Issues of satellite images decoding in modern development of forest management

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Abstract. The processes of natural overgrowing of poorly used lands have led to the formation of a significant amount of unaccounted forest resources. As a result of a survey of the territory adjacent to the city of Kazan, we have identified numerous land plots that are uncontrollably overgrown with forests, an example of such a plot is given. Accounting for all areas covered by forest vegetation will significantly increase the forest cover of the Republic of Tatarstan. Using modern methods of “contour decoding” of satellite images allows us to identify almost all areas covered by forest vegetation, significantly increasing the efficiency of the use of forest resources. Using the methods of the so-called “taxation (estimated) decryption” of satellite images allows us to assess the features of the dynamics of modern forests. An assessment of the species composition and origin of forests using remote sensing methods, including based on the results of decoding satellite images, gives an idea of the distribution of derivative forests in the region. Forest inventory allows not only to keep a record of the forest fund, but also to assess the resources of forest biota in regional fragments of the biosphere, as well as identify the main trends in forest dynamics.

1. Introduction
New opportunities for the solution of problems of forestry appear due to the improvement of methods for earth remote sensing. When assessing the state of forests, it is effective to carry out comprehensive work when using data from both a ground survey of the territory and satellite images [1]. We associate increasing the efficiency of forest management with taking into account all forest resources and assessing the prospects for their reproduction in modern conditions. Determination of forests and forest organization have always been the basis of forest management. The contour interpretation of satellite images using modern technologies allows one to effectively take into account all forest resources, which is quite relevant for regions with large volumes of protective afforestation and the massive spread of forest vegetation on poorly used lands. The widespread destruction of typically indigenous forests increases the value of the assessment and study of the dynamics of secondary – derivative forests. The taxation interpretation of satellite images, which is widely used in forest management, makes it possible to use methods for the qualitative assessment of forests, including the secondary forests productivity parameters. An assessment of short-, long-term, stable, irreversibly
derivative and other forests will provide scientifically significant data on the features of the dynamics of modern forests.

2. Methods and Materials
The research was carried out on the basis of the survey of forest vegetation of the Republic of Tatarstan. Forests were assessed using the data from the Forest Plan of the Republic of Tatarstan, forest inventory materials of forestry located in the outskirts of Kazan, and publicly available satellite imagery of the region.

The work was carried out comprehensively using ground-based survey data and satellite imagery. This order of work is widely used in the course of the so-called “decryption taxation” during forest management works in several regions of Russia.

The aerospace sounding data used in the study of forests included satellite images from Landsat-7 and Terra-ASTER satellites obtained in winter and spring for the site near the Bogatye Saby town settlement. Table 1 shows the main characteristics of the listed remote sensing space devices.

| Space device, surveying system | Spectral range, μm | Number of zones | Terrain resolution, m | Picture Resolution, km²×km |
|-------------------------------|-------------------|-----------------|-----------------------|-----------------------------|
| «Landsat-7», ETM+             | 0.52-0.90         | 1               | 15                    | 185×170                     |
| «Terra», ASTER                | 0.52-0.90         | 3               | 15                    | 60×60                       |

The images used were provided from the data archive of ZAO Institute of Aerospace Instrument Engineering (Kazan). Images obtained in the photographs in the visible and near infrared ranges have high detail and allow us to estimate the location of areas occupied by forest vegetation.

The assessment of the qualitative state of forests was carried out during routine-exploring survey based on existing methods [2, 3]. The trends in forest dynamics were determined taking into account the achievements of the “geographic and genetic” and other sections of the forest typology [4, 5]. The research results were compared to the data from different regions of Russia [5, 6].

3. Results and Discussion
The authors participated in the research and forest inventory works in several regions of the Middle Volga region, as well as in the Far Eastern regions of Russia. The obtained materials allow stating the presence of problematic issues in forestry. The solution of the problems depends on the priority tasks and the ways of solution.

The important problem of modern forestry is insufficient use of forest resources [5]. The determination of all forest resources and forest accounting is the primary task of forestry. The presence of so-called “newly emerged forests” has been noted in recent decades in the Republic of Tatarstan, other regions of Russia and several neighboring countries. Forest vegetation is actively distributed in areas emerging from commercial use. Significant forest resources are formed on such sites, suitable for forestry and the implementation of various environmental programs.

The mass destruction of forest biota puts on the agenda the tasks of anthropogenic regulation of processes occurring in the biosphere. Forestry will fulfill its purpose if it maintains the sustainability of forest biota, as the most important biosphere component in forest regions. For this purpose, it is necessary to determine forest resources formed both on unused lands and on areas specially designated for protective afforestation. Tatarstan is one of the few regions of Russia where various protective forest belts are created massively along roads, along the banks of water bodies and near gullies [6]. The organization of forestry in such areas is advisable from an economic and environmental point of view.

The authors identified unaccounted forest communities with appropriate resources in hundreds of sites only in the outskirts of Kazan and the adjacent territories of Prigorodny, Zelenodolsky,
Laishevsky forestries of the Ministry of Forestry of the Republic of Tatarstan. For example, figures 1 and 2 show and compare the fragments of the plan of afforestation (figure 1) and a satellite image (figure 2) of one site. The site covers the parts of forest blocks No. 101, 102, 103 of Laishevsky local forestry.

The leftmost forest on the site (beyond the river channel) refers to forest block No. 102, the rightmost forest (overgrown gulley) refers to section No. 101, in the center and slightly to the left two forest tracts belonging to section No. 103. The entire territory of the site between the forest massifs of blocks No. 101 and No. 103 are occupied by young self-seeding pine. This young forest is clearly visible in the satellite image (figure 2), and on the plan of afforestation (figure 1) we marked it as the largest stand in the center of the site.

In the winter satellite image (figure 3) obtained in the vicinity of the Bogatye Saby town settlement, against the background of the snow cover, all available forest stands are decoded very contrastingly. Due to the absence of interference from other (non-forest) vegetation cover, the winter image clearly displays the relief structure, road network, and settlements.
In the winter image (figure 3), the forest massif related to the forest fund and the areas of forest vegetation not included in the forest fund and requiring registration, are clearly distinguished. These are numerous forest belts created for protective afforestation and the forest vegetation that has arisen by natural overgrowing of ravine plantations and other unused lands. In the spring image (figure 4), which is a color-synthesized image of the 1st, 2nd and 3rd spectral zones of Terra-ASTER, protective forest stands, forest fund, ravines overgrown with forest vegetation, meadows and agricultural lands are well distinguished. The forest area is displayed on the left side of the picture in dark red. Farmland stands out on the picture along clear, straight-line borders and has various shades of red and green, depending on the crops sown and the state of crops.

The accounting and determination of forest resources will allow organizing their full use, for example, it will significantly (3-5%) increase the forest cover of the Republic of Tatarstan. The accounting and inventory of all forest resources can be quickly and efficiently performed by specialized units of the Federal Forestry Agency of Russia, in particular, the Kazan branch of the state budget institution of Federal forestry agency of the Russian Federation.
The identification of all areas covered by forest vegetation forms the basis of the so-called “contour decoding” of satellite images [7]. The technical features of the contour decoding of images are well known to specialists with experience in the forestry system. With the absence of such experience, the quality of work decreases significantly.

The use of aerial photographs and then satellite images in the arrangement of Russian forests has become mandatory since the mid-twentieth century. Along with “contour decoding” in forestry, experience has been gained in “afforestation inspection (assessment) decoding” of spectrozonal images. Remote sensing technologies for forests make it possible to assess the dynamics of forests and distinguish between primary and secondary forests.

Almost all modern forests in developed regions are secondary or derivative. Virgin, primary and conditionally primary forests that are in the center of attention of forest scientists disappear and lose their economic significance. Regulatory documentation needs to be adapted to the current state of forests. In regions with weak forest disturbance, “typical” succession series culminating in restoration of primary forests are described [5]. For the developed regions, the massive destruction of forest biota changes the ratio of biotic and abiotic factors interacting in the processes of environment formation and the formation of forest conditions [8].

The stabilization of the current state of forest biota allows determining the so-called “sustainable production” of forests. “Sustainable” forest productivity is close to the so-called “irreversible” production. Reforestation processes under the prevailing conditions do not provide restoration of native vegetation, and restoration successions in stably derivative forests are incomplete. The maps of the restored vegetation make it possible to compare primary and modern forests, derivative forests and the incomplete successions observed in the derivative forests clearly need to be compared to the “typical” successions typical of stable, successfully restored forests [5].

Degradation of oak forests are gradually replaced by secondary linden forests under the conditions of the Republic of Tatarstan. In the structure of the forest fund of Tatarstan, about 58% of the area is occupied by birch, aspen and linden forests, up to 25% are occupied by coniferous forests and 17% are occupied by oak forests (figure 5). The region belongs to the well-developed one. Forest cover here has decreased from 54% to 17% over the past two centuries, primary forests have been preserved fragmentarily and modern trends in forest dynamics have not been studied enough.

Local birch forests, aspen forests and most of lime forests belong to secondary forests of varying degrees of productivity. 80% of coniferous forests are of artificial origin, often created in inappropriate forest conditions and therefore unstable. 34% of oak forests are low-stemmed, have low quality wood, and often degrade in plantings. Under the conditions of “global forest devastation,” deciduous species receive certain advantages, which, when growing, inhibit growth indicators and lead to the subsequent death of plantings of valuable species - oak, pine and spruce.

![Forest Fund Allocation Republic of Tatarstan (as of January 1, 2018)](image)

**Figure 5.** Ratio of the area of oak forests (17%), other deciduous (58%) and coniferous (25%) species growing in the forests of the Republic of Tatarstan.
The determination of the state of primary and secondary - derivative forests, the assessment of forests by their origin and sustainability, the success of reforestation processes, and other indicators of their dynamics, are fully consistent with the objectives of modern forest management. The methods of decoding satellite images used in forest management allow proceeding to assess the main trends in forest dynamics. Decoding afforestation inspection (and state forest inventory) involves a combination of remote and ground (enumeration) methods for the assessment of forests. The effectiveness of the use of earth remote sensing methods, the latest equipment and technologies to a large extent depends on the purposes, tasks and skills of performers. The assessment of the state of forest biota in regional fragments of the biosphere, the identification of the degree of productivity of forest communities, the determination of the success (completeness) of restoration successions in modern forests can be performed only by specialists in forestry and forest science who have received the necessary experience in Lesproekt and the branches of Federal forestry agency of the Russian Federation. The assessment of the trends in the dynamics of modern forests requires the understanding of the basics of “biogeocenotic” [2, 3], “dynamic”, geographic and genetic” [4, 5] typology of the forest and knowledge of the patterns of functioning of various bio-geo-systems [8-10].

4. Conclusion
Earth remote sensing, including the decoding of satellite images performed during forest management, allows determining almost all forest communities and increasing the efficiency of the use of available forest resources. The mass destruction of forest biota in the developed regions, as well as the widespread change of primary forests to derivatives, increases the significance of the accounting results of the remnants of this biota and assessing trends in its dynamics.

The destruction of the balance of biotic and abiotic factors involved in environment-forming processes affects forest growing conditions and ultimately affects forest formation processes. Under the prevailing conditions, the productivity of emerging forests is becoming sustainable. Long-term and stable forest productivity in the developed regions can be established on the basis of the results of satellite images decoding. The existing system of forest management institutions allows determining modern forest resources with the assessment of the state of forests by the degree of their productivity. The assessment of forest dynamics trends using remote sensing methods will make it possible to predict the prospects for natural forest restoration, and increase the efficiency of designing measures for forest reproduction.

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