Satellite monitoring systems in forestry

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Abstract. Space technologies in Earth remote sensing are among the most relevant technologies for monitoring forestry. Difficulties of controlling tree felling and other activities by forestry employees constitute an objective problem which can only be solved by application of space monitoring instruments. The article shows that using the LandViewer Software would provide regional forestry a wealth of information needed for ongoing work and detection of violations. The considered examples demonstrate that space monitoring provides a more accurate determination of the size of forest blocks and the felling volume.

1. Introduction
The purpose of the forest utilization remote sensing is early detection and prediction of development of processes that have a negative impact on forests [1]. Data obtained from Earth remote sensing allow detecting violations of Forest law in specific uses of forests: timber harvesting; geological exploration of mineral deposits; construction and operation of artificial water bodies, hydraulic structures; construction, reconstruction and maintenance of power lines, communication lines, roads, pipelines and other linear objects [2]; wood processing [3].

Remote sensing in forest management is one of the key programs of the state forest inventory. To date, remote sensing is the only modern high-technology way to detect violations of Forestry law during forest utilization. Earth remote sensing data and results from their processing are practically used in the exercise of oversight functions and land use management [4].

The purpose of the research is to identify the capacity of the LandViewer system to observe the thinning. The objectives of the study are to mark current allotments, observe real-time logging through space images processing, determine the harvest areas and to develop recommendations on the use of LandViewer.
2. Methods and materials

Earth remote sensing materials are used increasingly in forest management due to the relative cheapness of area units sampling. In remote sensing there is also no direct contact between the object of research and technical tools, and provided materials are generally more informative.

There are two types of Earth remote sensing techniques: aerial survey and space survey. Aerial survey is very expensive and now obsolete [5]. Satellite Earth observing systems can make a significant contribution to large scale mapping (M 1:1000) and updating of digital vector maps, as they provide timely and detailed information on land use of large territories due to their synoptic coverage and high frequency of return visits [6]. Medium spatial resolution satellite images from the LandViewer resource have gained most popularities. Use of these images is based on information accessibility, relatively high frequency of information re-obtaining, availability of several spectral imaging bands and wide swath (185 km).

Modern means of satellite imagery provide most operational and accurate data on activities and forest health obtained from any territory, even the farthest one. Today forestry actively uses the following systems:

- the global positioning system (GPS). For the purposes of forestry work in the Samara region GARMIN GPSMAP navigators with cartographic documents are used.
- the global navigation satellite system (GLONASS).

Accuracy of data obtained from navigation systems can be influenced by satellite orbits dispersions, geometry of satellite positioning with respect to the coordinate system, propagation delay, relief and vegetation.

To understand the problem, consider the example of forest utilization control and detection of illegal clear-cutting. Indeed, it is very easy to locate clearcut areas using multi-temporal space images. However, the aim is not only to locate such places, but also to precisely estimate their parameters such as width, length, area and a number of other characteristics of the cut area and adjacent forest stands.

Multispectral images are more preferable and produce more accurate results. Using all types of space images makes it possible to reduce systematic errors during estimation of the felling area parameters and standard deviations with increase in the size of the cutting area.

If it is necessary to accurately estimate the parameters and area of every cut area during the forest utilization control, then case space images with spatial resolution of 1-2 m should be used. If it is only needed to locate the position of cutting areas and to estimate their total area, then it is possible to use images with lower resolution (IRS, Landsat, SPOT) [8, 9]. In the case when alongside with estimation of the cut area parameters there is also a need to assess its state (presence and character of incomplete felling, undergradhment, wood waste, soil condition, etc.), there is no alternative to the ultra-large-scale aerial survey complementing the space survey at the current stage. Speed of detection of the cut area by the expert depends only on weather conditions and access to the remote sensing system, as data are transmitted to the system every day from a large number of satellites.

One way of addressing the problem of continuous monitoring of forestry works is through the use of LandViewer. LandViewer is a resource that allows analysis of Earth images and real-time observation via browser.

EOS software developers have recently launched a cloud-based tool that allows to search and analyze massive amounts of Earth observation data. EOS solution gives users an opportunity to perform multipurpose queries, find and use any Earth observation image available from the Sentinel 2 [9] and Landsat 8 [11] satellites in one place and much faster that before [7]. It is a free service, easy to use, and which can be accessed from any browser or device. Thanks to LandViewer, users can explore images stored on the Amazon cloud platform, apply search filters for the date of the image, analyze the images, download and share them with others. Using Mosaic Generation technology, LandViewer cab retrieve scenes of file data with any magnification in less than ten seconds. Images can be viewed in different combinations of bands or in a spectral index in real time like the NVDI [6].
selected to offer the information that best meets the needs of the user. To make this possible, EOS experts have developed a technology that transforms, in real time, raw satellite image data stored in GeoTIFF format of 16 bits in tiles, which the user can immediately see in the browser window, therefore, there is no need to create and store preview windows in the browser or to archive the data, since the images are immediately displayed in the browser from the primary data. The user can apply various combinations of preinstalled and customized spectral bands to highlight and display data of any type in the image. For example, forest fires are most easily seen in the infrared spectrum. There are several bands available to analyze vegetation. Users can examine in detail all objects located in a scene, for example, those related to fire or illegal logging. Geospatial images of 2014, 2015, 2016 and 2017 can also be compared chronologically to identify changes in the development of forest and other natural features.

One of the remote survey techniques was developed for commercial forests. At the first stage preparatory work is undertaken that includes receiving primary sources: copies of the forest use report, forest stand purchase and sale agreements, stumpage appraisal, technological charts for logging of the cutting area, data from the State forest register and statistical report data. Primary sources, their completeness and correctness are analyzed, then the vector layer of forest blocks lines is created, attribute data on the forest range, a compartment, a unit, use of forest, area of the felling area, realizable volume on the cutting area, etc.

The second stage involves obtaining space survey panchromatic or polyzonal imagery with spatial resolution of no less than 5 m from SPOT-5 and ALOS (PRISM) satellites. Using data from WorldView-1, QuickBird, RapidEye an index of imagery can be created [11]. Further on, analysis of images is conducted with subsequent removal of flawed scenes. Vector schemes of coverage by images of objects under monitoring are created. If needed, color correction, geographic reference and orthotransformation of images can be made, and mosaics can be created using ENVI. To identify the changes in the Forest Fund territories, it is effective to use synthetic images created by merging two multi-temporal images.

Space survey for forests remote sensing should be conducted during the spring, summer or autumn seasons, primarily in growing season. Winter survey can be used as complementary to surveys conducted during the snowless periods.

During the third stage prepared space images are combined with lines of net of rides, forest units, and created vector layer of forest blocks (cutting areas and forest blocks). Contour decoding of used forest blocks is carried out based on multi-temporal composite and space images of the current year.

During the process of the space survey data decoding, areas of cutting areas and forest blocks are calculated, compliance with the provisions of the Forest law is assessed, areas where illegal cuttings or illegal utilization of the Forest Fund lands took place, and areas with incomplete felling are analyzed. The assessment of the state of felling areas allows to determine whether their parameters are in compliance with legal requirements. The accuracy of calculation of the felling area in the picture depends on the thinning grade, shape of the area and spatial resolution of the image.

At the fourth stage random on-site investigations of areas where violations of the Forest law were detected. Inspection of utilized forest blocks areas is carried out by geodetic boundary surveying. Non-compliances with boundary parameters of basic elements of deforestation are detected: leaving small incomplete felling areas that are less than 10% of the forest block area; logging without documents of entitlement; logging beyond the cutting area allotment; logging in the protected forest areas. Results of random on-site investigations of cutting areas where violations of law have been detected, confirmed the results of violations decoding using images in 90% of the cases.

Based on results of the work, violations of the Forest law are recorded, and reports on forests remote sensing are completed.

The issue of efficiency of observation can be solved by using the LandViewer resource that displays the state of the Forest Fund in real time in combination with the geographic information system of the forest rangers.
3. Results and discussion
It is proposed to consider the example of the Samara region to see the opportunity of application of the operational remote sensing method in the area of forest utilization and timber harvesting in order to locate the cutting areas, logging beyond the cutting area allotment, logging of unexploited forest in the allocated area, and analyze the consistency of their parameters with forest use reports.

When allocating forest stands for felling, Garmin 64 st is used, the track is recorded in memory, and then all forest block characteristics of interest are obtained through the use of opportunities of the Garmin Basecamp program. Further they can be used as creation data for forest block allotment materials. Then coordinates of landmarks are marked on the projection of the unit in raster mode as a combining site for verification of the allotment. To do so, Google Earth Pro [12], Map Info or GIS In-GEO can be used.

When concluding a forest stand purchase and sale agreement, it is important to specify the following information: the purpose of timber harvesting, location of the forest stand, characteristics and volume of wood subject to harvesting, forest stand layout, method of logging (clear-cutting, selective cutting), type of logging (mature or overmature forest stands, stands that died or were damaged during forest tending). Besides these, forest stands located in the cutting area should be mentioned: seed trees, vigorous trees of valuable species, forest stands not meant for wood harvesting, trees listed in the Red Book. In addition, terms and conditions of removal, methods and time for slash removal, management of harvested wood are specified. It is also stipulated that employees of the forest range are entitled to verify compliance with conditions of the agreement, and inspect the cutting area after the works are completed. In order to carry out inventory properly, the following algorithm was suggested. Once the contract is concluded, the coordinates of the allotment are put in LandViewer, and the sketch of the forest block under monitoring through satellite images is created. One it is discovered that the felling has started, monitoring of felling works execution begins.

Consider the example of such violation as hauling timber from cutting areas before it was accounted and the cutting areas survey report was drawn up. This violation is one of the most common ones, because the logger is under no obligation to notify the forest ranger station about felling until the completion of the process and further accounting, whereby the volume of unaccounted timber may vary from 25 m³ to 200 m³. Thanks to the LandViewer it can be seen that the felling took place in a certain part of the cutting area, therefore, it is possible to visit the area and check the volume of felled timber for consistency with stored wood. Due to continuous monitoring, a great deal of cases of illegal felling and unexploited forest felling can be avoided. If weather conditions are favorable, it is possible to track the violation day after it has occurred, and to avoid irreparable damage to the forest stand. The only drawback is the impossibility of monitoring in bad weather. In addition, the resource offers installation of the AOI instrument that allows the user to get email notifications every time changes occur in the chosen area of interest. This makes it possible to automatically track all felling processes.

This technique was tested in the Samara region forestry. In the first case, after the data on cutting areas based on placed coordinates was analyzed and compared to the planning data, it can be seen that a mistake of two degrees was made during the allocation of the forest block #3, therefore, the strips are not parallel. In the second case, a mistake of three degrees was made during the allocation of the forest block #2, therefore strips between forest blocks #1 and #2 are not parallel either. Cartographic services such as Google Earth Pro and Yandex have served as a platform for marking the forest blocks sketches according to coordinates obtained during allocation using Garmin 64 st.

Via LandViewer felling in forest blocks can be observed. In the first case images of 20/03/2019; 19/04/2019; 09/05/2019; 01/06/2019; 06/06/2019; and 13/06/2019. On 20/03/2019 no works were executed in the forest block. On 19/04/2019 a picture was taken showing a sharp contour of the cutting area in the forest block #2, where felling has started. Then works in the forest block #1 have started, and they were finished by 9/05/2019. Then works were executed in the forest block #3. On 01/06/2019, area of 0.1813 ha was cut, which is 60.4% of the total cutting area. On 06/06/2019 works were 90% completed, and on 10/06/2019 they were fully completed, which can be seen in the image of 13/06/2019: the cutting area was 0.2956 ha.
Based on the images, parameters of felled forest blocks can be estimated. Experimental research data on assessment of accuracy of the cutting area parameters estimation based on remote survey and allocation is presented in Table 1.

### Table 1. Determination of linear and areal parameters of deforestation.

| Forest Block Number | Numbers of Lines | Allocated Forest Block Lines Lengths, m | Forest Block Lines Lengths According to Remote Sensing Data, m | Allocated Forest Block Area, ha | Forest Block Area According to Remote Sensing Data, ha |
|---------------------|------------------|----------------------------------------|---------------------------------------------------------------|--------------------------------|--------------------------------------------------------|
| 1                   | 1-2              | 200                                    | 199.74                                                        | 0.5                            | 0.4962                                                 |
|                     | 2-3              | 25                                     | 25.55                                                         |                                |                                                        |
|                     | 3-4              | 200                                    | 199.28                                                        |                                |                                                        |
|                     | 4-1              | 25                                     | 24.8                                                         |                                |                                                        |
| 2                   | 1-2              | 200                                    | 200.40                                                        | 0.5                            | 0.4873                                                 |
|                     | 2-3              | 25                                     | 24.11                                                         |                                |                                                        |
|                     | 3-4              | 200                                    | 200.10                                                        |                                |                                                        |
|                     | 4-1              | 25                                     | 25.18                                                         |                                |                                                        |
| 3                   | 2-3              | 25                                     | 24.86                                                         | 0.3                            | 0.2956                                                 |
|                     | 3-4              | 120                                    | 120.06                                                        |                                |                                                        |
|                     | 4-1              | 25                                     | 25.16                                                         |                                |                                                        |

*Drafted by the authors.*

In this case, absolute error was 0.007 ha, average relative error was 1.39%. In this research such errors can be explained by the fact that crowns of trees located near the sight line are projected onto the raster image, and during the inspection based on coordinates of landmarks marked by using the GARMIN GPSMAP 64 st navigator, no illegal actions were detected.

The methodology for estimation linear parameters of the felled forest block #1 using the LandViewer service is described further in the paper. To measure the 1-2 line, click on the most south-westerly point of the forest block line and drag it in the south-eastern direction to the end of the cut strip, then click the mouse button, and the measured length will be displayed, equal to 199.74 m. For further measurements the same algorithm can be used, though it is important to remember that the purpose is to measure the perimeter. Therefore, to find out the length of the line, the previous measurement should be subtracted from the total measured value. After the contour is closed, the total area will be measured automatically. To verify the conformity of the forest block boundaries with the cutting area boundaries, the landmarks should be marked in accordance with coordinates, prior to the allotment.

### 4. Conclusion

Forestry practices can be observed in real time using the LandViewer resource. Besides mentioned forestry works, the following activities can be easily tracked: cutting out and reviewing firebreak lines; clearing and cutting glades; random inventory of forest management materials; inspection of sites leased out for laying and maintenance of linear objects; monitoring of protected natural areas.

Results of the research show that LandViewer is a very convenient and relevant platform for forest felling monitoring. The provided information is highly relevant due to the high frequency of data collection, availability of several spectral imagery bands and a wide swath. LandViewer works well with the existing technologies and materials. The accuracy of the cutting areas measurement using GIS LandViewer is acceptable and can be perfected given the access to space images of high spatial resolution. Therefore there is a need to pursue the possibility of ensuring access of forestry employees to existing databases containing real-time Earth remote sensing information of high spatial resolution.
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