

SPACE MONITORING WHILE PERFORMING STATE FOREST INVENTORY ACTIVITIES

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According to the Forestry Code and Resolution of the Government of the Russian Federation of July 26, 2007 No. 407 “About National Forest Inventory», National Forest Inventory (hereafter “NFI”) should become the main tool of federal authority in forestry affairs as for forest status monitoring, estimation of quantitative and qualitative characteristics, detection of modifications in forest health resulted from protection, regeneration and exploitation of forests, as well as compliance control of above measures to working plan of the constituent unit, forestry-based regulations, forest development plan, terms and conditions of the tender for protection, safety and regeneration forestry measures.

For the purpose of timely detection of violations of forest legislation and immediate response, the Federal Agency for Forestry Affairs in accordance with the Article 82 of the Forestry Code shall organize continuous monitoring and execution control by public authorities of constituent entities of the Russian Federation of the powers devolved with exploitation of the earth remote sensing data.

The following kinds of forest clear-cutting have the strongest impact on the resource and ecological potential of forest ecosystems: final cutting, regeneration, reformation and other sanitary cuttings, including sanitary clear cuttings. The procedure and action management should be specified in Standing Forest Cut Regulations of the Russian Federation, Regional Forest Regulation and Manual of Clear Cutting, Sanitary Rules in the forests of the Russian Federation. Nevertheless, current rules are often violated during cutting, especially in taiga zone. In many cases allocation of felling sites is allowed in the absence of felling plans or with some departure from them, as well as with violation of regulations concerning size and location of cutting areas. Overcutting and undercutting are taking place, as well as conditional clear felling and unauthorized cutting (cuttings without any authorization documents). A significant part of the violations is not registered by forestry administration. Consequently, the resource and ecological health of forest is deteriorating, and revenues from illegally felled (unaccounted) timber and penalties for violations committed by forest users are not entering the state budget. All this indicates the necessity of independent remote monitoring of forest felling and unauthorized (without any authorization documents) cuttings (hereafter “remote monitoring of forest exploitation”).

Forest remote monitoring is a special type of forest inspection, involving the compliance control over forest felling to the existing standards, forest lands health, affected by clear cuttings, regeneration, reforming, sanitation cuttings and other types of felling during forest exploitation.

Mining operations (production of oil, gas, coal, gold and others) have a strong impact on the health of forest ecosystems, bog complexes and other natural complexes in the territory of forest reserves. Primary violations of forestlands exploitation are considered to be the following:

- objects of oil production (well clusters) refer to forest resources and shall not be considered as objects of land inventory;
- construction sites are not corresponding with Land Allocation Acts, so ecological expert’s findings are actually cancelled and amount of charge collected for conversion of forests to nonforest land or for a conversion of forestlands into other categories of lands is miscalculated;

- massive disturbance of forest ecosystems and bog complexes is taking place during the construction with total absence of right stating documents; there is no restoration of such lands or it can be just a pro forma restoration without any silvicultural effect.

Detection of illegal forest lands exploitation is also a special type of forest inspection, involving compliance assurance monitoring of activity of deposits users and forest resources users as to terms of mineral deposit license agreements, forestland lease contracts, legislative and regulatory requirements in the sphere of nature management and efficiency improvement advice of forest resources economical use.

Multi-scale satellite data and aerial surveying materials are applied for effective assessment of forest exploitation and detection of illegal forestlands exploitation. The necessity of satellite data application is conditioned by its high observability and preset or periodical survey of one and the same area with high spectral and spatial resolution. In the absence of satellite data of required working quality, small-scale or average-scale aerial surveying materials may be applied. Selective aerial survey shall provide additional comprehensive data on condition of cutting areas, and other forestlands, which cannot be obtained by means of satellite data (small-scale and average-scale aerial photos).

Remote monitoring is carried out mainly in the interest of constituent entities of the Russian Federation, as well as authorities, organizations and residents of the corresponding areas, applying data on ecological health of forests. Monitoring objects involve lease forestlands, several forestry districts and forestry enterprises or their parts, a series of forestry enterprises, forest reserves of constituent entities. The following operations are carried out for monitoring objects: preparatory works, ordering and receipt of satellite data of forests which are subject to survey, selective air survey, thematic processing of survey materials and other data, selective field control of GPS decoding results, analysis of obtained results and report generation.

Remote monitoring involves the establishment of a dedicated group FGUP Zapsiblesproyekt of Tyumen branch, entrusted with the task of monitoring arrangements, monitoring data processing and preparation of proposals on monitoring results meant for forestry management and Tyumen Region authorities. Avialesohrana subdivisions should also take part in realization of monitoring project.

Remote monitoring findings should be applied for prosecution of legal entities and individuals for violation of applicable legislation, standards and regulations, as well as for updating of forest management (forest inventory) materials.

Territory under Survey

Monitoring of all forestlands including the forests, which had previously been under jurisdiction of agricultural organizations, is proposed. Total land amounts to 11502.6 thousand hectares.

Applied Data and Information Resources

Underlying satellite imagery of various resolution is applied according to monitoring type, GIS-based fire frequency maps and forest management materials. MODIS (installed on TERRA and AQUA satellites) data are applied for forest fire detection (spatial resolution is 250, 500 and 1000 m). Large-scale air survey materials are applied for more precise assessment of damages resulted from forest regulation violation.

Remote Sensing Data:

Terra and Aqua – 250, 500 and 1000 m

(USA) – 36 spectral channels

– 8 times a day

IRS-1C/1D – 6 m PAN, 23 m – 3 spectral channels

(India) – targeted survey– from 1 time in 5 days and less

IRS – P6 – 6, 23 and 56 m – 4 spectral channels

- EROS A**
 - targeted survey – from 1 time in 5 days and less
 - 1.8 m (PAN)
- RADARSAT**
 - targeted survey– from 1 time in 2 days and less
 - radar-location, all-weather
 - 9 m
 - targeted survey – once every day and less

Economical Goals of the Project

At present, all-around analysis of forests as national estate and control over its exploitation is of public interest.

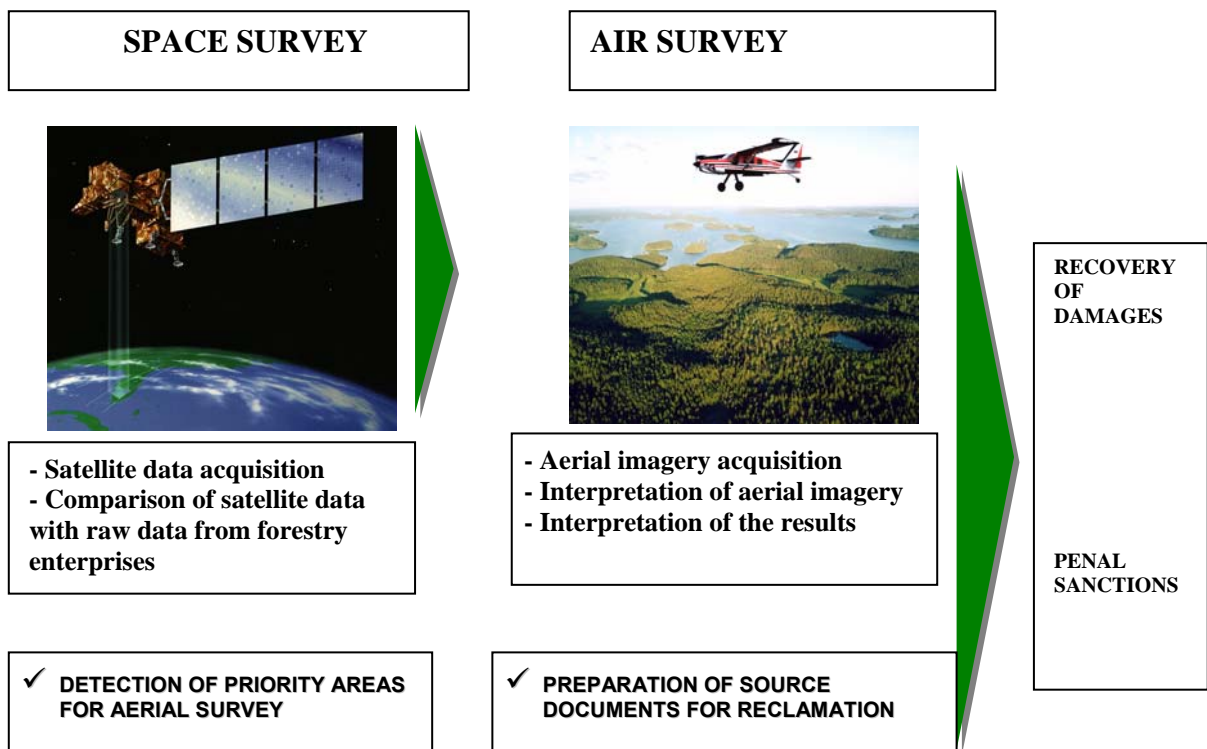
Constituent entities of the Russian Federation are interested in economic development of the areas and high tax receivables from timber enterprises, which are in turn interested in activity and terms of deriving a maximal profit from forest resources use: forest management planning, explanation and assessment of fees for forestlands use.

Consequently, **economical goals of above interest insuring are the following:**

1. Expansion of timber cutting volume, receipts and profits of forestry enterprises, increase in employment;
2. increase of fiscal revenues from forest exploitation, including revenues resulted from tax base expansion;
3. loss prevention:
 - loss resulted from breaching regulations on forest exploitation;
 - loss resulted from illegal forest exploitation;
 - loss resulted from forest fires;
 - loss resulted from breaching regulations on forestlands use in purposes unrelated to forest management (for example, mining operations).

1. Forest Management Monitoring Based on Satellite Data and Large-scale Air Survey Materials

1.1. Process Flow Diagram of Remote Monitoring System



1.2. Tasks, Objectives and Types of Forest Remote Monitoring

Tasks and Objectives of Monitoring are the Following:

1.2.1.. Compliance Control of Basic Rules and Standards of Forest Exploitation.

The following tasks are completed during the monitoring on basis of interpretation of satellite imagery or small- moderate-scale (satellite) aerial imagery:

- location, area and volume of unauthorized (without any approvals) clear-cutting are detected;

- detection of violation of existing rules and standards of forest exploitation and procedure of final felling, intermediate cut (regeneration cut and restocking cut) and other types of cutting.

The following breaches and deviations from regulatory requirements are subject to registration:

a) runover of felling volume approved for periodic yield within enterprises (coniferous, hardwood, softwood) and irregular arrangement of felling sites within the bounds of forestries, forest lands rented;

b) allocation of felling sites without any approved projects and plans of cutting or in unspecified places – inconsistency between actual allocation and project and cutting plan (except for timber stand allocated for cutting, requiring urgent cut);

c) allocation of felling sites falling into categories of protection, specially protected natural areas, where final cutting is prohibited;

d) violation of actual felling acreage and data of felling sites indicated in felling licenses, projects and felling plans (inconsistency between actual felling and allocation data), including extracutting;

e) violation of regulatory requirements of final felling as for width and length of the cutting areas developed;

f) non-observance of cutting cycle;

g) non-observance of regulatory requirements for cutting direction and amount of timber cuttings per quarter;

h) inconsistency between actual cutting method and regulatory requirements (illegal clear-cutting method), and cutting specified in the authorization document;

i) undercutting;

j) inconsistency between actual state of cutting area and survey report.

1.2.2. State Estimation of Felled Areas upon Completion of Forest Harvesting (Revision of Felling Record).

The following tasks should be completed during the estimation as a result of interpretation of large-scale and super large-scale aerial imagery (satellite imagery):

a) adjustment of outlines and felled areas to the data of allocation;

b) estimation of correspondence of actual scheme of cutting areas development to charts and existing projects and allocation of felling;

c) identification of irregular undercutting, individual trees and clumps of trees, subject to felling; area, composition and stock;

d) adjustment of valuation characteristics of dense undercut;

e) assessment of safety of mother trees, clumps and forest strips,

f) assessment of safety of medium and large-size undergrowth and saplings of commercially valuable species;

g) detection of converted wood at logged areas and near wood-transport roads (scattered and stacked timber) and assessment of its volume;

h) estimation of amount of unpeeled soft wood left for a summer period;

i) detection and assessment of cutting areas with poor clearing from logging residues;

j) assessment of soil covering damage degree, resulting in erosion process.

Other forest offences of timber-cutters during the cutting (damage of trees unauthorized for cutting, overtime cutting and logging of timber, warehousing of timber in unapproved places, wood transport before inventory with volume-based delivery; high stumps left on the legal wood-cutting areas, damage of soil covering, destruction of compartment (quarter) and other poles, marks and tags attached to the trees) shall be detected in the course of systematic monitoring of compliance with Cut Regulation for Standing Wood, Regional Regulation of Felling and Regulations of Cleaning Cutting, Sanitary Forest Regulations of the Russian Federation for Ground Revision of Felling Record.

1.3. Types of Forest Remote Monitoring

According to the tasks and objectives, there are **two types of monitoring**:

1.3.1. Compliance Monitoring of Basic Rules and Standards of Forest Exploitation

The monitoring is technically based on multi-spectral space imagery of high spatial resolution or small and medium-scale aerial imagery and geoinformational technologies. In addition to space imagery, large-scale aerial imagery may be applied in certain cases.

1.3.2. Estimation Monitoring of Felled Areas upon Completion of Forest Harvesting (Revision of Felling Record)

The monitoring is technically based on selective large-scale and super large-scale aerial imagery and GIS technologies.

Each type of monitoring may be applied both independently and in combination, simultaneously, as a multiproject.

1.4. Procedure of Regional Forest Remote Monitoring of Basic Rules and Standards

Fact-finding of illegal felling with violation of forest regulation and existing rules and standards involves the following:

- detection of clear-cutting areas;
- assessment of legality of applied felling method;
- estimation of cutting characteristics and conformity assessment of above characteristics to the standards specified in Cut Regulation;
- detection of violations in projects and cutting plans, and official data
- detection of violations in preparation of projects and cutting plans and cutting areas allocation, etc.

Detection of new clear-cutting areas shall be made by comparison of satellite data (small- or medium-scale aerial imagery) with previous data on forest health. Data source on forest health are considered to be the following:

- satellite imagery (small or medium-scale aerial imagery) of prior years;
- Map documents and forest databases (GIS).

Interactive detection is also possible – by means of visual comparison and on-screen manual tracing of newly detected cutting areas – as well as computer-based detection applying present-day methods of image GIS processing and classification.

Various computer-aided methods of nonsimultaneous images coprocessing can be applied for detection of new clear-cutting areas: synthesis method, method of brightness differences, Principal Components Analysis method and others. If map documents and forest databases (GIS) are used as data source on previous forest health, unsupervised methods of classification or training classification with subsequent exception of objects similar to the new clear-cutting areas according to GIS data from classification results shall be applied. Training is given according to GIS data. In addition to new cutting areas obtained from coprocessing or classification, findings may include other objects of similar graphic features (open forest, burned-out forest, windfall timber, pits, oil-and-gas complex objects, mines, etc.). Interactive interpretation with GIS data use is applied for final detection of new cutting areas.

Comparison of a detected cutting area image with cutting plans and felling licenses is applied for the detection of unauthorized cutting and extracutting areas. Failing to find above cutting areas in these documents, or in case of extracutting, the cutting is to be considered as illegal one (unauthorized). In this case, with maximum advisable magnification of satellite imagery (small or medium-scale aerial imagery), outlines of the cutting area will be displayed; total area shall be estimated, and logged timber volume is calculated according to the last forest inventory data. The allowance shall be made for the shoot of wood over the period following the forest inventory.

Assessment of forest valuation parameters is applied for detection of illegal clear cutting. Obtained data are analyzed for conformity with approved cutting standards.

Violations of forest protection class, areas of special protection and specially protected natural sites (NGO), with prohibited clear cutting are detected by comparison of cutting areas displayed by GIS methods or in interactive mode according to satellite imagery (small-scale aerial imagery) with classification documents for the area analyzed according to forest protection categories.

Conformity assessment of actual engineering and administrative elements and parameters of the detected cutting areas according to the standards is carried on basis of satellite imagery (small and medium-scale aerial imagery), using direct method of measurement with application of GIS technologies and designated software, or on a measurement basis by standards equipment using the formed expert system. In addition to satellite imagery, samples of large-scale aerial imagery may be applied if it is necessary. Cutting characteristics required for conformity assessment according to the standards specified in Cut Regulations are the following:

- logging area (width, length, total area);
- year of cutting, methods and cutting cycle, as well as cutting direction and amount of timber cuttings;
- cutting area direction towards meridian "south-north", and in mountain forests - horizontal direction.

Violations of projects and cutting plans, felling licenses are detected by comparison of interpreted satellite imagery (small or medium-scale aerial imagery), applying samples of large-scale aerial imagery if needed, outlines of new clear-cutting areas with outlines of authorized cutting areas. Obtained discrepancies will testify to unauthorized cutting areas and irregular and dense undercutting areas, if there are any. Timber volume of dense (unaffected by cutting) undercutting areas is calculated on the basis of undercutting area space and averaged evaluation characteristic, specified in felling licenses, adjusted if needed for forest inventory data, with the shoot of wood over the period following the forest inventory taking into account. Valuation characteristic and amount of irregular undercutting areas can be estimated on basis of large-scale aerial imagery or by ground revision of felling record.

Violations of projects, cutting plans and felling licenses are detected on basis of assessment of valuation, economic and administrative data on forest areas of planned cutting.

Assessment of untouched seed clumps and leave strips with interval sizing and comparison of aerospace imagery obtained data with felling licenses are carried out for reforestation forecast. Timber volume of cutting areas resulting from cutting of seed clumps and leave strips shall be estimated according to space and volume specified in felling licenses or forest inventory documents.

Soil disturbance and mineralization degree of cutting areas under the impact of harvesting technique shall be estimated by imagery, according to gross area occupied with logways, timber warehouses and other industrial sites. Degree of erosion process development

in the form of linear erosion or soil rain-wash is also estimated for cuttings in mountain forests.

Runover of felling volume approved for periodic yield within enterprises (coniferous, hardwood, softwood) and irregular arrangement of felling sites within the bounds of forestries, forest lands rented shall be determined by data comparison of space and volume of forest reserves allocated by forest management and updated according to remote monitoring data on actual felling volume within the bounds of abovestated forestries and area units with forest inventory data.

Non-conformity of Act of Acceptance (of cutting area) issued by forestry management with actual forest health shall be determined by discrepancy of the violations detected by remote monitoring with violations specified in the Act, in the event of their absence or understatement.

In case of non-conformity of all the above listed characteristics essential for the forest inventory with Cut Rules and Standards, Final Cut and Intermediate Cut Regulations and other types of cuttings, they should be considered as breaches of Forest Regulation. Persons and entities committed such violations shall bear responsibility in accordance with the procedure established by law.

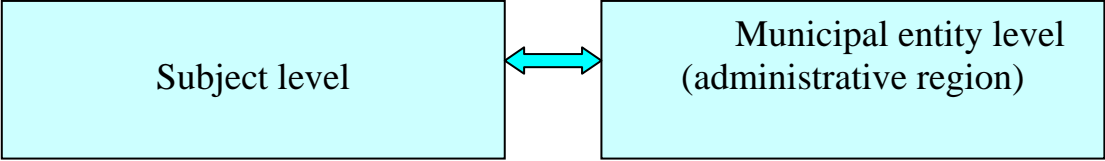
1.5. Cost of Forest Remote Monitoring

- 1. Information processing group fees – **2272.8** thous. rubles
- 2. Cost of large-scale aerial survey – **1250** thous. rubles
- 3. Satellite imagery
 - Landsat7 – **160** thous. rubles
 - EROS – **1115** thous. rubles
- Total: – **4797.8** thous. rubles

2. Forest Fire Monitoring

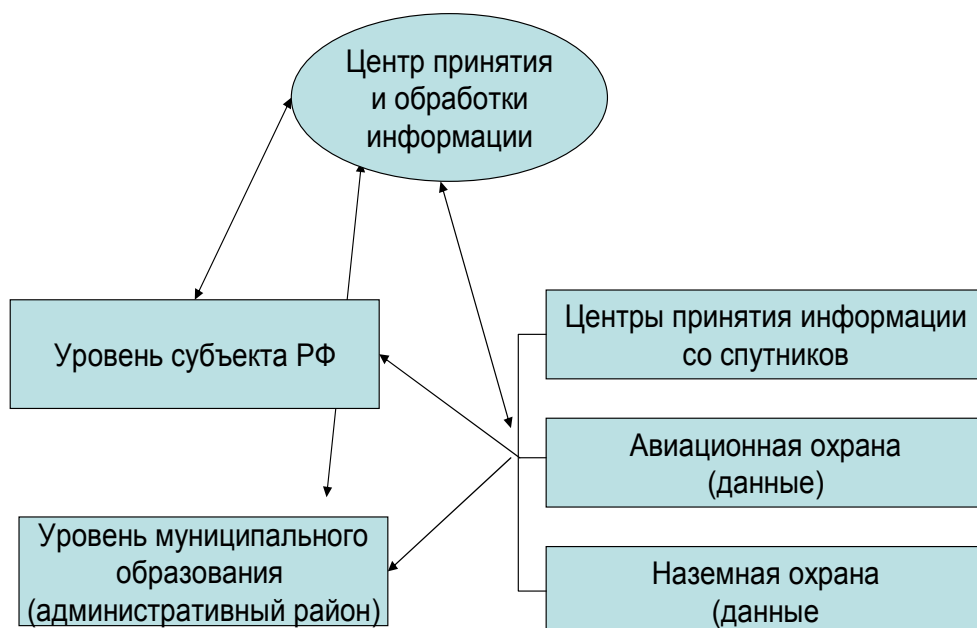
2.1. Forest Fire-Fighting System

Two-level forest fire-fighting system should be created in the region.



This system should be integrated into three-level federal system. Accordingly, control system, which is now at the formation in the region, should have an access to the federal level.

Information acquisition scheme designed for fire fighting system is the following:



2.2. Municipal entity level of preparation and acquisition of information

The following information flows required for creation of the forest fire-fighting system on administrative region level should be formed:

- data for the territorial subject annual planning of preventive and fire control improvements;
- data on covered amount of preventive and fire control improvements together with an indication of actual location of realization (mapping);
- data on fire-fighting equipment availability and readiness (POL, machinery and equipment, staff, communications);
- forest fire statistics – number of fires, forest fire area and fire class from the beginning of fire season, forest fire status (detected, isolated, extinguished);
- data on costs of fire detection and liquidation from the beginning of fire season in whole and on each liquidated fire separately (man-hours, machine-shifts, flying hours, POL, foodstuff, etc.).

2.3. Creation and up-to-date revision of forest fireproof digital map (scale: 1: 50000- 1: 300000) of the administrative region.

With a view to analyze the data acquired and decision-making, strategical fireproof map of the municipal entity with the following information groups is under formation:

- zones of ground and air forest protection;
- firefighting equipment concentration sites;
- transport routes, waterways;
- fireproof break (minimum fire safety separation distance);
- inhabited localities, population;
- individual data for each fire (date of origin, fire class, forest fire area, data on fire-fighting equipment availability);
- required amount of additional firefighting equipment;
- fire extinction date, fire cause;
- data on expended resources;
- flash points statistics.

2.4. Creation and up-to-date revision of forest fireproof digital maps (scale: 1: 25000- 1:50000) of the administrative region.

With a view to fire extinguishing, analysis of frequency of fire occurrence and determination of volume and event location, map with the following information groups is under formation:

- time-dependent coloring of fire dangerous areas, taking into account climatic factors and in a predictable manner (fire development);
- data on preventive measures taken;
- transport routes;
- inhabited localities, population;
- individual data for each fire (date of origin, fire class, forest fire area, data on fire-fighting equipment availability);
- required amount of additional firefighting equipment;
- fire extinction date, fire cause;
- data on expended resources.

2.5. RF subject (regional) level of preparation and acquisition of information

The following information flows required for creation of the forest fire-fighting system on subject level should be formed:

- data for RF government annual planning of preventive and fire control improvements;
- data on covered amount of preventive and fire control improvements together with an indication of actual location of realization (mapping);
- data on fire-fighting equipment availability and readiness (POL, machinery and equipment, staff, communications);
- forest fire statistics – number of fires, forest fire area and fire class from the beginning of fire season, forest fire status (detected, isolated, extinguished);
- data on costs of fire detection and liquidation from the beginning of fire season in whole and on each liquidated fire separately (man-hours, machine-shifts, flying hours, POL, foodstuff, etc.).

2.6. Creation and up-to-date revision of regional forest fireproof digital map (scale: 1: 500000- 1: 700000)

With a view to analyze the data acquired and decision-making, strategical fireproof map of RF subject with the following information groups is under formation:

- zones of ground and air forest protection;
- firefighting equipment concentration sites;
- transport routes, waterways;
- fireproof break (minimum fire safety separation distance);
- inhabited localities, population;
- individual data for each fire (date of origin, fire class, forest fire area, data on fire-fighting equipment availability);
- required amount of additional firefighting equipment;
- fire extinction date, fire cause;
- data on expended resources;
- flash points statistics.

2.7. Cost of Fire-Fighting Monitoring Project

1. Information processing group fees	– 2272.8	thous. rubles
2. Cost of large-scale aerial survey	– 1250	thous. rubles
3. Satellite imagery		
Landsat7	– 160	thous. rubles
EROS	– 1115	thous. rubles
MODIS	– 400.0	thous. rubles
Mapmaking of the Tyumen Region forests		
	– 3230.1	thous. rubles
4. Making of fireproof maps of administrative regions	– 1842.3	thous. rubles
5. Making of forest maps of frequency of fire occurrence based on digital Forest inventory maps	– 1448.6	thous. rubles
Total:	– 11718.8	thous. rubles

3. Ecological Monitoring of Forest Resources

3.1. Tasks and Objectives of Monitoring

Detection of illegal forest exploitation (ecological monitoring of forest fund health) is carried out to minimize loss to biotic communities, bog complexes and other natural complexes during construction works, mining operations, subsurface utility engineering, forest exploitation and execution of other works in the territory of forest reserves, process acceleration of field development, to estimate acceptability and practicability of subsequent reclassification of forest lands status into non-forest or other land classes.

Monitoring objects involve gas and oil producing enterprises, and other enterprises relating to geological survey, exploitation and conservation of earth reserves in the territory of forest reserves regardless of property category.

Monitoring involves the following:

- daily operations of forest and earth resource users and compliance of business activity with license agreement terms;
- compliance of business activity with mineral resources regulation, Forestry Code, Water Code and Land Code, existing regulations, project technical-and-economic and process documentation and reports of enterprises to obtain the comprehensive idea of legal entity (mineral resources user) cost estimate and exploitation efficiency of subsoil plots and forest lands leased.

Monitoring of forest resources should be carried out after making of digital maps of forestries or it should be based on the latest aerial survey material with subsequent situation control using satellite imagery.

Ecological monitoring scheme (Fig.10) is based on the processing of aerial and satellite imagery, made at different times for detection of modifications of manmade and natural objects happened during the inter-survey period.

Satellite imagery of medium-scale, which spatial resolution and costs best suited for problem solving, are applied for monitoring.

Advantages of medium-scale imagery meant for ecological monitoring of forest fund health are the following:

- relative low operational costs;
- year-on-year survey of main part of the area under control;

- detection of many characteristics of various objects owing to wide spectral range;
- large area of the territory displayed, which means considerable cost cheapening of spatial and radiometric correction.

Imagery disadvantage is the insufficient spatial resolution for large-scale mapping.

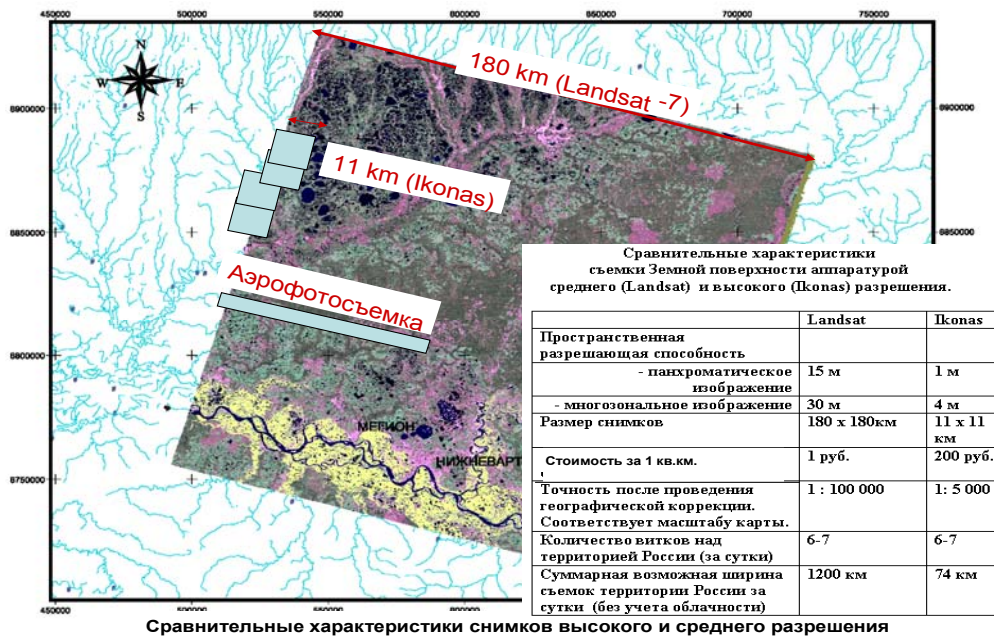
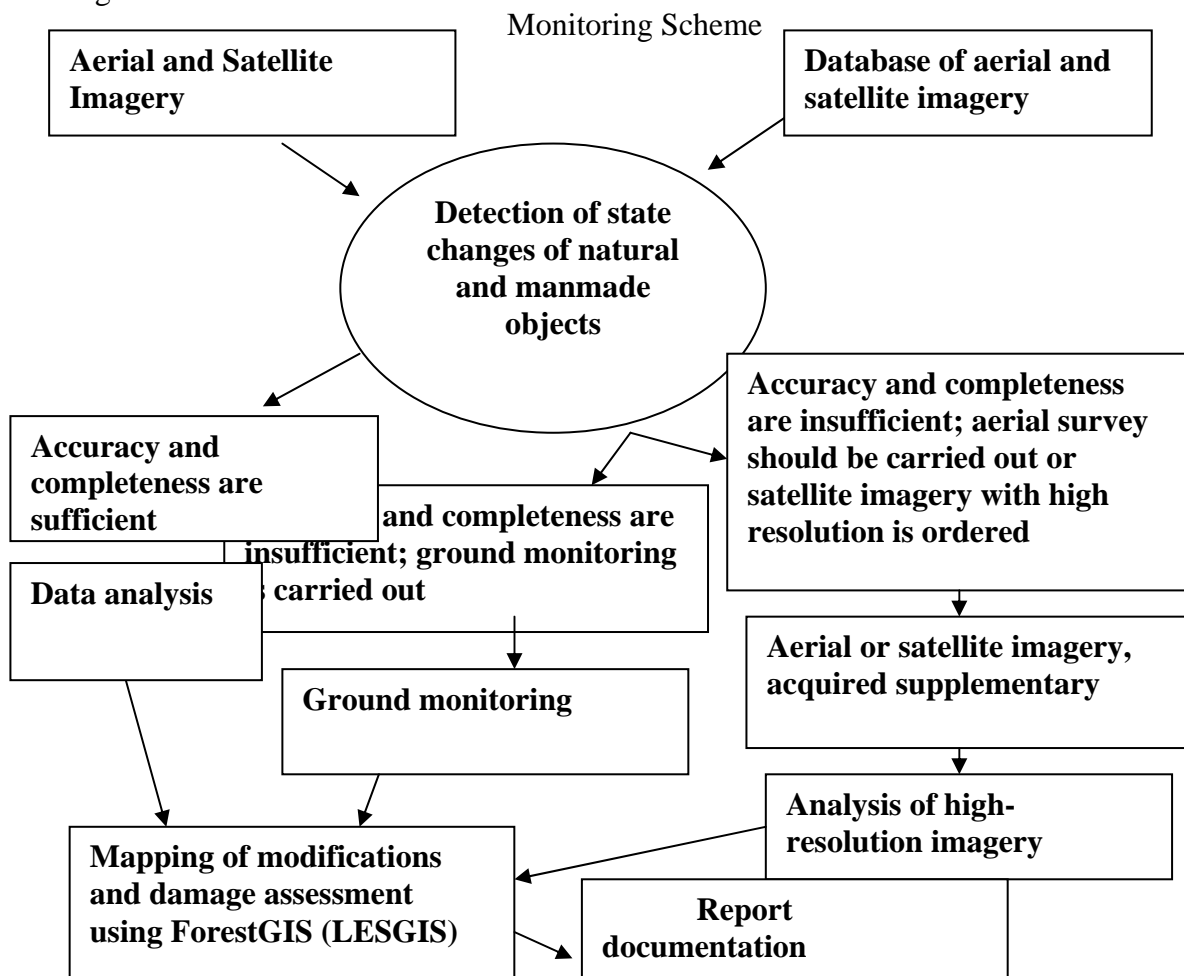


Fig.1



3.2. Procedure of illegal forest exploitation (ecological monitoring of forest fund health)

Determination of infringement of forest and land regulation, and working rules and standards involves the following:

- detection of construction sites and other working zones in the territory of forest fund, unrelated to forest management and forest exploitation;
- inspection of right stating documents for reclassification of forest lands status into non-forest or other land classes;
- detection of construction sites location and conformity control of above sites with the Land Allocation Acts;
- detection of violations of the approved Land Allocation Acts;
- detection of violations of construction including sites beyond the land allocation.

Detection of construction sites shall be made by comparison of satellite imagery (small or medium-scale aerial survey) with data on previous forest health. Data source of previous forest health are considered to be the following:

- satellite imagery (small or medium-scale aerial imagery) of prior years;
- Map documents and forest GIS databases.

Interactive detection is also possible – by means of visual comparison and on-screen manual tracing of newly detected cutting areas – as well as computer-based detection applying present-day methods of image GIS processing and classification.

Various computer-aided methods of nonsimultaneous images coprocessing can be applied for detection of construction sites: synthesis method, method of brightness differences, Principal Components Analysis method and others. If map documents and forest databases (GIS) are used as data source on previous forest health, unsupervised methods shall be applied.

Comparison of detected construction site image with the Land Allocation Act or with inventory data is applied for the detection construction sites. In case of data mismatch (absence of the Land Allocation Act; site location differs from that one specified in the Land Allocation Act), forest exploitation is to be considered as illegal one (unauthorized). In this case, with maximum advisable magnification of satellite imagery (medium or large-scale aerial imagery), outlines of the construction site will be displayed; total area shall be estimated, and damage assessment is made according to the latest forest inventory information. The allowance shall be made for the shoot of wood over the period following the forest inventory.

Location of construction sites is analyzed as for location in forests of I, II, III groups, and in areas of special protection.

3.3. Cost of Ecological Monitoring of Forest Resources

1. Information processing group fees	– 2272.8 thous. rubles
2. Cost of large-scale aerial survey	– 1250 thous. rubles
3. Satellite imagery	
Landsat7	– 160 thous. rubles
EROS	– 1115 thous. rubles
Total:	– 4797.8 thous. rubles