Study of reforestation after cuttings based on materials of open web-mapping services

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Abstract. The article considers the possibility of application of open cartographic materials for the analysis of reforestation on the territory of Sosnovsky subdivision of forest district in Priozersky district of the Leningrad region, after felling with a limitation of more than 15 years. With the increase in the pace of technological development, there is an annual increase in the natural resources of our planet and the consumption of wood resources, reforestation is a necessary part of the work after felling on the lands of the forest fund. However, studies based on the analysis of Earth remote sensing data allow us to conclude that there is no quality reforestation of forest land.

1. Introduction
In the authors' studies [1-3] different approaches in the use of remote materials for the analysis of cuttings were considered. According to the official data of the Federal Forestry Agency for 2017, reforestation activities in Russia were carried out on an area of 968174.3 hectares, including 28836.9 hectares in the Leningrad region.

Based on the materials of the GFW (Global Forest Watch) project to study the dynamics of changes in the forest cover of our planet using the analysis of satellite images, Russia ranks first in the world in terms of loss of forest cover. Using open web-mapping materials for retrospective analysis of low, medium and high spatial resolution images, it is possible to explore areas where logging was carried out 20 or more years ago. In accordance with the forest legislation, after the felling the lessee of the forest area must carry out reforestation. However, it should be noted that in practice the lessees are limited only to the composition of the work on the creation of forest crops, which does not guarantee the quality of forest regeneration in the felled areas in the future.

Earlier researches of the authors [4], on the basis of full-scale surveys and study of Earth remote sensing materials, give a clear and substantiated conclusion about the absence of the whole set of works, starting with the removal of cutting residues and ending with the carrying out of care in the studied territories, which as a result leads to a paradoxical situation. On the one hand, the lessees fulfill the requirements for forest restoration established by the legislation, which allows avoiding penalties from supervisory authorities. On the other hand, carrying out a more detailed study of the territories after the forest restoration measures, most of the territories, 20 and more years after the felling, remain unforested. In the areas left under natural forest restoration, the economic significance of the renewed forest species is low due to the replacement of former coniferous species with low-value, rapidly growing deciduous species.
There are several reasons for these circumstances. However, the lack of agrotechnical and forestry care is one of the most significant reasons.

The objectives of the study included the following stages: determination of quality Earth remote sensing (ERS) data, selection of the object of study where deforestation and combined reforestation were carried out, analysis and assessment of the quality of the conducted reforestation, as well as the development of methodological approach and criteria for assessment of reforestation based on Earth remote sensing materials.

2. Methods and Materials

Characteristics of the object of study. Sosnovskoye subdivision of forest district is a part of Priozerskoye forest district located in the Northern part of the Leningrad Region. As of 01.01.2018, the total area of the forest district is 287608 hectares and consists of 20 subdivisions of forest district. The relief of the territory of the forest district is flat. Forest lands make up 78.9% of the forest fund area. At the same time, the lands covered by forest vegetation make up 70.9%.

The total area of the Sosnovsky subdivision of forest district is 13740 ha according to the data presented in the forestry regulations of the Priozersky forest district of the Leningrad region. The forests of the subdivision of forest district belong to the taiga forest zone, the Baltiysko-Belozersky taiga district of the Russian Federation.

As a study of the territory based on Earth remote sensing data, 25, 26, 36, 37 forest blocks were selected, in which solid sanitary cuttings were carried out.

To compare the loss of woody species of plants, we compare the materials by means of the Global Forest Watch web-mapping service and the Global Forest Change service with the difference in the 20-year period. The initial stage of the research included the use of open web-services for the purpose of determining forest quarters, with felling in more than 20 years. The second stage of the study was the visual analysis of remotely processed materials to improve image quality for interpretation and assessment of the quality of reforestation over a period of time. The third stage is the interpretation of the results obtained and the conclusions of the study.

The image in green indicates the forested land, white indicates felling more than 20 years ago, pink indicates the felling carried out in the period from 2001 to 2017 (Figure 1).

![Figure 1. The territory of the object of study before and after felling.](image-url)

In order to carry out the study, it is necessary to select the most qualitative materials for compiling the criteria for analyzing forest restoration and assessing the quality of forest restoration. Open satellite images taken with the help of WorldView, GeoEye-1, Landsat, Sentinel-2B orbiting satellites will be used as analysis materials.

The Global Forest Change service data were used for the assessment of the felled areas in the temporal dynamics. The main difference between this service and Global Forest Watch is the change in the color of the felled area corresponding to a certain year of felled area, so the image (Figure 2) shows the area of the felled areas. However, this resolution is not sufficient for a more detailed analysis of the quality of reforestation at the selected sites. Trees on the image are defined as
vegetation above 5 m in height and are expressed as a percentage per each cell of the output grid. "Loss of forest cover" is defined as a disturbance of stand replacement or transition from forest to non-forest condition in the period of 2000-2018 [5].

Also, using the Global Forest Change service, you can define "Forest Cover Growth", which is defined as the inverse of the amount of loss or change in one color range over the period from 2000 to 2012.

The second step. High-quality reference images of the object of study for the periods 2000 and 2018 are heterogeneous open cartographic materials that have undergone preliminary image processing to improve the quality of detail for the interpretation of plantations. It is worth noting that remote materials obtained by unmanned aerial vehicles can be used to obtain maximum quality. [6] UAV materials have a very high spatial resolution and they can be viewed on images of both closed and unclosed forest crops.

To assess the quality of reforestation using remote sensing materials on selected forest blocks, three time intervals are required. The first time interval, images received at the moment of felling, these materials clearly show the recent felling and abandoned seed trees, the second time interval - intermediate, the viewing of images received 10 years after felling, allow to assess the preliminary changes after felling, the third time interval - final, images of the last year of felling allow to assess the quality of reforestation of the selected object of study, to compare the increase in green mass growth over the past period from the moment of felling (Figure 3).

The third stage. Evaluation criteria for actual reforestation in the Sosnovskoye subdivision of forest district. Analyzing multi-temporal images of Landsat-7 and Landsat-8 in the optical range, 25 and 26 forest blocks it is necessary to note the signs of green cover growth, which indicates the formed growth near the left forest strips, as a rule, not typical method of restoration, which is not observed on the images of other forest blocks. In our study, the following criteria for the assessment of reforestation processes were taken into account:

Criterion 1. Estimation of actual area of reforestation works.
Criterion 2. Assessment of the dynamics of increase/decrease in the area of reforestation.
Criterion 3. Assessment of species composition.
Criterion 4. Assessment of the density of forest plantations.
Criterion 5. Correspondence of actually performed works to the projected technology of forest crops creation.

In the process of image processing in the optical range, the analysis of reforestation areas, spatial distribution of renewed vegetation and density of plantations was performed. Semi-automatic decoding of cuttings was used to compare the area of reforestation works, which was carried out with the help of delineation of cuttings by means of creating a layer on the dynamic web-map using API technology (interface of applied programming), which allowed to establish the exact areas of cuttings. The digital contours of the initial felling period obtained during the images interpretation were combined with the latest actual high-quality Landsat-8 OLI images. These operations made it possible to visually assess the areas where young stocks were formed.

3. Results and Discussions
The study conducted in [4] shows that in the areas of forestry, where the combined method of forest restoration was used, the number of abandoned seed trees for the natural regeneration of the forest did not comply with the norm, 11 units per hectare, with the required 20 units per hectare. Moreover, an important role in the creation of an enabling environment for seed germination is played by measures to promote natural regeneration (clearing cuttings from cutting residues, soil tillage and removal of soil cover), which was also absent in the cutting areas. The field survey of the study sites revealed a high degree of logging residues littering, which was one of the reasons preventing successful forest restoration. Referring to the foreign experience, the harvesting practice in Finland includes the processing of cutting residues, which has a positive impact on the reforestation process.

It is worth noting that for the maximum quality can be used remote materials obtained with the help of unmanned aerial vehicles [6]. The UAV materials have a very high spatial resolution, and they can be viewed on images, both closed and uncoupled forest crops. The scientific paper [7] proposes the use of the method of calculation of trees on the occupied area, an automated approach by means of software data processing. The use of this method will allow to calculate all trees left after felling.

Annually several million hectares of forest are cut down on the planet, materials based on annual monitoring of geostationary satellites are the most objective, geoinformation technologies and web-technologies capable of processing these materials allow comparing data on a global scale of felling both individual countries of their regions and for the whole planet. Despite the fact that the forest is a renewable natural resource, it is impossible to return the whole complex of biological system after deforestation. An entire ecosystem is irrevocably dying with deforestation. Taking into account the adopted norms of the legislation in the field of reforestation, based on monitoring by means of web-mapping services, it is possible to make a conclusion that for today, on the lands of Sosnovskoye subdivision of forest district proper reforestation providing the most qualitative indicators of both the stand itself and the area after felling, practically is absent. Which means that on the lands where similar felling is carried out, the restoration processes will be similar. In spite of afforestation, without annual maintenance and measures to promote reforestation, there will be no high-yielding forests on these lands. At the same time, it is necessary to take into account the continuing rapid deforestation in this area, under the pretext of sanitary felling [5, 8].

4. Summary
1. According to the preliminary results of image analysis and in accordance with the established criteria and rules of reforestation [9], the studied objects of Priozersky district cannot be transferred to the covered forest area, which indicates the low quality of forest restoration works.
2. As a result of the images analysis it was established that the undergrowth is not evenly distributed by the felling area: the greatest density is observed near the abandoned forest strips, and between them the forest renewal is practically absent or observed locally.
3. Natural regeneration of felling takes place at the expense of deciduous species. Measures to promote natural regeneration at these sites were not effective.

4. Estimating the general indicators of reforestation on the studied territories, according to the given criteria according to the data of web-mapping materials it is possible to make a conclusion that the modern quality of images and diversity of materials, a large number of cartographic web-services with the laid down functions on an estimation of changes a vegetative cover, allow to study in details reforestation processes on felling.

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