DOI: 10.22449/2413-5577-2022-3-93-103

Identification of the Species Composition of Tree and Shrub Vegetation according to Airborne Laser Scanning Data of the Anapa Bay-Bar (Black Sea)

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Abstract
The article aims at testing a method for automatic identification of vegetation by species composition according to airborne laser scanning data with automatic determination of geometric attribute data. The article discusses the relationship between the geometric parameters of tree and shrub vegetation and its species composition. Accurate identification of the correlation of parameters allows automating the selection of species composition. This simplifies the process of inventorying vegetation by species composition on the territory. The work was based on the method of automatic identification of vegetation according to airborne laser scanning data with automatic determination of geometric attribute data. An area located on the Anapa Bay-Bar was chosen as a testing ground for the method of automatic identification of vegetation by species composition. During the work, field measurements and field interpretation of aerial photography data were carried out. The data from machine processing and field measurements were compared, the correlation indicators between the species composition and the geometric attribute data of vegetation were calculated. Based on the correlation values, verifying coefficients of the species are proposed. In addition, during the work, the error that occurs during automatic processing of airborne laser scanning data was calculated, quantitative indicators of vegetation by species composition were calculated, and average values of vegetation heights by species on the territory of the Anapa Bay-Bar were determined.

Keywords: laser scanning, Anapa Bay-Bar, automation, vegetation

Acknowledgements: this work was funded by the Russian Science Foundation under project no. 20-17-00060 “The modern stage of the evolution of sandy accumulative forms of the Azov-Black Sea coast of Russia”.

For citation: Karagyan, A.V. and Krylenko, S.V., 2022. Identification of the Species Composition of Tree and Shrub Vegetation according to Airborne Laser Scanning Data of the Anapa Bay-Bar (Black Sea). *Ecological Safety of Coastal and Shelf Zones of Sea*, (3), pp. 93–103. doi:10.22449/2413-5577-2022-3-93-103

Выделение породного состава древесно-кустарниковой растительности по данным воздушного лазерного сканирования на примере Анапской пересыпи (Черное море)

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Аннотация
Цель работы – тестирование методики выделения растительности по породному составу по данным воздушного лазерного сканирования с автоматическим определением геометрических атрибутивных данных. В статье рассматривается взаимосвязь между геометрическими параметрами древесно-кустарниковой растительности и ее породным составом. Точность идентификации корреляции параметров позволяет автоматизировать выделение породного состава. Тем самым упрощается процесс инвентаризации растительности по породному составу на территории. В качестве полигона для отработки методики выбрана территория, расположенная на Анапской пересыпи. В процессе работы были проведены натурные измерения и полевая дешифровка данных аэрофотосъемки. Были сопоставлены данные машинной обработки и полевых измерений, рассчитаны показатели корреляции между породным составом и геометрическими атрибутивными данными растительности. На основе значений корреляции предложены удостоверяющие коэффициенты породы. Помимо этого, в процессе работы была рассчитана ошибка, возникающая при автоматической обработке данных воздушного лазерного сканирования, определены количественные показатели растительности по породному составу, определены средние значения высот растительности по породам на территории Анапской пересыпи.

Ключевые слова: лазерное сканирование, Анапская пересыпь, автоматизация, растительность

Благодарности: работа выполнена при финансовой поддержке РНФ в рамках проекта № 20-17-00060 «Современный этап эволюции песчаных аккумулятивных форм Азово-Черноморского побережья России».

Для цитирования: *Карагян А. В., Крыленко С. В.* Выделение породного состава древесно-кустарниковой растительности по данным воздушного лазерного сканирования на примере Анапской пересыпи (Черное море) // Экологическая безопасность прибрежной и шельфовой зон моря. 2022. № 3. С. 93–103. doi:10.22449/2413-5577-2022-3-93-103

Introduction

Within the framework of complex studies of the Anapa Bay-Bar geosystem, it became necessary to develop a method for modeling the vegetation of the area under examination.

At the present stage of science and forestry development, laser scanning is widely used to determine various parameters of forest areas. Laser scanning makes it possible to determine the relief of the subsoil, the height and quality of the forest stand. Such methods will acquire great practical importance in the future.

However, these methods have been mainly developed for compact forest areas with the same-type forest stand. They are with little to no affiliation with the studies of sparse vegetation, especially maritime one.

The relevance of this work is due to the poor adaptation of laser scanning methods for automatic determination of the species in sparse non-uniform areas specific to the Black Sea coast [1].

The vegetation model of the Anapa Bay-Bar was formed on the basis of airborne laser scanning data, while it was not limited to a three-dimensional scene or a flat map [2]. The model included the localization of vegetation with the necessary attribute data. In the course of the study, an inventory map of the vegetation of the Anapa Bay-Bar was compiled, but it is not informative from the point of view of establishing the species of a shrub or a tree. For our purpose, vegetation was identified according to the height. Plants that did not exceed 1.5 m were classified as shrubs and those exceeded were classified as trees [3]. Further studies have shown that such identification results in an error [4]. This error does not play a major role, but it affects the accuracy of the received maps and data. Using the method of automatic vegetation identification [5] according to laser scanning data, it is possible to receive rather accurate attribute data consisting of the parameters of the height and radius of the crown projective cover. Having such data and knowing the relationship among them, it is possible to determine the species composition automatically, backing it up with mathematical justification and field observations. In this regard, the purpose of this work is to test the method for the automatic identification of the type of vegetation based on laser scanning data.

Materials and methods

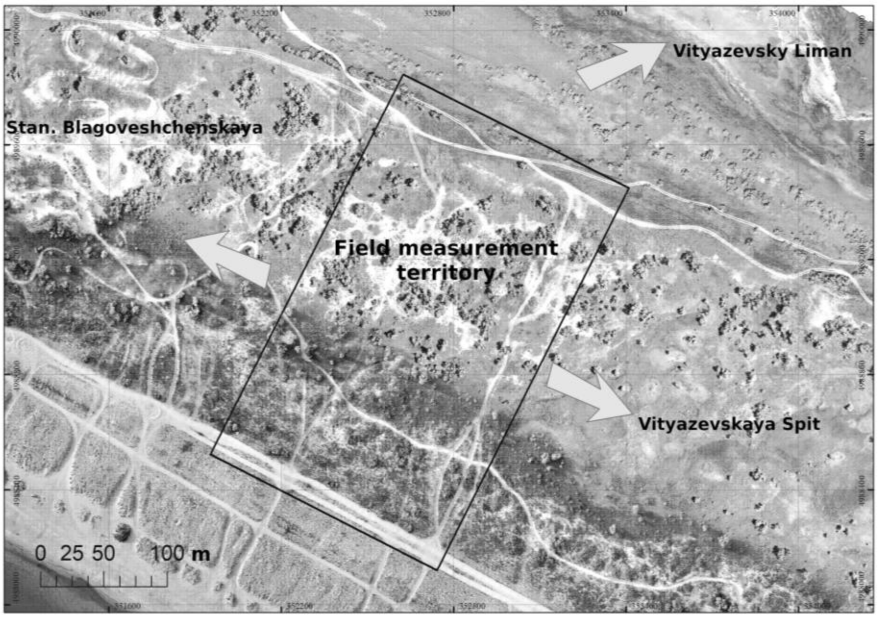
Airborne laser scanning of the territory of the Anapa Bay-Bar was carried out in 2013–2015. To test the method for the automatic identification of the species of tree vegetation, the most typical area for the Anapa Bay-Bar was chosen, which was dominated by such species of tree vegetation as *Elaeagnus angustifolia L.* and *Tamarix ramosissima* Ledeb. [6]. Based on the allometric correlation between the parameters and the species of vegetation, with the exact identification of a tree and a shrub, it is possible to trace the relationship between their location and various geological processes directly in the vegetation area.

Field data included the results of field measurements of parameters and identification of vegetation species in the study area, which is located in the central part of the Vityazevskaya Bay-Bar to the east of the coastal buildings of the stanitsa of Blagoveshchenskaya (Fig. 1). The area of the territory where field work was carried out made more than 1 km^2. With the help of a caliper and a tape-line, the values of the trunk circumference were determined for further comparison within the sample.

The identification of vegetation was carried out in the *ENVI LiDAR* software environment via the built-in algorithm for automatic vegetation detection. The algorithm selects those points from the point cloud that correspond to the established sample and to the height parameter specified by the user [7]. Height parameters used to determine the vegetation are as follows:

– from 1.5 to 8 m for *Elaeagnus angustifolia L.*;

– from 0.5 to 3 m for *Tamarix ramosissima* Ledeb.



F i g . 1 . Territory of field measurements and observations

It should be noted that [8] gives the description of the vegetation growing on the territory of the Anapa Bay-Bar, which shows that the maximum height of *Elaeagnus angustifolia L.* makes 3–4 m. However, the field studies showed different result for this area with the average tree height of 5 m.

As a result of machine analysis of laser scanning points and field measurements of vegetation in the pattern, the material was collected to compare and evaluate parameters the relationship between vegetation species. The value of the trunk circumference became the key parameter, on the basis of which the species coefficient was calculated.

While establishing the most influential relationships, the correlation was calculated using the Spearman formula [9]:

$$\rho = 1 - \frac{6}{n(n-1)(n+1)} \sum_{i=1}^{n} (R_i - S_i)^2, \quad (1)$$

where R_i – rank of observation x_i in row x; S_i – rank of observation y_i in row y.

The coefficient takes values between –1 and 1. Equation $\rho = 1$ indicates strict direct linear relationship, $\rho = -1$ indicates inverse relationship [9].

Attribute data resulting from automatic vegetation identification were exported in a tabulated form. It is important to note that the results of field measurements are also included in the attribute table. Thus, a statistical series of data with a representative sample was obtained. The sample consisted of 65 units of vegetation with measured trunk circumference, and the total amount of trees and shrubs made 225 units, including the sample.

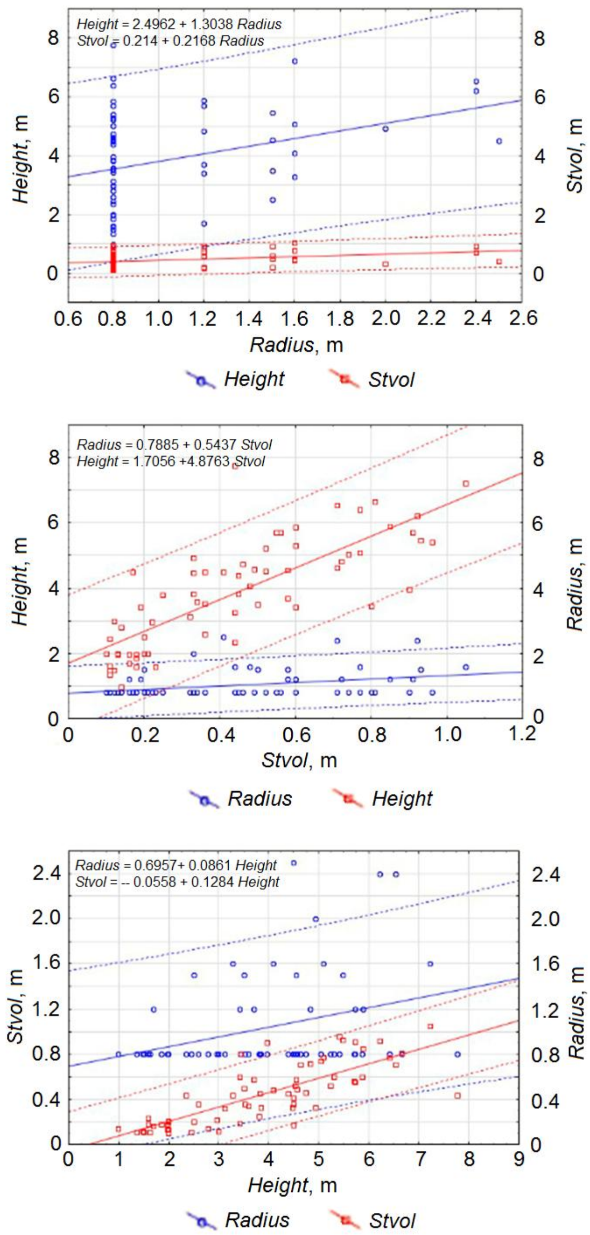


Fig. 2. Graphs of the correlation of vegetation parameters

Attribute data were processed using the *Statistic* 10.8 software. As a result, a clear picture of the relationship of vegetation allometric parameters was obtained. The correlation was calculated for the parameters of vegetation morphometry, namely: trunk circumference, projective cover radius, and vegetation height (on the graphs *Stvol*, *Radius*, *Height* respectively) (Fig. 2).

The graphs in Fig. 2 show the relationship between plant height and trunk circumference. Fig. 3 shows the initial parameters of vegetation in the form of a table of correlation indicators.

Analysis of the data in the table presented in Fig. 3 showed that there was a high correlation coefficient (0.82) between trunk circumference and height. This suggests that there is a direct relationship between these parameters. Based on this, an effort was made to calculate the individual coefficient of the plant.

The calculation was carried out empirically, as a result of which the following formula turned out to be the most accurate: $(h \cdot l_{trunk})/r$, where h – height, l – trunk circumference, r – radius of crown projective cover. The coefficients varied significantly. Thus, the average coefficient of *Elaeagnus angustifolia L.* species made 2.62, and that of *Tamarix ramosissima* Ledeb. made 0.34.

Pair of Variables	Spearman Rank Order Correlations (treedata in treedata) MD pairwise deleted Marked correlations are significant at p <.05000			
	Valid N	Spearman R	t(N-2)	p-value
Height & Height				
Height & Radius	66	0.309924	2.60779	0.011328
Height & stvol	66	0.826275	11.73549	0.000000
Radius & Height	66	0.309924	2.60779	0.011328
Radius & Radius				
Radius & stvol	66	0.374145	3.22758	0.001970
stvol & Height	66	0.826275	11.73549	0.000000
stvol & Radius	66	0.374145	3.22758	0.001970
stvol & stvol				

F i g . 3 . Example of presentation of correlation parameters in *Statistic* 10.8 software

However, a problem arose during the modeling. If in the standard classification shrubs were conventionally distinguished exclusively by height, in this case field studies showed that the height of an individual shrub could be higher than assumed 1.5 m, but could not reach 3 m. This difficulty was overcome by distributing the species according to the values of the trunk circumference, in addition to the coefficient. Field studies showed that even at the maximum height of *Tamarix ramosissima* Ledeb. its trunk circumference was no more than 0.2 m. This helped resolve the problem of two species falling into the same category [10].

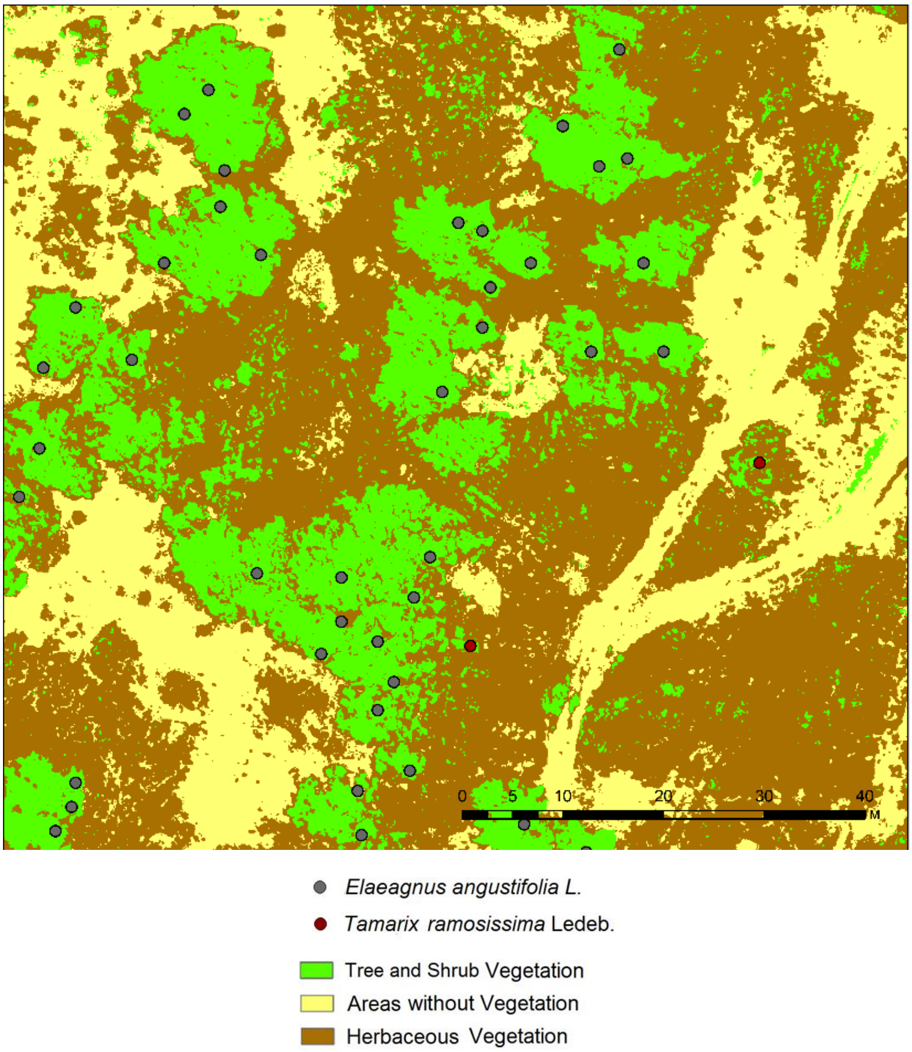
The next step was laboratory interpretation [11]. To calculate the error, it is necessary to accurately represent how many units of vegetation are determined incorrectly. Error calculation was performed manually [12]. The analysis showed that during the automatic identification of species, out of 2,559 vegetation units, 230 units were erroneously attributed, which made approximately 9 %. Therefore, it can be argued that this method makes it possible to automatically identify the species composition of tree and shrub vegetation with an accuracy of 91 %.

In addition, an analysis was made concerning the correspondence of the obtained *shape*-file with the vegetation index in order to eliminate the initial error in the model formation [13]. No inconsistencies were identified. Thus, the error values were established.

Results

Based on the proposed method of automatic identification of vegetation by species composition according to laser scanning data, a map of the study testing area was plotted. Areas with tree and shrub vegetation, with herbaceous vegetation and areas without vegetation were identified.

Fig. 4 shows a fragment of the study testing area. The identified areas are shown on the map. The territory without vegetation mainly includes soils or sands that cover the bay-bar.



F i g . 4 . Vegetation and areas of the study testing area

Fig. 5 shows the location of the points that display the geodetic center of the projection of vegetation according to the species composition of tree and shrub vegetation, which is determined by the method of correlation coefficients obtained as a result of this work [1)].

Based on the results of the image interpretation, it was found that the developed algorithm, built into *ENVI LiDAR*, determined 2,239 units of vegetation, of which 95 % were identified by the program as *Elaeagnus angustifolia L.* The remaining 5 % were identified as *Tamarix ramosissima* Ledeb. However, it should be noted that the data require additional verification [14].

[1)] Berlyant, A.M., 2002. [*Cartography. College textbook*]. Moscow: Aspekt Press, 336 p. (in Russian).

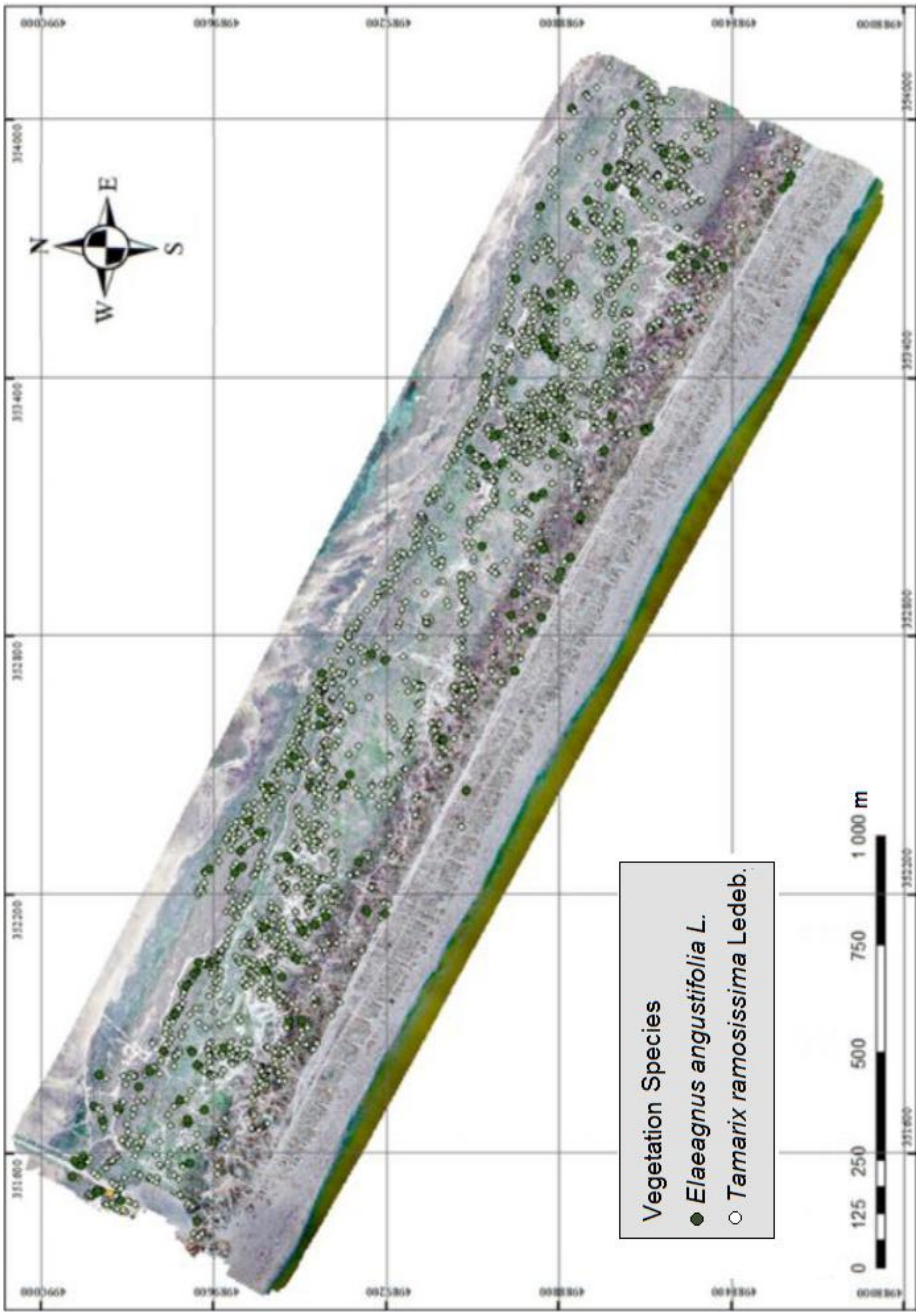


Fig. 5. Map of the study area with vegetation points

In the work, the average values of vegetation parameters were reliably determined for the study area. It was established that the average height of *Tamarix ramosissima* Ledeb. made 1.75 m, and that of *Elaeagnus angustifolia L.* made exactly 5 m. The total vegetation coverage space in the study area makes 20,351 m^2 with the space of the study testing area of 2.17 km^2 (2,170,000 m^2). This suggests that the territory covered with tree and shrub vegetation occupies only 1 % of the total study area, where *Elaeagnus angustifolia L.* prevails.

The Anapa Bay-Bar is a unique geosystem protected by the state, in the formation of which the local vegetation plays an important role. It is an indicator of various geological, soil and biological processes. The use of the method of automatic vegetation and species identification by key parameters showed that it was possible to identify vegetation with the attribute data acquisition. However, it is not known how the sample size and differentiation of the species composition will affect the algorithm. With small sample sizes, this method is useful, but with large amounts of data, accuracy can be lost.

Conclusion

1. A method to identify vegetation by species composition with its automatic determination from airborne laser scanning data was tested.

2. The individual coefficients of vegetation species were determined.

3. Maps of vegetation species and vegetation index correspondence were plotted.

4. It was established that *Elaeagnus angustifolia L.* prevailed on the territory.

5. It was established that the territory occupied by tree and shrub vegetation made 1 % of the total area.

The advantage of the method of automatic identification of the species composition of vegetation according to laser scanning data is in the speed and accuracy of such work. Owing to the automatic method of vegetation identification, it becomes possible to use attribute static data to obtain a correlation between parameters. As a result, the tasks set were solved and the necessary indicators were obtained for the automatic identification of vegetation by species composition.

Thus, it may be concluded that laser scanning as a method for obtaining spatial information is useful not only for building digital terrain models, but also in such specific areas as geomatics, dendrology, biology, and botany.

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Submitted 20.12.2021; accepted after review 28.05.2022;
revised 6.07.2022; published 26.09.2022

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Arsen V. Karagyan – task statement, data processing, coefficient calculation, model development, field observations and measurements

Sergey V. Krylenko – field observations and measurements, field interpretation of tree species, parameter description for model development

All the authors have read and approved the final manuscript.