Man-induced transformation of mountain meadow soils of Aragats mountain massif (Armenia)

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M H Avetisyan

Center for Ecological-Noosphere Studies NAS RA, 0025 Yerevan, Armenia
E-mail: marieta.avetisyan@cens.am

Abstract. The article considers issues of degradation of mountain meadow soils of the Aragats mountain massif of the Republic of Armenia and provides the averaged research results obtained for 2013 and 2014. The present research was initiated in the frames of long-term complex investigations of agroecosystems of Armenia's mountain massifs and covered sod soils of high mountain meadow pasturelands and meadow steppe grasslands lying on southern slope of Mt. Aragats. With a purpose of studying the peculiarities of migration and transformation of flows of major nutrients namely carbon, nitrogen, phosphorus in study mountain meadow and meadow steppe belts of the Aragats massif we investigated water migration of chemical elements and regularities of their leaching depending on different belts. Field measurement data have indicated that organic carbon and humus in a heavily grazed plot are almost twice as low as on a control site. Lysimetric data analysis has demonstrated that heavy grazing and illegal deforestation have brought to an increase in intrasoil water acidity. The results generated from this research support a conclusion that a man's intervention has brought to disturbance of structure and nutrient and water regimes of soils and loss of significant amounts of soil nutrients throughout the studied region.

1. Introduction

It is generally agreed today that human activities interfere with most processes produced by nature and finally lead to disturbances in ecosystem development, soil and vegetation pollution with diverse substances, loss of most essential biogenic substances from soils, decreasing contents of humus, deterioration of soil fertility and productivity of plants and as a consequence to soil degradation and desertification.

One of man-induced factors of transformation of the Aragats massif's soils has been heavy grazing and illegal deforestation. Heavy grazing across the study region has already brought to destruction of soil cover, sod slip and pasture degradation namely replacement of perennials by annual plants, decrease of root penetration depth, soil compaction, deterioration of soil water and air balance that finally leads to soil erosion [1, 2].

In respect of deforestation one should mention that such activities disagree with national forest protection standards and measures and largely contribute to acceleration of eluvial processes and consequent removal of biogenic elements by intrasoil runoff. A change in elemental composition of intrasoil runoff proves that actually there occurs a significant disturbance of balance between major biogenic substances. It is also essential, that in natural conditions the balance is maintained by a dynamic equilibrium of eluvial and illuvial processes running in forest soils [3, 4].

Due to manmade activities in the Aragats massif like other mountain regions of Armenia loss of stored biogenic elements (carbon, nitrogen, phosphorus) from soils is followed by mineralization of a considerable amount of organic matter. Simultaneously biogenic elements change from organic into inorganic form, thus contributing to their leaching from soil to ground and surface waters. One of factors determining loss of biogenic substances is intrasoil runoff [4].

One should mention that lysimetric studies of intrasoil runoff are one of best informative methods when implementing complex landscape-biogeochemical investigations into condition and functioning of mountain ecosystems. Lysimetric solutions characterizing vertical migration of a flow of substances not only partially reflect biogeochemical cyclisity, but also provide direct information about geochemical specificity and functioning of ecosystems [5].

This research was done in the frames of long-term complex investigations of geoecological problems of agroecosystems of Armenia's mountain massifs. We studied high-mountain meadows and pastures found in meadow steppe and alpine belts of the Aragats massif.

With a purpose of studying the peculiarities of migration and transformation of flows of major nutrients namely carbon, nitrogen, phosphorus in mountain meadow and meadow steppe belts of the Aragats massif we studied water migration of chemical elements and regularities of their leaching depending on different belts.

The article considers the averaged research results obtained in 2013 - 2014.

2. Material and methods

The research covered alpine mountain meadow sod soils (2700-3250m a.s.l., pastureland) and meadow steppe (2080-2700m a.s.l., grasslands) belts of southern slope of Mt. Aragats.

Soil sampling and analyses were carried out by accepted methods of landscape-geochemical investigations [6, 7].

Atmospheric deposition and lysimetric waters were sampled from monitoring stations located in the noted belts at 3250m a.s.l. (the Aragats station) and 2080m a.s.l. (the Hamberd station).

The initial stage of analytical treatment of samples included a solid-liquid phase separation of solution.

Vertical soil runoff was studied by lisymetric method that both provide information about the capacity of soil runoff, chemical composition and migration of soil water elements and allows to assess loss of nutrients in the result of leaching [5]. The lysimeters were installed plane into 0-10 and 0-50 cm deep soil layer to minimally damage soil structure and composition.

Macro components in all water samples were determined through accepted hydrochemical methods [8, 9].

3. Results and discussion

According to research results, concentration of solutes in atmospheric precipitation vary within wide limits that is typical of high-mountain regions and is associated with the dynamics of a number of meteorological factors namely temperature, air humidity, wind direction and velocity as well as intensity and amount of atmospheric precipitation [10].

Recent studies of composition of atmospheric precipitation in mountain ecosystems have indicated that over the years the contents of chemical substances in atmospheric precipitation and rates of mineralization (at pH – 7.3-7.4) have been increasing. Meadow steppe vs. alpine belt exhibited high contents of chemical elements which might possibly be connected with high levels of air pollution in the given belt [1].We have also established that in atmospheric precipitation hydrocarbonates and sulfates are present in large quantities. By averaged contents cations were dominated by calcium and magnesium, anions – by sulfates. A descending order of cations is represented by the following descending series: $Ca^{2+}>Mg^{2+}>K^{+}>Na^{+}$, anions – by $SO_4^{2-}>HCO_3^{-}>Cl^{-}$.

It is known that the basic ecosystem's equilibrium maintaining mechanism depends on soil cover, where the flow of atmospheric substances is distributed between vegetation and ground waters [3].

The soils of Aragats massif differ by thickness of humus horizon and contents of organic matter. Such differences are mainly determined by the height a.s.l, exposition and steepness of slopes and vegetation cover [10].

Collation between newly obtained and earlier data [11] has indicated that the contents of humus in meadow steppe soils vary 5 to 8%, those of total nitrogen – between 0.20 and 0.33%. The content of total phosphorus is high (0.19-0.26%), and potassium – low (1-1.4%). Those soils are not rich in available nitrogen and phosphorus and are moderately and well supplied with potassium. Mountain meadow sod soils of the alpine belt are characterized by high contents of humus (10-12%) and total nitrogen (0.30-0.80%). As compared with meadow steppe soils, the contents of total phosphorus in mountain meadow sod soils are higher (0.20-0.40%) which is determined by its more intense bioaccumulation in the humus horizon, potassium being significantly lower in mountain meadow sod soils. The latter vs. meadow steppe soils of meadow steppe belt are well lower in total and mobile potassium. This phenomenon is explained by a “lighter” granulometric composition of mountain meadow sod soils of alpine belt. From meadow steppe towards mountain meadow soils the content of humus, total nitrogen, phosphorus and soil acidity increases, whereas that of potassium decreases.

High contents of humus, total nitrogen and phosphorus in mountain meadow sod soils of alpine belt are determined by peculiarities of soil formation processes running under humid climatic conditions and relatively low temperatures. These conditions contribute to the accumulation of organic matter and make it difficult to decompose, which prevents the removal of organic matter from the ecosystem [10].

The important role of soil organic matter is that it improves soil structure when transformed by soil microorganisms. The organic and mineral acids released by microorganisms promote their cementation into water-resistant aggregates. Formation of soil aggregates is supported by microbial and chemical products of organic matter transformation, humine substances, polysaccharides and microorganic cells [3, 12, 13].

Soil organic matter being the major factor of development of a sustainable ecosystem has a double orientation. On the one hand, it serves as a feed source supporting the activities of microorganisms and therefore determining the intensity of redox processes in soil. On the other hand, soil organic matter involved in redox reactions, has a biochemical effect on soil conditions. Humic substances are also exposed to different transformations leading to destruction of water-resistant aggregates [3, 12, 13].

Earlier researches [2, 4] have indicated that organic carbon and humus in a heavily grazed plot are almost twice as low as on a control site. A decrease in soil organic matter is determined primarily by destruction of physical structure of a surface soil horizon, which - accounting for active reaction of excrements in the upper sod layer of soil - consequently leads to violation of stability of biochemical compounds i.e. soil degradation followed by loss of nitrogen and carbon compounds in gaseous form and leaching of elements.

When assessing deforestation-caused consequences as an ecological risk factor two aspects characterizing condition of soils must be taken into consideration. The first aspect includes disturbance of stability of vegetation cover in the result of negative deforestation-caused changes in soils and a possible significant and rapid change in physico-chemical properties of soil under humid climatic conditions and a sharply sloped relief. The second aspect includes assessment not only of changes in ecological conditions, but also associated ecological risks given the use of the natural resources of the study region. These two aspects underlie a full-scale assessment of natural potential and resource power of the study region and ecological changes in it [3, 4]. Hence, the eco-geochemical situation, which emerges on deforested areas leads to loss of nutrients, being determined by disturbance of dynamic equilibrium of soil formation and ecosystem processes.

Lysimetric data obtained from this research (table 1) have indicated that deforestation entails an increase in intrasoil water acidity by 1.4-1.7 units.

The influence of intrasoil water acidity accelerates eluvial processes and therefore contributes to the removal of biogenic macro and micro components by runoff. This in turn leads to a dramatic decrease of soil nutrients at root nutrition [4, 5].

In intrasoil water at a depth of 0-50cm concentration of Ca^{2+}, Mg^{2+}, K^{+}, PO_4^{3-} decreases by 1.5-2.6 times.

It is known that under direct solar exposure humus substances are built up in the uppermost layer, but in mountain conditions the intensity and duration of solar radiation associated with illuvial migration of substances determine the influence of photochemical destruction on humus composition and lower horizons [3, 12], and later on acid solutions influence the mineral composition of soil.

Table 1. Composition of lysimetric waters in mountain steppe zone (before and after deforestation, mg/L).

Study site	*pH*	$C_{org.}$	NO_2^-	NO_3^-	PO_4^{3-}	Ca^{2+}	Mg^{2+}	K^+
				0-10 cm				
Before deforestation (1998)	6.5	30.2	1.5	4.2	0.96	92.4	60.0	43.0
				0-50 cm				
	6.0	22.5	0.3	3.6	0.32	38.9	26.2	28.2
				0-10 cm				
After deforestation (2013-2014)	5.7	31.2	1.3	3.8	0.89	79.0	58.1	25.7
				0-50 cm				
	6.2	25.3	0.2	2.7	0.23	30.2	22.4	19.4

A change in elemental composition of lysimetric waters suggests that actually there occurs a significant disturbance of balance of substances including major components of mineral nutrition of plants: nitrogen, phosphorus, potassium. Under natural conditions the balance of elements is maintained by dynamic equilibrium of eluvial and illuvial processes [2].

Hence, over a relatively short period (15 years) the ecosystem responds to man-induced impacts (heavy grazing, illegal deforestation).

The changes mentioned above caused by an increase in soil acidity have a negative character as migration of substances is followed by disturbance of dynamic equilibrium of eluvial and illuvial processes in soils, changes in condition and physico-chemical properties of soils and intensity of eluvial processes.

The obtained results support a conclusion that in mountain ecosystems, in meadow steppe zone under conditions of intense water exchange on deforested plots peculiarities of transformation of soil and its further development is determined by peculiarities of soil formation processes and a relatively high activity of ecosystems [2, 3, 4].

The results obtained from this research provide exhaustive characteristics of migration and leaching of major nutrients from different soil types of the Aragats mountain massif.

So, man-made activities affect soil nutrient and water regime and trigger changes in mountain forest soils and consequent leaching of significant quantities of nutrients that finally brings to nutrient deficiency and destruction of soil structure, whereas duration and intensity of such activities determine further changes in ecological conditions of the study region.

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