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Above-Ground Biomass and Greenhouse Gas Emissions Using Lidar Survey

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Abstract. Space images from the Sentinel-2 satellite are a wide database for studying various attributes of large forest areas. One of these indicators is the aboveground biomass, which is related not only to the state and development of forests, but also to the accounting for carbon in them. To estimate the dynamics of the aboveground biomass, simultaneously with the method of field studies, methods in the field of remote sensing of the Earth were used. The study addresses the issues of assessing the carbon balance of forest areas. The article presents research methods, assessment of resources of a forest area, above-ground biomass of a forest stand, calculated the carbon stock in the biomass of forest stands by age groups of predominant species, and also calculated carbon absorption by a biomass pool. The necessity of carrying out calculations of carbon pools using various methods has been identified and justified. It has been established that plantations with a predominant species of small-leaved linden (12244.85 t C) have the largest carbon reserve in the study area, which is 77% of the total reserve. Coniferous plantations make up less than 1%. The calculation of the stock for the prevailing species per 1 ha showed that the highest value is characteristic of forests with a predominance of aspen - 245.59 tons C / ha and small-leaved linden - 235.75 tons C / ha. In the context of the average annual absorption of carbon, plantings with a predominance of linden also dominate - 4.0 tons C/ha.

1 Introduction

Aboveground forest biomass (AGB) is an important element of the global carbon cycle [1]. Therefore, AGB monitoring and mapping are necessary to understand the carbon balance in forests, to solve scientific and practical problems in the field of sustainable forest management [2], to characterize the state and climate change [3], and to characterize forest biodiversity [4]. In the last two decades, studies based on a combination of field measurements with Landsat remote sensing data [5] have become widespread. The popularity of using Landsat to estimate forest biomass in combination with sample plots is facilitated by the fact that images have medium spatial (30 m × 30 m) and temporal (16 days) resolution and wide coverage [6]. Methods for estimating biomass using RS in

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various media and using various sounding methods are presented in scientific reviews by Russian and foreign scientists [7].

The purpose of the study is to test the methods for studying the carbon balance of these forest areas using D33 and GIS technologies, as well as to verify the data obtained with ground forest inventory studies. A sequence of procedures for processing a series of satellite images of various spatial resolutions for monitoring the forest cover has been completed. The validation and assessment of the classification accuracy of satellite images, the results obtained with independent data on the forest fund of the study area, was carried out. The object of the study is the forest area of the carbonic polygon, in which it is necessary to determine the carbon balance using D33 data and GIS technologies.

The objectives of the study are to assess the resources of a forest area (Ufimsky district of the Republic of Belarus) based on the integration of ground-based (field, cameral) forest inventory studies, Earth remote sensing methods (D33) and GIS technologies.

2 Research Methodology

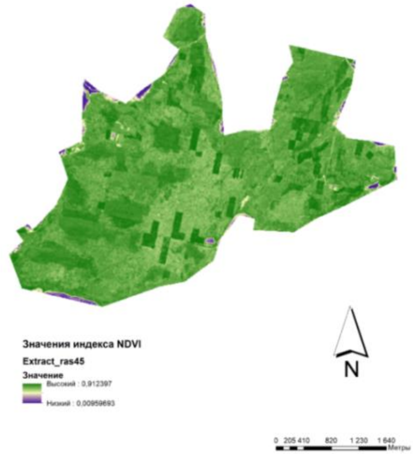
The study area is located within the Dmitrievsky district forestry of the Ufimskoe forestry, northwest of Ufa in the area of the village of Nachapkino between 54°46’ and 54°49’ north latitude and 55°43’ and 55°49’ east longitude. According to the forestry regulations of the Ufimsky forestry, the entire forest area under study belongs to forests located in the green zone.

The forests of the study area are even-aged secondary forests, which are the result of cuttings in the 20th century. The dominant types of vegetation in this forest area are plantations of small-leaved linden of the forest type group, its area was 432.7 ha (50.2% of the total area of land covered with forest vegetation). The assessment of biomass in the study area was carried out on trial plots in 2022. by integrating field research and remote sensing data. Sample plot data were integrated into pixel-based Earth remote sensing data from optical satellite images as sampling units from which spectral signatures can be easily extracted.

3 Results and Discussions

After pre-processing the images, the NDVI indices for 2021 were calculated for them using the Raster Calculator tool. The NDVI index values for 2021 ranged from 0.01 to 0.91. Images of NDVI indices are presented in fig. 1.

Using the method of field research on trial plots, average taxation indicators were calculated. Tree biomass is calculated using various biomass equations that are related to its biophysical variables such as diameter, height, etc. The biomass of each tree was calculated by calculating the exponential of various tree constants by adding and subtracting the natural logarithm of tree diameters. The coefficient of determination (R2) of the various models was obtained by correlating the aboveground biomass value and the diameter at chest height. The model that displayed the highest R2 value was used as the main model, and then this model was used to correlate the biomass value with different vegetation indices.



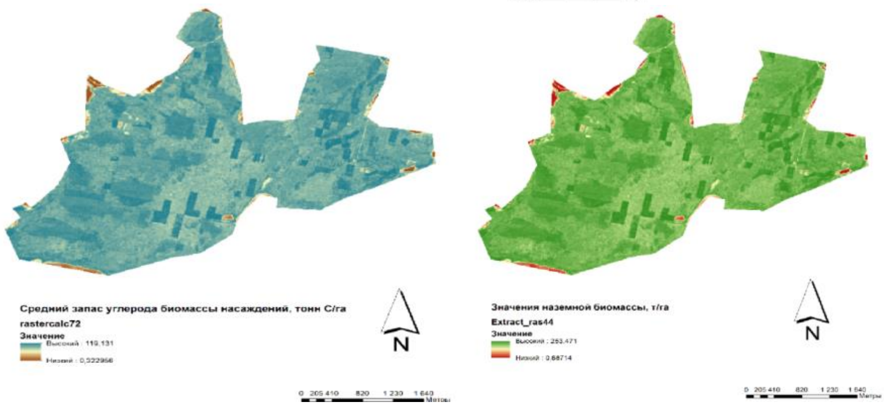


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Fig. 1. NDVI index

Fig. 2. Calculation of absorption, loss and budget of carbon according to the methodology of the Ministry of Natural Resources, approved by Order No. 20-r dated June 30, 2017 “On Approval of Guidelines for Quantitative Determination of the Volume of Greenhouse Gas Absorption. a) aboveground biomass values, b) average carbon stock values

The calculation of absorption, loss and budget of carbon by coniferous and deciduous forests was carried out according to the methodology of the Ministry of Natural Resources, approved by order of June 30, 2017 [8]. Depending on the age groups of plantations, the conversion coefficients used in determining the carbon stock were adopted in accordance with Appendix 2 (Table 14) of the guidelines for quantifying the amount of greenhouse gas absorption.

The efficiency of forest plantations performing ecological functions is largely determined by the amount of carbon sequestration, which depends on the species representation of plantations, age structure, forest area and tree productivity.

According to the above guidelines, we calculated: the carbon stock in the biomass of forest stands by age groups and predominant species, carbon absorption (Tables 1-4). Depending on the age groups of plantations, the conversion factors used in determining the carbon stock are taken in accordance with the guidelines for quantifying the volume of greenhouse gas absorption.

Table 1. Carbon stock in forest stand biomass, t C

Woody look	Stock of carbon in biomass of forest stands, t C						
	Juveniles of the 1st class	Juveniles 2nd class	Middle Age	Ripe-up	Ripe	Overmature	Total

Larch	-	-	150,48	-	-	-	150,48
Ash	-	-	62,01	-	-	-	62,01
Birch	-	-	1322,76	-	372,69	143,91	1839,36
Aspen	-	-	-	43,55	40,15	1547,6	1631,3
Linden	3,81	270,51	1034,88	-	242,64	10693,01	12244,85
	3,81	270,51	2570,13	43,55	655,48	12384,52	15928

Table 2. Average stock of carbon in planting biomass, tons C/ha

Woody look	Average stock of carbon in planting biomass, tons C/ha						
	Juveniles 1st class	Juveniles 2nd class	Middle Age	Ripe-up	Ripe	Overmature	Total
Larch	-	-	125,4	-	-	-	125,4
Ash	-	-	88,58571	-	-	-	88,58571
Birch	-	-	60,4	-	79,29574	62,56957	202,2653
Aspen	-	-	-	87,1	66,91667	91,57396	245,5906
Linden	4,233333	21,46905	50,97931	-	63,85263	95,21825	235,7526
	4,233333	21,46905	325,365	87,1	210,065	249,3618	897,5942

Table 3. Average annual carbon removal, tons C/ha per year

Woody look	Average annual carbon removal, tons C/ha per year				
	Juveniles 1st class	Middle Age	Ripe-up	Ripe	Total
Birch	-	-	-	2,225037	2,225037
Aspen	-	-	2,230556	-0,05635	2,17421
Linden	1,845461	-0,71563	-	2,912562	4,042388
	1,845461	-0,71563	2,230556	5,081253	8,441635

Table 4. Annual carbon removal, tons C/year

Woody look	Average annual carbon removal, tons C/ha per year				
	Juveniles 2nd class	Middle Age	Ripe-up	Ripe	Total
Birch	-	-	-	10,45767	10,45767
Aspen	-	-	1,115278	-0,03381	1,081471
Linden	23,25281	-14,5274	-	11,06773	19,79316
	23,25281	-14,5274	1,115278	21,4916	31,3323

4 Conclusions

The performed calculation showed that the sections with the predominant rock of small-leaved linden (12244.85 t C) have the largest carbon reserve in the study area, which is 77% of the total reserve. Coniferous plantations make up less than 1%. The calculation of the stock for the prevailing species was carried out and it was found that plantations with a predominance of aspen (245.59 tons C/ha) and small-leaved linden (235.75 tons C/ha) are represented by the highest value. This indicates that these plantations are represented mainly by higher density plantations. In the context of the average annual absorption of carbon, it was also found that plantations with a predominance of linden (4.0 tons C/ha) are represented by the highest value. The analysis of Table 4 showed that the plantations with the predominant species of small-leaved linden (19.8 tons C/ta per year) have the highest average annual carbon absorption, which is 63% of the total annual carbon absorption.

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