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GEOGRAPHY ABROAD

Influence of Some Landscape Factors on the Belowground Plant Biomass Distribution in Mountain Ecosystems of Armenia

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Abstract—Presented are the results from investigating the belowground biomass of grass associations as an important factor of functional stability of mountain ecosystems. Field investigations were conducted in plant communities of the dry-steppe, meadow-steppe and alpine belts of Armenia at altitudes of 1200–3250 m above the sea level. It is shown that the conditions of vertical belts, topography and the slope aspect of the mountain landscapes under investigation have influence on belowground biomass accumulation and distribution in the profile of the root layer of soils.

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It is common knowledge that productivity and functional stability of grass associations of mountain ecosystems are largely determined by the vigor of the plant root system, and by its optimal distribution in soils. Root penetration into the lower soil layers ensures the supply of the necessary amount of water and mineral elements to the plant organism, promotes adaptability of plants to adverse environmental conditions and expands the area of their occurrence. Furthermore, a well-developed root system is stimulatory to growth of the assimilation surface and raises the intensity of photosynthesis processes thereby ensuring an increase in biomass and bioenergy of phytocenosis.

A large body of research done to date [1–4] demonstrated that in grass communities, the belowground organs account for most of the total biomass, sometimes making up more than 80% of the annual net production. A high proportion of roots in the total biomass is characteristic for the dry steppes of Western Siberia (Russia), Spain, Tanzania, and other regions of the world [5–9].

On the whole, the belowground biomass of Armenia's mountain landscapes has not been adequately explored [10, 11]; there are only a few publications devoted to the study of its distribution across the profile of the root habitable soil layer [12, 13]. Nevertheless, in spite of the limited territories, the mountain landscapes are of great scientific interest. And they are located on different vertical belts (ranging from the semidesert to alpine belts) which differ substantially in the diversity of parent rocks, soil-climatic conditions, botanical composition of grass stand and anthropogenic impacts [14–16]. Note also that in the mountain landscapes of the arid zones, including Armenia, the growth of herbaceous plants is also governed in many respects by slope aspect and topography.

The objective of this paper is to determine the extent to which the aforementioned landscape factors influence accumulation and distribution of belowground biomass of grass associations across the profile of the rot habitable soil layer in the mountain ecosystems.

OBJECTS AND METHODS

The field investigations were made during 2002–2006 on grass associations of the dry-steppe (1200–1400 m above the sea level), meadow-steppe (2100–2400) and alpine (3000–3250 m above the sea level) belts of Geghama Mountain Range and Mt. Aragats on the territory of Armenia. In the three altitudinal belts, the necessary number of sampling points and areas differing in area was established. Thus, for determining the character of effects from the vertical belts, samples were collected on the territories adjacent to human settlements: in the dry-steppe zone – Arindzh, Mayakovskii, Dzhrvezh, Vokhchaberd, and Dzorakhpyur; in the meadow-steppe zone – Orgov, Antarut, Gekhard, Sevaberd, Lernagyukh, and Amberd, and in the alpine zone – to the lakes: Karilich and Aknalich as well as to the mountain summits: Vishapasar, Azhdaak, and Sevsar.

Thirty soil columns 25×20 cm in size and 30–40 cm in height were sampled in the areas of each zone. Samples were collected in the areas of the subalpine (2750–2800 m above the sea level) and Alpine belts of Mt. Aragats (3200 m, eastern slope) and Geghama Mountain Range (3000 m, western slope), and for determining the microrelief of the terrain – in the plain and hilly areas of the dry-steppe and meadow-steppe belts. For this purpose, 8–10 soil columns of the same size were sampled. In the laboratory, they were separated into 10-centimeter layers, and the roots were extracted from the individual soil layers by flushing through the sieve with the pores 1 mm in diameter. After that, the samples were dried at a temperature of 65–70ºC for 7–15 days in order to determine the absolutely dry weight – in the drying cabinet at 105ºC. Experimental material underwent statistical analysis through the use of relevant software packages [17].

RESULTS AND DISCUSSION

The results of our investigations revealed that, in general, the belowground biomass for the three soil layers in the altitudinal belts varied over the range 1518–2592 g/m² of dry matter, and the minimum indicator was observed in the areas of the dry-steppe belt, which appears to be due to overgrazing and excessive trampling of the territory [18, 19]. High indicators for the belowground biomass were recorded in the areas of the meadow-steppe belt (Table 1) which, usually to a lesser extent, undergo anthropogenic impacts and have relatively good moisture availability. Note that the precipitation amount in this belt is about twice as large as in the dry-steppe belt [19].

A pronounced difference also reveals itself in the belowground biomass distribution, especially in the case of comparing its indicators in the belts under consideration: the root biomass in the associations of the dry-steppe belt in the 0–10, 10–20 and 20–30 cm soil layers was 750 and 860, 200 and 130, and 125 and 40 g/m² smaller than the biomass from the respective soil layers of the meadow-steppe and alpine belts, respectively. In addition, the level of saturation of the 20–30 cm soil layer with roots in the alpine belt correlated with the 30–40 cm layer of the meadow-steppe belt, ad the level of saturation of the 10–20 cm layer with roots in the dry-steppe belt corresponded to the 20–30 cm layer of the meadow-steppe belt. In all the belts, however, the root mass was decreased dramatically across the profile from top to bottom. Thus, in the 0–10 cm layer of the dry-steppe belt, it made up 75% of the total belowground biomass in the 0–30 cm layer, in the meadow-steppe belt – 68% of the biomass in the 0–40 cm layer, and in the alpine belt – 78% of the biomass in the 0–30 cm layer.

Table 1. Soil profile distribution of belowground biomass in different vertical belts, in g/m² of air-dry weight

Soil layer, cm	Mean value	Variation range	Coefficient of variation
Dry-steppe belt			
0–10	1138 ± 78	490–2450	5.0
10–20	258 ± 25	80–650	8.1
20–30	122 ± 12	50–330	6.6
Meadow-steppe belt			
0–10	1885 ± 95	1100–3700	3.4
10–20	460 ± 38	107–1210	11.3
20–30	247 ± 21	20–500	25.0
30–40	168 ± 11	100–280	2.8
Alpine belt			
0–10	1997 ± 74	1300–2910	2.2
10–20	390 ± 31	190–900	4.7
20–30	161 ± 15	70–380	5.4

Statistical analysis revealed a substantial variation in the indicators relative to the mean selective variation where the coefficient of variation, i.e. the ratio of the maximum indicator to the minimum indicator, was, in an equivalent manner, dependent on the conditions of the vertical belts and on the soil profile. For instance, the maximum and minimum variation ranges of this indicator (2.8–25.0 and 2.2–5.4, respectively) were observed in the meadow-steppe and alpine belts; in all belts, the minimum coefficient of variation was observed for the 0–10 cm soil layer. T-test analysis confirmed the reliability of the difference in dry biomass of roots as detected between the different soil layers within each vertical belt; between the indicators for three soil layers of the dry-steppe and meadow-steppe belts as well as between the 0–10 and 10–20 cm layers of the dry-steppe and alpine belts.

The findings from determining the character of topographic effects on the soil profile distribution of roots in the dry-steppe and meadow-steppe belts revealed that the root habitable soil layer in the hilly and plain areas of the dry-steppe belt showed the presence of 1483 and 1315 g/m² of dry belowground biomass, with 2508 and 3268 g/m² corresponding to the respective areas of the meadow-steppe belt (Table 2). Some differences were also observed in the belowground biomass distribution in separate soil layers: in the hilly and meadow-steppe areas, the 0–10 cm surface layer accumulated, respectively, ≈ 80 and ≈ 64% of the total root biomass, whereas no substantial differences were observed in the plain area of the two belts. For the subsequent two soil layers the following regularity was obtained: in the hilly area of the dry-steppe belt, the level of saturation with roots was much lower than that in the meadow-steppe belt, with the opposite situation occurring in the plain area (see Table 2).

Thus the investigation into the belowground biomass from the areas used in the comparison showed that 76–80% of the total biomass in the dry-steppe belt is concentrated in the 0–10 cm soil layer, about 12% – in the 10–20 cm layer, 7–8% – in the 20–30 cm layer, and 1–4.5% – in the 30–40 cm layer; furthermore, the 20–40 cm soil layer showed a higher level of saturation with roots in the plain area than in the hilly area. In the meadow-steppe belt, the belowground biomass in the 0–10, 10–20, 20–30 and 30–40 cm layers made up, respectively, 64–80, 10–20, 6–12 and 2–4% of the total amount. On the other hand, compared to the hilly area, the level of saturation with roots in the plain area was higher in two layers: 0–10 and 30–40 cm.