ASSESSMENT OF THE RELATIONSHIP BETWEEN PHYTOMASS AND PHYSICAL-GEOGRAPHICAL FACTORS IN THE FOREST LANDSCAPES OF GEORGIA

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Abstract

This paper examines the relationship between phytomass, one of the most essential landscape-geophysical parameters, and the physical and geographical factors of forest landscapes in Georgia. Relief, climate and soil conditions are discussed to reveal the features of phytomass distribution in different physical-geographical environments and explain the reasons behind them. Additionally, the study establishes the limiting factors that determine favourable natural conditions for the accumulation of maximum phytomass. The study primarily uses materials from field expeditions, but also makes use of published scientific works and archive materials from various agencies. The data were processed using GIS technologies and a number of thematic maps were created.

Keywords: landscapes, phytomass, field work, Georgia

I. Introduction

The study of forest resources is a critical issue aimed at addressing various problems facing humanity. The solutions must be based on these resources' economic and environmental functions [Lakida, 1996]. Due to the continuous growth of population, industries, and urbanization, forest cover is steadily declining, leading to significant negative impacts on the climate [1]. The sustainable use of forest resources has become especially important and can only be achieved through a comprehensive assessment of all components of forest ecosystems [2, 3].

Phytomass is one of the best indicators for analyzing processes occurring in a landscape, such as humidification—aridification, preservation—degradation, stability—sensitivity, and others. Based on this, it becomes possible to identify the natural potential and productivity patterns of various physical-geographical environments and the trends of their changes and other related aspects.

Numerous studies on phytomass content have been conducted and published in the world literature, including issues related to the dynamics and structure of phytomass [3-7], their estimates, carbon reserves [8-10], etc. However, estimates of the extent of phytomass in the former Soviet Union have been limited in their publication within Western literature [11].

Some scientific studies have been dedicated to researching phytomass in Georgia [12-15]. These works focus on studying the phytomass of Caucasian landscapes at high taxonomic levels (subclass, types, subtypes) and address issues related to the dynamics of phytomass based on data from the Martkopi physical-geographical station. A map of the phytomass of Caucasian landscapes has also been compiled [Tediashvili, 1984, stock materials], and the average amounts of phytomass have been determined at the level of landscape genera.

II. Materials and Methods

The study is primarily based on field data collected by the Research Laboratory of Studying Conditions of Environment by Aerial Methods from 1977 to 2005 (Fig. 1). Field data from 2013 to 2015 and 2021 to 2025 were also used in various scientific projects. Results from stationary observations (Martkopi Physical-Geographical Lab.) and semi-stationary observations (Amtkeli, Bakuriani, Bevreti, Kovaluki, Lagodekhi, and Kazbegi semi-stations) across different regions of Georgia were also utilized (Fig. 1). These studies were mainly conducted during the summer, providing a solid basis for data comparison. Moreover, data from various literary sources (primarily related to timber stock and biomass productivity) and archival materials preserved in different institutions were used.

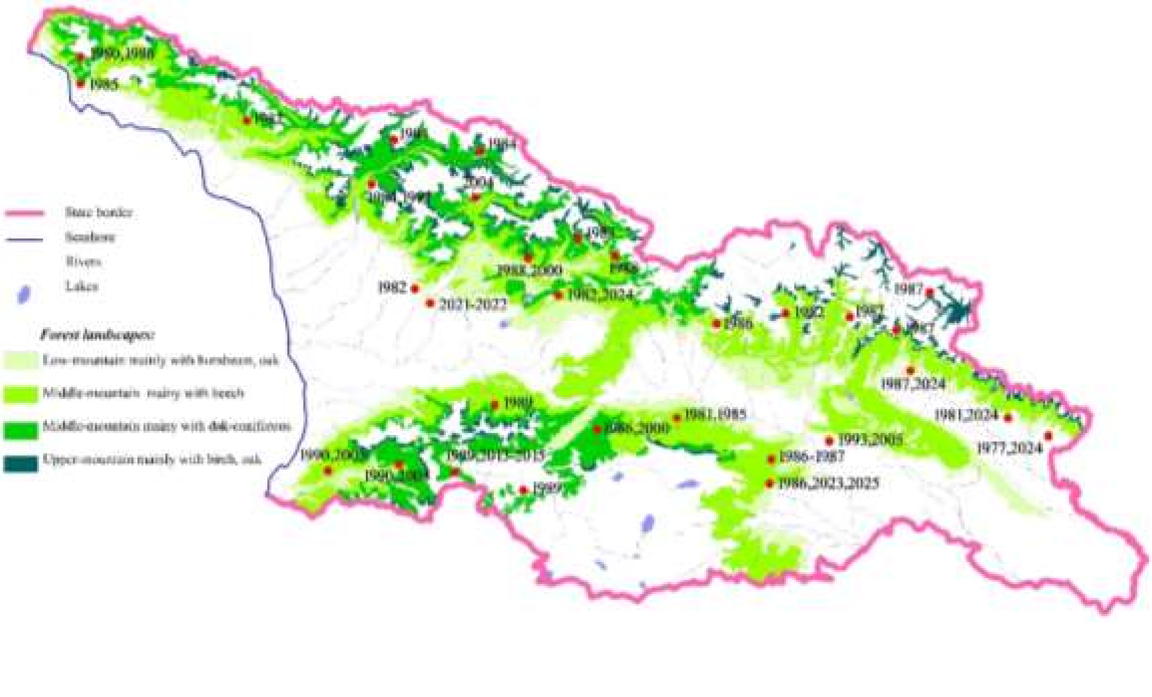

Figure 1: *Fieldwork in the forest landscapes of Georgia*

The research focuses on the concept of spatio-temporal analysis and synthesis of natural-territorial complex (NTK), developed by N. Beruchashvili in 1983 [13].

The identification of the spatial distribution characteristics of the geomass in Georgia's forest landscapes was carried out from various perspectives:

- Changes in the amount of phytomass across different physical-geographical environments;
- Identification of the physical-geographical factors that determine the accumulation of maximum geomass in specific conditions;

- Correlation of phytomass quantities with other geomasses (lithomass, pedomass, mortmass).
- Determination of the total amount of phytomass by landscapes of various ranks (types, subtypes, genera) and by types of the vertical structure of geosystems (average amount, variation range, and reserves).

III. Main Results

The general patterns of phytomass distribution in the mountain forest landscapes of Georgia.

The average amount of phytomass in Georgia's landscapes is 230 tons per hectare (t/ha), but it varies significantly, ranging from 0.1 t/ha to 1200 t/ha. Landscapes of mid-mountain beech-dark coniferous forests rank first in terms of average phytomass amount (over 500 t/ha) [Nikolaishvili, 2009], while semi-desert and high mountain subnival landscapes rank last (0.1 t/ha). Forest landscapes also differ in terms of phytomass quantity, although the variation is not as extreme as in the previously mentioned cases.

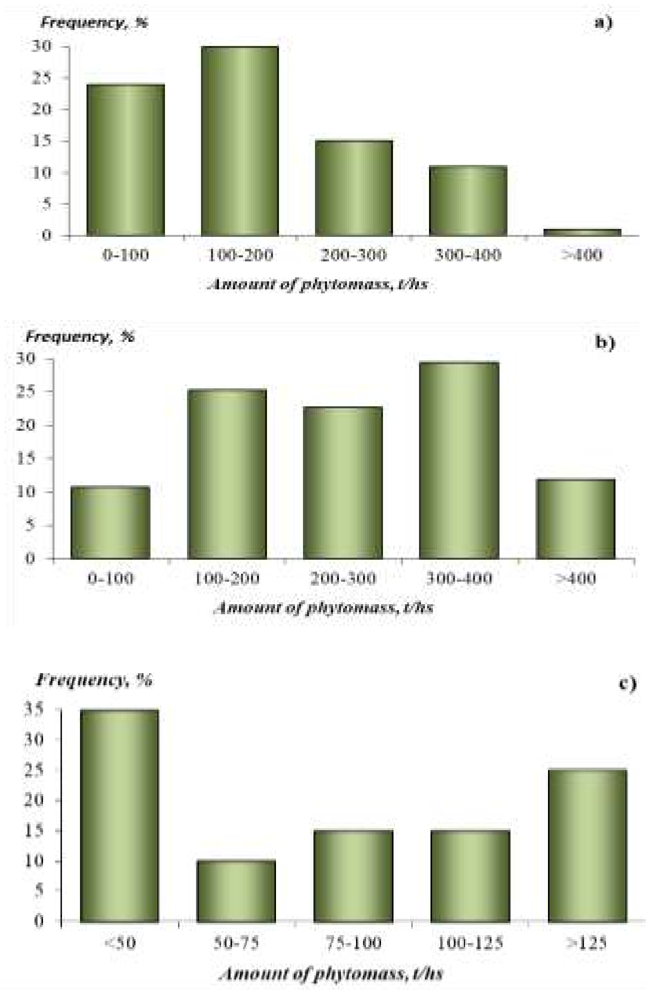

Figure 2: *Frequency of phytomass in mountain forest landscapes of Georgia*
Forest landscapes: a) low-mountain, b) middle-mountain, c) upper-mountain

Non-forested areas, often resulting from anthropogenic transformation, are also present within forest landscapes. Accordingly, undisturbed and minimally altered areas have high phytomass amounts, whereas degraded forests and secondary meadows lag significantly behind. Another observation is that this variability is expressed with less intensity in relatively undisturbed environments.

The lower mountain forest landscapes are characterized by extensive phytomass quantities, with forest stands ranging from 75-100, 100-200, and 300-400 t/ha. However, their distribution is highly uneven. Forest stands with 300-400 t/ha are much rarer in these landscapes (Fig. 2a). The reason for this is easy to explain. These landscapes are relatively close to densely populated lowlands, and due to their less complex terrain, they are more accessible and better utilized. As a result, the scale of anthropogenic impact in these areas is significant. Alongside undisturbed forest stands, whose area continues to decline, there are transformed landscapes and those under intense anthropogenic pressure.

A completely different situation is observed across the entire hypsometric spectrum of mid-mountain forest landscapes. These are some of the most well-preserved landscapes, maintaining much of their original natural appearance. The reason for this lies in the predominance of steep and moderately sloped terrains (20-35°), which, in turn, have resulted in sparse population settlement. In these areas, forest stands with phytomass amounts ranging from 100-400 t/ha account for nearly 70% (Fig. 2b).

The upper mountain forest landscapes also exhibit a wide range of phytomass quantities (Fig. 2c). This can be explained by the fact that these landscapes border both forested and sparsely forested or completely non-forested landscapes, resulting in the presence of vegetation types characteristic of both.

Field studies have also shown that in all forest landscapes of Eastern Georgia, the range of phytomass quantities is higher, as within the boundaries of a single subtype, one can find not only extrahumid (with relatively limited distribution) and humid but also semihumid, semiarid, and even arid geosystems [14]. This is less common, or not observed at all, in the relatively evenly humid landscapes of Western Georgia.

Topographic factors

The relief conditions significantly affect the amount of phytomass – absolute altitude, surface slope, exposure, type of relief, and location on ridges or slopes, among others. This, in turn, is determined by the differences in heat and moisture that various geosystems, located in different relief conditions, receive. The relief factor is especially evident in mountain landscapes, unlike in lowland landscapes, because all the aforementioned relief conditions act as limiting factors in highly fragmented mountain-valley landscapes. In such situations, the relief primarily determines the migration, transit, and accumulation of substances. Consequently, different conditions form for the development of vegetation cover and the accumulation of phytomass.

The correlation between phytomass and elevation is not very stable within the boundaries of a landscape taxonomic unit. There are landscapes with different amounts of phytomass at the same elevation [15]. The correlation between phytomass and absolute elevation is more evident in mid-mountain forest landscapes, while it is weaker in lower mountain forests and even less so in upper mountain forest landscapes. This can be easily explained by the fact that mid-mountain forest landscapes have a much broader hypsometric range than the other two.

For most of Georgia's mountain landscapes, the maximum amount of phytomass is characteristic of slopes with moderate inclinations under a transeluvial migration regime. This is especially evident in the lower and mid-mountain forest landscapes. Geosystems under the transeluvial migration regime occupy the largest area in Georgia (49’000 km²), where the transit of substances exceeds the eluvial processes. This accounts for more than 65% of the country’s total area. The proportion is even higher in forest landscapes. About three-quarters of the total area comprises geosystems under the transeluvial regime, where the surface slope ranges from 30° to 45°. In such conditions, the amount of phytomass varies significantly (from 5 to 500 t/ha and more). Despite this, due to less anthropogenic impact, the maximum amount of phytomass is observed under exactly this migration regime.

A low amount of phytomass is observed on ridges, especially in areas under anthropogenic impact. The dryness of ridges and ridge-adjacent slopes hinders the natural regeneration of vegetation cover and the accumulation of significant amounts of phytomass. This feature is characteristic of almost all mountain forest landscapes in Georgia. The situation is quite the opposite in geosystems under the transeluvial migration regime. Here, the amount of phytomass is high, despite the presence of geosystems that are particularly vulnerable to deforestation. It is obvious that deforestation is inadvisable in such conditions, and only selective (sanitary) cutting should be considered. Otherwise, the diversification, degradation, and destruction of natural complexes are likely.

Climatic factors

It is known that mountain landscapes in Georgia are greatly influenced by air temperature, while plain landscapes are significantly affected by precipitation [15]. This general characteristic manifests differently across various landscapes, depending on the degree of anthropogenic transformation in the area. In forest landscapes with minimal human impact, the amount of phytomass correlates well with the balance of heat and moisture. Specifically, an increase in atmospheric precipitation corresponds to the rise in phytomass. Notably, a significantly higher amount of phytomass accumulates in landscapes where precipitation is evenly distributed throughout the year, with no drastic reductions in summer and no extreme fluctuations in air temperature. For instance, in the middle-mountain forest landscapes of western Georgia (dominated by beech forests), the maximum amount of phytomass (over 400 t/ha) is observed in areas where annual precipitation exceeds 1,000 mm. In similar landscapes in eastern Georgia, the maximum phytomass is found where precipitation exceeds 780-800 mm. Under conditions of relatively low atmospheric precipitation, the amount of phytomass is closer to the lower limit of the range typical for the landscape, while in areas with abundant rainfall, it approaches the upper limit. Additionally, landscapes with minimal anthropogenic impact are not characterized by a wide range of phytomass variation.

The situation is different in landscapes with a high degree of anthropogenic transformation. In such areas, it is more challenging to establish a correlation between the balance of heat and moisture and the amount of phytomass. This balance no longer acts as a limiting factor, and anthropogenic influences take precedence.

A significant correlation is also observed between the amount of phytomass and atmospheric precipitation during the growing season (from May to November). This is one of the main reasons why mountain forest landscapes in western Georgia typically have a higher phytomass than those in eastern Georgia. The only exception to this trend is the mountain forest landscapes of the Kakheti Caucasus, where precipitation is distributed more evenly throughout the year.

Edaphic factors

Soil thickness, moisture, texture, humus content, and stoniness are physical characteristics of the soil that significantly influence the productivity of the vegetation cover. These characteristics, in turn, are determined by various physical-geographical factors [16].

In this regard, soil thickness plays one of the most critical roles. An increase in soil thickness corresponds to the rise in phytomass [17]. However, this characteristic does not exhibit uniform patterns across all landscapes. For instance, in the eastern part of the distribution of mid-mountain forest landscapes, there is a relatively pronounced direct proportional relationship between the amount of phytomass and soil thickness. This, however, cannot be said for mid-mountain forest landscapes formed on karst substrates. In these areas, ecosystems with large amounts of phytomass are found even on relatively thin soils, while complexes with comparatively low phytomass are frequently observed on thicker soils.

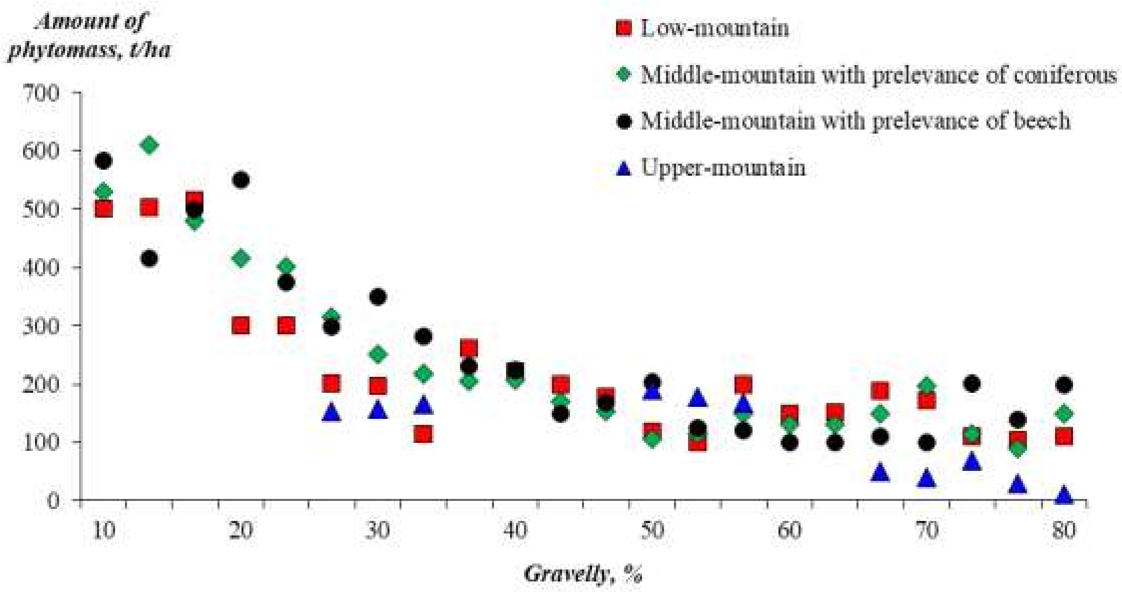

Figure 3: *Relationship between phytomass and the soil's gravelly*

Soil stoniness also has a specific influence on the amount of phytomass. Logically, an increase in stoniness should correspond to a decrease in phytomass [18]. However, it is impossible to definitively argue for an inversely proportional relationship between them, as low phytomass levels are observed in ecosystems where the lithomass's projected cover varies widely within the soil profile (10-60%). The most remarkable diversity in this regard is characteristic of the lower mountain forest landscapes (Fig. 3). When lithomass's projected cover is high in the landscape, ecosystems with 100-150 t/ha phytomass levels are more common. In mid-mountain forest landscapes with a predominance of beech forests, phytomass levels reach 100-200 t/ha. In mid-mountain forest landscapes with a predominance of beech and dark coniferous forests, levels rise to 250-350 t/ha. In upper mountain forest landscapes, phytomass levels range from 60-110 t/ha. Regarding ecosystems with high phytomass levels, in nearly all cases, the lithomass's projected cover does not exceed 20-25% [18].

IV. Conclusions

The study identified the relationships between relief, climatic, and edaphic conditions and the amount of phytomass in the mountain forest landscapes of Georgia. Specifically:

- The territorial distribution patterns of phytomass were revealed in various physical-geographical environments, considering factors such as absolute altitude, surface slope, the balance of moisture and heat, and depth and stoniness of soil.
- Limiting factors determining favorable natural conditions for the maximum phytomass accumulation were also identified.

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CONFLICT OF INTEREST.
Authors declare that they do not have any conflict of interest.

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