant communities [15].

For maps of each group were identified differences and peculiarities of the thematic content.

Maps of plant community types. Maps of this group unite the two-pronged approach. Mapping is performed by vegetable cenoses but within classification units of physiographic division of the territory. The vegetation is characterized by a complex hierarchical spatial structure. This group includes: the vegetation map of the Tibetan Plateau [20], the vegetation map of the Republic of Bashkortostan [7], the vegetation map of Volgograd Oblast [12], the forest cover map of Primorye [6], the coastal vegetation map of the Gulf of Finland [3], and others. Displaying the vegetation structure is also the subject of this group of maps. An example is the forest cover map of Altai Krai [10] and the steppe vegetation map of Russia [8]. These maps contain information on plant associations prevailing in the study area.

Maps of vegetation degradation. The maps display changes associated with worsening of growing conditions, such as simplification of plant cenoses caused by anthropogenic activity. There are very strong, strong, medium, weak and very weak degrees of vegetation degradation. Besides, vegetation degradation is expressed as a percentage. An example of this type of maps can serve the vegetation degradation map of the Aral Sea region [5], the forest degradation map of Irkutsk Oblast [19], and others.

Maps of plant community dynamics. The maps contain information about the stages of revegetation, the nature of variability and speed of changes in phytocenoses. They can be used for forecasting and scenario planning of the environmental situation. The examples are: the map of stages of revegetation in the Angara river neighborhoods [21], a schematic map of revegetation of Nizhny Novgorod Oblast [13], the map of forest change during the 1949-1988 period of CIS countries [9], the map of forest dynamics of Lake Baikal basin [19], the map of revegetation of Western Siberia after disturbances [9], and others.

Maps of plant community disturbances (destruction). The maps display disturbances of plant cenoses caused by natural conditions or human activity. Natural factors causing vegetation disturbances include various pests, droughts, wildfires; anthropogenic factors include deforestation, plowing, fires started by human activities, and others. The maps are used for making recommendations for restoration work. The examples are: the map of assessment of vegetation damage from burning fire in Perm Krai [13], the map of forest logging in the water protection zone of Lake Baikal [19], the map of forest disturbance by fire in the water protection zone of Lake Baikal [19], the map of vegetation disturbance in Southern Kamchatka [9] .

As part of the geoinformation, ecological and phytogeographical mapping of Altai Krai was applied an integrated approach based on the combination of classical ecological (bioecological) and eco-geographical (ecological and landscape) research methods of vegetation. Were analyzed: Atlas of the Altai Territory [1], a number of large-scale landscape maps of 1:500 000 - 1: 1 500 000 and ecological landscape map (1: 1 000 000) created by Institute for Water and Environmental Problems of RAS [14, 16 17], as well as the schematic map of the vegetation of the Altai district, made in 1899 [18]. As a cartographic basis for geoinformation, ecological and phytogeographical mapping was adopted a landscape scale map at 1:500,000, comprising 193 types of areas [14]. Characteristics of landscape sites include geomorphological, vegetation and soil components. The landscape structure is given in conjunction with physical and geographical zoning.

The schematic map of the vegetation of the Altai District (Fig. 1), transformed into the computer version, the original scope of which (35 miles to one inch) in modern units can be equated to the scale of 1:1 700 000 (or approximately 1:1 500 000), is used as the initial (basic) geobotanical characteristic of the territory. Thus, on this map are charted relic pine forest belts, with the habitats having significantly decreased within a hundred years. Some forest areas have almost disappeared, which were mapped as "thick birch and aspen forests" in 1899 [18].

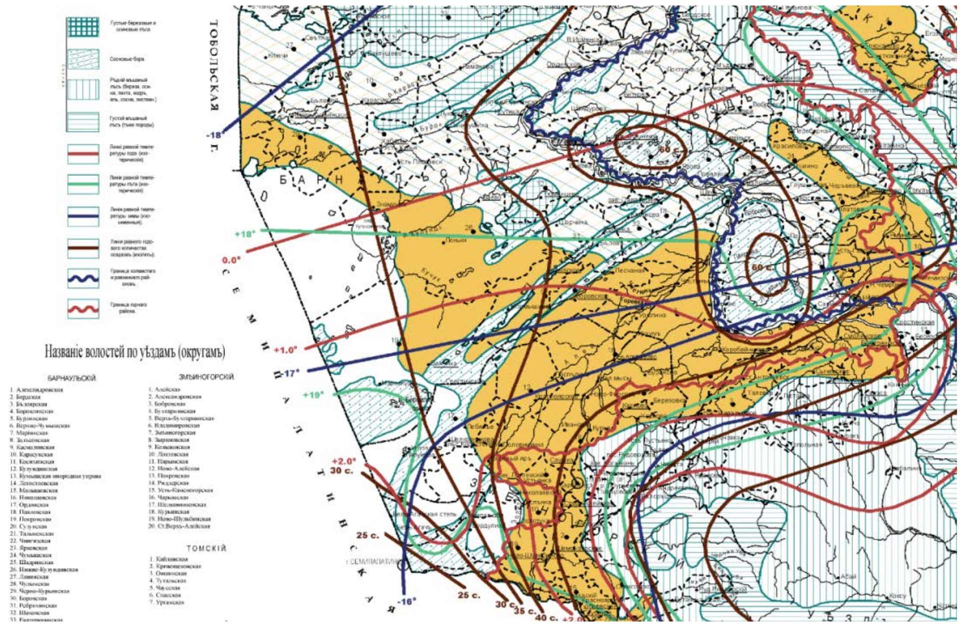

Figure 1. Schematic map of the vegetation of the Altai Mining District (fragment) [18].

Created in the 1990s the ecological and landscape map of Altai Krai (scale 1:1 000 000) contains in its table legend a diverse and detailed information about the types and levels of human impact on natural systems (Fig. 2).

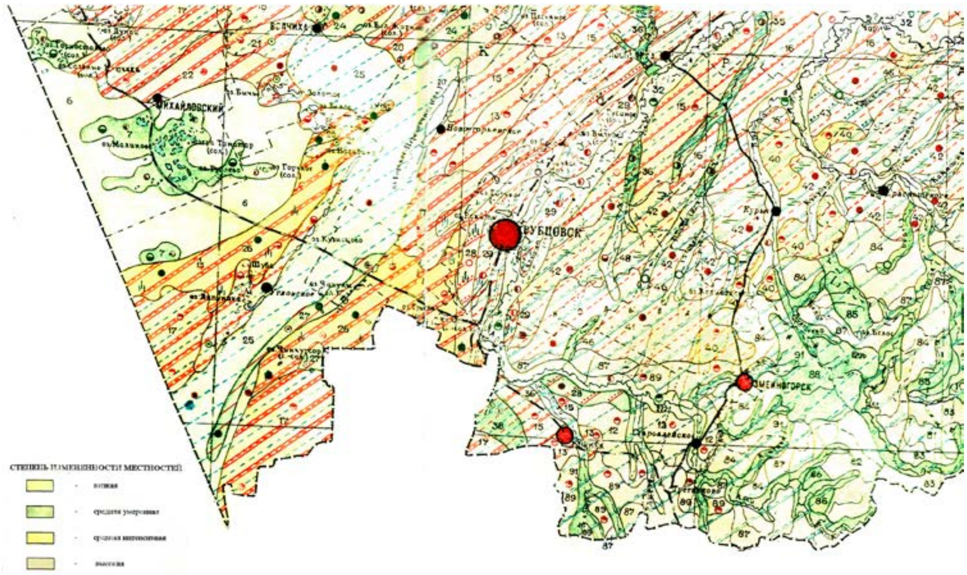

Figure 2. Ecological and landscape map of the Altai Territory (fragment, author I.N. Rotanova, unpublished, work materials of IWEP SB RAS).

The types of impact are differentiated according to the territorial basis into areal, linear and localized; levels of impact are reflected in the multiplying factor, varying from 1 to 4. According to the ratio of the ecological potential of landscapes and the level of impact was evaluated the degree of change in the area according to the four-stage grading: high, medium intense, moderate and low. The high degree of change is typical for landscapes undergoing the impact of agriculture, in particular, plowing. Thus, these landscapes have a high degree of vegetation degradation, almost complete replacement of natural vegetation by cultural phytocenoses.

Attribute data of the analyzed maps forms the basis of the structure and database records for geoinformation, ecological and phytogeographical mapping of Altai Krai. The dependencies and algorithms for the application of quantitative methods to create maps have been built.

In practical terms, a mapping study of the stabilizing function of vegetation is important for identification of the limits of the stability of biotic communities to anthropogenic factors. Demand for mapping support increases with the development of the tourism industry in Altai Krai, in particular, on the specially protected natural territories, currently operating and planned to organize. Assessment of the potential sustainability of vegetation allows normalizing anthropogenic impact with the aim of prevention of irreversible destructive processes that is necessary for forecasting and recommendation development within the ecological and geographical works.

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RELATING BIG DATA TO LOCAL NATURAL HAZARDS: LESSONS LEARNED FROM DATA MINING THE TWITTER API FOR VOLUNTEERED GEOGRAPHIC INFORMATION ON EARTHQUAKES, WILDFIRES, AND PRESCRIBED FIRES IN THE CONTIGUOUS UNITED STATES

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KEYWORDS: Social Media, Text Mining, Geocoding, Prescribed Fire, Wildland Fire, Earthquake, Geospatial Techniques

ABSTRACT

New media are increasingly used to capture ambient and volunteered geographic information in multiple contexts, from mapping the evolution of the social movements to tracking infectious disease. The social media platform Twitter is popular for these applications; it boasts over 500 million messages ('tweets') generated every day from as many total users at an average rate of 5,700 messages per second. In the United States, Japan, and Chile to name a few, Twitter is officially and unofficially used as an emergency notification and response system in the event of earthquakes, wildfires, and prescribed fires. A prototype for operational emergency detections from social media, specifically Twitter, was created using natural language processing and information retrieval techniques. The intent is to identify and locate emergency situations in the contiguous United States, namely prescribed fires, wildfires, and earthquakes, that are often missed by satellite detections. The authors present their methodologies and an evaluation of performance in collecting relevant tweets, extracting metrics such as area affected and geo-locating the events. Lessons learned from data mining Twitter for spatiotemporally-explicit information are included to inform future data mining research and applications.

1. INTRODUCTION

The automated extraction of volunteered and ambient geospatial information from social media has proven to be useful in a variety of contexts (Lampos et al. 2010; Stefanidis et al. 2013). A significant body of work currently exists that showcases the use of Twitter for disaster alerting, mitigation, and response (MacEachren et al. 2011; USGS 2012; Wendel 2015) where information derived from Twitter often performs equal to or better than conventional techniques (Petrovic et al. 2013; Wendel 2015). Sakaki et al. (2010) found that the operational earthquake alerting system in Japan provides alerts faster than the national Meteorological Agency. A young boy in Chile has over 405,000 users for his twitter-based earthquake information system (https://twitter.com/AlarmaSismos). In the domain of prescribed burns and wildland fires, however, Twitter has previously been used only for qualitative assessments and case studies (Longueville et al. 2009; Vieweg et al. 2010).

Twitter's popularity for natural hazard detection and alert applications can be attributed to its volume of users and frequency of use: 200 million active users, 60% of those on mobile devices, sending over 500 million tweets every day (Moore 2013; Twitter 2013a). Twitter is used by a number of federal, state and local officials in the United States as well as by motivated individuals in a number of countries world-wide to report prescribed burn plans in advance (sometimes as part of a reporting obligation) or to communicate detection, response to, and containment of wildfires. These publicly announced fire reports, like all Twitter messages (or 'tweets'), are limited to 140 characters of text, making it easily accessible for mobile phone users and the SMS 160 character limit.

This paper describes the experience of using Twitter to detect earthquake activity in southern California as well as prescribed and wildland fires in the contiguous United States (Endsley and McCarty, Accepted). We report lessons learned from using two separate approaches: Natural Language Processing (NLP) with the streaming Twitter API and a structured text search with the Twitter archive data. Both of these data mining methods of social media aimed to assess the predictive power of information extracted from Twitter for useful event occurrence information for environmental and natural hazard applications.

2. MATERIALS AND METHODS

2.1 Natural language processing of tweets for prescribed and wildland fire reporting

A prototype framework was developed to collect messages from the streaming Twitter API that potentially described wildfire or prescribed burn activity data for the contiguous United States, to extract from information from the tweets such as the type of fire and acreage burned, and to map the location of the tweet-derived fires in near-real time. The general approach employed NLP, information retrieval (IR), and data mining techniques. The specific steps involved were, in order: (1) Collect potential wildland and prescribed fire tweets; (2) Detect and remove duplicate tweets (or 'retweets'); (3) Determine burned area of the prescribed and wildland fires; (4) Classify the fire incident as either a prescribed burn or wildfire; and (5) Locate the fire described in the tweet with real world coordinates. Basic NLP techniques such as tokenizing (breaking text up into individual signifiers, usually single words), removing 'stopwords' (common words like 'if, and, or, but') and parts-of-speech (POS) tagging are applied at almost every step of the process to facilitate computation (Russell 2011).

A total of 13,241 tweets were collected starting July 4, 2012 and continuing until June 11, 2013 (Fig. 1) when the version of the Twitter Search API being used at the time was deprecated (Twitter 2013b) and tweets could no longer be collected. This version of the Twitter Search API allowed access to millions of tweets going back approximately one week in time (Twitter 2012). The collection spanned 342 days with an average rate of 38 tweets per day and represents the contributions of 6,351 unique users. In defining 'fire-related' tweets, we distinguish between (1) relevant, well-formed tweets that provide actionable information about prescribed burn(s) or wildland fire(s) and (2) everything else.

Search terms submitted to the Twitter Search API were chosen such that the bulk of tweets returned were almost exclusively well-formed and relevant, following the method of Vieweg et al. (2010). The terms were case-insensitive and could be partially contained by other words (e.g. a search for 'fire' also returns 'FIRE' and 'wildfire'). The chosen query also contained words that were most likely to convey information about the location and size of the fire, such as U.S. state abbreviations and the following terms with associated abbreviations: road, highway, county, and acre.

Acreage burned was extracted from the tweet text using basic regular expressions. The date and time of the fire were taken from the tweet's metadata, assuming that the date and time the tweet was written was proximate to the date and time of the fire incident. This approach assumed that the majority of fire tweetsn on Twitter is about wildfires with one or more of a finite set of tokens that are exclusively associated with prescribed burns (e.g. 'prescribed' and '#RxFire').

2.1.1 Retweet detection to determine single fire events

Only unique reports describing wildfires or prescribed burns were of interest, to avoid documenting the same fire twice in order to produce accurate estimates of burned area and to reduce the overall number of tweets that needed to be processed. Once a tweet was determined to sufficiently describe a fire, we aimed to filter out all later tweets describing the same fire - including exact or near duplicates of an earlier tweet. These so-called 'retweets' had no reliably definitive textual signifiers or the metadata to distinguish them from original compositions. The common convention of using 'RT 'within a tweet to signify a retweet was not universally adopted across the Twitterverse. Our approach determined the similarity, or distance, between two tweets as if they were arbitrary points in some feature space so that tweets within a certain distance of one another indicated the one or the other must be a retweet.

We employed locality-sensitive hashing (LSH) called minhashing (Moulton 2012; Jaffer 2013) to compare the text of any two tweets, which is also used by Twitter Inc. for search engine optimization (Twitter 2011). If the tweets were authored by two different Twitter users, the younger (more recent) tweet was marked as a retweet.

2.1.2 Geocoding of fire tweets

Some tweets were explicitly geotagged, with geographic coordinates derived from global positioning system (GPS) chips in a mobile device. This geocoding was appended to the metadata of each tweet. However, in practice, geocoded tweets account for less than 1% of all tweets in the Twitterverse (Cheng et al. 2010, Lee et al. 2011). Therefore, the majority of tweets for any data mining application must be geocoded. We defined geocoding for this project as an attempt to determine the real-world coordinates of an entity from unstructured or loosely-structured data. Geographic coordinates were assigned to a tweet based on its textual content, specifically, the tweet text and some metadata from the user profile (after Leetaru et al. 2013). The approach used in this study was a synthesis of named-entity recognition (NER) and gazetteering with clustering to resolve ambiguous cases. NER is an NLP technique that chunks adjacent words into meanings (such as ‘location’ or ‘person’) based on POS. NER is used to identify words or groups of words with potential geographic significance—so-called toponyms, or words that might be successfully mapped to a place through gazetteering.

Gazetteering is the process of using a geographical lookup table (gazette) to associate place names with their coordinates. Each toponym is then searched for in the geographic gazette. We used the GeoNames collection (GeoNames.org) as the geographic gazette, which contains over 2.1 million geographic entities in the United States and U.S. territories. If more than one match is found per tweet (i.e., if more than one term in the tweet is found in the gazette) and if those matches are not duplicates of the same gazette entry, then the tweet has ambiguous geographic coordinates. Only one set of coordinates can be assigned to the tweet, so k-means clustering was used to pick a centroid of geographic locations based on all of the retrieved locations. The developed algorithm searches for two clusters in k-means clustering (k=2) as it assumes that it is retrieving two types of entries from the gazette: those that describe the true location of the fire and those that describe faraway places with similar names (e.g. Riverside, California versus Riverside, Iowa). In k-means clustering, the centroid of the ‘tightest’ cluster is assigned as the geographic coordinates of the tweet where ‘tightest’ is determined as the minimum total distance between cluster members.

2.2 Extracting earthquake information from structured text While similar NLP methods can be used to evaluate the extent of an area affected by an earthquake, certain key details regarding an earthquake event, namely the location and magnitude of the quake at the epicenter, are more standardizable than in the case of fires. Volunteer reporting on social media regarding earthquakes has been practiced and improved by various individuals and organizations (USGS 2012; Wendel 2015). While this diminishes the capacity for social media to perform the actual detection of an emergency, social media can still provide information regarding the extent of the affected area. The earthquake data mining framework developed here seeks to integrate this work that has already been done by public services and scientists.

The USGS provides up to date information on earthquakes that documents its detection of a seismic event, including features such as depth, locational uncertainty, and distances from nearby populated geographical features (USGS 2012). All of this information is included as text or via a link generated by a USGS Twitter account (@USGSted). All of this information builds a much more precise query that can be made at the Twitter API, with a keyword search that is delimited in both time and space.

In this project, the Twitter Search API was queried for any and all tweets relating to earthquakes located in and around southern California. This query was conducted between January 2014 and December 2014. Initial earthquake locations were determined from the epicenter metadata provided by the @USGSted Twitter account. Similarly, earthquake-impacted areas for each individual earthquake were estimated from the distances and/or nearby cities metadata. Twitter queries were targeted within these estimated earthquake-impacted areas. Tweets from the earthquake-impacted area were recorded, counted, and then mapped on Google Maps and ESRI ArcGIS to classify the total number of tweets coming from populated towns or cities within these areas. Fig. 2 shows an example from an earthquake detected in November 2014 nearby Anchorage, Alaska.

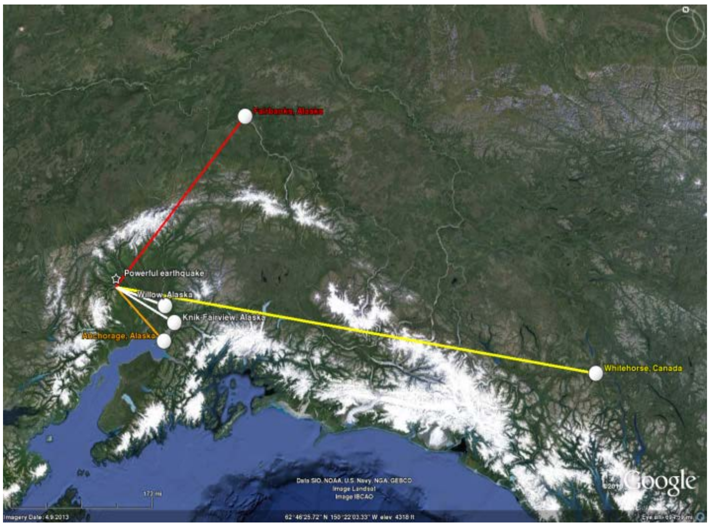

Figure 1: The results of the earthquake Twitter approach for a November 2014 earthquake near Anchorage, Alaska.

2.2.1 The expanding geographic gazetteer: challenges of inherited structure data

One of the challenges of this method was the ever-expanding geographic gazetteer. While initially this Twitter query approach was targeting southern California, earthquake data from the USGS included global locations. During the study period, there were no significant seismic activities within southern California, so the approach to include all English-languages from global locations of earthquake activity. Like the wildland and prescribed fire study, this algorithm would need to develop a custom gazette for individual regions of interest, implemented through geolocation metadata analysis (e.g., human evaluator) or machine learning.

While building on available USGS data is a more direct way of obtaining well-formed and relevant earthquake-related tweets, relying on the classification schema provided by the Twitter API would cause relevant tweets that lack the metadata for full classification of earthquake event to be missed. For example, if a Twitter user reporting on earthquake damages does so from an account that does not have geotagging enabled, then the API query would not return this tweet as potential relevant variable within the established earthquake-impacted areas. As was discovered in the fire data mining analysis, the overall lack of geocoded tweets further complicated geospatial queries and filtered out potentially relevant data for mapping outputs (i.e., no further NLP to discover textual location).

3. RESULTS

3.1 Lesson Learned: Custom Geographic Gazetteer

Assessment of the geocoding algorithm performance for the wildland and prescribed fire data mining algorithm involved a human evaluator who manually attempted to determine the location of 60 tweets randomly sampled from those located successfully (if not accurately) by the algorithm, excluding those explicitly geotagged. Of the original 60, the human evaluator was able to determine the unambiguous location of the fires in 32 tweets. The evaluator employed any information in the tweet and on the web to learn where the fire referred to within the text of the tweet was located. This includes sources of information not used by the algorithm, such as web pages linked in the tweet or official fie webpages from federal, state, and local agencies. The intended effect was to compare the performance of an algorithm to the best geocoder available: human intuition applied to the largest library of spatial information available (the internet).

For each of the 32 tweets in the wildland and prescribed fire tweets sample, the Vincenty distance (Vincenty 1975) between the actual and geocoded locations were calculated and compared to one of 32 random locations within exactly the same geographic extent allowed by the geocoder. Two clustering schemes were also compared, resulting in three assessments: a random geocoding, geocoding using the defined algorithm with k-means clustering (k=2), and geocoding using the defined algorithm with pair-wise clustering. The results are displayed as a flipped cumulative frequency plot in Fig. 2.

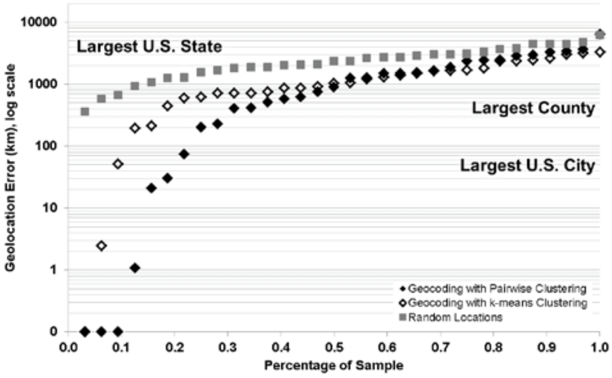

Figure 2: The geocoding performance of the algorithm developed in this study is compared to that of a random geocoding for two different clustering schemes. Though both clustering schemes perform better than random, the proprietary clustering scheme, pairwise clustering, performs significantly better than k-means.

In the case of the fire data mining application, the automated geocoder of tweets performed better than chance with either clustering scheme. However, there was significant room for improvement. With pair-wise clustering, the best clustering in terms of geocoding performance, less than 10% of the geocoded tweets in the sample were geocoded to within 8 km of the actual location of the fire. This distance was a significant threshold as it represented the approximate instantaneous field-of-view (IFOV) of the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor at swath's edge (in the 1 km resolution data), which ranges from approximately 4.83 km to 9.71 km (Yang and Di 2004). The 1 km MODIS Active Fire Product is still used by the U.S. Forest Service for early warning fire mapping (http://activefiremaps.fs.fed.us/) and in the NASA Earth Observing System Data and Information System (EOSDIS; https://earthdata.nasa.gov/data/near-real-time-data/firms/active-fire-data). Roughly 15% of the samples were geocoded to within 22 km of the true location and 22% to within 100 km.

3.1.1 The 'gold standard': Human evaluators still needed

A performance evaluation of the fire data mining methods was performed using human evaluators, which are justifiably the 'gold standard' in tweet text interpretation. Evaluators used in this project were all research professionals familiar with both the geospatial and fire sciences. In each evaluation, the results of the algorithm were compared to that of one human evaluator (in some cases, out of a group) over a random sample of tweets that had been identified as non-retweets—that is, each performance evaluation is an assessment in light of the retweet detection algorithm having been applied.

Assessment of the retweet detection algorithm for the fire data mining application involved a manual classification of 120 tweets from a simple random sample of all tweets, all of which were classified by the algorithm. The evaluator considered as a retweet any tweet for which there could be found an earlier tweet of sufficient similarity. The 'sufficient similarity' criterion is, of course, based on the human evaluator's own intuitive assessment. The human classifier's results were compared to the retweet detection algorithm. The algorithm achieved an overall accuracy of 72% with a recall, or true positive rate, of 82%. The majority of the error is commission error. Almost half of the truly independent tweets were mistakenly classified as retweets by the algorithm. The naïve approach to the problem of retweet detection is predicated solely upon the presence of the 'RT' token in the tweet text. A comparison of this approach was made to the naïve approach. While the naïve approach's omission error indicates that some retweets lack the 'RT' token, the overall accuracy of the naïve approach exceeded 83%.

This research found that region-specific earthquake detection data mining applications still need human evaluators to extract contextual location information from streaming tweets. As most earthquake epicentre data is provided automatically from a global system of seismological sensors and volunteer scientists, determining earthquake-impacted areas would require more than the 1% tweets to be geodocoded and/or a sophisticated interpretation of location from the text of the tweets themselves. This research has shown that sophisticated machine learning and/or trained human evaluators necessary for extracting geospatial information from tweets.

3.3 Lesson Learned: More rigorous integration of metadata

Tweets are generally considered unstructured text in data mining applications. However, public service announcements on social media often contain information in a consistently structured format (USGS 2012). While the computational price may become prohibitive with regard to machine learning and making common sense inferences from unstructured text, maintaining compatibility with reliable data sources and structures could provide valuable context to the information parsed from the unstructured data. This would entail that both the Twitter API and governmental agencies using Twitter to facilitate the transfer of data (i.e., @USGSted) must use consistent metadata structure and labeling as well as provide details on deprecation of the metadata schema. Future applied research related gleaning natural hazard-related information from Twitter should focus on the selection and evaluation of machine learning algorithms and techniques for discriminating relevant tweets and their approximate geolocation.

3.4 Lesson Learned: Data mining Twitter can produce geospatial data of natural hazard occurrences unknown to the satellite record

The geocoded results of the prescribed and wildfire data mining application were further compared to the satellite record. The positional accuracy of the tweet geocoding against the MODIS Active Fire Product (Giglio et al. 2003) and the accuracy of tweet-derived burned area estimates against the MODIS Burned Area (MCD45A1) Collection 5.1 product (Roy et al. 2008). In terms of positional accuracy, only about 4% of the geocoded tweets were located within 8 km of the corresponding fire's location in the MODIS Active Fire record. Approximately 33% of the geocoded tweets in our collection correspond with the coincident MODIS-based MCD45A1 burned area estimates. This implies that the targeted fire tweet collection, equal to 1,697 tweets from July 2012 to June 2013, likely contained references to fires potentially unknown and currently missed in the satellite record.

3.5 Lesson Learned: Systematically re-evaluate search terms and NLP corpus

Fig. 3 shows the word cloud produced by analyzing the most common non-trivial words in the collection of wildland and prescribed fire tweets. Future improvements to the Twitter Search API query would better integrate key terms based on their prominence in a word cloud visualization. Additionally, future data mining activities aimed at differentiating types of wildland and prescribed fire (e.g. forestry vs. agriculture vs. rangeland) would benefit from word cloud visualizations to determine best key terms and/or terms causing false detections.

Figure 3: A word cloud based on the tweets collected provides a view of the common terms used in fire-related tweets within the contiguous United States and can be helpful for designing new or improved queries to the Twitter Search API.

Further improvements could be made to any social media-based data mining prototype through outreach efforts to educate current fire and land managers, scientific community, citizen scientists, and the general public to safely share their observations of prescribed and wildland fires on social media. This type of outreach would need to provide appropriate and standardized key terms to identify location, burned area, and fire type. However, this type of outreach would require systematic evaluations of search terms or text within the NLP corpus to ensure the right keywords and/or terms are being communicated. Moreover, this type of outreach – established through analysis of continuously evolving search terms - could further enhance the value of social media data mining for natural hazards managers seeking to monitor earthquakes, earthquake damage zones, wildfire outbreaks, fire conditions, and post-fire regrowth from crowd-sourced information.

4. CONCLUSION AND DISCUSSION

This paper has presented data mining methodologies used to detect and map fire and earthquake-related information from Twitter. Any geocoding approach needs to be rigorously tested before implementation in an operational natural hazard event detection system. In general, the geocoding error can be attributed almost entirely to failures in disambiguation between common toponyms (Leetaru et al. 2013). Multiple solutions to this problem are now known but perhaps the most appropriate and effective for this application would be to construct a custom geographic gazette. Starting with the GeoNames.org database, for instance, future data mining work would benefit from filtering out entities that do not meet certain criteria (e.g. population, feature type, urban versus rural index, landscape and/or locational suitability indices for targeted natural hazards). Alternatively, ambiguous results could be ranked by these criteria, which allows for either fuzzy or discrete matching of geolocation for targeted tweets. Including the contextual information of the location and biography from the author’s Twitter profile could also be used to further refine custom geographic gazetteers. Leetaru et al. (2013) describe both custom gazette generation and these disambiguation approaches, comparing the effect on accuracy in choosing between geocoding on tweet text, the profile biography, and the author’s stated location. They found that the majority of accurate gazette matches came from the stated location in the author’s Twitter profile. While this location would be too coarse for mapping wildland and prescribed fires, it could be used to disambiguate results from full-text retrievals based on the tweet text and/or biography text and would likely be adequate for earthquake and earth impact detection.

The wildland and prescribed fire prototype described in this paper treats incoming text as unstructured data and only classifies specific information regarding the event and its location. It does not take into account how information may already be structured within the data. In addition to helping to curb geocoding error, providing a more distributed classification schema would offer more options for discerning relevant tweets and even integrating further information. Future applied research related gleaning natural hazard-related information from Twitter should focus on the selection and evaluation of machine learning algorithms for discriminating relevant tweets.

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DEFORESTATION MONITORING AT DIFFERENT PERIODS BY SATELLITE IMAGERY

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KEYWORDS: forest monitoring, cuttings/deforestation, remote sensing, satellite image, controlled classification, maximum likelihood method, post-processing of image

ABSTRACT
The paper concerns on the topical problem of forestry connected with the destruction of forests including unauthorized deforestation. It is indicated that large-scale deforestation is one of the causes of social and environmental disasters. The method of determination of different periods of forests' cutting on the basis of usage of high resolution satellite images is proposed. The methodology consists in automatic definition of cutting areas based on controlled classification according to the Maximum likelihood method with further post-classification processing, which greatly improves the results of cutting areas determination. In addition, the conducted research is connected with cutting areas, which are defined for different periods of satellite imaging. The work was done using satellite images from satellites Ikonos-2 (2002), Ikonos-2 (2007), QuickBird-2 (2010), WordView-2 (2014) on the forested area of Lviv region.

1. INTRODUCTION

In the system of forest management the problem arises, which is associated with the evaluation of the state and dynamics of forests development, including their destruction through cutting.

This problem may be solved with high reliability in a short period of time, using modern methods and means of information systems. Due to the high information content and data objectivity of remote sensing, the regularity of their receiving, and multifold possibilities during these data processing for the large areas, remote data sensing has become one of the major sources of organization of the forests monitoring (Bartalev et al., 2007; Slobodianyk, 2014).

In order to meet the meets of forestry, the use of remote sensing space information is carried on the following directions: control of deforestation, forests inventory, mapping, detection of cutting framework dynamics.

In most of the cases, in order to obtain reliable results it is necessary to certify the remote sensing information in the field survey, which enables to perform the accuracy estimation of the conducted work.

The Forest Code of Ukraine contains a number of legal provisions related to important directions of forest management, preservation, and protection of forests. It includes a set of measures aimed at preservation of forests from the following adverse effects: fire; cutting; damage, weakening and other harmful effects; protection from pests and diseases.

Evaluation of deforestation becomes particularly topical among the tasks of forestry.
In general, forestry legislation identifies four main types of cuttings (http://www.dklg.kmu.gov.ua):

- Cuttings of main use;
- Cuttings of formation and improvement of forests (care, sanitary, forests-renovative, rearrangement, associated with reconstruction and landscape) as well as other activities of formation and improvement of forests (care for tellers, for underwood, for forest edge, according to the shape of the trunk and crown, laying quarterly rides and creation of fire-resistant breaks);
- Cuttings during other activities related to forest management (felling of woodlands, felling of single trees, cutting area definition, clutter clearing, construction (repair) of forest roads, care felling in free-growing forest plantations, etc.);
- Cutting during other activities unrelated to forest management (clearing of forest areas covered with woods, in connection with construction of hydroelectric power plants, pipelines, roads, extension of the existing engineering structures, security zones, lanes along the border etc.).

A set of guidelines is defined for each type of cuttings, which is contained in the relevant legal acts of forestry legislation.
Unauthorized cutting of trees is carried out mainly in deep woods. Ukrainian legislation provides criminal, administrative, civil and disciplinary responsibility for different types of illegal activities.
In general, in 2013 – 8264 cases of forest laws violation were recorded, including 7247 cases of illegal logging, resulting in the destruction or damage of 24.4 thousand M3 of wood that caused 63.7 million UAH harm. Most violations were recorded in Lviv Region – 1813 cases, estimated at 15.5 million UAH (http://www.lesovod.org.ua).
Google Inc. presented the project Global Forest Watch (http://www.globalforestwatch.org), developed in collaboration with the World Resources Institute and 40 organizations that enable to monitor deforestation around the globe in real time. Map at the project's site is formed based on images from NASA satellites. However, algorithms of the images' processing allow to calculate the volume the forests' loss as well as new forests, which annually appear on each country's territory.
The total loss of the Ukrainian forest area for 2000-2013 period consisted of 565.6 thousand hectares, while the increase for 2000-2012 period was 352.9 thousands ha (http://www.eco-live.com.ua).
In general, the project worth 25 million dollars is quite convenient in use, however it has global character. Therefore, small areas of forest are not identified, which leads to erroneous conclusions.

2. RESEARCH OBJECTIVES

The purpose of the work is to study the accuracy of the definition of forest cutting areas over different periods of time based on high resolution satellite images:
To achieve this goal the following tasks were performed:

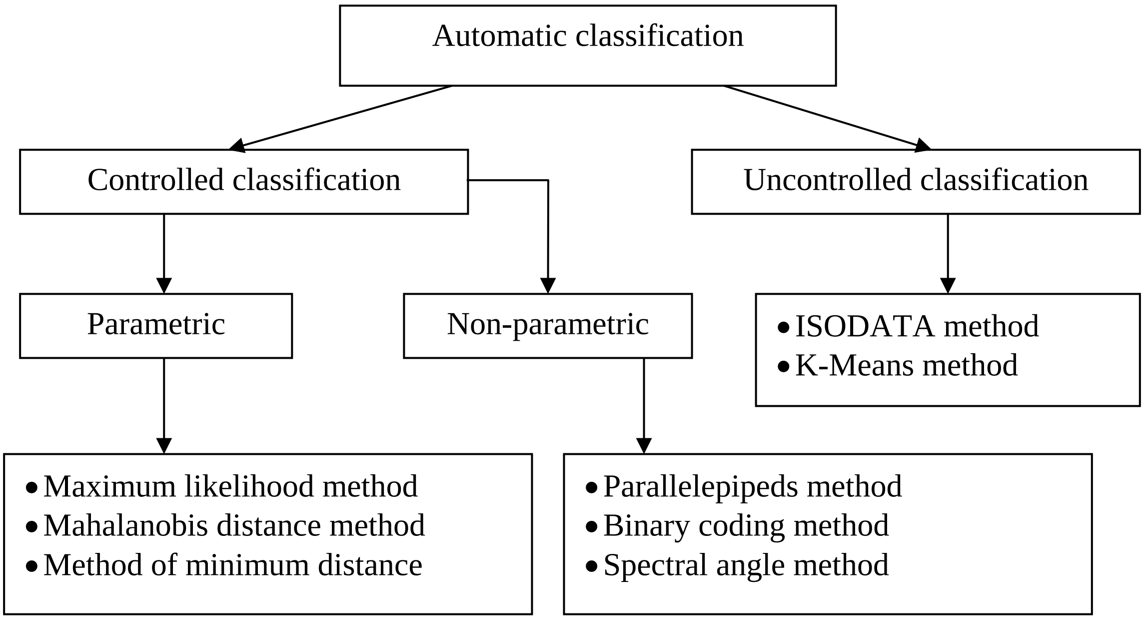
- Satellite image pre-processing in software ENVI 4.5;
- Selection of types of forest cutting using test information;
- Identification of different periods of cuttings according to the method of controlled classification;
- Post-processing of image according to the controlled classification results with the assessment of cutting areas definition accuracy;
- Identification of the forest cutting areas according to different periods of satellite imaging and comparative analysis.

3. MAIN THEORETICAL APPROACHES TO THE CLASSIFICATION OF FORESTS

Forest monitoring using space data includes:

- Acquisition, accumulation and pre-processing of specific space information;
- Obtaining and accumulation of field survey test data containing forestry parameters;
- Combined processing of space and field survey test data using GIS technologies and software package such as ERDAS Imagine, ENVI;
- Management decision making and development measures concerning the creation of optimal conditions of natural resource use (Burshtynska et al., 2013).

In order to implement forests monitoring by satellite data, the thematic classification of satellite images is done.
Classification – in fact, is the interpretation of images or computer-aided process of separation of image pixels into groups (classes) that correspond to different objects.
Automatic classification is the process of partitioning of the image’s pixels into categories based on their spectral values, resulting in the assignment of new value to each pixel.
Currently, there are two approaches to the implementation of automatic classification: controlled and uncontrolled (Lialko and Popov, 2006; Labutina, 2004; Svidzinska, 2014; Swain and Davis, 1978).
Based on these approaches the methods are established. The most important of these methods are shown in Fig. 1 (Burshtynska et al., 2013; Svidzinska, 2014).



Source: authors’ study

Figure 1. Main methods of automatic classification

It is known from the literature (Lialko and Popov, 2006; Swain and Davis, 1978) that the maximum likelihood method has advantages concerning the reliability of the results compared to other methods. Classification by maximum likelihood method is performed according to the following algorithm:

$$D = \ln(a_i) - \left[0.5\ln(|K_i|)\right] - \left[0.5D_M\right], \qquad (1)$$

where D - weighted distance (probability); a_i - probability percentage of the ranked pixel belonging to a class i (equals to 1.0 or is introduced based on a priori information); K_i – covariance matrix of pixels of class brightness i; $|K_i|$ - determinant of covariance matrix K_i; D_M - Mahalanobis distance.

The elements of covariance matrix K_i are determined by values of pixel brightness of signatures of different class. It is written in the following form:

$$K_i = \begin{Vmatrix} \sigma_{11} & \sigma_{12} & \dots & \sigma_{1m} \\ \sigma_{21} & \sigma_{22} & \dots & \sigma_{2m} \\ \dots & \dots & \dots & \dots \\ \sigma_{m1} & \sigma_{m2} & \dots & \sigma_{mm} \end{Vmatrix}, \qquad (2)$$

where: σ_{jm} – elements of covariance matrix; $j = 1,2\ldots m$ – quantity of channels.

Mahalanobis distance is written:

$$D_M = (X - M_i)^T \times (K_i^{-1}) \times (X - M_i), \qquad (3)$$

where: X – measurement vector of classified pixels in channel; M_i – average value of class brightness i; K_i^{-1} – inverse matrix to K_i. Its dimension corresponds to the number of channels.

Pixel belongs to the class, in case D_M is minimum for it.

4. ANALYSIS OF THE INPUT DATA

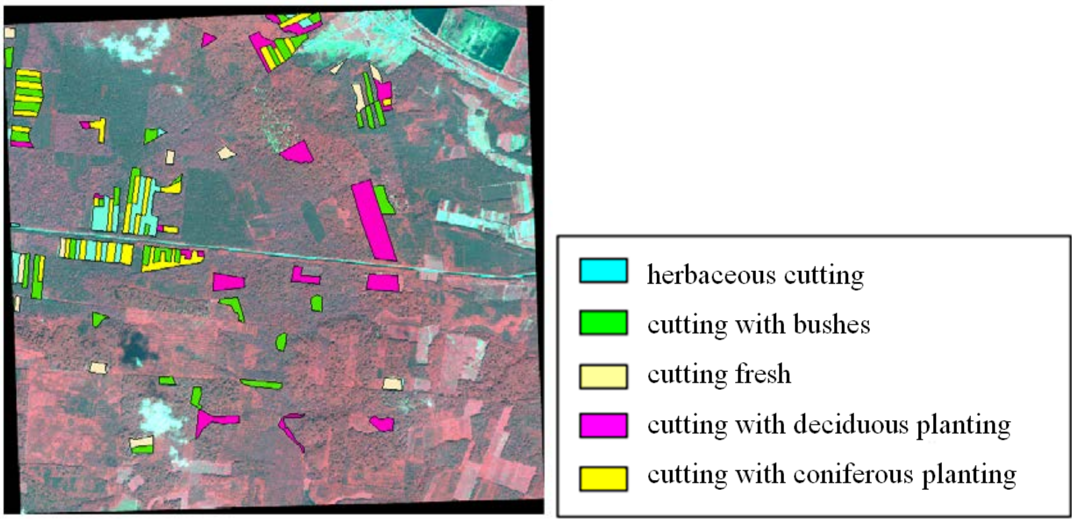
Satellite images obtained on the forest area in Yavoriv district of Lviv Region from the satellites Ikonos-2 (March 2002), Ikonos-2 (June 2007), QuickBird-2 (June 2010) and WordView-2 (October 2014), were the source information for the classification of different periods of cutting. These systems provide satellite images in five spectral bands (panchromatic, blue, red, green, and near infrared). A spatial resolution of Ikonos system is 1 m in panchromatic range and 4 m in spectral ranges, system QuickBird-2 – 0.61m and 2.44m, and the system WordView-2 – 0.46m and 1.84m, respectively.

The area is dominated by coniferous and deciduous forests of different ages and breeds, and in northeastern and eastern parts of the image the agricultural areas (gardens) and locality are situated. In addition, the picture contains a number of cuttings made at different times and lands with herbaceous and shrubby vegetation. This causes significant changes of characteristics of the object's brightness. Since the area is flat, it possible to disregard the impact of the relief on the image.

Test information was collected from data obtained through field survey, with the division of the image into landfills and appropriate description of each landfill with temporal interpolation of changes. Test information was received in 2011.

It has been established that cutting of vegetation is different. It indicates that they occurred in different periods of time. Based on the test information and visual interpretation the following main types of cuttings are defined: fresh cutting, not overgrown by vegetation; cuttings, covered by grassy vegetation; cutting of planting deciduous trees; cutting of overgrown shrubs; cutting of coniferous plantations. The visual interpretation data are controlled according to test information done by field survey.

Fig. 2 shows an image obtained from QuickBird-2 (2010). Each landfill with cutting is interpreted according to test information.



Source: authors' study

Figure 2. Digitized cutting with division into 5-types objects

Data is collected according to the following parameters (Table 1):

- General description of the polygon (e.g, mature coniferous forest, uncontrolled underwood, etc.);
- Average height of the trees;
- Average thickness of trunks;
- Average distance between the trees;
- Species of the trees;
- Percentage of dominant tree type;
- Square of the polygon.

Table 1. Test information on the territory

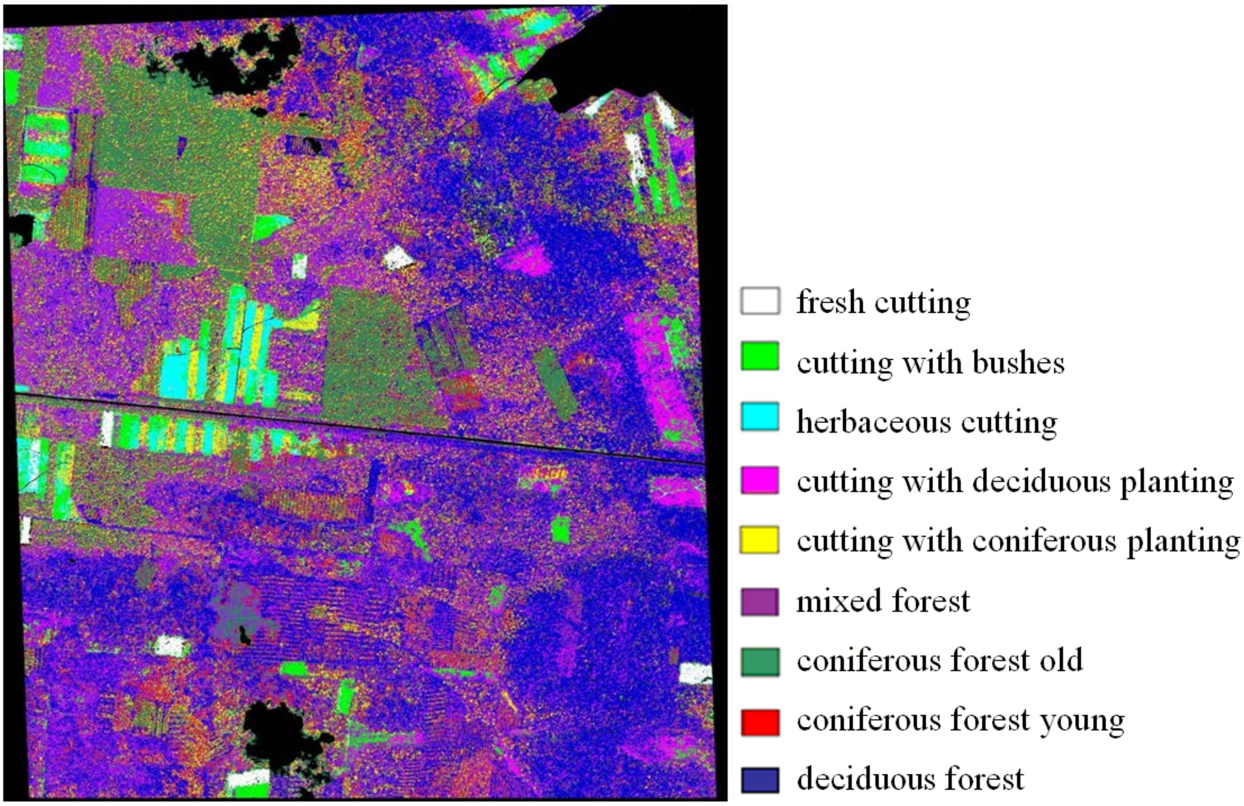
№	Characteristics of cutting	Valuation characteristics					Square, ha
		Height, m	Thickness, m	Distance between trees, m	Species of trees	Species of trees relation, %	
1	Herbaceous vegetation						23,9
2	Young coniferous	2	0,08	2	pine/birch	85/15	38,8
3	New deforestation						16,3
4	Young deciduous	2,5	0,10	1,5	beech/birch	95/5	55,3
5	Overgrown bushy	0,8	0,05	0,5		100	51,0

In order to determine the classification accuracy, the boundary coordinates of some interpreted polygons are determined using a portable GPS – Garmin GPS MAP 62, the coordinate determination accuracy – 3 m.
Images are referenced in the cartographical system WGS 84.

5. METHODOLOGY OF CONDUCTING THE CONTROLLED CLASSIFICATION, POST-PROCESSING OF THE IMAGE AND DEFINITION OF AREAS OF DIFFERENT PERIOD CUTTING

Previous processing of images provided channels of synthesizing and "masking" clouds, cities, roads. The combination in accordance with the reflectivity faculties of plants was applied for the interpretation of forests. The infrared, red and green channels were selected. The mask in software package ENVI 4.5 was created and the synthesized image was used.
The main interpretation features for the identification of cutting are geometry forms and spectral brightness.

The formation of signatures is the important step in the controlled classification. For this case the test information is used, gathered by the field survey. The number of pixels in each sample should not be small or large. According to the studied literature (Swain and Davis, 1978), if in the image there are *n* channels, so in each training sample there should be from *10n* to *100n* pixels. Accordingly, the size of standards about 400 pixels is selected for the research. Controlled classification is performed by maximum likelihood method. The method is selected on the basis of the studied literature (Lialko and Popov, 2006; Burshtynska et al., 2013; Sakhatsky et al., 2002). The results of classification of the image objects are shown in Fig.3. Classifying image divided into 9 classes includes: fresh cutting; cutting, covered by grassy vegetation; cutting of overgrown shrubs; cutting of coniferous plantations; cutting of deciduous plantings; old pine forest; coniferous young forest; mixed forest and deciduous forest.



Source: authors' study

Figure 3. Classified image according to the method of controlled classification with algorithm of maximum likelihood

From the previous studies it has been found (Burshtynska et al., 2014) that cutting of coniferous plantations correlates with coniferous forests and deforestation of plants with deciduous trees – with deciduous forests. Comparing visually this image with the results of test information and the original image, its clear that the reproduction may be seen according to the classification results by maximum likelihood method. At the same time, the calculated area according to the number of pixels of a certain class does not meet the real square of class because of a complex brightness distribution of pixels. This famous phenomenon that occurs during the classification is called “salt-pepper”. For example, areas with coniferous plantations contain pixels that according to the characteristics correspond to young coniferous vegetation and pixels of underlying surface (herbaceous vegetation).

Accordingly, the error in areas defined by calculation according to the test information data and by the controlled classification method for certain classes reaches 35-50%. Only fresh cuttings and areas with dense vegetation are identified with high accuracy.

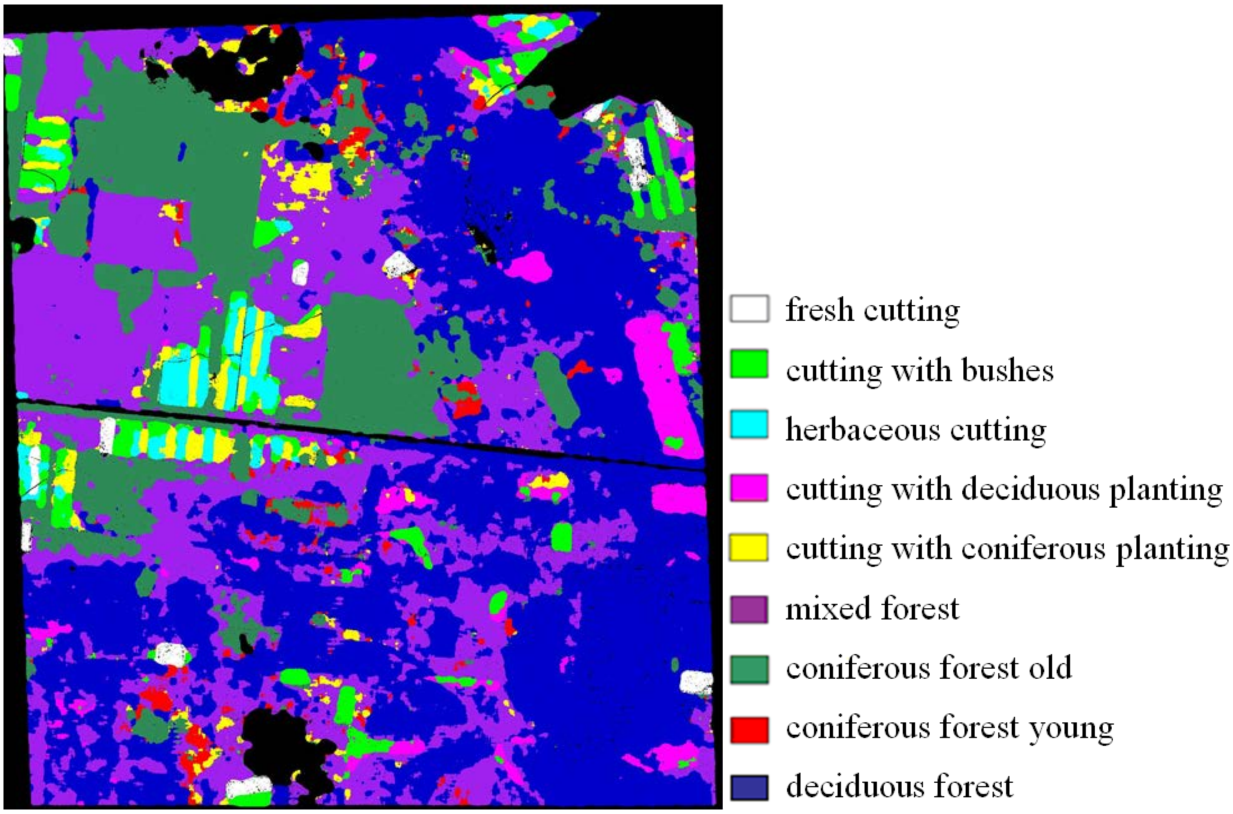
Individual pixels or even their groups within the complex image significantly distort the results of the areas definition. In order to improve them, the reclassification of pixels is made. For this case the tool of the program Majority Analysis is applied. We conducted the study for choice of the neighborhood within which reclassification of pixels is made. As result of the comparison of the cuttings areas obtained from the test information and calculated pixels from reclassification – the optimal neighborhood of reclassification is defined. Overall neighborhoods were investigated with a size 3×3, 5×5, …, 17×17, ..., 23×23. It has made possible to determine that the neighborhood size 17×17 gives the smallest error in determination of the areas. Table 2 presents cutting areas identified during the field survey, and the areas identified during the reclassification at different meanings of neighborhood.

Table 2. Dependence of areas accuracy determination of the different periods cutting according to the size of neighborhood.

Types of cutting	**Test results, ha**	**Size of neighborhood**										
		3 × 3	**5 × 5**	**7 × 7**	**9 × 9**	**11 × 11**	**13 × 13**	**15 × 15**	**17 × 17**	**19 × 19**	**21 × 21**	**23 × 23**
		Determined areas, ha										
Fresh cutting	16,3	14,8	14,5	14,6	14,8	15,1	15,4	15,9	16,2	16,5	16,9	17,1
Cutting with bushes	51,0	59,4	56,8	55,3	54,5	54,0	53,7	53,5	53,4	53,3	53,3	53,4
Herbs cutting	23,9	29,2	27,8	27,4	27,3	27,3	27,4	27,6	27,7	27,9	28,2	28,3
Cutting with coniferous planting	38,8	117,2	89,2	71,3	60,5	53,6	49,5	46,6	44,3	42,4	40,8	39,3
Cutting with deciduous planting	55,3	90,0	69,9	60,6	56,2	53,8	52,3	50,9	49,6	48,3	47,3	46,3

Instrument (Majority Analysis) works according to the principle that for central pixel in the neighborhood will be assigned a value of the most of the pixels class in a given neighborhood.

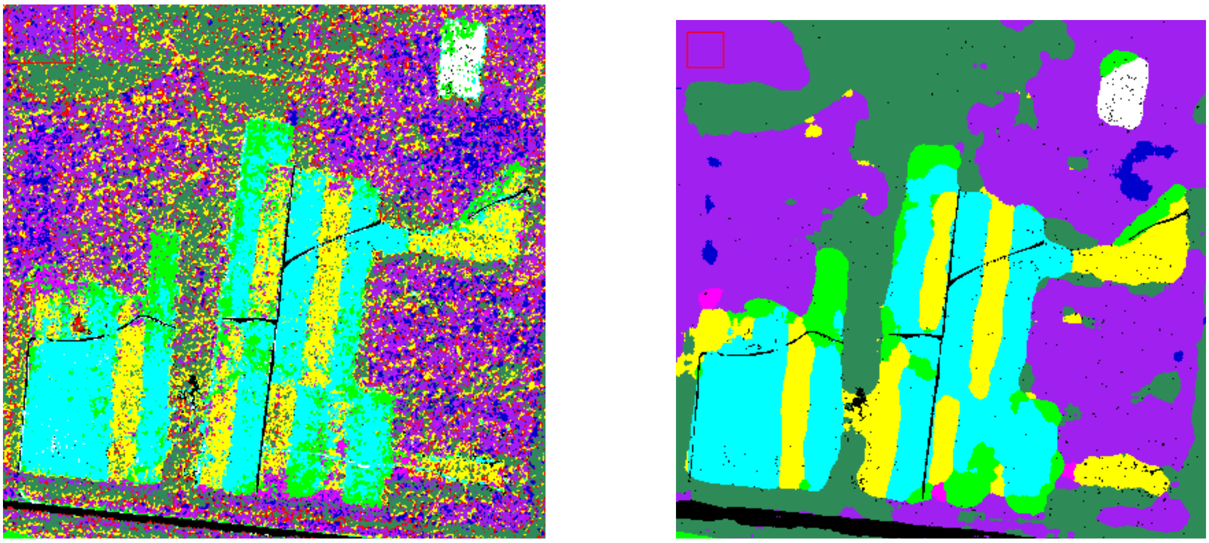
Fig. 4 shows the results of post-processing.



Source: authors’ study

Figure 4. Results of post-classification image processing

For the visual comparison of the results in Fig. 5 fragments of classification results by the method of maximum likelihood and post-classification image are provided.



a *b*

Source: authors’ study

Figure 5. Image fragments: a) classified by method of maximum likelihood; b) post-classification image processing

Differences of type cutting areas obtained from post-classification image processing and testing areas are presented in Table 3.

Table 3. Differences of areas of different time cutting

Types of different time cutting	Testing areas ha	Areas calculated on the basis of post-classification ha	Differences of areas ha	Divergence of areas %	Accuracy of determined areas%
Fresh cutting	16,3	16,2	0,1	0,6	99,4
Cutting with bushes	51,0	53,4	2,4	4,7	95,3
Cutting with coniferous planting	38,8	44,3	5,5	14,2	85,8
Cutting with deciduous planting	55,3	49,6	5,7	10,3	89,7
Herbs cutting	23,9	27,7	3,8	15,9	84,1

So, fresh cutting and cutting with bushes are identified with the highest accuracy. This accuracy is respectively 0,6% and 4,7%. Herbaceous cutting, cutting with coniferous and deciduous planting are identified with accuracy 10-15%.

Based on the defined coordinates of sample points of cuttings boundaries with GPS – measurements, obtained after the post-classification processing, the Table 4 has been formed. Boundary points are selected on clear and non-clear contours.

The calculated RMS errors of measurements for clear contours are 4-5m and for non-clear contours are within 10-11m.

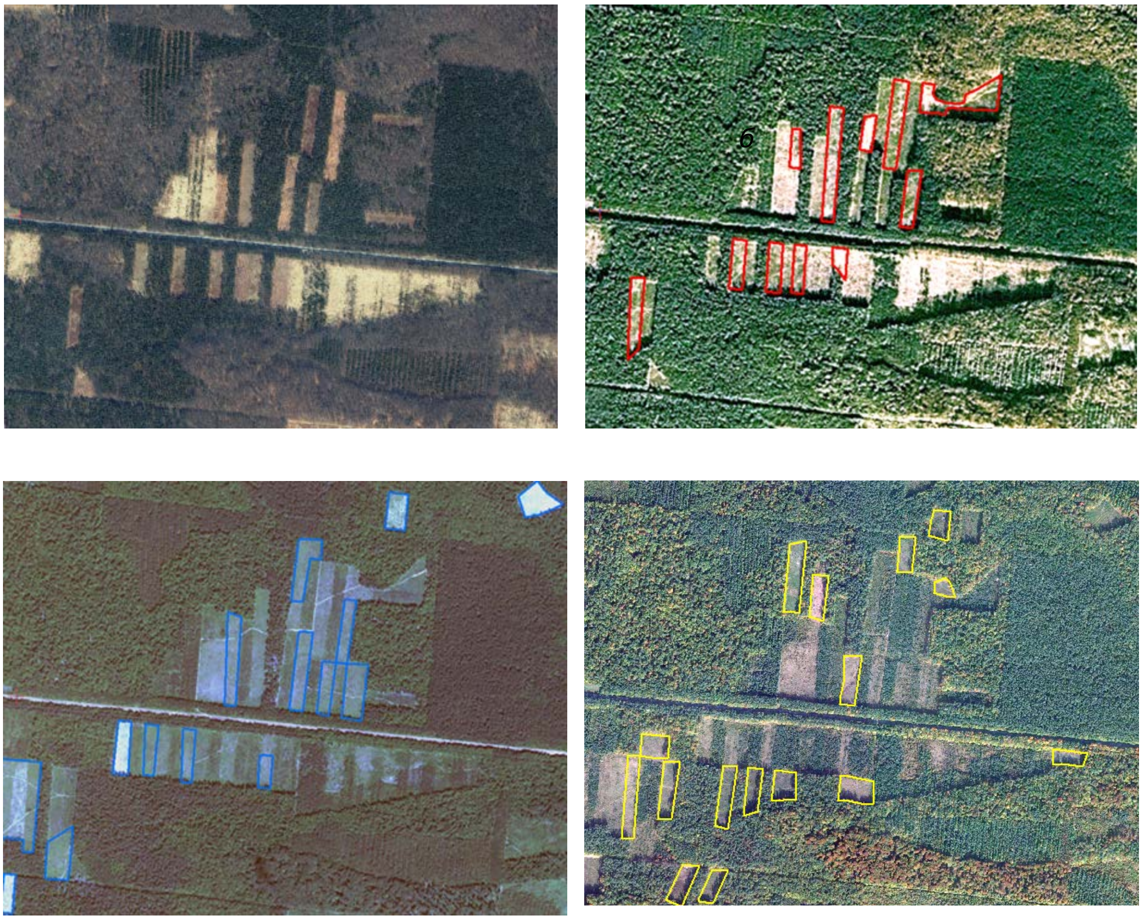
As a result of post-classification processing it is possible to create a thematic map of forest.

Table 4. Determination of accuracy coordinates of boundary points of cuttings after post-processing

№ of point	Measurement results				Differences		δX^2	$\delta У^2$
	GPS		Post-processing					
	Clear contours							
	X, m	У, m	X, m	У, m	δX	δУ		
1	689708	5533403	689713	5533400	-5	3	25	9
2	689726	5533593	689730	5533588	-4	5	16	25
3	690125	5533665	690128	5533663	-3	2	9	4
4	692612	5535122	692608	5535128	4	-6	16	36
5	692575	5535123	692580	5535120	-5	3	25	9
6	690660	5534097	690655	5534098	5	-1	25	1
7	690819	5533650	690813	5533648	6	2	36	4
8	691297	5534513	691293	5534518	4	-5	16	25
9	690001	5532369	690008	5532373	-7	-4	49	16
10	691425	5531769	691428	5531773	-3	-4	9	16
						[ΔΔ]	226	145
						m, m	**5**	**4**
№ of point	Vague contours				δX	δУ	δX^2	$\delta У^2$
1	690794	5532141	690775	5532138	19	3	361	9
2	689476	5533000	689488	5533008	-12	-8	144	64
3	689340	5533108	689333	5533105	7	3	49	9
4	689286	5533441	689270	5533430	16	11	256	121
5	690709	5534338	690708	5534345	1	-7	1	49
6	690557	5534187	690550	5534178	7	9	49	81
7	692615	5534864	692618	5534853	-3	11	9	121
8	690595	5534063	690608	5534050	-13	13	169	169
9	690507	5533825	690498	5533828	9	-3	81	9
10	690464	5533830	690473	5533848	-9	-18	81	324
						[ΔΔ]	1200	956
						m, m	**11**	**10**

6. IDENTIFICATION OF CUTTING AREAS ACCORDING TO SATELLITE IMAGES OF DIFFERENT PERIODS

Besides research of different periods cutting according to single satellite image of high resolution (QuickBird-2), the cutting area determination is carried out according to different periods images: Ikonos-2 for 2002, 2007, QuickBird-2 for 2010 and WordView-2 for 2014 years, which makes it possible to evaluate changes of deforestation areas over a certain time period. We show in Fig. 6 elements of cuttings which are clearly identified and allow seeing how cuttings were carried out at certain times. The cutting areas are identified in software package ArcGIS9.3.



Source: authors' study

Figure 6. Identification of deforestations on the images: a) Ikonos (2000); b) Ikonos (2007); c) QuickBird-2 (2010); d) WordView-2 (2014).

Identification of deforestations is made according to images: Ikonos-2 (2002), Ikonos-2 (2007), QuickBird-2 (2010), WordView-2 (2014). Image Ikonos-2 (2002) that clearly identifies cutting serves as original to compare the scale of deforestation during the period from 2002 to 2007 (Fig. 6a). Differences of cuttings are presented as red polygons (Fig. 6b). Differences of cuttings for the period 2007-2010 are shown in Fig. 6c with blue colour, and the differences of cutting made for the period 2010-2014 are shown in Fig. 6d with yellow.

Cuttings areas and their changes, which happened over the period 2002-2007, 2007-2010 and 2010-2014, are shown in Table 5.

Table 5. Cutting areas at different time periods

<table>
<tr><th>Year</th><th>Cutting areas for the time period, ha</th><th>Cutting areas on average per year, ha</th></tr>
<tr><td>2002</td><td rowspan="2">68,6</td><td rowspan="2">13,7</td></tr>
<tr><td rowspan="2">2007</td></tr>
<tr><td rowspan="2">59,7</td><td rowspan="2">19,9</td></tr>
<tr><td rowspan="2">2010</td></tr>
<tr><td rowspan="2">52,4</td><td rowspan="2">13,1</td></tr>
<tr><td>2014</td></tr>
</table>

Thus, the research results make it possible to assert that by using high resolution satellite images it is possible to identify deforestation, set the time of cutting and determine their areas.

7. CONCLUSIONS

1. It is defined that high resolution satellite images automatically allow, according to spectral characteristics of objects, to identify forests, including deforestation.
2. On satellite images of high resolution by QuickBird-2 satellite cuttings of coniferous and deciduous plantings obtained in result of controlled classification by method of maximum likelihood, correlate with other objects, similar by their spectral characteristics: coniferous forests, deciduous forests.
3. Application of post-classification images processing allows significantly improving the results of controlled classification of cuttings that allows determining their areas more accurately. On the basis of the area analysis obtained from the test information and from the post-classification it is defined that the results of divergence of cutting areas range from 0,6% to 15,9% for different types of underlying surface.
4. The methodology of comparison of high-resolution satellite images in appropriate time intervals is effective for the determination of deforestation areas.

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MAPPING OF PHYTODIVERSITY WHEN DESIGNING THE BELOKURIKHINSKY NATURE PARK

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KEYWORDS: phytodiversity, geobotanical map, nature park, Belokurikhinskiy nature park, Altai Krai.

ABSTRACT
Mapping of the vegetation cover is of great importance for learning the geographical nature conditions, evaluation of nature resources, solving a great variety of practical tasks. Active development of tourist-recreational activity in the Altai Krai contributes to the expansion of the network of territories under special protection which are designed for regulated tourism and recreation. Such nature conservation territories are represented by state nature parks of regional importance. Belokurikhinskiy Nature Park, which is planned to be created, is aimed at preserving mountain-forest territory of the south-western part of the Altai Krai and developing tourist-recreational potential of the resort of federal importance “Belokurikha”.

Active development of tourist-recreational activity in the Altai Krai contributes to the expansion of the network of territories under special protection which are designed for regulated tourism and recreation. Such nature conservation territories are represented by state nature parks of regional importance. The decision about establishing a nature park is made by local authorities.

According to the state federal law of the Russian Federation “About Specially Protected Territories” a nature park is a specially protected territory of regional importance within which there are areas of ecological, cultural and recreational importance, so the prohibitions and restrictions of economic and other activities are set in accordance with the latter ones (Federal Law No. 33-FZ).

On the territories of nature parks various modes of special protection and usage are set dependent on economic and recreational value of the nature areas. The following zones can be found on the territories of nature parks: nature conservation, recreational, agricultural and some others including the areas of protecting historical and cultural complexes and objects. Any activity entailing alterations of historically formed nature landscape, decrease or destruction of ecological, aesthetic and recreational properties of nature parks, maintenance violation of historic-cultural monuments is strictly prohibited. The peculiarities, zoning and the routine of each nature park are determined by the regulations of the latter (Federal Law No. 33-FZ).

Mapping of the vegetation cover is of great importance for learning the geographical nature conditions, evaluation of nature resources, solving a great variety of practical tasks. Vegetation as the object of mapping has a number of features which determine principles and methods of its cartographic study and its specific character in comparison with the mapping of other nature components. Vegetation is of twofold origin and develops according to biological and geographical laws. This peculiarity is reflected in one of the basic principles used in geobotanical mapping. It is performed in accordance with the features of the vegetation cover but due to the geographical conditions (Rotanova, Gaida, 2014).

Vegetation is characterized by a complex hierarchical spatial structure:

- Floristic and phytocenological structure;
- Vertical structure – layerage;
- Synusia – the existence of a range of plants representing one or several life-forms;
- Horizontal extent – spatial, morphological structure;
- Functional structure.

It is difficult to depict all the components of the spatial structure of vegetation cover on one map, therefore, they constitute the subject of a series of maps. To create a map a GIS project is worked out; its functional potential enables to inventory, analyse, estimate the vegetation and phytodiversity of a nature park, to map the territory when zoning and running the tourist sphere.

The diversity of the tasks being solved makes it possible to use GIS at the stage of designing a specially protected nature territory, that is to provide advance geoinformational and cartographic support that allows optimizing the subsequent field study and complex evaluation of the environment (Rotanova, Popova, 2014).

Belokurikhinskiy Nature Park, which is planned to be created, is aimed at preserving mountain-forest territory of the south-western part of the Altai Krai and developing tourist-recreational potential of the resort of federal importance "Belokurikha". The nature park is being created on the territory covering about 40,000 hectares, spanning the area from the spurs of the Anuiskiy Range in the West and South-West, and the spurs of the Cherginskiy Range in the East and South-East. The northern border lies along the front of the Altai Krai – a well-marked area of the tectonic zone separating the mountainous part from the plain one (the Prialtai Valley). According to the geobotanical zoning the territory belongs to the Altai mountain province, West-North-Altai mountain-taiga-scrub-steppe subprovince, Belokurikhinskiy-Chemalskiy mountain-taiga district of pine, birch and birch-larch grass forests. The vegetation is typical of South-Siberian mountain pine-birch-aspen-fir, larch and coniferous spruce forests. Also the poplar, elm, sea-buckthorn, oak, mountain ash, arrowwood, etc. grow there. There is a great variety of medicinal and melliferous herbs, a lot of fruit and berry plants growing wild, and mushrooms.

It is of paramount importance of nature protection activity in Belokurikhinsky Nature Park to preserve its pfytodiversity; the following measures are included:

preservation of boreal mountain-forest vegetation with the features typical of low mountain-taiga forests; preservation of rare plants in their natural habitats; forming reserve population of rare flora specimen; expansion of the activities aimed at reintroduction of valuable flora species in their biotypical habitats.

It is possible to map phytodiversity in accordance with:

- Taxonomic system of vegetation cover;
- Ecological interconnection with physical-geographical factors of the environment;
- Properties of the communities of general scientific and practical importance.

The purpose of a map, a set of general and specialized maps is determined according to the first-priority approach.

General geobotanical maps comprise different information about vegetation. They are a basic source of information and are interesting for a wide range of users. General maps depict the regular character of distribution of vegetation categories, formed in the course of historical development as well transformations caused by human activity. The maps are categorised into the ones of vegetation recovery (indigenous) and of modern vegetation cover.

The explanatory notes of the general map of the nature park being designed is based on regional-typological approach of geographic-genetic classification and various principles of classifying plant communities on various taxonomic levels. To reflect the regular character of vegetation spread on the map, the explanatory notes are structured; a graphic model of the explanatory notes is designed with the help of the following graphic techniques: relative position and graphics of symbols, fonts and others. The structure of the explanatory notes is determined by botanic-geographic peculiarities of the territory, the concept and the purpose of the map, the scale. The general geobotanical map of Belokurikhinskiy Nature Park is being created on a scale of 1 to 50,000; according to the classification of geobotanical maps it is considered to be general and large-scale. The objects of mapping are associations and groups of associations (Atlas…, 1978).

The diversity of geomorphological conditions, peculiarity of hydrographical network, mosaic structure of soil cover, anthropogenic transformation determine a rather high level of phytodiversity of the territory of Belokurikhinskiy Nature Park. Forests comprise about 80% of its territory, meadows and valley complexes take up about 10%, secondary grown vegetation and scrubs occupy about 5%, and other lands comprise not more than 5%. Formation and typological structure of forests is determined by a combination of nature and anthropogenic factors. Due to the prevalence of low mountain steep sloped mild topography the greatest part of the forest covered territory is occupied by the formations of South-Siberian mountain-taiga pine and cedar-fur-spruce forests with typical valley clusters of birch and aspen grass (or swampy in some places) and fur-aspen-birch fern-grass forests.

Among the specialized maps the following ones are given: forest types, useful growing wild plants – alimentary fruit and berry and medicinal – percentage of forest lands, distribution of forests according to their type, age, rare and extinct plants, growing wild ornamental plants, natural forage lands, etc.

The map "Forest Types" reflects a diverse characteristic of forests including the composition of the latter, the type of lower layers which demonstrate the bioecological potential of ecotypes, growth class and so on. To create the map, the plans of forestry enterprises and taxation descriptions were used. The main mapped units are the groups of forest types and their combinations which are typical of modern forest cover of the territory. The groups of forest types and their combinations are united into genetic cycles which reflect the modern stage of forest formation process manifesting itself in definite geographical environment. The cycles are named according to the names of wood species which comprise the so-called indigenous forest and semi-indigenous forest types.

Significant practical importance in terms of tourist-recreational activity in Belokurikhinsky Nature Park is ascribed to mapping the areas where growing wild alimentary fruit and berry and growing wild ornamental plants are spread. The territory of the park is rich in growing wild alimentary vegetation resources. In the map "Growing Wild Alimentary Fruit and Berry Plants" they depicted complexes of fruit and berry plants with prevalence of constant species and the data about accompanying species, the abundance degree of species and their classification into plant communities. The following complex-forming species are typical of the territory: raspberry, wild strawberry, dog rose, red currant, blackcurrant, mountain ash, bird cherry tree; in the valleys – blackcurrant, arrowwood, strawberrie.

The map "Growing Wild Ornamental Plants" gives information about the habitat of mainly flowering plants with the period of blossoming and division into cultivated and introduces species.

In the map of Belokurikhinskiy Nature Park the habitats of the following species are shown:

- Peony (Paeonia anomala), Siberian globeflower (Trollius asiaticus), Adonis Siberian (Adonis sibirica), meadowsweet (Spiraea), Siberian dame's rocket (Hesperis sibirica) and others – in birch-larch grass forests, scrubs, forest meadows;
- Yellow lady's slipper (Cypripedium guttatum), blue anemone (Anemone caerulea), corydalis (Corydalis bracteata), ladybell (Adenophora liliifolia), primrose (Primula cortusoides) – on the edge of birch-pine grass forests, in the meadows, in the scrubs, less often on the stone slopes;
- Martagon lily (Lilium martagon), aconite (Acontium volubile), Altai anemone (Anemone altaica), Sibirean atragene (Atragene sibirica), green violet (Viola uniflora), hairy spurge (Euphorbia pilosa) – in aspen-fur coniferous high-grass forests, scrubs, in the forest meadows;
- Clematis (Clematis integrifolia), Siberian dame's rocket (Hesperis sibirica), lychnis, Maltese cross campion (Lichnis chalcedonica) – in the river valleys (Atlas…, 1978).

At the stage of designing Belokurikhinskiy Nature Park, the maps of phytodiversity being designed with the help of GIS-technologies and the already created ones will contribute to collecting, systematization, storage, processing, access, mapping and spread of the information about the protected territory and will cause a thorough analysis of factors and conditions for creating it.

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REMOTE SENSING APPLICATIONS FOR ONLINE MAPPING OF AGRICULTURAL VEGETATION

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KEYWORDS: agroecosystem, interpretation of remote sensing imagery, supervised classification, spectral transformations, Landsat 8.

ABSTRACT
Automated recognition of agricultural crops on multispectral images is proposed. The results of efficiency analysis of spectral transformations (using the method of principal component, transformation Tasseled Cap, normalized difference vegetation index NDVI) are provided in the article. The map generated as a result of remote sensing imagery interpretation is outlined.

1. INTRODUCTION
Artificially created and regulated by people biotic communities of cultivated plants with their ecotopes (locations) in order to get agricultural products are defined as agroecosystems. Availability of reliable and timely information on the main agroecosystem component, that is agricultural crops, is an important constituent of efficient agricultural policy. However, analysis and mapping of agroecosystems is particularly difficult process because the latter are characterized by highly dynamic agricultural vegetation due to annual crop-rotation.

The so-called "history books of the fields" represent the main source of information on cultivated crops in Belarusian agricultural organizations. However, the information provided by these sources may not be highly reliable due to these books are based on the data produced by agronomists and different distortions may occur for a variety of reasons. In order to create an adequate system for estimating the agricultural policy efficiency, it is necessary to develop a number of methods for independent and efficient interpretation of crop types.

2. RESEARCH AREA AND INITIAL DATA

The results of experimental analysis of automated crop type recognition (winter rye, winter wheat, spring wheat, winter triticale, winter rape, barley, oats, buckwheat, corn, perennial grasses and legumes) are described in the article. Analysis was based on remote sensing data using GIS technologies.

Landsat 8 satellite imagery is the main source of information. The fields being tested are located within the territory of agricultural company 'Smolevichsky district' (Minsk Region). The total area divided on 257 fields is about 9799 hectares. During the period from 23 March to 30 August 2014 the archive of 8 scenes was compiled for the tested area.

3. METHODOLOGY OF AUTOMATED CROPS RECOGNITION

While pre-processing, all images have undergone radiometric and atmospheric corrections (extraction of absolutely black bodies). In order to improve the quality of subsequent thematic processing the vector layer of fields was used as a mask for interpretation (Fig. 1.) [Myshlyakov 2012].

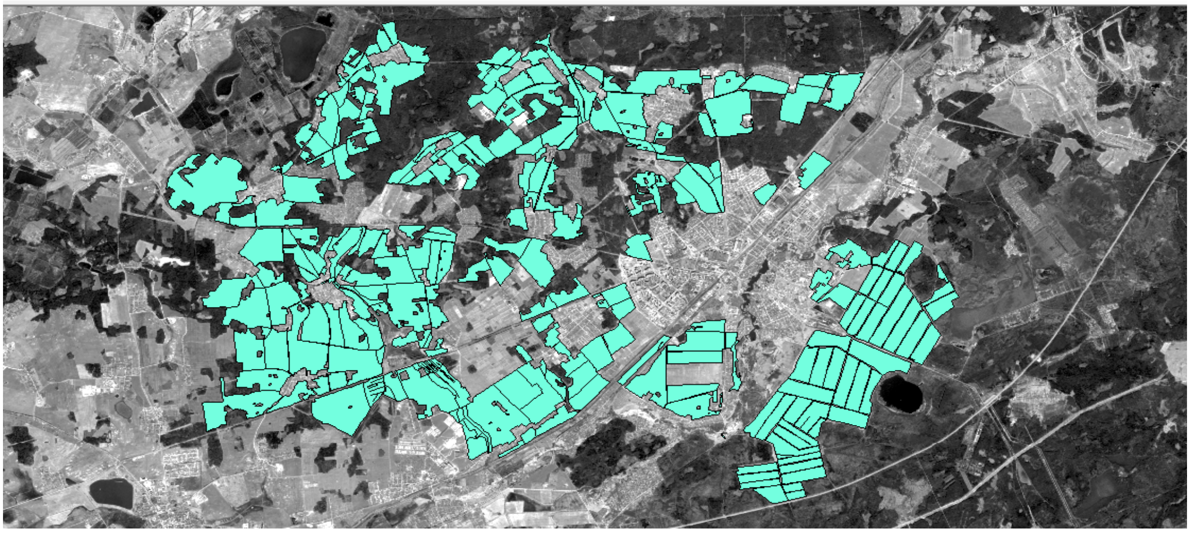

Figure 1: Vector map of observed field area

The key element of analysis is application of different spectral transformations of multispectral images in order to enhance the efficiency when recognizing the results. Spectral transformations include algebraic transformations of intensity, or reflection coefficients of multispectral satellite channels (Table 1). Three spectral indices (method of principal component, transformation Tasseled Cap, normalized difference vegetation index NDVI) were calculated in ENVI 5.2 software for three cloudless scenes of Landsat 8 (19.05, 29.07 and 14.08.2014)

Table 1: Formulae of spectral indices under analysis

Principal component	1	0,054TM2+0,130TM3+0,143TM4+0,595TM5+0,709TM6+0,321TM7
	2	-0,079TM2+0,121TM3+0,212TM4+0,787TM5+0,421TM6+0,372TM7
	3	0,230TM2+0,504TM3+0,616TM4+0,140TM5+0472TM6+0,266TM7
Tasseled Cup	1	0,304TM2+0,279TM3+0,474TM4+0,599TM5+0,508TM6+0,186TM7
	2	-0,285TM2-0,244TM3-0,544TM4+0,704TM5+0,084TM6-0,180TM7
	3	0,151TM2+0,197TM3+0,328TM4+0,341TM5-0,711TM6-0,457TM7
NDVI		(TM5-TM4)/(TM5+TM4)

Original image and spectral indices cartograms were considered as the basis for the supervised agricultural vegetation classification. For this purpose several testing sites were created for each crop. Testing sites are areas representing each known crop type that appear fairly homogeneous on the image (as determined by similarity in spectral values). They was located and circumscribed with polygonal boundaries drawn using the computer mouse on the image (Fig.2).

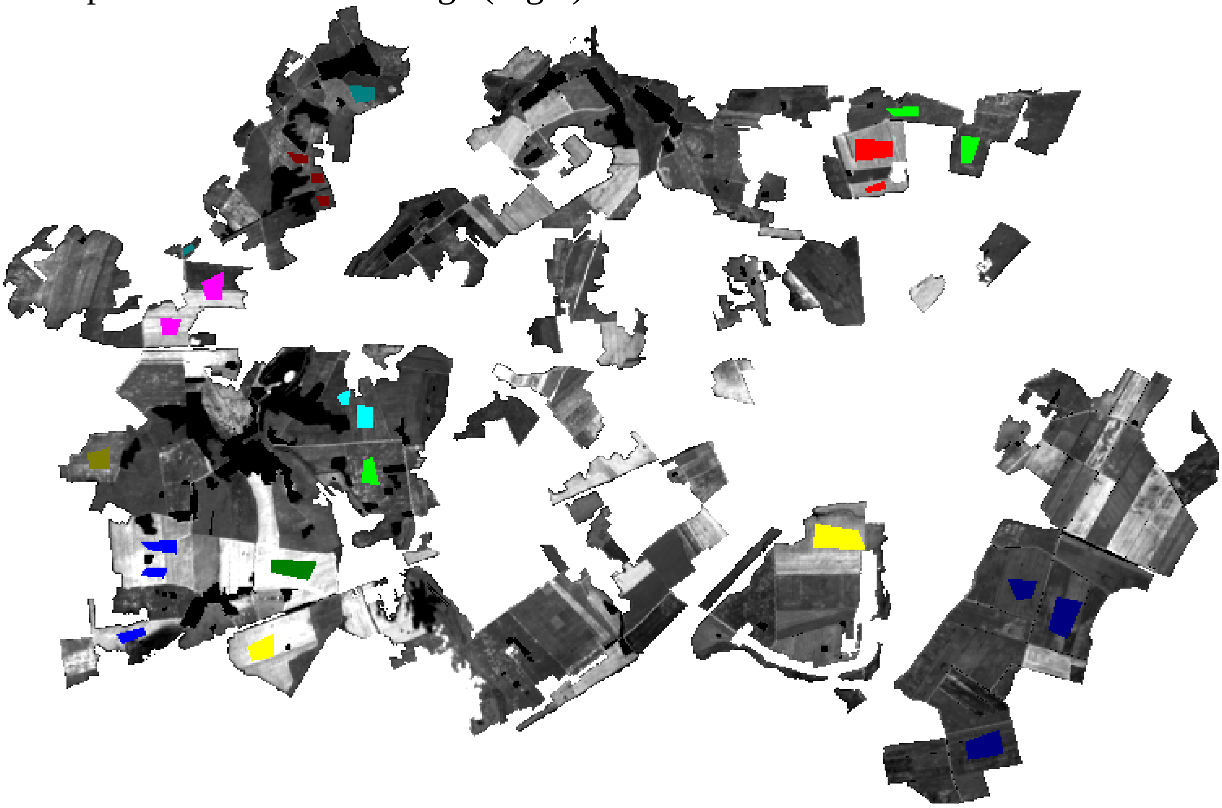

Figure 2: Testing sites location

Then three original images and indexed images were exposed to supervised classification and after that the verification of its accuracy was carried out. For the reliable comparison of index efficiency it was necessary to apply for all analyzed images the same testing sites and classification rules [Terechin 2012]. In this case the classification was carried out according to the maximum likelihood rule.

Classification accuracy was estimated as a percentage of correctly recognized fields for a particular crop. In addition, overall classification accuracy of crops shown on a picture and the value of each index were estimated according to the results of interpretation (Table 2).

As can be seen from Table 2, the overall interpretation accuracy is very high. The usage of vegetation index NDVI reduces the recognition reliability of agricultural crops. It should be noted that the classification accuracy greatly depends not only on the chosen method for spectral transformations but also on the date when satellite imagery was taken. 19/05/2014 was noted for the highest accuracy value. This is due to the fact that during this period (usually it’s late May – early June) the reflective characteristics of crops differ one from the other to the greatest extent. The imagery taken in August showed lower results. It is explained by the fact that the crop had already been gathered from the fields and soil reflective properties began to change the reflection spectrum by introducing to the spectrum their peculiarities.

Table 2: The interpretation accuracy of crops on the original picture and its spectral index cartograms (%)

index / crops	19.05.2014				29.07.2014				14.08.2014			
	Original image	NDVI	Tasseled Cup	Principal component	Original image	NDVI	Tasseled Cup	Principal component	Original image	NDVI	Tasseled Cup	Principal component
winter wheat	100	38.9	100	100	100	38.9	100	100	73.4	46.1	70.6	73.4
winter rye	100	31.5	100	100	100	31.5	100	100	85.6	25.7	84.4	85.6
triticale	99.7	32,0	99,3	99.6	99	31.9	99,3	99,6	74.0	9.76	71.7	74.0
rape	100	82.9	100	100	100	82.8	100	100	100	38.9	100	100
spring wheat	98.8	43.1	97,6	98.8	97	43.0	97,0	98,8	90.5	33.1	89.8	90.6
barley	99.6	81.4	99,6	99.6	96	81.3	98,1	99,6	69.9	22.9	69.6	70,0
oats	100	53.4	98,7	100	100	53.4	98,6	100	82.0	15.8	76.2	82.0
buckwheat	94,9	65,1	96,2	94,9	94,9	65.1	96,2	94,9	82.5	8.98	68.4	82.6
legumes	95,5	35,5	96,4	95,6	95,6	35.4	96,4	95,6	32.4	0.00	33.7	32.5
corn	100.	87.7	99,7	100	100	87.7	99,7	100	83.2	26.8	79.9	83.3
Perennial herbs	100.	93.0	100	100	100	93.0	100	100	88.2	78.2	84.3	88.3
total accuracy	93.2	64.9	94,4	94,0	90,2	62.8	91,4	91,9	77.0	35.5	75.7	77.4

Combined analysis of images in ENVI using GIS technology allowed us to get the original map of crops (based on data provided by agronomists) and a map showing the real structure of agroecosystems vegetation (Fig.3).

The variances revealed from GIS analysis are shown in Fig. 4. In this case it can be assumed that introducing crop information into “the book of history of fields” was not done accurate.

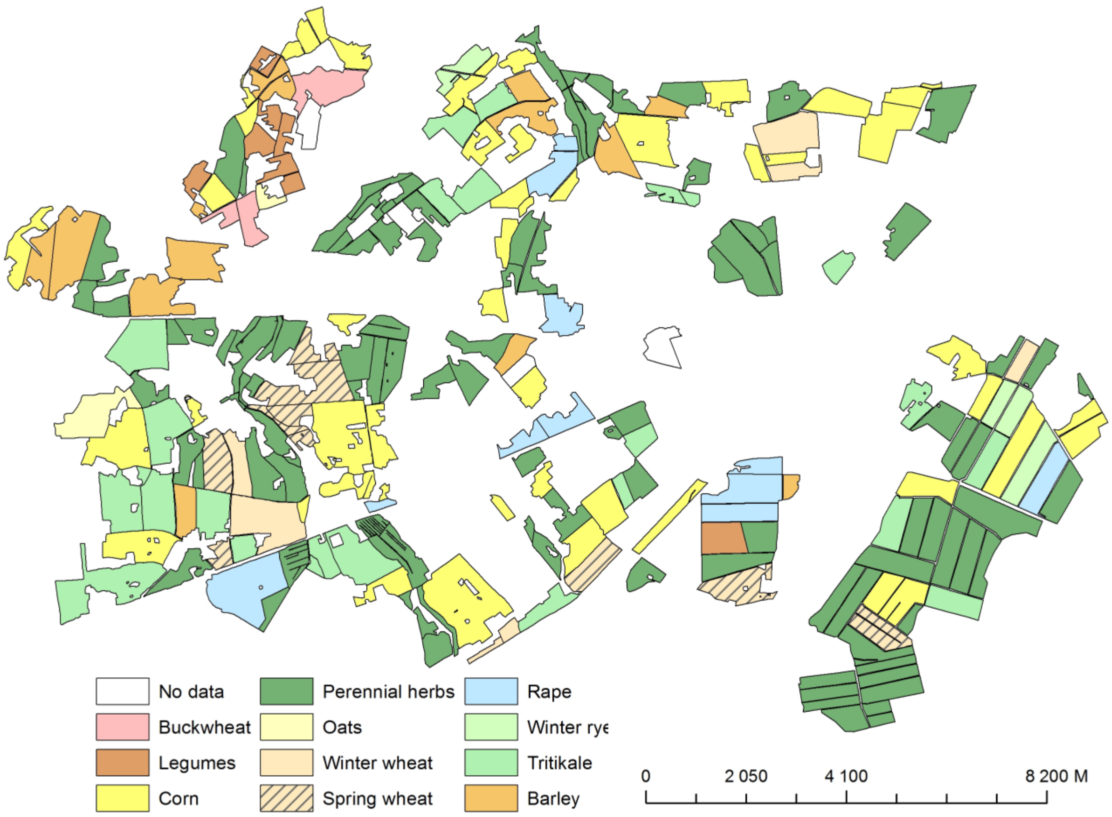

Figure 3: The map of real agroecosystem vegetation structure (based on remote sensing data)

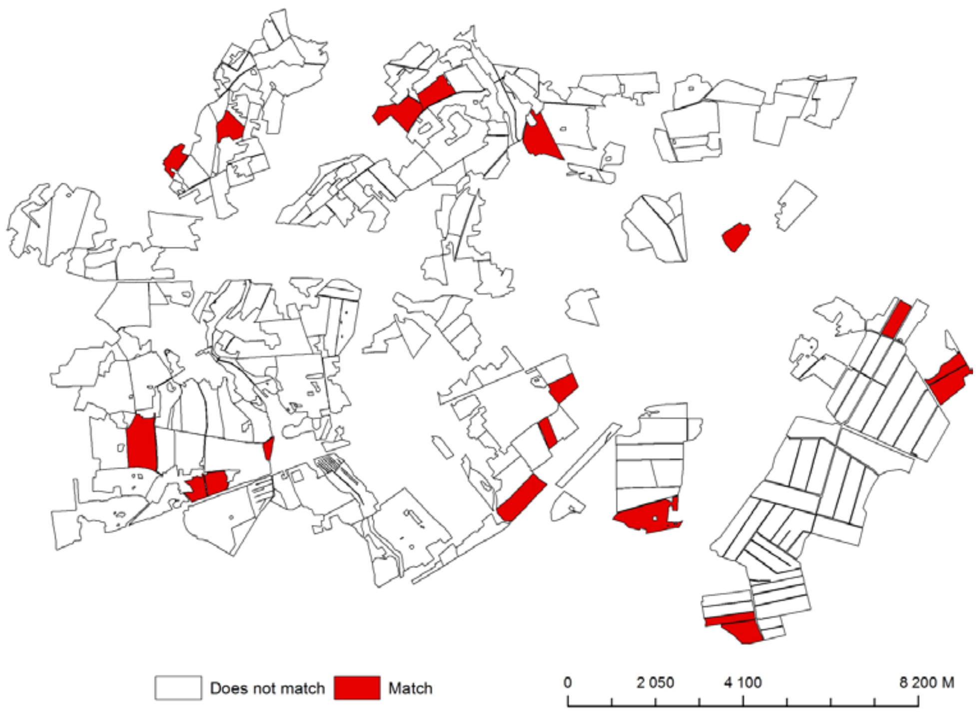

Figure 3: The map of differences between interpretation results and data provided by agronomists

CONCLUSION

Analysis confirmed that remote sensing data are the most reliable source of unbiased and objective information on agroecosystem vegetation structure. The developed approach and agroecosystem recognition peculiarities can be used for detailed interpretation of crops and analyzing the seasonal reflectance curves of vegetation indices. The availability of a series of such maps created for different years will allow providing a qualitative analysis of agroecosystems, to carry out efficient planning and land use control.

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REMOTE SENSING BASED ANALYSIS OF LAND COVER DYNAMICS IN THE POLESIE STATE RADIOECOLOGICAL RESERVE

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Commission IV, WG IV-2

KEYWORDS: automated land cover interpretation, protected areas (SPNA), geosystem dynamics.

ABSTRACT
Automated analysis (radiometric and atmospheric corrections, supervised and unsupervised classifications) of Landsat imagery was conducted. The current structure and land cover dynamics of Polesie SRR is considered in the paper. A thematic map of lands within the reserve territory was created.

1. INTRODUCTION

Global satellite data obtained from Landsat satellite system was used for geographical research on highly protected natural reserves. This also makes possible detection and estimation of changes taking place there. Advanced satellite technologies help to improve the quality of the object recognition and classification. They are also intended for analysis of natural ecosystems within vast territories (Labutina et al. 2011).

Polesie State Radioecological Reserve (PSRR) is very important area for the investigation of the modern natural landscape structure and geosystems of Belarus. The Reserve lies in south-eastern part of Belarus and occupies 216 800 hectares (it is the largest natural reserve in the country). This unique territory is not affected by the man-caused load, thus it can be treated as a reserve intended for protection of the Polesie region biodiversity in Belarus and Europe. The Reserve was created in 1988 after the Chernobyl nuclear disaster with the purpose of monitoring changes taking place in the Zone of Alienation.

2. BACKGROUND STUDIES

In addition to radiation-related problems the Reserve is facing quite a number of other problems. Land use and land cover is a very important aspect of national strategies for managing natural resources and monitoring environmental changes. Evolution processes occurring in reserve landscapes lead to serious biological and geographical changes. The reserve monitoring system created in Belarus does not meet current requirements for the efficiency and accuracy of information (Sipach et al. 2009). At the same time traditional techniques of field investigation require a lot of time and financial costs. The Reserve has a vast territory with large forest areas and almost impassable marshes. Today the area is unpopulated and has a high level of radiation.

The most informative method for land dynamics study is mapping. The most suitable solution of this problem is the application of advanced geospatial techniques of remote sensing analysis and GIS methods of digital mapping (Prakasam 2010).

3. METHODOLOGY OF AUTOMATED LAND DYNAMICS RECOGNITION

In this study were used Landsat- 5 TM (date 31. 05.1986) and Landsat -8 (date 31.07.2014) images. These data sets were imported in satellite image processing software ERDAS IMAGINE version 9.3 (Leica Geosystems, Atlanta, U.S.A.).

The main step during pre-processing was the atmospheric correction. For this purposes was used the module ATCOR (the module for computing a ground reflectance image for the reflective spectral bands, and emissivity images for the thermal bands).

Then image classification procedure is used for classification of multispectral pixels into different land cover classes. In order to find the optimal number of land classes unsupervised classification was carried out. Thereafter several testing sites (for each land class) were created. Such testing sites are areas that represent each known land type that appear fairly homogeneous on the image (as determined by similarity in spectral values). They were located and circumscribed with polygonal boundaries drawn on the image. For pixel clustering the maximum likelihood algorithm of supervised classification was used.

Algorithm based image classification techniques used for digital change detection in land cover classes gave good results. The overall digital classification was found to be satisfactory. The accuracy assessment results were obtained about 89.22 percent of overall and 0.7783 Kappa accuracy for the year 1986 while the accuracy for the year 2014 image was found about 87.72 percent overall and 0.7633 Kappa.

As a result of automated recognition six land cover classes were mapped in the Polesie State Radioecological Reserve, in particular: water areas, forest areas, thin forests, areas covered in trees and bushes, bottomland meadows and agricultural lands. In addition, the new class - wetland areas - was outlined on the images of 2014.

The classified layers were compared with Google earth high resolution images and error matrix was prepared. Mapping and analysis of land cover classes were performed in ArcGIS 9.1 software. The land cover maps obtained from image classification shown in Fig. 1, 2 for the year 1986 and 2014 respectively.

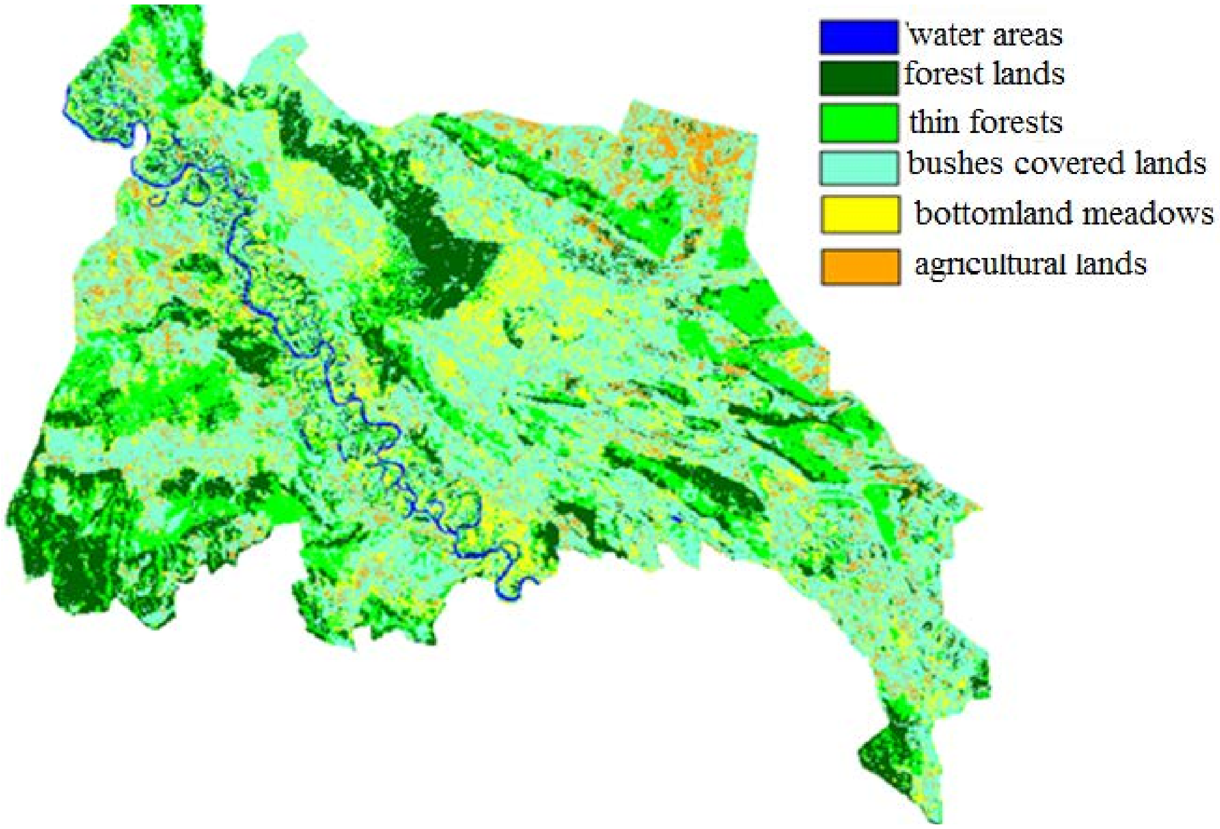

Figure 1: Map of spatial structure of land cover in 1986 (based on remote sensing, Landsat 5 TM)

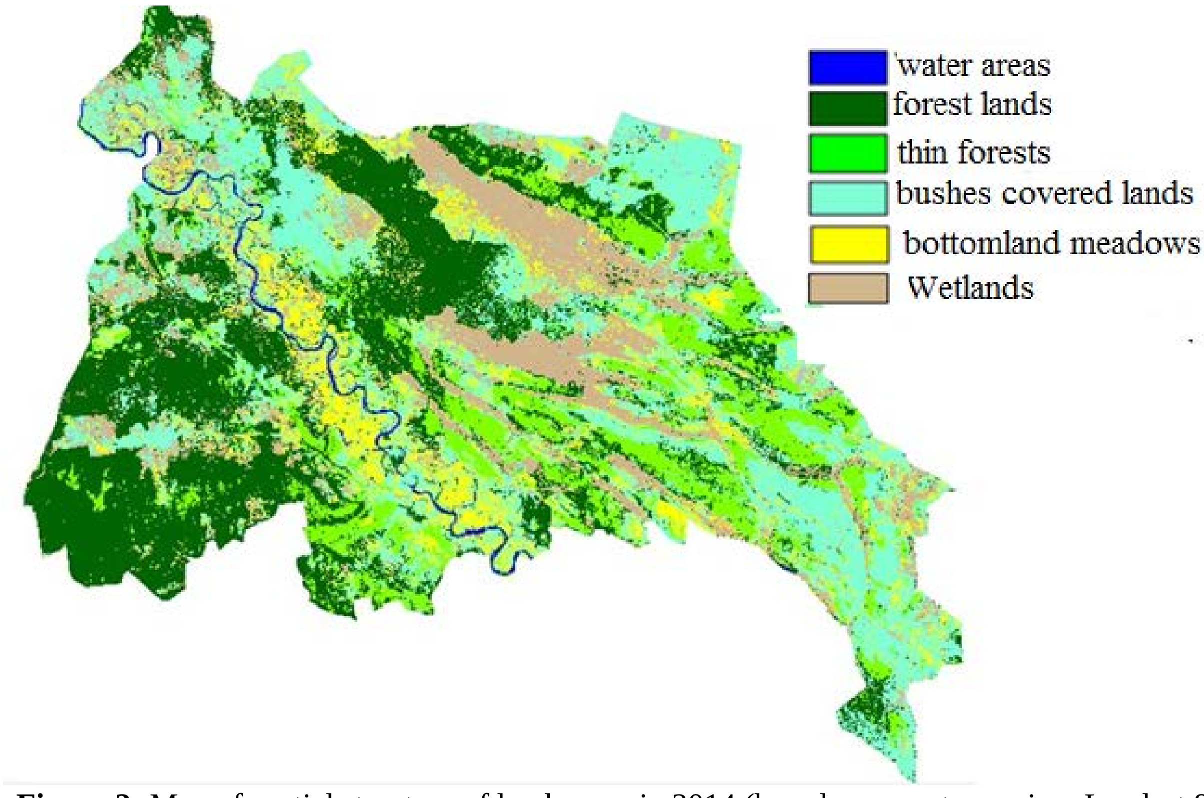

Figure 2: Map of spatial structure of land cover in 2014 (based on remote sensing, Landsat 8)

The analysis of images has led to the conclusion that during the 28 years of the existence of the Reserve large changes have occurred in the land structure. The dominant changes which occurred in the study area are the croplands dissolution. Agriculture areas degrade persistently. The forest area on the contrary has increased significantly. By the reason of reclamation systems degradation the repetitive eutrophication and areal saturation is developed. The traditional use of bottomland meadows for haying and grazing was stopped. This has caused the meadows' bushing.

4. CONCLUSION

In current research 788 we carried out mapping of different land cover types and their change detection using digital image processing techniques. The spatial pattern and land cover change detection can be successfully used in biodiversity conservation and environmental development. The study of structure and dynamics of land areas in the Polesie State Radioecological Reserve will allow foreseeing the nature of future changes and undertake all necessary measures to prevent further losses during the highly dangerous occurrences (e.g. fires). Integration of GIS-technologies with remote sensing allow developing strategies to improve the efficiency of undertaken economic, environmental and monitoring measures.

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GEOBOTANICAL MAPS IN THE ATLAS "GREATER ALTAI: NATURE, HISTORY, CULTURE"

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KEYWORDS: geobotanical map, map of land cover, map of land community types; map of vegetation degradation; map of plant community dynamics; map of disturbances in plant communities, Great Altai, the atlas "Great Altai: nature, history, culture".

ABSTRACT

Atlas "Great Altai: Nature, History, Culture" is an interdisciplinary unique cartographic model that is being developed by an international team of scientists. The main objective of the Atlas is to ensure the maximal possible access of the international community to reliable, current, and accurate spatial information on the transboundary Great Altai region for its effective development. Section "Nature" will contain the spatio-temporal information about the natural conditions, economic impact on the natural environment, and environmental quality in Great Altai in the beginning of XXIth century.

The atlas "Great Altai: nature, history, culture" is created as an international mapping project of the four states: Russia, China, Mongolia and Kazakhstan. Atlas is an interdisciplinary unique cartographic model that is being developed by an international team of scientists. The main objective of the Atlas is to ensure the maximal possible access of the international community to reliable, current, and accurate spatial information on the transboundary Great Altai region for its effective development. Systemic integrity of the Atlas content and coherence of the maps are be provided by creating the Atlas-GIS.

The structure, content, and thematic division of the Atlas are currently at the stage of development and coordination. The title of the main Atlas sections corresponds to the names of the Atlas title: Nature, History, and Culture. These sections will be preceded by the introductory section. This section will contain geographic information on the country borders and the near-border administrative-territorial divisions – the subjects of Great Altai, and satellite imagery of the region.

Section "Nature" will contain the spatio-temporal information about the natural conditions, economic impact on the natural environment, and environmental quality in Great Altai at the beginning of XXIth century. The environmental quality is considered as a result of economic, social, and cultural development of near-border administrative-territorial entities of the four countries located within the Altai mountain system. Section “Nature” will have three major subsections: Natural conditions; the impact of economic activity on the environment; sustainable territorial development; protection and optimization of natural environment.

The maps included into the section “Natural conditions” will have three major topics: Landscapes. Ecological Potential of Landscapes. Climatic division into districts. Comfort of climate. Hydrological areas. Glaciers and mudflows. Permafrost: distribution, temperature, power. Seasonal frost penetration and thawing. Types of plant communities. Land cover changes. Disturbances in plant communities.

The atlas “Great Altai: nature, history, culture” includes the following geobotanical maps:

- Vegetation types
- Land cover degradation
- Disturbances in plant communities.

A systematic (geosystems) approach to study the organization of ecosystems’ plant community components, with basic theoretical positions laid in the works by V.B. Sochava provide high ecological information richness of maps. They contain information about environmentally relevant geographical factors that determine the structure and vegetation dynamics at different levels of its organization, the dynamic and environmental potential of the area occupied by specific plant taxa, and much more.

The diversity and features of the subject scope were defined for each group of maps.

Geobotanical maps reflect the ecological and resource potential of a territory - a number of conditions and resources of the environment (geosystems, region), which ensures the existence of a human and is essential for his business activity.

The maps being created fall into the category of evaluation maps. They are based on the information of inventory maps and characterize the compliance of natural environment states and conditions with certain (specified) criteria or standards.

The central position occupied by vegetation maps in the Atlas “Greater Altai: nature, history, culture”, results from the fact that it is vegetation which largely determines the ecological state of a territory. Although there are other biogeographical maps of great scientific and practical importance aimed at solving ecological and geographical problems.

Vegetation dynamics, its variability under the influence of internal and external factors, on the one hand, provides a variety of forms for its coenotic organization and types of connections and relationships with the living environment, including anthropogenic factor here; on the other hand - it is a condition of its evolution occurring in close connection with the historical development of the entire landscape and geographical environment.

In the application context the cartographic study of vegetation stabilizing function is important to identify the stability limits of biotic communities to natural, and especially, to anthropogenic factors. Potential assessment of anthropogenic stability of vegetation within natural complexes of different taxonomic rank allows normalizing the anthropogenic influence to prevent the development of irreversible destructive processes in natural complexes, which is necessary for forecasting and recommendation development within the ecological and geographical works.

Within the system of ecological and geographical assessments of vegetation the central position is given to identifying and assessing various aspects of its complex and diverse geosystem-forming functions – productional, stabilizing, regulatory, protective, etc. - and determining its role in development and operation of many processes and phenomena.

The peculiarities of vegetation mapping are determined primarily by modern concepts of the systemic nature of its organization as an integral part and the most important component of landscape and geographical environment, largely determining its development and spatial differentiation

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