Study of landscape differentiation to optimize the use of natural resources in mountainous regions

A N Gunya\textsuperscript{1,2}, F D Alakhverdiev\textsuperscript{2}, U T Gairabekov\textsuperscript{2}, R S Elmurzaev\textsuperscript{2}

\textsuperscript{1} Institute of Geography, Russian Academy of Sciences, 29, Staromonetny per., Moscow, 119017, Russia
\textsuperscript{2} Chechen State University, 32, A. Sheripov Str., Grozny, 364024, Russia

E-mail: a.n.gunya@igras.ru

Abstract. The landscape approach is relevant for the study of mountainous areas, and serves to bring order to the complex differentiation of natural conditions and resources. Based on landscape mapping in the different mountain regions of the North Caucasus, Tien Shan and Altai, there are three levels of operational units that can form the basis for optimising mountain nature management: habitats (year-round residence, seasonal farming and fragmented visits), micro-areas (within individual mountain valleys) and mountain areas. The lower mountain range is the subject of interdisciplinary research, involving natural and social scientists.

1. Introduction

The development of mountainous areas and the effective use of natural resources requires knowledge of the basic boundaries that characterise the heterogeneity of natural resource conditions in space and time. Developments in remote sensing techniques and imagery have shown that the extreme diversity of mountain nature is difficult to unify. The available knowledge about physiographic differentiation focuses mainly on differences due to the distribution of vegetation. Consideration of other landscape differentiation factors (relief, moisture, soil-forming rocks, etc.) requires field mapping, large-scale maps of physical-geographical differentiation are only available for individual areas, and extrapolation of the resulting patterns to other areas requires proven algorithms.

Although there are geo-information methods, the GIS data set is so large that it exceeds the capacity of scientific teams and, again, raises the challenge of developing simplification and streamlining algorithms. The pursuit of new data, facilitated by the development of GIS and remote sensing techniques and the acquisition of high and ultra-high resolution images of the earth's surface, does not completely solve the problem of data collation with further access to the user and solution of specific environmental problems [5].

There are currently two main approaches in the study of natural differentiation of mountainous areas. The first approach involves the study of individual processes and components with the selection of relatively simple indicators (e.g. forest boundary, snow boundary, land use types, etc.). The study of altitude belts (including the upper limit of the forest) generally serves to relate to and assess current changes.

The second approach focuses on studying structures and selecting integrated indicators of landscape, landscape structure, nature-population-economy geosystems [4]. A landscape is a complex structured and well-organised system that is not reducible to a simple combination of components. The
landscape approach to the study of mountain territories is well developed in the works of the scholars of mountain landscape science (N.A.Gvozdetsky, G.P.Miller, N.L.Beruchashvili and others). The best known and most detailed tool for mapping mountain landscapes lay in N.A. Gvozdetsky’s ideas about the typological understanding of natural complexes [3]. However, the second approach is seldom used to date to map mountain landscapes. Landscape mapping refers to any delineation of spatial units, often without a hierarchy (in an extreme case, a delineation of altitude-zonal units occurs).

Landscape differentiation is, on the one hand, to be understood as the process of identifying and ordering natural complexes of different ranks and types, and, on the other hand, as the result of natural differentiation recorded at a certain point in time, involving the spatial visualisation of identified natural structures.

Landscape mapping, as one of the main methods of ordering natural complexes, involves the identification of natural complexes themselves, revealing spatial organisation and hierarchy. The researcher often settles on one type of landscape differentiation appropriate to the research objectives. It is common to think that as many researchers as there are variants of a landscape map. It seems that there may be differences, but the main structures and boundaries will be similar from one researcher to another. In the mountains, these more or less clearly distinguishable boundaries include altitude-zonal boundaries.

Landscape structure is a reflection of a complex combination of different factors. The landscape allotment characterises a living space of a certain type and rank. The hierarchy of factors reflects the different “strengths” of natural boundaries. There is no single hierarchy - it can vary from region to region and even locality to locality. Landscape organisation is usually identified on the basis of field research experience. Identifying landscape differentiation allows the levels of natural hierarchy to be compared with the scale of human action and institutional levels of governance.

Environmental management is more effective when the scale of natural processes is well aligned with the human institutions responsible for managing human-environment interactions [2]. On the other hand, the reference point for physiographic research can be the scale of human activity, the search for optimal spatial operational units that would, on the one hand, characterise a certain hierarchical level of physiographic differentiation and, on the other hand, the territorial scale (coverage) specific to particular natural resource users. It is this aspect related to the relationship between physical-geographical differentiation and the scale of human activity in the mountains that served as the objective of this study.

2. Materials and methods

The materials for the study include field research in the regions of the Caucasus, Central Asia and the Altai, resulting in landscape maps and land use maps for different years. To study land use and settlement boundaries, we have produced large-scale maps (1:100,000) for areas within the valley of rivers Argun and Yaghnob, as well as the Kosh-Agach district of the Altai Republic.

The study of boundaries was facilitated by the creation of altitude profiles that crossed the most characteristic combinations of landscapes of different types and subtypes (steppe, forest, meadow), formed on unequal rocks and slopes of different exposition. We paid special attention to determining the upper limits of forest and mountain meadows, the steppification of meadow landscapes, the characteristics of forests of different types (small-leaved, broad-leaved), and the influence of mountain rocks on the differentiation of biogenic components.

Extrapolation of field data used large-scale 1:50,000 and 1:100,000 scale topographic maps that are available in the Internet environment, as well as Google Maps and satellite images of various scales. Establishing the lower boundary of the mountains was important in the process of preparing altitude profiles and studying the settlement system. The identification of this boundary faced the need to involve not only data on natural processes, but also on land use. Belonging of settlements to mountains or foothill plains is an unexplored area of research that requires the development of interdisciplinary methods (not only physical-geographical, but also social).
3. Results and discussion

The most distinct landscape differences in elevation are associated with two altitude limits: the upper limit of forest distribution and the upper limit of vegetation distribution. The mountain-steppe zone is usually absent in arid depressions. It is replaced by mountain-steppe and its modifications (mountain-meadow-steppe, mountain-forest-steppe, rarely mountain-desert). The altitude spectrum of landscapes represents the basis of management for the three main habitat zones, which are confined to the main landscape types: 1) nival, represented by nival-glacial landscapes, with fragmented visitation, mainly for recreational and scientific purposes, 2) alpine, represented by mountain-meadow landscapes, with seasonal farming (mainly summer pastures), 3) mountainous proper, often designated as montane and represented by mountain forest, mountain-steppe, mountain-grassland landscapes with year-round habitation and management (Table 1). The boundaries of the habitat zones gradually descend towards the north and west. Economic activity within the zones is fragmented along individual gorges and river valleys, forming distinctive micro-areas. The micro-areas have landscapes with specific villages, localised grassland habitats and mountain recreational facilities.

**Table 1.** Habitat zones and their altitude boundaries (average variant) in the mountains of the North Caucasus, Tien Shan and Altai

| Habitat zones        | North Caucasus (easten part) | Tien Shan (southern part) | Altai (within the Republic of Altai) |
|----------------------|------------------------------|---------------------------|-------------------------------------|
| Fragmented visits    | above 3000-3500               | above 3200-3500            | Above 2800-3000                     |
| Seasonal farming     | 2600-3200                     | 2800-3500                 | 1900-3000                           |
| Year-round residence | Up to 2600                    | Up to 2800                | Up to 1600-1900                     |

The fragmentation of habitats in the mountains, making natural resource management difficult and increasing development costs, has led to the need for support programmes for mountain dwellers. In this context, the question of which mountainous areas need state support and investment became a central issue. The uncertain status of mountain territories creates difficulties in reflecting mountain specifics in the most important strategic planning and development documents and programmes of Russia. We can consider the inclusion of the item “On criteria for attributing municipalities of the Russian Federation to mountain territories, as well as on the formation of a set of measures for the sustainable development of some territories of the Russian Federation belonging to mountain territories” in the implementation plan of the Spatial Development Strategy of the Russian Federation as a breakthrough in this respect and recognition of mountain specificity at the state level.

Studies have shown that municipalities can be located in foothill areas but use the resources of mountainous landscapes. The establishment of a list of mountain municipalities is closely linked to the establishment of a lower mountain boundary, which does not follow administrative boundaries, but is closely related to the landscape structure in the mountain-foothill catenary [1]. There are currently several definitions of "mountainous area". For example, the Law of the Republic of Dagestan (2010) defines mountainous areas as areas above 1,000 metres and areas with rugged terrain and relative elevations of 500 m or more within a radius of 25 km.

According to the Law on the Status of Mountainous Areas in the Republic of North Ossetia-Alania (2019), a mountainous area is an area with rugged terrain and an absolute elevation above 800 m. Research shows that a formal criterion such as absolute altitude above sea level is not sufficient to classify a municipality as a mountainous area. For example, the area of mountainous areas in the Russian Federation, according to geo-information calculations of areas, changes several times depending on altitude. If we assume that mountains begin at altitudes above 1,000 metres, the mountainous areas of the Russian Federation account for about 8%. If we count mountains above 300 m, then the area of mountains in the Russian Federation would be 40%. However, in the Far North, mountain hills are also less than 300 metres high and should be classified as mountains.
According to geo-information calculations, the area of mountainous territories in the North Caucasus Federal District (NCFD) above 300 m covers almost half of the entire NCFD, and above 1,000 m only a quarter (Table 2).

| Altitude limits | Area, % |
|-----------------|---------|
| more than 300 m | 47.7    |
| more than 500 m | 40.3    |
| more than 800 m | 33      |
| more than 1000 m| 26.7    |

The maximum altitude of settlements varies by almost 1,000 metres: 1,600 metres in the West (Dombai) and 2,650 metres in the East (Kurush). In the Urals, the mountains of Siberia and the Far East, the vast majority of settlements are below 1,000 metres. Rare settlements in the mountains of southern Siberia, such as the Altai, reach up to 1,500 metres. This means that areas above these marks are not inhabited. However, the local population uses the resources of the landscapes here for distant livestock husbandry or tourism. Assessing the extent to which the population resides in a given mountainous area reveals large differences in actual and formal (registration) residence. In Dagestan, the majority of mountain dwellers live on the plains (in kutans) and are actually assigned to mountain settlements (not living there permanently).

Studies of the full diversity of mountainous terrain in three key areas in the North Caucasus, Tien Shan and Altai showed that it is advisable to develop criteria for classifying municipalities as mountainous based on the identification of altitude zones that differ in the complex natural and socio-economic conditions for livelihood and natural resource use. The location of rural settlements in a particular altitude zone, as well as the location of the main land areas that form the basis of life for the population of these settlements, are important criteria for classifying municipalities as mountainous. The list of mountain municipalities should be determined not "from above" but at the local level, based on the historical settlement system and on detailed local analysis with the involvement of scientists, experts and representatives of local municipalities.

The results of the analysis of natural-geographical and historical-cultural conditions made it possible to identify the main altitude zones in certain regions of the North Caucasus. Thus, 41 municipalities in the Republic of North Ossetia-Alania belong to the mountainous regions of low, middle and high mountainous areas. It is important to emphasise that the resource base of livelihoods in all these zones combines the use of resources from the whole spectrum of high-altitude zones. In Kabardino-Balkaria, 26 municipalities should be classified as mountainous, the lowest boundary being 750 metres above sea level. The Chechen Republic has 400 m as the lowest altitude for the classification of municipalities as mountainous (there are 180 settlements higher than this in the mountains), which marks a sharp complication of the terrain, dissected by mountain gorges. Thus, the examples show that fixing a single altitude for all mountainous entities in the North Caucasus is inadvisable. It is more preferable to define a list of mountain municipalities at the local level, where it is possible to consider both natural and historical-economic aspects.

4. Conclusion
This analysis of the landscape differentiation of mountainous areas has shown that there is a hierarchy of natural boundaries. There are various ways to take these boundaries into account in economic activities and in optimising the use of natural resources. Based on landscape mapping in the different mountain regions of the North Caucasus, Tien Shan and Altai, three main boundaries can form the basis for optimising mountain nature management: the lower mountain boundary, the boundary separating the zone of permanent residence and settlement from the seasonal farming zone, the
boundary above which there is only occasional visiting. Initiatives for legal improvements in the regulation of livelihoods in the mountains require detailed elaboration by scientists in close cooperation with regional authorities and local municipalities.

References

[1] Ataev Z V 2008 Landscape analysis of the low-mountain foothills of the North-East Caucasus Proceedings of Dagestan State Pedagogical University. Natural and Exact Sciences 1(2) 59-67

[2] Baumgärtner J, Tikubet G, Gilioli G 2010 Towards adaptive governance of common-pool mountainous agropastoral systems Sustainability 2(6) 1448-1471

[3] Gvozdetsky N A 1979 Main Problems of Physical Geography (Moscow: Vysshaya Shkola) 222 p

[4] Gunya A N 2008 Dynamics of the development of a mountainous region: structural and institutional factors (on the example of the dynamics of settlement and land use in Kabardino-Balkaria and Karachay-Cherkessia) (Nalchik: KBSC RAN)

[5] Kolbovsky E Y 2016 Geo-information modelling and mapping of landscape locations in the journal Proceedings of Higher Education Institutions. Geodesy and Aerial Photography 60(5) 20-24