ANTHROPOGENIC ACTIVITIES AND ITS ROLE IN THE FORMATION OF LANDSLIDE PROCESSES IN THE MOUNTAIN TERRITORIES OF THE CHECHEN REPUBLIC

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Abstract

Landslides are considered as a complex process in which anthropogenic activity plays an important role. The purpose of this work is to describe the cause-and-effect relationships in the system "anthropogenic activity - landslides" using the example of mountainous regions of the Chechen Republic. The article is based on field studies and materials from the interpretation of high-resolution space images, which made it possible to identify about 1800 landslides in the territory of the Chechen Republic. They were characterized in terms of landscape position (coordinates, height, exposure, slope, vegetation composing rocks) and involvement in economic activity (forestry, pastures, agriculture, settlements, etc.). The results of the work made it possible to assess the mutual influence of landslides on settlement, on the one hand, and land use (in particular, road construction, irrigation, etc.) on the nature of landslides. A detailed analysis of the obtained database made it possible to identify 356 landslides that somehow fall within the analysis field of the "landslide - person" system. The analysis of the relationships was carried out based on the superposition of various layers of the created geoinformation system. Anthropogenic activity was assessed in three aspects: 1) spatial proximity of landslides and economic objects; 2) intensity and type of economic activity influencing landslide manifestations; 3) dynamics of land use over time, in particular, a sharp change from one type of use to another.

Keywords: landscapes, slope exposure, human impact, landslides

I. Introduction

Mountains and mountain ranges are complex and multifaceted geosocio-ecological systems and play a crucial role in biodiversity, hydrological cycles and human society. Mountainous areas face numerous challenges, including climate change, land use change, which lead to slope instability, erosion, mudflows, landslides. Landslides are caused by geological, meteorological and human factors, which vary not only depending on the natural environment, but also depending on the socio-territorial context. In recent years, the impact of landslides on the economy and settlement has become more serious due to the overlap of various interacting factors. Therefore, mountainous regions around the world are faced with an increase in poorly predictable catastrophic events, cascading effects and an increase in natural disasters. Landslide phenomena often form areas that can be considered as specific disaster zones - risk landscapes. Risk landscapes are complex, heterogeneous and uncertain territories, which confirms the need to consider the relationship between nature and society at different levels of time and space. The mountainous territories of the Chechen Republic have long been well developed [1]. There is a

well-developed settlement system here, which underwent significant changes in the 20th century, many settlements were abandoned, the population migrated to the foothills and to the plain. On the other hand, the developed territories in the mountains were affected by slope processes, primarily landslides. Traditional forms of life activity allowed for the formation of relatively long-term symbioses of the environment and settlement with a high degree of adaptation. However, the development of new technologies for the construction of residential buildings, roads, communications and, in general, land use, led to the disruption of traditional adaptation mechanisms and the intensification of landslides.

II. Methods

The article is based on field studies and high-resolution satellite imagery interpretation materials, which allowed us to identify about 1,800 landslides in the Chechen Republic. Profiles were built for key areas, which included not only the landslide body itself, but also the surrounding landscape, including land use and settlement. This allowed us to assess the mutual influence of landslides on settlement, on the one hand, and land use (in particular, road construction, irrigation, etc.) on the nature of landslides. A detailed analysis of the resulting database allowed us to identify 356 landslides that, in one way or another, fall within the scope of the analysis of the "landslide - person" system [2]. The remaining landslides were classified as conditionally natural, since the main factors influencing their dynamics were natural processes: river erosion, natural instability of slopes, earthquakes, etc. All 356 landslides were characterized in terms of geographic location (coordinates, height, exposure, slope, vegetation, landscapes that make up the rocks), as well as in terms of inclusion in economic activity (forest management, pastures, agriculture, settlements, etc.). The analysis of the relationships was facilitated by the presence of various layers of the created geographic information system. The use of layer overlay operations and loading of images from different years made it possible to assess the dynamics of the relationship between economic activity and landslides in different periods of development: in Soviet times (intensive land use), in the 1990s (weakening of economic activity, migrations caused by military actions), in the 2000s and to the present (construction of roads, communications, creation of new settlements in safe places, migrations to the city, etc.). The study of changes in land use was also supported by field surveys of key areas, landscape mapping and profiling [3].

Landscape management within the high-altitude zonal landscape-landslide complexes has undergone significant changes over the past 80 years. The highland landscapes, densely populated before the deportation of the Chechens in 1944, were used as a basis for life – for arable land, hayfields and grazing. The destruction of the settlement system and the deportation of mountain dwellers to the plain led to the expansion of use in the form of distant-pasture livestock farming, mainly as pastures for sheep driven in the summer from collective farms in the foothills and plains. The settlement of abandoned villages was prohibited in Soviet times. In the late 1980s, individual families began to gradually reclaim their ancestral lands. The process stopped during the military actions, but then resumed in the 2000s. However, individual entrepreneurs gradually began to drive small herds (mainly bulls) to summer pastures. With the construction of roads, the development process accelerated. In recent years, high-mountain areas, in particular the basin with Lake Galanchozh in the center, have become a weekend tourism destination. However, the laid dirt roads significantly reduced the stability of the slopes and began to serve as sources for the development of landslide processes. In the foothill-low-mountain zone, where the densely populated areas of the Chechen Plain and the Black Forest meet, mountain forests have long been used for firewood, and individual farms developed sections of clearings in the mountain forests. However, this process was slowed down due to the lack of areas suitable for farming. In Soviet times, forest management began to be regulated. The return of the Chechens in the late 1950s and the restoration of villages led to a change in the settlement structure, an increase in the number of livestock and an increase in the need for firewood [4]. During the military actions of the 1990s, the surrounding landscapes suffered greatly. The restoration in the post-war period was accompanied

by the installation of gas supply, which had a positive effect on the forest cover. In addition, the basis of the population's life has changed, which is now largely associated with work in cities. This has led to a decrease in the livestock population, stall keeping and driving to high-mountain areas are used. All this gave the mountain forests a chance to recover.

The development of the oil industry played a major role in the use of the landscapes of the front ranges. The network of wells and infrastructure of the oil industry led to fundamental changes in the landscapes [5]. Population growth due to the oil industry, and later due to internal migration led to an increase in the number of privately owned livestock and, as a result, an increase in the pasture load. Local residents have long used the adjacent slopes for year-round grazing of privately owned livestock, which prevented the restoration of shrubs and trees.

The main load on the landscapes came from the oil industry facilities. Almost everywhere there are roads, slag ponds, oil pipelines. Currently, the number of oil industry facilities has decreased, regulated grazing is underway, which allows us to hope for a reduction in the load due to the regulation of use. Mountain-forest landscapes of the front ranges are experiencing a stage of restoration: forest areas are being compacted, in some places land is being developed for the construction of private houses, mainly for recreational use.

III. Results

Analysis of statistical data for different years on settlement, economic activity and landslide distribution allowed to detail the main factors that directly or indirectly affected the intensity of landslide manifestation. These include: 1) intensive development of oil fields, which affects the change in the seismogenic situation and the state of rocks, 2) changes in the historically established settlement system, the layout of settlements, technologies for building houses of other designs, intra-settlement arrangement of communications and infrastructure with asphalt and concrete pavements, while increasing the number of continuous development centers, 3) changes in the use of land in the host landscape [6]. Development of oil fields. Overlaying oil fields on a landslide map shows that the correlation between them is manifested only in the foothills (Fig. 4). Geological exploration and exploitation of fields leads to a change in the dynamic state of geological structures, the formation of weakened zones and voids, which leads to a violation of the seismic regime in the area. Most of the observed landslide processes on the slopes of the Tersky Range are closely related to oil production processes (mainly the road network to the wells and along the oil pipelines). In the areas of oil production and exploration, slopes are being cut and flooded (Fig. 1). There are several hundred abandoned wells, the injected water overflows from the layers and contributes to the instability of the slopes. The dominant natural complexes here are slopes composed mainly of Neogene deposits of sandstones and clays, partially covered by Quaternary deposits, northern exposure, gentle and medium steep, stepped and hollow, complicated by artificially leveled terraces and roads of the oil industry complex, under mountain forest vegetation of oak, small forests and shrubs of thorn tree on mountain forest chernozem-like and chestnut soils. Subdominant natural complexes are slopes with shrub steppes on chernozem-like and chestnut soils.

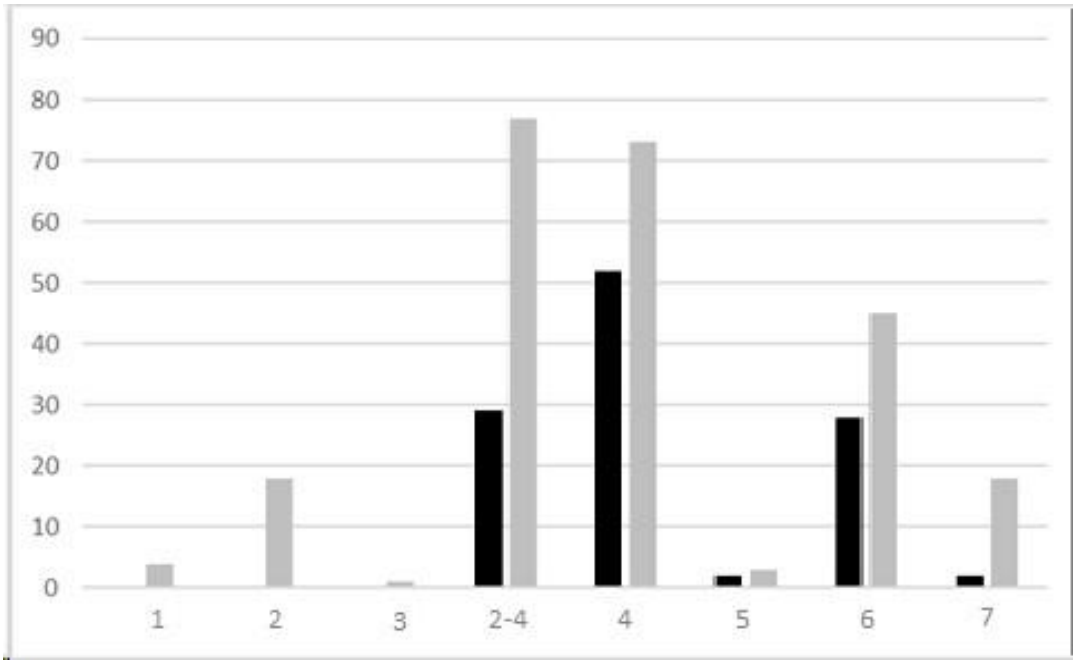

Figure 1: *Distribution of landslides in villages (black) and near villages (gray) in different landscapes: Mountain-forest: 1 - mixed broad-leaved and small-leaved, 2 - broad-leaved, 3. Mountain-forest-meadow. Mountain-forest-meadow-steppe: 4 - typical, 5 - forest-meadow-steppe and forest-steppe. Mountain-steppe: 6 - meadow: 7 - mountain-dry-steppe shrub*

IV. Discussion

Analysis of statistical data for different years on settlement, economic activity and landslide distribution allowed to detail the main factors that directly or indirectly affected the intensity of landslide manifestation. These include: 1) intensive development of oil fields, which affects the change of seismogenic conditions and the state of rocks, 2) change of the historically established settlement system, planning of settlements, technologies of construction of houses of other designs, intra-settlement arrangement of communications and infrastructure with asphalt and concrete pavements, while increasing the number of continuous centers of development, 3) change in land use in the host landscape. Development of oil fields [7]. Overlaying the landslide map of oil fields shows that the correlation between them is manifested only in the foothill areas (Fig. 2). Geological exploration and exploitation of fields leads to a change in the dynamic state of geological structures, the formation of weakened zones and voids, which leads to a violation of the seismic regime in the area. Most of the observed landslide processes on the slopes of the Tersky Range are closely related to oil production processes (mainly the road network to the wells and along the oil pipelines). In the areas of oil production and exploration, slopes are being cut and flooded. There are several hundred abandoned wells, the injected water overflows from the layers and contributes to the instability of the slopes [8]. The dominant natural complexes here are slopes composed mainly of Neogene deposits of sandstones and clays, partially covered by Quaternary deposits, northern exposure, gentle and medium steep, stepped and hollow, complicated by artificially leveled terraces and roads of the oil industry complex, under mountain forest vegetation of oak, small forests and shrubs of thorn tree on mountain forest chernozem-like and chestnut soils. Subdominant natural complexes are slopes with shrub steppes on chernozem-like and chestnut soils.

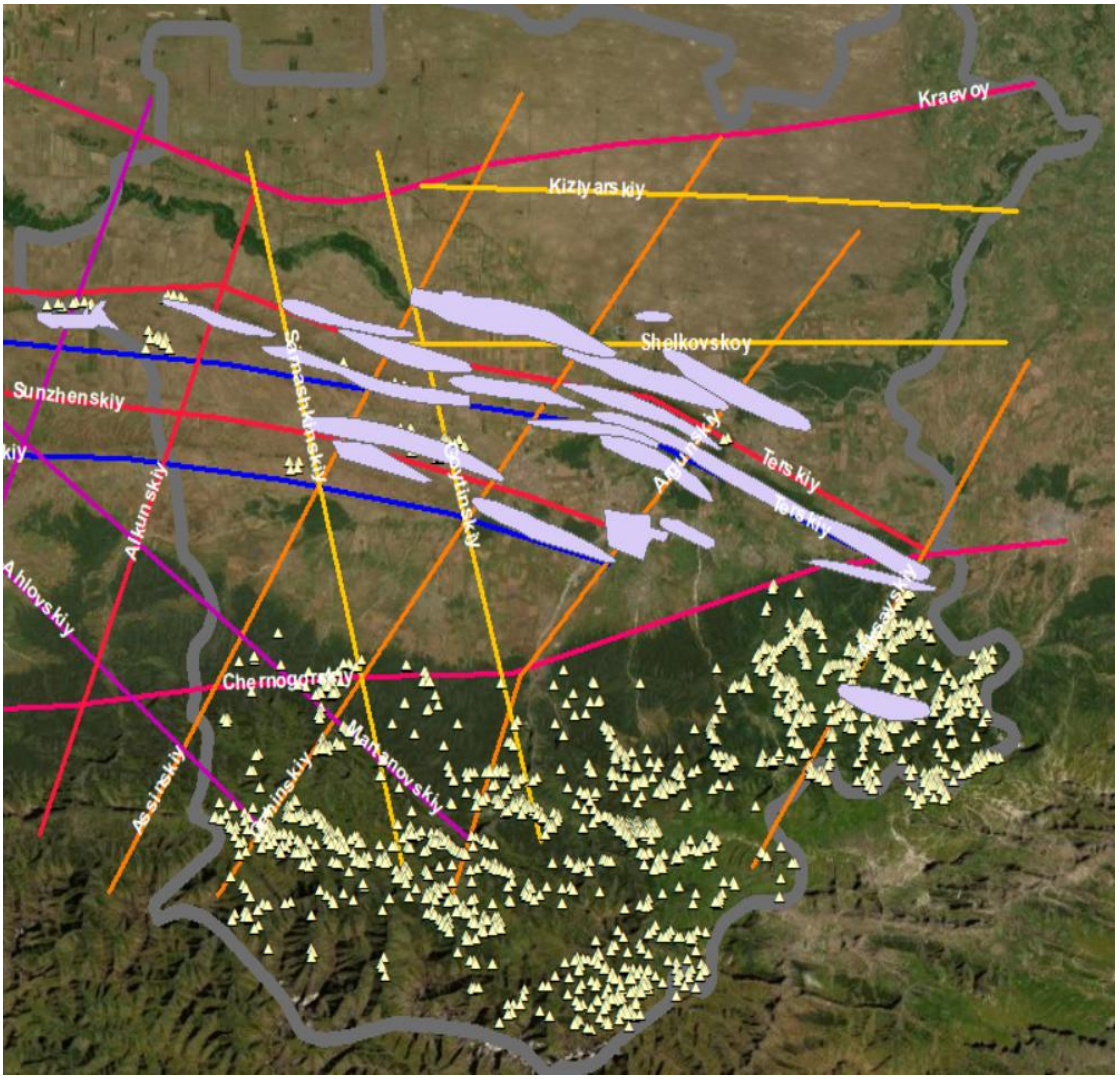

Figure 2: *Landslides (indicated by light triangles), faults (straight lines of different colors) and oil fields (light-colored lenses) in the Chechen Republic.*

A striking example of the impact of land use on landslides is observed in the area of the village of Varanda. After the eviction of the Chechens, Old Believers arrived in these territories, who carried out intensive agricultural activities - arable land with mechanical soil cultivation. As a result, instead of small parcels of arable land and vegetable gardens, which had a terraced nature of distribution, large fields were formed on which the water supply regime of the soils was disrupted [9]. The torrential nature of summer rains contributed to the formation of erosion furrows, subsidence, which disrupted the stability of the slopes. A decrease in the infiltration properties of soils with an increase in water supply led to the occurrence of landslides in watershed areas.

Landslide areas coincide in terms of moisture conditions, fertile substrate with favorable conditions for life. In natural terms, the mountainous territories of the Chechen Republic have a relatively limited number of areas for agriculture and settlement, mainly areas unfavorable for settlement predominate: dissected relief, steep slopes and mountain gorges with turbulent watercourses that wash away these slopes [10]. In the lowlands and midlands, where climatic conditions are relatively favorable for permanent residence, the slopes are composed of loose, rapidly eroding and unstable deposits of clays, argillites and siltstones. Vegetation contributes to the consolidation of landslide-prone areas. However, the very uneven precipitation regime, especially in early spring, when the vegetation cover has not yet formed, serves as a factor in increasing landslide manifestations [11].

Fertile fine-grained substrate has always been attractive for development under arable land. Near such areas, which also had outlets of groundwater used for economic needs and irrigation, people settled, founded new villages (Fig. 3). Traditional Chechen houses in the low-mountain and partly mid-mountain zone, where rocky rocks were rare, were built of light material (usually a wooden frame, and the filler consisted of straw and clay). The roads were unpaved and narrow, they were winding and fit into the relief. Houses and outbuildings also fit into the relief, buildings were scattered along the slopes, and roads were rare. In the second half of the 20th century, with the use of heavy machines, roads began to expand, heavy construction and agricultural machinery passed along them [12]. Houses, starting with foundations and walls, began to be built using brick and concrete structures, which significantly increased the load on the soil. The increased need for water and energy (gas, electricity) led to the emergence of linear water and energy supply facilities. All this together significantly increased the load on the host landscape in landslide areas.

Figure 2: *Landslide processes near the Gendargen-Shunoy road*

The distribution of landslides and the features of settlement and land use differ in different high-altitude landscape zones; the most extensive landslide areas are confined to low-mountain densely populated landscapes of the eastern part of the Chechen Republic. Several types of cause-and-effect relationships are distinguished in the "landslide occurrence - economic activity" system: on the one hand, landslide areas are characterized by good water supply and the presence of fertile substrate for agriculture [13]. On the other hand, landslide processes cause destruction and force the population to migrate to cities and plains. The main factors that influenced the connections in the "landslide occurrence and anthropogenic activity" system should be considered changes in settlement and land use caused by socio-political events of the last century.

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