ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Anthropogenic Fragmentation and Evaluated Indices in Forest Sustainability Impact Assessment.

Shaykhutdinova Galiya A*, Mukharamova Svetlana S and Rogova Tatiana V.

Kazan Federal University, Russia, Kazan, Kremlevskaya 18.

ABSTRACT

The results of the basic metric characteristics statistical evaluation concerning the forest vegetation pattern (in the rank of formations) according to electronic geobotanic map of the Republic of Tatarstan with the scale of 1:200,000. The analysis of results revealed a number of forest formation patterns in different natural regions and proved the existence of links with the land-use and the factors that cause degradation, assessed the prospects for the state and stability of the main forest species.
Keywords: forest fragmentation, landscape pattern, geostatistics, spatial structure analysis.

Corresponding author

INTRODUCTION

Currently, the practice of environmental management, as well as the biological diversity reservation concept development are increasingly using the approaches based on the landscape patterns analysis. The researchers believe that the main reason for the life characteristics of individual populations and species diversity decline is the loss and "anthropogenic fragmentation" of natural habitats [1, 2]. Remote sensing images and maps, regardless of their resolution and scale, demonstrate the modern landscape like a mix of patches (contours) of different sizes and geometric forms. This mosaic structure is formed by the replacement of the natural vegetation cover with various systems operated by people with the growth of urbanization, the development of agriculture and forest management [3].

In this context, along with the study of landscape fragmentation [4] the special attention is paid to the forest vegetation fragmentation - the replacement of natural forest ecosystems with other ecosystems of large areas [5]. This leads to the formation of isolated woodlands and the enhancement of boundary effects, which adversely affects the forest biota.

Along with the reduction of biodiversity and the influence on the dynamics of abundance and the distribution of populations, the anthropogenic fragmentation violates the cycles of matter and energy, affects the productivity of ecosystems, which ultimately leads to a prolonged decrease of the environment properties. Therefore, the consideration of spatial data characterizing the landscape pattern, the modeling of the natural component response to this or that effect are presented as an essential condition for the rational land-use strategy development [2, 6, 7].

The methods of landscape mosaics statistical analysis and the quantitative evaluations of the vegetation cover pattern are varied and appear as the result of special studies, so as during the solution of nature use practical problems [4, 8-15]. Along with the usual methods that operate with the pattern geometric characteristics depending on the selected scale geometric characteristics the fractal methods are used [16, 17] which allow to avoid large-scale map generalization.

METHODS

The geobotanical maps as the "multifunctional phytocoenological models" [18] are the main way to display the vegetation pattern. On the Republic of Tatarstan territory (6783.7 thousand hectares) located in the center of the "boreal ecotone" - the transition area from the southern taiga to the northern steppes [19], zonal climatic features are collided with the azonal lithogenic and geomorphological conditions, forming a wide variety of natural-territorial complexes. At a long history of the territory development by people, a complex spatial mosaic of forest cover was developed in the region, the character of which is noticeable even on medium-sized maps. The work demonstrates the results of the basic metric characteristics statistical evaluation of the forest vegetation pattern (in formation rank) using an electronic geobotanic map of the Republic of Tatarstan at the scale of 1:200,000. The estimation results analysis of the basic integral and individual pattern values revealed a number of its formation regularities in different natural regions of the republic territory, proved the existence of relations with the nature of use and the factors that cause degradation, assessed the prospects of the main forest species state and stability.

MAIN PART

The general characteristics of the forest cover pattern, the evaluation results of its complexity and the relative position of the constituent objects (contours) are demonstrated by the integral indicators (Table 1, 2).
The spatial mosaic of the leading woodlands is composed of 12583 contours the total area of which makes 12594 km^2. The average area of the contour makes about 1 km^2. The standard deviation of the area sizes makes 2.4, the variation coefficient makes 0.42, indicating that the pattern heterogeneity and its strive for grouping. The analysis of the contour relative position metrics shows that the spatial mosaic of woodlands is characterized by high complexity and differentiation: it consists of a large number of small contours. The minimum possible length of the borders makes 75% of the actual total contour perimeter. Therefore, it should be noted that the contours do not differ significantly by the border irregularities within a given scale.

Table 1: Simplest metrical characteristics of woodland pattern

Woodlands	Contour number, pcs	Total area, km^2	General perimeter, km	Average contour area, km^2
Oakwoods	2370	1925,40	10534,04	0,81
Lindenwoods	1706	2256,46	9660,17	1,32
Aspen forests	2230	2754,55	11809,38	1,24
Birch forests	2130	2235,45	10638,97	1,05
Pinewoods	447	498,61	2349,43	1,12
Spruce and fir forests	259	153,36	942,07	0,59
Oak cultures	615	502,13	2542,95	0,82
Spruce cultures	785	534,01	2900,35	0,68
Pine cultures	1755	1593,01	7583,54	0,91
Willow and alder forests	89	78,69	401,22	0,88
Others	197	62,24	503,65	0,32
Total:	12583	12593,91	59865,76	1,00

The dominance index (0.14) and the high value of Chi-square indicate the uneven distribution of classes: the presence of the dominant and relatively rare area formations. The main dominant class of the forest cover is aspen forests, which occupy 21% of the total area. Relatively high values of entropy and the heterogeneity coefficients, taking into account the distribution of contours by classes, confirm the conclusion about the pattern complexity and heterogeneity.

Table 2: Integral indices of forest formation pattern

Index	Formulae and designations	Estimated values
Total area, km^2	S	12593,9098
Number of contours, pcs.	n	12583
Number of contour types	m	12
Contour average area, km^2	S_0	1,0009
Mean square pattern deviation	$\sigma = \sqrt{\frac{(S_i - S_0)^2}{n-1}}$	2,41
Variation ratio	$V = \frac{S_0}{\sigma}$	0,42
Fragmentation index	$K_d = \frac{n}{S}$	1,00
Complexity ratio	$K_s = \frac{n}{S_0}$	12572,10
Differentiation ratio	$K_r = \frac{S_0}{S}$	0,0001
Dominant class		aspen forests
Dominant class area from the total one, km^2	W	0,22
Dominance index	$R = W - \frac{1}{m}$	0,14
Chi—square	$C = \sum_{i=1}^{m} \frac{\left(S_i - \frac{S}{m}\right)^2}{\frac{S}{m}}$	10980,03
Entropy measure of pattern complexity	$H = -\sum_{i=1}^{m} \frac{S_i}{S} \log_2 \frac{S_i}{S}$	2,88
Heterogeneity ratio	$K_n = \frac{m}{m-1}\left[1 - \sum_{i=1}^{m}\left(\frac{S_i}{S}\right)^2\right]$	0,92
Total border length, km	$L = n 2\sqrt{S_0 \pi}$	44624,91

The total area of plantation contours, where one of the zonal forest tree species is common oak (*Quercus robur* L.) acting as the lead forest species (oak woods and oak culture), is less than one-fifth of the total area (19.3%), and the average area of a single contour does not exceed 0.8 km^2. However, they form almost one quarter of the map contours - 24%. The oak pattern has small contours as the inclusions of small spots in the complex configurations of other mosaics, mainly of long and short derivant plantations. The similar situation is observed concerning the formation pattern with the dominance of zonal conifer species (*Picea x fennica* (Regel) Kom., *Abies sibirica* Ledeb.). Individual indicators are calculated for each contour and allow the analysis of their shape. Table 3 demonstrates some of the calculated parameters characterizing the tortuosity of the contour boundaries. The comparative analysis of the forest formation pattern complexity was conducted according to the natural regions of the republic or by its generalizing groups [20], in accordance with the landscape conditions matrix and zonal vegetation: 1) subtaiga coniferous-deciduous forests region; 2) region of northern broad-leaved forests with spruce parts; 3) region of western broadleaf forests with spruce in the north, and ash in the south; 4) regions of the southern broadleaf forests; 5) regions of northern meadow steppes in combination with deciduous forests. The most common differences are the change of the dominant formation classes by regions: subtaiga region is dominated by pine cultures, oak forests in northern and western broad-leaved forests, aspen and birch forests in other regions.

The comparative analysis of the statistical indicator characteristics shows the difference of vegetation pattern in natural regions - the boundary contours of formations in the regions № 1-3 are more convoluted and complex and less homogeneous. The contours with the maximum fractal dimension (i.e., the most winding ones) are located in the subtaiga region. The mosaic contours of formations in the regions № 4 tend to form a circle more than others. In the forest-steppe regions the size and the shape of the contours are more uniform.

The statistical impact evaluation of the contour (formation) class and the fact of its displacement in certain landscape conditions (in one or another natural region) was carried out at the calculation of the dispersion relations and the Kruskal-Wallis criterion on the values of individual indicators. The calculations indicate the full accuracy of the above-mentioned differences in the natural region and show that the shape and complexity of the contour boundary are truly associated with its content. For example, the fractal dimension values of the culture contours are much smaller than that of natural stands.

Table 3.Statistical characteristics of contour individual indices

Natural regions	Number of contours	Mean value	Median	The standard deviation	Minimum	Maximum
Fractal dimension: $FRACT = \frac{2\ln(P)}{\ln(S)}$						
1. subtaiga region	3616	1.247	1.243	0.028	1.181	1.430
2. region of northern broad-leaved forests	1221	1.254	1.249	0.029	1.191	1.384
3. region of western broadleaf forests	1324	1.249	1.245	0.028	1.191	1.369
4. regions of the southern broadleaf forests	4143	1.233	1.229	0.022	1.183	1.401
5. regions of northern meadow steppes in combination with deciduous forests	2222	1.235	1.232	0.021	1.177	1.370
Total by Tatarstan	12583	1.241	1.237	0.026	1.177	1.430
Differentiation ratio: $K1 = \frac{P}{2\sqrt{\pi S}}$						
1. subtaiga region	3616	1.464	1.342	0.413	1.017	6.700
2. region of northern broad-leaved forests	1221	1.455	1.342	0.397	1.020	4.488
3. region of western broadleaf forests	1324	1.455	1.342	0.397	1.020	4.488
4. regions of the southern broadleaf forests	4143	1.439	1.316	0.430	1.019	5.491
5. regions of northern meadow steppes in combination with deciduous forests	2222	1.397	1.275	0.395	1.025	6.834
Total by Tatarstan	12583	1.423	1.306	0.392	1.017	6.834

CONCLUSION

The electronic version of the vegetation cover map allowed to determine the integral and individual quantitative characteristics of the forest vegetation pattern as for the whole territory, so as for the individual landscape regions.

SUMMARY

Firstly, the pattern of the territory forest vegetation within the republic territory is characterized by considerable complexity, heterogeneity, uneven distribution of formations and the prevalence of derivatives (aspen, birch, linden forests and cultures), which is largely the result of its appearance active transformation at the implementation of forest management and other activities.

Secondly, the expression of the anthropogenic dynamics pattern occurs at the landscape heterogeneity of the territory, which significantly complicates the overall picture. Within the forest regions on the background of the natural tendency to aggregation, the formation of large clusters of forests, a specific and often very complex internal mosaic is developed. It consists of the contours with different sizes and shapes, and the zonal types of formations are represented mainly by small contours; in the forest-steppe regions the forest cover mosaic is characterized by a more fractional pattern, the contours are equally small and simple, making the overall pattern more uniform.

The fractal dimension estimates and the other coefficients characterizing the contour shape, revealed that these figures are dependent on the anthropogenic load intensity and duration for the territory. The use of these indicators, based on the study of the object spatial structure, allows to make conclusions about damaged areas and is recommended for the assessments of vegetation and environmental systems as a whole.

REFERENCES

[1] Harris LD, Silva-Lopez G. The theory and practice of nature conservation preservation and management 1995. — P. 197-237.
[2] Dale VH, King AW, Mann LK, Washington-Allen RA, McCord RA. Environm Manag 1998;22(2):203-211.
[3] Krummel JR Gardner RH, Sugihara G, O'Neill RV, Coleman PR. Oicos 1987;48:321-324.
[4] Jaeger JAG. Landscape Ecol 2000;15:115-130.
[5] Murcia C. Tree 1995;10(2):58-62.
[6] Knogge C. Tropical Forests Affected by Habitat Fragmentation / Store Less Biomass and Carbon Dioxide. Dec. 10, 2009.
[7] Marcelo Tabarelli, Ariadna V. Lopes, Carlos A. Peres. Edge-effects Drive Tropical Forest Fragments Towards an Early-Successional System. 2008.
[8] Fox J, Krummel J, Yarnasarn S, Ekasingh M, Podge, N. Ambio 1995;24(6):328-334.
[9] Miller JR, Shulz TT, Hobbs NT, Wilson KR, Schrupp DL, Baker WL. Biolog Conserv 1995;72:371-379.
[10] Trani MK. Landscape pattern analysis related to forest wildlife resources / PhD dissertation, 1996.— 183 pp.
[11] Olsson EGA, Austrheim G, Grenne SN. Landscape Ecol 2000;15:155-170.
[12] Entel B, Hamilton NTM. Landscape Ecol 1999;14:277-281.
[13] Viktorov AS. Landscape pattern. M 1986:48-63.
[14] Viktorov AS. Landscape Mathematic Morphology. M 1998:6-46.
[15] Rogova TV, Mukharamova SS, Saveliev AA. Effects of landscape fragmentation on coniferous/broad-leaved forests / Proseedings IAVS Symposium, Opulus Press Uppsala. Printed in Sweden, 2000.— P. 174-177.
[16] Mandelbrot BB Fractals: Form, Chance and Dimension. San Francisco, 1977.— 365 pp.
[17] Mandelbrot, B.B. The Fractal Geometry of Nature. N.-Y., Freeman, 1983.— 468 pp.
[18] Ogureeva GN, Miklyaeva IM, Suslova EG, Shvergunova LV. Geobot Mapp 1994-1995.- Spb., 1996.- Pages 3-15.
[19] Kolomyts EG. Landscape-zonal systems polymorphism. Pushchino, ONTI PNTS RAS, 1998.- Pages 24-31, 47-58.
[20] Bakin OV, Rogova TV, Sitnikov TV, Vascular plants of the Republic of Tatarstan. Kazan, Kazan University publication 2000. - 496 pages.