Journal of Environmental Biology
p-ISSN: 0254-8704 • e-ISSN: 2394-0379 • CODEN: JEBIDP

JEB®

Original Research Paper
Volume 45 Issue 2 March 2024 pp. 145-151
DOI: http://doi.org/10.22438/jeb/45/2/MRN-5201

J. Environ. Biol., 2024

Journal website : www.jeb.co.in ★ E-mail : editor@jeb.co.in

Socio-ecological system of the mountainous region: A case study from Georgia

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Received: 24 November 2023 **Revised:** 25 December 2023 **Accepted:** 30 January 2024

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Abstract

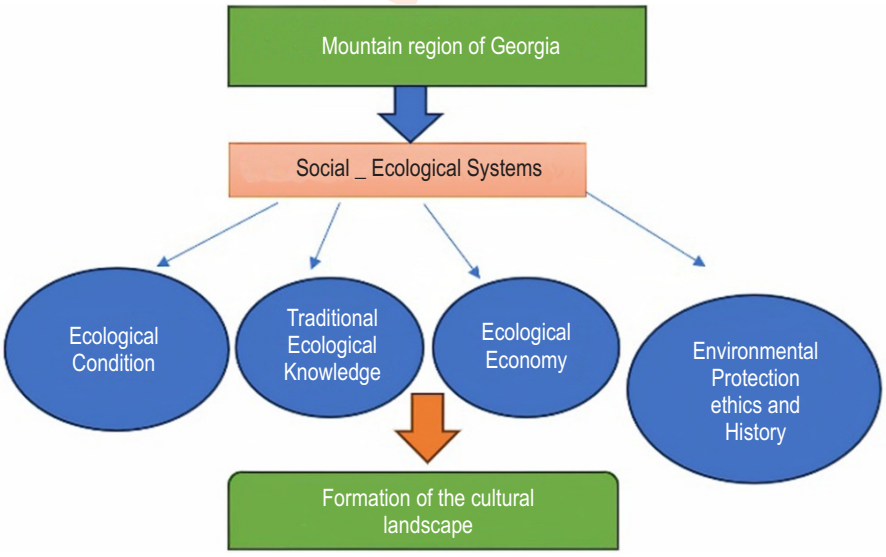
Aim: The research aim to study the change to characteristics of the socio-ecological system of the mountain regions of Georgia.

Methodology: Research methods included geographic, cartographic, ecosystem, and landscape research methodology, landscape-ecological analysis and synthesis methods, and social-ecological systems concepts.

Results: The results showed the following: Ecological characteristics of medium and high mountain natural landscapes and ecosystems within the Central Caucasus (Georgia's historical-geographical province of Pshav-Khevsureti); Main forms of cultural landscape, their economic and social values of the mountain region; Environmental protection of the local population, ethics and environmental history and the ecological, economic, and social culture of the population of the mountain region.

Interpretation: In the mountainous regions of Georgia, there is a high potential for creating cultural landscapes, based on the results of the long-term and effective interdependence of man and nature. Cultural landscapes, depending on their importance, will further increase the sustainability of the socio-ecological system of mountainous regions.

Key words: Cultural landscape, Ecological culture, Georgia, Mountainous regions, Socio-ecological system



How to cite: Elizbarashvili, N., T. Pilauri, R. Elizbarashvili, L. Grigolia, G. Sandodze, S. Abramishvili and L. Bubashvili: Socio-ecological system of the mountainous region: A case study from Georgia. *J. Environ. Biol.*, **45,** 145-151 (2024).

Introduction

Mountain areas occupy almost a quarter of the world's land area. Mountain regions differ in geographical location, area, height, orography, altitudinal zonation, barrier properties, origin, development, bio-and-landscape diversity, air, natural resources, demographic conditions, ecological problems, etc. Natural and socio-economic processes are connected in a specific way in the mountains, which determines the features and problems of sustainable development of the local society. A cultural landscape is part of natural and cultural heritage. It clearly shows the peculiarities of the origin and development of the country (territory), the mutual dependence of man (local community) and nature. The historical, ecological, agrarian, ethno-cultural and other values of the area are reflected in the cultural landscape. The main ones are: Urban - reflects the historical value of the landscape; Ecological-considers the environmental, recreational and environmental restoration value of the ecosystem; Religious-takes into account the religious value and status of the landscape; and Traditional and ethnocultural. Through cultural landscape, it is possible to get an idea of the natural potential of the landscape and ecosystem, ecological features, and economic and social values (Elizbarashvili *et al.,* 2022; Tarolli and Straffelini, 2020).

High, medium, and low mountains are mainly related to the height of the place (Price *et al.,* 2013; Elizbarashvili *et al.,* 2018). If we consider mountains according to terrain, in this case, we will have three forms: high mountain, medium mountain and low mountain terrains. The division of mountains in the world according to their height is conditional (according to geographical location and climate), which cannot be said in the case of landforms. High mountains are characterized by steep slopes and clearly defined peaks, which are due to glaciation and intense physical exhaustion. The medium-mountainous and low-mountainous terrain is characterized by relatively rounded peaks and steep slopes. Low-mountainous and sub-mountainous landforms can be found in the high mountains, where different ecological environments and socio-economic opportunities are created (Price et al., 2013; Elizbarashvili *et al*.,2018).

In the highly dissected landscapes of mountainous ecosystems, bioclimatic conditions change rapidly and vary within short distances, resulting in a pronounced heterogeneity of soils and their chemical, physical and biological properties (Bäumler, 2015; Bargali *et al.,* 2018; Vibhuti *et al.,* 2020). Physico-chemical properties of soils vary in space and time because of variations in topography, climate, weathering processes, vegetation cover and microbial activities (Paudel and Sah, 2003; Bargali *et al.,* 2019; Manral *et al.,* 2022) and several other biotic and abiotic factors (Bargali *et al.,* 2015; Manral *et al.,* 2020). This could directly affect the vegetation types and their functions in these fragile ecosystems (2022; Bisht *et al.,* 2023). Agricultural expansion and intensification along with population pressure and other developmental operations have changed the land use patterns at a global scale (Karki *et al.,* 2021). The land use systems effectively influence the fertility and stability of an ecosystem and have been accepted widely as a vital source of nutrients due to their quick turnover (Manral *et al.,* 2023). The Central Caucasus is the highest in the Caucasus Mountains and is characterized by a well-defined altitudinal belt. Here, with the increase in altitude, the geological structure, weather, soil-vegetation cover and ecosystems change (Elizbarashvili *et al*., 2021). The orographic factor reflects the peculiarities of the seismic activity and geological structure of mountainous areas, which, together with the climate, determines the division of the terrain and the intensity of geodynamic processes. They directly determine the potential of human living and economic space in the mountains. The latter determines the level of development, ecological culture, and social problems of the mountain population. An important geographical factor creating a climate in the mountains is the exposure of the terrain, which creates a different microclimate and consequently different ecosystems (Elizbarashvili *et al.,* 2018). It is also worth noting the barrier properties of mountain systems, which significantly determine not only the nature of the formation of the natural environment or the character of natural events, but also the peculiarities of geopolitical and socio-economic processes. In the historical past, mountains were mainly a natural barrier that defined the air, river basins, landscapes (Erikstad, *et al.,* 2015; Li *et al*.,2020; De Groot and Born, 2003), ecosystems (Bailey, 2009) and also–the configuration of states.

Several independent peoples, cultures, languages, and traditions were formed in the mountains. The territorial distribution of the population in the mountains is determined by the natural-geographical, socio-economic, historical, and cultural values. Despite harsh climatic conditions, high fragmentation of the terrain, steepness of the slopes and lack of arable land, in the historical past, the population was ten times more in the mountainous regions of Georgia. Currently, intensive population migration and a negative age structure are noticeable in most of the highland settlements. In addition, several ecological problems are clearly expressed in the mountainous ecosystems, which lead to the degradation and impoverishment of natural diversity (Elizbarashvili *et al*., 2021), due to the following reasons: Degradation of the productivity of subalpine and alpine meadows caused by the increase in the number of cattle on pastures; Degradation of high and medium mountain forests, due to intensive use of forest resources); Intensive erosion and denudation processes (related to climate change). and 4. Reduction of water resources (related to the melting of glaciers and changes in the seasonal distribution of snow cover).

It is a fact that the law "On the Development of Mountainous Regions" adopted a few years ago did not have the expected effect. The policy of "containment" of the population in the mountainous regions of Georgia also requires a detailed study of the social-ecological system of the mountain (Partelow *et al.,* 2019). The development policy of mountainous regions of European countries should be considered, which is essentially related to the Alps, Carpathians, and European landscape conventions (Nève, 2019). Conservation, planning, management, and development of mountain ecosystems can be

carried out based on the mountain socio-ecological system. This research work surveys the complex study of the socio-ecological systems of the mountainous regions of Georgia, which has not been carried out so far. The reason of the research is related to the assessment of the geographical environment of the mountainous regions, the study and analysis of the traditions of natural environment use, the environmental ethics of the local population and the history of environmental use. The reason of the research is also related to the problems of climate change trends and depopulation, preservation and sustainable use of the natural environment in mountainous regions of Georgia.

Materials and Methods

The research methods following during the causes of study were geographic, cartographic, ecosystem and landscape research methodology, landscape-ecological analysis and synthesis methods, the concept of social-ecological systems, field and aerial survey methods, statistical analysis, social research and landscape planning methodology. During the landscape and ecosystem analysis of the area, attention was paid on the characteristics as the modern state (structure and functioning), forms and scales of impact, natural potential, sustainability and socio-economic functions (Elizbarashvili *et al.,* 2022; Kiryushin, 2018).

The status of landscapes, natural and anthropogenic conflicts, natural potential and sustainability of areas were evaluated by geo-ecological analysis and synthesis, and methodology of landscape planning (Sayadyan *et al.,* 2009, Elizbarashvili *et al.,* 2023). The methodology can be used to gain and distribute information about the modern state of the landscapes, types and scales of anthropogenic impacts, and potential, stability, and functions of landscapes. However, the methodology of landscape planning fails to consider the specifics of mountainous areas, and the principles of realizing a "Green Plan", methods to plan the resorts and agro-landscapes, etc., are to be developed within the scope of the given methodology.

The goal of the geo-ecological investigation of the landscape is to identify various mutual connections and the spatial-temporal variety, which exists between nature and society. By that, the research of territorial organization, landscape and ecosystem components ecological condition of its morphological units, and their interrelation are the main essence of the geo-ecological investigations. Special attention was paid to the study of the ecological culture of the population of the middle and high mountainous region of the Pshav-Khevsureti historical-geographical province of Georgia within the Central Caucasus, which has not been carried out in detail to date. A methodology related to environmental ethics, environmental history, ecological economics and traditional ecological knowledge was used in the research of social-ecological systems of Pshav-Khevsureti (Partelow, *et al.,* 2019; Nagel *et al.,* 2022, Colding and Barthel, 2019; Elizbarashvili *et al.,* 2012). In Pshav-Khevureti agriculture was mainly related to the production of grain, the remainder of which was used in animal husbandry, arable land is divided into rural, man-made, or riverside terraces, and mountain fields. Environmental ethics are related to regulations (related to the use) of mountain forest ecosystems.

Results and Discussion

Forms and scales of external influence determine the condition of landscapes and ecosystems. The character of influence can be considered by the ability of self-regeneration of the landscape and ecosystem structure. It is admitted that if the influence concerns the biological components only, the landscape maintains the self-regeneration ability. The self-regeneration mechanism is impossible to maintain, if the influence coincides with or stimulates (increases) the negative natural processes (machines, salinity, ravines, erosion, and so on); The basic landscape and ecosystem creator component or relief and climate is under influence and if one ecosystem is replaced by another equivalent one (Elizbarashvili *et al.,* 2022).

In many mountainous regions of Georgia, cultural landscapes are presented in the form of fortified villages, which represent a classical type of socio-ecological system. They simultaneously had a residential, religious, defensive, household, and economic purpose. It is interesting that in the poetry and ethnographic materials of the people living in the mountainous regions, castles and castle towers are full-fledged characters that God created to serve the people and, if necessary, to fight the enemy. The medieval castles built on rocky slopes in Pshav-Khevsureti were distinguished by their special architectural structure, construction art, sustainability, and landscape design. For example, the fortress-village of Shatili and Mutso is a unity of military towers, residential houses (towers), agricultural buildings, monuments, and cult-religious monuments. Here, five-six-story residential buildings are built in the form of several-level terraces, for which dry piles of clay and shale are used. The first terrace of the house is oval shape and is surrounded by fortress houses. The outer walls of the residential buildings on the second or middle terrace have a combat and defensive function. In the castle houses, the first floor housed a cattle pen, the second floor-a sheep stall, and the third and fourth floors housed living space. The fifth and sixth floors were used to store food and ammunition. Khevsurian Villages were planned empirically, taking in an order scale of human needs, space experience based on walking speed, and spiritual imprint. Today this type of planning is known as flânerie-style settlement space construction (Zhang *et al.,* 2024). Flânerie-style planning is the most harmonic way to develop settlements in line with the relief (terrain).

The population of Pshav-Khevureti was mainly engaged in farming and cattle breeding, however, the difficulty of the terrain and harsh climatic conditions prevents the development of these industries at a high level. In Pshav-Khevsureti, cattle breeding

Table 1: Geographical and ecological characteristics of mountain ecosystems

Landscapes	Geographical area (Schematic map)	Geographical characteristics	Ecological characteristics
Middle Mountainous Thermo-Moderate Semi-humid (meadows)		Altitude 800 - 1300 m, T^0= -3.0, +25.0 Precipitation: 400 - 500 mm Evaporation - 800 mm Phyto mass: 3 - 5 t/ha	Drought - 3 months Process: accumulation, erosion Impact - Animal husbandry, mowing Climate change – low Sustainability - medium
Middle Mountainous Thermo-Moderate Semiarid (meadows)		Altitude 1700 - 2000 m, T^0= -1.0, +24.0 Precipitation: 400 - 500 mm Evaporation - 900 mm Phyto mass: 1 - 3 t/ha	Drought - 2 months Process: erosion, denudation Impact - Animal husbandry, mowing Climate change – low Sustainability – medium
High Mountainous Cold-Moderate (meadows)		Altitude 2000 - 2600 m, T^0= -5.0, +13.4 Precipitation: 1500 - 2000 mm Evaporation - 700 mm Phyto mass: 20 - 30 t/ha	Drought - 0 months Process: erosion, denudation Impact - Animal husbandry, mowing Climate change – low Sustainability - high
High Mountainous Thermo-Moderate Semiarid (meadows, steppe)		Altitude 1700 - 2300 m, T^0= -7.0, +24.0 Precipitation: 600 – 700 mm Evaporation - 900 mm Phyto mass: 10 - 40 t/ha	Drought - 2 months Process: accumulation Impact - Animal husbandry, mowing Climate change – low Sustainability - high
High mountain alpine (meadows)		Altitude 2800 - 3400 m, T^0= -5.0, +13.4 Precipitation: 1500 - 2000 mm Evaporation - 600 mm Phyto mass: 30 - 40 t/ha	Drought - 0 months Process: erosion, denudation Impact - Animal husbandry, mowing Climate change – low Sustainability - high

and sheep breeding were developed. Agriculture is mainly related to the production of grain, the of which was used in animal husbandry. In Phshav-Khevsureti, the husbandry was developed as pastoralism, plant cultivation, largely of grain, mainly used to feed animals during winters. In mountainous regions, the arable land is divided into rural, man-made or riverside terraces and mountain fields. The agricultural lands located close to the dwelling house were easily fertilized with organic fertilizers, which were characterized by high fertility. The terraces and the lands in the hilly part of the mountain, which were quite far from the villages, were enriched with biological fertilizer every three years. They were periodically used as pastures, where cattle or sheep fertilized the soil naturally.

The process took place at an altitude of 2000-3000 m. This is a unique example of agropastoral farming and agrarian trilogy. Summer pastures and meadows were present in quite large areas within the subalpine and alpine ecosystems. Due to lack of winter pastures, they did not have a large amount of goods. The winter lasted for 7-8 months, during this time the cattle were kept on stallfeed. The mowers were in good number, however, due to steeps slopes, mowing and gathering fodder for livestock during winter was difficult. A special salt is used for cattle, which contains minerals and is useful for the animal. It was brought from neighbouring regions and was expensive. Mineral waters were used, and the people boiled mineral waters and obtained salt from them in large quantities.

In the mountainous regions of Georgia, hunting was an auxiliary of farming, at the same time, it was also a part of training of the military forces. Hunting was considered a prestigious activity for men. There were different rules for hunting in different regions of Georgia. Not everyone could become a hunter, he needed physical strength, courage, and right-handedness, at the same time it was believed that the hunter should have the support of the local deity. Both alpine and middle mountain forest animals were hunted in Pshav-Khevsureti. The rules that had to be followed for the hunter's safety and successful hunting were widely known. A hunter was not allowed to kill a large number of animals because it would displease the religious deity of the hunt. The skin of the hunted animal belonged to the one who killed the animal, the horns were given to the shrine, and the meat was shared equally with other hunters. Environmental ethics are also related to regulations (related to the use) of mountain forest ecosystems.In Pshav-Khevsureti, there was one main shrine and several other shrines in the territory of each community.

Among them was definitely "the Mother of the place" (Genius Loci).

The shrines were built in prominent places and among sacred trees. Ash (Fraxinus) and Oak (Quercus) were considered sacred trees here. Pshav-Khevsureti shrines also had forests, which were considered a sacred place and public property. It was forbidden to cut wood in such a forest, even goods were not allowed in it, if the goods were to enter and get lost in the forest area, no one would start looking for them. It was forbidden to harvest the fruit of the tree and even the berries. It should be noted that the forest groves connected to the shrines were distinguished by their biodiversity, environmental protection and environmental restoration function. They protected settlements from avalanches and slopes from erosion and denudation processes. The forest ecosystems associated with the shrine are still abundant in the mountainous region of Georgia, which the local population protects according to old traditions. Forest resources are poor in Khevsureti, therefore, Khevsurians had a particularly careful attitude to the forest. It was forbidden to cut trees after May, grazing was not allowed in the new cut forest. Areas of the forest belong to the Shire (Khat-Jvari), which is a strictly protected zone. The forests belonging to Khat-Jvari (Shrine) have been preserved to this day, and Khevsurian people still take care of these forests in accordance with the Khevsurian social law, called “Sjuli”. Hunting was also prohibited in the vicinity of shrine. In our opinion, the traditional variety of protected areas and their location should be determined by natural factors (Elizbarashvili *et al.,* 2021).

The mountainous region of Georgia, in particular the historical-geographical province of Pshav-Khevsureti, is distinguished by a unique socio-ecological system. It was formed over millennia. The local population, under difficult geographical and climatic conditions, was able to fully protect environmental ethics, develop an ecological economy, transfer traditional ecological knowledge from generation to generation, and create a history of sustainable ecological development. Herding and hunting traditions, architecture, land cultivation and fertility enhancement rules, forest and biodiversity preservation principles create a unique socio-ecological system of the mountainous landscapes. This means that the mentioned province stands out not only in Georgia but also in the entire Caucasus. The study of the socio-ecological system of mountainous regions is an interesting and promising scientific-practical task. This is especially true for the Caucasus, where such studies were practically not carried out. (Elizbarashvili *et al.,* 2018). There are a large number of ethno-cultural publications, but the ecological culture of the local population is rarely covered among them. However, preliminary studies show that the ecological ethics, ecological history and traditional ecological knowledge of the mountain population of Georgia deserve a lot of attention. The experience related to the use of water and climatic resources, traditions of using plant and mineral raw materials in folk medicine, forms and means of light industry and food industry are especially interesting. It is a fact that climate change trends increase reimmigration trends in mountainous regions, the importance of tourism and energy development, and the importance of sustainability of ecological and socio-economic processes of the area. It is also worth noting that in the mountainous regions of Georgia, there is a high potential for creating cultural landscapes, which is based on the results of long-term and effective interdependence between man and nature (Elizbarashvili *et al.*, 2012).

The creation of cultural landscapes, depending on their importance, will further increase the sustainability of the socio-ecological system of mountainous regions. Mountain ecosystems are important repositories of terrestrial biodiversity and play a key role in influencing the socio-ecological and cultural attributes of human societies including livelihood activities of traditional societies living as well as those associated with these forests (Karki *et al.,* 2017; Awasthi *et al.,* 2022). Anthropogenic pressures have created major threats to biodiversity and the environment (Bisht *et al.,* 2022) which cause an increase in CO_2 in the atmosphere. The overexploitation of natural resources has created a big gap between the demand and supply of natural resources. These ecosystems provide a wide range of ecosystem goods and services to the inhabitants (Gosain *et al.,* 2015). Thus, these ecosystems are essential for human survival and economic well-being and for ecosystem function and stability. Therefore, proper management along with the maintenance of the carbon pool becomes important to protect these ecosystems from the context of arresting further environmental degradation.

Acknowledgments

We would like to thank Tbilisi State University and the academic staff, where the work on the article was carried out.

Authors' contribution: N. Elizbarashvili: Led the article process; **L. Grigolia, R. Elizbarashvili, G. Sandodze and S. Abramishvili:** Participated in field work and preparation of the article; **T. Pilauri and L. Bubashvili:** Literature search and processing.

Funding: The study was not funded by grants or donor organizations.

Research content: The research content of the manuscript is original and has not been published elsewhere.

Ethical approval: Not applicable.

Conflict of interest: The authors declare that there is no conflict of interest.

Data availability: All authors agree to make the data available to interested parties.

Consent to publish: All authors agree to publish the paper in *Journal of Environmental Biology.*

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