CARTOGRAPHIC DISPLAY OF LANDSLIDE AREAS AND LANDSCAPE-GEOMORPHOLOGICAL PROFILING OF LANDSLIDE SLOPES IN THE TERRITORY OF THE CHECHEN REPUBLIC

Alexey Gunya[1], Rustam Gakaev[2]

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[1]Institute of Geography, Russian Academy of Sciences, RUSSIA
[2]Kadyrov Chechen State University, RUSSIA
gunyaa@yahoo.com
rustam.geofak@yandex.ru

Abstract

Landslide processes are typical for the territory of the Chechen Republic. Loose deluvial material on the slopes created favorable conditions for the development of fertile soils and mountain agriculture in the main areas of residence of Chechens in the low-mountain and mid-mountain parts of the region. Population growth and the use of new technologies for land cultivation, irrigation, road construction - all this led to an increase in the load on the slopes and, as a consequence, to the activation of landslide activity. Mass destruction of houses and roads, often accompanied by human casualties, led to an outflow of population from the mountains to the plain, planned resettlements from areas of increased landslide danger. All this could have become one of the factors increasing social tension in the region in the late 1980s. Currently, the problem of reducing the risks of landslide danger in the region has not been solved, although there are detailed studies. The purpose of this work is to develop a comprehensive geoecological approach to landslide mapping using the landscape concept. To achieve this goal, two levels of mapping detail were used: 1) mesoscale mapping of landslides in the mountainous part of the territory of the Chechen Republic; 2) large-scale mapping in a key area in the low-mountain zone.

Keywords: landscape-landslide areas, relief, slope exposure

I. Introduction

Landslide processes are widespread in the mountains and are the result of a complex combination of exogenous and endogenous processes, which are also affected by economic activity. The study of landslides is relevant due to the increased risks associated with the implementation of projects for the recreational development of mountains, road construction, and communication lines. For a long time, the study of landslide processes was the prerogative of industry specialists, mainly engineering geologists and geomorphologists. The development of this field has attracted specialists studying not only geology and relief, but also vegetation, climate, and socio-economic processes in areas with landslide processes. Currently, landslide mapping cannot be done without reflecting on the maps the connections between natural components (relief, lithology, climate, vegetation), on the one hand, and natural and anthropogenic ones, on the other. This formulation of problems fits into the integrated direction of studying mountainous areas. The development of an integrated geoecological direction of landslide mapping is facilitated by modern methods of geoinformation mapping using high-resolution remote sensing materials obtained at certain intervals [3,9].

II. Methods

The work is based on field research materials combined with image interpretation. Landslide identification was based on images provided by the Google Earth service. It was a detailed analysis of images from different years together with field surveys that formed the basis for creating the database. The algorithm for identifying and analyzing landslide dynamics includes a detailed review of the territory of the Chechen Republic using images of different scales, plotting the identified landslide processes on maps in the GIS environment, verifying the established landslide areas using images from different years, and field surveys to establish the nature of landslide dynamics. As a result, about 2,400 landslide areas were identified, and after clarification and generalization, 1,800 landslides in the Chechen Republic were entered into the database. At the regional level, landslide mapping was based on establishing the locations of landslide manifestations, their confinement to slopes of different exposures and inclinations, as well as to certain landscapes. For this purpose, slope and aspect maps obtained using geoinformation modeling were used, as well as a landscape map created earlier in the field [4,12].

For a more detailed assessment of the complex of natural and natural-anthropogenic connections underlying landslide manifestations, landscape mapping of a typical landslide in the low-mountain zone of the Chechen Republic was carried out. For this purpose, a combination of field and office interpretation of large-scale photographs of different years was used, with the allocation of landscape contours and elements of the landslide body.

Landslide mapping varies in industry and complex scientific fields. The study of landslide phenomena has long been the prerogative of geologists and geomorphologists. There are more than 140 definitions of landslides in the literature, most of which are based on geological and geomorphological classification features. Over the past decades, many fundamental works have been published that consider landslides as geological bodies and complex slope processes [6]. As a rule, a classic landslide map included graphic tools and symbols that showed the geological and geomorphological features of the landslide: a breakaway wall, a pressure shaft, boundaries and composition of rocks, groundwater, etc. Much attention was paid to profiling in order to show the angles of inclination and bends, the relationship of geological rocks in the structure of landslides. In rare cases, information about vegetation was used as additional designations. Landslide mapping from a geoecological perspective shifts the focus to the entire host landscape, and the mapping is based not on the landslide bodies themselves, but on the so-called landscape-landslide complexes. A comprehensive study of landslide phenomena within the landscape concept takes into account the hierarchical structure of natural differentiation, which implies that in addition to studying individual landslide bodies, it is necessary to study the structure of natural complexes from local to regional levels of landscape differentiation. At the regional level, the study of landslides implies taking into account the altitudinal-zonal structure of landscapes. At the local level, mapping aims to reflect landscape-landslide complexes: in addition to the landslide body, mapping includes elements of the landscape structure and land use.

III. Results

The mountainous part of the Chechen Republic is characterized by a complex relief, the predominance of sedimentary rocks of different ages (from Neogene-Paleogene deposits in the foothills to Cretaceous and Jurassic in the foothills and highlands), subject to exogenous processes. The orographic features of the ridges and the composition of the sedimentary rocks that compose them, metamorphosed to one degree or another, reflect a consistent transition from low-mountain ridges to mid-mountain and mid-mountain basins (Rocky ridge) up to the highlands of the Lateral ridge.

Layer-by-layer visualization, with an emphasis on a particular relief characteristic, makes it possible to approach the analysis of landslide distribution from different angles. The maximum height of landslides identified in the Chechen Republic reaches 2700-2800 meters on the northern slopes of the Snow ridge (on the border with Dagestan). As will be shown below, these territories and landscapes are characterized by severe degradation of the soil and vegetation cover as a result of long-term grazing. The lowest absolute heights (about 100 m), to which landslides are confined, are typical for the slopes of the Gudermes Ridge. Here, landslide stimulation is associated with oil production areas. Most landslides are confined to the altitude step from 500 to 600 meters (193 landslides). The second maximum (146 landslides) gravitates towards heights of 1700-1800 meters.

Above 2000 meters, the number of landslides drops sharply due to worsening conditions for landslide formation: rocky slopes and a decrease in the thickness of the loose cover, a decrease in anthropogenic activity, etc. The slope of the surface determines the potential energy of the relief and the intensity of the processes of exogenous geodynamics, including landslides of various types. Slopes also increase from north to south along with the growth of absolute height.

The ratio of the areas of slopes of northern and southern exposures is approximately the same due to the sublatitudinal bends of river valleys and the extension of ridges. The distribution of landslides is also approximately the same, which indicates a weak influence of slope exposure on landslide formation processes; landslides are formed almost equally on slopes of different exposures, although there are some deviations [2,10].

As can be seen from figures 1 and 2, the greatest number of landslides (55%) are confined to slopes of warm exposures (southern, southwestern and southeastern). Although in terms of area, slopes of northern orientation prevail in the region, related to the northern slope of the ridges of the North Caucasus. All this emphasizes the complex nature of the confinement of landslides to slopes of various exposures and different steepness. The revealed regularities can be explained by the following hypotheses: 1) the slopes of southern exposures are less forested, and therefore less resistant to landslide formation; 2) the slopes of southern exposures were more developed, which means that the soil and vegetation cover was changed here, which could also lead to instability of the slopes to landslide formation. The combination of the terrain height, slope inclination and slope exposition generally provides the set of conditions that are inherent in landslide formation. Slope inclination, height and slope exposition are three variables, the combination of which allows us to assess the nature of the combination of factors and highlight the role of each of them in landslide formation. Exposition differences do not play a large role in the confinement of landslides to small angles of inclination (up to 150). This is generally consistent with the known geoecological regularities: the differentiating role of exposition is weak for slopes of small steepness. With increasing steepness, the role of "warm" exposures increases, where most landslides occur. The differentiation of landslide distribution by exposure is most noticeable in the altitude range of 500-2000 meters. Here, the difference in the intensity of landslides on the slopes of southern (frequently) and northern (comparatively less) exposures is especially noticeable. With increasing absolute altitude (more than 2000 meters above sea level), this pattern does not manifest itself [7,11].

Landslides in mid-mountain and low-mountain forest landscapes are a special phenomenon. Such landslides often occur in old forests far from settlements. A number of landslides can only be detected from photographs; there are no roads or paths to them, and they can only be reached along river beds. The most striking example of landslide manifestation in mountain-forest landscapes, transitional from mixed to broad-leaved, is a landslide near the Sharoargun river opposite the village of Ulus-Kert. The study area is characterized by the development of landslides, the formation and development of which are caused by the impact of mainly regional factors, such as the clay composition of rocks, physicochemical and deformational features of rocks, which determine their ability to quickly loosen and soften, neotectonic movements, bottom and lateral erosion, seismicity and hydrometeorological factors [1,5]. The scheme of the Ulus-Kert landscape-landslide complex reflects the main features of the integration into the altitudinal-zonal structure and the relationship with the dominant background natural complexes at the level of groups and types of landscapes. The landscape-landslide complex in plan has several longitudinal parts with different ages of landslide activation (Fig. 1,2). The upper wall of the breakaway is at an absolute height of about 770 m above sea level, and the discharge ends in the river bed at an altitude of 410 m. There are several classic landslide elements characteristic of a block landslide: 1 - landslide block; 2 - landslide terrace area; 3 - landslide failure wall; 4 - landslide pressure shaft ending in the river.

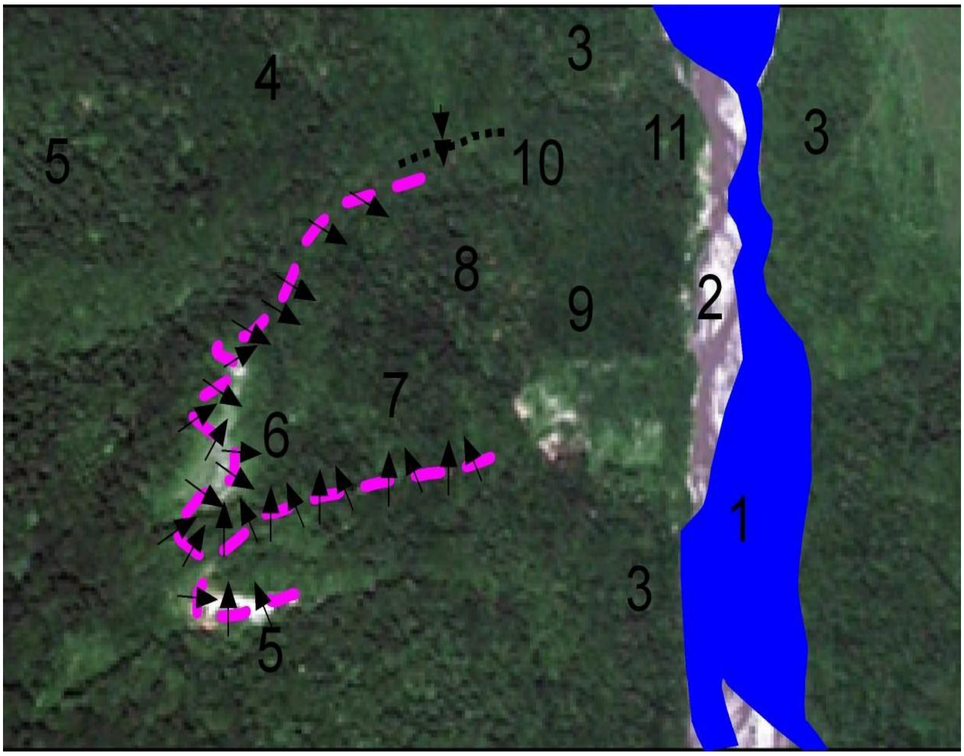

Figure 1: *Landslide in the bed of the Chanty-Argun River*

Legend: 1 - floodplain natural complexes (river bed), 2 - high floodplain overgrown with shrubs (about 10 years), 3 - slopes of river terraces under small forests of beech, hornbeam, hawthorn, maple; 4 - under hornbeam-beech forests with undergrowth of hawthorn and maple on mountain brown soils, 5 - beech forests on mountain brown soils, 6 - landslide failure wall, not sodded; 7 - area of the upper landslide terrace with clumps of beech undergrowth, less often hornbeam and hazel; 8 - section of the slope of settling, hummocky-ridged under the "drunken" forest of beech, hornbeam on pocket and skeletal brown soils, 9 - the site of the lower landslide terrace under blackberry thickets and willow clumps, 10 - lateral depressions of settling under beech forests, 11 - pressure landslide rampart under willow thickets with alder.

Analysis of landscape embeddedness shows that landslide formation sharply contrasts with mountain-forest landscapes, characterized by a relatively stable state of slopes. Landslide foci in this case are not typical for local geosystems. Rather, they characterize a certain shift in the regional ecobalance.

For a more comprehensive understanding of the landslide phenomenon, considering it as a landscape-landslide complex, it is necessary to take into account its embeddedness in the landscape structure (Fig. 3). [4,10]. Embeddedness in the landscape structure of the Kert landscape-landslide complex is characterized by the following features:

1) at the level of landscape types - a weakly contrasting ecotone position between the mountain-forest and mountain-forest-meadow-steppe zone, as well as between mountain-forest broad-leaved and mountain-forest mixed landscapes;

2) at the level of landscape groups: the borderline position between rocks with different proportions of clays and sandstones of Paleogene-Neogene age is weakly expressed. A more important factor is the location in the zone of tectonic faults and seismic dislocations;

3) at the level of landscape types - fragmentation of forest cover due to successional

differences in forests of different ages and phytomass reserves. The dynamics of landslides may seem quite simple: the deepening river bed washes away the right side and leads to instability of the slopes. However, field studies have shown that other factors may also play a role in the dynamics of landslides: increased seismicity, contrast of rocks forming the slope, succession processes in forests leading to an increase in above-ground phytomass with a decrease in sod cover in dead-cover beech forests, leading to the development of erosion centers, torrential precipitation at the beginning of summer, leading to instability of soils to erosion, etc. [9].

Figure 2: *Landslides Manifestation in the bed of the Chanty-Argun River (from the side of the village of Kert*

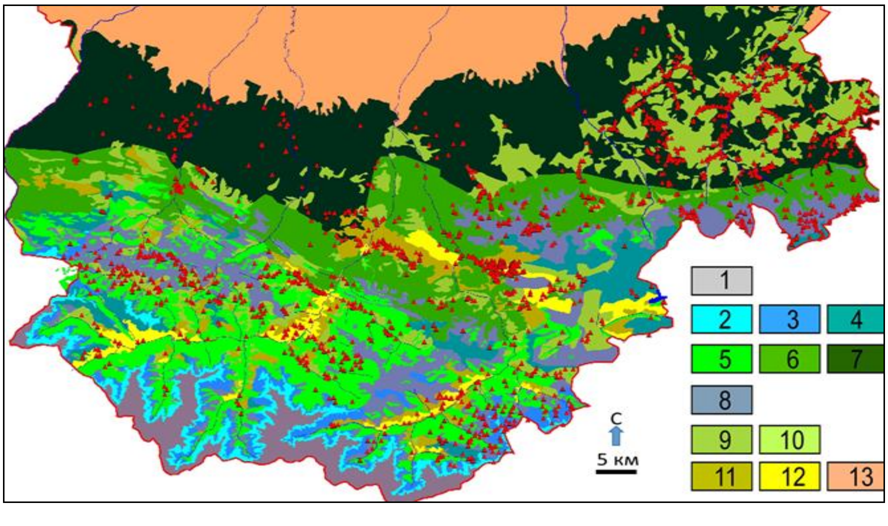

Figure 3: *Mapping of landslide areas in the mountainous part of the Chechen Republic*

Landscape differentiation at the level of landscape groups is determined by differences in rock types and relief. As can be seen from the map of landslide distribution by landscapes, the altitudinal-zonal distribution of landslides is discrete and uneven: areas of landslide concentration alternate with areas where they are practically absent.

IV. Discussion

An analysis of landslide distribution in the mountainous part of the Chechen Republic showed that the maximum height of the identified landslides reaches 2700-2800 meters on the northern slopes of the snow Ridge. The lowest absolute heights (about 100 m), to which landslides are confined, are observed on the slopes of the Gudermes ridge, which is associated with oil production. Most landslides (out of 1800 identified) are confined to the altitude interval from 500 to 600 meters (193 landslides). The second maximum (146 landslides) is confined to heights of 1700-1800 meters. The largest number of landslides is confined to slopes with a steepness of 25-350. The number of landslides on steep slopes (more than 350) decreases, but still remains relatively large. The largest number of landslides (55%) are confined to slopes with warm exposures (southern, southwestern and southeastern). This is due to the deforestation of the southern slopes and anthropogenic activity. Large-scale mapping of the landslide made it possible to identify the main elements of the landscape structure, which are at different stages of vegetation succession and experience different anthropogenic loads. The ecotone position between two types of landscapes (mountain-forest and mountain-forest-meadow-steppe) plays an important role in the dynamics of the Belgatoy landscape-landslide complex [8]. The dynamics of landslide processes in this area are largely due to the fragmentation of forest natural complexes due to selective deforestation, construction of plowed terraces and serpentine roads. Landscape-geomorphological large-scale profiling and mapping of specific landslide areas and landslides using GPS and GIS technologies (primarily, superimposing layers of geology, quaternary deposits, vegetation on a digital elevation model is an effective method for analyzing landslide mechanisms in specific natural and economic conditions. GIS modeling allows us to establish a number of patterns in the distribution of landslides. However, formal tools of morphometric analysis cannot fully explain the distribution of landslides and their nature. Field data are needed for this.

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