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MEASUREMENT INTERPRETATION AND ASSESSMENT OF MENSURATION CHARACTE-RISTICS OF PINE FOREST STANDS ON DIGITAL IMAGES OF ULTRAHIGH RESOLUTION

This article provides a brief analysis of forest mensuration deciphering digital images by using GIS technologies. The short review of the basic methods of deciphering of digital satellite images is done. The technique of performance of works to determine deciphering characteristics of stands is described and results of analysis of correlation between data had been done from ground-based inventory and measurement interpretation of digital images. It was revealed that there were close interrelations between mensuration and deciphering characteristics of forest stand.

Introduction. Nowadays update methods, information processing technology and geographic information system are intensively developed and implemented in the forestry industry. Update digital technologies of the image processing open a new opportunities in the measuring determination of the remote sensing materials.

On the digital high resolution satellite images crowns of trees are shown up quite good, which allows to realize the assessment of the stands composition and density, sizes of crowns, canopy density and based on these features using regression models of the determination and taxation index's intercalation, and mechanism of growth we get growing stock [1].

In case of making of taxation stand conditions by the method of the measuring determination of aerial-space images we can get just a little part of the stoking stands, which characterize its canopy. That's why we face with the problem of using connection between size of crowns, which can be seen on the images and other taxation features, which can't be seen on the images [2].

Therefore it is the necessity to develop the models of interconnection between determination indexes, which we can be measured directly on the digital images, using geographic information systems and taxation stands of the stock, which are measured under the full-scale taxation.

Main part. Questions connected with the aerial-space researches, remote assessments of the forest stand characteristic and monitoring of the forest lands are described in the works of both native and foreign scientists: Bartalev S.A, Danilin I.M, Danulis E.P., Dmitriev I.D., Vinogradov B.V., Jirin V.M., Isaev A.S., Kalashnicov E.N., Kozoderov V.V., Samoilovich G. G., Suhih V. N., Hardin N. G., F. Lambin, J. Landsberg, D. J. King, M. L. Nordberg, J. A. Tullis and many otheres.

The works of the listed scientists point on the possibility of the use of the Earth remote sensing's methods for the assessment of the forest stand taxation indexes and mapping forest lands, and also on the perspectives future researches in different directions.

There are many scientists such as Baginskii V. F., Lubimov A. V., Hardin N. G., Kireev D. M., Kolosova A. E., Tovyanskas T. B., Berezin A. M., Brest ova T. I., Demidov E. S., Efimov P. V., Jukov A. U., Prokudin Y. A., Suhih V. I., Trunov I. A. who applied the using of the forest taxation determination in the forestry and signification of the regularities and interconnections between taxation and determined indexes of the stock.

Update methods of the determination digital images provide enough reliable measure of the morphologic indexes, pictured on the images, of certain trees and canopy of the stock, the biggest diameter of crowns, the length of crowns, the number of trees which were pictured apart on the unit of space, canopy.

The main taxation indexes are - the middle diameters of the forest elements, relative density, deposits on the one hectare, quality of the stock, age - which are not identified proximally on the images. They can be calculate according to the taxation, determined earlier, -T (diameter of the trunk, density, deposit, age) and determined -D (diameter of the crowns, the number of trees, canopy closure) indexes [3].

Within forest elements the simple connections of taxation and determined indexes are analyzed initially: diameter and high of tree, diameter and high of the biggest diameter of crown, diameter and length of the crown, diameter of the trunk and diameter of crowns, high and length of crown, and then - plural regression plots, which include the influence of 2-3 and more variables [4].

There are different plural regression interconnection between the diameter on the pick of face, high and density: $d_m = f(h, P)$ or diameter on the on the pick of face , high, diameter of crowns, canopy and capacity class: $d_m = f(h, D_k, C_n,$ quality class), which are assisted by the different correlation relation or evaluated in the figure of graphics, bunch graphs, tables, which includes growth course and added by the determined indexes (high, diameter of crowns, canopy closure, sweep of the crowns, high for the biggest diameter of the crowns, high of the rope of the crown) [5].

Using geographic information systems, specialists get powerful features of scaling duplication and colorful correction of the digital images, and also combine processes of digitizing and vectorization of the borders, what simplify the technology of the production of the forest maps and let computerize the process of the measuring. Assisted by the GIS resources we can measure in the automatic mode such indexes as density, structure, diameter of crowns, canopy closure, the middle high of the stock [1].

For the right understanding of the image feature of crowns on the digital images it is very important to research the construction and shapes of the top part of the crowns, which are located upper then the biggest diameter. In case of digitizing of the structure of the forest crop it is important to take into account the availability of the connections between the height by up the biggest width of the crown (h_{Dc}) and height of the trees (h) [2].

Interconnections between taxation and digitizing indexes for the certain crops hardly suitable in actual fact and have theoretical signify in the sensible degree. For the use in practice they should be grouped within some complexes, whose classification features are evidential found out on the images.

Using different methods of measuring determination of the digital images, we can get such indexes as canopy closure, density of the stock, distance between the trees and the diameter of the crowns. It is possible to identify the middle diameter of the stock on the top of the face, the density of the stock, the sum of the section areas, the middle diameter, middle height of the stock and deposit due to the measuring determination indexes and correlation relations on the digital images.

In case of the definition of the density and structure of the forest crop in GIS we can use analogical methods, which are based on the counting of number of kind of wood which we can see in the crown canopy on the unit of square. The object with the known square or the line objects, which formed the grid of squares, are chosen for this purpose. We can also identify the density of the stock by the middle distance between the trees.

We can identify canopy closure using the dotty or the line methods. Dotty layer, with the systematic location of dots ,forms in GIS. Then, there are the counting of the dots, which fall into the crowns, into the brine of the crowns, and the general number of dots on the division. Ratio between dots, which fall into the crowns, and a half, which a fall into the brine of the crowns, give the canopy closure to the general number of the dots on the division.

Measuring of the distance between the trees, diameters of the crowns in GIS are made by the standard methods of the measuring of the line's lengths. For the calculating of crowns projection's square of the ordinary tree the polygonal object is created and it's square is counted.

The pure pine stocks of the I and Ia quality class are chosen as an objects of research. Taxation characteristics of the stocks on the taxation-determination divisions was fixed according to the statistics of the chosen measure-listed taxation using backfill of the circular test square CTS of the constant radius. The number of the circular squares of the constant radius, which is important for the definition of the taxation indexes, depends on the density and the square of the division.

Systematic selection was used in case of the taxation of the stocks to the CTS of the constant radius. Within the CTS enumeration of the trees are completed with the measuring of the diameter in two directions (North-South, East-West), with the sensitivity 0,1 sm of the metallic caliper with the 1 mm points. In case of the enumeration according to the attendance of crowns in the creating of the canopy, trees were divided into opened, closed trees.

For the closest to the center of the fifth accounted trees the height was measured, the height for the biggest diameter of the crown and the height of the pick of the crown. The diameter of the crowns was measured in both perpendicular directions, also the density and shape of the crowns was described (using the classification of G.G. Samoilovich).

For the data processing, which were found due to the measuring taxation of the forest stand, math-statistics methods were used.

According to the information in the Statgraphics program, due to the analysis of the preferences of the multiple regression, the models of the interconnections between the determination and taxation indexes for the l and la capacity class were composed. Analysis between taxation indexes of the stock and stand were made initially for l and la capacity classes. The differences between the a equations weren't valuable, that's why on the next stages statistics was united into the one complex. Coefficient of the equations valuable for the t-criterion of Student, which information is in the 5th table.

The equation, which characterized the connection between full density (P) of the stock, canopy closure (C_c) and the middle distance between the trees (L_{tree}) in the pine stands is:

$$P = -1.27677 + 3.03996\ C_c - 0.047351\ L_{tree}. \quad (1)$$

The coefficient of the determination complicates is (R^2) 83.57%; the middle quadratic mistake of the equation (S_y) - 0.042, f-criterion of Fisher (F) - 663.81. The limits of the equation for the closure is $0.50<C<0.95$.

Table 1

Value of the Student t-criterion of the independent variables for the counting of the stocking density

Constant	Constants	C_c	L_{tree}
Student t-criterion	–12.4895	25.0612	–13.8546

There was the research of the interconnection between the middle diameter of the stock and it's taxation indexes, such as the middle height of the stock, the age, the middle diameter of the crowns, density, closure, the sum of the cross section areas and another one. Consistent exception of the variable for the t-criteria was found the next equations of the multiple regressions:

$$D_{av} = –6.52007\ D_{cr\ av} + 0.923253\ D^2_{cr\ av} + \\ + 5.29728\ L_{tree} + 27.3359\ C^2_c, \quad (2)$$

where D_{av} –mid-diameter of the stock, см; $D_{cr\ av}$ – mid-diameter of the stand canopy crown, m; L_{tree} – middle distance between the trees, m.

The coefficient of the determination complicates (R^2) is 97,8%, the middle quadratic mistake of the equation (S_y) - 0.762 f-criterion of Fisher (F) – 3127,05.

Table 2

Value of the Student t-criterion of the independent variables for the counting of the mid-diameter of the stock

Constant	$D_{cr\ av}$	$D^2_{cr\ av}$	L_{tree}	$C^2_п$
Student t-criterion	–18.086	17.846	46.522	24.432

In case of the research of the interconnection between the middle height of the stock and the indexes of the canopy the next function has the best results:

$$H_{av} = 51.849 – 0.3424\ D^2_{cr\ av} – \\ – 0.0502\ N_{tree} + 0.00003\ N^2_{tree}, \quad (3)$$

where H_{av} – middle height of the stand, m; $D_{cr\ av}$ – mid-diameter of the stand canopy crown, m; N_{tree} – density of the stand, pc.

Table 3

Value of the Student t-criterion of the independent variables for the counting of the mid-height of the stock

Constant	Constant	$D^2_{cr\ av}$	N_{tree}	N^2_{tree}
Student t-criterion	31.915	–10.191	–15.024	11.964

The coefficient of the determination complicates (R^2) is 73.66%, the middle quadratic mistake of the equation (S_y) - 1.11 F-criterion of Fisher (F) – 242.31.

This function shows, that the middle height of the stock depends on the middle diameter of crowns and the density of the stands.

The regression equation of the connection between the sum of the of the cross section areas, the middle diameter of the stock and the density are in the formula (4):

$$G = –4.7481 + 0.16281\ D^2_{av} + 40.2027\ P, \quad (4)$$

where G – the sum of cross sectional area, sm^2; D_{av} – average diameter of the stand, sm; P – relative density of the stand.

Table 4

Value of the Student t-criterion of the independent variables for the counting of the sum of cross sectional area

Constant	Constant	D^2_{av}	P
Student t-criterion	–6.6273	14.073	73.527

The coefficient of the determination complicates (R^2) is 95.74%, the middle quadratic mistake of the equation (S_y) – 0.809 F-criterion of Fisher (F) – 2931.92

The result analysis of the research of the interconnection between the taxation and determination indexes shows, that there are the dense connection between the density of the crop, canopy closure and the middle distance between the trees, and high coefficient of the determination (R^2), which is 83.57%. In case of the multiple regressions the dense connection is observed between the middle diameter of the stock, the middle diameter of the canopy's crowns, the middle distance between the canopy closure , which confirm the high coefficient of the determination (97.80%) . Also there are the connection between the middle height of the stock, the middle diameter crowns of the canopy and the density of the stock (coefficient of the determination – 73.66%).

The researchers show that for the obtaining of the deposit of the stock it is important to know such determination indexes as the middle distance between the trees, the middle diameter of the crowns and canopy closure. The regression equation of this is the following (5):

$$M = –497.96 + 56.29\ L_{tree} – 3.91\ D^2_{cr\ av} + \\ + 1231.17\ C^2_c, \quad (5)$$

where M – stand stock, m^3; $D_{cr\ av}$ – mid-diameter of the stand canopy crown, m; C_c – canopy density.

Table 5

Value of the Student t-criterion of the independent variables for the counting of the stock stand

Constant	Constant	L_{tree}	$D^2_{cr\ av}$	C^2_c
Student t-criterion	–11.395	10.272	–4.572	19.972

The coefficient of the determination complicates (R^2) is 65.11%, the average quadratic mistake

of the equation (S_y) – 34.44, *F*-criterion of Fisher (*F*) – 161.75.

Conclusion. The results of the researches confirm the conclusions of the other authors about the existence of the dense interconnections between the taxation and the determination indexes of the stocks.

The analysis of the results of the interconnection between the taxation and the determination indexes of the stands allows to make a conclusion , that there are the dense connection between the density of the stand, canopy closure and the middle distance between the trees, and high coefficient of the determination(R^2), which is 83.57%. In case of the multiple regressions the dense connection is observed between the middle diameter of the stand, the middle diameter of the canopy crowns, the middle distance between the canopy closure, which confirm the high coefficient of the determination (97.80%). Also there are the connection between the middle height of the stand, the middle diameter crowns of the canopy and the density of the stand (coefficient of the determination – 73.66). There was a research between the sum of the cross section areas, the middle diameter of the stand and the density, which show the dense connection between this indexes (coefficient of the determination-95.74%). In the future, it is necessary to perform a regression analysis to assess the relationship between the stock and taxation-determination performance of the stands.

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