Satellite monitoring of Russian forests: current condition, concerns and outlook

Maslov, Ph.D (biology), senior researcher of Institute of Forest Science of the Russian Academy of Sciences, forestry expert of the ScanEx R&D Center

In late 2004 – early 2005 many Russian inhabitants learnt for the first time about the forest monitoring from space. The titles like “Star wars”, “Big picture from above” were in all the newspapers’ cover pages and on the TV screens – Russian Federal Forestry Agency (Roslezkhoz) leaders were telling about the creation of a satellite system for monitoring illegal logging in the country. In February 2005, minister Yu. Trutnev submitted the new monitoring system to the Russian President Vladimir Putin. At the same time a number of Greenpeace representatives claimed that there is no such system in Russia whatsoever and that the announced monitoring is nothing but “an expensive toy and a means of showing off”. Meanwhile, there is nothing new about the application of remote sensing methods (forest imagery from space). They have already been used in Russia for 10 and even 20 years.

We will try to find out why does the remote sensing experience a rise of interest to it recently and what are the possibilities of the forest satellite imagery nowadays and what are the near-term prospects.

Space imaging, as a new method of getting data about the Russian forests

The current splash of interest to forest space imaging data can be explained by active introduction of the Russian forest resources into the world economy, as well as by the eagerness of the international and Russian nature protection organizations. Typical signs of globalization are the appearance of major foreign timber companies on the Russian market, introduction of international certification standards, and involvement of Russia in the process of illegal logging control, especially within the frames of the G8 Group.

Basically, all the urgent problems of the forest sector (leasing relations development, certification, old-growth forest protection, illegal logging control) require the most up-to-date and independent information about the forest for decision-making. There are very few sources of such information. Topographic maps are updated less than once in 10 years and contain almost no data about the forests, whereas detail maps at the scale of 1:100 000 and larger are still “classified”. Similar forest inventory data on many regions is desperately obsolete, since even during the Soviet Union the forest inventory was performed once in 10-20 years. In some regions even these terms were exceeded. Fresh forest inventory data (in case it was recently performed) is hardly accessible for its users – forest business enterprises, local authorities, scientific and nature protection organizations. Typically, even forest administration authorities can experience problems with receiving forest inventory data (especially electronically).

In this situation satellite imagery turned out to be in great demand and the most accessible kind of data in Russia, mostly due to the distribution of the compact UniScan ground stations; creation of the data reception, processing and distribution center by ScanEx (www.scanex.ru) and NGO “Transparent World” activities (www.transparentworld.ru).

Which features make satellite images in demand in the first place in the current Russian conditions?

Objectivity. Each space image is a document, reflecting actual condition of the area for the time of imaging. For example, the size and direction of the logging area detected by the image are independent on the land allotment in the leskhoz (forest farm) in subject. Image falsification is a useless effort, because many other operators are making their own images of the same spot and the "faked images" can be easily revealed. Basically, satellite imagery gives an opportunity of an independent cross check of the forest sector by different Russian and international organizations, including the Rosprirodnadzor (Federal Service for Supervision of Natural Resource Usage) and Rosleskhoz (Federal Forestry Agency).

Table 1. Approximate correlation between space images resolution (pixel size) and map scales

Resolution, m	Map scale
2	10 000
6	25 000
23	100 000
55	250 000
250	500 000

Urgency. Satellite data can be obtained for the images of different acquisition dates. As a rule, the archive history of the middle resolution images (around 1:25 000) for the Russian forest territory does not exceed 1-2 years. Middle and high resolution satellite imagery can be usually ordered within several weeks.

Fig.1. Size and location of one scene of the IRS-P6 AWIFS image on the map of Russia.

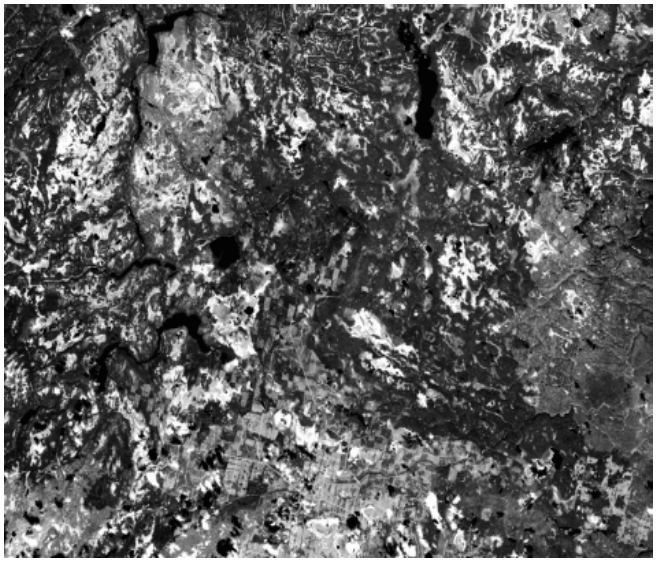

Fig. 2. IRS-P6 AWIFS fragment, spatial resolution 55 m. Acquisition date August 24, 2005, Arkhangelsk Region, Pinezh District, Kholmogorsky leskhoz (forestry enterprise)
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Immensity. Modern general scale imaging enables to take the image of vast territories in quite high details. Thus for example, the size of one scene of the new IRS-P6 satellite is 740x740 km. Such scene covers almost half of the European North of Russia (Fig.1), whereas the 55 m resolution images enable to detect the cutting areas starting from 5-10 ha (Fig. 2).

Exterritoriality. Imaging areas are not bound to the state or administrative borders; no permits are required for imaging. All this allows the operator to receive unified data on the forest status in different leskhozes, federation subjects, on “this” and “that” side of the border.

Accessibility. This is perhaps the most important reason of active use of satellite images for the past years. (In the former Soviet Union times, images were accessible only to a narrow circle of specialists of the closed high-security organizations). Currently, all the data on satellite images with 2 m resolution and lower is free to use. The procedure to order and to obtain such images is simple and is described in details in the internet on the sites of the internet service providers.

Remote sensing methods in resolving state forestry tasks

Countries with biggest forest areas arrived at an understanding of the necessity of the forest remote sensing monitoring a few years ago. Russia is slightly lagging behind the other countries in this respect, mostly in sphere of the national information policy. In Finland and Sweden all the forest areas are annually covered by middle-resolution satellite images (10-30 m) for account of the state budget. The received data are actively used in forest inventory, forest funds assessment and illegal logging detection. For example, in Sweden, annual satellite imagery (starting 2000) enabled to reduce illegal logging from 10 to 2 percents. The government is not only financing the imagery, but also promoting up-to-date remote sensing methods and GIS technology to the forest sector, providing for the proficiency training of the forest specialists and operators. Already proven and implemented “Scandinavian” remote sensing technology can enjoy even better success in Russia, taking into account the sizes of the Russian forest.

The acting Russian Instruction on Forest Inventory (1994) provides for the use of space images in decision-making within a wide range of tasks, especially when managing unexploited forests of northern and eastern regions of Russia. For the years past since the publication of this instruction both surveying equipment technology and interpretation capabilities had a dramatic increase. Manuals written by the local scientists (V.I. Sukhikh, V.M. Zhirin) for the use of satellite images in forestry are as good as the foreign tutorials, however these works were regarded as experimental scientific studies for the past few years (due to the absence of state orders for imaging). The situation started to change only in early 2005, when Rosleskhoz initiated the introduction of satellite imagery into illegal logging monitoring practices.

Recurrent satellite imagery of the Russian territories at middle and high spatial resolution will enable to resolve the following forestry tasks on a new level:

* logging monitoring (including illegal logging detection);
* forest fires damage assessment;

* forest health monitoring;
* inventory of forest fund, forest blocks certification;
* reforestation assessment.

It should be noted that all these tasks can be resolved independently on the federal, regional, as well as on the major forest leasing companies' levels.

Space monitoring problems

At the beginning of the Russian forest space monitoring system development there were serious obstacles connected with myths. Let's mark out three principle delusions:

1) Russian territories are being continually surveyed from space by a big number of satellites, including Russian ones;

2) Imagery data can be downloaded from the internet for free;

3) If you pay for the order, you can quickly get satellite images of any area and date within a couple of days.

All these myths, having little truth at the bottom, are far from reality. For example, regular space imagery of the Russian territories is indeed performed by several satellites; however their spatial resolution is very low (250 m and more). Principal tasks of the forest sector can not be resolved using such low resolution images (forest fire detection is the exception). To date, none of the satellite operators do a complete and recurrent middle- or high-resolution imagery of Russia. Such imagery is made only on order, therefore the archive data is available in form of area and time fragments.

Until recently regular imagery of Russia at middle resolution was performed by the American satellites of the Landsat series. However, in 2003 the last satellite almost became inoperable. For the past few years, French SPOT series satellites, as well as Indian IRS series satellites, became an efficient alternative to Landsat in many countries (including Scandinavia). However, imagery of Russia using these satellites is also made on order. Besides, for all these satellites (as well as for most of the others) Russian imagery possibility and efficiency depend on the ground equipment (ground stations, receiving space images within the footprint).

In this context, all the arguments of some officials about the possibility of purchasing the required data from the archives abroad looked inconsistent. As to the free internet data (including the new Google Earth project), only small advertising fragments or outdated images (over 3 years old) are available.

Satellite monitoring system components

The following satellite system components are required for the forest fund monitoring (including illegal logging control):

* Ground stations network, covering the whole territory of the country;
* Availability of relevant licenses for the data acquisition from satellites;
* Data processing and archiving centers;
* Special software for images processing.

Russian R&D Center ScanEx has a great experience in resolving complex remote sensing tasks. This implies a comprehensive management control cycle: production of different types of ground stations; license purchase and direct broadcasting from various satellites; building of big space imagery archives; development of special processing software. ScanEx personal ground stations (software/hardware complexes) constitute currently the backbone of the Russian ground stations' "fleet".

Table 2. Access to space imagery data in Russia

Data type	Operating satellites/sensors	Access mode
Extra-high resolution (<2 m)	IKONOS-2, QuickBird and OrbView-3	Order and delivery via an operator in the US
High resolution (2-10m)	EROS-A, IRS-P6/LISS-4, SPOT-5	Direct reception by ground stations in Russia (ScanEx's know-how)* Data ordering and delivery via the operator in USA, France Reception via the operator of Federal Space Agency (ScanEx and FSA technology)
Middle resolution (10-100 m, multispectral images)	IRS-1C, - 1D, -P6, SPOT-2, 4, 5, Landsat-5/7, EO-1 Meteor-3M-1	Direct reception by ground stations in Russia (ScanEx know-how)* Data ordering and delivery via the operator in the USA and France Data reception via the operator of the Federal Space Agency (ScanEx and FSA know-how)
Low resolution (>100 m, multispectral images)	Terra and Aqua, ENVISAT-1/MERIS	Direct reception to stations in Russia (direct readout mode)** Data ordering and delivery via the operator in Europe
Meteo-data	NOAA, FY-1	Direct reception**, Internet-technology
* Data reception by license ** Direct readout (free access)		

Three UniScan stations are required for an efficient monitoring of most of the Russian forest funds, whereas at least five UniScan series stations can provide for the full coverage of the Russian forests (Fig. 3). Nowadays, only two stations – one in Moscow and one in Irkutsk – are acquiring data from the relevant satellites. Other stations of the Ministry of Natural Resources did not receive enough funds over the last few years, and many stations suspended the operation. Moreover, these stations need to be upgraded in order to acquire middle and high-resolution images.

Another important issue of the monitoring system is the availability of relevant licenses to receive the data from foreign satellites (with no Russian satellites currently available). By 2006, R&D ScanEx has obtained licenses for the direct acquisition of images from IRS-1C/1D, IRS-P6, SPOT-4 satellites, as well as EROS-A and Radarsat-1 for the whole Russian territory (Table 2). It is obvious, however, that a systematic imagery of the entire Russian forest fund can be financed only by the government or big partnership between the government and a private agency – such tasks are not affordable to a stand-alone private company.

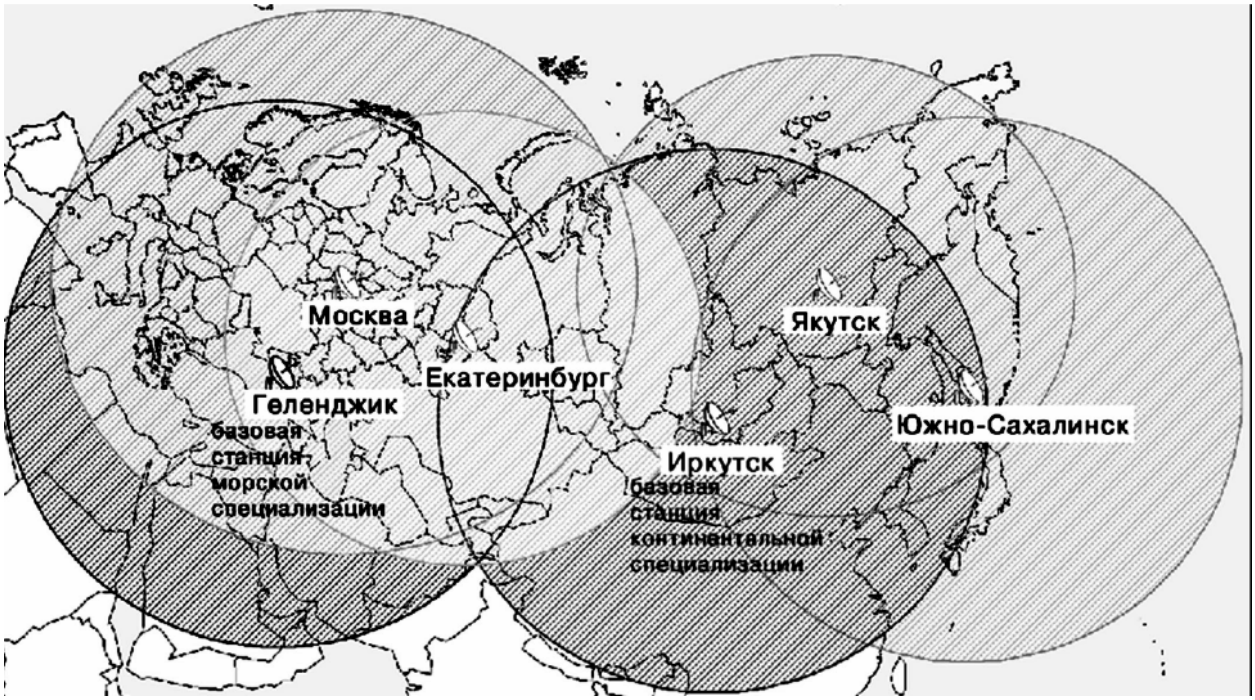

Fig.3 Network of ground stations of the Russian Ministry of Natural Resources for satellite data reception.

Operation of the net of ground stations and availability of relevant licenses allowed R&D ScanEx to build the biggest archive of satellite imagery in Russia, accessible for ordering via the internet (more than 96000 scenes). A number of software products have been worked out to process the imagery – ScanMagic, ScanEx Image Processor, ScanEx NeRIS and ScanEx SAR Processor. The above products enable to do a thematic processing of the images and to create maps, models or export the data to popular GIS and image processing programs, including forest processing ones – TopoL, LesGIS, etc.

Illegal logging control program features

Starting early 2005, Federal Forest Management Agency has been implementing a project of the illegal logging control using remote sensing assets. AviaLesoOkhrana (aerial forest fire center) coordinates these activities. Satellite imagery is one of the elements of such monitoring system.

Satellite imagery technique was fine-tuned (January-April 2005) using the example of some Arkhangelsk Region leskhozes as follows:

1) The area of the selected by the federal agency leskhozes was covered with middle (23m) and high resolution (6m) images, selected from the ScanEx archives for 2004. If possible they were selected in pairs (for 2003 and 2004 respectively).

2) Middle resolution IRS 1C/1D LISS images were used to detect the intensive logging areas. Recent clearcuts were detected by merging the images for two years, if available.

Fig.4. IRS-1D LISS image fragment, resolution 23 m, acquisition date – March 31, 2004. Arkhangelsk Regions, Kholmogorsky District

3) High resolution IRS 1C/1D PAN images (Fig. 5) in the GIS environment were used to verify the square kilometers and location of the cutting areas, detected at the previous stage.

4) To detect the infringements, satellite images were merged with the net of rides and logging plans taken from leskhozes.

Initial processing and automated middle-resolution imagery fusion followed by the color separation was made in the ScanEx Image Processor® program. Composite images with sharp outlines of the recent clearcuts were submitted to forest inventory enterprises to be uploaded to GIS, combined with the net of rides, digitized and compared with the logging plans and permits.

Large-scale aerial photo survey of separate cutting areas was applied when "suspicious" logging areas were detected. Video-recording of a cutting area from the plane with subsequent interpretation was also used. This work was done by AviaLesoOkhrana together with the St-Petersburg company "Aero ecology". Under the leadership of V.I. Sukhikh (Center for Forest Ecology & Productivity of the Russian Academy of Sciences) "Guidelines for aero-space monitoring of the forest use" were developed by May and approved at the scientific and technical council of Rosleskhoz.

At the second stage (June-October 2005) remote sensing monitoring was performed in six regions of the Russian Federation (Republic of Komi, Permsky Territory, Krasnoyarsky, Khabarovsky and Primorsky Territory and the Irkutsk region). Fresh high-resolution summer images (6–10 м) from IRS 1C/1D PAN and SPOT-4 satellites were prioritized. Minimal cutting area and compact undercut, according to the images and the "Guideline recommendations…" was 1 ha. In some leskhozes high-resolution EROS-A satellite imaging was performed, which may in some cases replace aerial photo survey, as the individual trees are visible on the image (Fig. 6).

First imaging year results

Joint activities of the R&D ScanEx and the forest inventory enterprises on monitoring illegal logging in 2005 enable to sum it all up as follows:

1) Clear sky conditions (required for space imaging) in most parts of the European North, Siberia and Far East can hardly be forecast and rarely fall on the specific satellite orbit pass time. Therefore, getting the images of the vast territories (unlike aerial photo survey), as a rule, require more time (3-4 months).

2) The most efficient approach to space imaging of big territories is in performing a ***continuous imagery*** from April to October until getting the clear sky coverage. To expedite the clear sky coverage, it is worthwhile to use several satellites with different orbit passing dates.

To transfer from the trial period of illegal logging monitoring to a regular annual imagery, the following is required:

* modification of receiving stations of the Ministry of Natural Resources for the acquisition of middle- and high-resolution images;
* state involvement in the license payments for the satellite-based illegal logging monitoring (gradually transferring to permanent licensing);
* arrangement of state-controlled regular high-resolution imagery (IRS-P6 LISS-4, SPOT-4, EROS-A) of the intensive timber logging areas with the creation of a federal information resource;
* provision of the facilities and training of specialists on the use of remote sensing methods in forest management.

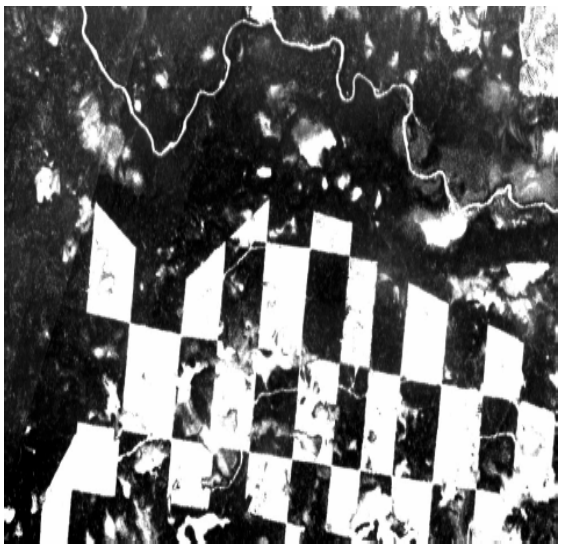

Fig. 5. IRS-1D PAN image fragment, spatial resolution 6 m. Acquisition date March 31, 2004. Arkhangelsk Regions, Kholmogorsky District

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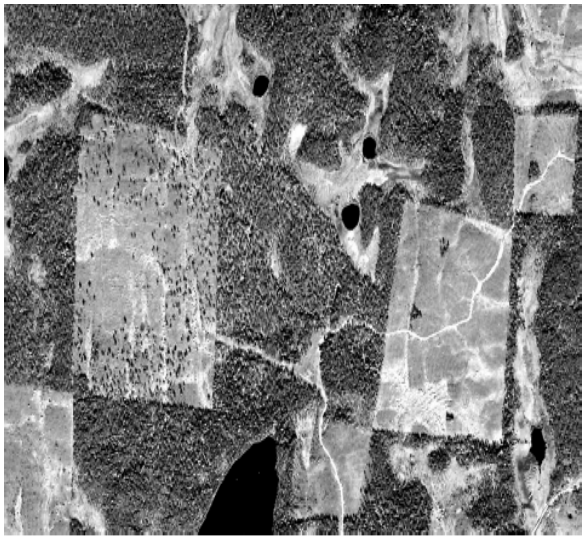

Fig. 6. EROS-A image fragment, spatial resolution 2 m. Acquisition date: June 19, 2005. Republic of Karelia, Kostomukshsky Region.

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The last item (provision of the facilities and training of specialists) is as important as the others. Remote sensing monitoring development demonstrated an acute shortage of forest GIS hardware-software complexes, associated with space images processing programs, as well a shortage of personnel, capable of working with such complexes. As a result, part of the interpretation activities is still being carried out using the hard copies (with the loss of data and poor accuracy). Methods of using satellite images during forest monitoring and inventory together with GIS and GPS need to be also developed and implemented into forest management.

Overall results and the outlook

In 2005, remote sensing monitoring of the forest use covered over 52 mln ha of forest within the areas of intensive logging on the territory of seven federation subjects. Around 16 000 fellings were inspected, about 100 000 ha of large-scale ground truth aerial photo surveys performed.

According to the press-service of the Russian Ministry of Natural Resources, the total amount of revealed penalty costs constituted 900 mln rubles, with 500 mln rubles claimed by December. The offenders volunteered to pay off 50 mln rubles of the total. In 2006 Rosleskhoz is planning to cover the entire territory of the intensive logging in Russia by aerial survey and satellite-based monitoring (about 100 mln ha of the forest fund). Federal budget is allocating 200 mln rubles for this purpose. Satellite imagery has the lowest costs in remote sensing monitoring – in 2005 satellite imagery expenses did not exceed 12% of the total project funding.

The most important result of the year 2005 was the fact that for the first time Rosleskhoz obtained the data on the main types and volumes of infringements directly after the independent interpretation of space images, rather than via their own local authorities and leskhozes. In most cases the results were shocking. Flagrant violations are made both by logging operators and leskhozes. For example, in Permsky Territory a random inspection of leskhozes revealed the absence of logging plans, nonconformity of logging cycles (up to one third of all logging sites) and of logging area condition to their certification acts. To the credit of Rosleskhoz leaders, all these facts are taken into account and serve as guidance for response actions.

“Pictures”, showing the frontal moving of the logging operators onto the intact frontier taiga in Arkhangelsk Region made a dramatic impression on the forest inventory officials and forestry executives. Greenpeace representatives were demonstrating such images many times before. However, only after the start of their own remote sensing monitoring program the forest inventory enterprises performed the analysis of leased areas and cutting sites location, showing how the manipulations with the annual allowable cut (spread over a large territory) are resulted in extensive and destructive ('concentrated') clearcuts within a few years in terms of their scale. Consequently, the question of changing the annual allowable cut definition rules was put in the nearest plans of the Russian Forest Agency.

Remote sensing monitoring development requires overall introduction of forestry GIS and GPS, electronic flow of documents, transfer to digital aerial photo survey and introduction of new computer image interpretation techniques. Basically, the remote sensing monitoring program is part of the technological breakthrough in Russian forestry and forest service. Monitoring of illegal logging program became the first functioning governmental high-resolution remote sensing monitoring program in the country, in this respect putting the importance of this project far beyond the frames of the forest sector proper.