
The Study of the Dynamics of Forest Landscapes in Georgia Based on the Analysis of Spatial-Temporal Concept of Natural-Territorial Complexes

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Abstract: The study of the forest dynamics of Georgia's landscapes is based on the analysis spatial-temporal concept of natural-territorial complexes (NTCs), which was developed by Prof. Nikoloz Beruchashvili. This question allows analyzing and evaluating the following issues: forest resource potential of landscapes and restoration of the retrospective picture of the forest area in the different historical periods. This landscape approach allowed us to identify the trend of changes in the horizontal structure of the landscapes having occurred on the territory of Georgia in that long period of time. In particular, the following factors were analyzed and identified: areas of the landscapes, forest area and degree of its diminution, amount of phytomass, etc. Thus, on the basis of the research some peculiarities of the modern horizontal structure of the landscapes of Georgia were identified, also the trend of change of the horizontal structure of the landscapes of Georgia from the early days of human society to present was identified and the degree of diminution of the natural-territorial complexes of the forests of Georgia from the early days of human society to present was identified.

Keywords: Natural-Territorial Complexes, Forest Resource Potential, Horizontal Structure

1. Introduction

The impact of the human and landscape was different in different periods of time and in different regions of the world. It was changing along with the development of society.

About the trace of anthropogenic influence on forest landscapes in Georgia can be discussed from the early stage of development of society. The destruction of forests, especially in the plains, started in the beginning of Holocene. For example, there is an opinion that the landscapes of the Armenia-Javakheti Upland are of secondary origin, and human destructed forests existed there once. Also, the forest destruction is related to human in the eastern Georgia's plain. However, it should be noted that in the early period the forests had not been basically transformed and the reduction in forest areas was not the irreversible process; it was mainly

of a limited local character. More lately, this process gains a wider scale. Although the anthropogenic changes in the territory of Georgia did not have such a large scale, as, for example, in North America and Western Europe, but it can be said that some landscapes have been irreversibly transformed in many areas. The biggest changes in the environment were related to the 19th century – the creation of new urban settlements and industrial objects, extraction of minerals and forest exploitation. The royal treasury of the Russian Empire, the high-ranking military and civilian elite, local or foreign owners exploited the natural resources without taking the environmental conditions into the consideration. Coal and manganese extraction and cutting of forests were conducted in a predatory manner. It was not possible all of these not to

cause major changes in separate regions and landscapes.

Today Georgia's significant area is destroyed. It is noteworthy that the landscapes that were almost untouched for centuries got under the anthropogenic influence. They are first of all the forest massifs in the area of medium mountain forest landscapes. In this respect, the areas of Adjara, Kvemo Imereti, Meskheti and Borjomi municipalities are especially noteworthy. The upper mountain forest and high mountain subalpine landscapes have also been influenced.

Due to the current situation, it is very important to study the dynamics of the change in forest areas and its causes. It is also important to analyze and create a retrospective picture of forest rate. From this point of view, analysis and intercomparison of different types of sources, including cartographic one, should be carried out.

2. Methods and Initial Data

The study of the forest dynamics of Georgia's landscapes is based on the analysis spatial-temporal concept of natural-territorial complexes (NTCs), which was developed by Prof. Nikoloz Beruchashvili. This question allows analyzing and evaluating the following issues:

- 1) Forest resource potential of landscapes;
- 2) Restoration of the retrospective picture of the forest area in the different historical period.

It is clear that the degree of transformation of the forest areas and bio-resources in the historical past is impossible to identify with high accuracy. However, the maps created at different times help solve this problem at least, partially. We tried to compare the data of several maps:

- a. "The map of the restored vegetation cover of Georgia" by N. Ketskhoveli [1] showing the distribution of the types of the vegetation cover in the past, approximately up to the time when a man changed the environment totally;
- b. "General Maps of Georgian SSR by Al. Javakhsihvili Al. and S. Tskhakaia[2] showing the forest cover on the bridge of the XIX-XX centuries;
- c. "The landscape map of Georgia" by N. Beruchashvili [3] showing the types of the vertical structure of the natural-territorial complexes (showing the situation by the end of the XX century).

Based on the analysis of these maps, the areas of the different types of vegetation cover and vertical structure of the natural-territorial complexes were identified. In order to compare the data of these maps, one assumption was made: each type of the vegetation cover was matched with specific landscape and specific type of the vertical structure of the NTCs. This is the landscape approach of the concrete study having allowed us to identify the trend of changes in the horizontal structure of the landscapes having occurred on the territory of Georgia in that long period of time. In particular, the following factors were analyzed and identified: areas of the landscapes, forest area and degree of its diminution, amount of phytomass, etc.

In identifying the amount of phytomass, among other

things, we considered the regional peculiarities. In particular, the restored map of the vegetation cover shows the "Beech forests of east Georgia" separately. As per the landscape map of Georgia, they cover 3 types of middle-mountain landscape with dominating two types of vertical structures of natural-territorial complexes: humid mesophytic natural-territorial complex with deciduous bushes grass cover of a macro-structure. Clearly, we could take a single datum as the average amount of phytomass, e.g. 350 t/ha, but this would have harmed the accuracy of calculations. As under the landscape map of Georgia, the "Beech forests of east Georgia" cover 3 types of middle-mountain landscape, the average amounts of phytomass for each of these types and NTCs are different: 500 t/ha ("Kakhetian" Great Caucasus), 300 t/ha (the main area Great Caucasus in East Georgia) and 250 t/ha (Traileti Range). Therefore, the different average amounts of phytomass for the "Beech forests of east Georgia" will be identified. Such an approach allowed identifying the supply of phytomass quite accurately in accordance with the degree of study specification.

Besides these, we were used field data, obtained during the researches carried out in 1980-2005 by LAB for Studying Environmental Conditions by Space Methods, Tbilisi State University (Georgia). These materials cover nearly the entire spectrum of landscapes of Georgia from plains to high mountain alpine and subnival landscapes.

3. Research Object

Georgia is characterized by high natural diversity. The landscape spectrum on the territory of Georgia is quite diversified and is distinguished for clear signs of the territorial distribution. This fact is described in a number of scientific works [4; 5; 6; 7; 8; 9; 10; 11; 12]. These sources give quite a clear description of the questions of territorial definitions of Caucasus, Georgia and its regions.

Here are represented the landscapes varying from humid subtropical in West Georgia, semiarid and arid in East Georgia, to meadows, subnival and glacial-nival in high mountains. There are 14 types, 23 subtypes, 71 general landscapes and more than 300 types of NTCs in Georgia. One major peculiarity of Georgia is the existence of a comparatively large amount of virgin landscapes. Virgin forests that comprise almost 10% of the total territory of Georgia are particularly significant. Forest as such, occupies 40% of the total territory [13].

Western and eastern parts of Georgia differ from each other by the landscape diversity. The eastern Georgia is more diverse than the western one. This is revealed in all classification levels of the landscapes. It is true that eastern Georgia has more area than the western one. In eastern Georgia all types of natural-territorial complexes (NTC) can be found that are characterized to western Georgia (extra-humid, humid and semi-humid). In addition, there are such types of vertical structure of NTCs that cannot be found in western Georgia (semi-arid, arid). NTCs with steppe and semi-desert vegetation, as well as arid light forests belong to them.

4. Main Results

4.1. Some Peculiarities of Distribution of Landscapes of Georgia

The common peculiarities of the distribution of the landscapes of Georgia can be clearly seen by analyzing the areas occupied by them. This has a certain practical value as well, as it allows identifying the real amounts of resource potential of landscapes.

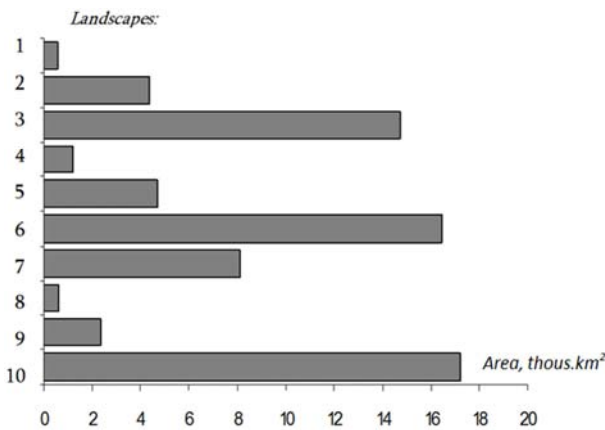


Figure 1. Area of Georgia's landscapes.

Landscapes: 1 - high mountain subnival and nival; 2 - high mountain alpine; 3 - high mountain subalpine; 4 - high mountain steppe; 5 - upper-mountain; 6 - middle-mountain; 7 - lower-mountain; 8 - mountain depression; 9 - low mountain; 10 - plain.

The analysis of the Landscape Map of Georgia scaled 1:500,000 [3], showing the types of the vertical structure of natural-territorial complexes, identified the area for each landscape type. As it was expected, the largest areas are occupied by mountain landscapes (53,1 thousand km²) making 76% of the total area of Georgia; the plains and valleys and piedmonts occupy 24% of the total area of the country (17,2 thousand km²). According to the altitudinal zones in the mountains, the landscapes were classified as follows (Figure 1) – low-mountain (9) landscapes make 3% of the total area of Georgia; mountain depressions (8) make 1% of the total country area, lower-mountain (7) landscapes occupy 12% of the country area, middle-mountains (6) occupy 24% of the total country area, upper mountains (5) occupy 7% of the total country area, high-mountain subalpine (3) landscapes occupy 21%, high-mountain alpine (2) landscapes occupy 6%, high-mountain subnival and nival

(1) landscapes occupy 1% of the total country area and as for the high mountain steppe (4) and plain (10) landscapes, they occupy together about 25 % of the total country area.

The meadow and meadow-steppe landscapes occupy almost equal areas in the plains and valleys and mountains. These landscapes are mostly spread in the South Caucasus mountain depressions and on the high plateaus of South Georgia.

In this respect, the horizontal structure of Georgian landscapes differs from the general picture of Caucasus where the largest part of the meadow-steppe and steppe landscapes are concentrated within the boundaries of plains and valleys.

Karst and volcanic landscapes occupy small areas making 8% and 6% of the total area of Georgia, respectively.

4.2. Distribution of Landscapes by Different Regions of Georgia

The landscapes are distributed quite unevenly in different regions of Georgia (Table 1).

Plain landscapes spread over the largest areas in Kakheti occupying 5.4 thousand km², making over 40% of the total area of the region. Kakheti is also distinguished for its low-mountain and upper-mountain forest landscapes. Mtskheta-Mtianeti with its upper-mountain forest landscapes falls a bit back Kakheti region. The largest areas of middle-mountain forest landscapes are found in Apkhazeti making almost 30% of the total area of the region. The largest areas of high-mountain subalpine landscapes are found in Imereti and Samegrelo-Zemo Svaneti, while high-mountain alpine landscapes occupy the largest areas in Mtskheta-Mtianeti.

Larger areas of middle-mountain forest and high-mountain subalpine landscapes are found in west Georgia, while the largest areas of lower- and upper-mountain landscapes are found in east Georgia. As for the alpine landscapes, they occupy almost equal areas in both parts of the country.

4.3. Forest Dynamics of Georgia's Landscapes from the Early Days of Human Society to Date

The analysis and comparison of the above-mentioned maps has shown that the horizontal structure of the landscapes of Georgia from the early days of human society to present has changed a lot what is clearly seen with the regions and landscape units. These changes are particularly evident if looking at the landscapes and forest natural-territorial complexes.

Table 1. Area of Georgia's landscapes by the regions (thous.km²).

Landscapes	Plain	Mountain depression, Low mountain	Average mountain			Total	High mountain subalpine, high plateau	High mountain alpine	Others	Total
			Low mountain	Middle mountain	Upper mountain					
Abkhazia	2,959	0,000	0,876	2,506	0,237	3,619	0,990	0,191	0,667	8,426
Samegrelo-Zemo Svaneti	2,624	0,010	0,126	1,800	0,144	2,070	2,474	0,456	0,809	8,443
Imereti	2,865	0,144	0,195	2,427	0,143	2,765	2,564	0,092	0,000	8,430
Achara	0,768	0,000	0,709	0,718	0,272	1,699	0,219	0,046	0,000	2,732
Guria	1,443	0,000	0,043	0,444	0,156	0,643	0,387	0,600	0,000	3,073
Racha-Lechkhumi-Kvemo Svaneti	0,000	0,055	0,000	1,106	0,618	1,724	0,564	0,351	0,088	2,782

Landscapes	Plain	Mountain depression, Low mountain	Average mountain			Total	High mountain subalpine, high plateau	High mountain alpine	Others	Total
			Low mountain	Middle mountain	Upper mountain					
<i>Western Georgia</i>	10,659	0,209	1,949	9,001	1,570	12,520	7,198	1,736	1,564	33,886
Kakheti	5,396	2,571	0,756	1,846	0,963	3,565	0,982	0,165	0,287	12,966
ShidaKartli	1,045	0,000	1,137	0,328	0,078	1,543	0,336	0,203	0,087	3,214
Mtkheta-Mtianeti	0,371	0,000	0,614	1,640	0,920	3,174	1,056	1,247	0,642	6,490
Samtskhe-Javakheti	0,144	0,901	1,626	0,856	0,253	2,735	1,923	0,671	0,161	6,535
KvemoKartli	1,814	0,193	0,867	2,162	0,000	3,029	1,615	0,099	0,000	6,750
<i>Eastern Georgia</i>	8,770	3,665	5,000	6,832	2,214	14,046	5,912	2,385	1,177	35,955
Total	19,429	3,874	6,949	15,833	3,784	26,566	13,110	4,121	2,741	69,8

It is known that in the historical period, a great part of forests on the earth surface were destroyed due to the human economic activities. The trend of the forest diminution in some regions of the world was significant, while in other regions, the forests preserved their natural originality relatively better. Georgia is one of the countries with quite well-preserved large areas of intact forest massifs [14]. However, this does not mean that the forest changes are insignificant.

Mostly, plain forests were destroyed in Georgia, both in the western and eastern parts of the country. Relatively better are the plain forests survived in the mountain areas of Great Caucasus and Lesser Caucasus. The floodplains were destroyed almost totally although they were quite widely spread along the gorges of the rivers in east Georgia (Mtkvari, Alazani, Iori, Aragvi) even at the beginning of the XX century. At present, they have survived as fragments only.

If analyzing the regional trends of reducing the forestation coefficient according to certain gradations (<20%, 20-40%, 40-60%, 60-80% and >80%), we will see that the gradation was changed from high to low in almost all regions, except two regions: Mtskheta-Mtianeti and Samtskhe-Javakheti, where the forest massifs are spread over relatively limited areas even at the earlier stages of the societal development [15]. Clearly, this does not mean that the forest areas did not diminish in these districts. They did diminish, but the diminution of the degree of forestation is particularly high in the densely populated areas with vast areas of forests. For example, particularly intense changes in forestation occurred in Imereti. In the past (according to the map of restored vegetation by N. Ketskhoveli), the forestation coefficient in Imereti was over 96% in the past, while it is only 56% at present, i.e. the forestation coefficient in this area decreased by two gradations.

Particularly high forestation coefficient was fixed all over east Georgia, which was within the range of 60-80% or higher interval, with Shida Kartli and Kakheti having the highest forestation coefficient (50% and 44%, respectively). The reduced forestation in Georgia is also evidenced by the fact that at present, none of the regions of Georgia has over 80% of forestation coefficient. In addition, there is a region (Kvemo Kartli), where forestation is even less than 20%. Such low level of forestation was uncommon in the early days of human society in any region of Georgia. In the past, the least forestation coefficient was fixed in Samtskhe-Javakheti (30%), while at present such region is Kvemo Kartli (<20%).

The area of forest NTCs is significantly reduced on the territory of Georgia from 50% to 38% (Table 2). The analysis of the forest areas according to the landscapes evidences that the decline is quite extensive. In the early days of human society, the forest occupied half of the territory of Georgia. As expected, most significant changes occurred with plain and piedmont landscapes.

If considering the dynamics of changes of the areas of Georgian forests from the early days of human society to present, we will see both, the reduction and the increasing trends. However, it is clear that these trends show a general picture only and cannot be absolutely adequate to the reality. This is caused by the following circumstances:

- The results of the analysis of the sources of the early days of human society, as well as historical sources are evaluative and rough;
- Different or incorrect forest registration methods were used at different times and by different establishments.
- In 1943-57, the change of the territory of Georgia made up 6.7 thousand km² [16]; however, the total area of the forests did not show any significant change.

Table 2. Area of forest natural-territorial complexes (NTC) of Georgia.

Landscapes	Forest area	Non-forest area	Settled area and Agriculture lands	Total
Lowland plain	1.71	0.235	3.835	5.78
Foothills	1.835	0.515	3.74	6.09
Plain-hills	0.29	0.445	2.565	3.3
Plateau	0.41	0	0	0.41
Accumulative plain	0	0	1.65	1.65
Mountain depression	0.03	0.11	1.22	1.36
Low mountain	0.76	1.6	0	2.36
Low-mountain	5.963	0.075	1.336	7.374
Middle mountain	14.726	0.8	0.88	16.433
Upper mountain	4.71	0	0	4.71
High plateau		0.1	1.12	1.22
High mountain subalpine	0.11	10.67	0	10.78
High mountain alpine		1.76	0	1.76
High mountain subnival and nival		1.39	0	1.39

The data registration following the changes of the area of the forest fund of Georgia was duplicated. This happened when an owner of a forest massif changed and the massif areas was appropriated to the old and new owners at the same time.

Despite the above-listed gaps in the registration of the forest areas, it may be said that the general trend is clear. In particular, from the early days of human society to present, the forest area in Georgia decreased by almost 1/3, with approximately 12 thousand km² of forest destroyed [17]. This is quite a big figure. It is interesting that this figure complies with the mean world deforestation value, i.e. the process of deforestation in Georgia was almost similar to the same process on the earth surface. The analysis of the I and II centuries give a different picture. Based on the historical sources, it is established that about 6 thousand km² of forests is destroyed in Georgia, while about 4 thousand km² has become sparse [18]. Thus, the degree of reduction in this period made 1/5 only, while the area of forests in the whole world decreased twice in recent 200 years.

4.4. Phytomass Dynamics of Forest Landscapes of Georgia

Each vegetation group in the restored vegetation cover map can be attributed to a certain landscape dominant type of the vertical structure of natural-territorial complexes. This allowed comparing the supply of phytomass in different time intervals and identifying the degree of diminishment [17; 19].

The analysis and comparison of the data of the above-mentioned maps revealed that the supply of phytomass on the territory of Georgia reduced from 1296 to 981.9 mln. tons. However, the degree of reduction is quite different across the landscapes and regions of Georgia. Mountain landscapes occupy large areas (46 thousand km²) and a great part of the Georgian forests grow here. Therefore, the maximum amount of phytomass (795.3 mlt t, making 88% of the total amount of phytomass of Georgia) is accumulated here. At the early stage of the societal development, this figure was lower (79%), as a significant proportion of the amount of phytomass was accumulated in the plain landscapes, as well. Due to high anthropogenic transformation, the supply of phytomass in the plain landscapes has reduced by almost 3 times. The least reduction was fixed in the middle-mountain forest landscapes, making only 14%, while the reduction in the plains and valley and upper mountains was 46% and 75%, respectively.

Different works [20; 21] note that the maximum amount of phytomass in Georgia (and in the Caucasus as a whole) is accumulated in the middle-mountain forest landscapes with dominating beech-dark coniferous forests amounting to 400 t/ha, while in the middle-mountain forest landscapes with dominating beech forests, it is 300 t/ha.

The analysis of supply of phytomass gives a different picture. In particular, the largest supply is found in the middle-mountain forest landscapes not with dominant beech-dark coniferous, but with dominant beech forests. Particularly large supply of phytomass is fixed in west

Georgia, in the middle-mountain forest landscapes. As compared to East Georgia, the supply of phytomass is also great in the plain landscapes of west Georgia. The only thing east Georgia is distinguished for, is the lower-mountain, high-mountain subalpine and high plateau steppe landscapes. This can be explained by the fact that the subalpine landscapes occupy quite large areas within the limits of the mountainous region of east Georgia, while high mountain plateaus occupy large areas in South Georgia.

It is natural that West Georgia houses relatively large amount of phytomass than East Georgia. This peculiarity is seen with all landscapes. An exception is the high-mountain subalpine landscapes.

With the supply of phytomass, the regions of Georgia differ much, with the common trend of reducing amounts of phytomass. This is particularly true with two regions: Imereti and Kvelo Kartli, where the degree of diminishment is almost 50%. Clearly, such drastic decrease in phytomass is associated with the anthropogenic factor. For instance, Tbilisi and its environs (most of their part) were once covered with forests [22]. N. Ketskhoveri names a great number of goats the population had in this area as one of the reasons for the forests destruction. Light forests widely spread in the plain area of east Georgia (of the adjacent mountainous areas) in the past reaching the gate of Tbilisi, are totally destroyed at present because of irregular pasturing. If it has survived elsewhere in its original state, it is only in Vashlovani Protected Area [18].

At the early stage of the societal development, the maximum amount of phytomass was accumulated in Imereti and Apkhazeti. Guria ranked the last. At present, the picture has changed a lot and the maximum supply of phytomass is found in Apkhazeti and Samegrelo-Zemo Svaneti, Imereti has shifted to the third place and Guria ranks the last as before. In terms of percents, the most drastic reduction of the amount of phytomass is seen in Imereti and Kvemo Kartli. The change was the least in Mtskheta-Mtianeti and Samtskhe-Javakheti. Surely, this is caused by the decreased forest areas.

5. Conclusions

Thus, based on the analysis of the forest dynamics of the NTCs, landscape approach, not only the modern peculiarities of the horizontal structure of the landscapes of Georgia were identified, but also the situation in the early days of human society and trend of its changes. In addition, the advantage of this approach is that it can be used to identify not only the forest area, but also the horizontal structure of the whole territory of the landscapes.

It is interesting to know how much representative are the gained results. Surely, the results of the analysis of the modern state of the horizontal structure of the landscapes of Georgia cannot be doubtful, as they are based on the data of the maps of the modern period. The accuracy in this case is determined by the accuracy of the accomplished calculations.

As for the results of the analysis of the horizontal structure of the landscapes of Georgia in the early days of human society, their representativeness is evidenced by the fact that they are somewhat adequate to the past data found in the scientific literature. At this point, we mean only the adequacy of the trend of the diminution of the forest area making it clear that the areas of the natural-territorial complexes without forests are identified with the same accuracy. Therefore, we can assume that this landscape approach is quite reliable to solve similar issues and can be used for different periods of the societal development based on the historical maps surely, provided we have relevant cartographic basis. Perhaps, one can assume that this approach can be used for large-scale studies as well. This will give the possibility to restore the gradual and more detailed picture of the historical change of the horizontal structure of Georgia's landscapes. There is one more worthwhile circumstance making the said approach advantageous. It is one of the best means to identify the resource potential of the landscapes.

Thus:

- a. Some peculiarities of the modern horizontal structure of the landscapes of Georgia were identified.
- b. The trend of change of the horizontal structure of the landscapes of Georgia from the early days of human society to present was identified.
- c. The degree of diminution of the natural-territorial complexes of the forests of Georgia from the early days of human society to present was identified, and

The representativeness of the landscape-geophysical approach to study the trend of change and modern state of the horizontal structure of the landscapes of Georgia was established.

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