Problems of identification in information systems

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METHOD OF IDENTIFICATION OF TREE SPECIES COMPOSITION OF FORESTS ON THE BASIS OF GEOGRAPHIC INFORMATION DATABASE

Abstract. Monitoring of the forests with the help of remote sensing of the Earth systems is actual on the present stage of people development. Existing systems of research do not allow to use geographic information databases and don't include the spectrum of exploration that are presented in our work. The aim of this article is to develop the method of identification of tree species composition of forests on the basis of geographic information database in the integration with correlation analysis. It will give the possibility to find the most negative things that influence on the condition of forest ecosystems and neutralize them at the first stage of their influence. Satellite images that are received from the satellites Landsat 5 and 8 are used to make the database. Tree species composition of Mozhariv forest during 20 years is analyzed as an example in this article. Classification of tree species composition of forests using space images is made on the basis of Bayes classifier. There is a special geographic information database for further data processing and identification of tree species composition is developed. Forest is analyzed on the number of trees in each species during continuous time measures (in 2000, 2010 and 2020) in this article. Results of the work are presented with the help of graphics. Correlation analysis, which helps to make the analysis of tightness of connections between changes trees in number and different forest criteria, is made to identify tree species composition of forest. Developed method together with well-known methods of monitoring of forests help us to make effective application for analysis of tree species composition of forest changes and to make better existing information systems including different quality demands. Peculiarity of developed information system is in using of the data processing module as a part of geographic information system and implementing correlation analysis with identification of factors that influence each other. It helps to increase quality in management and monitoring of forest resources. Geographic information becomes available for users.

Keywords: space images; geographic information database; Bayes classifier; tree species composition; correlation analysis.

Introduction

Fast development of means of remote sensing of the Earth systems and availability of data processing contribute to the need of making the methods of forest analysis better. Space imagery and forest inventory are used to identify tree species composition of forests. Increasing amount of satellites that make constant space imagery helps us to identify changes in forests.

Modern satellite systems help us to get multiple images of the Earth surface with high resolution and find their usage in marine objects studies, forests, harvest control and prediction, disaster monitoring, climate identification, etc. Operational thematic mapping of surface on big territories is possible only with the help of remote sensing of the Earth technology. It is needed to create effective methods of image analysis with their further interpretation (classification of images, identification of different objects on the Earth) because of their unprocessed condition in space imagery.

Forests are main components of global ecosystem. Research of their deposits and dynamics is needed to evaluate the condition ecosystems are in, changes in carbon-dioxide and greenhouse gases, potential of resources. Forest fires are big problem nowadays. They are unpredictable and have high potential of destroying. A lot of forests are dying as a result of forest fires. Unauthorised deforestation is also a big problem. Destruction of forests has negative influence on the atmosphere condition. Temperature increasing, soil erosion, devastated water circulation and changes of forest biota are the results of forest destruction.

Out of date possibilities of calculation and forest mapping, small amount of mapping data about the condition of forests are main problems in forests nowadays. One of the conditions of geographic landscape information presentation is geographic information database (GID) that can help to show the condition of the studied territory. That's why complex of works in remote sensing of the Earth and informational parts with specific applications are needed to monitor changes of forests over time.

Analysis of latest researches and publications. Analysis of latest researches and publications shows that scientists all over the world make their researches in the field of image analysis to do practical tasks not only in the sphere of information technology, but in the sphere of forestry and agriculture [1-6].

Authors of the works [7-8] use methods and instruments of remote sensing of the Earth database analysis in their researches to find out changes of plants that have been made under the influence of industrial waste.

Decoding of satellite imagery for calculation of different tree species are shown in the articles [9-10]. Distant methods development of getting information about natural processes is made because of the need of forest monitoring that occupy huge territories and environmental processes that originate during forests exploitation.

The results of modelling of components of biomass of main tree species that form forests and carbon-dioxide deposit in them are shown in the article [11]. A big digital multilayered map and geographic identification analysis of carbon-dioxide deposits of forests are made. Instruments for analysis of emissions and greenhouse gas absorption in forestry, for forest digital map construction and evaluation of carbon-dioxide deposit according to the statistical data of forest deposits, tree species, dividing into classes of ages and using other forest inventory data are made.

Summarizing of all experience of forest analysis in Ukraine with the help of satellite imagery is made by the author [12]. It is studied that our researches use multi-zonal images that are made mostly with the space satellites SPOT and Landsat to account changes of forest area, finding out types of forests, their tree species composition and age at the regional level preferably.

Satellite systems opened huge possibilities in providing reliability, efficiency and periodicity of measurements related to the study of forest conditions and dynamics of its changes. The authors built digital plant maps according to normalized vegetation index using the K-means method to monitor the dynamics of vegetation changes over 20 years in their work [13]. The authors consider the need to use geographic information system and remote sensing of the Earth data for forest monitoring in their work [14]. Visualization method of the normalized vegetation index NDVI is used to increase mobility and efficiency of monitoring.

Monitoring of forest ecosystems can also be carried out with the help of software and hardware complexes based on unmanned aerial vehicles (UAVs). Article [15] demonstrates the great potential of high-resolution UAV data and photogrammetric methods that allow collecting multispectral images and making estimates of various vegetation indexes. The main limitation of this approach is the lack of ground-based radiometric measurements, which could give a better quantitative picture of the ground situation. Monitoring was carried out only within the field of agriculture.

The authors of the work [16] emphasize the fact that modern global trends in state forest management require development in the sphere of using modern geographic information systems. At the same time, it is noted that the creation of GID requires significant physical and financial costs. It is important to ensure the possibility of authorized access to information. Creation of a convenient and accessible GID is needed.

A number of computer platforms for analysis and visualization of natural plant changes in forest areas were also studied: InciWeb, Earth Observing System, WorldView, ClearCut [17–22].

The conducted analysis shows that existing systems do not have the functionality to detect dependencies between the remote sensing of the Earth data and forestry indicators, as well as to identify the changes of forests in time over several decades.

The purpose of this work is to develop a method for identification of tree species composition of forests on the basis of a geographic information database in integration with correlation analysis. This will make it possible to identify the most negative factors affecting the condition of forest ecosystems and to neutralize them at the initial stage of their influence.

Main part

With the help of modern information technologies, the necessary web applications are created for effective forest management which include monitoring changes and forest resources analyzing. The vast majority of work was previously carried out manually, the control of qualitative and quantitative changes in forests and the territories adjacent to them was carried out with help of passing by large areas. As a result, the development and implementation of new software and information systems is an urgent task.

Modern information technologies tend to constant changes, so there is no universal product with functionality that would satisfy all the needs of users at this stage. The main requirement is to adapt to the specific requirements of users according to their profile. Therefore, it was decided to implement the basic functionality, which will be used by everyone and can be expanded in the future.

Space images of forestry obtained by the Landsat 5 and 8 satellite programs during 2000-2020 on the territory of Mozhariv Forestry are used to analyze forests. The picture is downloaded from the open electronic resource http://earthexplorer.usgs.gov/.

Free cross-platform geographic information system QGIS was used for classification of satellite images - this is an additional software that stores many geographic information software products. The platform provides ready-made elements familiar to the user for displaying text, images, tables, lists and buttons. A significant benefit is the ability to reuse code between applications on the platform with the help of controlling and displaying elements that adapt to their context and presentation.

In order to further classification and identification of images, it is necessary to create a geographic information database (GID) as a fundamental basis. Raster thematic maps of forest quarters and forest divisions of the Mozhariv Forestry, created on the basis of topographic maps on a scale of 1: 50,000, were used to create the GID. Identification is the main classification unit for the separation of forests according to their functional and qualitative characteristics. The administrative map of Ukraine 1:200,000 with a specific area and corresponding space images of this area is also needed to work with GID. Input data that will be stored in the database must correspond to a certain format: class number, class name, number of trees in the selected area.

The classification of tree species composition of the forest is one of the components of the mapping process, which consists in the computer verification of the images, which is ensured by the systematic distribution of all pixels of the image into groups related to different objects. A certain functionality is created to implement the task, which provides collecting, saving, accumulating and analysing of the spatial database of

the forest resources in the region, providing primary accounting of forests and the regional forest cadastre.

The technology of creating a GID involves the following algorithm:

- identification of image zones;
- establishment of the study sample;
- sample filtering;
- partitioning of the featured space;
- establishment of intra-interval evaluation for classes;
- classification of spectral channels.

One of the challenges is to combine classification data using cross-platform capabilities. For correct classification, polygons of each type of tree species must be identified so that the software product can accurately select the desired pixel and assign it to the class that meets its standards. For our image, the Bayes classifier was chosen – a classification algorithm based on the principle of posterior probability. For each pixel, the probability functions of each of the classes are calculated, according to which the posterior probabilities of the classes are calculated. We propose to calculate the following probabilities:

- a priori probability $P(K)$,
- conditional probability that is responsible for the distribution of the training sample $P(O/K)$,
- posterior probability $P(K/O)$, which can be found by the Bayes formula:

$$P(K/O) = \frac{P(O/K)P(K)}{P(O)}, \quad (1)$$

where O – is a vector of pixel features, K – is the number of classes, and $P(O)$ – the total probability is determined by the formula:

$$P(O) = \sum_i P(O/K)P(K). \quad (2)$$

The decision-making rule is formulated with the help of posterior probabilities from formula (1). A pixel belongs to a class with a higher posterior probability than it is in other classes. This classifier is optimal, because in all research cases it will give an unambiguous answer about whether a pixel belongs to one of the classes.

The more polygons we allocate for each tree species, the larger the statistical sample will be and the more accurate the classification of the tree species composition will be in the entire studied area. We identified 7 main classes of tree species combining polygons for each class. Class 8 was chosen to denote an area where there is no forest (Fig. 1).

Class name	Value	Colour	Number of trees, pcs
Aspen	101		2005
Pine	11		4897
Hornbeam	61		3988
Birch	91		2569
Alder	121		5760
Ash	71		1752
Class 8	8		0

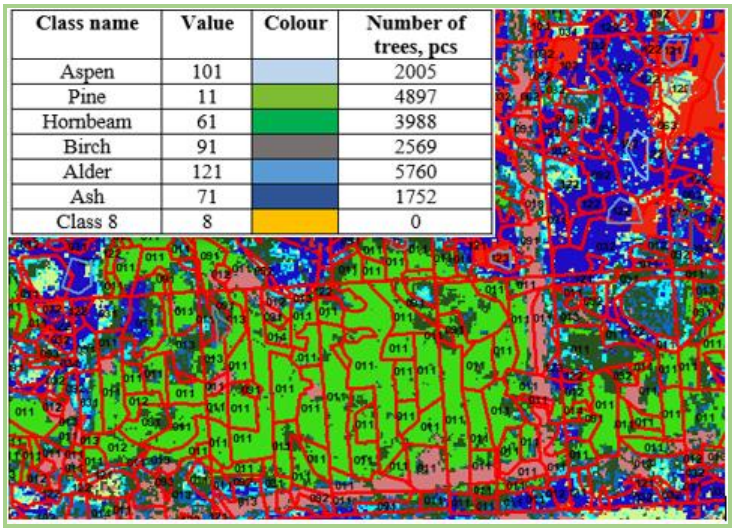

Fig. 1. Classification of tree species composition in forest segments of Mozhariv Forestry in 2020

As a result, we received a map of the forest in the identified area with a classification of trees with numbered colors which correspond:

8 – non-forest area,
11 – pine forest,
31 – oak forest,
61 – hornbeam forest,
71 – ash forest,
91 – birch forest,
101 – aspen forest,
121 – alder forest (Fig. 2).

It has been established that 70% of the forests are pine forests. Aspen, hornbeam, birch, alder, oak and ash tree species are also found in the forests. The number of conifer forest fires increased last years. Therefore, objective and timely information about changes in the forest cover is necessary to solve a wide class of applied forestry tasks, including forecasting the occurrence of fires and creating a simulation model of forest fire development.

The monitoring of forest changes in one territory by the number of trees over several decades for the years 2000, 2010, and 2020 is carried out to make a qualitative analysis of the tree species composition (Fig. 3).

The data shown in fig. 3 indicate that tree species composition during the last decades has changed very often for different tree species. This is due to the fact that foresters carry out sanitary felling every year, and there is also uncontrolled felling of trees. Sometimes large fires occur, which also lead to significant losses of forest plantations.

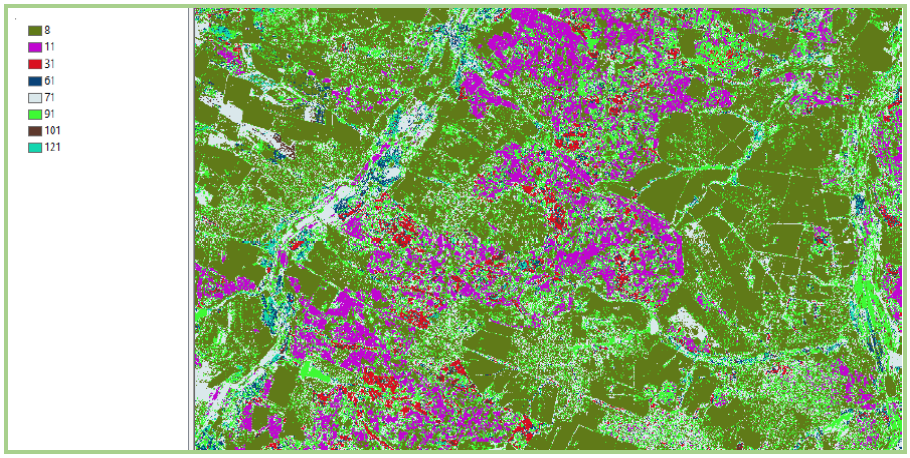

Fig. 2. Thematic map of tree species composition of the Mozhariv forestry in 2020

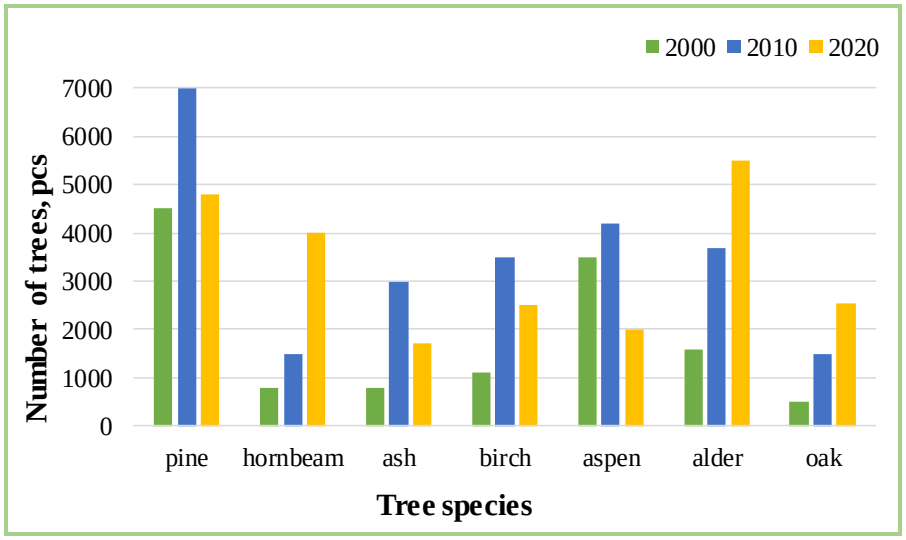

Fig. 3. Change of tree cover in Mozhariv Forestry during 2000-2020

In order to improve the accuracy of the analysis and establish additional characteristics of the forest condition, it is advisable to use high-resolution satellite images in further work. They will help us to analyze the situation at the level of parts of a single tree, which is necessary for timely detection of changes and early decision-making.

Various mathematical methods are used to analyze the changes that occur in forests due to forest fires, unauthorized and sanitary felling, forest reproduction [11–16]. It is advisable to conduct the analysis when there is a sufficient amount of statistical information, and the conditions of the external environment are stable enough. One of these methods is correlation analysis.

Most of methods of strength measuring of the correlation bond involve comparison of the deviations of the absolute values of the parameters from their averages:

$$corr(X,Y) == \frac{\mathrm{cov}(X,Y)}{s_X s_Y} = \frac{M\left[(X-M_X)(Y-M_Y)\right]}{s_X s_Y}, \quad (3)$$

where M_X and M_Y – mathematical expectations of values X та Y, s_X and s_Y – average square deviations of values X and Y in accordance.

We will determine with the help of the correlation coefficient how indicators of the consequences of forest fires affect the change in forest cover (Table 1). The values of the indicators of the consequences of forest fires were obtained from the official data of Mozhariv Forestry.

Table 1 – **Dependence of the loss of forest cover on the consequences of forest fires in Mozhariv Forestry**

	Correlation coefficient	Indicators of consequences of forest fires
Loss of forest cover according to DZZ data, number of trees	-0,225	Number of forest fires, pcs
	-0,110	Area of forest lands affected by fires, ha
	0,562	Burnt and damaged forest on a stump, m^3
	0,363	Damages caused by forest fires, thousand hryvnias

According to the results of Table 1, it can be concluded that the loss of forest cover depends on the consequences of forest fires, although they are not the main reason for the change in the number of trees.

In order to increase the accuracy of the analysis and establish additional characteristics of the forest state, it is advisable to use high-resolution satellite images in further work. This will make it possible to analyze the situation at the level of parts of a single tree, which is necessary for timely detection of changes and early decision-making.

Conclusions

Today, there are a large number of already implemented systems for forest land monitoring that require detailed improvement.

The method described in the article makes it possible to create a system for identifying tree species composition of forests on the separated territory and monitoring the temporal changes in the forest cover over several decades. A geographic information database has been created, which allows classifying the studied territory by tree species composition on the basis of space images which are taken using the Bayesian classifier. This system makes it possible to analyze changes in forest areas over a long period of time. A correlation analysis of the species composition in relation to various indicators of forestry was carried out and dependencies between the studied parameters were established.

One of the most interested parties in the developed system is the State Agency of Forest Resources of Ukraine. Obtained research results will be useful for the militarymen, who perform combat or tactical tasks in the forest area.

The developed method together with well-known methods of forest monitoring allow to create effective software for the analysis of changes in tree species composition of forests and to improve existing programs taking into account different quality requirements.

Prospects for further research are seen in the improvement of the system due to the addition of new functionality, for example artificial intelligence usage for analyzing and evaluating the classification of tree species composition of forests.

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Метод визначення породного складу лісових насаджень на основі геоінформаційної бази даних

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Анотація. На сучасному етапі розвитку суспільства актуальним є моніторинг лісових насаджень за допомогою дистанційного зондування Землі (ДЗЗ). Існуючі системи дослідження змін рослинності неефективно використовують геоінформаційної бази даних (ГБД) та не охоплюють спектр спостережень, розглянутих у даній роботі. Метою статті є розробка методу визначення породного складу лісових насаджень на основі геоінформаційної бази даних в інтеграції з кореляційним аналізом. Це дасть можливість виявляти найбільш негативні чинники, що впливають на стан лісових екосистем та нейтралізувати їх на початковій стадії впливу. Для створення бази даних використовуються космічні знімки, отримані від супутників Landsat 5 та 8. В якості прикладу проаналізовано лісовий покрив Можарівського лісництва за останні 20 років. Класифікація породного складу лісових насаджень за космічними знімками виконується на основі класифікатора Байєса. В роботі створена спеціалізована геоінформаційна база даних для подальшої обробки даних та встановлення породного складу. В роботі проаналізовано лісовий покрив за кількістю дерев по кожній породі окремо протягом тривалих часових рядів (2000, 2010 та 2020 роки). Результати досліджень мають графічне відображення. Для аналізу лісового покриву також проведено кореляційний аналіз, який визначає щільність взаємозв'язків між зміною кількості деревних насаджень та різними лісовими показниками. Розроблений метод разом з відомими методами моніторингу лісів дозволяють створити ефективне програмне забезпечення для аналізу зміни лісових насаджень та удосконалити існуючі інформаційні системи з урахуванням різних вимог до якості. Особливістю створюваної інформаційної системи є використання модуля обробки даних в складі геоінформаційної системи та проведення кореляційного аналізу з встановленням залежності факторів. Це сприяє підвищенню якості управління та моніторингу лісових ресурсів, доступності геоінформації для користувачів.

Ключові слова: космічні знімки; геоінформаційна база даних; класифікатор Байєса; породний склад дерев; кореляційний аналіз.