Development of a methodology for calculating carbon units of heterogeneous territories based on machine learning

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***Abstract* — The paper describes a methodology for calculating carbon units of heterogeneous territories based on machine learning. The hierarchical structure of areal territories and the structure of the interconnection of of various scales images are described. The approach for identifying and classifying terrain objects for more accurately calculation of the carbon stock of the territory is presented.**

Keywords* — *carbon units, heterogeneous territories, segmentation, deep neural networks, machine learning, image processing

I. Introduction

According to the modern world climate agenda, enshrined in the Paris Agreement of 2015 [1], all countries participating in the agreement should strive to maintain the growth of the global average temperature, including by reducing carbon emissions. "Forest" countries, which include Russia, Brazil, Canada, have competitive advantages, since the costs on the part of the state are minimal in the process of absorption of greenhouse emissions by forest areas.

It should be noted that in the process of regulation of carbon markets, not only the state takes part, but also business representatives, participating in the implementation of climate projects. Such carbon markets are a legal, economic and technological tool for the implementation of transactions for the sale of carbon units (greenhouse gas emission units). In our country, at the moment, the market for carbon units is only in its infancy, the launch of which can be considered the start of work in 2022 of the register of carbon units [2]. As part of the reduction of greenhouse gas emissions, emissions from industries on the one hand and their absorption by vegetation on the other hand are considered. It is the second side of the issue that is of great interest as an opportunity to reduce emissions. Therefore, the question arises of correctly calculating the carbon balance of territories.

To date, there are a large number of methods for assessing the carbon balance of the territory [3-5]. Most of them are based on the compilation of mathematical models approximating data from point field studies, and partly using machine learning methods. Due to the complexity, high cost, and sometimes impossibility in hard-to-reach areas to collect indicators of the carbon balance of the territory by ground methods, a remote method is used. To do this, the territory is surveyed from satellites and unmanned systems, then analyzing data pixel-by-pixel in different channels [6]. The presented methods are mostly focused on the calculation of the carbon balance of forest areas and are based on accounting for the stock of large areas, without taking into account their heterogeneity. For a more accurate calculation, carbon polygons have now been created in Russia [7, 8]. On their basis, information is collected on the absorbing capacity of various types of vegetation as reference indicators, as well as the collection of remote data on the territory. The entire resulting data set is supposed to be analyzed using machine learning, but no developed calculation methods have yet been presented.

In this regard, the relevance of the study on the development of approaches for calculating the carbon balance of a heterogeneous territory based on the segmentation of homogeneous vegetation elements using deep neural networks is justified.

II. Methods

The developed methodology takes into account the specifics of calculating the stock of carbon units for heterogeneous territories, where the type of areal objects can be different: forest, swamp, tundra wasteland, littoral, meadow, and others.

In general, the method for calculating carbon units of heterogeneous territories based on machine learning consists of the following steps:

- obtaining detailed images from space vehicles and unmanned aerial vehicles (UAVs) of the territory to calculate the stock of carbon units;
- drawing the border of the territory on images for processing;
- identification of the boundaries of large areal objects on satellite images using deep neural networks;
- detection of the boundaries of objects of small areal objects inside large areal objects in UAV images using deep neural networks;
- calculation of carbon stock in biomass for each small areal object depending on the size of the occupied area and type of object using machine learning;
- Obtaining a general indicator of the carbon stock for the territory based on data on the hierarchy of objects of the territory.

To obtain the values of the carbon stock of the territory, it is proposed to calculate the indicator as the sum of the stocks of carbon units in homogeneous areas. All territories have varying degrees of heterogeneity and at different levels. In this method, the territory is considered as a hierarchical structure, where the root is the entire territory, at the second level there are large areal objects, such as forest, swamp, tundra wasteland, littoral, meadow and others, at the third level - homogeneous vegetation objects with uniform carbon stock over the entire area. To automate the selection of homogeneous objects and the calculation of the carbon stock, in accordance with the hierarchy of objects of the territory, a hierarchy of images (space and from UAVs) is built with varying degrees of detail (Figure 1). With the help of deep neural networks [9], homogeneous objects are identified in the images of the third level of the hierarchy, classified by the type of objects (Figure 2). The quality of the definition of homogeneous segments of vegetation by the model is equal to the value of Dice coefficient = 89% on the test sample.

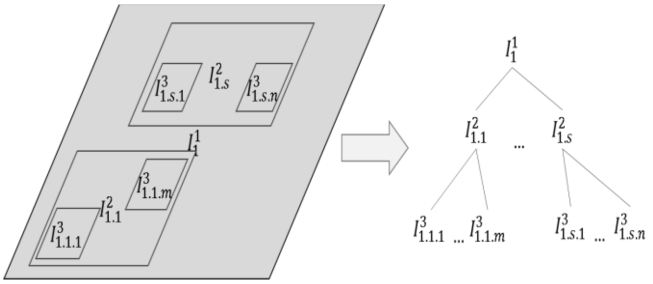

Fig . 1. Scheme of the hierarchy of images

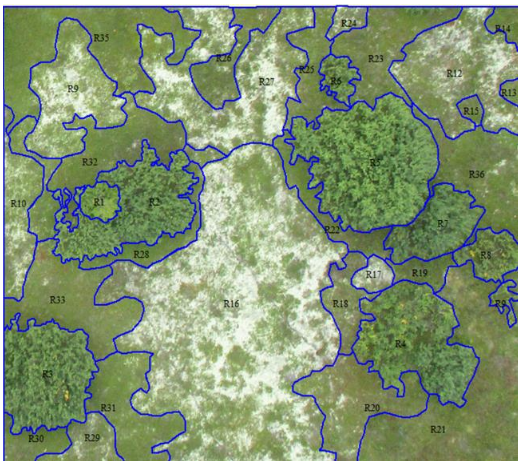

Fig. 2. The xample of identifying homogeneous objects in the area

Further calculation of the carbon balance of each allocated area of the territory will be determined on the basis of reference field data of vegetation objects with a known carbon stock using a machine learning model. We can talk about the degree of accuracy in determining the carbon stock of a homogeneous area comparable to the degree of accuracy in identifying segments. The indicator of the stock of carbon units of the entire heterogeneous territory is calculated as the sum of all stocks of homogeneous territories.

III. RESULTS

Developed methodology Calculation of carbon units of heterogeneous territories based on machine learning makes it possible to take into account not only forest areas, which makes calculations more accurate. In addition, this approach will provide the following new features:

- allow protected areas (reserves, national parks and others) to calculate the stock of carbon units that can be sold to enterprises that harm the environment;
- this will also be in demand for hard-to-reach and uninhabited territories of Russia;
- it will be possible to estimate the carbon stock of the Arctic zone of the Russian Federation (the surface part), traditionally represented by a non-forest area with a long littoral zone.

Acknowledgment

This work was supported by the Russian Science Foundation and government of the Government Arkhangelsk region under grant No. 22-11-20025.

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