Estimation of the vegetation diversity of the Western Tannu-Ola Range

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Abstract. This paper discusses the main indicators diversity of vegetation in key areas of the northern macro slope of the Western Tannu-Ola Range. The degree of forest cover and vegetation fragmentation were estimated using Landsat-TM/ETM+/OLI images for June 25, 1992, June 18, 1998 and June 24, 2015 in QGIS using the plugin Landscape Ecology. The Simpson index shows of increasing biodiversity in different altitudes. The results showed that with increasing climate warming in the region and maintaining this trend, the proportion of dark coniferous forest at all altitude levels (foothill, mid-elevation and high-elevation zones) will increase. And this led to a decrease in the fragmentation of the forest cover of northern macro slope of this range.

1 Introduction

Within the framework of "The Biodiversity Conservation" were recommended to assess ecosystem diversity. For assess ecosystem diversity it was proposed to use the ratio of the areas of different forest types relative to the total area, as well as the fragmentation of forest cover [1]. Among the priority tasks is the assessment of mountain biodiversity.

Currently, the impacts to climate change in territory of Central Asia are manifested noticeably. The mountainous ecosystems of Southern Siberia are remarkably sensitive to the vulnerable environment conditions. The most serious among them are the processes of change in the southern boreal forests. Central Asia is characterized a variety of plant and climatic conditions. Taking into account and assessing the diversity of forest communities in the republic remains a problem due to the limited availability of a significant part of the region. It is possible to evaluate the values indicators the diversity of vegetation in hard-to-reach mountain areas which employed remote sensing techniques.

The purpose of this study is assessing the forest cover and fragmentation on key areas of the northern macro slope of the Western Tannu-Ola Range using data of the Landsat-TM/ETM+ and Landsat- OLI.

2 Material and Method

The study areas are situated in the territory of the Western Tannu-Ola Range within the boundaries of 50 ° 55'-51° 15'N and 91°30'-92°20'E. The Western Tannu-Ola range occupies in the southwestern part of the republic and plays an important role in ensuring the sustainability of the mountains forests of Southern Siberia. The range is one of the large climatic borders, the final barrier on the way of moist northwestern airflows which have reached the mountains of South Siberia.

The study areas are characterized by sharply continental climate, with annual average precipitation of 229.8±65.1 mm and annual mean temperature of is -1.0±0.8°C (1988-2018). An anomaly of the mean annual temperature amounted to 1.4±0.1°C compared with the base period (1961-1990) [2].

The Western Tannu-Ola Range own highly heterogeneous characteristics with a large variety of climate, vegetation and soil. It is characterized by a unique combination of different landscapes – from dry mountain steppes to tundra [3]. This diversity of vegetation helps maintain the stability of the range vegetation. The main

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forest-forming species are larch (*Larix sibirica*), cedar (*Pinus sibirica*), spruce (*Picea obovata*), and birch (*Betula microphylla and Betula rotundifolia*).

The processing was performed in the Quantum GIS of data Landsat-TM/ETM+/OLI. A band combination 5, 4 and 3 Landsat-TM/ETM+ and 6, 5 and 4 Landsat-OLI were used for image analysis, where different classes have been identified. Information for identification was obtained from the forest scheme-map of the Tyva Republic (scale 1: 300 000, 1992).

Three altitude levels (foothill, mountain-taiga and high-mountain zones) were identified in the study areas. The foothill zone (1100-1300 m above sea level) - the slopes bordering the steppe are covered with larch forests with birch. In the mountain-taiga (1300-1700 m above sea level) are dominated by the Siberian cedar and Siberian larch. Cedar (5C3L2S) is dominates in the composition of the 1-st tier, where the conditions are favorable for it. In drier areas larch is dominates (7L3C+S). Dark coniferous species (4C4S1L, 5C5S) are dominated in the composition of 2d tiers. In the high-mountain zones (1700-2120 m above sea level) larch and cedar forests grow. Here mainly grows dark coniferous forest and cedar is dominates in the composition of 1 and 2 tiers (10C, 7C3L).

Within the key areas the vegetation was divided into the main classes of the underlying surface: 1 - dark coniferous forests (cedar), 2 - light coniferous forests (larch), 3 - dark coniferous forests (spruce), 4 - small-leaved leaves (birch), 5 - non-forest areas, 6 - natural grassland, 7 - wetlands/tundra, 8 – sparse growth, 9 - shrubs, 10 - water bodies (rivers, lakes), 11 - new forest areas / reafforestation.

The identified classes is verified in cross examination way at present context, whether the category exists or not or converted into another pattern. Diversity of vegetation was calculated based on the above vegetation classification using the plugin Zdetsaka. The diversity indices (forest cover, the number of fragments, and the Simpson index)) were estimated fusing the plugin Landscape Ecology.

3 Result and Analysis

Forest integrity which is defined as the ratio of the area covered by forest vegetation to the total area of forest land, as well as the proportion of dark coniferous forests, the proportion of light coniferous forests, and the proportion of small-leaved forests characterize the ecosystem diversity of study areas forests. Forest cover is described by the following formula:

$$EP = \frac{Sa}{S} \cdot 100$$

(1)

where S – total area of forest land, Sa – area of forest.

An assessment of forest cover based on the percentage of forest covered area of key plots on each elevation levels (table 1). The table shows that the shares of dark coniferous forests with a predominance of spruce (class 3), small-leaved forests (class 4) and shrubs (class 9) increased at all altitudes levels compared to previous image data.

Table1. Forest cover (%) of classes of the Western Tannu-Ola Range

№ class	Foothill zone			Mountain-taiga zone			High-mountain zone		
	I	II	III	I	II	III	I	II	III
1	2.8	2.8	1.0	4.2	5.3	1.8	8.6	14.6	3.5
2	7.2	4.9	8.6	6.3	2.4	3.2	6.5	1.2	1.9
3	23.3	25.1	28.6	32.7	32.9	49.0	12.7	12.8	28.0
4	24.3	23.6	26.6	14.4	19.1	19.9	20.4	23.6	27.0
5	12.7	18.5	14.8	4.3	7.1	5.5	10.2	16.0	10.0
6	1.6	0.5	2.7	1.1	0.6	1.3	1.4	0.5	2.1
7	7.5	5.1	3.6	5.8	7.5	5.1	11.5	10.7	7.0
8	2.7	3.4	5.0	2.3	1.4	5.5	6.8	6.5	8.1
9	3.0	3.6	8.1	2.0	2.7	7.8	4.6	6.0	11.7
10	0.8	0.4	0.5	0.9	0.3	0.4	0.8	0.1	0.3
11	14.1	12.0	0.4	26.1	20.6	0.6	16.3	7.9	0.3

Designations: I – за дату 25.06.1992, II - 18.06.1998, III - 24.06.2015

Fragmentation of landscapes is an essential factor in reducing biodiversity [4; 5; 6]. Fragmentation of the forest cover is the division of entire forests into isolated fragments. From Table 2, it is seen that summarizes fragmentation of each elevation levels. The total fragmentation at three elevation levels was decreased on average 3 times more, of coniferous forests - 2 times more, of light coniferous forests - 4 times more.

Fragmentation of small-leaved forests occurs unevenly, but compared to first image, fragmentation also was decreased 1.3 times more. In general, the decrease of forest fragmentation is associated with overgrowth of the range forests with the establishment of favorable conditions during climate warming.

Table 2. Fragments on the key areas of the Western Tannu Ola Range

№ class	Foothill zone			Mountain-taiga zone			High-mountain zone		
	I	II	III	I	II	III	I	II	III
1	3274	3055	1308	3274	3441	1813	3274	3441	1813
2	5155	3827	1939	5155	2037	1093	5155	2037	1093
3	2922	3014	2024	2922	3545	1190	2922	3545	1190
4	3864	5631	2575	3864	6860	3202	3864	6860	3202
5	1120	1689	669	1120	2256	720	1120	2256	720
6	635	384	1883	635	404	1126	635	404	1126
7	987	1266	1969	987	975	1619	987	975	1619
8	2045	1650	2254	2045	1712	1871	2045	1712	1871
9	2188	2303	2750	2188	1692	2598	2188	1692	2598
10	119	227	95	119	201	83	119	201	83
11	2735	4198	154	2735	3528	137	2735	3528	137

Designations: I - 25.06.1992, II - 18.06.1998, III - 24.06.2015

The Simpson index had been a similar trend. The values of Simpson index for each altitude level are presented in the table 3. The Diversity Simpson Index [7], which takes into account both wealth and uniformity when measuring diversity. The Simpson diversity index is described by the following formula:

$$C = \sum \frac{n_i}{N}$$

(2)

where ni – the significance rating of each species (abundance or biomass), N - the sum of the significance ratings.

From Table 3, it is seen that that the Simpson index decreases which shows an increase in the diversity of vegetation in the key areas of the West Tannu-Ola range. It was shown that over the study period the fragmentation of the studied areas decreased which is associated with forest overgrowth during climate warming.

Table 3. The Simpson index of the Western Tannu-Ola Range

Simpson index	25.06.1992	18.06.1998	24.06.2015
Foothill zone	0.84	0.82	0.81
Mountain-taiga zone	0.87	0.86	0.81
High-mountain zone	0.87	0.67	0.81

From Table 4, it is seen that the change in the area of the studied key areas. In foothill zone the area of small-leaved forests with a predominance of birch increased 1.1 times more, in the mountain-taiga - 1.4 times more, in the high-mountain zones - 1.3 times more. In the foothill zone the area of dark coniferous forests with the predominance of spruce increased 1.2 times more, in the mountain-taiga - 1.5 times more, in the high-mountain zones - 2.2 times more; may be, part area of cedar forest is included here. In foothill zone the area of light coniferous forests increased 1.2 times more. In the mountain-taiga and high-mountain zones the light coniferous forests decreased (1.4 - 4.6%) probably because of the wildfire.

Table 4. Forest area (ha) of key areas of the Western Tannu Ola Range

№ class	Foothill zone			Mountain-taiga			High-mountain zones		
	I	II	III	I	II	III	I	II	III
1	5664	5736	1977	7783	10012	3291	19191	32371	7730
2	14619	9999	17402	11809	4538	6006	14513	2655	4297
3	47120	50684	57837	61313	61706	91767	28302	28437	62188
4	49099	47709	53793	26945	35852	37295	45231	52359	59972
5	25603	37451	29949	8055	13358	10337	22574	35627	22139
6	3297	1088	5531	1968	1107	2473	3216	1100	4626

7	15083	10399	7318	10839	13967	9465	25591	23791	15602
8	5367	6837	10150	4287	2562	10215	15159	14468	18072
9	6044	7242	16327	3712	5135	14639	10187	13433	26037
10	1695	758	1010	1710	520	742	1809	225	698
11	28528	24215	824	48958	38624	1149	36262	17569	674

Designations: I – за 25.06.1992, II - 18.06.1998, III - 24.06.2015

4 Conclusion

The calculation of landscape indices has been (the proportion of forests, the number of fragmentations and the Simpson index) in key areas of Western Tannu-Ola to assess changes in southern mountain forests for 1992, 1998 and 2015 using remote sensing data. An analysis of this data showed that over the past 23 years there has been a decrease in forest fragmentation and has led to an increase all elevation levels of forest on the Western Tannu-Ola ridge. The results showed a positive relationship between the growths of vegetation diversity in response to climate warming.

References

1. A.S. Isaev. *Monitoring the biological diversity of Russian forests: methodology and methods*. (2008).
2. V.N. Smagina, S.A. Ilyinskaya, D.I. Nazimova, I.F. Novoseltseva, Yu.S. Cherednikova. *Types of mountains forests of the Southern Siberia*. (Sciences, Novosibirsk, 1980).
3. Kh.B. Kuular. Sovr. Probl. DZZ Kosm. **15(7)**. 67–77. (2018).
4. L. Fahrig. Ann. Rev.ecol., evol.&syst. **34**. 487–515. (2003).
5. J. Fischer, D.B. Lindenmayer. Global Ecol. Biogeogr. **16(3)**. 265–280. (2007).
6. J. Wu. Princ. Guide Ecol. 438–444. (2009).
7. E.H. Simpson. Nature. **163**. 688. (1949).