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SIBERIAN STATE UNIVERSITY OF GEOSYSTEMS AND TECHNOLOGIES (SSUGT)
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ISPRS WG IV/2 Workshop

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

21 April 2016
Novosibirsk, Russian Federation

Proceedings

2016

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The ISPRS Workshop WG IV/2 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 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”

Since more than a decade the Siberian State University of Geosystems and Technologies (SSUGT) or its predecessor Siberian State Academy of Geodesy (SSGA) organized the largest geospatial exhibition event in the Russian Federation with a large international participation. Through this interchange SSUGT soon became involved in international scientific exchanges carried out by international scientific organizations in the geoinformatics disciplines, such as the International Federation of Surveyors (FIG) and the International Cartographic Association (ICA). For Photogrammetry and Remote Sensing, represented by ISPRS, it became possible in 2005 to reestablish the excellent relations with Russian scientists existing from 1980 to 1984, when Prof. Ivan T. Antipov of the former NIIGAiK was Vice President of ISPRS. In 2012 at the ISPRS Congress in Melbourne, Australia, Prof. Vladimir Seredovich was elected as chair of the ISPRS Working Group IV/2 with Argina Novitskaya as Secretary. They organized two successful ISPRS workshops in Novosibirsk at the Interexpo GEO- Siberia 2013 and 2015. Prior to the ISPRS Congress in Prague in July 2016 the ISPRS Workshop in 2016 offers the possibility for a target oriented review for the future international activities in global mapping efforts. The Russian Federation is the largest country in the world in which mapping and satellite remote sensing make an important contribution to economic development and environmental protection. Therefore, ISPRS appreciates the organization of the third ISPRS Workshop 2016 and the participation of Russian scientist in this global effort.

Em. Prof. Gottfried Konecny
Leibniz University Hannover, Germany
ISPRS WG IV-2 Vice Chair

THE STATUS OF TOPOGRAPHIC MAPPING IN THE WORLD A UNGGIM - ISPRS PROJECT 2012 – 2014

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KEY WORDS: status of topographic mapping, map data coverage, UNGGIM - ISPRS Project, map updating

ABSTRACT
In December 2011 UNGGIM initiated a cooperative project with ISPRS to resume the former UN Secretariat studies on the status of topographic mapping in the world conducted between 1968 and 1986. After the design of a questionnaire with 27 questions, the UNGGIM Secretariat sent the questionnaires to the UN member states. 113 replies were received from the 193 member states and other regions the 51 non-member countries and territories. Regarding the global data coverage and age the UN questionnaire survey was supplemented by data from the Eastview database. For each of the 27 questions an interactive viewer was programmed permitting the analysis of the results. The authoritative data coverage at the various scale ranges has greatly increased between 1986 and 2012. Now a 30% 1:25 000 map data coverage and a 75% 1:50 000 map data coverage has been completed. Nevertheless there is still an updating problem as date for some countries are 10 to 30 years old. Private Industry with Google, Microsoft and Navigation system providers has undertaken huge efforts to supplement authoritative mapping. For critical areas on the globe MGCP committed to military mapping at 1:50 000. ISPRS has decided to make such surveys a sustainable issue by establishing a working group, which also will enlarge its scope toward global land cover mapping.

1 ORIGINS OF THE PROJECT

In 1986 the Department of Technical Cooperation for Development of the United Nations Secretariat has completed the last survey on the “Status of World Topographic and Cadastral Mapping”. The results of the survey were published by the United Nations, 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	11 countries	17 territories

Antarctica was not included in the survey.

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:

	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%	95.7%
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:

	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 1986	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%

Since the last survey in 1986 considerable progress has been made in data coverage:

	range I	range II	range III	range IV
2012 map coverage	33,5%	81.4%	67.5%	98.4%

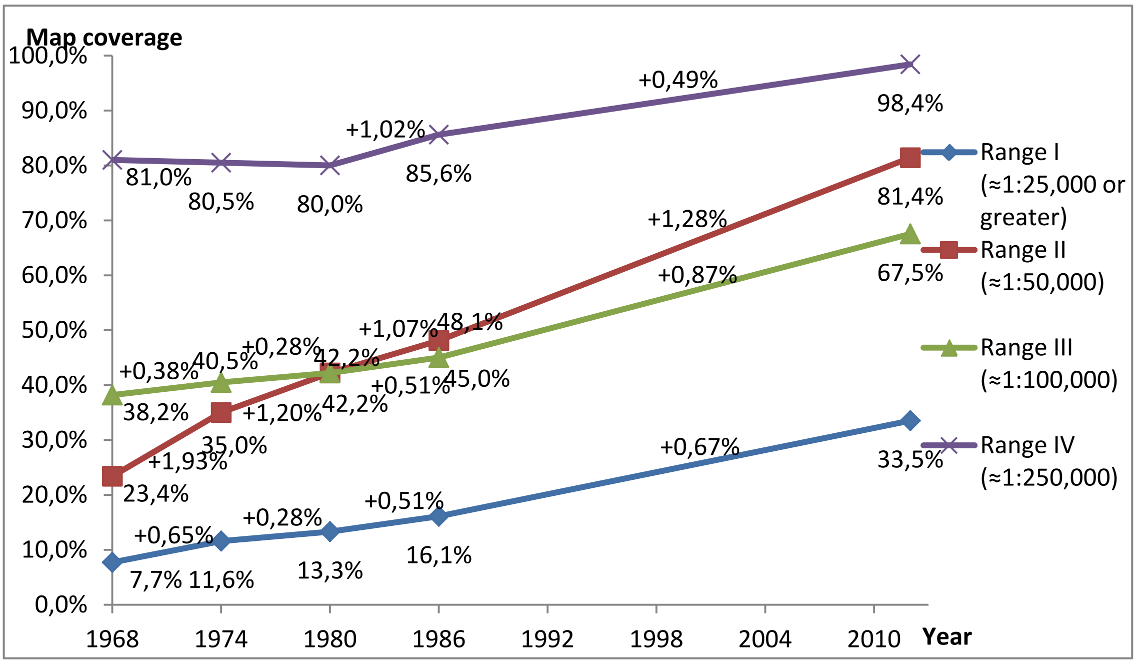


Chart 1: Percentages of total world area covered in each scale category, 1968-1974-1980-1986-2012

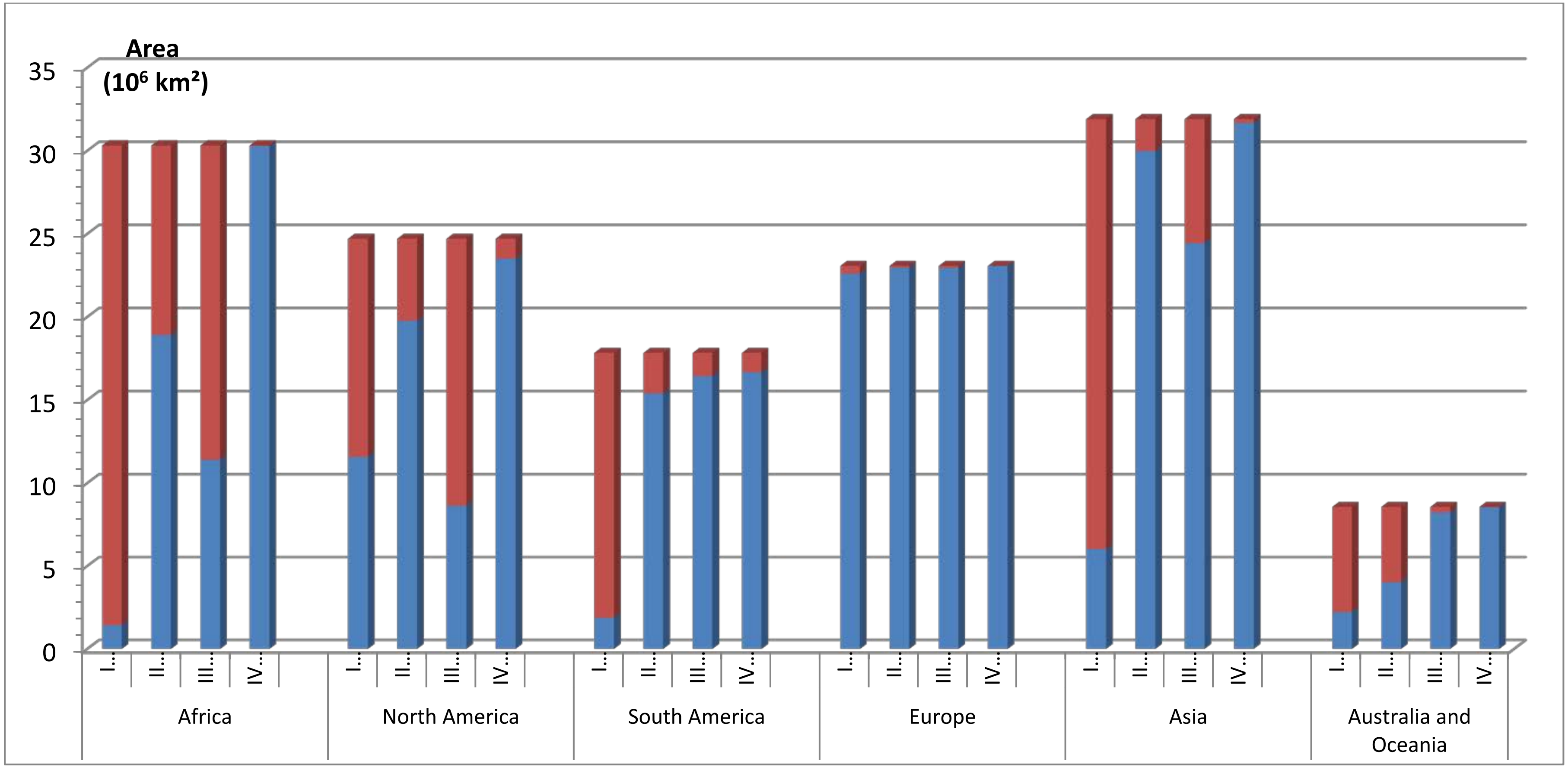


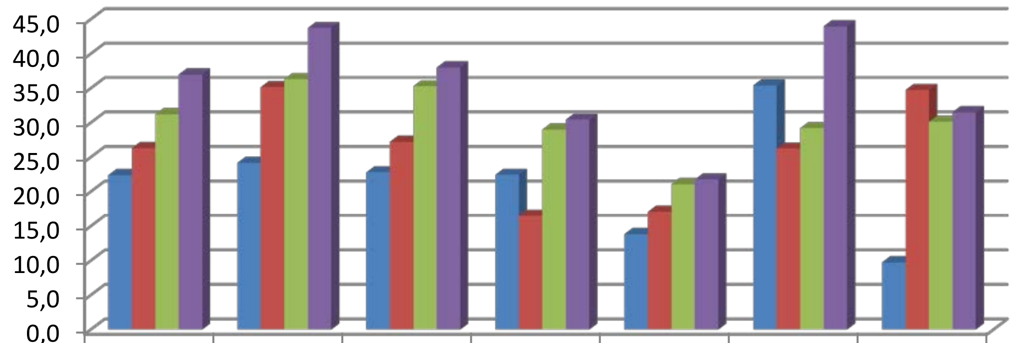
Chart 2: Area covered by topographic mapping on four scale ranges, by geographical region, 2012

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 1986	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.

	range I	range II	range III	range IV
update rate 2012				



	Global	Africa	Asia	Australia and Oceania	Europe	North America	South America
Range I	22,4	24,2	22,8	22,4	13,8	35,4	9,8
Range II	26,3	35,1	27,2	16,5	17,1	26,3	34,7
Range III	31,2	36,3	35,3	29,0	21,1	29,2	30,1
Range IV	37,0	43,7	38,0	30,4	21,8	44,0	31,5

Chart 3: Average map age in years counting from 2012

Other aspects of the surveys conducted in 1980 were directed toward the existence of geodetic networks and their density. In 1980 there existed 3.67M horizontal and 3.16M vertical control monuments on the globe, but again their density varied from 2.66km^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.
Today the GNSS technology makes control point densities irrelevant, except for the case, when old map data need to be referenced to a global datum.
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.

Again, the availability of geodetic instrumentation is not of essence to judge progress any more.
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.
The financing of geospatial information is a very complex issue. To track progress these tasks should now be transferred to another UNGGIM Working Group.
The rather inaccurate and inconclusive results of 1986 may have discouraged the UN Secretariat in continuing the past 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 UNRRCC 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
- 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
- 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. Paul 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 they were placed in a database designed by Uwe Breitkopf for further analysis.

3 THE QUESTIONNAIRE

The jointly designed questionnaire consists of five parts including 27 Questions:

- PART A: Background Information
- PART B: National Topographic Mapping Coverage
- PART C: National Imagery Acquisition
- PART D: National Surveying and Cadastral Coverage
- PART E: Organization

See Appendix I for the original Questionnaire.

Until March 13, 2015 altogether 113 responses have been received from 193 UN member states. In addition, there are 51 non-UN member countries and territories, which are also covered by map data. These map data for 244 UN member states and regions were generated in UN member states, but these have in general no direct responsibility for mapping these territories.
Figure 1 shows the 113 UN Member States, which have answered the UNGGIM-ISPRS questionnaire.

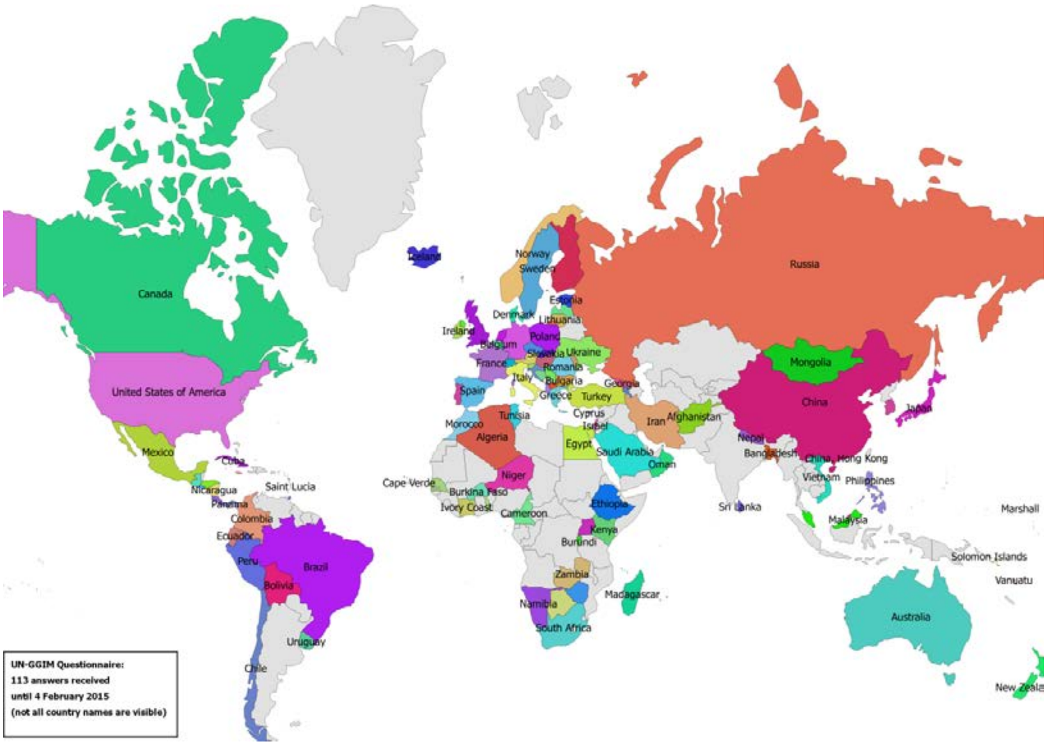


Figure 1: 113 countries have replied the Questionnaire until February 2015

4 CONTENT OF THE DATABASE

While not all of the 27 questions need to be answered globally, this is, however, important for questions 1 and 2, since they characterize the global data coverage at the different scale ranges and their 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.

Regarding question 1 Figure 2 to Figure 5 show the global coverage in the scale ranges 1:25 000 or greater, 1:50 000, 1:100 000 and 1:250 000.

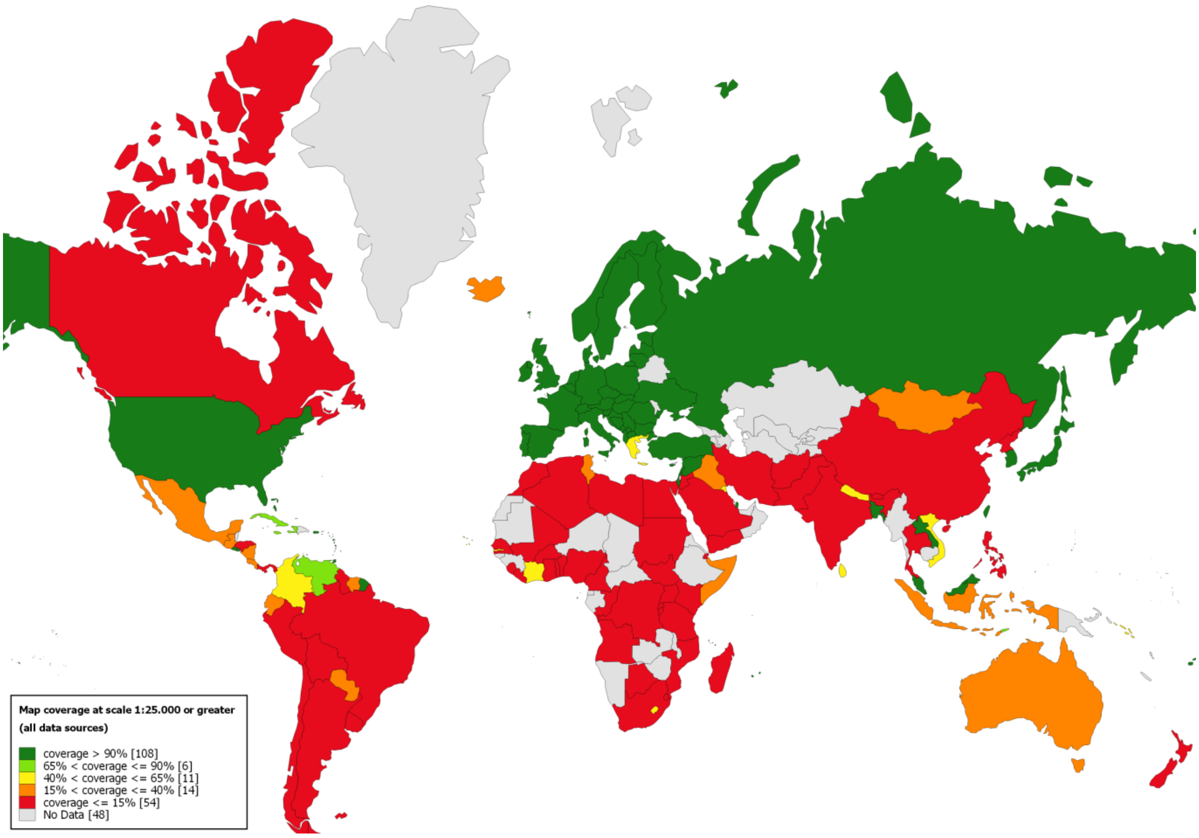


Figure 2: Map coverage at scale 1:25 000 or greater

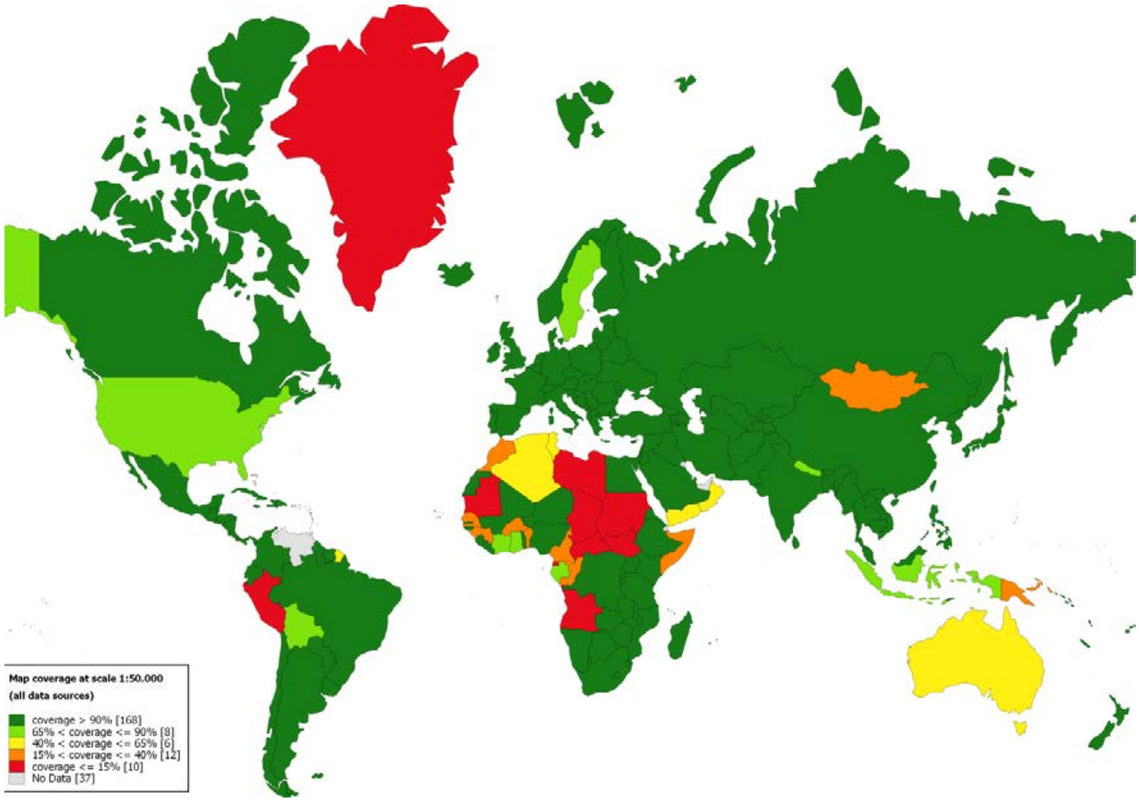


Figure 3: Map coverage at scale 1:50 000

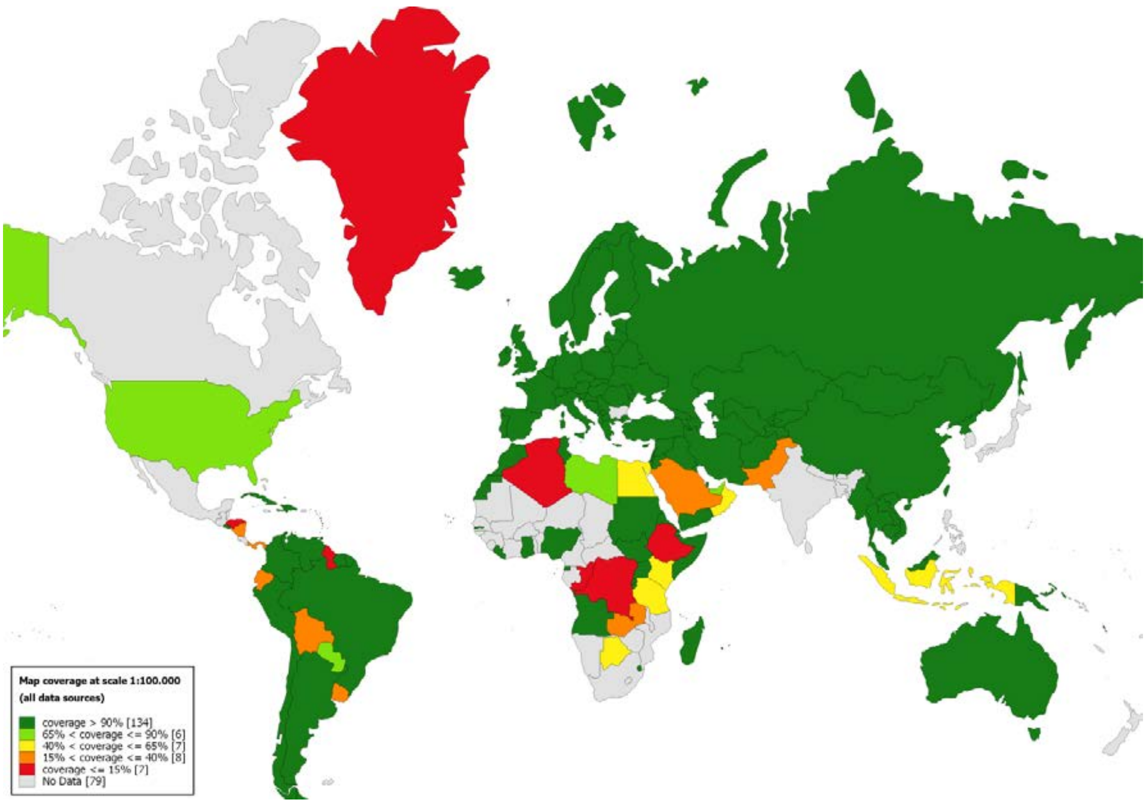


Figure 4: Map coverage at scale 1:100 000

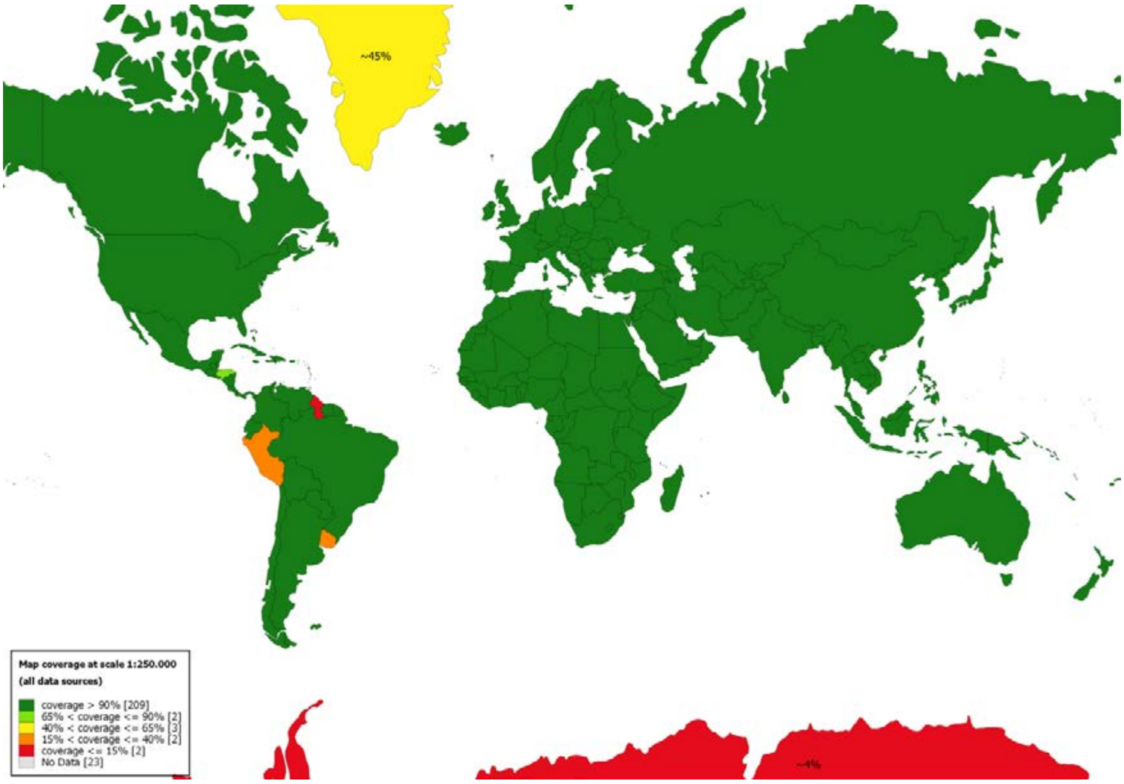


Figure 5: Map coverage at scale 1:250 000

Chart 1 and Figure 6 to Figure 9 give the source of the metadata information for Figure 2 to Figure 5. This answers question 1.

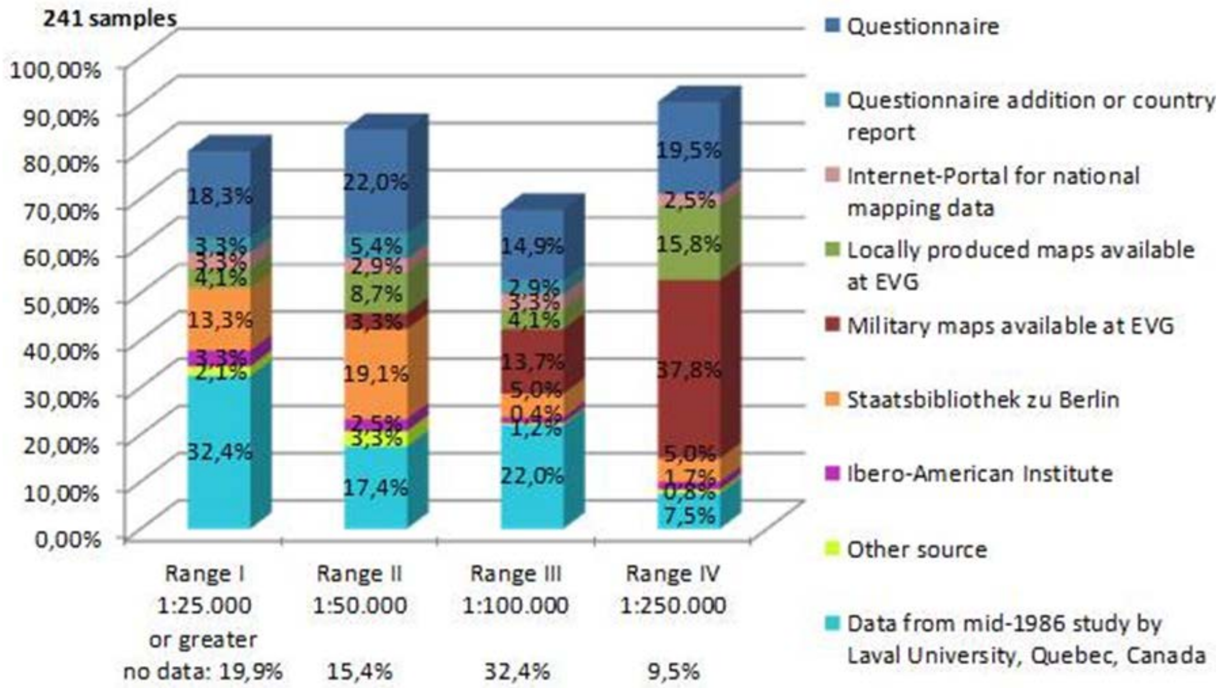


Chart 4: Data source for coverage per scale category

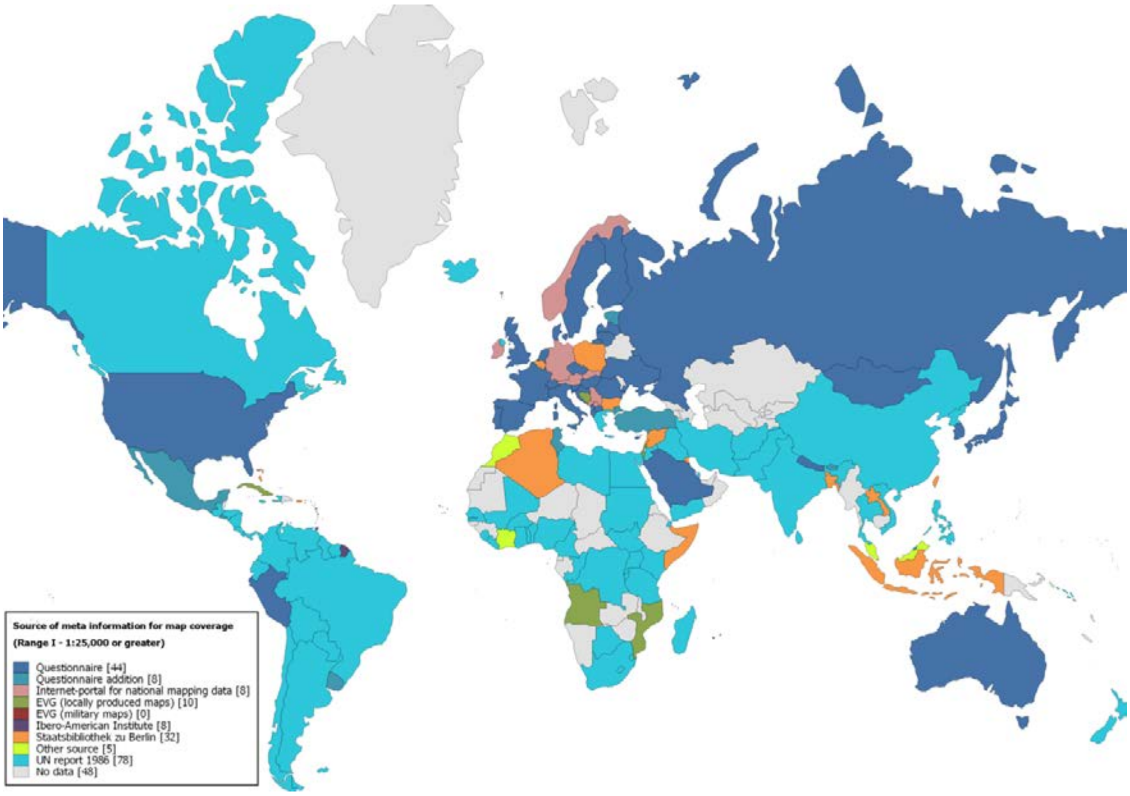


Figure 6: Source of meta information for map coverage in range I - 1:25 000

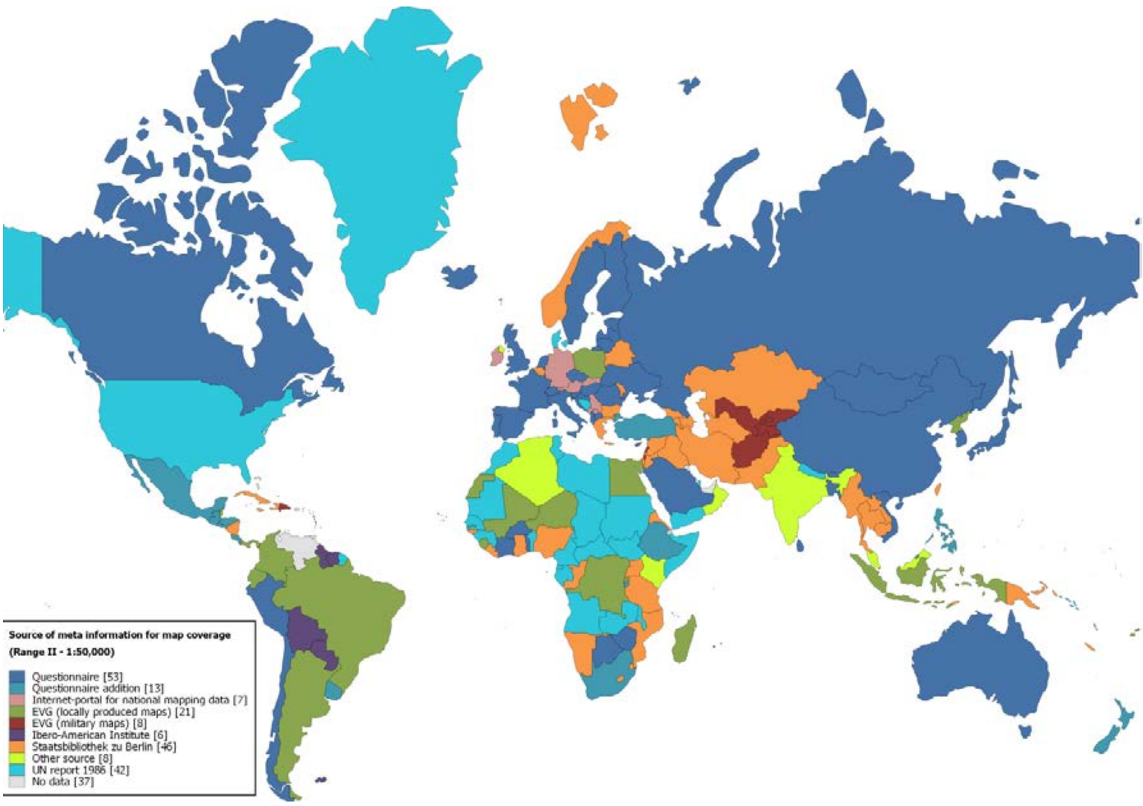


Figure 7: Source of meta information for map coverage in range II - 1:50 000

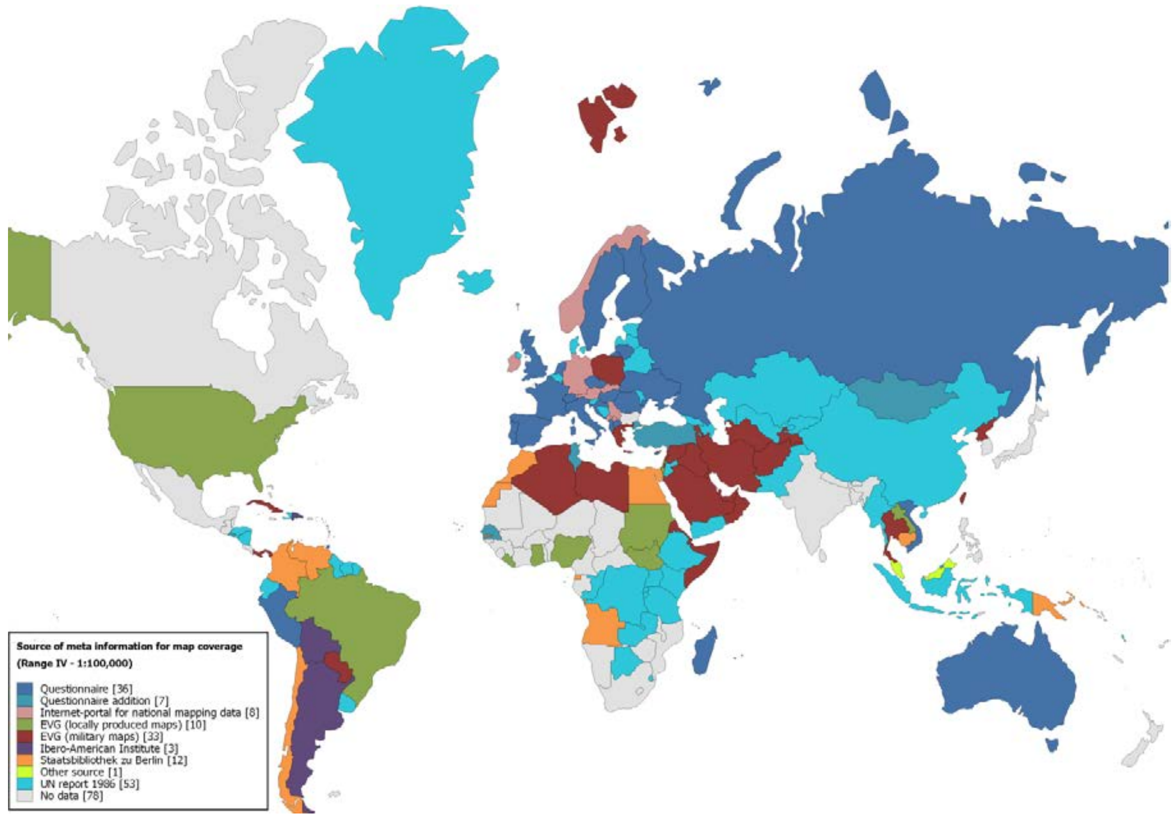


Figure 8: Source of meta information for map coverage in range III - 1:100 000

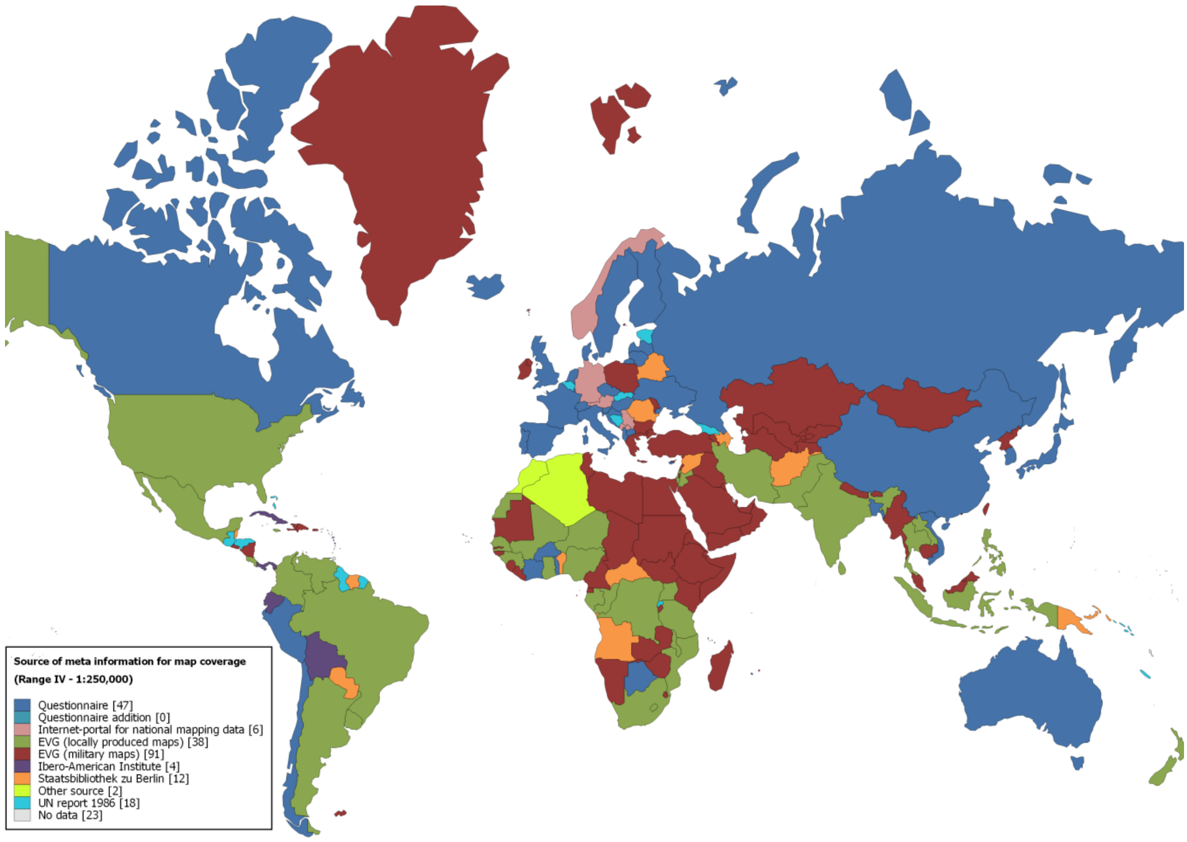


Figure 9: Source of meta information for map coverage in range IV - 1:250 000

Figure 6 to Figure 9 shows the equivalent data to Figure 2 to Figure 5 for the year 1986, depicting the huge progress made through technology from 1986 to 2012. Also Figure 14 highlights the change in map coverage between 1986 and 2012.

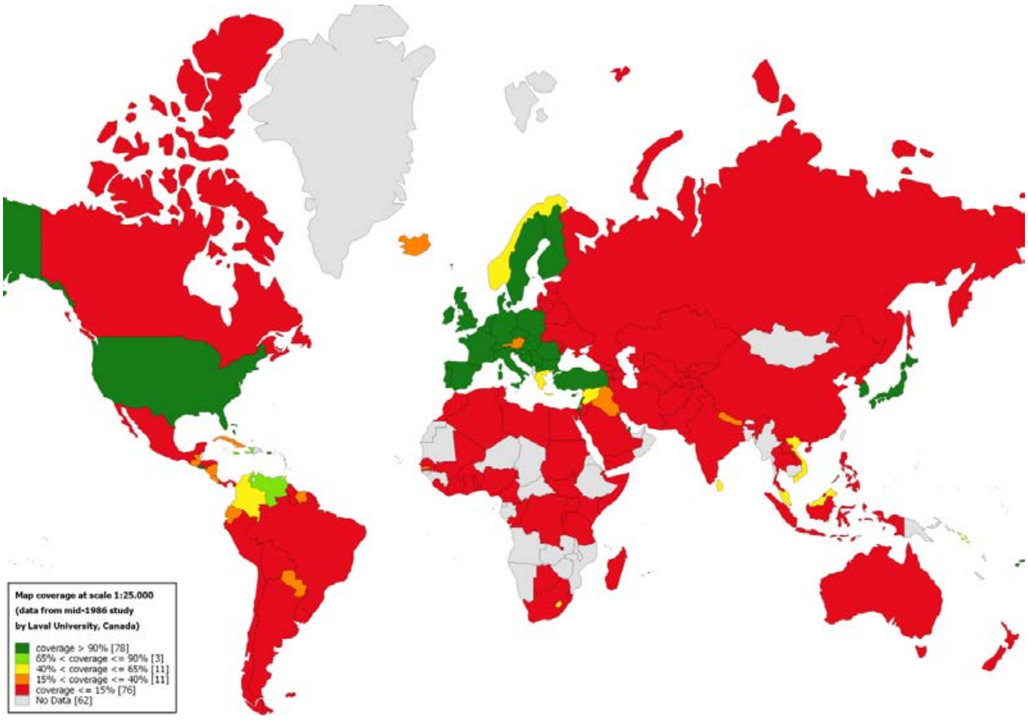


Figure 10: Map coverage 1986 at scale 1:25 000 or greater

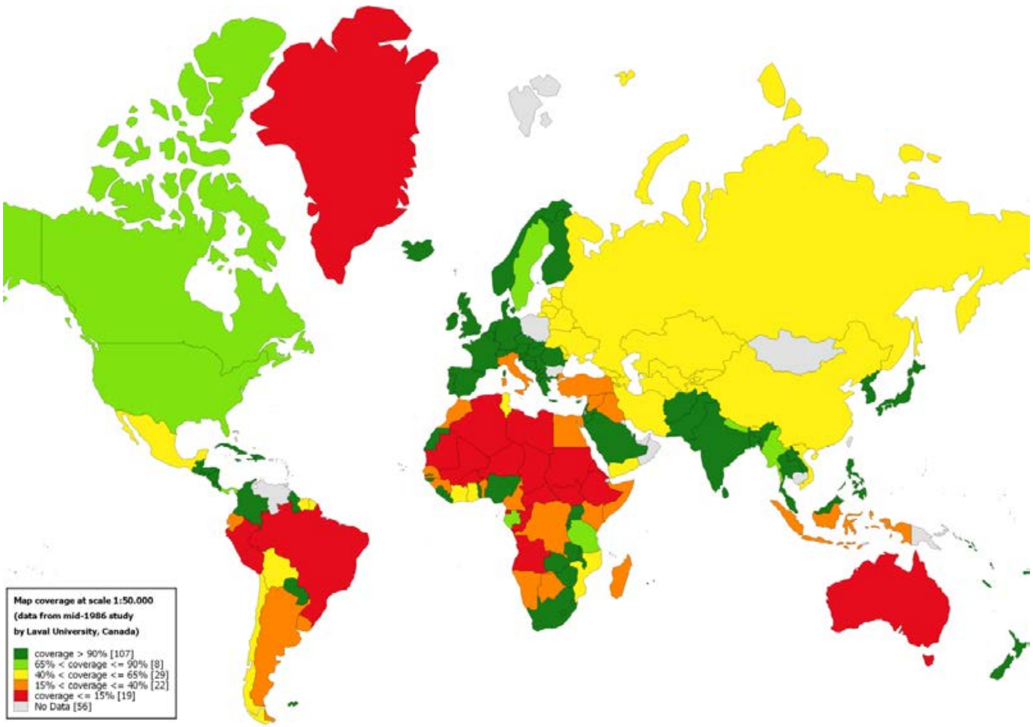


Figure 11: Map coverage 1986 at scale 1:50 000

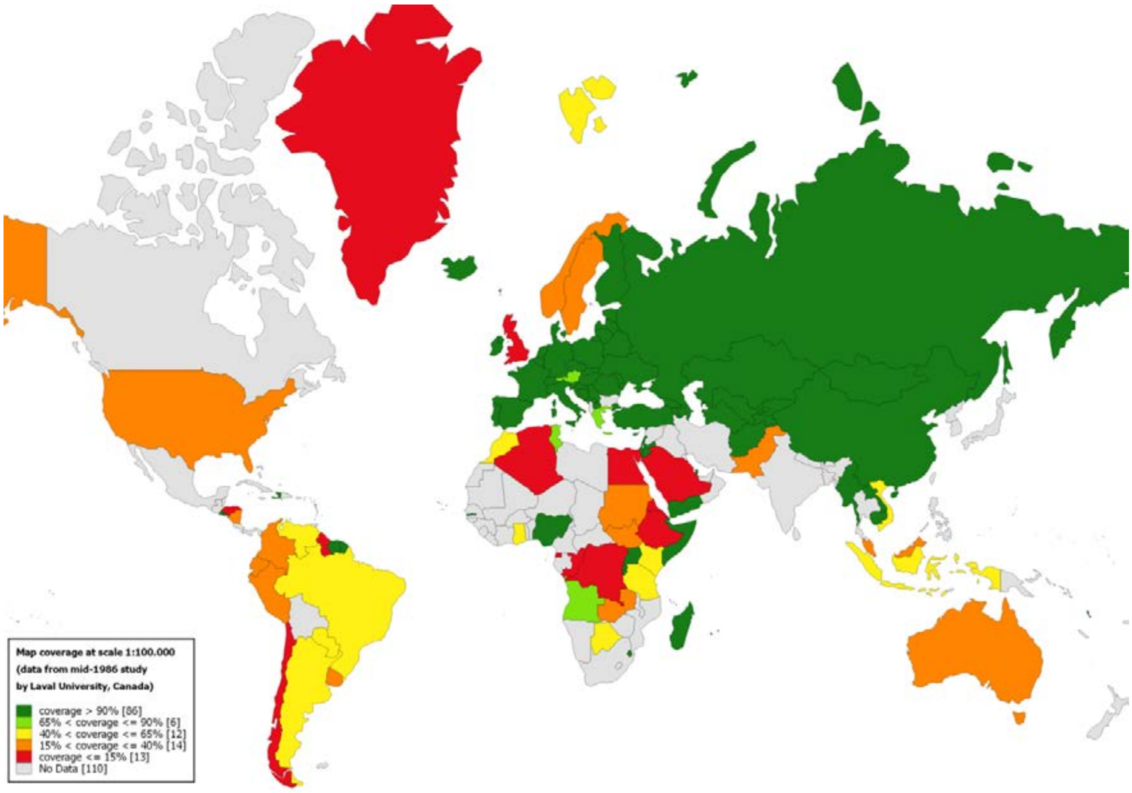


Figure 12: Map coverage 1986 at scale 1:100 000

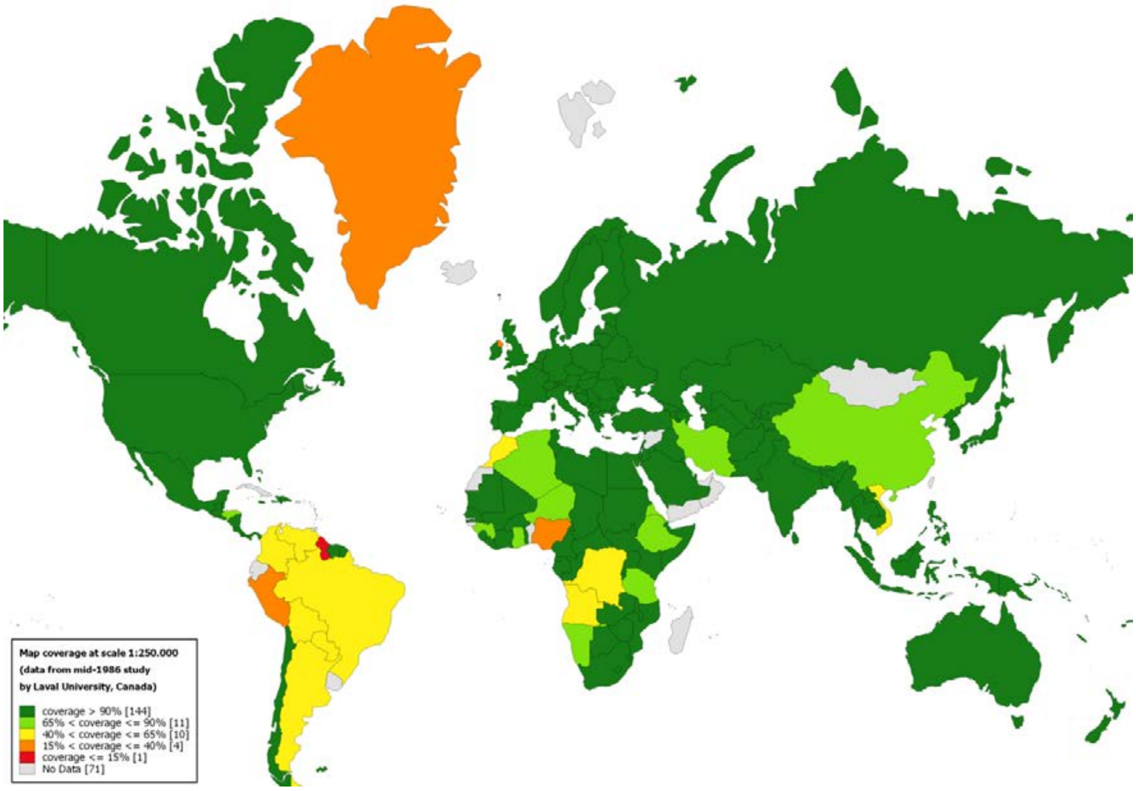


Figure 13: Map coverage 1986 at scale 1:250 000

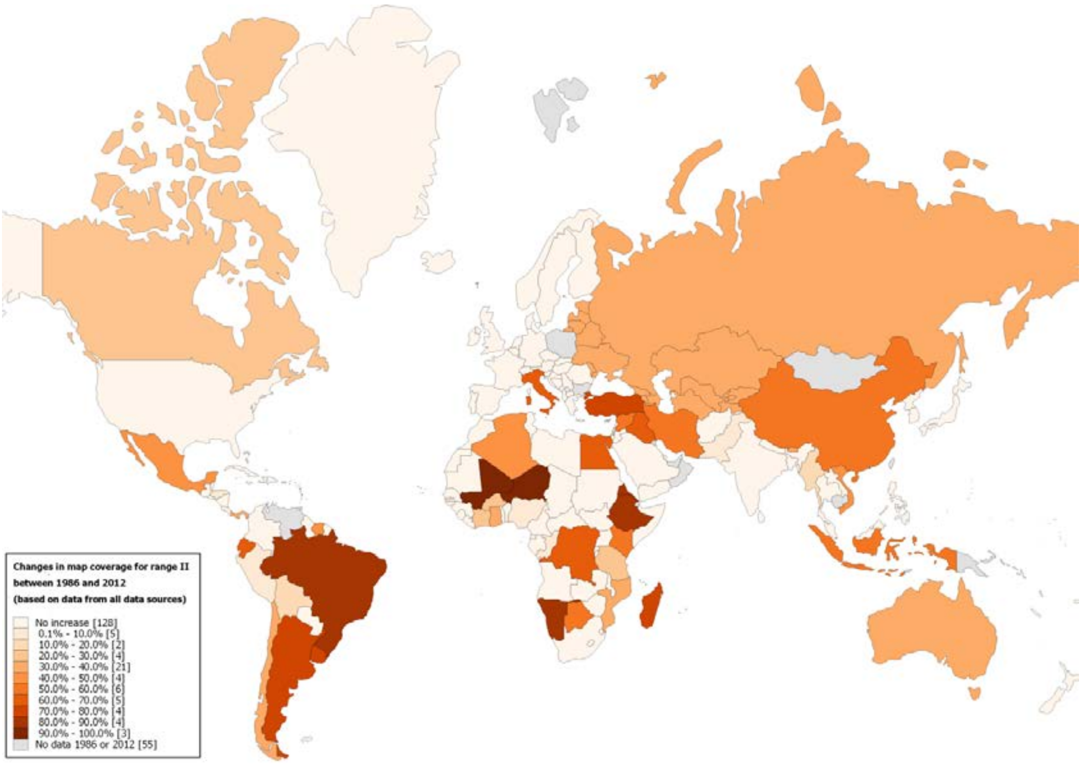


Figure 14: Change in map coverage between 1986 and 2012 for range II - 1:50 000

This answers question 2 at least in part.

The other 25 questions characterize the general global infrastructure for provision of map data. Figure 10 to Figure 30 give answers to most of the questions 3 to 27.

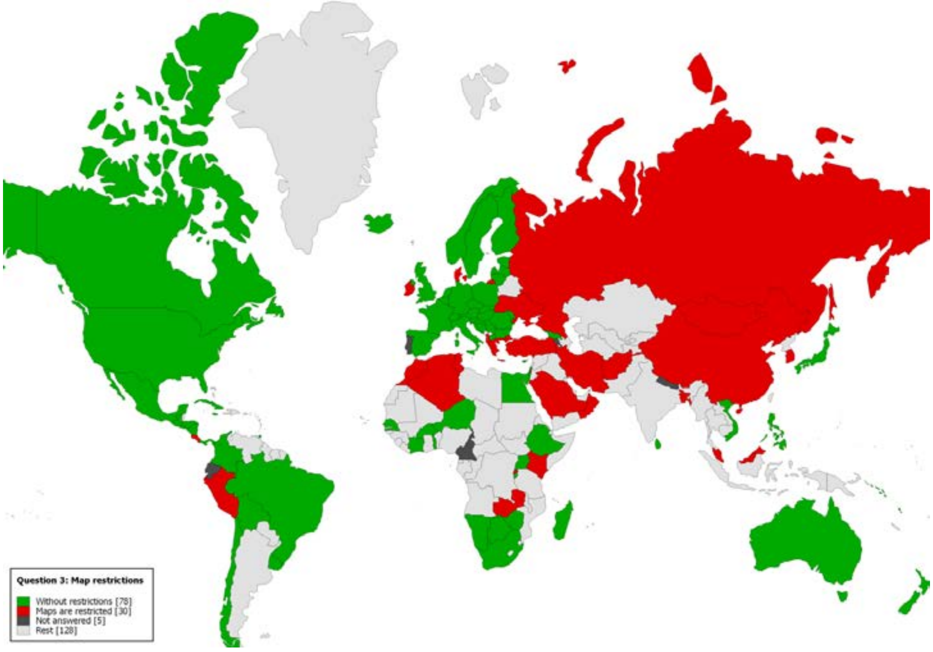


Figure 15: Question 3. Restricted access or limited circulation to maps and/or data

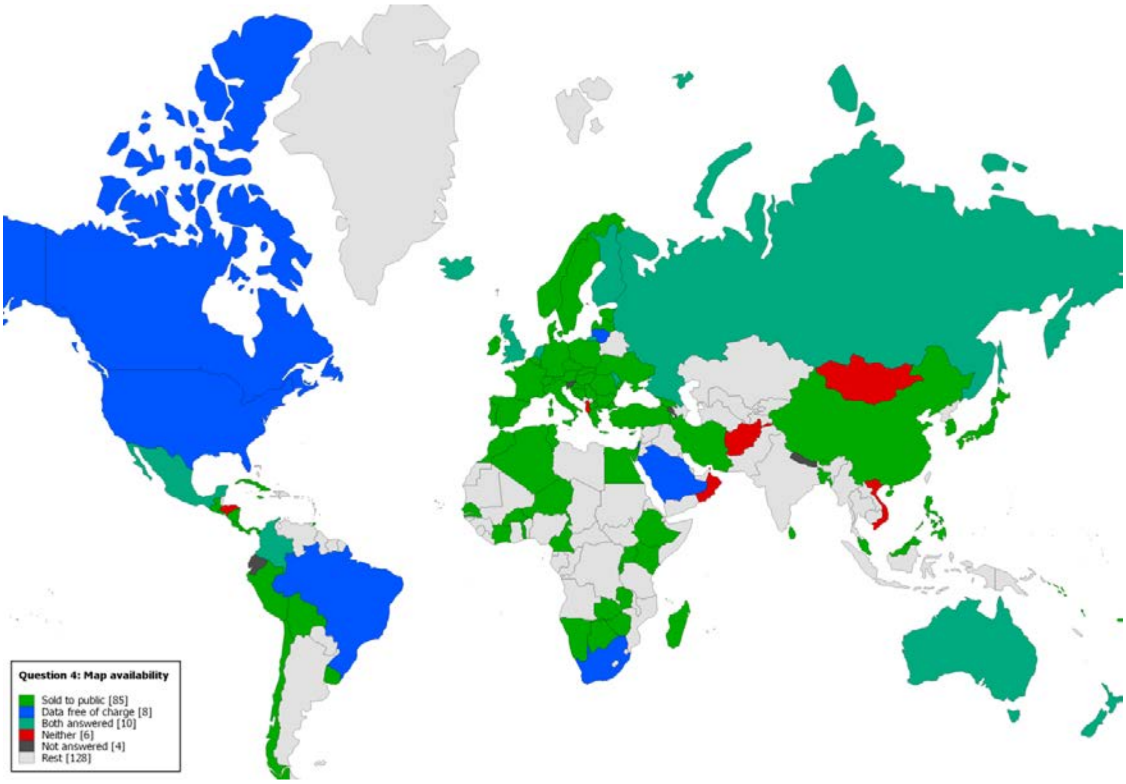


Figure 16: Question 4. Maps and/or digital data sold to the public or data free of charge

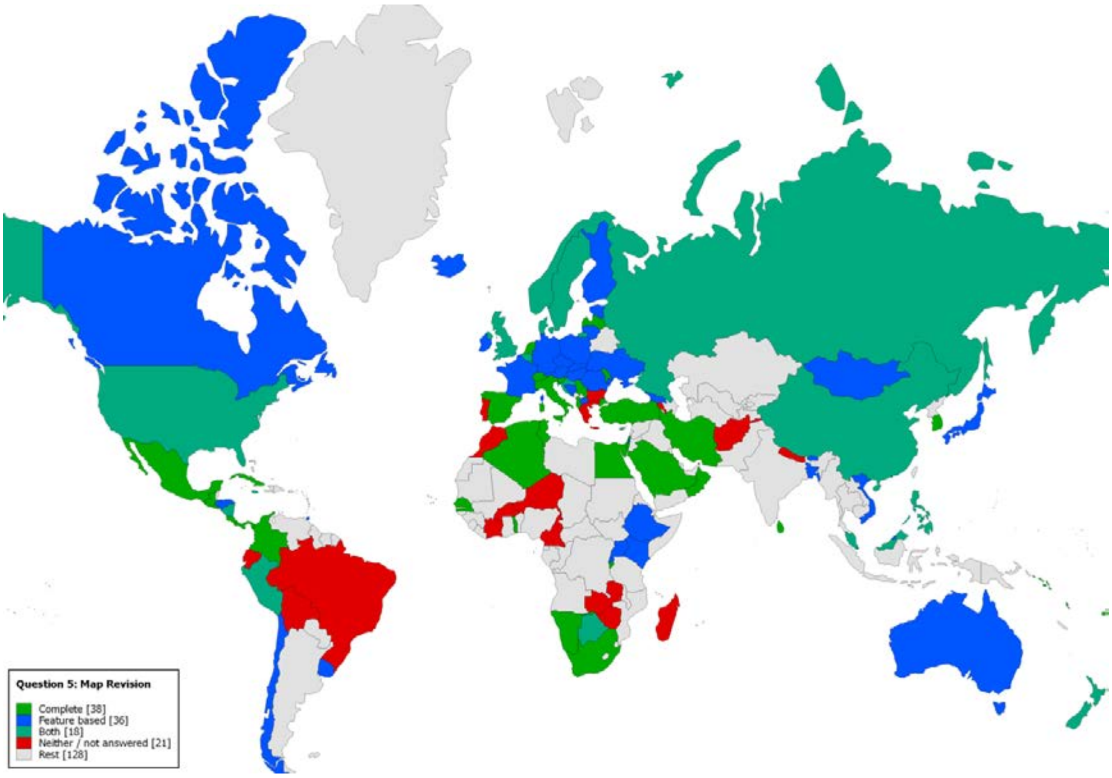


Figure 17: Question 5. Cycle of map and data revision by complete mapping, i.e. revision of a national series or mapping of changed features

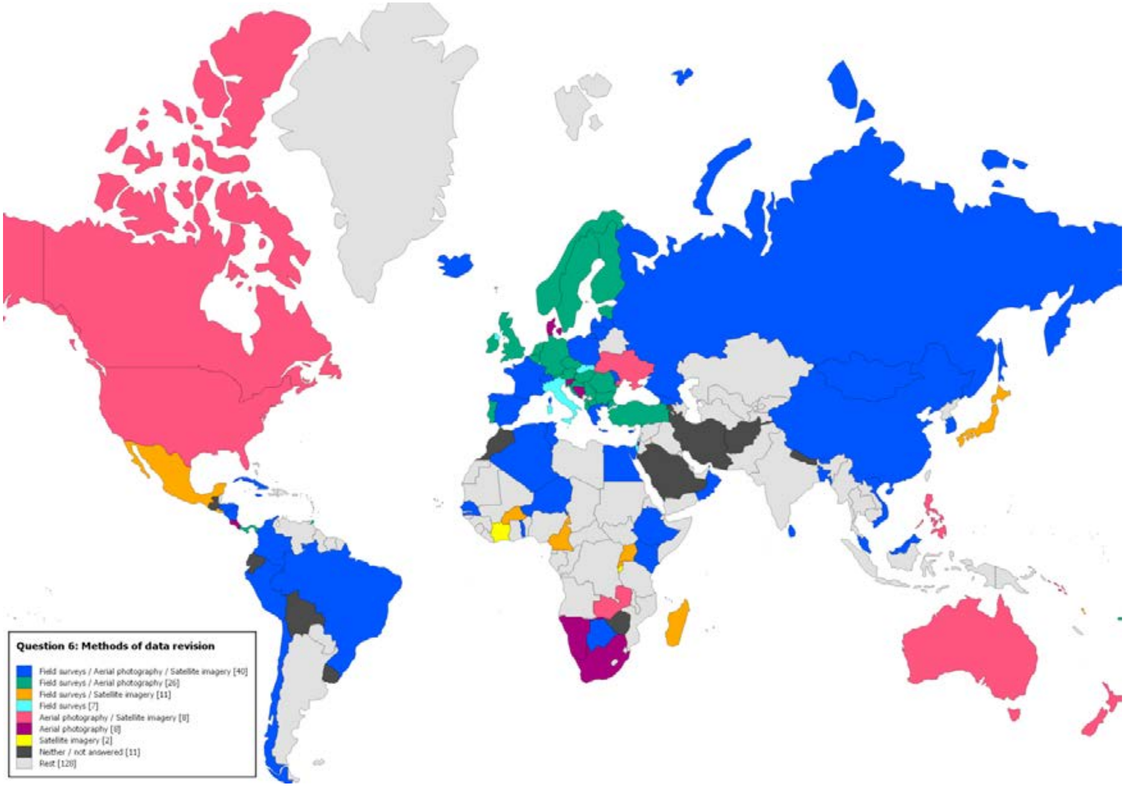


Figure 18: Question 6. Methods of national data revision and map updating

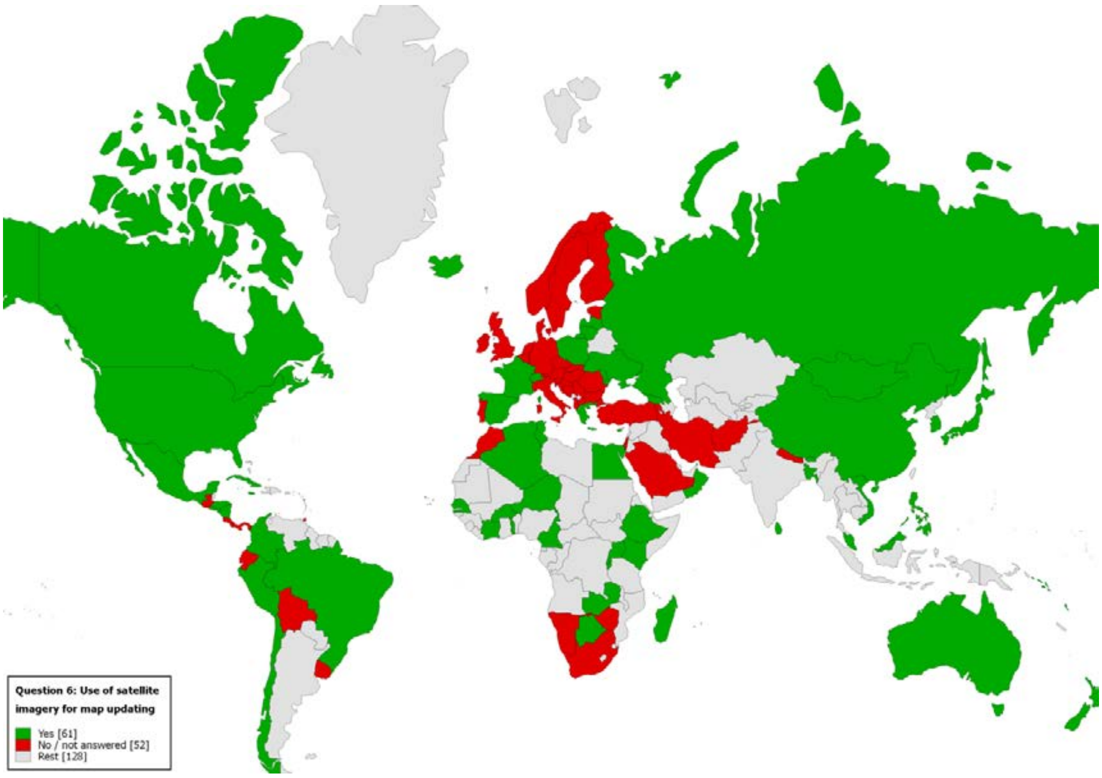


Figure 19: Question 6. Use of satellite imagery for national data revision and map updating

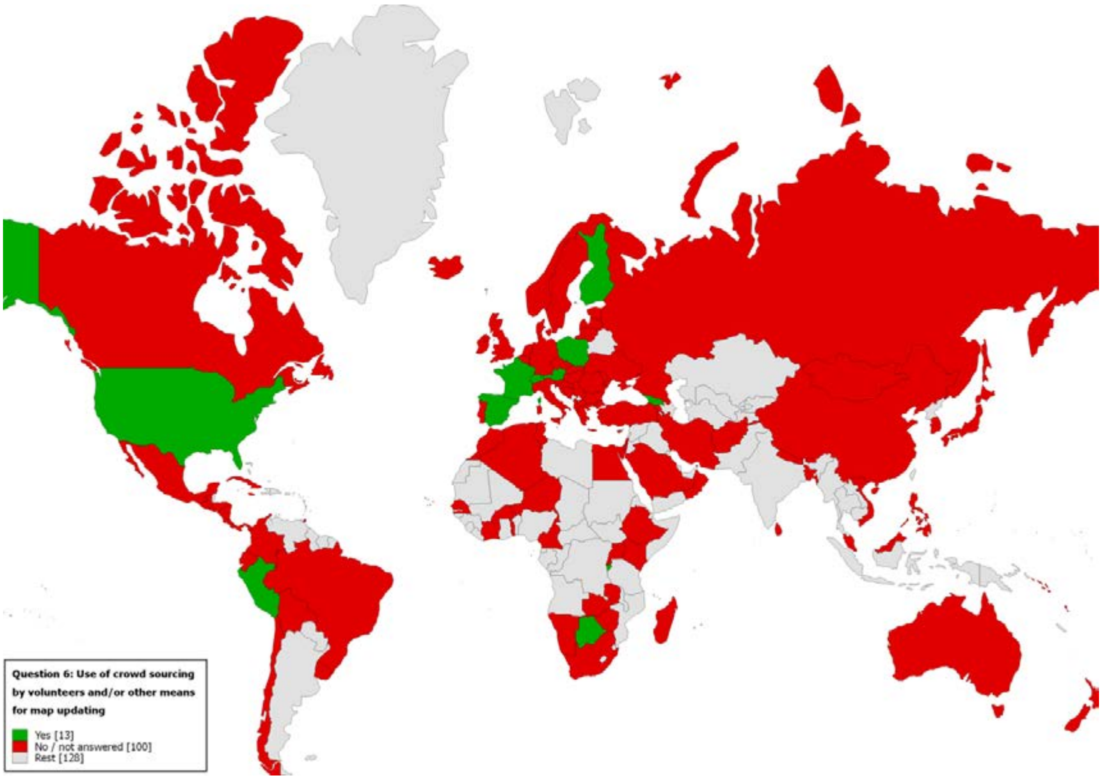


Figure 20: Question 6. Use of crowd sourcing for national data revision and map updating

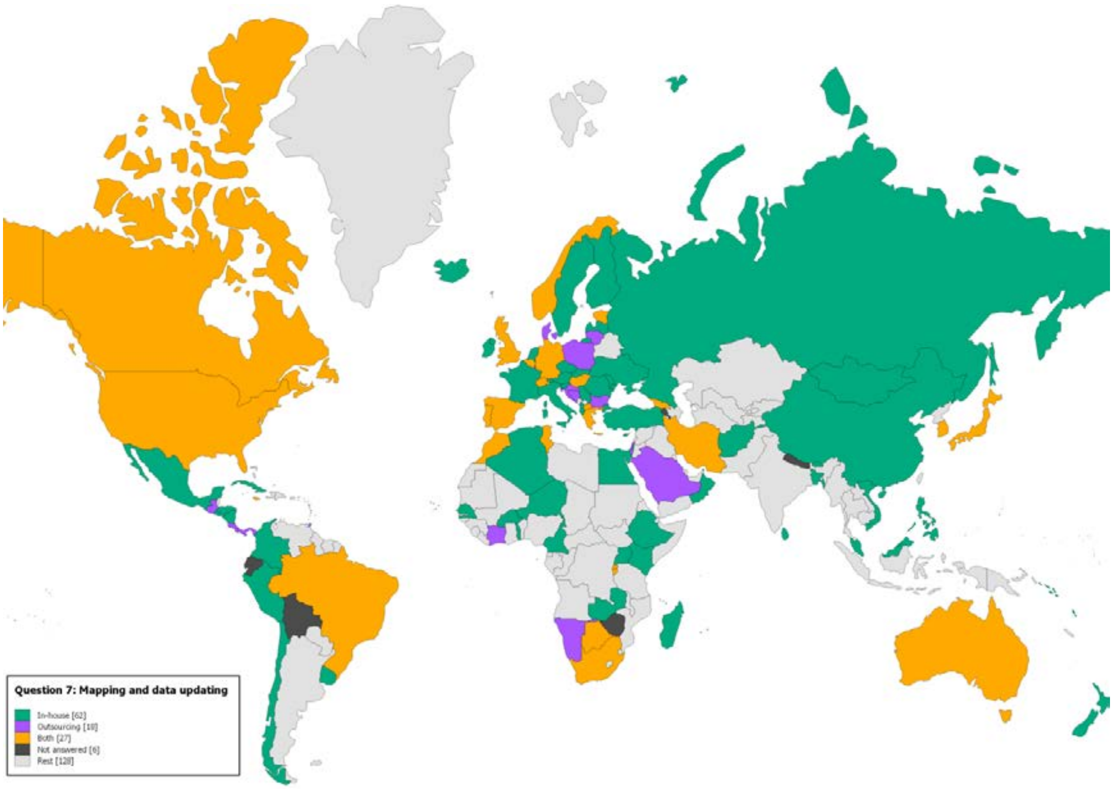


Figure 21: Question 7. Mapping and map updating done in-house or by outsourcing

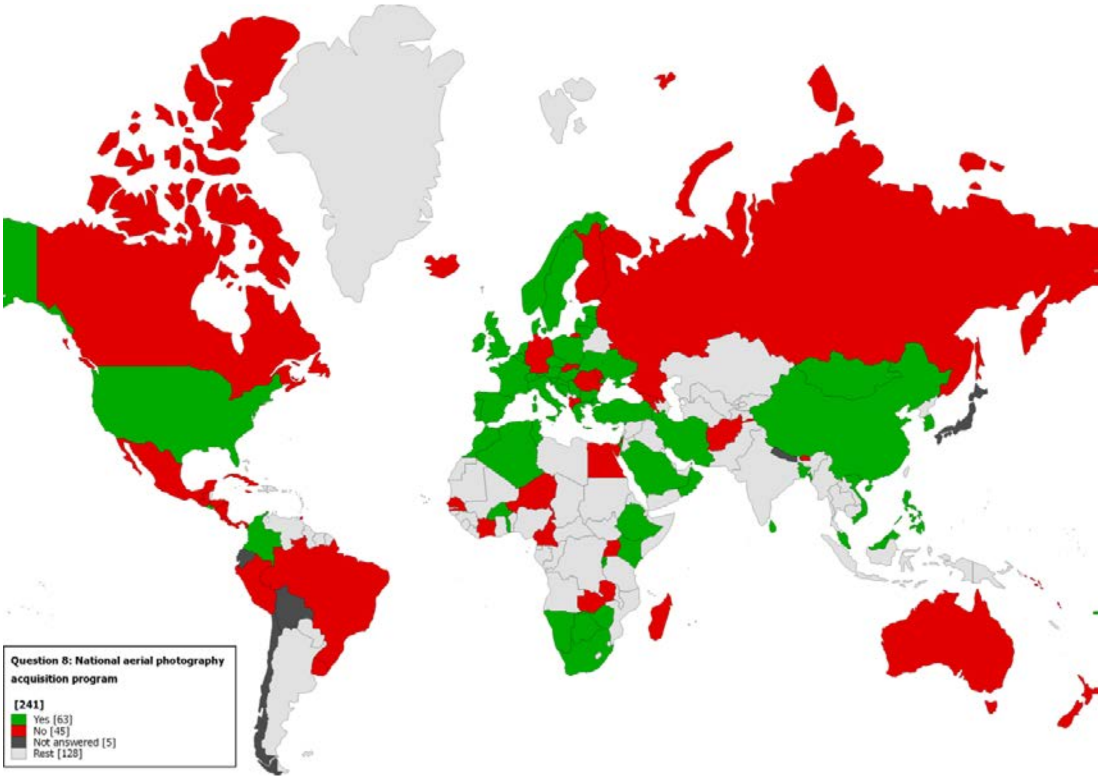


Figure 22: Question 8: National aerial photography acquisition program

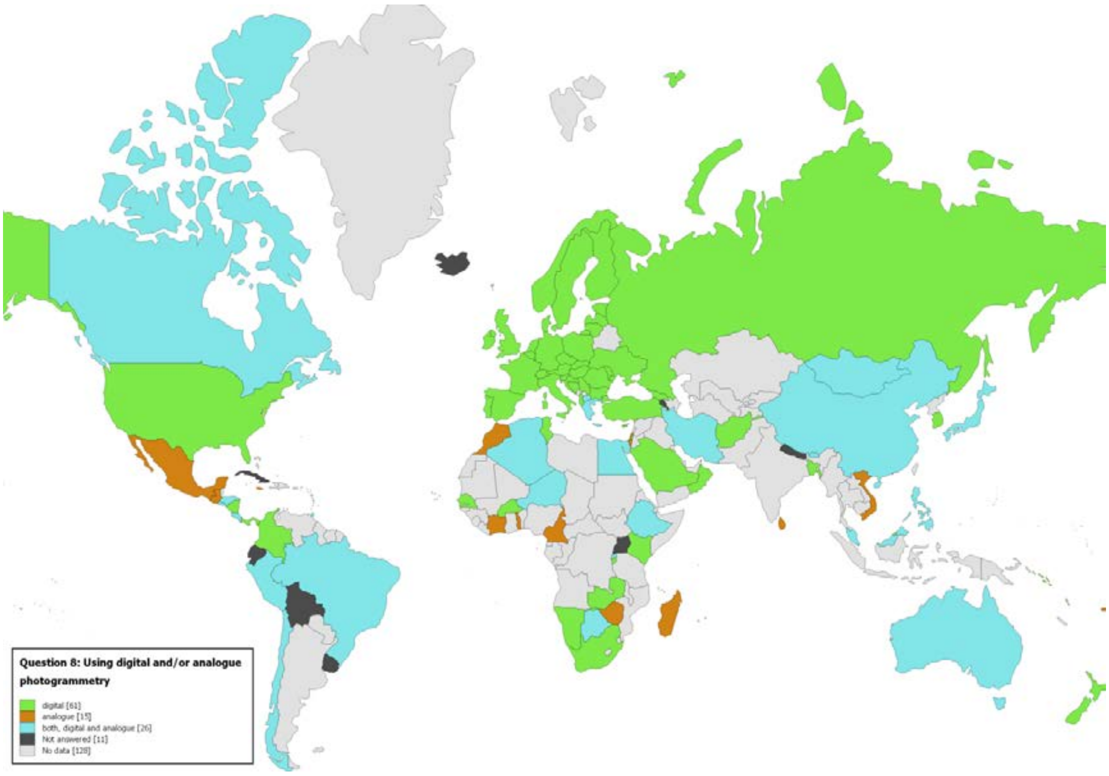


Figure 23: Question 8. Using digital and/or analogue photogrammetry

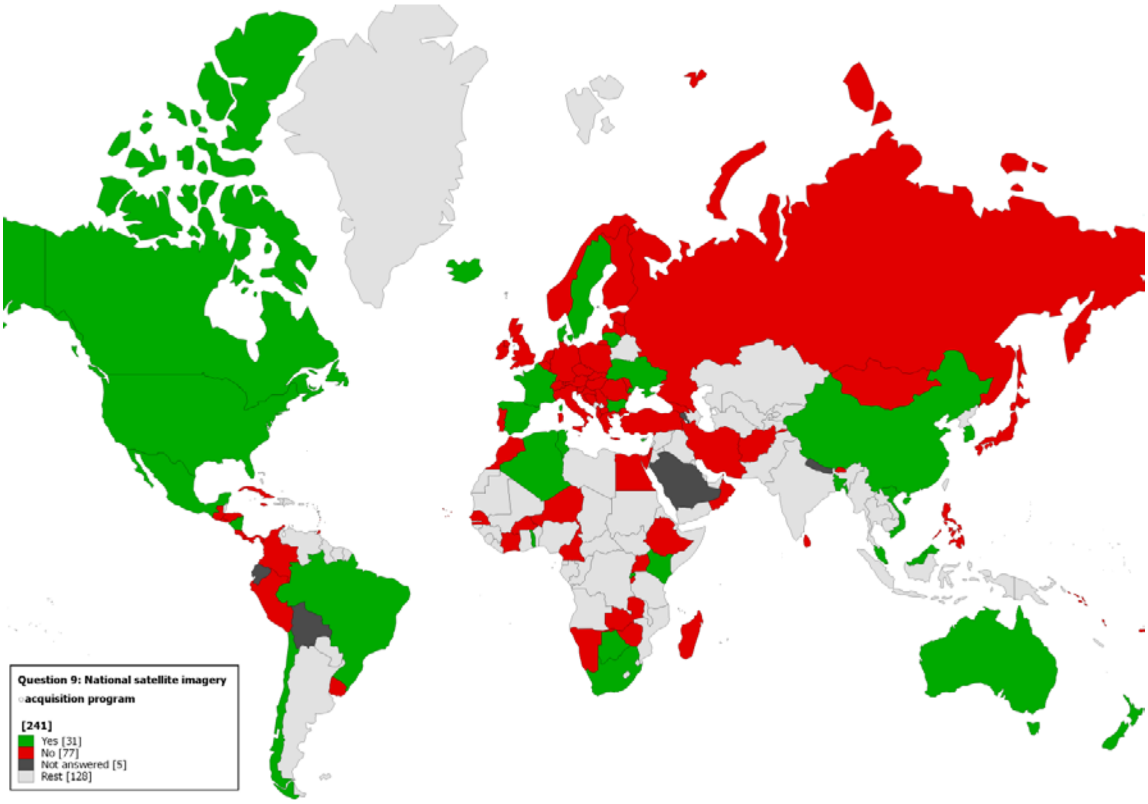


Figure 24: Question 9: National satellite imagery acquisition program

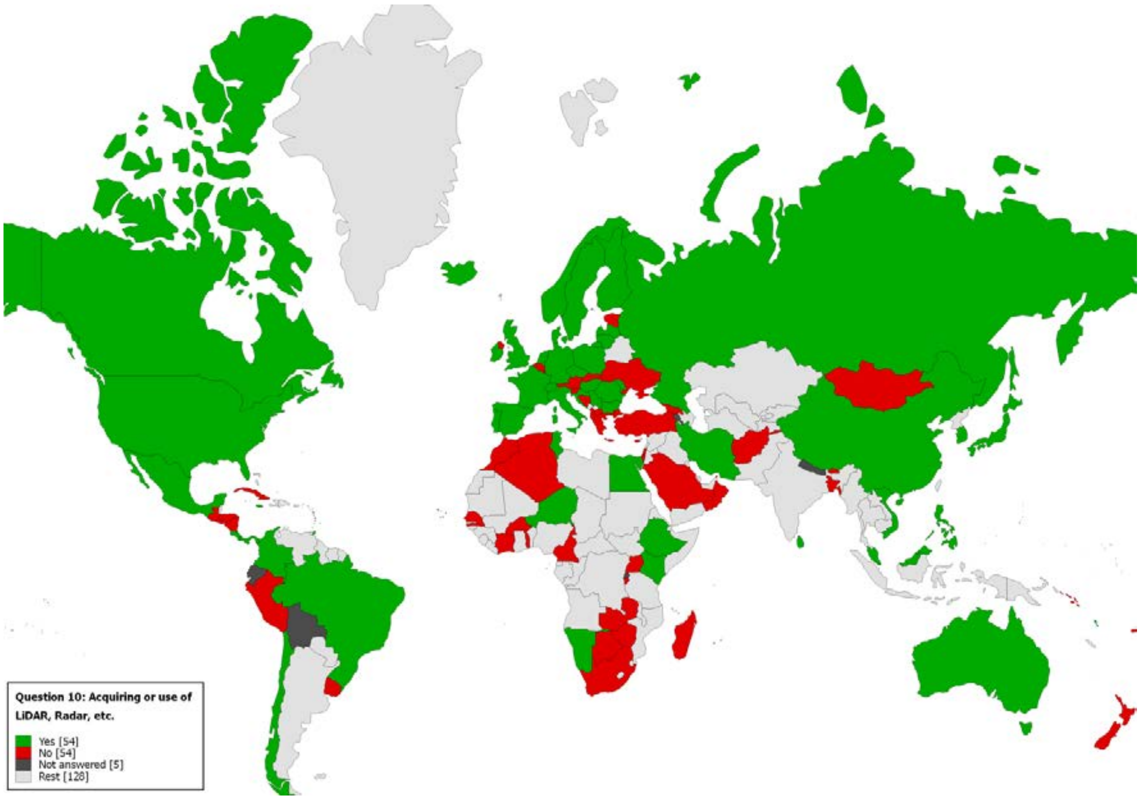


Figure 25: Question 10. Acquiring and/or using other imagery types (such as LiDAR, RADAR, etc.)

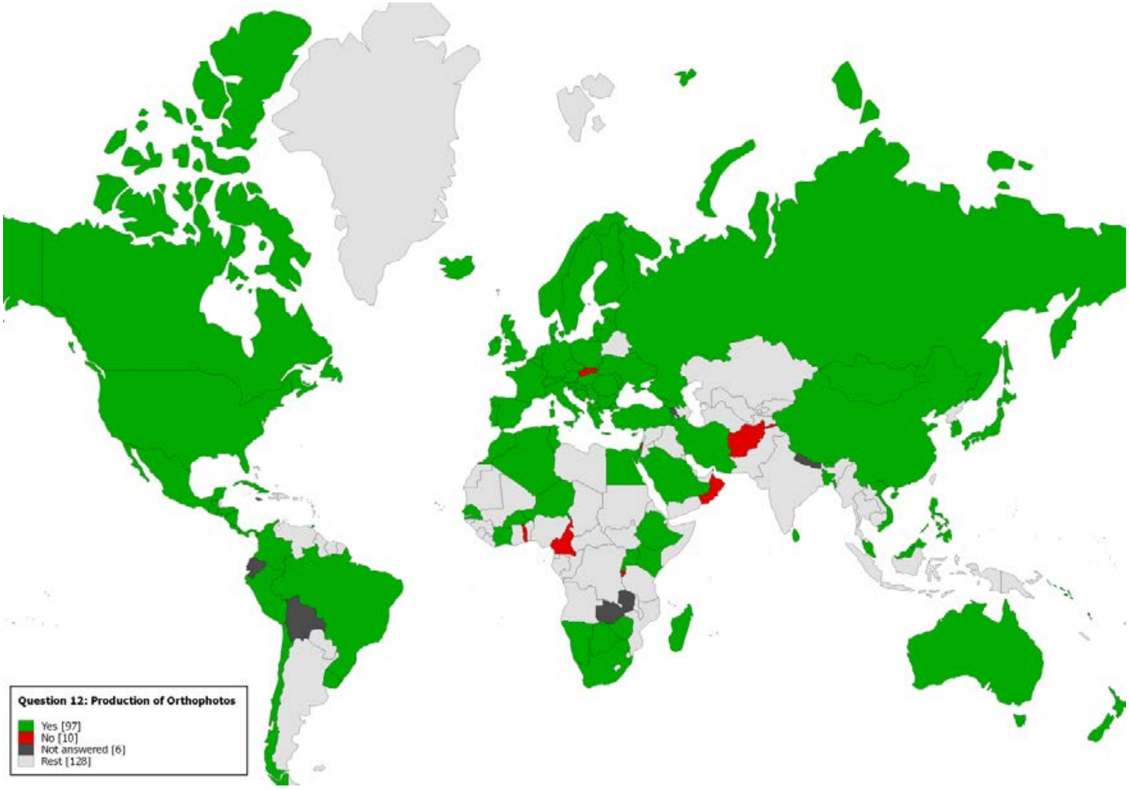


Figure 26: Question 12. Production of orthophotos and orthophotomaps

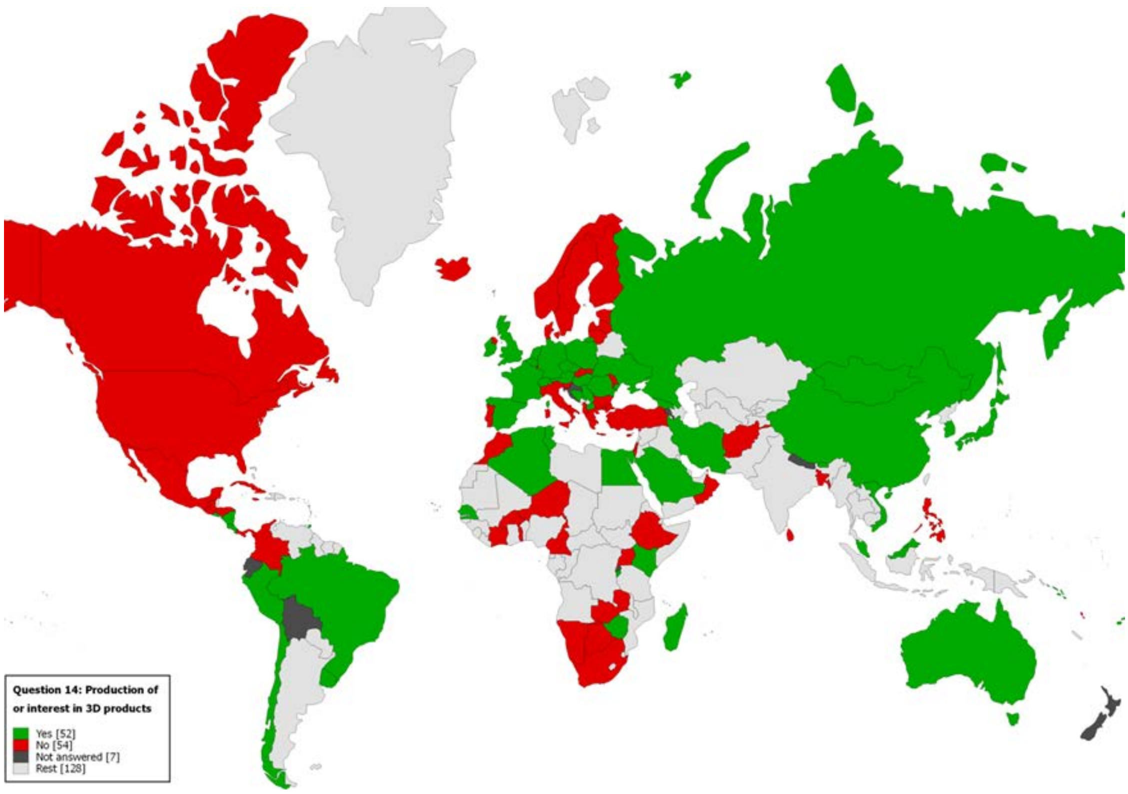


Figure 27: Question 14. Production or intention to produce, 3D urban and rural landscape models and/or product visualization

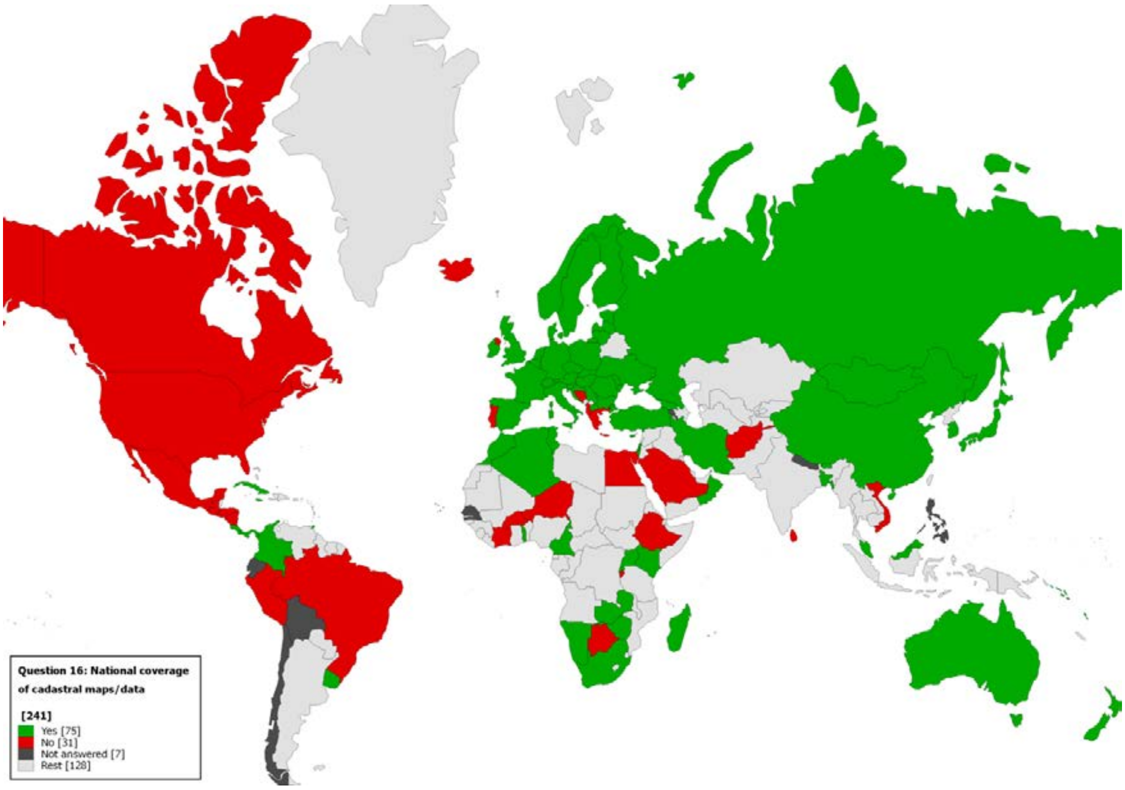


Figure 28: Question 16. National coverage of cadastral maps and/or data available

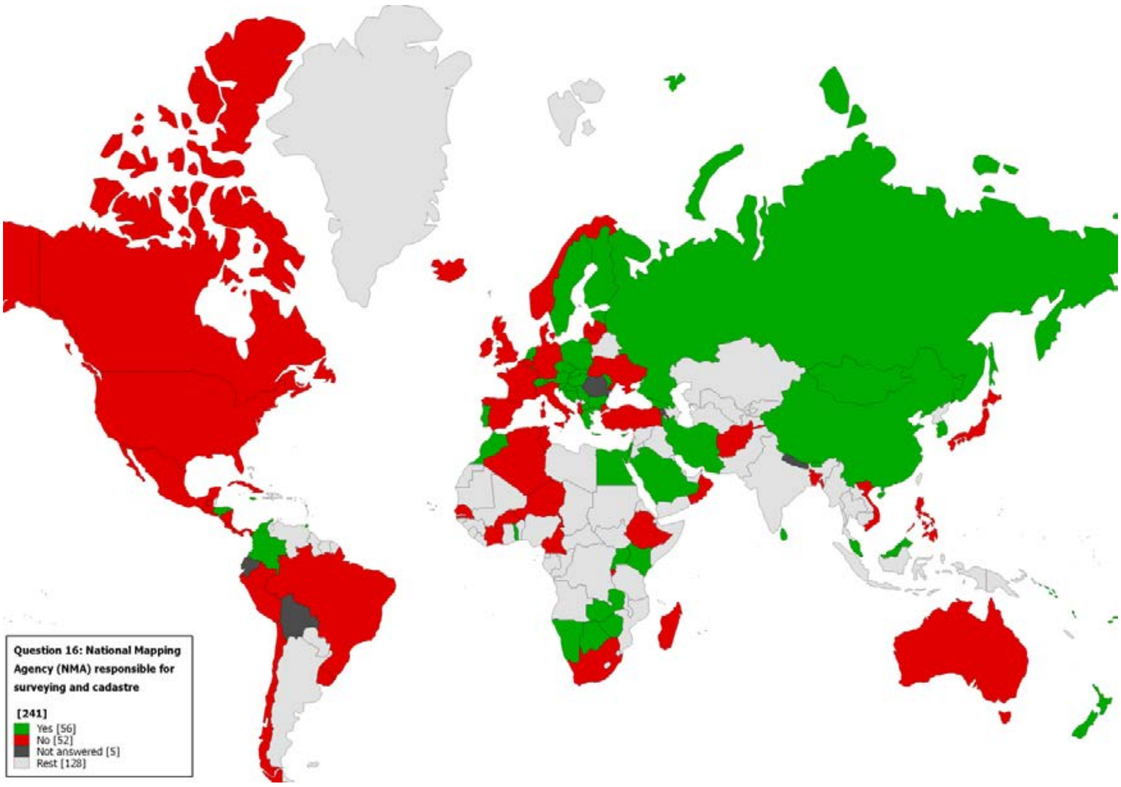


Figure 29: Question 16. National Mapping Agency (NMA) responsible for surveying and/or land titles and cadastre

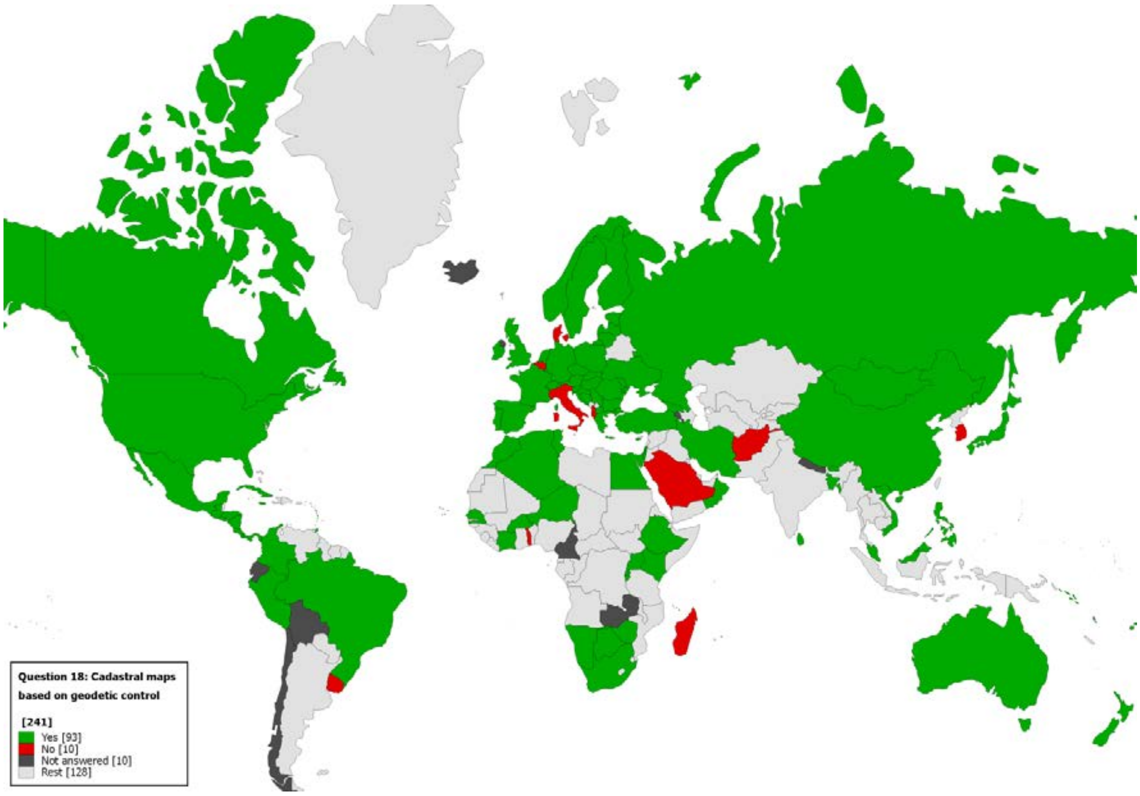


Figure 30: Question 18. Cadastral maps based on geodetic control

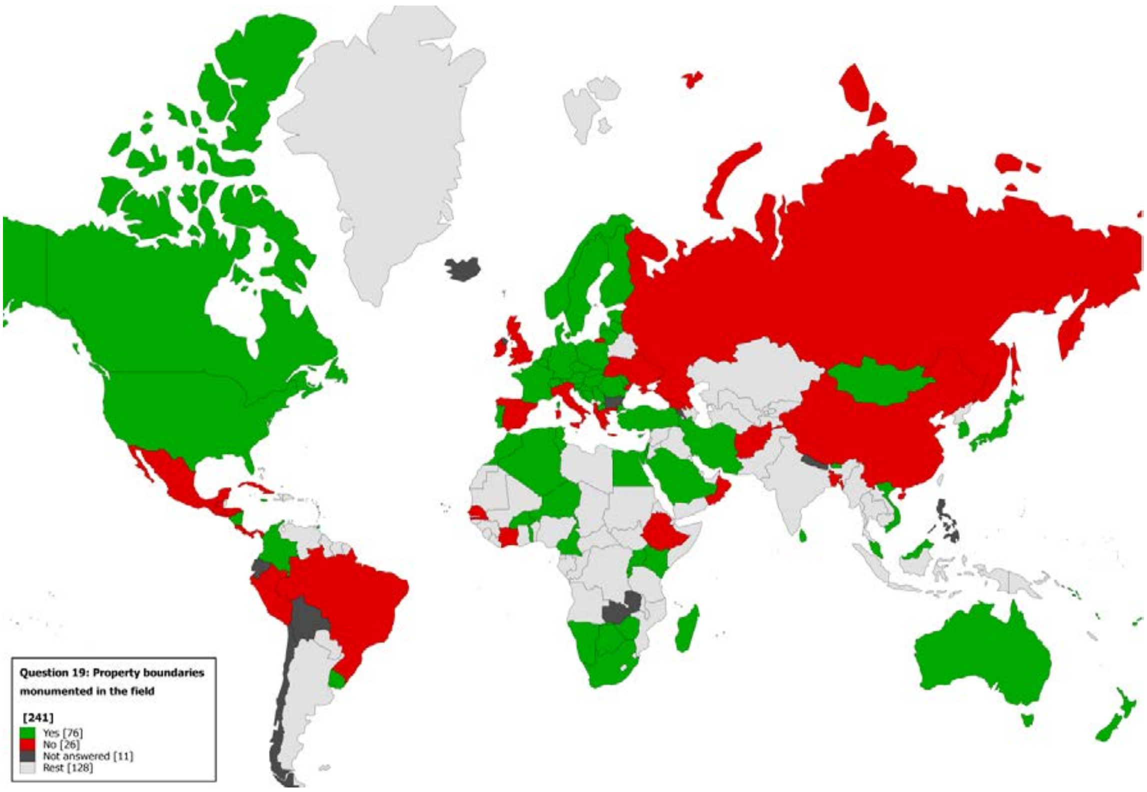


Figure 31: Question 19. Property boundaries monumented in the field

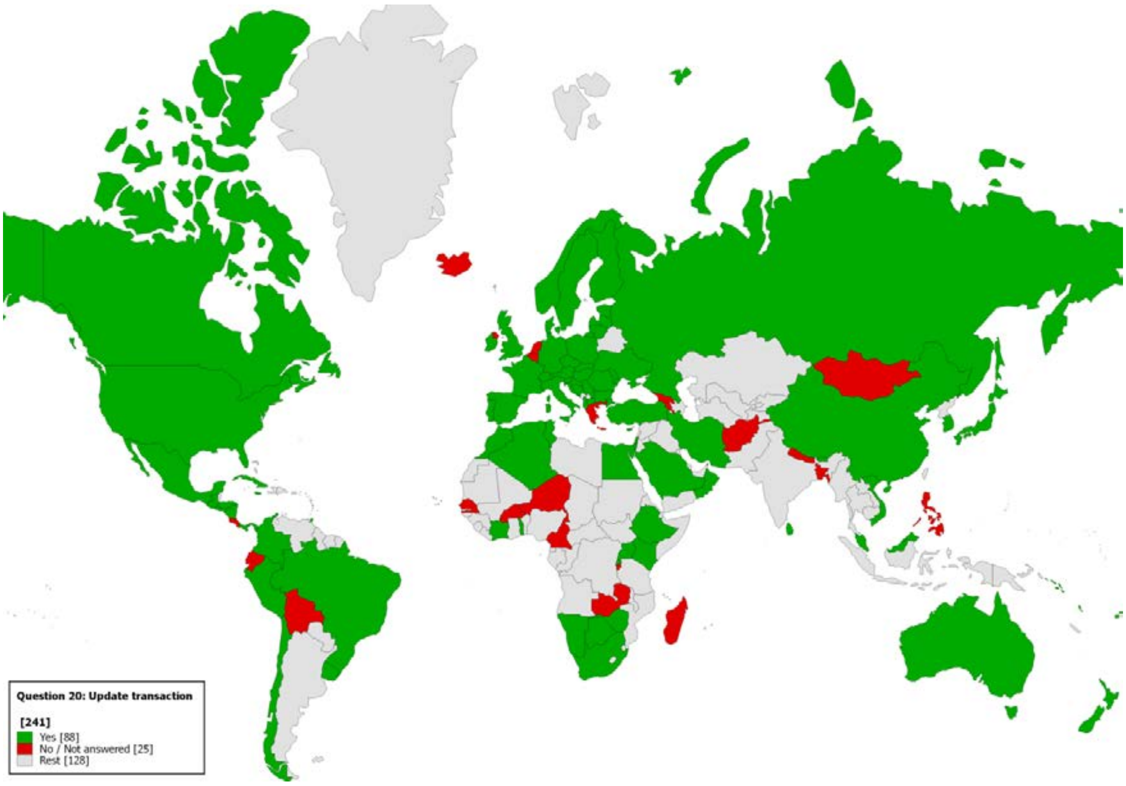


Figure 32: Question 20. Update transaction of property maps and/or data

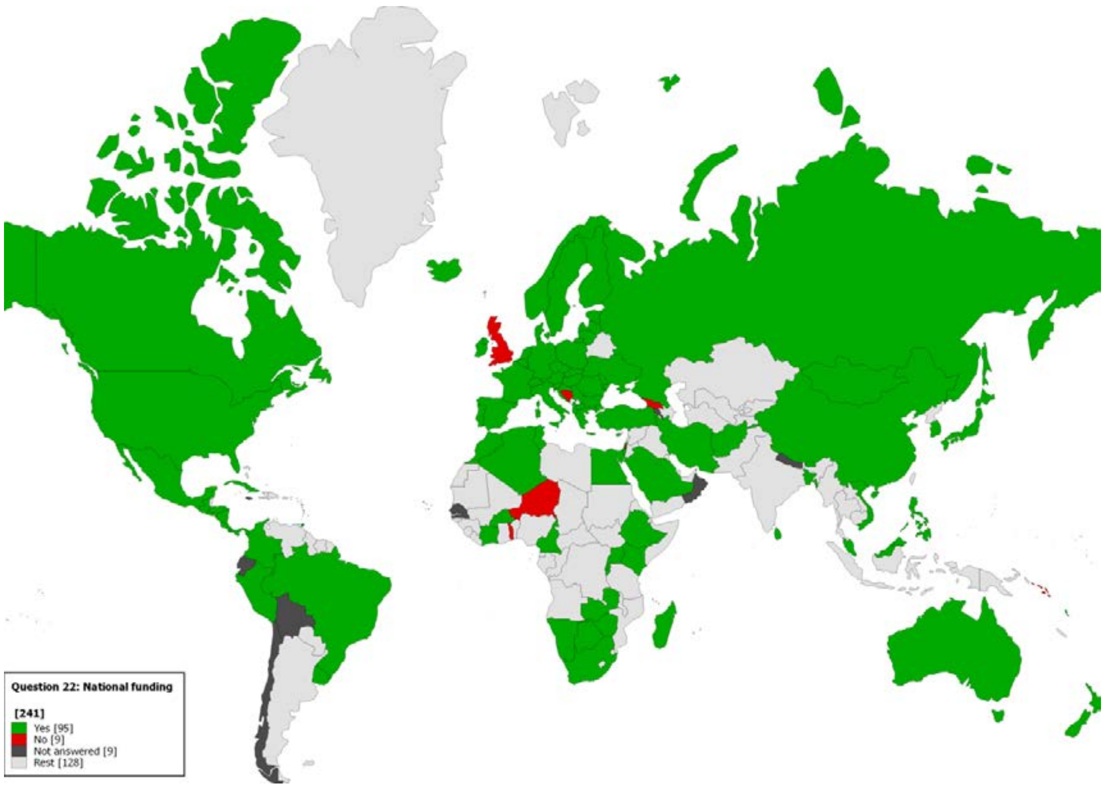


Figure 33: Question 22. National topographic mapping, imagery acquisition, surveying and cadastral programs funded by your national Government

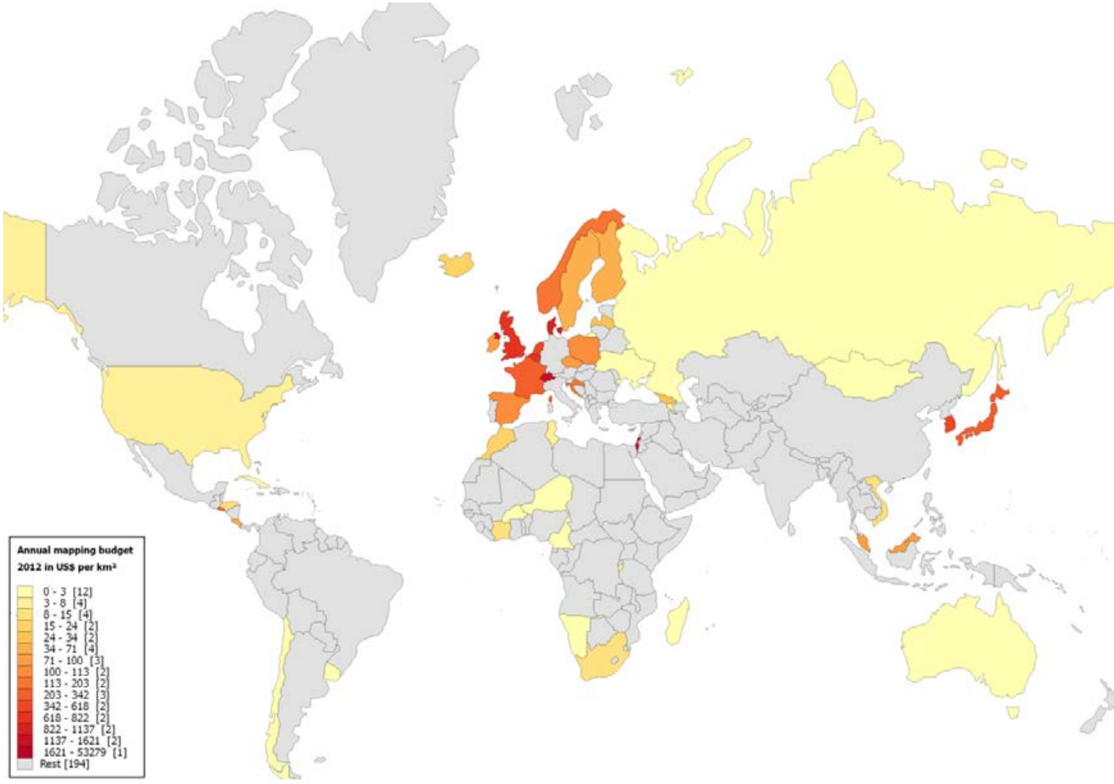


Figure 34: Question 23. Annual mapping budget of the National Mapping Organization converted to million US$ per square kilometre of the country area

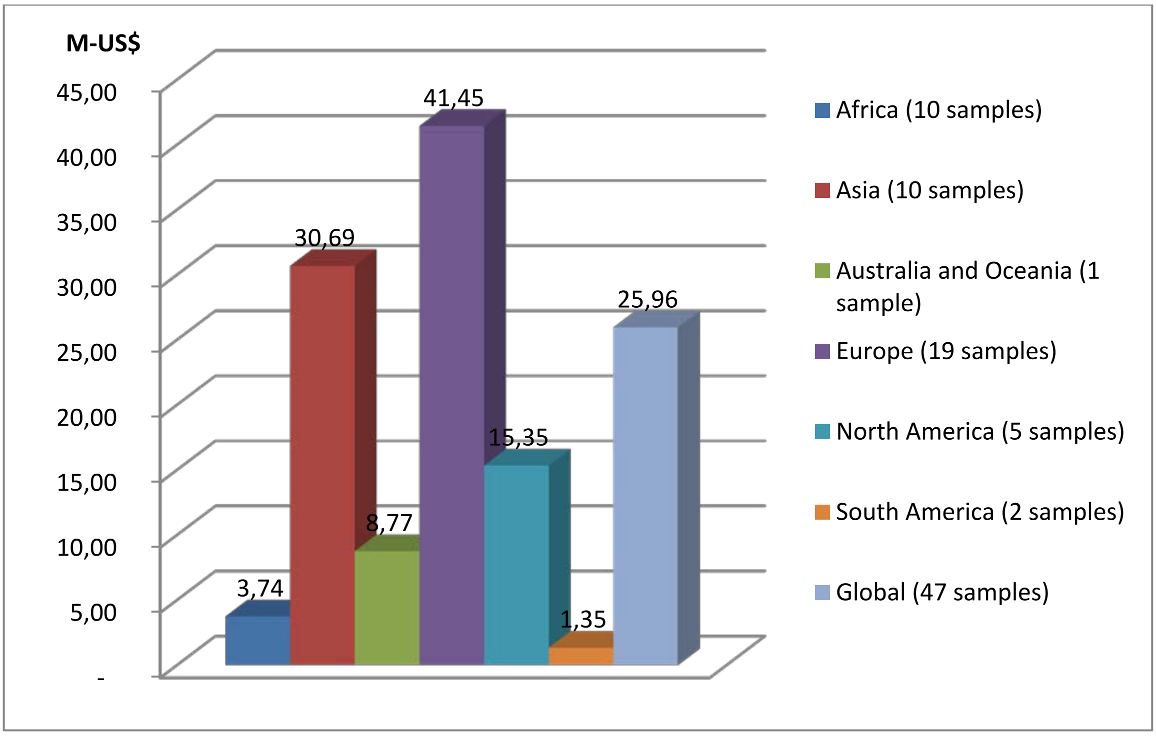


Chart 5: Question 23. Average annual budget 2012 per region converted to million-US$

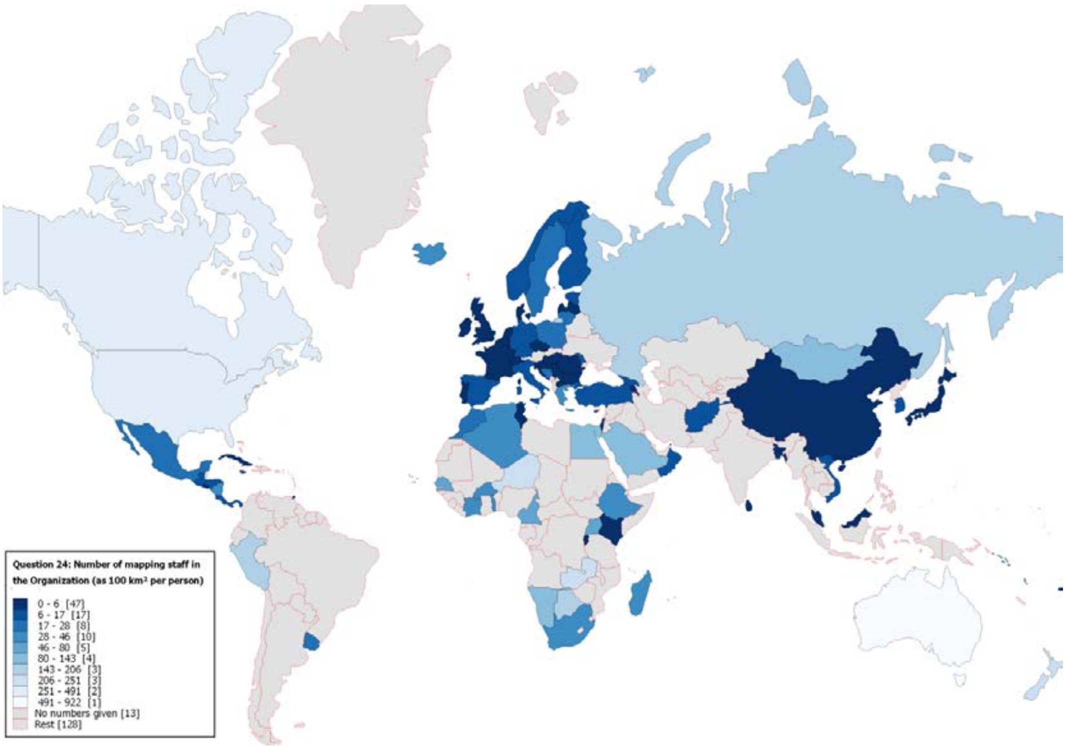


Figure 35: Question 24. Number of mapping staff in the organization as hundreds of square kilometres of country area per person

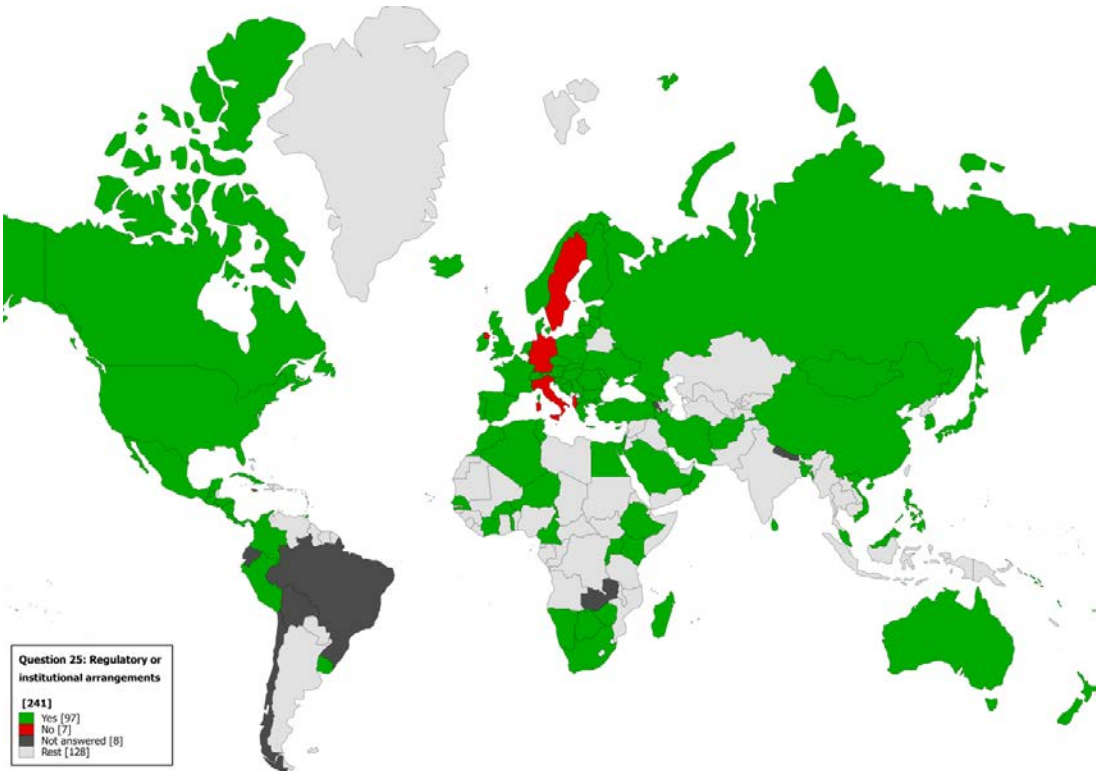


Figure 36: Question 25. Regulatory or institutional arrangements mandating the organization to fulfil its role as the lead mapping agency

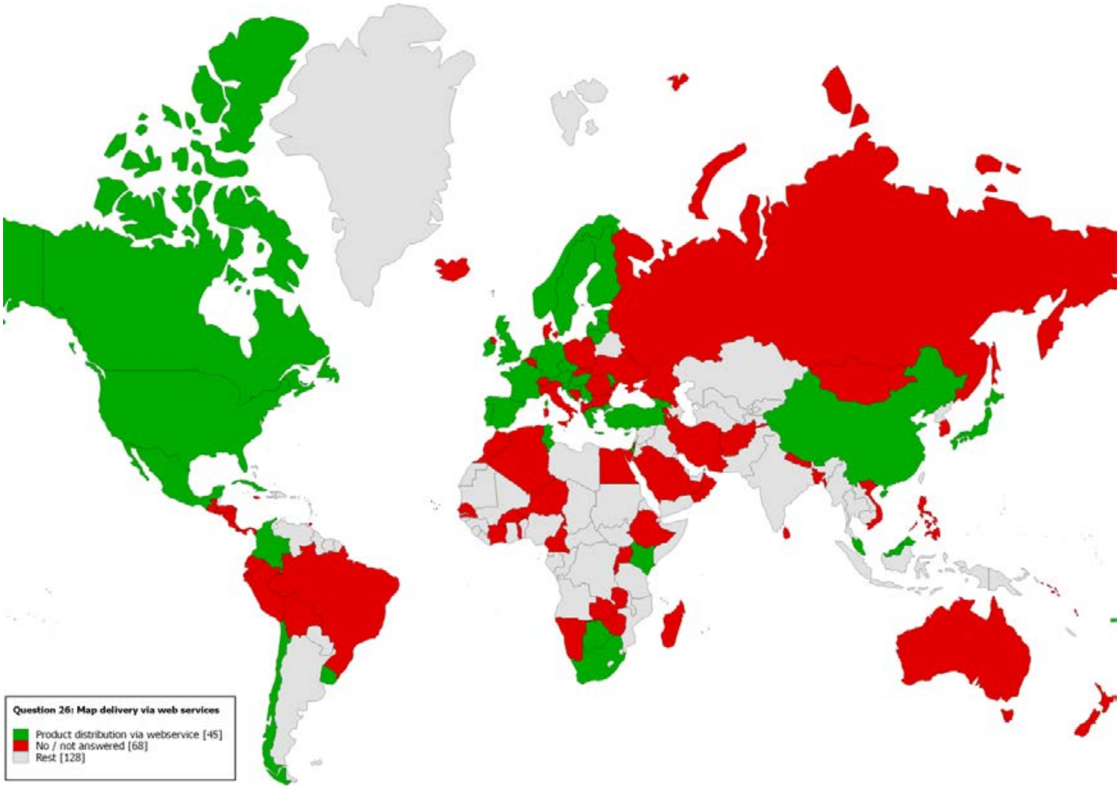


Figure 37: Question 26. Delivery of different map and data products via web services

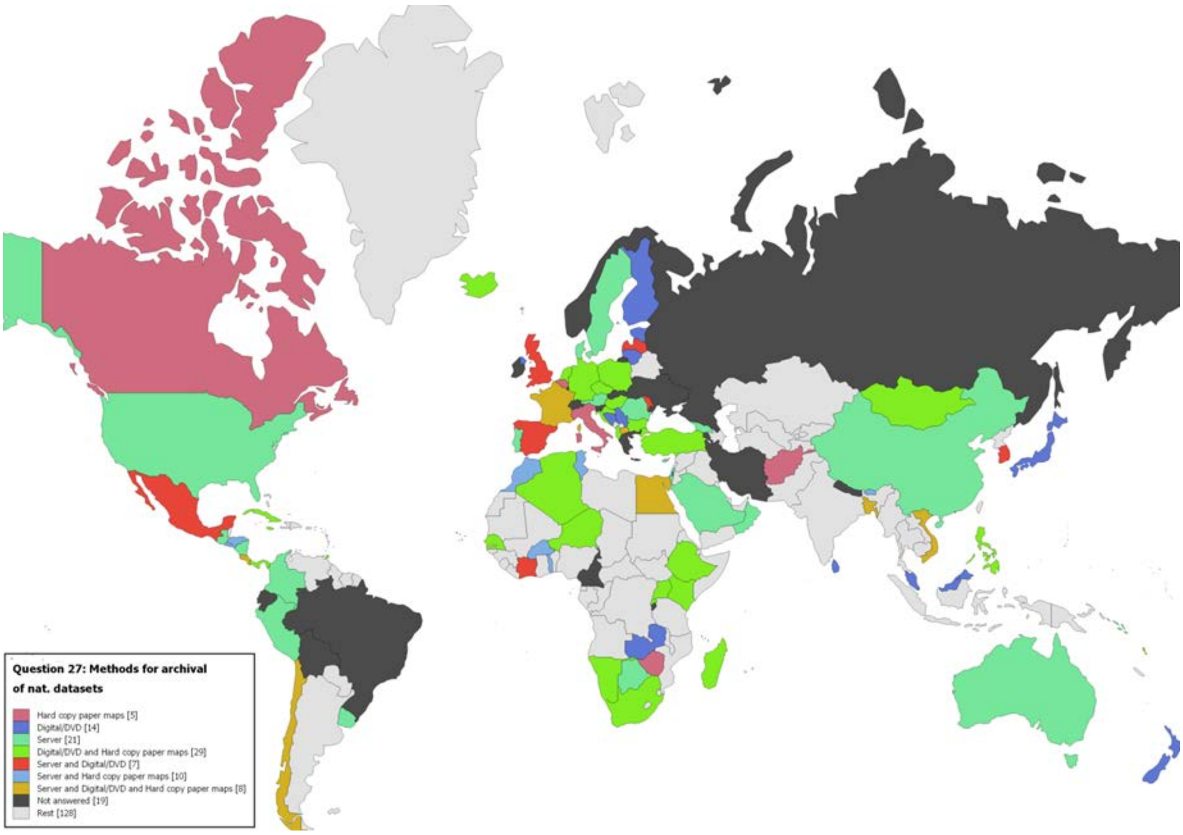


Figure 38: Question 27. Methods of archival for the national data sets

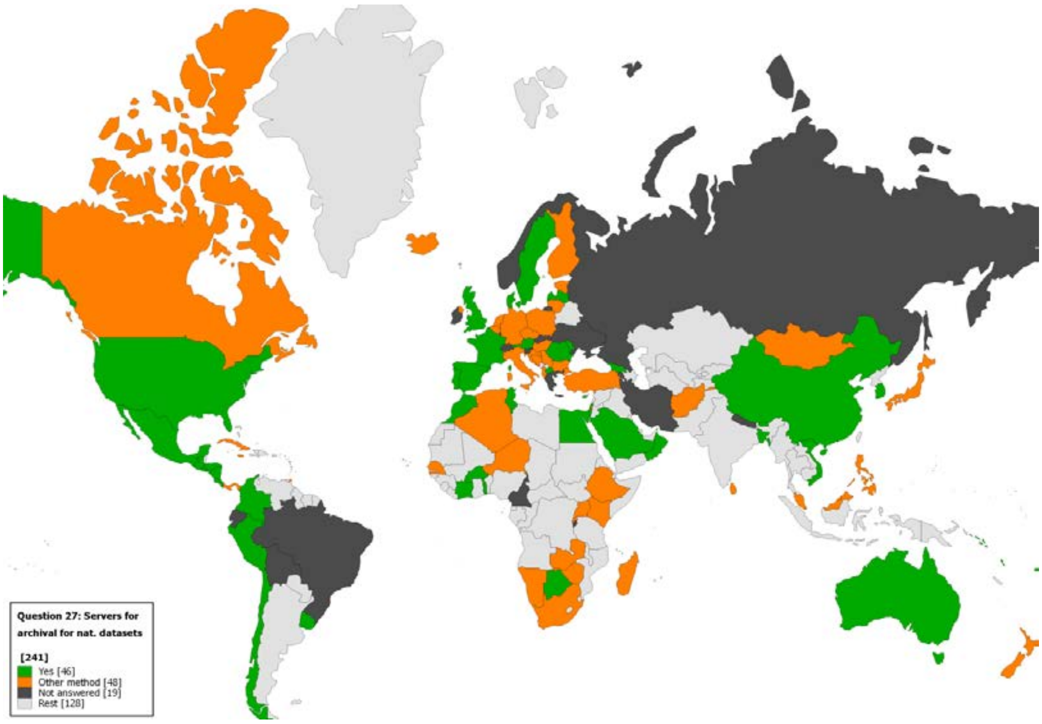


Figure 39: Question 27. Using servers/databases as method of archival for the national data sets

5 MAPPING CONTRIBUTIONS BY PRIVATE INDUSTRY

As has been demonstrated, official and authoritative mapping by governments provides a reliable 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 for 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 coverage with ground sample distances between 0.1 m and 0.5m as well as high resolution satellite imagery overages with ground sample distances (GSD) between 0.5 m to 2 m 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. The coverage is global for all land areas.
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, wherever possible, 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. The 3 models for creating Google Maps are shown in Figure 40: a) relying on authoritative data in North America, Europe, Australia as “Google Ground Truth” b) Map Maker outsourced, leaving the initiative of mapping using Google Earth to other companies (Africa, Middle East, India) c) “Video Rental” model offering Google Earth imagery to other countries for mapping use (Russia, China).

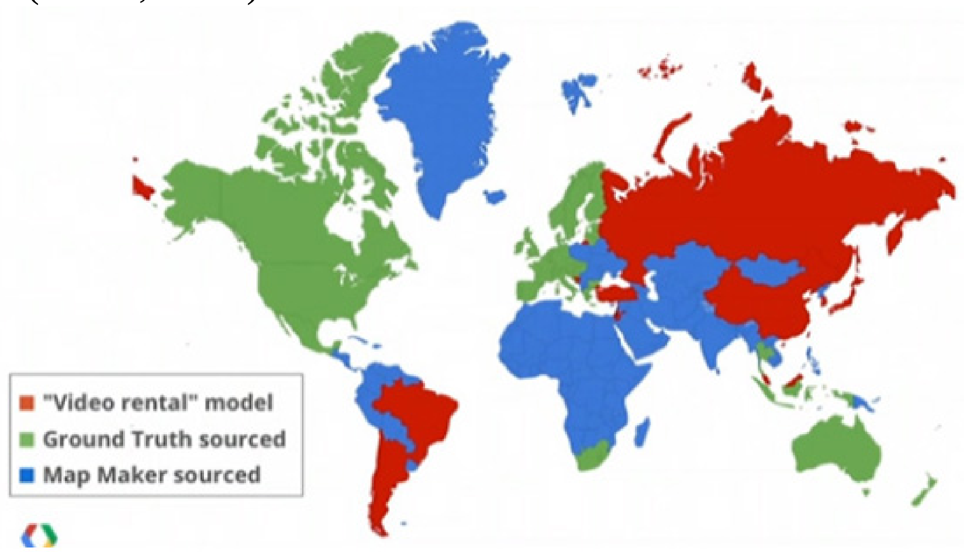


Figure 40: Google Maps

5.1.3 Google Street Map

Google Street Map has been developed as a tool to image buildings and streets with 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 met resistance by some members 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 Maps content as an internal operation.

In this manner Google Street Map has proved to be an effective tool to quickly update the Google Maps content for buildings and roads. The update of these features can generally be done much faster than by the regular update intervals for authoritative mapping without a reporting system in operation and without a multitude of fast survey options, rather than by a centralized mapping procedure. For coverage see Figure 41.

Figure 41: Google Street Map Coverage

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, see Figure 42.

Figure 42: Google Ground Truth

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.

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. Whether the originally foreseen updates of every 3 years can be achieved as planned, is still an open issue. See Figure 43 (a,b,c,d).

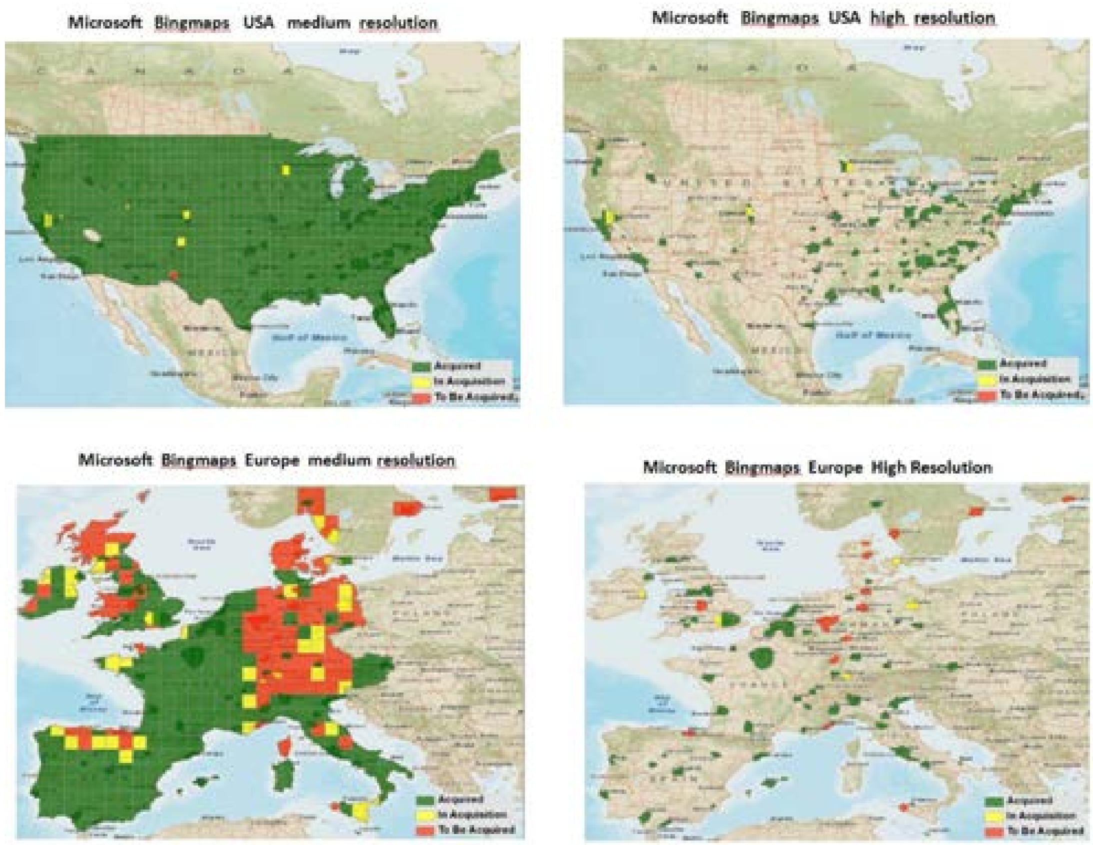


Figure 43: a,b,c,d: Bingmaps

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. This also includes unidirectional restrictions of traffic flows.

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. See Figure 44:

Here (formerly Navteq)

Figure 44: HERE Global Coverage

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. See Figure 45:

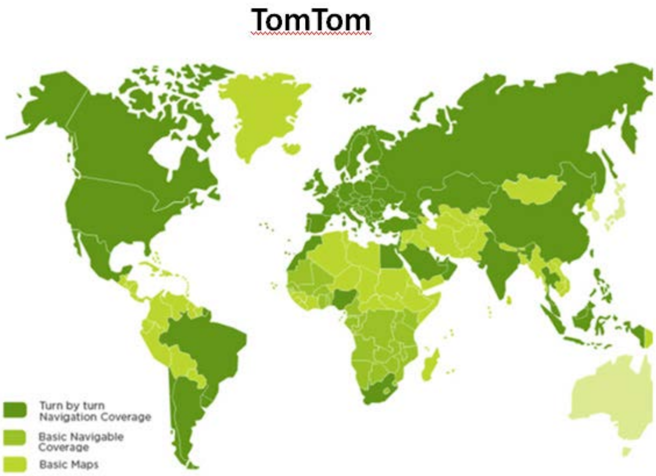


Figure 45: Tomtom Global Coverage

6 MAPPING BY MILITARY ORGANIZATIONS

Like it 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, Republic 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. See Figure 46:

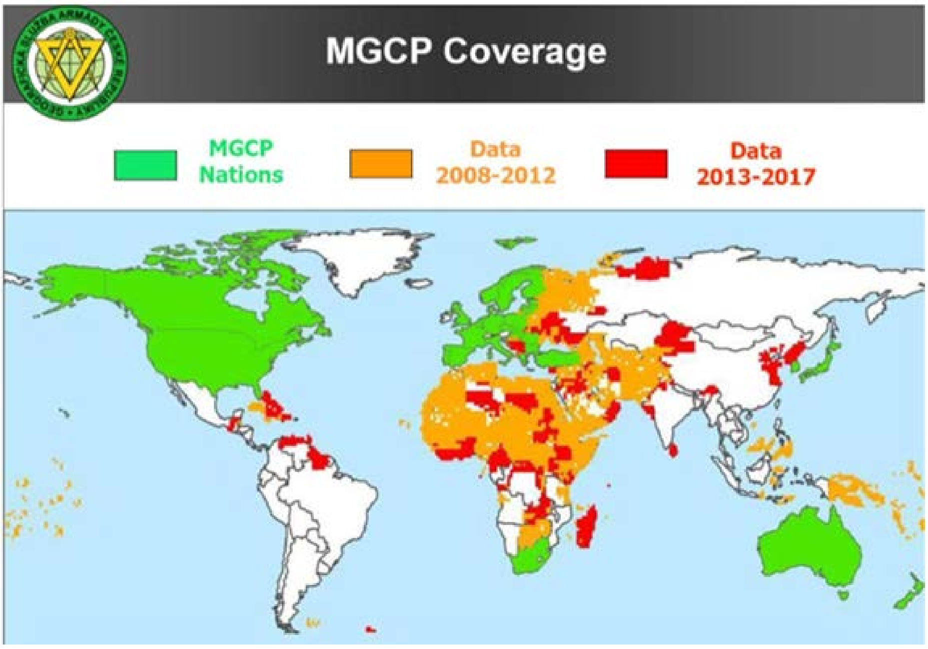


Figure 46: MGCP Mapping Coverage

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.

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.

9 REFERENCES

UN Secretariat document E/CONF78/BP7 1986, prepared by A. J. Brandenberger & S.K. Ghosh, published in World Cartography XiX, 1990

UN Secretariat document E/CONF78/BP8 1986, prepared by G. Konecny, published in World Cartography XIX, 1990

UNRESOLVED ISSUES OF MAP UPDATING

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Commission IV, WG IV-2

KEY WORDS: topographic mapping, coverage, status, study, unresolved issues

1. The ISPRS-UNGGIM Study on the Status of Topographic Mapping in the World

ISPRS Working Group IV/2 has undertaken a global survey on the Status of Topographic Mapping in the World. Topographic Mapping is considered as the base for other type of mapping.

The results of the study have been posted on the Internet in the UNGGIM Knowledge Base: ggim.un.org/knowledgebase/KnowledgebaseCategory63.aspx.

ISPRS has also distributed a printed brochure of 64 pages. It is available on the Internet for download under:
http://www.isprs.org/documents/reports/The_Status_of_Topographic_Mapping_in_the_World.pdf.

A shorter version was published in 2016 in the Zeitschrift für Vermmessungswesen und Geoinformation ZFV (January 2016).

2. Results of the Study

1) The progress in global topographic mapping is scale dependent. The larger the scale range, the more detail needs to be mapped, and the more costly the mapping becomes. In 2012 the global land areas are covered to 33.5 % at the scale range 1:25 000, to 81.4 % at the scale range 1:50 000, to 67.5 % at the scale range 1:100 000 and to 98.4 % at the scale range 1:250 000.

2) Progress since the last UN Secretariat survey in 1986, that is within the last 26 years has been very good. The coverages for the 25 000 scale range were then 17.9 %, 49.3 % for 1:50 000, 46.4 % for 1:100 000, and 87.5% for 1:250 000. Chart 1 shows the development at these scale ranges since 1968.

3) Nevertheless the average age of maps in the world for 2012-2015 was 22.4 years for the 1:25 000 range, 26.3 years for 1:50 000, 31.2 years for 1:100 000 and 37.0 years for 1:250 000. Chart 2 shows the ages of maps for the different continents with

the best values for Europe (13.8 years for 1:25 000 in Europe) and for South America (9.8 years for the small mapped areas at 1:25 000). This is due to the fact, that the conventional technologies used for authoritative mapping are still relatively slow. Nevertheless, there has been an improvement since 1986, when the annual update rate was 3.2% for 1:25 000 (equivalent to an age of 31 years), 1.8% (56 years) for 1:50 000, 2.7% (37 years) for 1:100 000 and 3.6% (28 years) for 1:250 000.

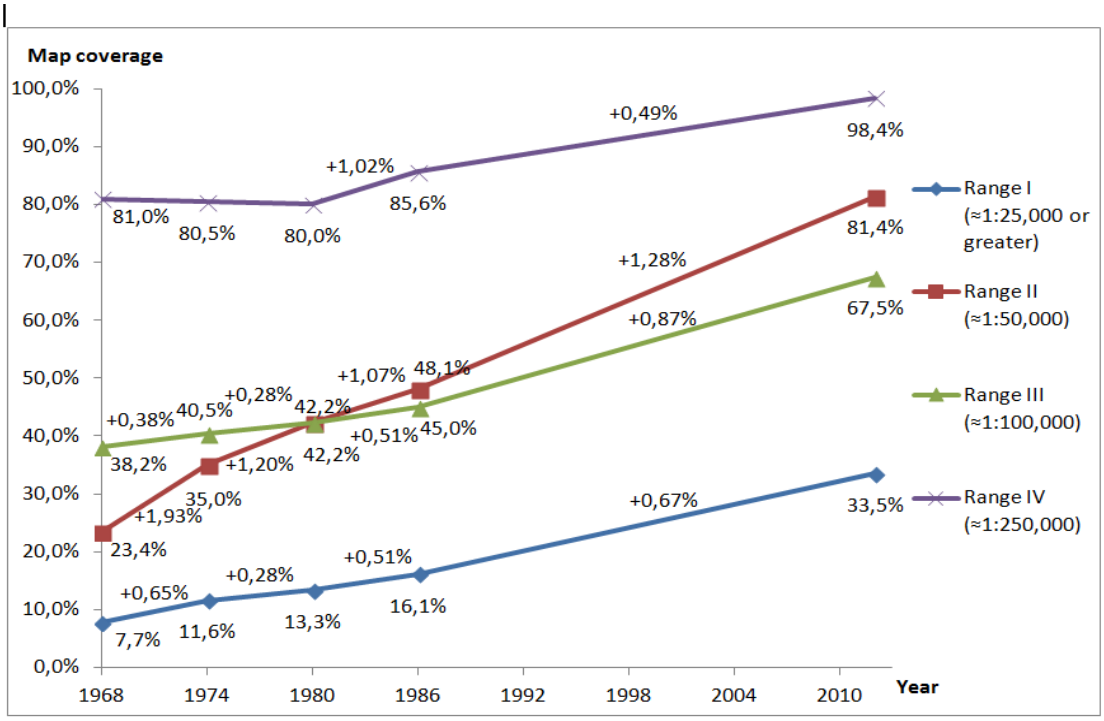
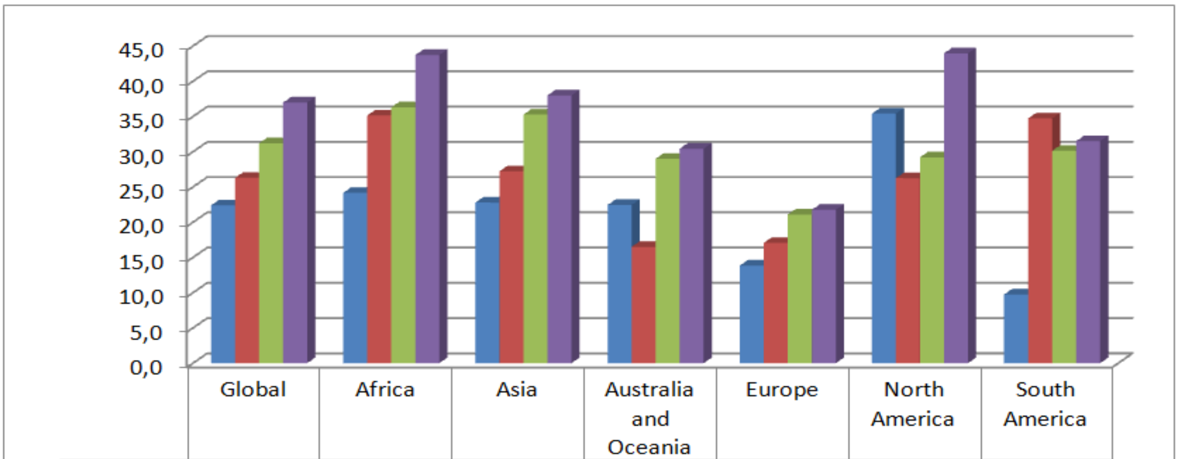


Chart 1: Percentages of total world area covered in each scale category, 1968-1974-1980-1986-2012

update rate 2012



	Global	Africa	Asia	Australia and Oceania	Europe	North America	South America
Range I	22,4	24,2	22,8	22,4	13,8	35,4	9,8
Range II	26,3	35,1	27,2	16,5	17,1	26,3	34,7
Range III	31,2	36,3	35,3	29,0	21,1	29,2	30,1
Range IV	37,0	43,7	38,0	30,4	21,8	44,0	31,5

Chart 2: Average map age in years counting from 2012

4) These studies have all been done for authoritative maps produced by governmental agencies, either by own production or by outsourcing. The possibilities to repeat the mapping effort for a map update were dependent on governmental funding reflecting demand and political decisions.

The important aspect of authoritative mapping has always been its reliability and its accuracy of geolocation. While governmental mapping agencies have always maintained their position as a civilian base data supplier to the user agencies, which enhanced the map and data content for their own purposes despite of their relatively slow mapping progress, the mapping efforts of the private sector have become noticeable. These efforts are less concentrated on accuracy and completeness, but they can diminish the time gap between map compilation and map completion.

5) Here especially high resolution satellite imaging and also progress in digital aerial imaging gave the private sector a head start. Google Earth, Google Maps and Bingmaps have been using this technology to derive geocoded image products very rapidly (Google Earth) and to even derive a limited number of features (roads, buildings) in vector form from the image products (Google Maps). Their feature content could even be verified and enhanced by mobile van terrestrial imaging (Google Street View, Cyclomedia).

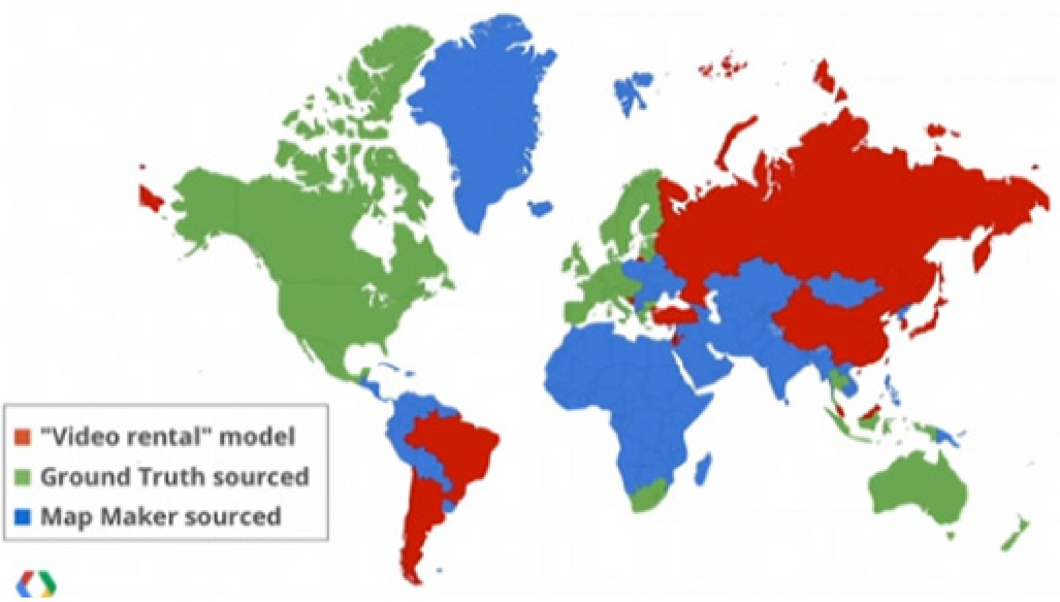


Figure 1: Google Ground Truth areas (green) use authoritative data as a base, the others use other means

Google Street Map

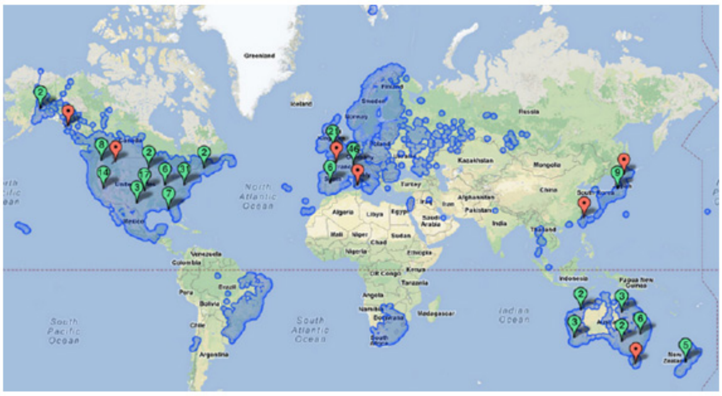
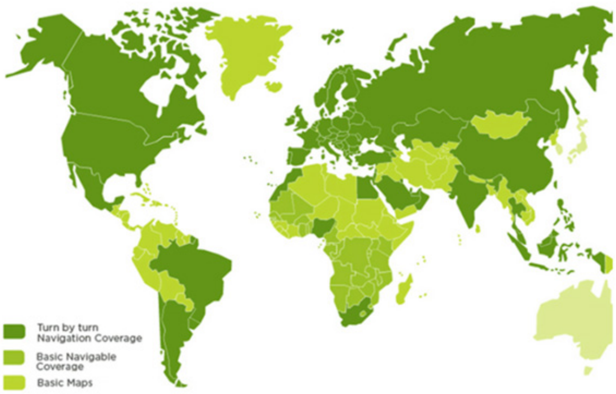


Figure 2: Google Street View is an efficient tool for updating map content

6) Further progress for limited features, such as roads and buildings has been introduced by navigation system providers, such as TomTom and HERE, which added traffic information to their transportation network data.

TomTom



Here (formerly Navteq)

7) Other interesting mapping efforts have been introduced by Yandex in Russia and Turkey, deriving vector information from a combined use of high resolution satellite imagery with ground based GNSS feature localization.

8) These methodological improvements have not only given a significant push to geoinformation technology per se, but they also have generated public use of their data. A recent map user survey made by the State Mapping Administration of the State of Lower Saxony LGLN in Germany has shown that authoritative geodata customers use Google and Tomtom or HERE products in parallel with authoritative data to check feature content and up-to-date status. They appreciate the existence of both public and private data.

9) Google, and to a lesser extent Bingmaps, are global operators. Google relies on the procurement of WorldView 3 or Pleiades images for updates, Bingmaps (now under responsibility of Uber) on Vexcel digital aerial images. Google has even the additional capability to crate local update information by the Skybox constellation of satellites using images or videos. Likewise Tomtom and HERE are global operators, mapping roadways in more than 190 countries.

10) But another more local initiative is the “Open Street Map”, for which map features are compiled by local private operators as their contribution to the user community. Naturally this effort cannot be systematic. It concentrates on a number of regions predominantly in Europe, America, Asia and Australia, but also in Africa.

11) It looks at present, that none of these systems will be able to replace authoritative mapping, but indeed there is a potential for private-public data exchanges for the sake of up-to-dateness and feature content verification.

12) One of the basic advantages, but also difficulties faced by governments in their authoritative mapping effort lies in the fact, that this mapping is the base for operating geographic or land information systems.

In doing so, the governments not only concentrate on the production of map features, but also on the possibility to link a wide range of attributes to the graphic features, such as point, lines and polygons. The analysis in these data systems can be well handled by relational data bases. One of the leading global GIS suppliers is ESRI with ArcGIS.

13) But if the maintenance of the geographic or land information system also requires changes in the feature geometry (new points, new lines, and new polygons) then the modification of relational data bases may become cumbersome, even though FME tools are available to permit a certain amount of object orientation for the data in the relational database, e.g. ArcGIS.

Such object oriented databases are advisable, if their features, such as buildings, parcels or roads need frequent updates, or if the updates are made by very different measurement tools.

The Ordnance Survey uses Oracle Spatial to maintain the object oriented data base for the topographic features at the 1:1200 scale. In the German Survey Administration the operation of a cadastral registration system ALKIS requires object orientation at the 1:1000 scale. But also the topographic database at the 1:5000 scale range level is modelled via UML in object orientation. These are highly sophisticated developments. Their definition and software effort required more than a decade to lead to implementation.

Countries, which do not have the monetary or the intellectual resources to introduce such systems for fast updating will achieve a faster and more effective topographic update possibility with ArcGIS with FME modifications, even if this may be less stringent.

On the other hand it is quite interesting, that GEO Star, a dual use object oriented and relational database has been developed in China.

14) There is rich material available in academic dissertations and publications on geodatabase modelling, but an international discussion of these issues and their importance has been greatly non-existent, even though it plays a role in solving the problem of updating map objects, rather than replacing map content patch by patch. Even Google has not offered an opinion on how to update their databases in public.

TOWARDS 3D RASTER GIS: ON DEVELOPING A RASTER ENGINE FOR SPATIAL DBMS

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KEYWORDS: Voxel, Raster 3D, Built Environment Modelling, Urban Modelling, SQL primitives

ABSTRACT
Three-dimensional (3D) raster are simple representations, which have long been used for modelling continuous phenomena such as geological and medical objects. However, they can result in large data sets when high resolution is used, which poses challenges to algorithms for vector-to-raster conversion and data storage. This paper presents a research towards developing generic techniques and tools for efficient storage, management, and analysis of 3D spatial data types in the context of the column-store database system MonetDB. This paper focus on some issues in converting vector to raster data models in 3D spaces.

1 INTRODUCTION

Rasterization in 2D is nearly as old as computer graphics itself. It involves representation of continuous objects such as lines and curves on an inherently pixelated screen (i.e. monitor). As line rendering happens very frequently, the efficiency of these graphics algorithms will determine the latency of the whole visualization process. Therefore, these algorithms are often implemented in hardware to achieve highest performance.

In this paper, we look at the matter of rasterization from a different angle. We want to obtain rasterization of real-world objects while preserving all object's semantics, properties as well as topological relations between the objects. Our aim is a unified 3D representation framework based on a single primitive data type called *voxel*, a volumetric pixel. Each voxel is a quantum unit of volume and has a numeric value (or values) associated with it that represents properties or independent variables of a real object or a value from a continuous field (e.g. magnetic field).

Such a representation is highly beneficial for advanced analytic procedures on digital 3D city models such as urban flow simulations (e.g. wind streams, water runoff, noise models and heat island effects), urban planning, and analysis of underground formations. Currently, digital city models can be reconstructed from massive point clouds obtained through airborne LiDAR (Light Detection and Ranging) or terrestrial scanning campaigns and reconstructed to 3D surface representations. Modelling urban objects (e.g. buildings, roads, trees) as surfaces has bottlenecks: calculating intersections and volumes, and creating cross-sections is complex.

Representing 3D urban scenes by voxels bring a number of advantages: calculating volumes is a matter of counting the number of voxels that constitute an object, 3D bisections become simple selection operations, storing volumetric spaces such as air, water and underground is possible. An additional benefit of voxel storage is the atomicity of the data type; every object is represented by only one primitive (3D cube) instead of the surface representation (i.e. points, lines and polygons).

During the last decade, many database management systems (DBMSs) have been successfully extended with support for spatial and geo-spatial applications. For instance, the OGC implementation specification “Simple feature access: SQL option”, which defines basic geometry types like points and polygons, is followed by PostGIS, Oracle, MySQL, Microsoft SQL Server, and MonetDB. Using the user-defined functions (UDF) functionality of these systems can be augmented in some cases with spatial search accelerators, which operate using the abovementioned geometric data types. In other words, knowing that a series of data entries are points and inserting them as such (i.e. using a 3D point data type) we can potentially benefit from spatial indexing and geometric search operations within the database. However, contemporary DBMSs still lack advanced functionality and efficient implementations needed for analysis of big spatial data. A new data type implementation targeting 3D point clouds is under development by Oracle Spatial and Graph 12c and PostgreSQL 9.2. GRASS is one of the few GIS that provide support of voxels.

This paper reports on designing and developing a generic-purpose raster engine for spatial DBMS. We outline the quality criteria considered in the design of a raster engine and report our experiments with a laboratory tool set (developed in VB.NET, C#.NET) towards implementation of a rasterization kernel developed in C (i.e. to be integrated with MonetDB DBMS).

2 BACKGROUND

A large number of 2D raster- and vector-based applications have been developed in the last 40 years for management of spatial data: GIS (ArcGIS, QGIS, Hexagon AB), DBMS (Oracle, PostGIS), spatial extensions of CAD software (BentleyMap, AutodeskMap), image processing software (ERDAS). Despite the progress in 3D, an integrated management of 3D vector and raster is hardly possible. GRASS (http://grass.osgeo.org/) is one of the few GIS that provide support of voxels; Rasdaman (http://rasdaman.org) is an array database for storing 2D/3D raster and point data. These applications still offer limited functionality.

We envisage a high demand for a 3D information system integrating both 3D vector and 3D raster data, serving a vast range of applications. Three approaches for storage and management of data can be then distinguished:

- 3D vector data models with functions for conversion to 3D raster
- 3D raster data models with functions for conversion to 3D vector

- 3D hybrid, keeping the objects in their most appropriate representation (e.g. vector for building and raster for natural phenomena)

Each of the approaches has its advantages in certain applications. 3D vector models are often more suitable for visualization since smooth surfaces are not discretized as in the case of rasterized objects. On the other hand, 3D raster models have simpler data structure, which efficiently facilitates volumetric and neighborhood operations. Hybrid models have the potential to integrate the benefits of the two representations, if strict rules for data consistency between the two representations can be defined are introduced.

To be able to realize such systems, research and developments of both 3D vector and 3D raster domain should be integrated. A critical operation is the conversion between raster and vector. Namely, points, lines, surfaces and solids need to be converted into voxels (Figure 1) [and vice versa], while preserving the semantics of the objects.

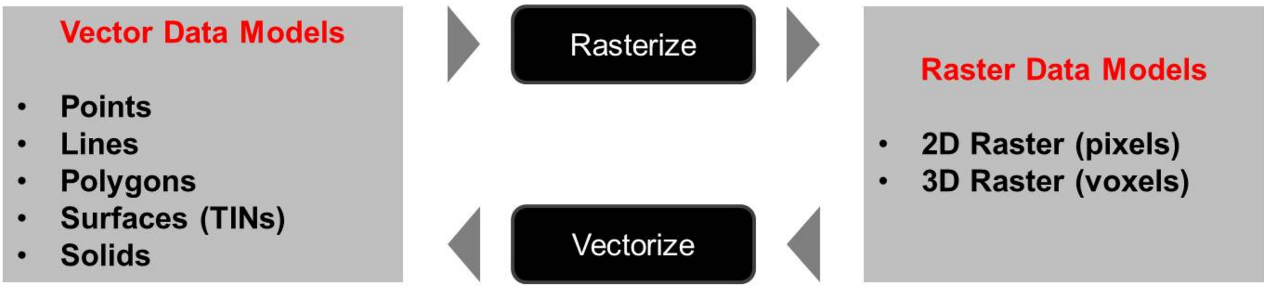


Figure 1: Data model conversions. Vectorization processes are not as well defined as rasterization processes. However, we consider this as a conceptual framework for the structuring of both our research process and the final products (the raster engine and its supported operations)

2.1 Creating 3D rasters

3D raster can be created from different sources: existing 3D vector models, 3D discrete measurements (e.g. point clouds, boreholes). The vector data can be represented according to the rules of either GIS or BIM models, i.e. they are structured data. Typically, GIS models contain simple geometries such as points, curves, surfaces and solids in a global coordinate system. BIM models allow for parametric representation (cylinder, sphere, cone), NURBS curves and surfaces, sweep shapes, etc., which can be embedded in each other. The coordinate system is mostly local and many of the objects represented with relative coordinates (e.g. doors, windows). Most of the natural phenomena and man-made objects are maintained in GIS models and only newly constructed man-made objects such as buildings, bridges, tunnels, and quays are available as BIM models. GIS models can contain different level of sematic/geometric coherence: 'soup of polygons' with or without semantics; structured geometry with or without object semantics.

Furthermore, some of the models can have topology. BIM models are better structured, having well-defined geometry-semantic coherence, but more complex.

2.2 Size of voxels

Modelling of objects with voxels requires a different way of representation compared to boundary (vector) representation. Voxels represent the interior of an object, while vector models represent the boundary. The boundary does not exist in raster representations. A notion of boundary between two objects is the thin surface between two voxel (see Figure 3). This implies that the size of the voxels should be smaller than the size of the actual object to be represented. Alternatively, the objects have to be exaggerated to the size of a voxel. Voxelization should comply with both the geometric accuracy and the semantics of the object:

- Semantic identification: For example, to represent walls of a house, the voxel size has to be at least 0.1m. If the wall is of no interest, the voxel size could be set even to 1.0m and all voxels will have semantic tag 'building' (Rosenfeld, 1981).
- Geometric accuracy: The voxel size depends on the shape of an objects as well as the accuracy of the measurements. For example, if a building has small corners of about 0.5m, the size of the voxel should be less than 0.5m. Similarly, higher accuracy measurements will require smaller size voxels.

Apparently, depending on the application, the size of the voxels can vary from fine (e.g. 0,1m for representing interiors) to coarse (e.g. 100m for representing geological or climate features). One uniform 3D raster would be advantageous for representing the model, but if the resolution is very fine, the size of the data can grow tremendously. In many applications (e.g. 3D raster, which contains buildings and geological objects) variable size voxels would be required.

2.3 Correct vector-raster conversion

Correct 3D vector-raster conversion requires correct representation of geometry, topology and semantics, which is specific for each model. In this paper we consider CityGML and IFC (BIM model).

Geometry: CityGML inherits the GML data types point, line, polygon and solid. This implies that real world objects represented as point, lines and polygons (surfaces) will be always smaller (in some direction) than the voxel size. If the objects have to be preserved in the resulting 3D raster, it has to be 'enlarged', to be represented with at least one voxel (Figure 3). IFC can have more complex geometries but the model used for the tests contains only surfaces.

Semantics: The semantics of the objects depends on the semantic level of detail (LOD). For example, the buildings LOD1 are 'buildings', LOD2 semantic is extended with 'ground surface', 'wall surface', and 'roof surface'; LOD 3 has in addition to LOD 2 ‘window’ and ‘door’; LOD4 ‘room’, ‘ceiling surface’, ‘interior wall surface’, ‘floor surface’, closure surface’, ‘door’, ‘window’, ‘building furniture’ and ‘building installation’. Depending on the LOD, a voxel can have different semantic tags, e.g. (building, roof), (building, wall), (building, wall, window), etc.

Topology: The neighborhood relations in the vector domain are represented by the boundary of the objects, which completely enclose the object. As boundary does not have an explicit representation in raster domain, the closeness of the object should be ensured by investigating the neighboring pixels/voxels. The neighboring pixels give an indication of *connectivity*. Each pixel has 4 neighboring pixels counting the shared edges and 4 neighboring pixels counting the shared vertices. Similarly, each voxel can have respectively 6 neighboring voxels considering the shared faces, 12 neighboring voxels considering shared edges or 8 neighboring voxels considering the shared vertices (Rosenfeld, 1981). This results in 4 (edges) or 8 (edges & vertices) connectivity in 2D and 6 (faces), 18 (edges & faces) or 26 (faces& edges & vertices) connectivity in 3D (Figure 2).

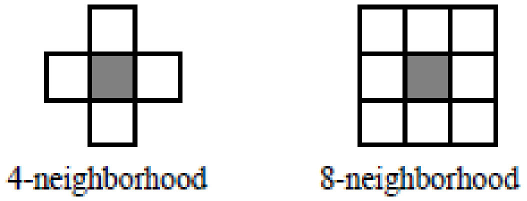
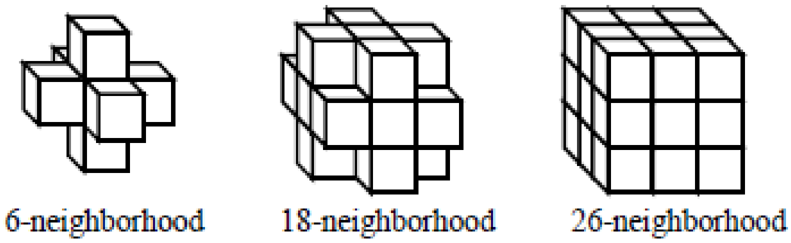
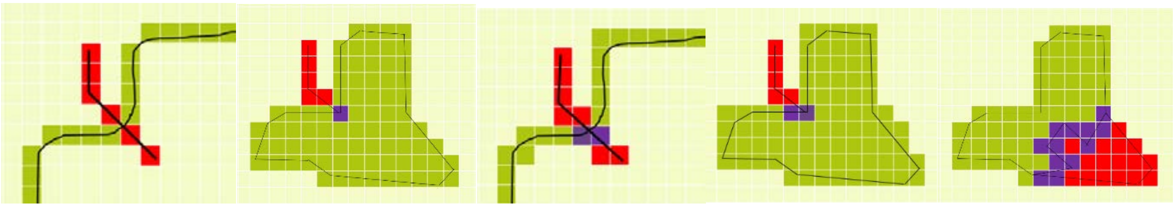
2D	Sharing Edges: 4 Neighbors Sharing Vertices: 8 Neighbors	
3D	Sharing Faces: 6 Neighbors Sharing Edges: 18 Neighbors Sharing Vertices: 26 Neighbor	

Figure 2: Adjacency and neighborhoods in raster models.
Images from Huang et al ###

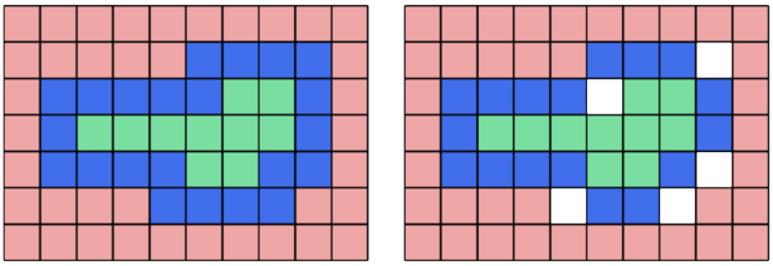
The type of connectivity influences the shape of the rasterized object and can disturb the topological relationships between the objects. Figure 3 illustrates four cases in which the connectivity may lead to disconnecting or penetrating objects in 2D raster. 8-connectivity is favorable for crossing lines (a), but not for touching line and polygon (b). On the contrary, 4-connectivity is favorable for touching polygon line (d), and may lead to discontinuity of line in case of crossing lines (c).



a b c d e

Figure 3: 2D raster: crossing 8 connected lines (a), touching 8 connected line and polygon (b), crossing 4 connected lines (c), touching 4 connected line and polygon (d and 8-connected touching polygons. The dark violet pixels in (b), (c) and (e) can lead to penetrated or disconnected objects

To deal with such cases, the *separability* of voxelization is introduced (Rosenfeld, 1981). A voxel is k-separating if there is no any path of connected voxels between ‘inside’ and ‘outside’. The rasterization of a closed line (blue pixels) on Figure 4a is 4-connected, which ensures 8-separability. In contrast, 8-connected rasterization results is 4-connectivity. The white pixels require further processing Figure 4b.



a b

Figure 4: Separability of voxels: 4-connected voxels are also 8-separable, while 8 connected voxels are 4-separable

Semantics (tagging) identification during the rasterization process is a critical issue. The examples above, clearly illustrate the semantic identification of the pixels (i.e. ‘line’ and ‘polygon’) can result in disconnected objects or penetrated objects. If the dark violet pixel in Figure 3b is tagged as ‘line’, the line will be penetrating the ‘polygon’ object. If the dark pixels in Figure 3c are semantically identified as part of the green line, the red line is being disconnected. Similar semantic issue is observed for the touching polygons in Figure 3e. Depending on the semantic tagging the originally touching polygons might penetrate.

3 ON RASTER-VECTOR CONVERSION METHODS

As mentioned above, we envisage a 3D application to be capable of converting 3D vector and 3D data models to one another in a consistent way. The following are a few algorithms that can be used in such conversions. It is important to note that these conversions are generally irreversible because certain information is lost during a conversion. However, the importance of these methods is in their practical applications, in which this loss of information is not an important issue. For instance, many of these algorithms are developed for rendering, where the size of pixel is invisible for the human eye and incorrectness along the borders of the objects is hardly noticeable. Most of these algorithms concentrate instead on performance issues.

It might appear that voxelization is as trivial as intersecting objects with voxels; however, this naïve approach is firstly very inefficient. Furthermore, we need to ensure preservation of certain topological properties such as connectedness and separability as discussed above. We can define three quality criteria for voxelization algorithms:

- Efficient enough to be done on the fly
- Result in a ‘thin’ voxel collection that minimally represents voxelized features
- Provide explicit control and guarantee on preservation of topological and [thus] semantic structure of input

3.1 Rasterization approaches

Since most of the objects in 3D City Models are composed of multiple surfaces, the review is specifically on voxelization of surfaces.

Two general approaches can be distinguished: object rasterization and scan-conversion rasterization. Object rasterization concentrates on the object of interest following two steps: boundary rasterization and interior filling. The continuous rasterization scans in a given raster volume which voxels get what kind of value. All of the presented methods in these studies were based on extensions of the well-known scan-conversion method, which is well studied and commonly used in the field of 2D computer graphics.

(Kaufman & Shimony 1986) and (Kaufman 1987) presented a set of algorithms serving the purpose of voxelizing a range of specific parametric primitives including 3D lines, polygons, polyhedral, cubic parametric curves, bi-cubic surfaces, circles, quadratic objects and tri-cubic solids. Voxel models resulted from the algorithms are ensured to be 26-connected. It is, however, not possible to alternate the level connectivity to 18 or 6. Computational efficiency has been rigorously optimized by keeping repetitive operations as simple as possible (i.e. use addition, subtraction instead of multiplication or division) and integer arithmetic has been utilized whenever feasible. Consequently, temporal costs of the algorithms are kept consistently lower than linear to the number of resulting voxels.

The issue of limited connectivity control has been revisited by the same research group a decade later (Cohen-or & Kaufman 1997). In that research a so called Tripod algorithm has proposed allowing changing the connectivity level to six. Nevertheless, only line was investigated. The lack of connectivity control remains a significant drawback of the assortment of algorithms.

(Huang et al. 1998) addressed the topological property of resulting raster models but not the efficiency issue. Two and three dimensional planes have been investigated in that research. The proposed solution is based on the intersection between a regular voxel grid and a buffer zone constructed around an input object. By changing the size of the buffer zone, it is possible to switch between different connectivity levels. However as pointed out by a recent study by (Laine 2013), voxel models produced by (Huang et al. 1998) are not guaranteed to be minimal. Additionally, many spatial operations such as computation of distances, intersections and constructing planes are required. The significant complexity makes the algorithm potentially inefficient and re-implementation is not straightforward.

The above methods are all object-type specific, meaning different algorithms must be used for different kinds of input primitives. As opposed to that, a generic solution can be achieved simply by creating a voxel if it is overlaid by a portion of an input object. This approach is intuitive but generally leads to conservative results (i.e. minimality is not ensured). Moreover, the temporal cost associating with this solution is usually high due to the demanding spatial operations. Utilization of graphical hardware can alleviate the issue (Chen & Fang 1998) and (Schwarz & Seidel 2010) just to name a few.

A topological method presented by (Laine 2013) is very interesting option due to its capability of voxelization generic objects while rigorously ensuring connectivity property of resulting voxel models. The method is intersection-based, which set a voxel whenever its intersection target crosses an input object. A voxel's intersection target is a spatial subset of the cubical space occupied by the voxel such as the quadrilaterals bisecting the voxel along its three axes. Intersection targets are chosen based on the desired connectivity level and the dimensionality of the input vector object. Since the proposed method is intersection-based, computational efficiency would be an issue.

In addition to the methods presented in research papers, there are a number of accessible open source programs for voxelization such as ***binvox*** (Min 2014), ***Voxelization toolkit*** (Milossramek 2013). Those tools are usually restricted to watertight meshes, unable to directly parse CityGML file or assign semantic for voxels. Due to the restrictions, we opted to a re-implementation from scratch.

3.2 Our topological voxelization algorithm

Based on the topological voxelization method devised by (Laine, 2013), we have implemented two algorithms for voxelizing 1D inputs (curves) and one for 2D inputs (surfaces). Apart from these two, we have developed a voxelization algorithm for 0D inputs (points). Full scripts of algorithms is available in (Nourian, P, Goncalves, R, Zlatanova, S, Arroyo Ahori, K, Vo, A, 2016).

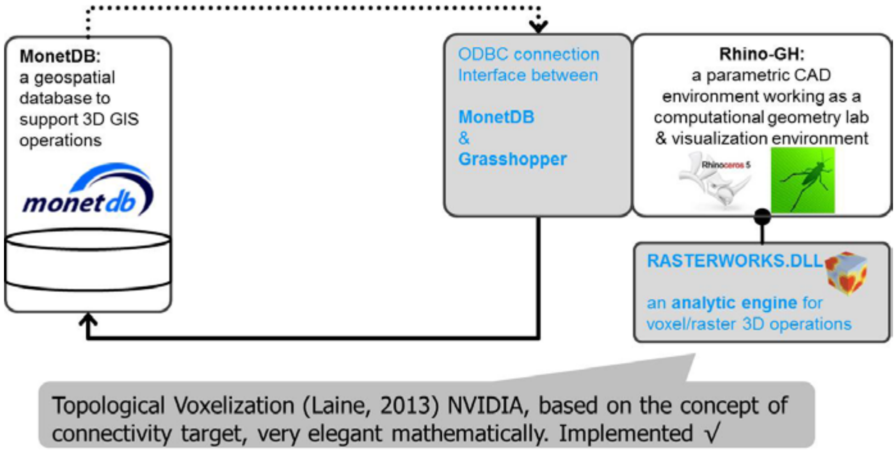


Figure 5: Vector-to-raster conversion directly in the database, avoiding unnecessary data traffic.

3.3 Rasterizing test environment

We focus on vector-raster conversion algorithms in a laboratory setup as schematized in Figure 5. The system consists of MonetDB, Rhinoceros® and Grasshopper© [1]. MonetDB (https://www.monetdb.org/) is intended for storage and management of integrated 3D vector and 3D raster representation. Rhinoceros is a CAD environment and is intended for query and visualization of vector/raster data. Grasshopper is used as a laboratory workbench for testing the algorithms. The rasterization algorithms are organized in a raster engine (RASTERWORKS.DLL), which is currently working in this architecture as a library of methods for rasterization, in combination with several utility functions. The connection between the MonetDB[2] DBMS and Rhino is established by ODBC (the standard programming API for accessing DBMS). The chosen algorithms have been implemented in C#.NET and VB.NET. Source codes are available on GitHub:

1. https://github.com/Pirouz-Nourian/TUD_RasterWorks_V_0.1
2. https://github.com/NLeSC/geospatial-voxels (Nourian, P, Goncalves, R, Zlatanova, S, Arroyo Ahori, K, Vo, A, 2016)

3.4 Rasterizing 3D indoor models

We have worked with two types of models: CityGML of one building at the TU Delft campus and a building model provided by Bentley systems. We investigated two approaches for voxelization, one as including empty space voxels with a colour code as black, visualizing empty space (Figure 6). Including empty voxels can be very problematic to produce larger datasets, e.g. a model of a whole city.

[1] http://www.grasshopper3d.com/
[2] https://www.monetdb.org/Home

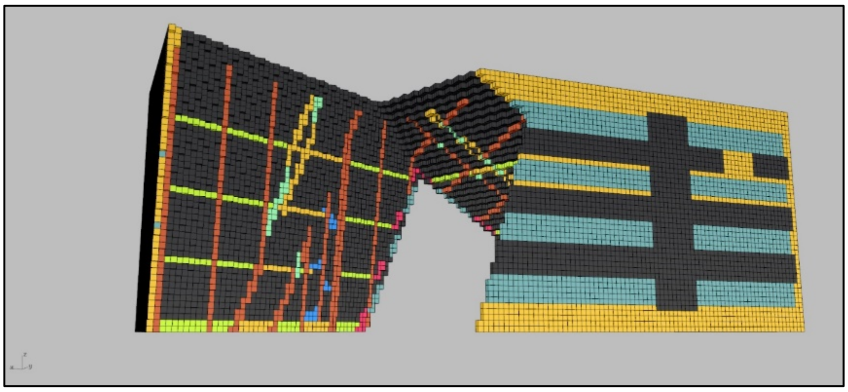


Figure 6: A building on the campus of TU Delft, rasterized from a CityGML model

The second building called 'the Bentley building' was used to experiment if all type of objects indoor/outdoor can be voxelized. The experiments show that the proper choice of voxel size can be critical for some objects. Some objects might not be representable with inappropriately sized voxels, for instance the wind turbine in this building disappears or becomes disjoint when choosing a coarse resolution (Figure 7, Figure 8). We suspect that this issue might be resolved by taking into account the importance of the object.

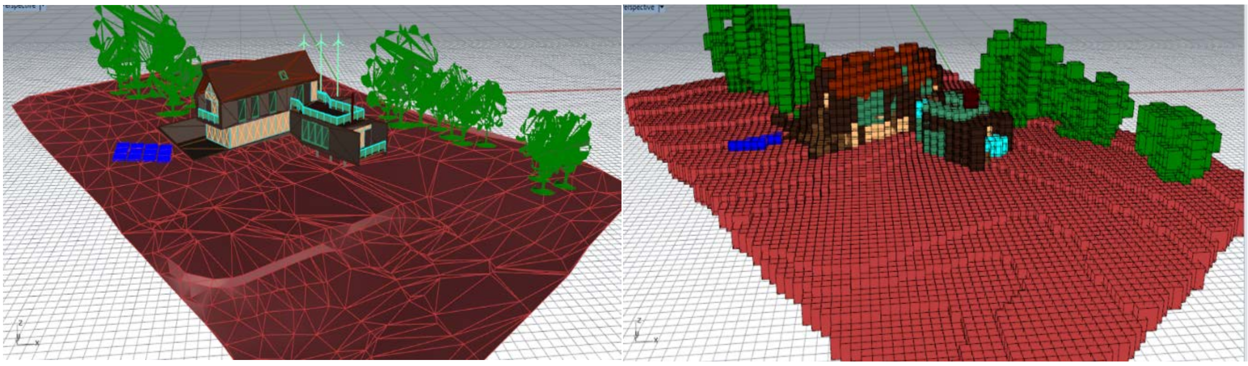


Figure 7: IFC building model imported as OBJ generated from original BIM model, corrected and coloured to represent objects of different semantics.

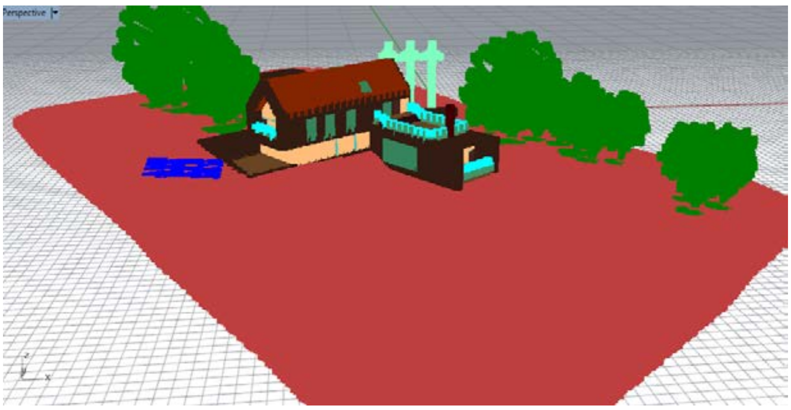


Figure 8: Topological Rasterization with Semantics from a BIM model [0.1 by 0.1 by 0.1 M]

3.5 Rasterizing CityGML LOD2 models (GIS)

In voxelizing CityGML LOD2 models (Figure 9, Figure 10), the main issues are defining a proper schema both for raster 3D and voxels in order to keep semantic information such as the ones modeled in a CityGML. Both of these issues and also the matter of ensuring uniqueness of voxels (avoiding duplicates when joining multiple voxel collections) requires further investigation.

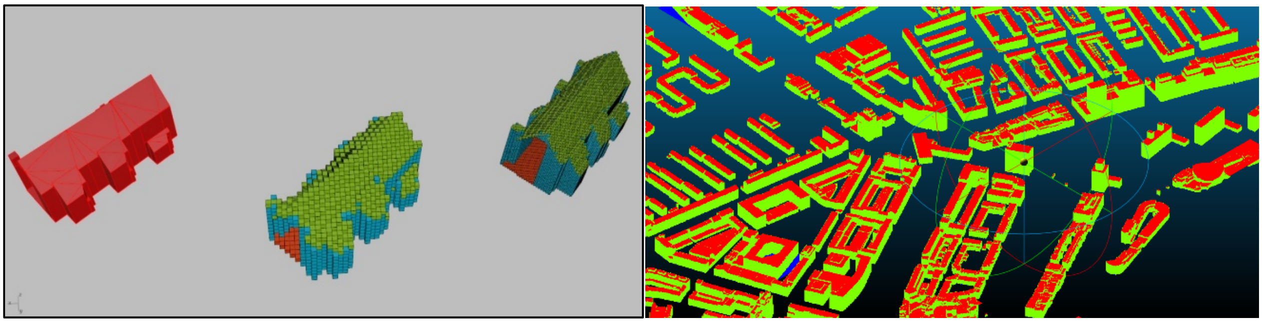


Figure 9: LOD2 building model from CItyGML models of Rotterdam (Rubroek), rasterized with 40 cm and 1 meter resolutions, colors encode semantic properties roof, wall, and ground floor as green, blue and red respectively.

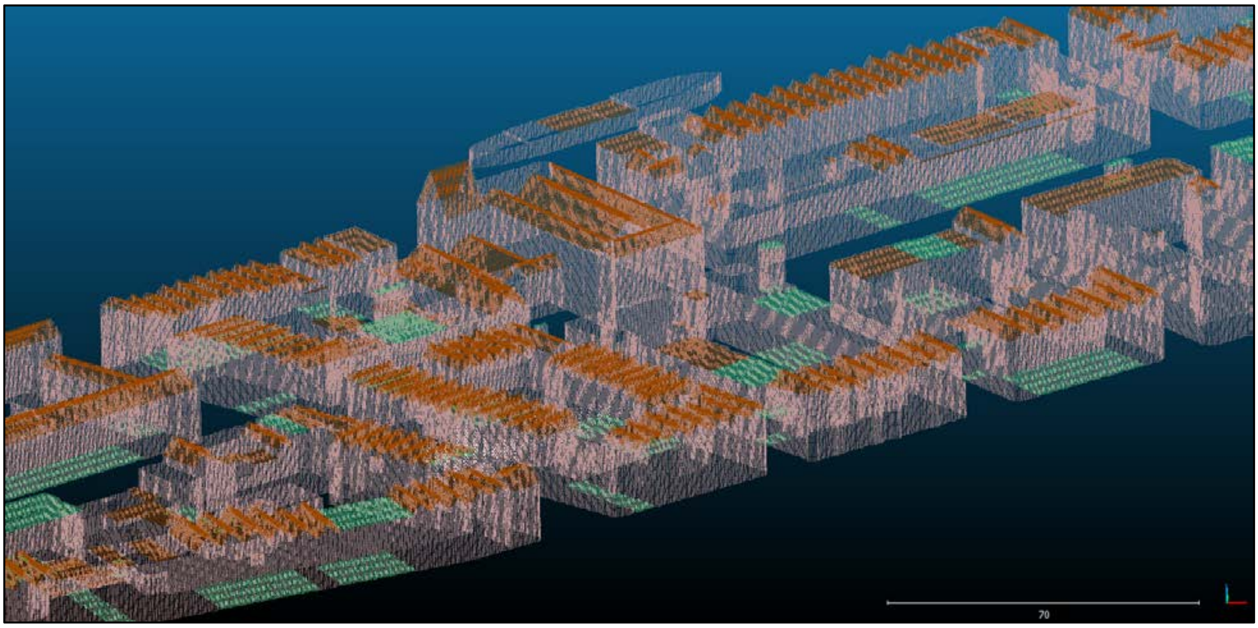


Figure 10: Rotterdam CityGML, Noorderiland, 0.2x0.2x0.2; zoomed in.

3.6 Loading in MonetDB

Using the described rasterization algorithms, we have loaded a collection of approximately 60 million voxels into MonetDB for testing. The voxels have been stored initially as tuples of [double x, double y, double z, double numeric attribute, integer semantic tag] and later as tuples of [integer ID, double x, double y, double z, byte R, byte G, byte B] in which IDs correspond to the objects voxelized and RGB colours encode semantic attributes of the CityGML files of Rotterdam.

The load of 60 million voxels takes 30 seconds using bulk loading from a comma-separated-values (CSV) file. MonetDB is a columnar-oriented relational DBMS, each column is stored sequentially in an independent file. Hence, if the coordinates are stored as doubles the disk footprint for X, Y, and Z is 1.34 GB. If instead of doubles we use decimals due to the small coordinate range, i.e., the coordinates are saved into a 4 byte-integer and the scale is stored as a table property, the disk footprint for X, Y, and Z is 686 MB.

Column-oriented architectures allow us to have efficient compression by using column-specific compression algorithm such as delta compression (https://en.wikipedia.org/wiki/Delta_encoding). With delta compression MonetDB reduces the size of X, Y, and Z from 686 MB to 171 MB.

The use of compression not only reduces the disk footprint to store the coordinates but it also improves query response. Such improvements are due to lazy decompression during query execution, i.e., a predicate is evaluated against the compressed data which improves I/O and speeds up data skipping. A performance profile is however not covered in this article. Such study will be published in a future publication.

We have performed tests with a set of 15 queries. Queries 1-7 extract voxels in a given MINMAX box, queries 8-11 are sematic selection (i.e. according to a semantic criterion) and 12-15 are update statements. The following are examples of the three groups of queries

Query 2: Select the whole set of voxels
```
DROP TABLE voxels_within_box;
CREATE TABLE voxels_within_box (x double, y double, z double, m double, s int);
INSERT INTO voxels_within_box SELECT * FROM Rubroek_voxels;
```

Query 10: Select all 'ground' voxels
```
DROP TABLE semantic_collection;
CREATE TABLE semantic_collection(x double, y double, z double, m double, s int);
INSERT INTO semantic_collection SELECT * FROM Rubroek_voxels WHERE s=3;
```

Query 15: Create a 'floor' voxels by assigning a value relative to their relative height (two versions, one in a loop)
```
UPDATE Rubroek_voxels SET m= ROUND(Z/3,0)
```

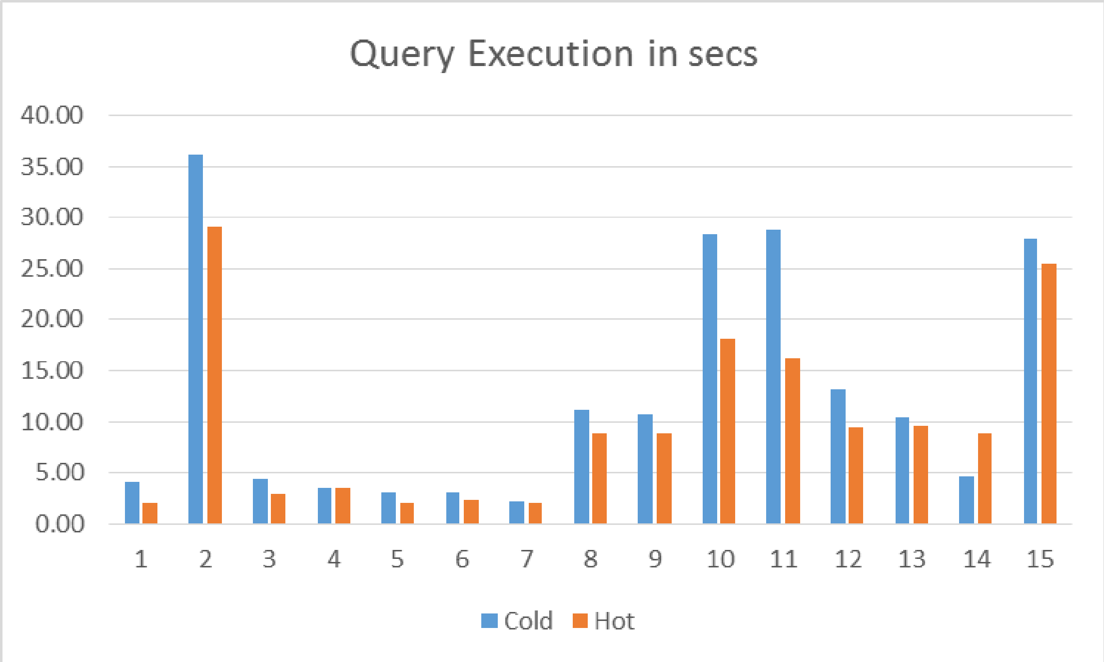


Figure 11: Execution of the queries in seconds.

The results (Figure 11) are in the range of 15 seconds with exception of some 'expletive' queries as extracting all voxels (query 2) or performing some computations in de update statement (query 15). It is also apparent that after several executions of one query the results improve, i.e. the result given in red (hot).

4 DISCUSSION

This paper presented some of our research and development of an extended raster engine for voxelization of semantically rich 3D city models. The rasterization engine is one of the components needed for realizing a raster 3D GIS. We have developed algorithms, which are able to rasterize 3D CityGML and IFC models. However, many issues are still open.

4.1 Some bottlenecks

The main bottleneck in the current process is a data parser, for instance in reading from CityGML files. We can currently only read the lowest level of semantics from CityGML files as we have to use a file format converter (FME) which can produce the file formats (.dwg or .obj) that Rhino can import. In this process of conversion, the higher levels of semantic get lost. Reliable data convertors have to be developed, which can keep all semantics and properties of objects.

The current working prototype of the voxelizer engine in C is significantly slower than the C# version. Although this does not sound logical, the problem is that the OBJ file parser we have implemented now reads the whole OBJ file of an urban neighborhood as one big mesh. This results in a very big bounding box and thereby an enormous number of voxels to be iterated on. The solution to this problem is in fact tightly related to the problem of semantics: when parsing a CityGML file we need to be able to read objects one by one building. Our OBJ parser is still naïve and rather simplistic and can be easily jammed by unexpected features in an OBJ file. Rasterizing large data set such as CityGML models of Rotterdam is currently done by rasterizing neighborhood models one by one. As the models do not have overlaps it might seem to be a good approach. However, we have not yet implemented any procedure to prevent creation of duplicate voxels. We envisage that by implementing a special type of spatial indexing this issue can be prevented. This case is closely related to the matter of standardization of a data model as for 3D raster data models. We regard this matter as one of the most important unsolved problems that requires further investigation.

4.2 Future research

The main issues that need further investigation are related to resolution of semantic issues shown in test results, namely conflicting semantics and standardization of a voxel datatype to be capable of serving a multitude of environmental modelling application such that semantic properties of objects can be preserved seamlessly. Ingestion of large vector data models can be problematic, as it will currently result in many duplicates of voxels.

Proper 3D raster data models have to be investigated, developed and tested in order to deal with this issue in a systematic manner. Voxel data type is atomic and needs to be defined in reference to a voxel collection as 3D raster. In order to standardize a 3D raster data model, we need to investigate and test more case studies in real-world environmental modelling/simulation scenarios and improving both algorithms and data models.

We currently present voxels in absolute geographical coordinates; however, this might have negative effects when dealing with big data. In addition, the main unanswered question is whether a 3D raster should be defined using the coordinates of every single voxel in the collection or integers referring to their (i, j, k) entries in a 3D array or only Boolean values corresponding to (i, j, k) entries. Each of these methods has their specific advantages and disadvantages. In order to answer this important question; more research and development have to be undertaken in collaboration with partners specialized in both data science and environmental modelling.

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6 REFERENCES

Akio, Doi, and Akio Koide, 1991. An efficient method of triangulating equi-valued surfaces by using tetrahedral cells. *IEICE TRANSACTIONS on Information and Systems* , 74(1), pp. 214-224.

Boekhorst, M., 2007. *Method for determining the bounding voxelisation of a 3D polygon.* USA, Patent No. US Patent 7,173,616, 2(12).

Borrmann, A. & Rank, E., 2009. Specification and implementation of directional operators in a 3D spatial query language for building information models. *Advanced Engineering Informatics*, 23(1), p. 32–44.

Cohen-OR D., Kaufman A., 1995. Fundamentals of surface voxelization. *Graph. Models Image Process,* 57(6), pp. 453-461.

Cohen-OR D., Kaufman A., 1997. 3D line voxelization and connectivity control. *Computer Grpahics and Applications IEEE* , 17(6), pp. 80-87.

Huang, J, Yage R, Filippov V and Kurzion Y, 1998. An Accmate Method for Voxetiting Polygon Meshes. In: *IEEE Symposium on Volume Visualization (Cat. No.989EX300).* s.l.:IEEE, p. 119–126.

Kaufman, A. & Shimony, E., 1987. *3D scan-conversion algorithms for voxel-based graphics..* New York, ACM Press, p. 45–75.

Kaufman, A., 1987. *Efficient algorithms for 3D scan-conversion of parametric curves, surfaces, and volumes.* New York, ACM Press, pp. 171-179.

Laine, S., 2013. A Topological Approach to Voxelization. *Computer Graphics Forum*, 32(4), p. 77–86.

Lorensen, William E., and Harvey E. Cline, 1987. Marching cubes: A high resolution 3D surface construction algorithm. *ACM Siggraph Computer Graphics,* 21(4).

Nourian, P, Goncalves, R, Zlatanova, S, Arroyo Ahori, K, Vo, A, 2016. Voxelization Algorithms for Geospatial Applications. *Methods X,* Volume 3, p. 69–86.

Rosenfeld, A., 1981. Three-Dimensional Digital Topology. *Information and control*, Volume 50, pp. 119-127.

Schwarz M., Seidel H. P., 2010. Fast paralell surface and solid voxelization on GPUs. *ACM trans. Graph.* , 29(6), pp. 179:1-179:10.

Varadhan G., Krishnan S., Kim Y.J., Diggavi S. Manocha D., n.d. *Effeicient max-norm distance computation and reliable voxelization.* s.l., s.n., pp. 116-126.

Wang, S.W. & Kaufman, A.E., 1993. *Volume sampled voxelization of geometric primitives.* s.l., IEEE Comput. Soc. Press, p. 78–84.

Xie, X., Liu, X. & Lin, Y., 2009. The investigation of data voxelization for a three-dimensional volumetric display system. *Journal of Optics A: Pure and Applied Optics,* 11(4), p. 45707.

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FUSION OF MOBILE LASER SCANNING AND UAV DATA FOR CARTOGRAPHY PURPOSES

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KEYWORDS: mobile laser scanning, UAV, cartography, digital elevation model, horizontal and vertical object position

ABSTRACT

Both mobile laser scanning (MLS) and UAV aerial survey are new techniques in surveying. Data obtained are mainly used in cartography for large scale topographical mapping and for 3D modelling. Both MLS and UAV aerial survey used for cartography purposes have their own pos and cons. If we use UAV aerial survey, the topographic plans are created based on a digital surface model (DSM) in the form of a point cloud and an orthophoto plan. The point cloud is generated from pairs of non-metric UAV images. An orthophoto plan should be used for determining the horizontal object position, whereas a point cloud – for determination of the vertical object position. If we use MLS data, a point cloud is applied for determination of both horizontal and vertical object position. The horizontal accuracy of both techniques is usually sufficient for creating a topographic plan at any scale. In case of generating contours it is important to be sure that low points belong to the ground. Digital elevation model (DEM) is generated by means of low point extraction from the whole point cloud. In some cases UAV aerial survey can provide reliable position of ground, in other cases – only MLS. Depending on an area, it is necessary to choose any surveying technique which is more suitable. For built-up areas actually without vegetation and for areas having large slopes it is better to apply UAV aerial survey. For areas with dense vegetation layer MLS is more suitable because the laser beam can penetrate through the vegetation layer. Thus, it is more difficult task to generate contours with appropriate accuracy using data obtained both from UAV aerial survey and MLS. The better decision is fusion of point clouds from MLS and UAV data. Then advantages of both techniques can be combined. The method of MLS and UAV data fusion is described. The results of data fusion are presented for a highway in Novosibirsk Region.

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WARFARE-INDUCED VEGETATION COVER CHANGE MAPPING IN EAST UKRAINE USING MULTITEMPORAL SATELLITE IMAGERY

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KEYWORDS: vegetation cover, LAI, change detection, multispectral satellite imagery

ABSTRACT
Analysis of vegetation cover changes using multispectral satellite imagery is performed along the delimitative line, so called “grey zone”, which conditionally divides the Ukrainian territory from the area under anti-terrorist operation in the eastern part of Ukraine. The primary tool for landscape changes detection is the remote mapping of vegetation cover change over the study area. Deforestation is detected within zones of warfare operations and characterized by spotted distribution through all over the “grey zone”. It is correlated with anthropogenic activities led to vegetation clearance along the highways and railways, along the artificial forest plantations, infrastructure destructions within urban areas because of fire spread, direct military operations followed by fire explosions and landscape degradation.

1 INTRODUCTION

The warfare operations on the east of Ukraine lead to unprecedented environmental impact. Lack of controllability and observability over the study area and periodic shelling do not allow assessing damage to the environment without bias.

As it is known, the steppe Donbass landscapes were severely transformed and vegetation cover degraded before the armed conflict because of intensive industrial stress. This makes the warfare load even more stressful. The environmentalists already ring the alarm and emphasize on international legislation in protecting the environment during armed conflicts [1]. Recent publications on effects of the warfare impact on the processes in ecosystems have demonstrated benefits from remote methods application and necessity of their further development [2, 3].

It has also to be considered their application for the environment risk assessment and ecosystem vulnerability during war disasters and in the context of climate change.

2 STUDY AREA

All the Donbass landscapes components from parent material, underground and surface water bodies, to soil-vegetation cover, have been severely suffered for the period from May, 2014 till present. The natural vegetation cover of the study area is presented mainly with motley grass and remains of ravine forests. The last ones are left along the small river valleys, on the slopes of gullies and ravines. But they are still there and it is a high threat to the environment when those rare remnants fall under fire destruction. Since vegetation is a key component of an ecosystem and involved in the regulation of various natural cycles, in this publication the authors concentrate their attention on vegetation cover change detection through comparison of satellite images taken before and after the warfare activities started. Analysis of vegetation cover was performed along the delimitative line, so called "grey zone", which conditionally divides the Ukrainian territory from the area under anti-terrorist operation in the eastern part of Ukraine.

3 DATA AND METHODS

Leaf area index (LAI) was assigned as the main indicator of vegetation state. LAI can be determined by special processing of multispectral satellite imagery [4]. Processing dataflow is presented in the Figure 2 diagram with unified modeling language (UML) standard.

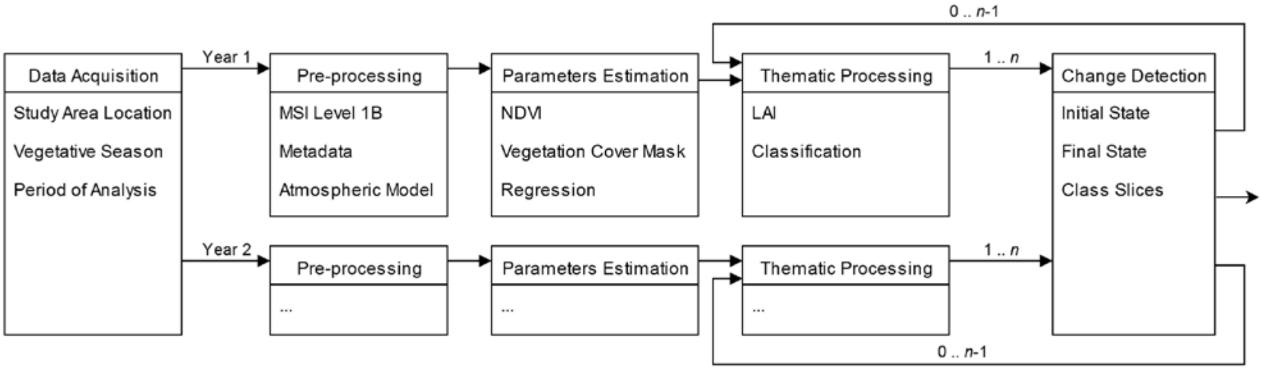


Figure 1: Satellite data processing flowchart

After the data acquisition the vegetation analysis process is subdivided into 3 main components. The first component is pre-processing, which consists of radiometric and atmospheric correction.

Vegetation parameters estimation is the second component. The woodland vegetation analysis was performed on this stage. Normalized difference vegetation index (NDVI) was calculated. The farmlands area was suppressed using vegetation cover mask. The resulting NDVI map for woodland vegetation has been obtained.

Thematic processing is the third component. NDVI map was transformed into LAI using a known regression relationship [5].

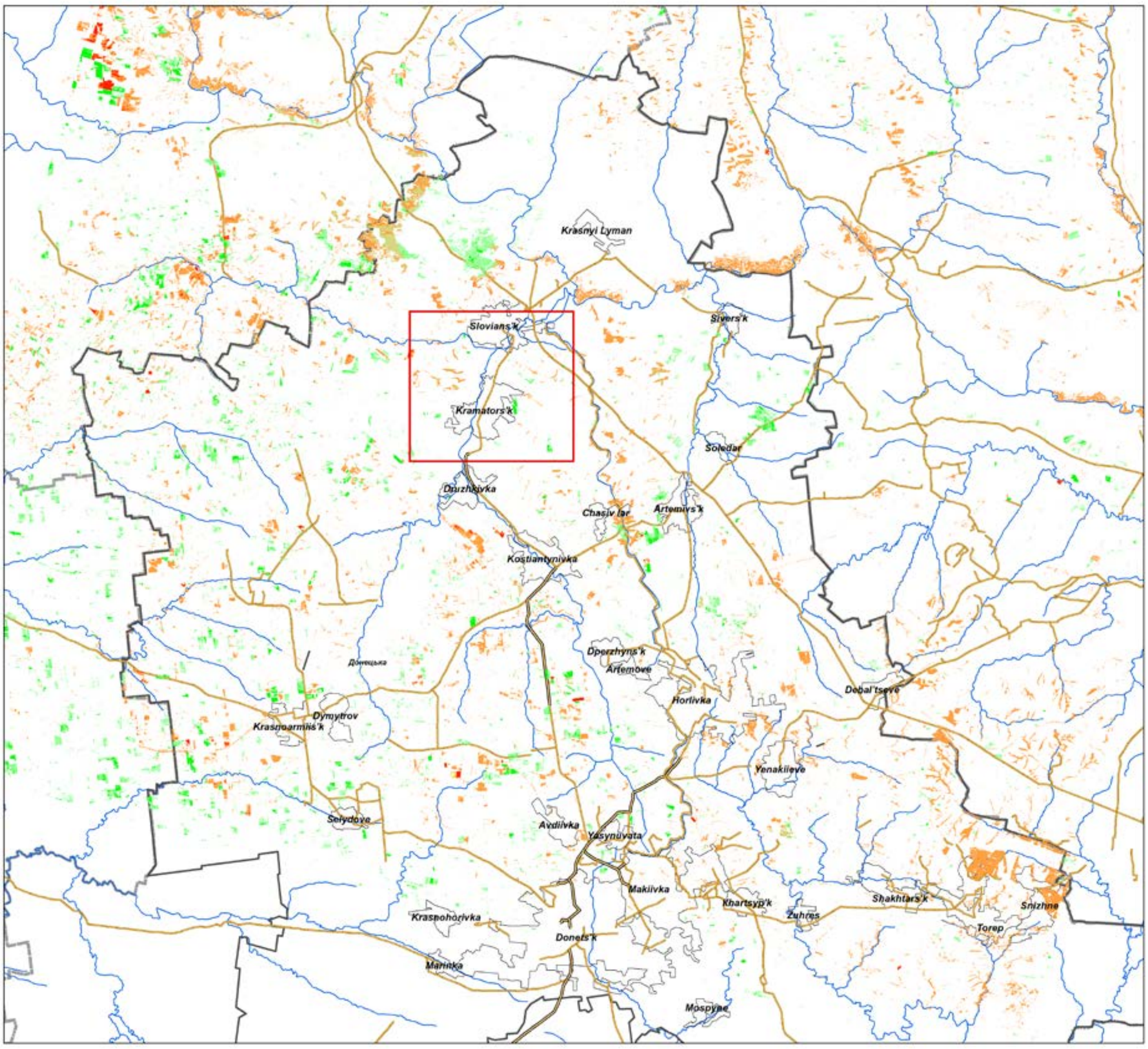
Finally, the change detection procedure is performed [6], which one repeated iteratively with thematic processing and classification component. In the Figure 1 the *n* is an iterations number.

Upon change detection completing the vegetation state final map was produced. The map provides information on seven classes of vegetation state, between strong growth and high degradation [7], as shown in the Table below.

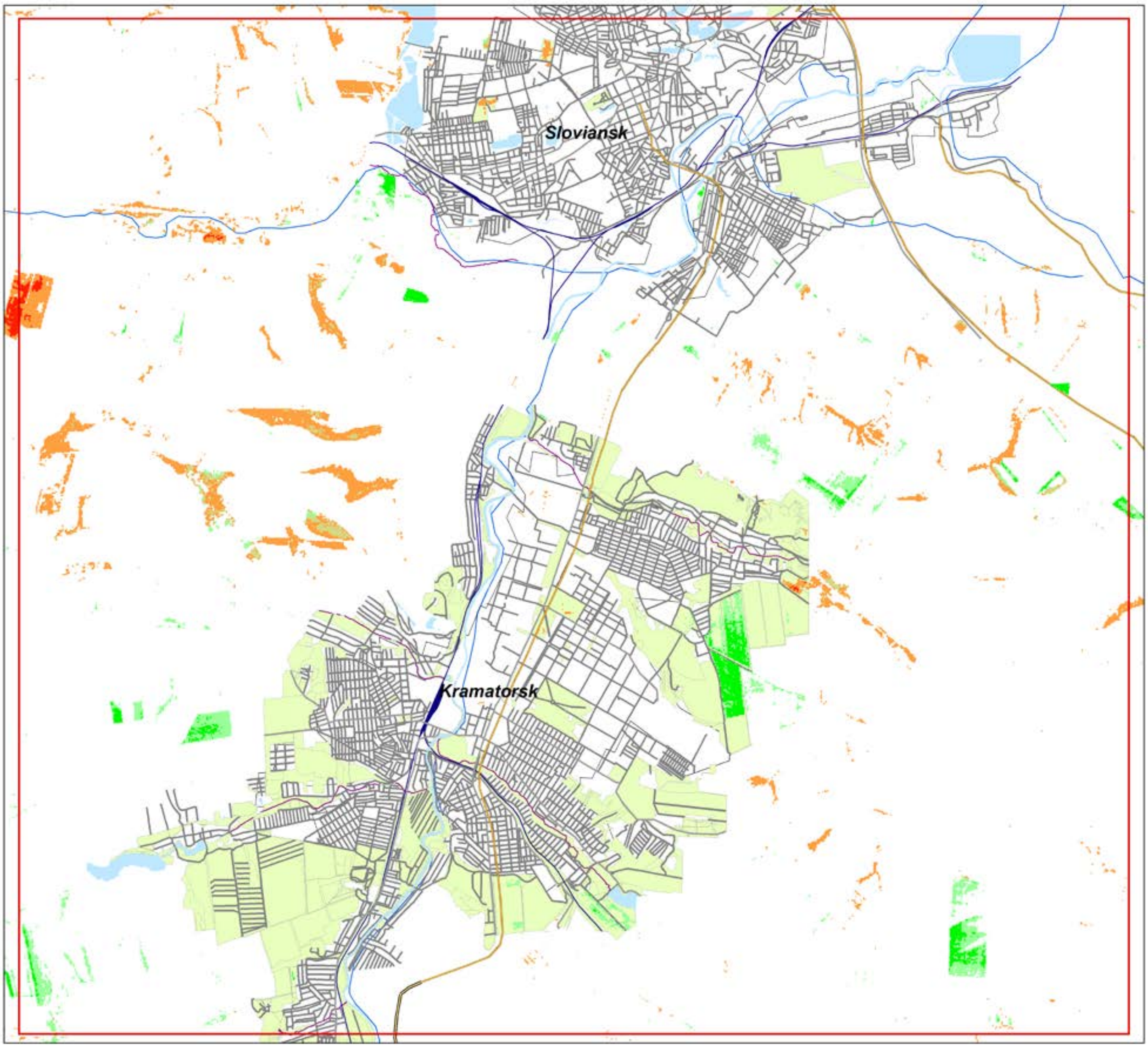
Table: Vegetation cover change classes legend

Code	Class [Color]
	Strong growth [Bright Green]
	Moderate growth [Pastel Green]
	Weak growth [Pastel Grey]
	No change [Sea Shell]
	Low degradation [Yellow]
	Medium degradation [Pastel Orange]
	High degradation [Alarm Orange]
	Water surface [Blue]

Changes in vegetation patterns were detected using the images of Landsat/OLI Level 1B for the period from May 2013 to May 2014 (Figure 2) and from May 2014 to May 2015 (Figure 3) for the northern part of the Donetsk region and the western part of the Lugansk region.



a



b

Figure 2: Vegetation change map for the period from May 2013 to May 2014: *a* – overview map, *b* – Sloviansk-Kramatorsk area enlarged

When it comes to warfare consequences, vegetation is the first to be influenced as it is very sensitive towards abrupt change of environmental conditions. Unfortunately, the nature reserve fund of the study area has been significantly decreased partially because of fortifications on their territories and development of severe fires through all over the study area. The images of 15 May 2013 and 18 May 2014 were used (Figure 2*a*) and high level of vegetation degradation is obvious.

Upon a closer view, deforestation is detected within zones of warfare operations and characterized by spotted distribution through all over the “grey zone”. It is correlated with anthropogenic activities led to vegetation clearance along the highways and railways, along the artificial forest plantations, infrastructure destructions within urban areas because of fire spread, direct military operations followed by fire explosions and landscape degradation.

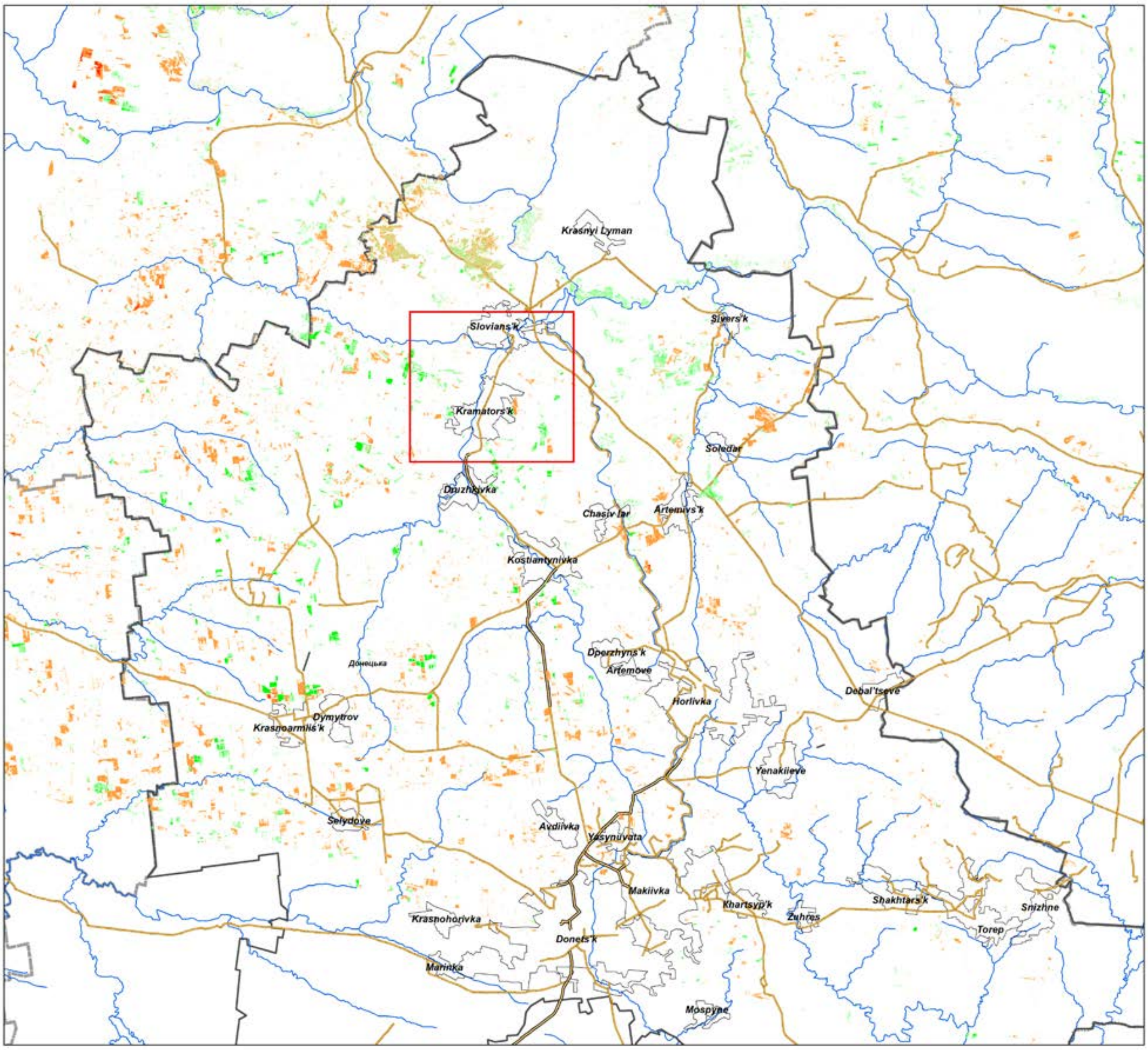
Let us consider the northern suburbs of the Sloviansk city (Figure 2*b*). It was one of the focal points in the early stages of the 2014 conflict in Ukraine. The territory is covered with dense vegetation that was recently planted and known as one the youngest among the regional landscape parks called "Sloviansk resort".

Different levels of vegetation degradation (mostly medium and high) are fixed along the green massif in the north-western part of the Svyatogorsk resort area, sparsely spotted around the Slaviansk radon resort area, and the area around the city itself. At the same time a green forested massif is observed between two cities – Krasnyi Luch and Svyatogorsk. It was not disturbed and bright and pastel green colors prove the environmental enhancement.

The territory south of the Sloviansk city is less covered with vegetation (Figure 2*b*) and thus any apparent change is observed. Nevertheless the Kramatorsk Park located within the city area and its vegetation has not been degraded. Significant vegetation growth is observed on the eastern part of the city suburbs.

Another example is the city of Gorlivka and its suburbs. It is located on the up hills of the former upland ridge with gentle slopes. This mining area is very rich of coal and other metal deposits and so was highly transformed before the warfare activities started. Vegetation cover in the eastern and south-eastern suburbs of the city is highly degraded as well as within the eastern area of the town of Chasov Yar where famous clay deposits were operated through development of open pits. The mystery of nature is how vegetation remains life-asserting and manages to improve life conditions wherever human beings do not interfere.

The same research was made for the period from May 2014 to May 2015. Different levels of vegetation cover degradation (mostly low and medium) are fixed along the woods areas, sparsely spotted through all over the study are but obviously less than a year before (Figure 2a and 3a). Especially it is evident when a closer look at the enlarged territory between the same cities (Sloviansk-Kramators). Moderate and even strong vegetation growth is fixed to the south-east and north-west of the city of Kramatorsk (Figure 3b). On the one hand, it may be forced because of climate conditions change during the study period. On the other hand, private farming acreages were not properly cultivated and nature invasion took place.


Krasnyi Lyman
Sloviansk
Sivers'k
Kramators'k
Soledar
Druzhkivka
Chasiv Iar
Artemivs'k
Kostiantynivka
Dzerzhyns'k
Artemove
Horlivka
Debal'tseve
Dymytrov
Krasnoarmiis'k
Yenakiieve
Selydove
Avdiivka
Yasynuvata
Makiivka
Khartsyzk
Zuhres
Shakhtars'k
Snizhne
Torez
Krasnohorivka
Donets'k
Marinka
Mospyne

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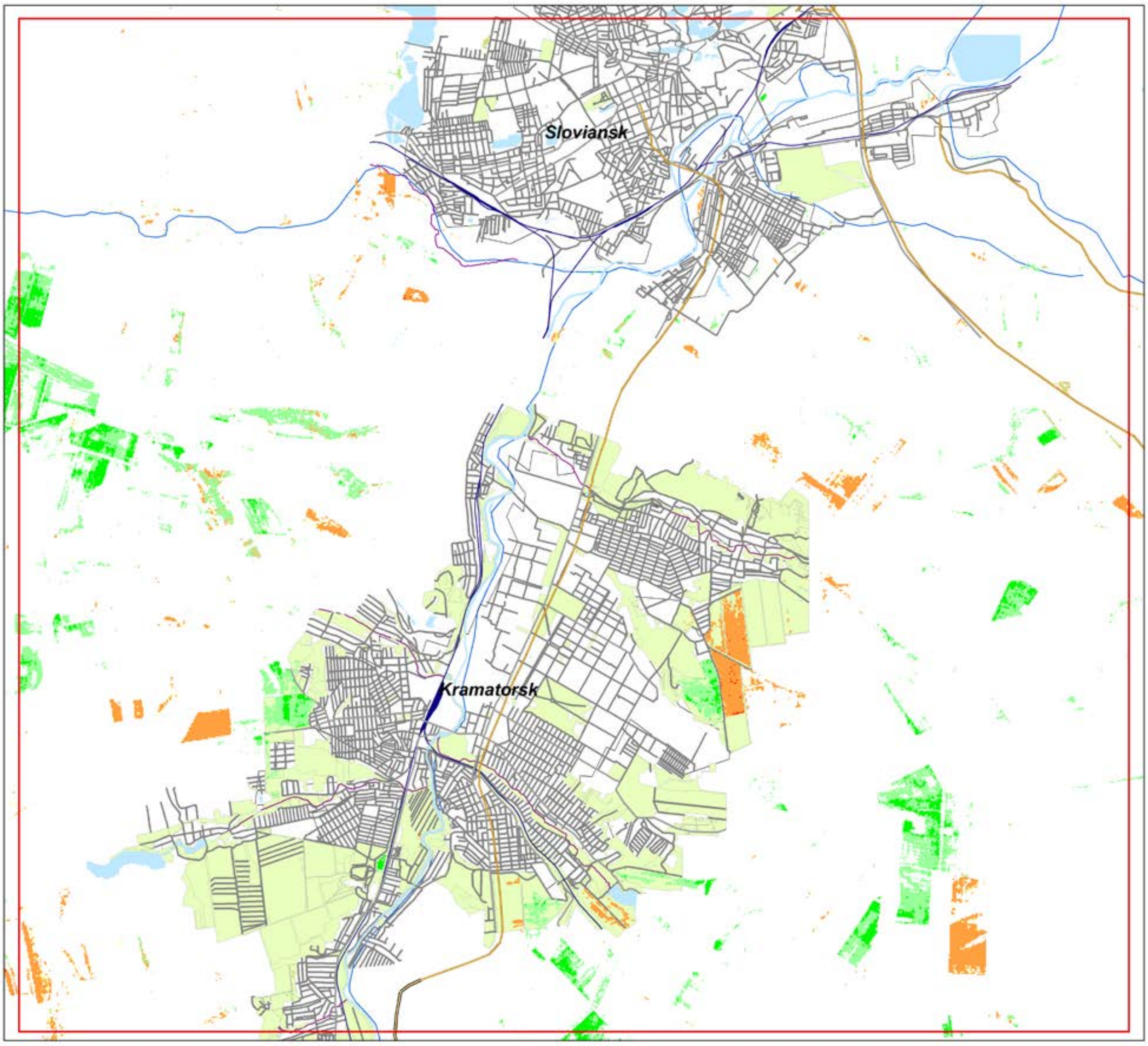

b

Figure 3: Vegetation change map for the period from May 2014 to May 2015:
a – overview map, *b* – Sloviansk-Kramatorsk area enlarged

CONCLUSIONS

Since vegetation cover is very vulnerable towards environmental conditions abrupt change, the sites of high level vegetation degradation might serve as "hot spots" to be taken attention to in terms of their rehabilitation. Vegetation cover degradation is detected within zones of warfare operations and characterized by spotted distribution through all over the "grey zone". It is correlated with anthropogenic activities led to vegetation clearance along the highways and railways, along the artificial forest plantations, infrastructure destructions within urban areas.

Remote detecting of vegetation cover change is of high importance when direct measurements are not possible. Early detection of "hot spots" can help for further improvement of environmental condition.

REFERENCES

1. Stankevich S.A., Dudar T.V., Loik I.V., Neizmailova N.S. Belligerent landscape change analysis using remote mapping of vegetation cover // Proceedings of ISPRS WG IV/2 Workshop "Global Geospatial Information and High Resolution Global Land Cover / Land Use Mapping".– Novosibirsk: SSUGT, 2015.– P.64-71.

2. Voytsikhovska A., Norenko K., Vasyliuk O. A brief outline of the state of environment in Donetsk and Luhansk regions before the beginning of military actions in Ukraine's East // Military Conflict in Eastern Ukraine – Civilization Challenges to Humanity. – Lviv: Environment-People-Law, 2015.– P.47-57.

3. Donbass Recovery Assessment of Social and Economic Losses and State Policy Priority Directions.– Kyiv: National Academy of Sciences of Ukraine, 2015.– 37 p.

4. Cohen W.B., Maiersperger T.K., Stith T.G., Tumer D.P. An improved strategy for regression of biophysical variables and Landsat ETM+ data // Remote Sensing of Environment, 2003.– Vol.84.– No.4.– P.561-571.

5. Piestova I.A. Quantitative vegetation mapping of urban area using high-resolution multispectral satellite imagery // Science-Based Technologies, 2015. – Vol.2.– No.26.– P.153-158.

6. Stankevich S.A., Kozlova A.A. Long-term land cover change computer-aided mapping by remote sensed imagery // Proceedings of the International Conference on Information and Digital Technologies (IDT 2015).– Žilina: IEEE, 2014.– P.327-329.

7. Stankevich S.A., Dudar T.V., Matveyeva O.L., Kovtun R.V. Mapping technique for human-inspired landscape changes using satellite imagery and geoinformation technologies // Proceedings of the II International Scientific and Practical Conference "Ecological Safety as the Basis of Sustainable Development. European Experience and Perspectives".– Lviv: Lviv State University of Life Safety, 2015.– C.151-152.

RATIONAL LAND USE AS A FACTOR OF NATURAL SOIL COVER CONSERVATION

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KEYWORDS: pollution of soil, land conservation, rational land use, soil contamination prevention

ABSTRACT
The issues of soil cover conservation are considered. Classification of soil technogenic pollution types is presented. Interrelation of the concepts of "land conservation", "rational land use" and "environment protection" is shown. Main directions of environmental protection of settlements are emphasized.

Issues of territorial management and rational land use are significant for meeting the requirements of ecological and land legislation. The concepts of sustainable development and priority development of territories are to embrace various factors of natural and anthropogenic environment determining ecological state of the territory. With regard to cadaster, territorial planning and land use, special attention should be paid to the soil cover. The state and quality of soil cover determine the directions of land management. The higher is the soil productivity the more valuable it is, for example, for agricultural use. Contaminated soils with progressing negative processes resulting from different types of technogenic pollution have low cadastral value and are not investment - attractive. The example of technogenic pollution is shown in Figure 1.

General classification of soils technogenic pollution types is shown in Figure 2 [1-2].

a) b)

Figure 1: Photo examples of land technogenic pollution: a) pipe-line breakage; b) Norilsk territory

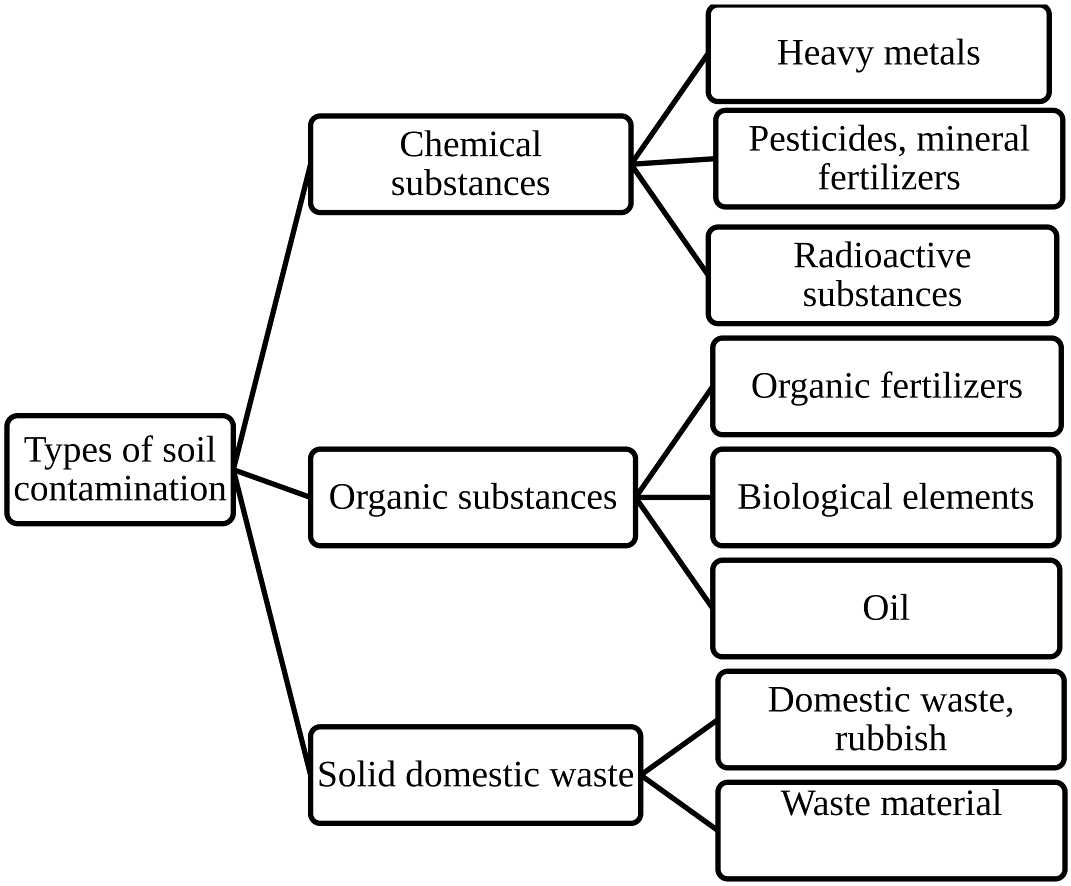

Figure 2: Classification of technogenic soil pollution types

Classification of technogenic soil contamination types allows for determining main contamination pathways to soil.

Technogenic soil pollution is one of its most dangerous types, as chemical substances penetrating the soil are absorbed by plants forming the food chain when they enter the human body [3, 4]. In this connection, it is important to determine the soil contamination threat criteria (Figure 3).

In terms of hygiene, the threat of soil chemical pollution is determined by the level of its possible negative effect on food, contacting media (air, water) and directly on man as well as on the biological activity of the soil and its self-purification processes.
The threat of soils chemical pollution is evaluated separately for different soils (different land-use types). The assessment is based on two basic points [3]:

- Economic use of territories (settlements soils, agricultural lands, recreation zones, etc.);
- Most significant (for the territories under study) exposure pathways of contaminated soil to man.

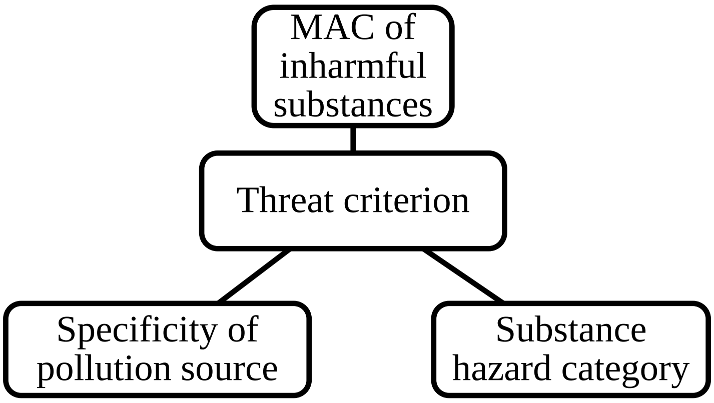

Figure 3: Soil pollution threat criteria

Rational use and conservation of settlements lands are interrelated concepts as under the condition of current urbanization any type of economic land-use is accompanied by the harmful environmental effect (Figure 4) [5, 6].

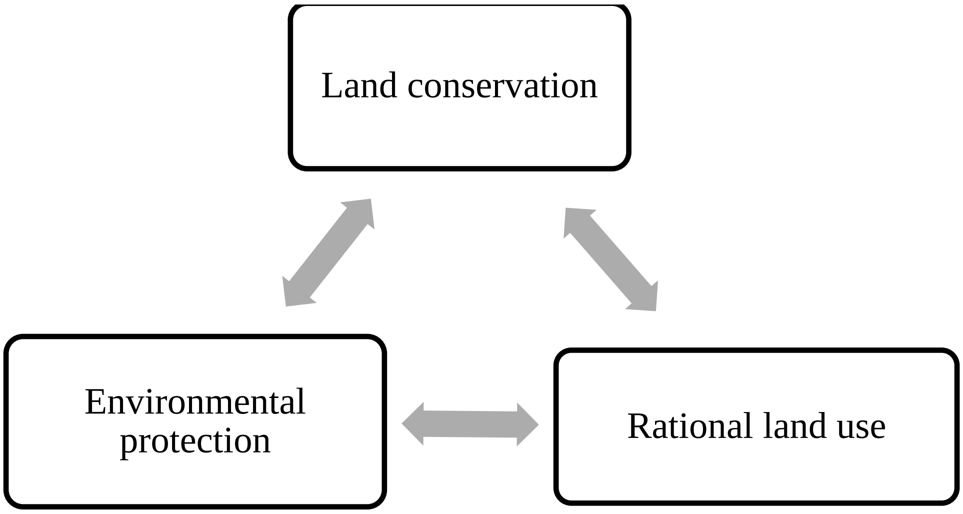

Figure 4: Interrelationship of concepts "land conservation", "rational land use" and "environmental protection"

Environmental protection of cities and settlements includes several directions, with their priorities and contents for certain territories being determined by the environment conditions, economic situation and the level of ecological-and-legal culture of the land-relations subject [7-8]. When developing the system of land conservation measures one should take into account anthropogenic "stress resistance" of the soil cover. In different soil types, accumulation and neutralization of harmful elements show up in different ways. For example, in case of radiation pollution with cesium-137 the process of self-purification is the fastest in black earth and gray forest soil, with sod-podzol soils being inclined to long-term accumulation of radioactive substances. The accumulative effect of negative factors on soils has not been adequately investigated as yet. There is hardly any scientific forecast for the soils under permanent anthropogenic pressure. The forecast for the settlements soils should be primarily aimed at the evaluation of ecological comfort for the population distribution.

In process of assessment, the following conditions are to be taken into account:

- Natural factors have evident time and space regularities which are easy to assess and allow for forecasting their effect on soils;
- In case of simultaneous effect of several negative factors, anthropogenic impact and synergetic character of the factors are difficult to assess.

Evaluation of the ecological comfort of population distribution is important as its results determine cadastral value of the lands.

Scientific forecasts for the level and character of negative factors impact should be used for correcting the monitoring system. In particular, modern remote sensing systems are to be used on the territories with forecasted deterioration of the soils ecological properties and fertility fall. Moreover, geobotanical point research is required for the areas mostly exposed to anthropogenic impacts [9-11].

REFERENCES

1. Ivlev, A.M. Soil evolution. [Text] / A.M. Ivlev - Vladivostok, 2005.

2. Reshotkin, O. V. Ecological features of urban soils [Text] / O. V. Reshotkin, O. I. Khudyakov // Problems of Regional Ecology.− 2007.- № 2 - P. 6-10.

3. Korolev, V.A. Monitoring of geological environment: textbook [Textт] / V.A. Korolev; edited, V.T. Trofimova. – M: Stroyizdat, 1981. – P. 24 – 40.

4. Akumov, A.I. Environment conditions and population sickness rate in Novosibirsk [Text] / A.I. Akumov, I.F. Mingazov - Novosibirsk: “Nauka”, 1999. P. 52-53.

5. Karetina, I.P. Place of retrospective maps of settlements soil cover in cartographic products classification [Text] / I.P. Karetina – Vestnik SGGA № 3 (23), 2013 – P. 138-147.

6. Larionov, Y.S. Alternative approaches to current agriculture and growing soil fertility (new paradigm) [Text] / Y.S. Larionov –Vestnik SGGA, № 1 (21), 2013 – P. 49-61.

7. Dubrovsky, A.V. Experience of creating digital soil maps for the territory of Novosibirsk region [Text] / A.V. Dubrovsky, V.A. Seredovich, K.S. Baikov – Information technologies, systems and instruments in agro-industrial complex. P.2: proceedings of 4th International scientific and practical conference “Agroinfo-2009”. – Novosibirsk, 2009. – p. 2. – P-81-86.

8. Dubrovsky, A.V. Experience of using geoinformation technologies for designing the systems for adaptive-landscape agriculture on Novosibirsk region territory [Text] / A.V. Dubrovsky, E.S. Trotsenko / Interexpo GEO-Siberia -2012. VIII International scientific congress, 10-20 April 2012, Novosibirsk: International scientific congress “Economic development of Siberia and Far East. Environmental economics, land management, forestry, real property management”: collected materials, 4 vol. Vol. 3. – Novosibirsk: SGGA, 2012. – P. 64-68.

9. Dubrovsky, A.V. Application of adaptive landscape land information systems under conditions of risk farming [Text] / A.V. Dubrovsky, N.I. Dobrotvorskaya - Proceedings of higher education establishments, unit: Geodesy and Aerial Survey № 4/c. – M.:MIIGAIK, 2013. – P. 152-155.

10. Dubrovsky, A.V. Structure of geoinformation support and agro-ecological land use under conditions of risk farming [Text] / N.I. Dobrotvorskaya, A.V. Dubrovsky, C. Y. Trotsenko, S. Y. Kapustyanchik - Interexpo GEO-Siberia -2014. X International scientific congress, 8-18 April 2014, Novosibirsk: International scientific congress "Economic development of Siberia and Far East. Environmental economics, land management, forestry, real property management": collected materials, 2 volumes, Vol. 2. - Novosibirsk: SGGA, 2014. – P. 64-73.

11. Dubrovsky, A.V. The problem of creating plans for development of Novosibirsk agglomeration inter-settlement territories [Text] / A.V. Dubrovsky, N.I. Dobrotvorskaya – International scientific congress "Economic development of Siberia and Far East. Environmental economics, land management, forestry, real property management": collected materials 4 volumes, Vol. 3. – Novosibirsk: SGUGIT, 2015 – P. 106-113.

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USING DIFFERENT TYPES OF INITIAL DATA FOR MONITORING OF THE COASTLINE INLAND SEAS

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KEY WORDS: coastline, visible satellite image, visible spectrum range, topographic map, transformation, monitoring

ASTRACT

The methodology of marine coastline monitoring by satellite imagery taken in the visible spectrum range is considered. The main steps of the proposed methodology of monitoring are: collection and analysis of initial data; referencing and transformation of topographic maps; referencing and satellite imagery transformation; digitizing of coastline from the topographic map; satellite imagery filtering; automatic vectorization and coastline underlining; overlay of coastline from topographic map to the visible satellite imagery; plotting the cartograms of coastline changes. Practical implementation of this methodology using visible satellite imagery (in the visible spectrum) has been completed. As a result of undertaken studies in the area of 405 km long on the eastern coast of the Black Sea, the dynamics of coastline shift with the general tendency towards the sea has been determined. Thereby, the average value of the coastline shift at the level of 50 m with the maximum shift up to 200 m has been determined.

INTRODUCTION

Among advanced technologies for object positioning the remote sensing tools are of most important. Remote sensing technologies have the particular advantages in problem solving of global monitoring of the terrestrial object state. They allow determining the object state covering a large area by means of a high frequency data collection at a fixed time. The marine coastline, undoubtedly, belongs to the objects that change their location on large areas. The problem of determining the marine coastline location changes is inherently global. The necessity to monitor the marine coastline position is caused by several factors. According to (Bondur 2005, Chandra et al. 2008, Knizhnikov et al. 2011), the efficient use of natural resources is one of the most important conditions for economic development of the country. All countries in the world actively use the resources of the seas, especially, shelf zones as a source of mining, building and maintenance of harbour facilities, business and fishery management, creating tourist recreation areas. On the one hand, the management of such activities requires knowledge of the marine coastline position and what is the most important the prediction of their position changes. From the other side, the environmental aspects associated with determination of the influence caused by certain types of activity on the environment become especially relevance (Hlebnikova 2002, Hlebnikova 2011). Ukraine is washed by the Black Sea and the Azov Sea. With regard to the possible activities on these sea coasts, to solve the coastline monitoring problems is extremely necessary (Ivanov et al. 2008).

Development of methodology and technological schemes for the monitoring of the marine coastline position by integrated use of various types of satellite imagery is the topical problem. Its decision will give rise to the further development of other types of studies related to satellite environmental monitoring.

INVESTIGATION AND RESULTS OF MONITORING

Analysing the possibility of using remote sensing data for monitoring of marine coastline position, we should mention the requirements for the accuracy of problem solving. Actually, it corresponds to the accuracy of hydrographic survey. The accuracy of hydrographic survey is regulated by the decision of the International Hydrographic Organization (IHO) in Monaco and distributed by a Special Decree №44. IHO establishes several survey accuracy standards. According "IHO Standards for Hydrographic Surveys (S-44), 5th Edition, dated February 2008" the following classes were set: a special class of survey, that is a horizontal coastline position error with 95% confidence level equals to 10 m (such accuracy is required only for coastal areas with the engineering structures. In this case a coastline, as a rule, is regulated and fixed by traditional surveying methods on a regular basis); for classes 1a and 1b, class 2 a horizontal coastline position error with 95% confidence level equals to 20 m.

Therefore, we may come to the conclusion that according to the international requirements a root-mean-square (RMS) error for marine coastline position is specified as equal to 10 m. In this case, it is recommended to use for the purposes of monitoring the following data:

- Topographic maps at scale 1: 50 000 (RMS = 0.2 m = 10 m)
- Visible satellite imagery with 30 – 10 m resolution (the object width occupies 0,5 pixel);
- Satellite radar imagery with 30 – 10 m resolution of (the object width occupies 0.5 pixel) (Fleming, 2005).

The analysis allowed us to develop and offer the general technological scheme. At the first stage the coastline position is determined using topographic maps at scales 1:50 000 – 1:100 000. The coastline obtained is the basis according to which future position changes are determined.

The current coastline position is determined by the visible satellite imagery. The next step is to compare the border of water / land obtained from a topographic map and satellite images. The result of this comparison is the cartogram of a coastline shift by which we may determine the value and the rate of coastline position change. Geoinformation analysis is carried out for solving the problem of further coastline position change prediction. This approach allows us to reveal the reasons of coastline position changes as well as to predict the future changes.

Taking into consideration mentioned above, the methodology of monitoring marine coastline by visible satellite imagery is offered. The technological scheme of methodology is given in Figure 1.

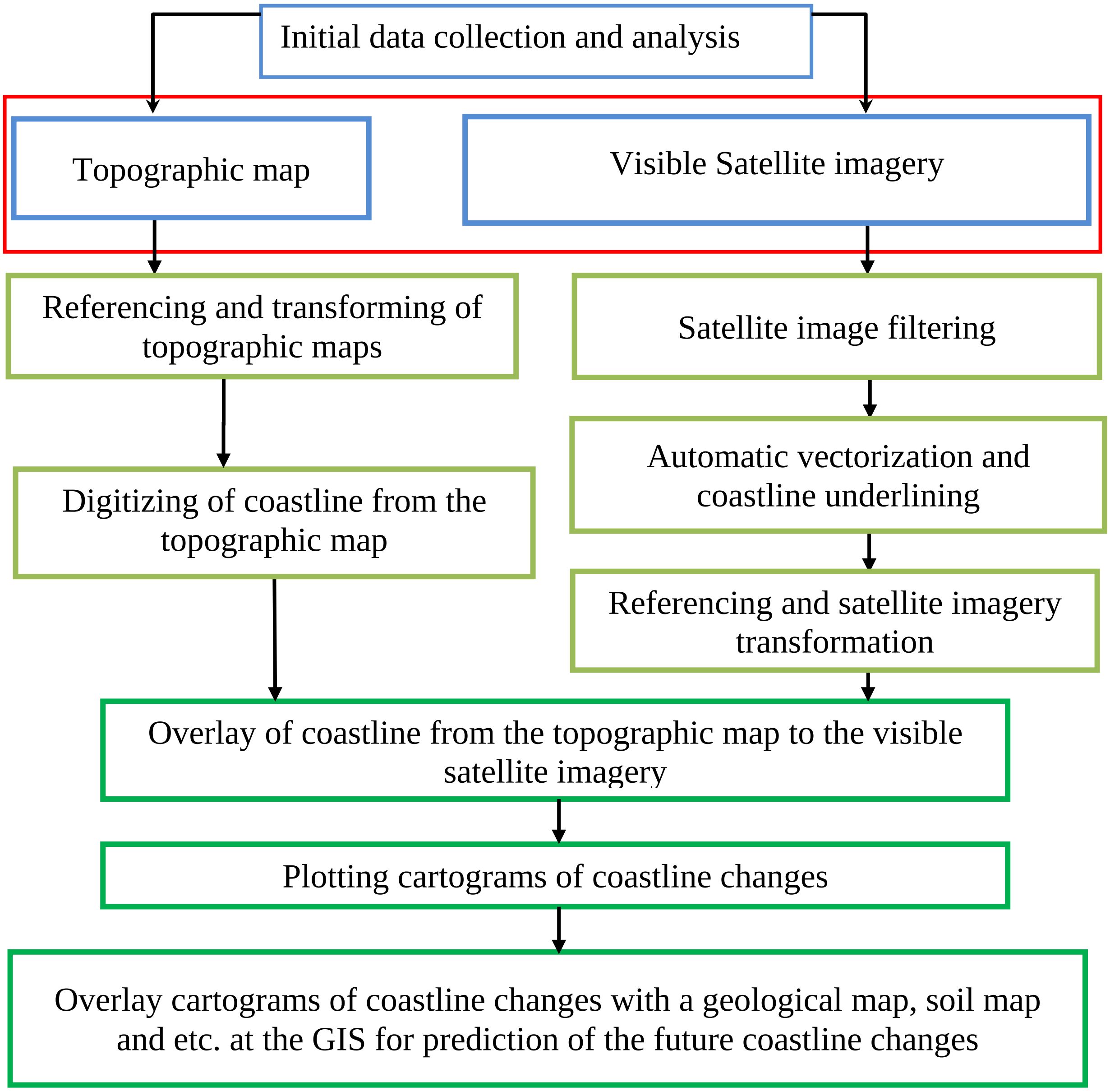

Figure 1: The technological scheme of methodology for monitoring of coastline changes

Now the proposed methodology is considered in detail. The methodology includes the following stages:

1. *Initial data acquisition and analysis*. The monitoring process is planned at this stage and includes the correct selection of satellite imagery of the appropriate area, determination of the water level, correct registration of tides and meteorological factors.
2. *Referencing and transforming of topographic maps*. The coastline obtained from topographic maps serves as a source of the initial data, which can be used for comparison of further obtained results. Therefore, it is important to make a correct referencing of topographic map in the chosen coordinate system. For these purposes it is necessary to take into account the two factors. The first one

is to choose the coordinate system. Since the imagery is obtained in WGS-84 / UTM, then either the images are projected into the coordinate system of the topographic map or there is a necessity to refer the topographic maps and their further projecting to WGS-84/UTM. The second factor concerns the initial topographic maps having significant deformations. That is why the models of topographic map deformations should be chosen in the right way.

3. *Referencing and satellite imagery transformation*. In contrast with the ultra-high resolution imagery the high resolution satellite imagery is often available with the binding file. If the binding file is unavailable, the imagery should be referred to the larger scale topographic map having regard to the special aspects described at the stage 2.
4. *Digitizing of coastline from the topographic map*. It is performed after referencing in any GIS.
5. *Filtering of satellite image*. Due to objective reasons satellite images have radiometric errors or distortions (Hong 2007, Shovengerdt 2010). When carrying out automatic digitization of objects from the imagery, such distortions can significantly distort the vectorization results. To eliminate these distortions, the imagery should be filtered.
6. *Automatic vectorization and coastline underlining*. There are several algorithms for contour extraction on photographic images (Hong 2007, Ris 2006, Shovengerdt 2010). After contour extraction the automatic vectorization of them is performed.
7. *Coastline overlay from the topographic map to the visible satellite imagery*. At this stage any of the known GIS is used (Gomarasca 2004).
8. *Plotting the cartograms of coastline changes*. After coastline overlay from the topographic map and the satellite imagery we obtained areas which point to the coastline position changes. These areas are generated either automatically or by direct measurements.
9. *Overlay the cartogram of coastline changes on the geological map, soil map, etc. in the GIS to predict the further coastline changes*. The purpose of this final stage is to reveal the possible reasons of coastline changes as well as to generate the mathematical models for prediction of further changes.

According to above considered stages, first of all it is necessary to analyse the mathematical models of transformation of initial cartographic data (topographic maps) with the purpose to select the transformation models, which on the one side, provides the necessary accuracy of referencing, and on the other side, does not lead to the initial cartographic data deformation. Modern monitoring tools include the use of information only in digital form (Konecny 2003). In such a case the topographic maps should be scanned and referred to the required coordinate system. Therefore, we have to choose a corresponding mathematical model for topographic map transformation, which will be able to take into account the possible deformations of cartographic originals caused by the map aging and scanning errors.

We have taken the well-known mathematical models for transformation of raster images in our investigations. For any type of transformation we use the redundant measurements to carry out the accuracy estimation of obtaining coefficients by least squares estimation with subsequent assessment of transformation accuracy.

The easiest type of transformation is a linear and it is applied for the shift. For the calculation of transformation parameters, we should have at least one point. This transformation in analytical form is as follows:

$$x = x_0 + \hat{x}; \quad y = y_0 + \hat{y} \tag{1}$$

Where: x, y - the point coordinates in the new coordinate system, $\hat{x}, \hat{y}$ - the point coordinates in the old coordinate system; x_0, y_0 - shifts of the one coordinate system relative to the other.

Another, more complex type of linear transformation is a shift-rotation. For the calculation of transformation parameters, we should have at least two points. This transformation in the analytical form is written as:

$$x = x_0 + \hat{x}\cos\alpha - \hat{y}\sin\alpha; \quad y = y_0 + \hat{y}\cos\alpha + \hat{x}\sin\alpha \tag{2}$$

Where: α - rotation angle of one coordinate system relative to another.

Among the models discussed above the most advanced transformation is the shift-rotation-scaling. For the surveyors this transformation is known as the Helmert transformation. We should have at least two points for the calculation of transformation parameters. This transformation in the analytical form is presented in terms of the following formula:

$$x = x_0 + m\left(\hat{x}\cos\alpha - \hat{y}\sin\alpha\right); \quad y = y_0 + m\left(\hat{y}\cos\alpha + \hat{x}\sin\alpha\right) \tag{3}$$

Where: m - a scale coefficient.

The latest model of linear transformation, which we analyse, is an affine transformation. For the calculation of transformation parameters, we should have at least three points. This transformation in the analytical form may be written as:

$$x = a_0 + a_1\hat{x} + a_2\hat{y}; \quad y = b_0 + b_2\hat{y} + b_1\hat{x} \tag{4}$$

Where: a_i, b_i - affine transformation coefficients.

Among the well-known nonlinear transformation models we took for the analysis a polynomial transformation. For the calculation of transformation parameters, we should have the number of points equal to the number of the polynomial coefficients. The transformation in the analytical form can be written by the following formula:

$$x = \sum_{i=0}^{n} \sum_{j=0}^{n-i} a_{ij}\hat{x}^i \hat{y}^j; \quad y = \sum_{i=0}^{n} \sum_{j=0}^{n-i} b_{ij}\hat{x}^i \hat{y}^j \tag{5}$$

Where: n – a polynomial degree.

Topographic maps covering the territory of the Black Sea coast at scale 1: 50 000 in SC-42 coordinate system were used for our investigations. The total number of raster images is 139. In this case for identification of deformation behaviour and choose of the required transformation model has been suggested that the deformation behaviour is related to the date of topographic map creation and production. Therefore, all raster images have been divided into approximately uniform four groups: maps issued before 1975, before 1980, before 1985, and before 1990. The coordinates of 25 grid reference were measured using each raster image.

The results of the measurements made possible to calculate the transformation parameters for different raster groups and transformation models. The averaged values for the transformation parameters are given in Table. 1

Table 1. The results of raster transformation

Type of transformation	Number of points	Year of map production							
		1975		1980		1985		1990	
		mx/my, m		mx/my, m		mx/my, m		mx/my, m	
Helmert	9	15,2	15,4	5,6	6,7	15,5	15,2	7,5	9,4
	13	14,0	14,0	5,4	7,5	15,2	14,7	6,6	8,5
	25	14,4	15,1	6,7	7,3	16,7	15,5	7,2	8,5
Affine	9	7,1	5,5	4,0	5,3	4,6	3,2	3,5	7,0
	13	7,6	6,3	3,5	6,3	4,6	5,4	4,0	7,0
	25	6,7	6,4	3,6	5,6	5,0	4,8	5,0	7,0
Polynomial n=2	9	3,3	1,6	3,3	4,3	2,2	2,6	2,6	4,8
	13	5,0	3,2	3,1	5,6	2,9	4,5	3,7	6,6
	25	4,1	4	3,1	5,5	4,3	4,1	4,6	6,3
Polynomial n=3	13	1,5	2,2	1,3	2,7	2,2	2,6	1,9	1,7
	25	2,2	3,7	2,0	4,1	2,8	2,6	3,0	3,4
Polynomial n=4	25	1,5	2,8	1,4	2,4	1,6	1,6	2,0	2,5

Analysing the data from Table 1, we can make a conclusion that there is a relationship between the deformation behaviour and the date of topographic map production. Comparing the transformation results using linear and polynomial models, we make a conclusion that the rasters under study have nonlinear distortions. In spite of the fact that 3d and 4th order polynomials provide a high accuracy for transformation of raster images, we ought to bear in mind that high-degree polynomials lead to undesirable distortions in the raster coordinates, and even a distortion of the original image.

According to the Guidelines for topographic map creation we have defined the required accuracy that the RMS error of point position on the map should not exceed:

$$m_p \leq 0,2M$$

Where: M - a scale denominator.

For topographical maps scale 1: 50 000 the RMS error of measuring contour point position is 10 m. Hereby, in order to exclude the influence of the residual transformation error on the accuracy of further measurements, it is sufficient that the RMS of transformation is not exceeding the follows:

$$m_t \leq \frac{1}{3} m_p = 0,07M$$

or per each of the coordinate axes:

$$m_{t_X} \leq 0,05M; \quad m_{t_Y} \leq 0,05M \,. \qquad (6)$$

If analyse Table 1 taking into account the criterion (6), it becomes evident that the model transformation using 2nd order polynomials or 3rd order polynomials with the number of points up to 13 satisfies the criteria in the best way. Increasing the number of points leads to the occurrence of the non-linearity effect and original raster distortions. If residual deviations are negligible, it is sufficient to use the affine transformation. If local deformations are significant and cannot be removed by the earlier mentioned transformation methods, then it is advisable to use the method of "sheet rubber".

According to the technological scheme given in Figure 1, all the main stages for monitoring of marine coastline position were investigated. Now we pass on to the overlaying the coastline from the topographic map to the visible satellite imagery.

We have used for monitoring the following initial data:

- LANDSAT-7 satellite imagery (panchromatic) with a resolution 15 m covering the western and the eastern coast of the Black Sea in WGS-84, UTM 35, Zone 36.
- OrbWiev-3 satellite imagery (panchromatic) with a resolution 1 m covering the western and the eastern coast of the Black Sea in WGS-84, projection UTM 35, Zone 36.
- A digital elevation model covering the entire coastline of the Black Sea obtained as a result of ASTER satellite imagery processing with the declared horizontal accuracy of 8 m in WGS-84, projection UTM 35, Zone 36.
- Topographic maps at scale 1:50 000 covering the eastern coast of the Black Sea.

Data processing has performed with the following parameters:

1. Referencing of satellite imagery was made using MapInfo 11.5 software, WGS-84, UTM 35, Zone 36.
2. Referencing of topography maps was made using MapInfo 11.5 software, CS-42 coordinate system, Gauss-Kruger projection, Zone 5 with a further projection into WGS-84, UTM 35, Zone 36.

3. Satellite imagery filtering was made using ScanEx IMAGE Processor v.3.6.9 software package and ERDAS 9.1 and by means of a median filter. Smoothing was made after filtration by Hermite splines.
4. Automated coastline underlining on the satellite image was made by ScanEx IMAGE Processor v.3.6.9 and ERDAS 9.1 software package
5. Automatic coastline vectorization was made by EasyTrace ERDAS 9.1 software.

The main results obtained at stages 1-5 are given below.

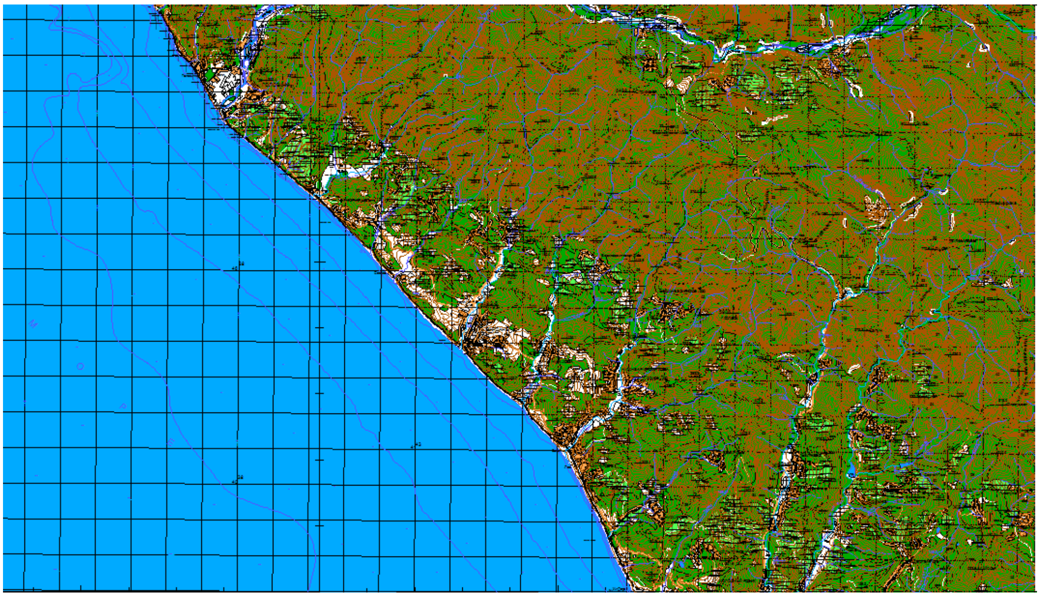

Figure 2: Vector map fragment of the eastern Black Sea coast

Figure 3: Digitizing marine coastline of the eastern Black Sea coast from raster topographic maps

The marine coastline was obtained from the topographic vector and raster maps. It characterizes the marine coastline position for 1975-1990.

In order to get the actual position of the coastline LANDSAT-7 satellite imagery (2005) was used. The positional checking was done by OrbWiev-3 satellite imagery and a digital elevation model generated using ASTER satellite imagery.

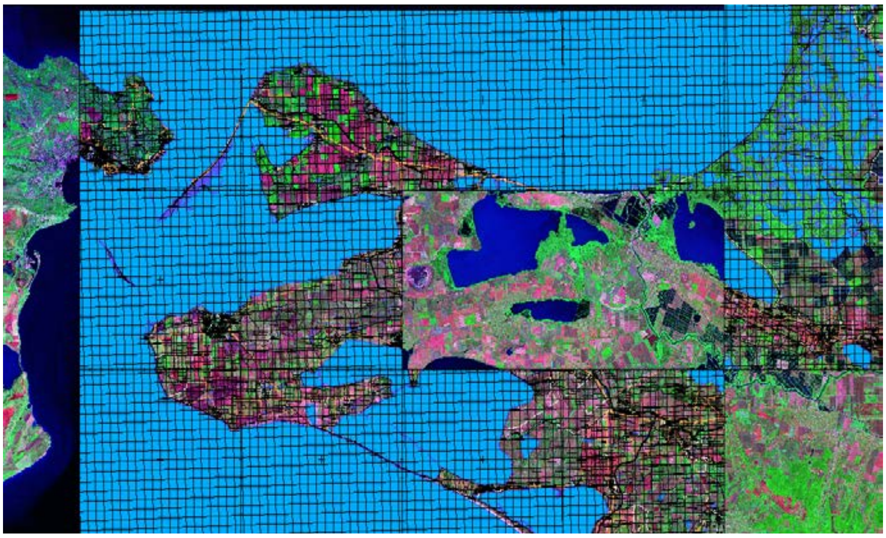

Figure 4: Digitalization of the eastern Black Sea coast from LANDSAT-7 satellite imagery

Overlapping of two coastlines from topographic maps and satellite imagery was made after digitizing the marine coastline.

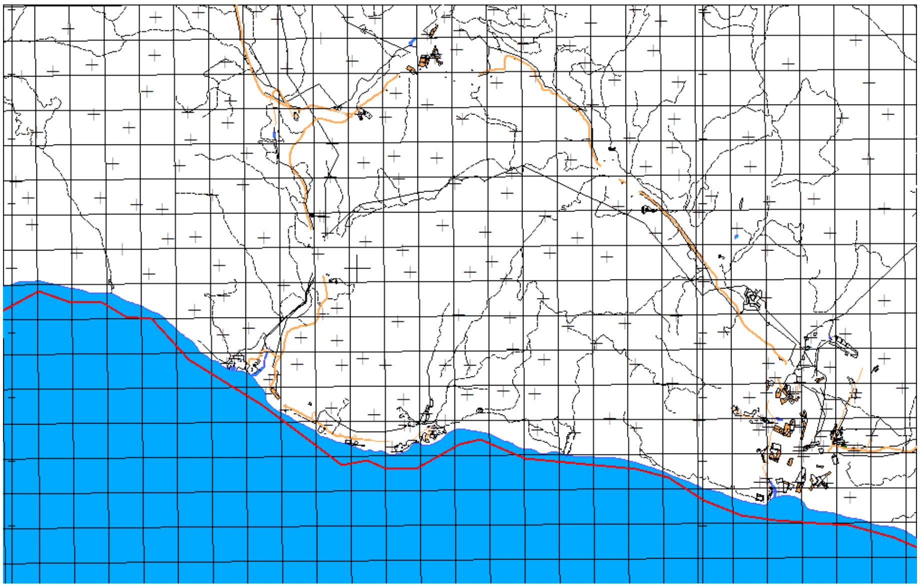

Figure 5: A fragment of overlapping the two eastern Black Sea coastlines

Drawing coastline was checked in some disputed point using ASTER digital elevation model, the accuracy of which permits to apply it as a reference one, and its quality is confirmed by a lot of studies.

As a result of undertaken studies in the area of 405 km long on the eastern Black Sea coast, the marine coastline shift dynamics with the general tendency towards the sea has been determined. Thereby, the average value of the coastline shift at the level of 50 m with the maximum shift up to 200 m has been determined.

Control measurements on OrbWiev-3 satellite imagery with 1-m spatial resolution confirmed these results.

CONCLUSION

The methodology of marine coastline monitoring on satellite imagery in the visible spectrum range has been developed as a result of our studies. The general stages of the proposed monitoring methodology are as follows: initial data acquisition and analysis; referencing and transforming of topographic maps; referencing and satellite image transformation; digitizing of a coastline from the topographic map; filtering of satellite images; automatic vectorization and coastline underlining; overlay of coastline from topographic map to the visible satellite imagery; plotting the cartograms of coastline changes. This methodology allows modelling of predicted future coastline and revealing the possible reasons of coastline changes based on overlap cartograms of coastline changes with the geological map, soil map, etc. in the GIS.

The developed methodology for marine coastline monitoring by satellite imagery in the visible spectrum range has been implemented in practice. As a result of undertaken studies in the area of 405 km long on the eastern Black Sea coast, the dynamics of marine coastline shift with the general tendency towards the sea has been determined. Thereby, the average value of the coastline shift at the level of 50 m with the maximum shift up to 200 m has been determined.

Control measurements on OrbWiev-3 satellite imagery with 1-m spatial resolution confirmed these results.

REFERENCES

BONDUR V.: *The complex space monitoring of coastal waters*. Moscow, Scientific Center of Aerospace Monitoring Problems, "Aerocosmos", 2005, 12 p.

CHANDRA A., GHOSH S.: *Remote sensing and geographic information systems: Textbook.* Moscow, Technosphere, 2008, 312 p.

FLEMING, J.N.: *Design of a Semi-Automatic Algorithm for Shoreline Extraction using Synthetic Aperture Radar (SAR) Images*. M.Sc.E. thesis, Department of Geodesy and Geomatics Engineering Technical Report No. 231, Fredericton, New Brunswick (Canada): University of New Brunswick, 2005,149 p.

GOMARASCA, A.M.: *Basics of Geoinformatics*. London, Springer, 2004, 690 p.

HLEBNIKOVA E.: *Features of recognition for monitoring of water objects*. Herald SSGA, Novosibirsk, 2002, №7, Pp 101-107.

HLEBNIKOVA E.: *Pre-processing of multispectral satellite imagery to improve the state of* *water quality object recognition.* Herald SSGA, Novosibirsk, 2011, №11, Pp 325-329.

HONG, G. *Image Fusion, Image Registration, and Radiometric Normalization for High Resolution Image Processing.* Ph.D. thesis, Department of Geodesy and Geomatics Engineering Technical Report No. 247, Fredericton, New Brunswick (Canada): University of New Brunswick, 2007, 198 p.

IVANOV V., MINKOVSKAYA R.: *Marine estuary Ukrainian rivers and estuarine processes*. Textbook in 2 parts, National Academy of Sciences of Ukraine, Marine hydrophysical institute, Sevastopol, 2008, 806 p.

KNIZHNIKOV Y., KRAVTSOVA V, OV TUTUBALINA O.: *Aerospace methods of geographical research.* Moscow, Publishing Center "Academy", 2011, 416 p.

KONECNY, G. *Geoinformation. Remote Sensing, Photogrammetry and Geographic Information System*, New York and London, Taylor & Francis, 2003, 266 p.

RIS U.: *Fundamentals of Remote Sensing*. Moscow, Technosphere, 2006, 336 p.

SHOVENGERDT R: *Remote sensing. Models and methods for image processing: Textbook*. Moscow, Technosphere, 2010, 560 p.

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EVALUATION OF THREATS TO PHYTODIVERSITY USING GEOINFORMATION CARTOGRAPHY

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ABSTRACT
Ecological and phytogeographical maps are of paramount applied significance and are used to evaluate the quality of the environment and perspective economic use of the territories. They are made using of common scientific methods, in accordance with the problems to be solved; they are included in a set of ecological geographical maps created to demonstrate a range of features and peculiarities of the spread of vegetation cover.

Modern ecological phytogeographical cartography, in its conceptual and methodological aspects, is based on theoretical and practical knowledge of vegetation, accumulated in Russia and foreign countries. There is a number of summarizing publications which thoroughly describe the peculiarities of mapped vegetation [1-10]. Considerable quantities of general and specific geobotanical maps have been created to solve various scientific and applied problems.

Ecologization (environmentalization) has broadened the informative and methodological basis for geobotanical mapping using scientific and geographical approaches [11]. Ecological phytogeographical maps are different from the traditional geobotanical and phytoecological ones in terms of the applied scientific approach: they demonstrate distinctive geographical features; represent vegetation as a component of geosystem (landscapes), show changes in vegetation caused by anthropogenic influence; and are created to solve ecological geographical problems of the environment quality maintenance. As a rule, the creation of ecological phytogeographical maps is based on a twofold approach: traditional ecological (bioecological) and ecological-geographical [12-16].

The geosystem approach, based on V.B. Sochava's works and developed to study the way the vegetative component is organized, provides thorough and various ecological information. They have data on ecologically important geographical factors, which determine the structure and development of vegetation on various strata; on dynamic and ecological potential of the territory covered with specific plant taxa, and many others [17].

The basic units of studying and mapping the landscape are considered to be a group of adjacent territories or a natural complex which is structurally more complicated in comparison with a natural boundary, but which is taxonomically lower than a landscape, as a typological unit of physical and geographical territory differentiation [18].

Phytodiversity is considered to be a species diversity of vegetation related to a definite territory unit (in ecological geographical research it is related to the landscape) [19]. The threat to phytodiversity is a danger of vegetation transformation and conditions under which the evolution and functioning of species can aggravate or stop [20].

To create the map of threats to phytodiversity a landscape map of 1:1000000 scale, which shows taxa of territories, was taken as a base (IWEP SB RAS, 1995, not published). It features 111 types of natural complexes. The map was created in accordance with morphogenetic approach; and the following structural features were taken to mark landscape areas: geomorphological structure, vegetation and soils.

The main threat to vegetation in the area is caused by land use, mainly agricultural and occasionally forest lands. In the map creating the areal factors of anthropogenic influence were taken into account, as they allow seeing clearly the extent of vegetation degradation on the studied territory [21]. The quantitative data is related to the territories according to the basic ways of land use: arable lands, haylands, grasslands, forest utilization. To analyze vegetation degradation, the following factors were taken into consideration: complete destruction of natural vegetation as a result of ploughing; the extent of damage caused by timber harvesting and grassland digression. The evaluation was made according to the area of arable lands, grasslands and forests in each district. If more than 50% of the area was arable, the threat to phytodiversity was not assessed as almost none of the natural types of phytocenosis were left.

The threat to phytodiversity was assessed by means of quantitative-qualitative method and categorized according to a 3-level scale, leading criteria and analysis of economic use (grasslands, forest use) (table). To assess the threat to phytodiversity, the area of haylands was not taken into account as they cover comparatively small territories and are capable of fast revegetation.

Table. Assessment criteria of threats to phytodiversity

Degree of threat	Landscape use (grassland, forest use) %
Low	less than 40
Medium	41-69
High	70 and more

The following criteria were used to create the map of vegetation degradation and the degree of threat to phytodiversity on the territory of the Altai Region.

The Altai Krai is situated within steppe and forest steppe zones. The territory is densely built-up and intensively developed; its landscapes are under a great economic load and are considerably damaged in many areas. The main features of vegetation cover are determined by its geographical position, complicated geological history, and diversity of climatic conditions of both plain and mountainous areas. Being surrounded by steppe and forest steppe areas of western Siberia and Kazakhstan in the north and the west, woodlands of the Salair in the east, the northern dip slope of the Altai in the south, the vegetation cover comprises various elements of floras of the neighboring territories [22].

Ribbon-like and island-like pine forests, the pine forests of Kulunda (as well as the area adjoining the right bank of the Ob, the northern foothills of the Altai) span the territory of steppe and forest steppe areas of the Krai. A considerable part of woodland is comprised by unique relict pine forests. They stretch in four ribbons from the north-east to the south-west into the interfluve of the Ob and Irtysh. The sand terrain of ridges and hills, where ribbon-like pine forests are quite common, has determined the diversity of vegetation here. On the slopes of the ridges there is a combination of pines and birches, aspens, ferns and forbs. The plain at the foothills, with its hilly terrain, is mainly covered with small-leaved birch forests, sometimes combined with aspen trees. The territory of birch forests has sharply shrunk recently due to deforestation, stubbing and ploughing. As for the plain areas, there are occasional small-leaved groves on flat watershed lowering.

There are thick larch, birch and larch, cedar forests; dark coniferous taiga forests; spruce paludal forests of river valleys in the mountains. Dark forests of Salair refigium are dark coniferous taiga with the Siberian linden. Birch and aspen forests in various combinations are widely spread here; willow and poplar forests are common in the areas adjoining rivers. Forests cover more than 20% of the Altai territory. About 40% of the wooded area is comprised by pine forests [22].

Steppe vegetation is represented by meadow steppes, steppes and arid steppes. The typical feature of present time is secondary steppes which have developed on former dry meadows, fallows, deforested areas and degraded initial steppes. Forbs and gramineous meadow steppes, frequently combined with halophyte plants, are typical of Northern Kulunda and Priobskoye Plato. The meadow steppes of the forest steppe area, adjoining the right river bank, have a more mesophytic character. They can be found on the Ob terraces and are quite common on the Altai foothills and in the low mountains. On the steep gravelly slopes meadow steppes change into petrophyte meadows; and on the knolls – into shrubby steppes. The edaphogenic variant of steppes is psammophyte steppes, found in slightly deforested sandy areas, on the edges of pine forests and sandy soils. Dry steppes can be found in the south of the steppe zone. On the foothills and in the low mountains there are real steppes with prevailing bunchgrass steppes and their petrophyte variants.

Grassland vegetation occupies vast territories in the region. Gramineous and mixed herbs steppes as well as mixed herbs and gramineous steppes are common on typical fertile chernozem. On low river terraces and bottomlands there are lush mixed herbs lowland meadows and gramineous and mixed herbs water meadows. Lowland meadows are common on the foothills and in the low mountains of the Altai and the Salair. Alms are typical of the Tigiretskiy and Korgonskiy Ranges. Bottomland meadows are common in big river valley.

Shrub vegetation can be both of primary and secondary origin and in the region it is represented by mesophilous and steppe shrubs; in the valleys – by willow beds, sea buckthorn, prairieweed and Sibiraea altaiensis thickets; in the mountains – by dwarf (Arctic) birches, willow beds, junipers, etc.

In the mountainous part of the region, in the Alpine belt, there are gramineous sedge tundras, which develop on highly moisture soils, as well as shrub and stony tundras (on the Tigiretskiy and Korgonskiy Ranges). The territory covered with moss and lichen tundra is not vast. Cliff vegetation is represented by plant communities and associations on various lithogenuous substrata [22].

Sinanthropus vegetation, represented by subtypes of ruderal, segetal vegetation and the one of settlements, is widely spread in the region.

In the course of anthropogenic transformation of the vegetation cover, there can appear “anthropogenic deserts” of a scarce diversity and low productivity. In this case, revegetation is almost impossible.

The lowest degree of threat to phytodiversity is observed on the territory of the Salairskiy Ridge, the Altai foothills, and in big river valleys (the Ob, the Alay, the Chumysh, the Charysh, etc.). The reason of such a situation is mountainous terrain, which prevents farming and thus destroying natural vegetation. In relict pine forests natural vegetation has been partially preserved, as they are considered to be unique and are protected by the government.

On the territory on the Altai foothills and low mountains woodlands, subalpine tallgrass and short grass Alpine meadows combined with dwarf (Arctic) birches, patches of mountainous tundra, dark coniferous high grass forests, larch spruce grass forests, and second growth birch aspen forests have remained intact; gramineous and mixed herbs forests, gramineous forests with willow, poplar and white willow forests are common in the river valleys.

The average degree of vegetation cover degradation is observed on the territory of Biysk-Chumyshskaya Upland and Predaltayskaya Plain. The former is highly tilled and is considered to be the territory of intensive agriculture. The latter also provides favourable conditions for farming, which is the main factor of destroying natural vegetation [23].

On the territory of Priobskoye Plato and Kulundinskaya Valley natural vegetation has hardly remained. There is an extremely high degree of vegetation cover degradation.

A low degree of threat to phytodiversity is registered on the territory of Predaltayskaya Plain and in big river valleys.

Due to the intense forest use within the Salairskiy Range and the western part of the relic pine forest, the level of danger, phytodiversity is exposed to, is dramatically increasing. In the main part of the ribbon-like pine forest it is said to be of a mean level. A high and mean level of danger in the river valleys is provoked by intense pasturing.

The created map of threats to phytodiversity makes it clear that natural vegetation has been almost completely destroyed on the greatest part of the Altai Krai. An extremely high degree of vegetation cover degradation can be observed on 51% of the Altai Krai, a high degree of degradation is typical of 25%, a medium degree of degradation – of 10% and a low degree – of 13% [24].

Degradation of the vegetation cover is accompanied by numerous negative effects: insufficient species composition, structure simplification, replacement of natural plant associations by second-growth sinanthropous and cultural communities, decrease in genetic diversity of certain species, breaking up and isolation of populations.

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REFERENCES

1. Belov A.V., Lyamkin V.F., Sokolova L.P. Cartographic study of biota. – Irkutsk: Oblmashinform, 2002. - 160 p.

2. Volkova E.A., Hramtsov V.N., Isachenko G.A., Bublichenko Y.N. et al. Comprehensive mapping of the environment of the coast of the Gulf of Finland (Luga Bay Area) // SPb .: Publishing House, St. Petersburg. state. Chem-pharmacy. Academy, 2001. - 140 p.

3. Ilyina I.S., Yurkovskaya T.K. Phytoecological mapping and its current problems // Botanical journal. – 1999. – V. 84. – N 2. – P. 1-7.

4. Map of vegetation degradation of the Aral Sea region. [Electronic resource] - Access mode. - URL: http://soilinst.msu.ru/publ/2/image9.gif.

5. Map of Russian steppe vegetation. [Electronic resource] - Access - URL: http://oopt.info/index.php?page=195.

6. Komedchikov N.N., Liouty A.A .Ecology of Russia in maps: an annotated bibliography of maps and atlases // Moscow: CSRS Ministry of Science and the Russian Academy of Sciences, 1995. – 569 p.

7. The vegetation cover of Nizhny Novgorod Oblast. [Electronic resource] - Access - URL: http://dront.ru/old/lr/lr-analis-ris02.jpg.

8. Thematic map Forest Degradation of Irkutsk Region. [Electronic resource] - Access - URL: http://www.ntsomz.ru/img/temat_ip_Irkutskaya_obl_big.jpg

9. Moscow environment: map of affected vegetation [Electronic resource] - Access - URL. http://www.ntsomz.ru/img/temat_ip_Irkutskaya_obl_big.jpg.

10. Rotanova I.N., Gaida V.V. Ecological and geographical mapping of vegetation // The development of research competencies of young people in terms of innovative education cluster: a collection of scientific articles All-Russian scientific-practical conference / holes. Ed. Frolovskaya MN - Barnaul: Publishing House of Alt. University Press, 2014. - P. 332-338.

11. Kotova T.V., Ogureeva G.N. Biogeographical approachesin environmental mapping // Geobotanical mapping. – St. Petersburg.: St. Petersburg scientific center of RAS, – 2007. – 85 p.

12. Methodical installation on creation of ecological-geographical map of scale 1:2500000 / ed. by O. A. Evteev. – M.: Publishing house Mosk. University press, 1992. – 111 p.

13. Isachenko A.G. Introduction to environmental geography / A.G .Isachenko. - SPb .: Publishing House, St. Petersburg. University Press, 2003. - 192 p.

14. Complex environmental mapping (Geographical aspect) / ed. by N.S. Kasimov:.M.: Mosk. University press, 1997. - 147 p.

15. Geoenvironmental mapping / B.I. Kochurov, D.Yu. Shishkin, A.V. Antipova, S.K. Kostovska; ed. by B.I. Kochurov. – M.: Publishing center “Academy”, 2009. – 192 p.

16. Gaida V.V., Rotanova I.N. Peculiarities of the thematic content of the ecological-geographical maps of vegetation cover // Memoirs of Ust-Kamenogorsk branch of the Kazakh Geographical society. On the 70th anniversary of the Great Victory (1941-1945): Collection of articles.int. scientific and practical. conf. (26-27 Jan. 2015, Ust-Kamenogorsk). Ust - Kamenogorsk: Shygys Polygraph, 2015. - Vol. 9. - P. 69-76.

17. Sochava V.B. The progressiveness challenges of mapping vegetation on a large scale // Geobotanical mapping. – SPb.: St. Petersburg scientific center of RAS, - 1963. – P. 3-11.

18. Rotanova, I.N., Andreeva, I.V. Ecological and landscape study of the system of protected areas of the Altai Territory / I.N. Rotanova, I.V. Andreev; Ans. Ed. YM Cymbals; Ros. Acad. Sciences, Sib. Dep-set, Institute of Water and Environmental Problems. - Novosibirsk: Publishing House of SB RAS, 2010. - 159 p.

19. Rabotnov T.A. Phytozenology. 3rd edition – M.: Mosk. state university Press, 1992.

20. Mirkin B.M., Naumova L.G. Brief encyclopedic science Word of the old vegetation. – Ufa: Gilem, the Bashkir encyclopedia, 2014. – P.215.

21. Rotanova I.N., Purdik L.N., Shcherbakov A.N., Chernykh D.V. Ecological condition of the landscape of the Altai Territory (methodological approaches to the assessment and mapping) // Siberian Journal of Ecology. – Novosibirsk. - 1997. - V. IV. - № 2 - P. 215 - 229.

22. Silantyeva M. M. Flora of the Altai Krai: analysis and formation history. The dissertation on competition of a scientific degree of the doctor. Biol. Sciences Central Siberian Botanical garden, Siberian branch of the Russian Academy of Sciences, Novosibirsk. Barnaul, 2008.

23. Rotanova I.N., Gaida V.V. Ecological and Geographical Mapping of Altai Krai Land Cover // Global Geospatial Information and High Resolution Global Land Cover/Land Use Mapping / Proceedings of ISPRS WG IV/2 workshop, 21 Apr. 20105. – Novosibirsk: SSUGT, 2015. – P. 96-101.

24. Rotanova I.N., Gaida V.V. Evaluation of threats to using cartographic method of research (on the example of Altai Krai) // Natural conditions, history and culture of West Mongolia and adjacent regions: Materials of XII international scientific conference. Hovd, Mongolia, September 18-21, 2015 – I. Natural Sciences. - Hovd; Tomsk. Publishing House of TSU, 2015. – P. 64-68.

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MAPPING OF THE CURRENT STATE AND LONG-TERM CHANGES OF AGRICULTURAL LANDS IN THE VOLGA DELTA

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KEYWORDS: Volga Delta, fallow lands, mapping, satellite images, agriculture, Landsat archive

ABSTRACT
Landsat satellite imagery covering the period from 1970s to present and topographic maps have been used for map creation. Topographic maps were used for formation of a base field boundary layer, while Landsat imagery-based multi-seasonal colour composites served as a basis for thematic map contents. Agricultural arable lands categories and the dynamics of field abandonment are shown on the created map. Calculations made on the map revealed that in 2014 the category of fallows was attributed about 82% (1326 km2) area of arable land of the delta. A half of these fields was abandoned during the period since the mid-1990s to the mid-2000s.

1 INTRODUCTION

During the period from 1965 to 1987 the area of arable lands in the Russian Soviet Federative Socialist Republic (RSFSR) remained rather stable at the level of 133-134 million hectares. Significant part of these areas was dropped out of agricultural use as a result of agrarian reform of 1990s. The Russian Agricultural Census 2006 stated that the total area of abandoned arable lands in the Russian Federation was about 40 million hectares (Agroecological, 2008). These areas were set aside and fell within the category of fallows. Now they are undergone transformations under the influence of different natural and anthropogenic factors. In some cases, the abandonment of arable lands improves the state of ecosystems and biodiversity recovery owing to restoration of original vegetation, soil fertility and ecological functions (reforestation in non-chernozem zone is an example). But the abandonment of agricultural lands located in arid regions of Russia mostly causes degradation processes of different types: desertification, soil salinization, halophytic vegetation overgrowth, especially at previously irrigated sites. Thus, the inventory, the agroecological assessment and ranking of fallow lands are of high importance when specifying the activities on reclamation and melioration of these lands in returning them into the agricultural use.

2 TEST SITE

The Volga Delta represents a region of special interest, as it is a natural oasis in the semiarid climate zone owing to the river’s waters covering a huge catchment area, located mainly in the temperate climate zone with sufficient moisture (Figure 1). The climate is characterized by high summer temperatures and low precipitation rate.

Figure 40: The location of the Volga River delta

With regard to other coastal territories, the Volga River delta abounds with natural resources. This territory was actively used for farming and fishing during centuries. The efficient use of the agro-climatic resources and the success of plant cultivation at this arid region are highly dependent on the water supply. The Volga Delta area has undergone significant changes in the last decades. These changes have been driven by both environmental and socio-economic factors.

The expanding of arable lands here in 1950s was accompanied by extensive irrigation. By the middle of 1960s the most of arable lands was protected from spring tide by dams and moats, and cultivated fields were watered by pumps. Due to extensive growing of water-melons, vegetables and rice during the Soviet period this region was called "all-union garden".

Among natural changing factors of greater importance was the dramatic Caspian Sea level rise of more than 2.5 m between 1977 and 1996 and its following stabilization at a new higher mark. This resulted in a water table rise that led to abandonment of agricultural fields at the lower delta area.

Economic reforms of 1990s and lapse in subsidy for agriculture caused the next stage of changes that resulted in the abandonment of the most previously irrigated areas. As long as these unused agricultural fields were protected from spring tide, they were exposed to desertification, i.e. dehydration and degradation in various ways including such processes as shrub overgrowth and soil salinization. At present the fallow lands differ in their state depending on natural conditions, primarily the water availability and duration of abandonment period (Barmin, et al., 2006; Golub et al., 2012). The intensity and velocity of these changes demand to monitor the territory and effective land use management for sustainable development. Assessment of capabilities for land resources should be carried out taking into account their current state and conditions.

3 DATA USED

Cartographic and remote sensing data as well as different available sources of information were used for map creation to display the differences in agricultural land use, current state and duration of the abandonment period in the Volga River delta.

Cartographic data: Topographic maps at scale 1:100 000 produced in the USSR in 1970-80s. These topographic maps were used to create a base map of agricultural field boundaries needed for further thematic attribution. It should be noted that as a rule the topographic maps show only the averaged terrain state over an uncertain period but not on a particular year. However, the main advantage of these maps is their high geometrical accuracy and the reliability of objects displayed that allowed us to use them for our purposes.

Remote sensing data was the main information source used for determining thematic map contents. This data type is presented by Landsat satellite imagery taken from USGS archive (URL: http://earthexplorer.usgs.gov/). The archive contains imagery available from 1975. The first Landsat satellites were used for the multispectral observations with a spatial resolution of 80 meters. 30-m resolution satellite survey was carried out since 1984 (Landsat-5 Satellite and subsequent). As a significant part of the Volga Delta agricultural lands have a small size and cannot be distinguished well on the 80-m resolution imagery, data captured before 1984 were not used.

A list of Landsat imagery used is given in Table 1. We tried to select at least 3 cloudless images covering the whole crop season (spring-autumn) for each representative year. It was important for our study to have imagery taken in May-June (high water period) to distinguish leveed fields and flooded areas. The additional use of imagery taken in July (different stages of crops growth) and in August-September (harvesting) was necessary for cultivated fields and fallow lands discrimination.

It should be noted that for some years the archive contained least amount of images and this applies especially mid-1990s and mid-2000s in our case. Nevertheless, the used data set can be considered as sufficient to catch the trends in land use changes due to the availability of data gathered in the most major periods: the Soviet, after the collapse of the Soviet Union, and current.

Table 1: Landsat imagery

Year	**Month, day**
1984	April 12, June 24, July 1, July 10, September 3
1986	May 20, June 21, July 23, August 24, September 9
1987	June 17, July 26, August 27
1988	May 10, June 27, July 29
1989	June 5, July 7, August 24
1993	May 16, June 8, August 4
1998	May 30, June 6, June 15, August 18, September 19
2002	April 22, June 25, July 20, August 12, September 29
2007	May 14, May 30, June 15, July 17, August 2
2008	May 25, June 10, June 17, July 12, September 5
2009	June 4, June 20, July 6, August 7
2010	May 31, July 9, July 18, August 10, September 4
2011	May 25, June 26, July 12, July 28, August 13
2013	May 30, June 15, July 1, July 17, August 2
2014	May 1, May 17, June 2, July 4, July 20

4 METHODS

Map creation was done in two stages.

As the first stage a vector map (just contours) of agricultural lands cultivated in 1970s was created using topographic maps. Leveed fields, irrigation canals, rice paddies and fish ponds were shown on the maps by special symbols. It is clearly seen while comparing topographic maps with actual Landsat imagery that the field location remained almost unchanged.

At the second stage the agricultural land state and properties were determined based on remote sensing data analysis. Color composites made up of multi-seasonal Landsat imagery (R – the beginning, G – the middle, B – the end of the growing season) were used as a main source of data which allowed revealing Land Use/Land Cover (LULC) patterns (Figure 2). Near infrared band (0.76-0.90 µm) was used as the most informative for the synthesis because the vegetation cover, including agricultural one, has the highest reflectivity in this band, so the contrasts between water bodies, vegetated areas, crops and bare land are the greatest.

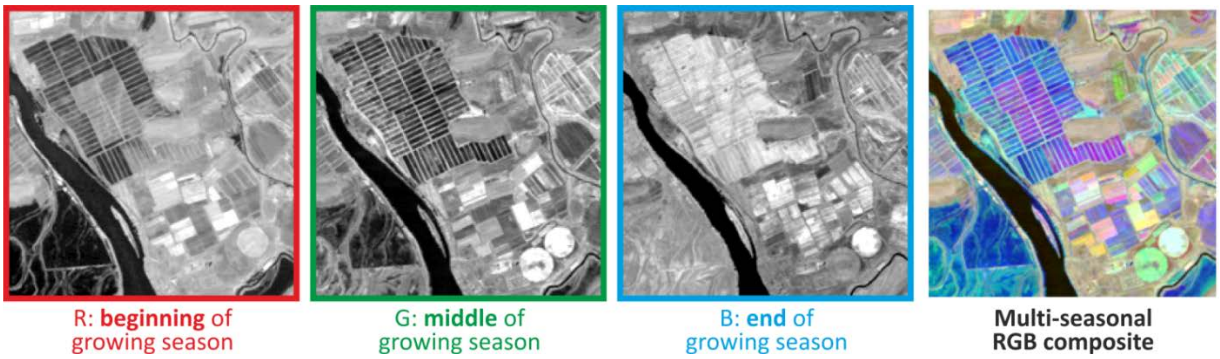

Figure 2: Multi-seasonal image synthesis for LULC patterns revealing

The types of agricultural land use were defined by the imagery taken in 2014. Fishponds can be recognized most accurately: as a rule, they have a rectangular shape and dark tone (almost black), with no changes during growing season. Arable lands are identified quite well too: as fishponds they have in general a regular shape but they are displayed in different colors according to the crops phenological stages in different seasons.

Panchromatic imagery with the highest resolution (15 m) was used for allotments detection. These objects are located around Astrakhan city and differ from it by low-rise building type and high percentage of woody vegetation.

All the fields, which were contoured using topographic maps and not cultivated in 2014 were referred to the category of fallow lands. As a rule, these lands are represented in gray tones at the color composites due to the weak seasonal variations and, therefore, small changes in images brightness. For fields abandonment monitoring a series of multi-year color composites obtained from 1984 to 2013 were analyzed (Figure 3). The age of fallow lands was determined according to the period in which a field was cultivated the last time (Table 2). If any area was marked at a topographic map as a field, but none of the multi-temporal Landsat imagery has fixed an agricultural activity here, this fallow field considered as the oldest (the duration of abandonment period is more than 30 years). It should be noted that fields which were not tilled in 1970s (i.e. not displayed on topographic maps) but which were used at least once during the investigated period were also digitized and attributed in a proper way.

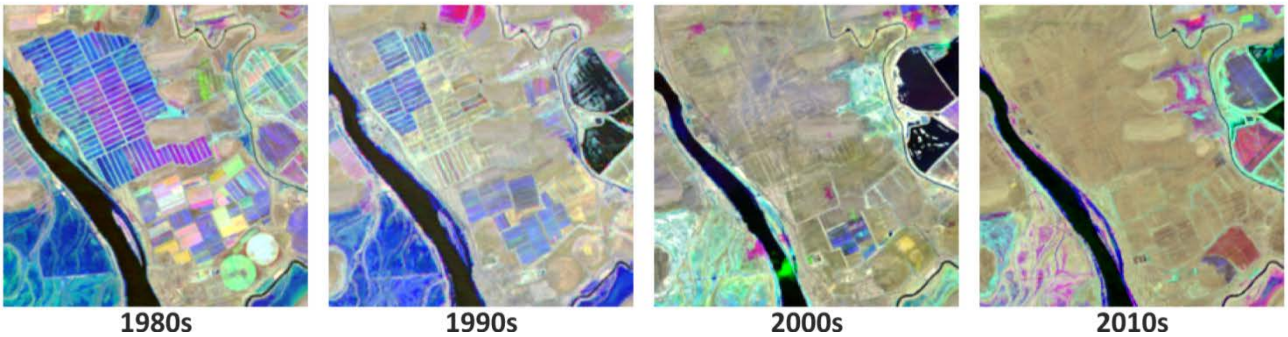

Figure 3: A series of multi-seasonal RGB composites for LULC change detection

Table 2: Fallow lands age revealing

Fallow land age in the map legend, years	Period of last field cultivation, years
1-5	2009-2013
6-10	2004-2008
11-20	1994-2003
21-30	1984-1993
>30	before 1984

The rest area was categorized in two classes: 1) flood-meadows and 2) natural grasslands, not or rarely flooded. To differentiate these two categories, an image taken at the peak of flooding (middle to end of May) was used.

5 RESULTS AND DISCUSSION

The main result of our study is the map "Agricultural lands use in the Volga River delta (RF) in 2014" at a scale of 1:250 000 (Figure 4). The map legend consists of two parts: agricultural lands and other areas and objects (water bodies, settlements and etc.). Agricultural lands in turn are categorized in three groups:

1) Lands, cultivated in 2014 (arable lands, fishponds, allotments);

2) Fallow or abandoned lands, classified by 5 categories according to the period of abandonment;

3) Flood-meadows and natural grasslands appearing partly as hayfields, pastures which serve spawning areas in spring tide periods.

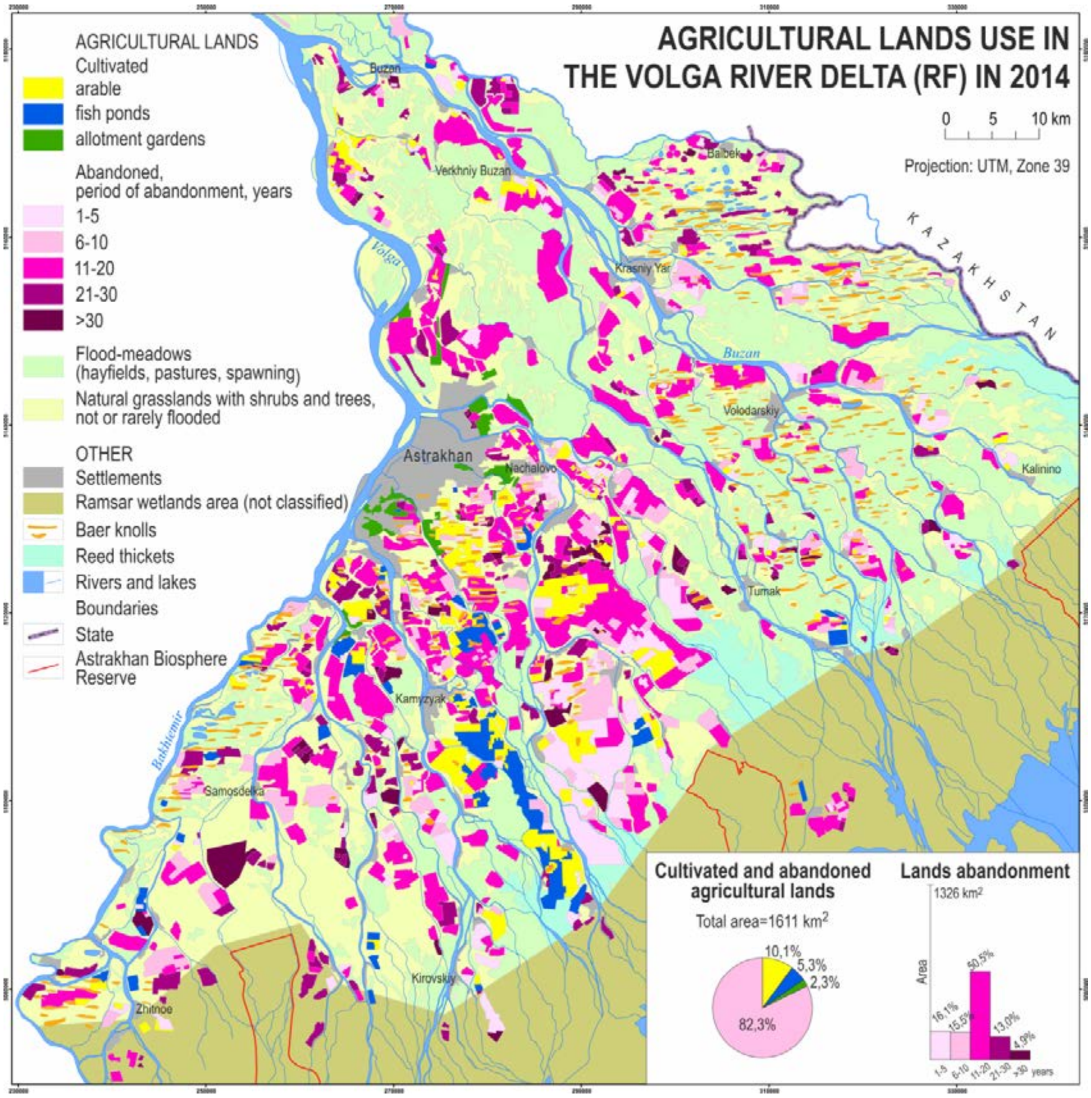

Figure 4: The map "Agricultural lands use in the Volga River delta (RF)" in 2014 (reduced)

Map creation in a GIS environment provided to make the subsequent quantitative estimation with ease. Some computations were done using the map. The total area of agricultural lands in the Volga Delta in 2014 was about 1611 km^2 (excluding the area of flood-meadows and natural grasslands). A land use structure is shown in Table 3.

Table 3: The area of agricultural lands in 2014

Categories of agricultural lands	**Area, %**	**Area, km^2**
Arable lands	10,1	163
Fishponds	5,3	85
Allotments	2,3	37
Fallow lands	82,3	1326
Total	100	1611

The agricultural land abandonment was observed throughout the whole studied period, but it was irregular. Table 4 represents the fallow lands distribution by their age: it can be clearly seen that the process of abandonment was the most active after the collapse of the Soviet Union.

Table 4: Fallow lands distribution in 2014 according to their age

The age of fallow land, year	**Area, %**	**Area, km^2**
1-5	16,1	213
6-10	15,5	206
11-20	50,5	670
21-30	13,0	172
>30	4,9	65
Total	100	1326

Additionally, it is important to note some general trends in the delta’s agricultural land use, which became clear through comparative image analysis. As compared with land abandonment these processes are spreading locally:

1) Conversion of fields to fish ponds and their alternation year by year in the direction to the south of Kamyzyak town (Figure 5a);

2) Conversion of fields into allotments around Astrakhan city (Figure 5b);

3) Reduction in size of cultivated fields up to 1 hectare that makes the process of fields identification by 30-m resolution imagery rather difficult (Figure 5c).

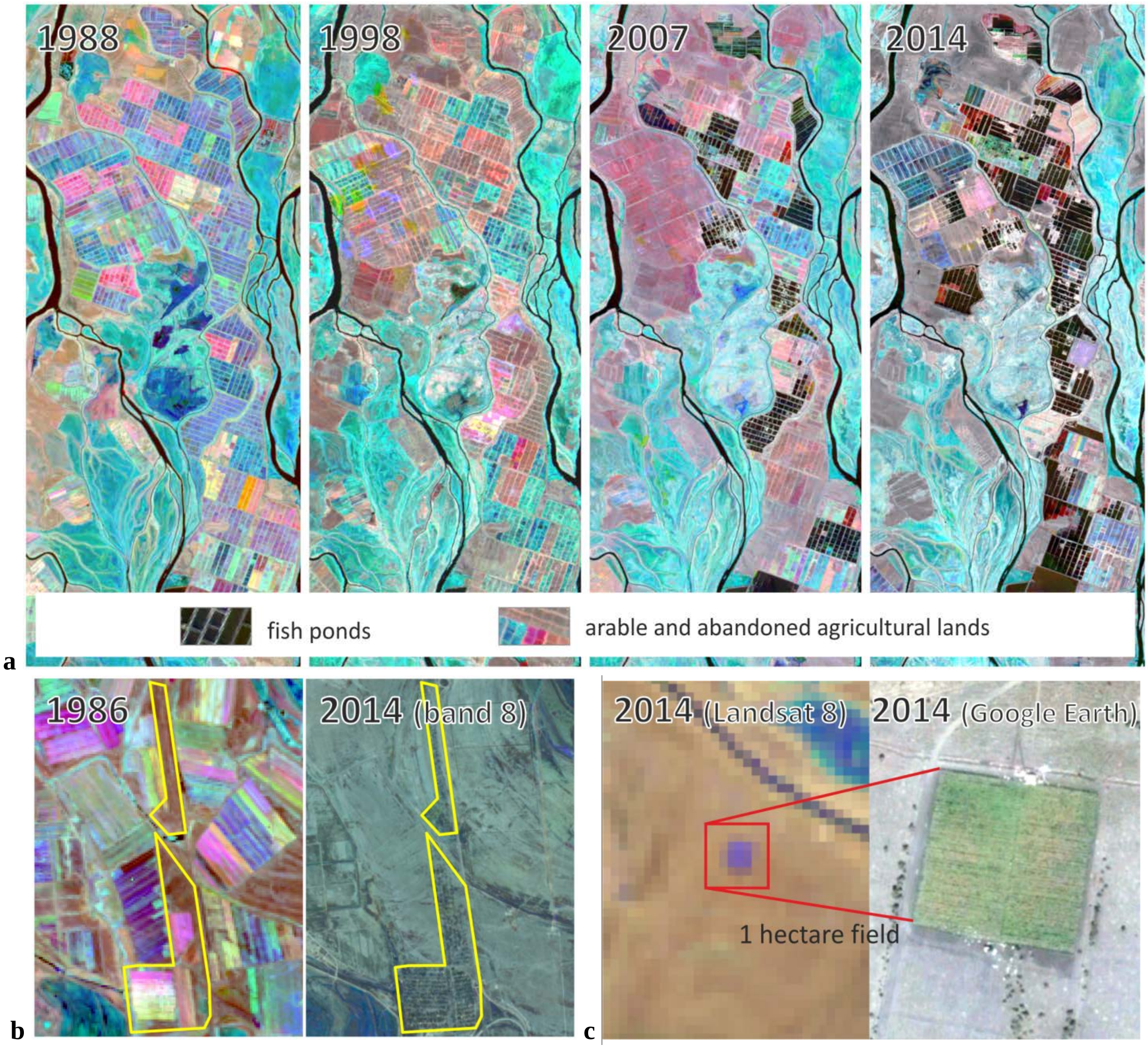

Figure 5: LULC patterns changes: a - conversion of rice paddies into fish ponds, b - conversion of fields into allotments, c - reduction in size of cultivated fields

6 CONCLUSION

Archive maps and present-day satellite imagery are the most valuable sources to analyse the land use dynamics within any territory due to their ability to cover a wide area using uniform symbols. Created map helps to reveal LULC changes in the Volga delta agriculture over the period from 1970s to 2014. Using GIS methods in map creation, it became possible not only to show the spatial distribution of agricultural lands and their dynamics but also to calculate some statistic parameters of changes.

This map is considered as a starting point for further study. It was created primarily manually using visual analysis in a GIS environment to reach the higher accuracy and reliability. Currently the map is used as a reference for evaluation of automatic methods in land use change revealing based on remote sensing data, and estimation of results.

Hereafter, we are planning to continue the study of the Volga delta agricultural lands. The degradation degree of abandoned agricultural lands will be the main point of the study based on remote sensing data captured by different sensors, including SAR, and ground truth data obtained in summer 2014. The expected result will be a map showing both the dynamics and current state of arable lands. The map will make possible to identify the relationships between the state of fallow fields, their age and natural conditions.

REFERENCES

1. Agroecological state and prospects of Russian lands retired from active agricultural use / Edited by Romanenko G.A., 2008. 64 p., Moscow, "Rosinformagrotekh" (In Russian)

2. Barmin A.N., Iolin M.M., Stebenkova M.A., 2006. Types of human impacts and environmental management optimization strategy in the Volga-Akhtuba floodplain and the Volga Delta for sustainable development // Changes of environmental systems in the areas of human impact, pp.172-188, Moscow, Media-Press (In Russian)

3. Golub V.B., Sorokin A.N., Maltsev M.V., Chuvashov A.V., 2012. Soil and vegetation of the perennial bed in the Volga Delta // Vestnik Volzhskogo Universiteta imeni Tatishcheva, #3, pp.308-317 (In Russian)

4. EarthExplorer. URL: http://earthexplorer.usgs.gov/

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THE SOIL COVER OF THE BARABA LOWLAND AND ITS MODERN USE

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KEYWORDS: Baraba Lowland, Western Siberia, elementary landscapes, soil cover, elementary soil processes, hydromorphism, salinization, solodizationm, land use.

ABSTRACT

The structure of soil cover (SSC) is an integral characteristic of the landscape. Component composition of the soil cover reflects the spatial differentiation of elementary soil processes. The soil cover of the Baraba Lowland in Western Siberia is very compound. The spatial distribution of the soils depends on the nature of the surface, meso- and microrelief. The main characteristics of the soils on the territory are hydromorphism, salinization, solodization. They determine the type of land use in agricultural production.

INTRODUCTION

The Baraba Lowland is a vast low drainless plain in south of Western Siberia. Its area is 17 million ha, or 170 thous. km^2. In conditions of semi-arid climate it formed as an area of accumulation of soluble salts. However, the spatial distribution of them in Baraba most of all depends on the nature of the surface, meso-and microrelief, which varies greatly in different parts of the lowland.

Intensive land use in agricultural production in the last 30-35 years has led to a significant deterioration of properties of the soils and other landscape components: vegetation, microclimate and hydrological conditions. Nature- and land protection direction in land use and ecological adaptation of agriculture become important concept. This circumstance gave new impetus to studies of the soil cover structure. Kozlowski F.I. has formulated the basic principle of SSC concept development: integration of soil studies and enclosing geosystem. It contains"coded" information about the soil cover as well as other ingredients and a geosystem in whole, including its history and modern modes" [Kozlowski, 2003]. The soil cover structure is an integral characteristic of the landscape. Component composition of soil cover reflects the spatial differentiation of elementary soil processes, but geometric characteristics (number and area of elementary soil areas (ESA) and elementary soil structures (ESS)) give the possibility for quantitative assessment of spatial distribution of these processes. Development of quantitative methods for studying the structure of soil cover provides the basis for the implementation of information technology, particularly, geographic information systems (GIS).

OBJECTS AND METHODS

Comparative geographical method was applied in our study [Friedland, 1972]. The Baraba Lowland is a huge accumulative plain. In the course of geological development taken place in this territory three geomorphological regions were emerged: the Ob plateau, high and low geomorphological steps of Baraba, which are in geochemical connection and consider as 'makrokatena'. The highest point of the lowland is located 160-200 m above sea level on the Ob plateau. The lowest point is located 100-115 m above sea level at Lake Chany and near the Chany depression. Makrokatena has an overall slope to the south-west. Its length is about 350 km. Key areas (1, 2, and 3) chosen for our study characterize each geomorphological region (Figure 1).

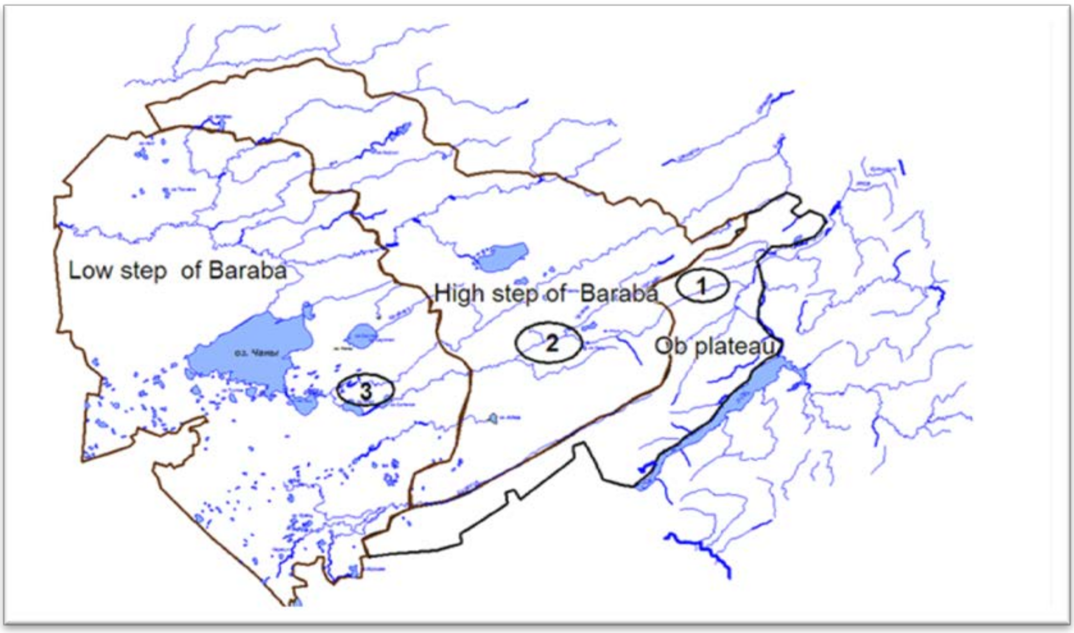

Figure 1: Location of key areas under study on the Baraba territory

The genetic and geochemical connection between elementary areals within key areas has been studied by means of caten approach [Milne, 1935]. Gradient character of ecological factors action is associated with the differences in altitude level and slope and allows for standardization of relief elements by the features. The standardization is based on Polynov's and Glazovskaya's systematics of elementary landscapes [Polynov, 1956; Glazovskaya, 1964]. It reflects the different migratory conditions of water runoff and substances. There are three main types of elementary landscapes or catena positions: eluvial with the dominance of substance removal processes with surface runoff, transit with different ratios of carry-over and substance afflux, and accumulative with predominance processes of inflow substances.

The mesorelief characteristic of three studied key areas varies considerably (Figure 2), and causes the differences in soil cover nature.

Geomorphological profile with length of 16 km on the key Ob plateau area was laid down from the highest point of 164 m above sea level to the lowest point of 107 m above sea level. Soil profiles have been made in soil habitats of the each type of elementary landscape and soil samples were selected. The component composition of soil cover, geometric characteristic of elementary soil areas and soil properties were studied.

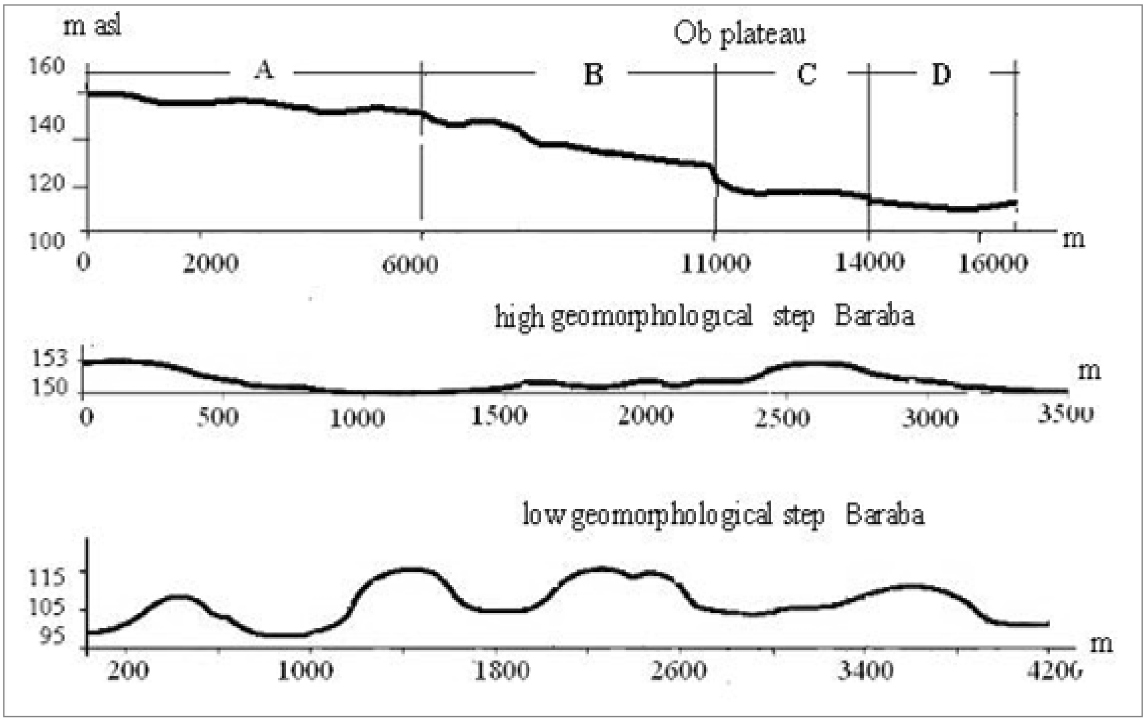

Figure 2: The relief character of key areas of the Baraba Lowland under study

Maps and the results of topographic survey made by the national soil service were used for the study of soils in key areas. A series of geomorphological profiles which were laid down in accordance with the naturally changed geochemical conditions reveals the regularity of genesis and factors of soils differentiation at the different levels of natural systems organization. The list of soil names are given in WRB system, 2006.

RESULTS AND DISCUSSION

The Ob plateau. Continuous ground line gradient from the southwest to the northeast is only 0,2°, but catena of great areal extent (up to 16 km) allows us to observe the manifestation of consecutive increase of hydromorphism and salinization.

The soils genesis was connected with the previous history of the Ob plateau formation. The general for the soil cover as a whole are the following factors: relict hydromorphism, loess carbonate sediments, surface uniformity, and the relative groundwater proximity to the surface. However, the waviness of relief even albeit insignificantly creates the conditions for spatial differentiation of water regime and elementary soil processes: leaching, salinization of soil, solonetzic and solodization. Their different combination depending on the areal location in the relief forms the diversity of soils and soil complexes.

Conditionally, catena can be divided into several sections - first order catena differing in the dominant type of water regime (Figure 2). The plot A with altitudes of 152.5 m above sea level has an angle of slope equals to 0.1°. On closed round-oval with altitudes of 163.72 - 153.75 m asl leached Voronic Chernozems Pachic are formed. These are the eluvial positions (El). In trans-accumulative weakly expressed flat depressions are located the combinations of Calcic Chernozems Sodic and Solodic Planosols Albicare. On the periphery of local depressions is Endosalic Gleysols Sodic. Substances balance in biogeocenoses of eluvial positions is determined mainly by the migration of cyclic type [Mordkovich et al, 1985], performing biological rotation of carbon and nitrogen, partly vertical, entering substances with precipitation, and horizontal, connecting the biogeocenosis with that of in the lower positions. In trans-accumulative position (TA) of the plot A the formation of combinations of Calcic Chernozems Sodic, Solodic Planosols Albic and Endosalic Gleysols Sodic is due to the formation of geochemical solonchak barrier on the border between the areals of leaching and accumulation processes.

The plot B with altitudes of 152.5 - 118.75 m asl has a more expressed slope to the north-east (0.3 °) and ends with steep slope (6.6 °) of ancient lakeside swell. This fact increases the process of surface leaching. On the other hand, a higher level of groundwater compared to the level of A determines the increase of solodization process. Therefore, the main soil cover of this site is constituted by Voronic Chernozems Pachic (Meadow-chernozemics leached) soils in complex with Greyic Phaeozems Albic.

The segment C of the studied mesocatena (118.75-112.5 m height above sea level) is characterized by a predominance of eluvial-accumulative (ElA) environments in which the complexes Calcic Chernozems Sodic with Greyic Phaeozems Albic are formed. However, on local heights automorphic soil was not formed as it was in the areas A and B, but semi-hydromorphic meadow-chernozemics soils. It is due to the vicinity of subsoil water to the earth surface. Areals of Solodic Planosols Albic and Haplic Gleysols Dystric are located in local depressions.

The plot D represents superaqueous (Ak) position of the described mezokatena and characterized by a predominance of concave surfaces with numerous micro-depressions. This fact causes a dominance of accumulation processes in soils differed by the degree of manifestation in microdepressions and associated microelevations. Additive effect of microprocessors solodization, alkalinization, peat formation generates extreme complexity of soil cover. Flow of matter and energy is due to water migration.

The ratio of elementary landscapes area with the appropriate soil combinations (Figure 3) shows the possibility of using soils in plowed field area and, in particular, in arable crop rotation. As seen in Figure 3, about 68% of the farm area falls on the top ridges soils and upper slopes (El, TEl, ElA). Soils of the trans-eluvial-accumulative and trans-accumulative landscapes, often saline, come to 28.1%. Less than 5% of the farm areas are wetlands. This distribution of the soils on the relief elements allows using the most part of the farm area in arable land.

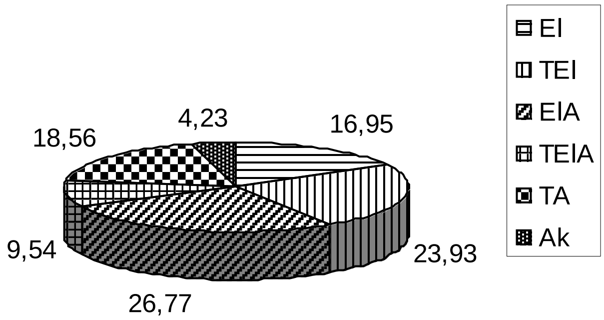

Figure 3: The soil area distribution on elementary landscapes, %
El –eluvial, TEl – trans-eluvial, ElA – eluvial-accumulative,
TElA – trans-eluvial-accumulative, TA – trans-accumulative, Ak – accumulative

As a rule, eluvial, trans-eluvial, eluvial-accumulative positions of relief with automorphic soils and their complexes, as well as the meadow-chernozem soils and their complexes are completely plowed. Often trans-eluvial-accumulative positions with chernozem-meadow complexes are involved in arable land, but their efficiency and technological quality is very low.

High geomorphological step of the Baraba Lowland

The relief of Baraba has been formed as a result of water erosion and accumulation on the background of epeirogenic movements. Pokrass E.P. and Bazilevich N.I. [Pokrass et al., 1954] distinguish the high geomorphological stage - the north-eastern part of Baraba with altitudes of 115-150 m above sea level, and low - southwest -105-115 m asl. Unlike the landscapes of the Ob plateau, the highest position on the high geomorphological step of Baraba cannot be attributed to eluvial elementary landscapes. Low altitude gradient in mesorelief and the vicinity of subsoil water to the earth surface causes semi-hydromorphic conditions.

Elevated meso-relief elements are mild manes, the relative height over the basis of erosion is not more than 3 m (Figure 2). The manes width is 0.5 -1.0 km, length - 2.5-3 km and more. The geochemical situation here is conditioned by two main processes: firstly, the humus-accumulative, migration of cyclic type (biological cycle of carbon and nitrogen) [Mordkovich et al, 1985], and secondly, eluvial-accumulative processes - vertical ascending-descending migration of water and mineral substances. Infiltration of water deeps into the soil profile in low alkaline groundwater helps manifestation solodization process - impoverishment of the humus horizon of meadow-chernozem soil with sesquioxides and the relative enrichment of silica. So, in eluvial-accumulative positions are formed:

1) Elementary areas Luvic Chernozems Sodic (Meadow-chernozemics solodic soils);
2) Combinations of Luvic Chernozems Sodic with Solodic Planosols Albic in microdepressions.

Automorphic (Calcic Chernozems Sodic) soils are characterized by island layout in the high Baraba territory. Their area is only 1.2%. Together with semihydromorphic soils, which amount is 3-9% in different farms, they are used in arable lands. However, because of a large number of microdepressions with Solodic Planosols Albic, there are limitations for winter crops due to their waterlogging and freezing.

The middle part of slopes, that is a transit catena position, is occupied by soils with a predominance of alkalinization processes of the soil profile: Luvic Chernozems Sodic (Meadow-chernozems solonetzic) and Gleyic Solonetz Albic (Solonetzes meadowish). Natric horizon is found at a depth of 12-18 cm. Here are mixed type of substances migrating - vertical and planar. These soils amount to 9-26% of the total farms area. They are characterized by a high density of solonetzic subsurface horizon, its swelling when wet and temporary deterioration aerated soils. These factors have a negative impact on the development of root system of spring wheat, so a high-quality food grain is difficult. Cultures such as rye, barley, mustard, and spring rape are more adapted to this land type.

Lower slopes with a small angle form a trans-accumulative catena position. It is characterized by a significant influence of saline groundwater on the whole soil profile. Type of migration is predominantly vertical, exudation-flushing water regime in this position results in the formation of complexes Endosalic Gleysols Sodic (Meadows solonetzic and solonchakous) with Solodic Planosols Albic. These soils amount to 44-58%. They are cold lands with slight biological activity, sustained waterlogging bottom of the soil profile. The types of use are hayfields and pastures.

Catena ends with extensive undrained depressions where is accumulation of organic matter and salts as a consequence of surface runoff from the upper biogeocenosis and salts from the groundwater. Haplic Gleysols Dystric (Meadow-boggy humus), Histic Gleysols Dystric (Peaty and peat boggy), often slightly saline in the lower part of the soil profile, seldom solonchakous are formed on this territory. These soils amount to 22-39%. It is most reasonable to use wetland spaces for water protection purposes.

The main trend in the current soil cover development is wetlands drying and their areas reducing. On releasing under the water spaces the concentration of salts in the upper horizons enhances and meadows solonchakous soils are formed.

Low geomorphological step of the Baraba Lowland

Alternation of narrow and extensive unidirectional ridges on the background of spacious wetland imparts the unique appearance of terrain and creates a special hydrological regime. Slopes of ridges are often terraced that emphasizes water-accumulative and water-erosion origin of ridges. The eluvial landscapes are formed on the ridges. On the general background of waterlogged areas the drainage ridges create conditions for the development of local automorphic processes due to which chernozem soils are formed. As a rule, soil profile still has the signs of alkalinity in the form of relatively heightened sodium amounts in the composition of absorbed cations and water-soluble salts. This type of land is a major part of the arable fund in farms used by grain-and-fallow rotations for the production of food grain. Often there are microdepressions on the ridges. They are occupied by Endosalic Gleysols Sodic (meadow solonetzic) loamy soils with predominance physical sand or chernozem-meadow loamy. The last are usually occupied by birch and aspen groves.

On the upper slopes under Luvic Chernozems Sodic (meadow-chernozemics solonetzic soils) are located chernozems solonetsous. They are also formed on the low flat ridges or elevated areas of interfluves, and are periodically influenced by groundwater. The characteristics of gleying are glaucous and rust stains on the bottom of the profile showing the modern overwetting processes. There are processes typical for trans-eluvial-accumulative elementary landscapes. On the flat lower ridges Gleyic Solonetz Albic (solonetzes meadowous deep) are formed. Natric horizon is usually located nearer to day surface as they reduce the height above sea level. Adverse agrophysical properties, moderate soil toxicity limit the crop rotation placement oriented to receive food grains. This type of lands is preferable for cultivation of forage crops. There are rational crop rotations with oats, barley, sunflowers, oilseed radish, etc.

The increase of the accumulation processes intensity results in the formation of chernozem-meadow alkaline soils, passing from decreasing altitudes to meadow solonchakous. Unfavorable soil properties prevent the use of this type of land in arable land, but here it is possible to obtain high-yield meadows.

The slope ends with salt marshes or meadow-boggy soils of inter-ridges spaces in the central part of which we often can see the lake water surface. The soils are characterized by constant waterlogging with stagnant regime, high salinity, and low biological productivity. Their use in intensive agricultural production is not effective. However, they are of large space with unique flora and fauna, which should be protected as environmental zones.

As the ridge slopes are very short, the change in soils is fast, sharp increase in salinity leads to the formation of contrasting soil cover on the slopes of ridges, especially in the lower position. In general, the territory is characterized by a dominance of accumulative elementary landscapes.

CONCLUSION

Summing up the analysis of geomorphological profiles, it should be noted that there is a relationship between soil combinations and relief positions with a certain geochemical conditions, which determines their similarity in genetic traits: a set of soil varieties, types of substances migration, the mechanism of soils differentiation that together create a certain type of elementary landscape.

As a rule, eluvial, transeluvial, eluvial-accumulative relief positions with automorphic soils and their complexes, as well as meadow-chernozem soils and their complexes have been ploughed up. Most often transeluvial-accumulative position with chernozem-meadow complexes is involved in arable land, but their efficiency and technological quality is very low. It requires a deep agroecological analysis to adapt the production to these conditions.

REFERENCES

1. Friedland V.M., 1972. The structure of soil cover. - M.: Misl. – 423 p.

2. Glazovskaya M.A., 1964. Geochemical aspects of typology and technique studies of natural landscapes. - Moscow: MGU. - 229 p.

3. Kozlowski F.I., 2003. Ways and prospects of further development of conception of soil structure // Theory and methods of studying soil cover.- M.: GEOS. - P. 283-298.

4. Milne G., 1935. Composite Units for the Mapping of complex soil association. Trans. of the Third Intern. Congress of soil science, Oxford, England, London. - V.1.

5. Mordkovich V.G., Shatokhina N.G., Titlyanova A.A., 1985. Steppe catenas. - Novosibirsk: Nauka. – 118 p.

6. Pokrass E.P., Bazilevich N.I., 1954. The main features of geomorphology and geology elements of Baraba Lowland. Proc. Soil Inst. Dokuchaev. – Moscow. T.XLII. - P. 5-103.

7. Polynov B.B., 1956. Geochemical landscapes. Selected Works. - Moscow: Publishing House of the USSR Academy of Sciences. - P. 477 - 486.

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