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Research on the role of relief in the anthropogenic differentiation of modern geosystems based on remote sensing

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Abstract

The article examines the anthropogenic transformation of landscapes depending on the relief in the Ajinohur foothills and adjacent areas located in the central part of the Republic of Azerbaijan. The continuous increase in population affects the landscapes. In this context, the natural conditions of the area, especially the relief conditions, play a significant role. The inclination of the relief, the steepness of the slopes, and the horizontal and vertical fragmentation influence the transformation to varying degrees. Our primary goal is to determine the influence of various elements of the relief on the anthropogenic transformation of landscapes. Addressing landscapes for zero hunger is a pressing issue. During the research, preference was given to modern methods. Both traditional methods (historical, mathematical, and others) and modern methods (decoding satellite images) were employed. The study focused on the relief's inclination, height, slope exposure, and horizontal and vertical division, and their roles in transformation were analyzed. The findings indicate that anthropogenic transformation is more pronounced on low-inclined slopes. However, if high-inclined slopes are intensively developed by humans, the transformation becomes more significant. Northern slopes contribute less to transformation than southern slopes. Areas with high relief height have a lesser impact on transformation because these high-inclined regions are less suitable for the economic activities of the population. The results of this research can be utilized in sustainable agricultural planning, environmental monitoring, and other related studies.

Keywords: Agriculture, Climate action, Landscape, Sustainable agriculture, Zero hunger.

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1. Introduction

The regular use of natural resources throughout history, in connection with the development of human society, has led to the transformation of landscapes [1].

When studying the anthropogenic transformation of natural landscapes, it is important to examine anthropogenic impacts across various sectors of agriculture and industry and analyze their dynamics [2]. For many years, anthropogenic impacts have comprehensively changed the natural appearance of landscapes, further complicating their morphological structure with anthropogenic modifications [3, 4]. The study area is complicated by the anthropogenic differentiation of natural landscapes of plains and ridges, which differ from each other [5].

Anthropogenic differentiation occurs in vertical and horizontal directions [6, 7]. Thus, anthropogenic impacts are significant in the plain areas. However, the eastern and western parts of the region differ. The western part consists entirely of winter pastures, and anthropogenic impacts here are mainly related to livestock farming and are seasonal. In these landscapes used as winter pastures, impacts intensify during the cold months. Several factors are not considered during grazing, leading to the following problems.

1. Soil erosion. Every year, the same roads are used to transport animals to pastures [8]. At the same time, vegetation and soil are trampled on these roads. As a result, the topsoil loses its quality. Soils are subject to erosion.

2. Destruction of vegetation or its replacement with other species. This is due to the destruction of plants trampled on the roads [9]. Over time, these plants leave the area.

3. Decrease in productivity. The winter pastures of Ajinohur are the most productive winter pastures in the republic. Such a high indicator leads to their irregular use [10]. Failure to comply with grazing norms during grazing in the current year reduces productivity for the following year.

2. Material and Methods

During the research, traditional and modern research methods were used. Along with mathematical-statistical and historical methods, satellite image decoding was also employed. In this case, data from Landsat 5, 8, and 9 satellites were utilized.

The following sequence was used in compiling the slope map.

DEM→Arctoolbox→Spatial analyst→Slope

The following sequence was used in the preparation of the aspect map.

DEM→Arctoolbox→Spatial analyst→Aspect

The DE model of the study area was used for horizontal and vertical decomposition of the relief.

3. Results and Discussion

Our study area covers the Ajinohur foothills and adjacent areas located in the central part of the Republic of Azerbaijan.

In the western part of the territory, along with pastures, extensive arable land is also spread [11]. Thus, arable land occupies a large area around Lake Ajinohur. The area of crops here is 184 km². There are also extensive melon plantations in the eastern part of the Khanabad plain. The relief of the western part is less broken by river valleys [12]. There are also a few settlements in this part. Mainly, extensive commodity farms are spread [13, 14]. This is, of course, connected with pastures. The eastern part is completely different from the western part. Winter pastures can also be found in these areas. However, these pastures cover a small area. Anthropogenic influences are mainly strong in the direction of agriculture [15]. Forests have been cut down in these areas, and extensive arable land has spread, sometimes replaced by forests and bushes, and extensive settlements have spread [16].

One of the relief factors that plays an important role in anthropogenic differentiation is the hypsometric index of the area [17]. Depending on the absolute height of the relief, both the strength and direction of anthropogenic impact differ. According to the hypsometric conditions, the study area is divided into five parts: 0-200 m, 201-400 m, 401-600 m, 601-800 m, 801-1105 m (Figure 1). This covers 22% (965 km²), 39% (1,733 km²), 29% (1,284 km²), 9% (391 km²), and 1% (46 km²) of the total area studied, respectively.

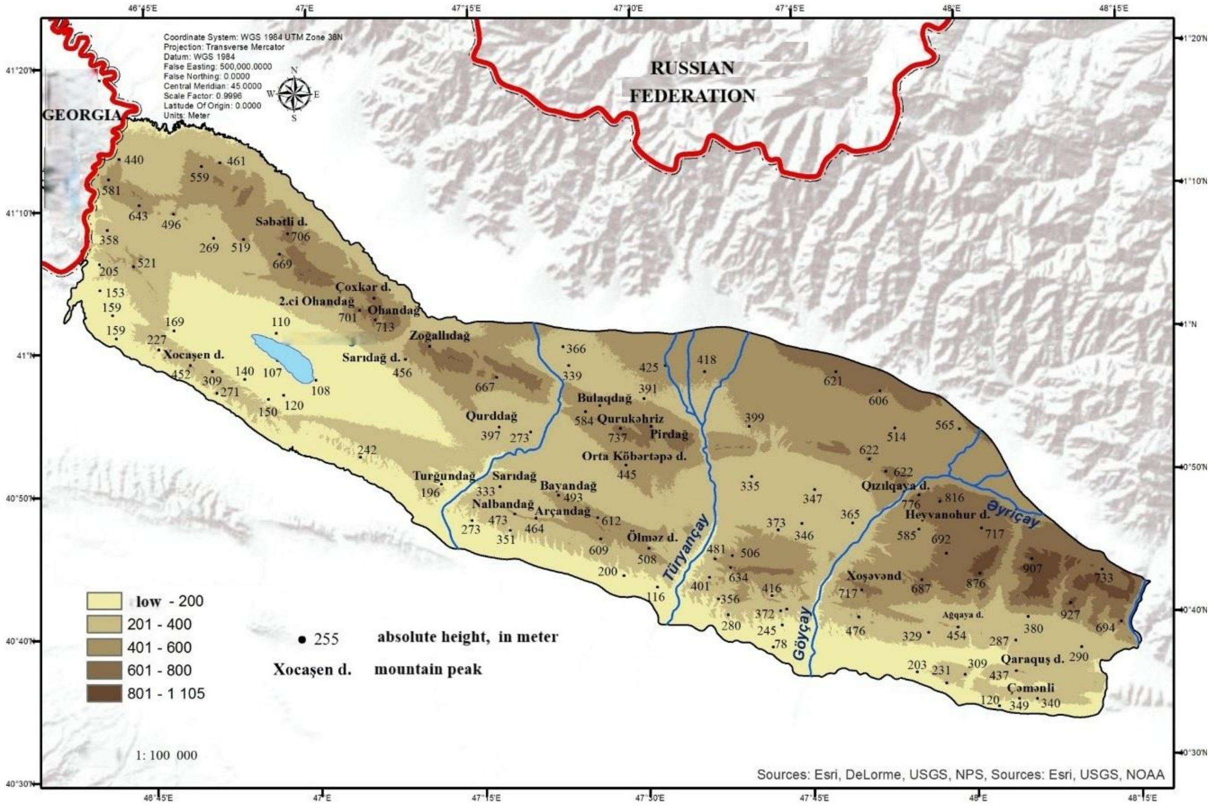

Figure 1.
Hypsometric map of the Ajinohur foothills and adjacent areas.

The areas with an absolute height of 0-200 m and above 601 m are less exposed to anthropogenic impact by the population. The area of villages and settlements at an altitude of 0-200 m is 43 km², and the area of administrative territorial districts is 10 km² (20%). An administrative territorial district is an administrative territorial unit of the Republic of Azerbaijan, consisting of two or more villages or settlements, within the boundaries of which local state authorities are established and operate in accordance with the procedure provided for by legislation.

The area of villages and settlements at an altitude of 201-400 m is 43 km². However, at this absolute height, the area of administrative territorial districts increases by 2 times and reaches 20 km². The most optimal height adopted as residential areas for the population is the absolute height of 401-600 m. Thus, 40% of villages and settlements (73 km²), and 33% of administrative territorial districts (16.2 km²) are located at this altitude. Starting from this altitude, the area of settlements both decreases and their number decreases. At an altitude of 601-800 m, 3% of villages and settlements (6 km²), and 5.8% of administrative territorial districts (2.87 km²) are located. Above 801 m, 11% of villages and settlements (19 km²), and 1.2% of administrative territorial districts (0.337 km²) are located.

The dependence on absolute altitude is also clearly visible in the distribution of pasture areas [18]. The absolute altitudes of 201-400 m are the most favorable for grazing. 43% of pastures (582 km²) are located at this altitude. Above 801 m, the area of pastures reaches 10 km² (1%). At an absolute altitude of 0-200 m, 445 km² (33%), 216 km² (16%) are located at 401-600 m, and 87 km² (7%) are located at 601-800 m. 1.3 km² (17%) of farms are located at an altitude of 0-200 m, 3.3 km² (42%) at 201-400 m, 1 km² (13%) at 401-600 m, and 2.2 km² (28%) at 601-800 m.

In areas with high absolute elevations (801-1000 m), crops are less widespread. Climatic conditions also affect the distribution of cultivated areas at this altitude. Only 1% of crops (3 km²) are spread above 801 m. The most suitable altitude for agriculture is 200-400 m above sea level. The area of crops decreases above and below this altitude. At 0-200 m absolute elevation, the area of crops is 270 km² (18.5%), at 201-400 m altitude it is 670 km² (46%), at 401-600 m altitude it is 380 km² (25.5%), and at 601-800 m it is 130 km² (9%).

However, this indicator is different in horticulture. Garden areas are not observed above 801 m. As the absolute height increases, the area of gardens increases. This is observed up to 800 m. While the area of gardens at 0-200 m is 10 km², at 201-400 m this indicator increases 2.7 times to 27.7 km², at 401-600 m it increases 4 times to 40 km², and at 601-800 m it increases 5.8 times to 58 km². The percentage composition of gardens according to the hypsometric distribution is as follows: 7%, 20%, 29%, 44%.

One of the factors affecting anthropogenic differentiation is the inclination of the terrain. According to the slope map of the study area, it is divided into 4 degrees: 0-5º, 5.1-15º, 15.1-35º and 35-67º (Figure 2). The slope index is less than 15 degrees in most areas. High-slope slopes are a minority compared to the total area. Of the total area of the studied Ajinohur foothills and adjacent areas (4,419 km²), 40% (1,759 km²) is located at a slope of 0-5º, 45% (2,010 km²) at a slope of 5.1-15º, 8% (636 km²) at a slope of 15.1-35º, and 7% (14 km²) at a slope of 35-67º. The distribution of anthropogenic modifications also becomes more complex depending on the slope. As the slope increases, the intensity of anthropogenic impacts decreases. Areas with low slopes and low absolute elevations are more exposed to anthropogenic impacts.

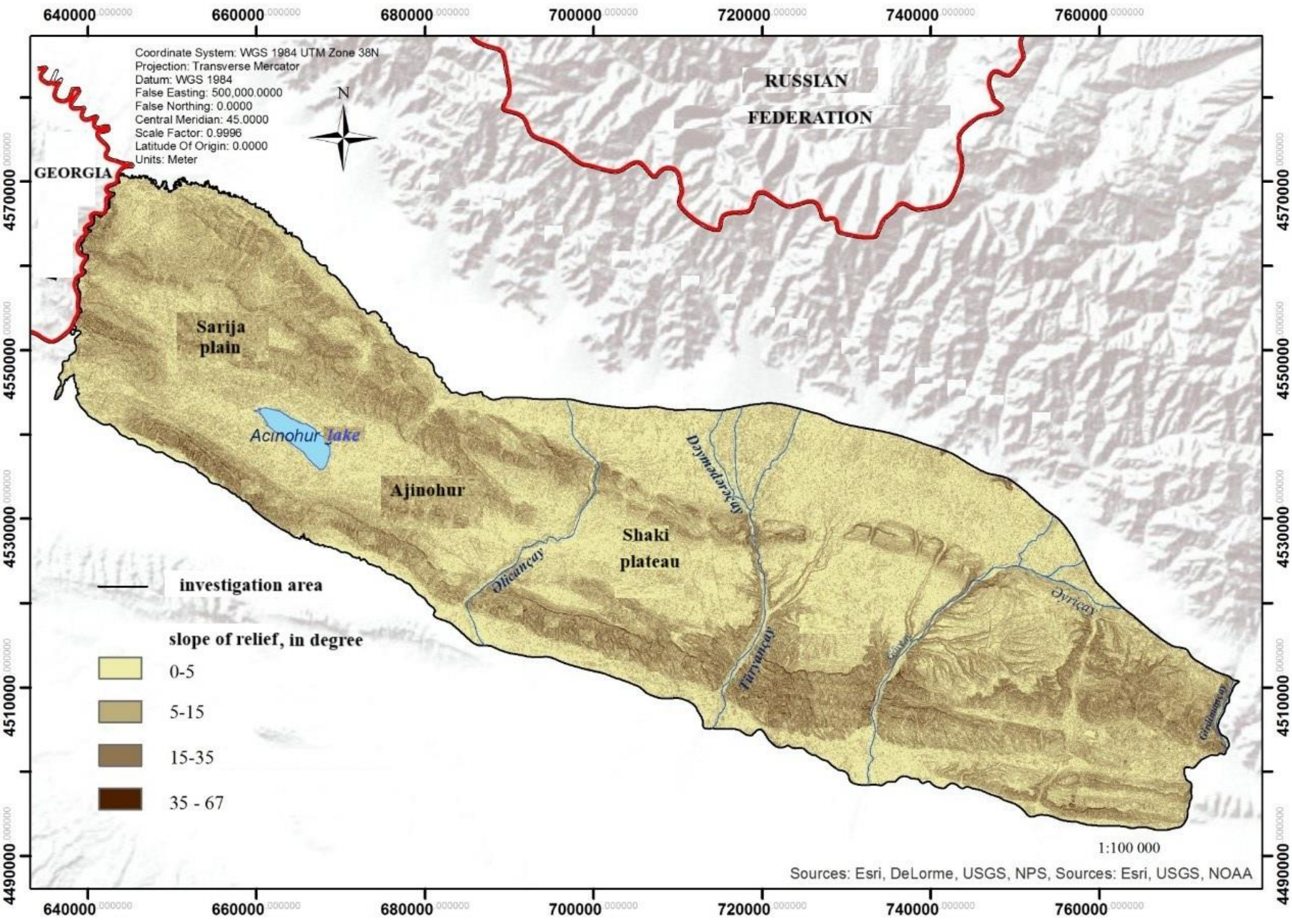

Figure 2.
Map of slope inclinations in the Ajinohur foothills and adjacent areas.

237.9 km² of settlements are located on slopes with an inclination of 0-20º. Of these, 6 km² belong to district centers, 183.5 km² to villages and settlements, and 48.4 km² to administrative territorial districts. Settlements are more widespread on slopes with low inclination. As the inclination increases, the number of settlements decreases, and their area diminishes. 1.463 km² of settlements are situated on slopes with an inclination of 20-40º. Even on slopes with an inclination of more than 40º, there are no villages and settlements. 0.034 km² (0.2%) of administrative territorial districts are located on slopes with such inclinations. Of the settlements on slopes with an inclination of 20-40º, 0.5 km² belong to villages and settlements, and 0.973 km² to administrative territorial districts.

These statistical indicators indicate the difficulty of mastering high-inclined slopes as settlements by the population.

A large part of the cultivated areas (99.9%) is located on slopes with an inclination of 0-20º, covering an area of 1,451.2 km². The remaining 1.8 km² (0.1%) of cultivated land are on slopes with an inclination of 20-40º. There are no crops on slopes with an inclination of more than 40º. The high inclination also creates an irrigation problem in an arid climate. This is one of the factors that make it difficult for the population to cultivate crops on high-inclined slopes.

The total area of the gardens is 135.7 km², of which 94% (127.85 km²) is located on slopes of 0-20º. On slopes of 20-40º, the gardens cover 7 km² (5%). On slopes exceeding 40º, only 1% (0.85 km²) of the gardens are situated. The slope also influences the development of the area by the population for pastures. Consequently, the movement of livestock to high-slope terrains presents certain difficulties. As a result, 92.5% (1,240.55 km²) of pastures are on slopes of 0-20º. Only 1.95 km² (0.2%) of pastures are on slopes of 40º. Additionally, 97.5 km² (7.3%) of the pasture area is found in relief with slopes of 20-40º. The anthropogenic transformation of pastures in these areas is minimal, since it is challenging to move livestock to high-slope terrains.

There are no roads in relief with a slope higher than 40º. Most of the roads are on low-slope (0-20º) relief, and their total length is on average 1,967.8 km. Of this, 395.41 km are asphalt and concrete-covered roads, 486.5 km are unpaved and unconcrete roads, 119.137 km are highways, 1,246.58 km are rural roads, and 191.8 km are dirt roads. Construction of roads in low-slope relief is both convenient and economical. Another reason is that most settlements, crops, gardens, and pastures are located on gentle slopes.

On slopes with an inclination of 20-40º, the length of asphalt and concrete roads is 7.59 km (2%), the length of roads without asphalt and concrete is 220 km (17%), the length of highways is 1.853 km (0.7%), the length of field roads is 36.420 km (0.8%), and the length of dirt roads is 20.2 km (0.1%). The area of roads in areas with an inclination of more than 40º is 2.4 km², 2.19 km², 1.2 km², 1.496 km², and 0.384 km², respectively. On slopes with an inclination of 20-40º, the sequence is as follows: 0.045 km², 0.99 km², 0.018 km², 0.0437 km², and 0.04 km².

When studying the anthropogenic differentiation of landscapes, the degree of horizontal and vertical fragmentation of the relief was also analyzed. A large-scale (1:100,000) horizontal fragmentation map of the area has been compiled. The following distribution is distinguished in the study area according to the degree of horizontal fragmentation: low - 0.3 km/km² (137 km² - 3%), 0.3-0.6 km/km² (598 km² - 13.7%), 0.6-0.9 km/km² (1,232 km² - 28%), 0.9-1.2 km/km² (1,284 km² - 29%), 1.2-1.5 km/km² (826 km² - 19%), 1.5-1.8 km/km² (236 km² - 5%), 1.8-2.1 km/km² (55 km² - 1.2%), 2.1-2.4 km/km² (37 km² - 0.8%), 2.4 km/km² and above (14 km² - 0.3%) (Figure 3). In most parts of the area, horizontal fragmentation ranges from 0.3 to 0.9 km/km². This indicates that the study area is sharply fragmented by a network of ravines. In areas with a high horizontal fragmentation index, semi-desert landscapes and dry steppes predominate, while in areas with a low horizontal fragmentation index, plain forests and arid sparse forest and shrub complexes are prevalent.

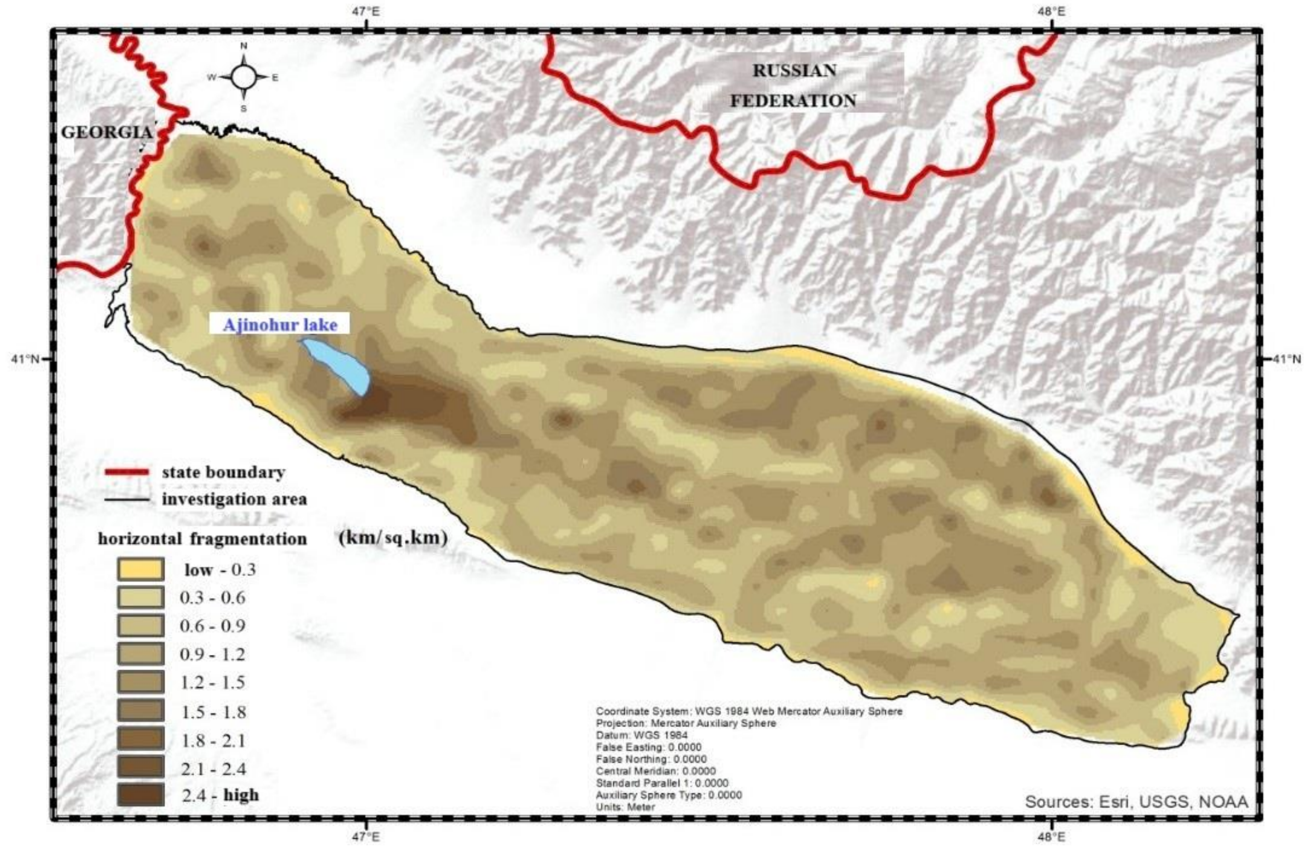

Figure 3.
Map of horizontal fragmentation of the relief in the Ajinohur foothills and adjacent areas.

When compiling the vertical fragmentation map, 5 divisions were distinguished: below 100 m/km² (703 km²-16%), 100-200 m/km² (1,488 km²-33.7%), 200-300 m/km² (1,283 km²-29%), 300-400 m/km² (720 km²-16.3%), 400-585 m/km² (225 km²-5%) (Figure 4). In areas where vertical fragmentation exceeds 300 m, arid, sparse forests and shrubs are widespread, while in areas up to 300 m, semi-deserts, lowland forests, and partly dry steppes are prevalent. Pasture complexes dominate in regions with high vertical fragmentation, whereas agro-irrigation complexes are common in areas with low vertical fragmentation.

Thus, the first factor that plays a role in the differentiation of landscapes is the approach of mountain ranges to the Greater Caucasus Mountains towards the east. The semi-desert landscape, which is distinguished by its simple biodiversity in the west, is replaced by arid, sparse forests and shrubs, forest-steppes, which are distinguished by a more complex ecological structure towards the east.

The second factor is the northern and southern slopes, which play an important role in the formation of geosystems. While wormwood-ephemeral semi-deserts prevail on the southern slopes, oak forests, and sometimes arid-forest shrubs and arid forests, are spread on the northern slopes in a weakly fragmented relief.

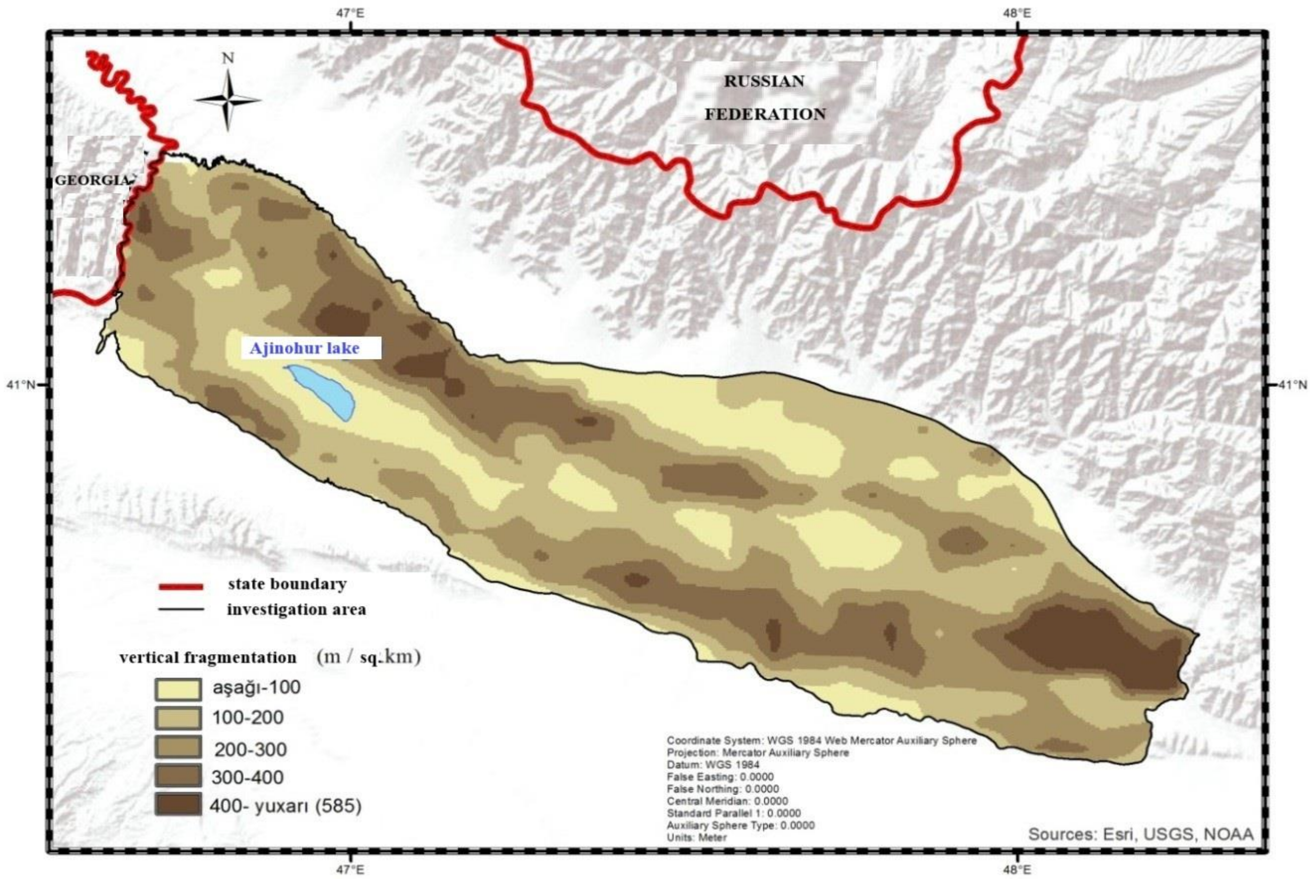

Figure 4.
Map of vertical distribution of relief in the Ajinohur foothills and adjacent areas.

The third factor affecting the differentiation of landscapes is the location of mountain ranges at different geographical latitudes. For example, the ecolandscape structure of the Dashuz-Amirvan range, located in the north of the study area, is different from the landscape structure of the Akhar-Baxar range, located in the south.

4. Conclusion

The absolute height of the relief is one of the factors that form ecolandscape differentiation. While saline, ephemeral semi-deserts are widespread in the western part of the study area, where the absolute height of the relief is low (300-400 m), and around Lake Ajinohur, dry steppes predominate in the central part (500-700 m), where the absolute height of the relief is relatively high, arid sparse forests and bushes and plain forests predominate in the eastern part, where the height is higher (800-1105 m).

An increase in absolute height also changes the direction of transformation. Thus, in areas where the absolute height is low, agroirrigation landscapes, settlements, roads, and in areas where the absolute height is high, pasture and grazing complexes and gardens predominate.

Another factor affecting the differentiation of landscapes is the lithology of rocks. For example, the predominance of clayey rocks in the Akhar-Baxar range led to the formation of arid-denudation structures and weak soil-vegetation cover.

From the above, it can be concluded that the slopes of the relief facing north and northeast, with an absolute height of 200-600 m and an inclination of up to 15°, play an important role in the differentiation of landscapes.

Another factor affecting the ecolandscape differentiation is human economic activity. As the altitude increases in the ridges, the anthropogenic transformation of landscapes weakens. The eastern part of the study area, which is intensively exploited for agriculture and settlements and is exposed to anthropogenic impacts throughout the year, has been subjected to stronger anthropogenic transformation than the western part, which experiences seasonal anthropogenic impacts and is exploited as pastures.

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