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Comprehensive soil erosion risk assessment using remote sensing (on the example of Zangilan region)

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Abstract

Determining the nature, extent and direction of changes is essential to determine the potential and future direction of ecosystem expansion. The article used GIS to track changes in the ecosystem and compare the results. It has been established that some parameters of the ecosystem have a positive trend, and some parameters have a negative trend. Thus, changes in the area of forest ecosystems due to negative environmental and anthropogenic impacts over different years (1990-2022) were compared. Change detection was determined by remote sensing from satellite images (LANDSAT 4-9 OLI/TIRS C2 L1) within the study area. The area of optimally developed forests decreased by 84.5% (10,838.05 ha). There has been a serious degradation of the currently existing forest area in a negative direction. In addition, a Universal Soil Loss Equation (USLE) was developed based on various geographic parameters (rain kinetic energy, average annual precipitation, soil erosion coefficient, slope length, slope steepness, land use/land cover) and erosion prevention methods a corresponding map was drawn up. The lands of the plains and foothills of the region have undergone all types of degradation (physical, chemical, biological) as a result of military-technical impact. As a result, the need to apply these parameters in the implementation of large-scale projects in the Zangilan administrative region, liberated from occupation, was determined.

1. Introduction

In the last 100-150 years, as a result of uncontrolled deforestation, the process of soil erosion has accelerated, and the unsystematic use of natural fodder lands has led to an intensification of this process. As the anthropogenic impact intensifies, the erosion process accelerates, and the soil formation process develops in a negative direction. Every year in the world, as a result of the erosion process, about 25-40 billion tons of arable soil are destroyed. If the erosion process develops so rapidly, then by 2050 1.5 million/km^2 of arable land will remain unused (Poluetkov, 2003). To assess the actual course of the erosion process, long-term management of soil resources in erosion-prone areas is necessary. Industrial concentration and population growth have led to a significant transformation of geographical components in space and time. All forms of anthropogenic impact (urbanization, mining, wars, etc.) have a negative impact on the environment.

In the selected study area, a 30-year period of occupation and the repetition of a phase of active hostilities led to the destruction of all ecosystems and infrastructure. In this direction, research work is being carried out in different regions of the world (Khrushch et.al. 2023; Ordway 2015). However, the research work carried out in this direction is devoted to the ethical, socio-economic and ethnic consequences of the war (Wirtz, Känel 2017). The effect of war on surrounding ecosystems has been little studied. Baumann (Baumann 2015) notes that as a result of the war, more than 60% of the agricultural land in Karabakh remained unused. Also, 30% of these lands were compensated by new agricultural land. As a result, the pressure on the surrounding areas has increased, pastures have turned into arable land.

2. Method

The study covers the territory of the Zangilan administrative region (70,099,177 ha). The description of the area is given on the basis of a digital elevation model (Figure 1).

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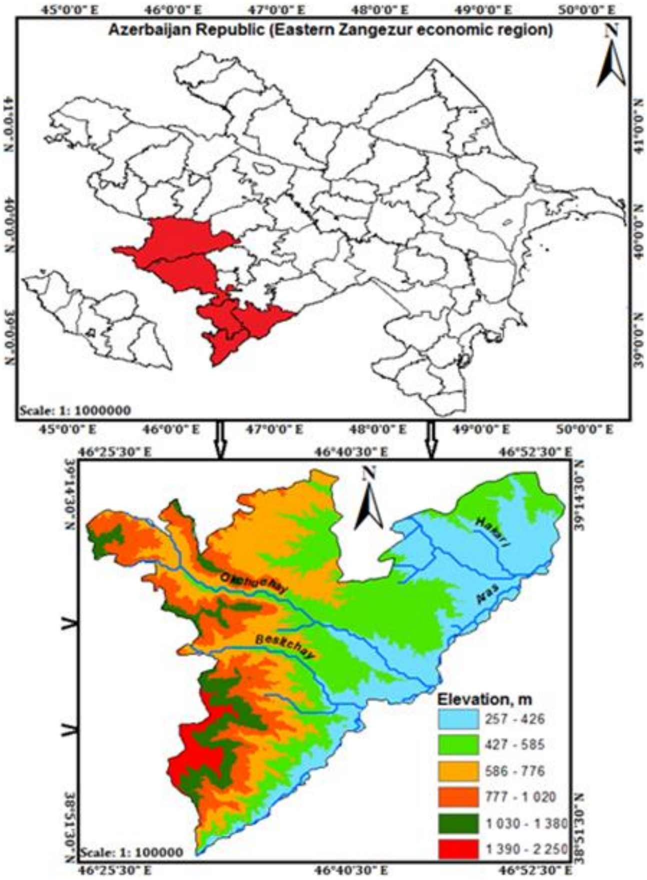

Figure 1. The geographic location of Zangilan district in Azerbaijan

The Universal Soil Loss Equation (USLE) was used to estimate the risk of erosion in the study area (Foster 2008). Universal soil loss equation (USLE) estimates long-term avarage annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system and management practices.

$$A=R\times K\times LS\times C\times P$$

A – is the avarage annual soil loss (tons, ha, year)
R – is the rainfall erosivity, rainfall erosivity is the kinetic energy of raindrops`s impact and the rate of sociated runoff;
K – is the soil erodibility factor, soil erodibility represents the effect of soil properties and soil profile characteristics on soil loss;
LS – is the topographic factor, topographic factors consist of slope lenght and slope steepness. İncrease in the slope lenght L causes increase in erosion due to a progressive accumulation of runoff in the direction of downslope. Increase in slope steepness factor S increase the soil erosion as a result of increasing velocity (SRTM 30 m);
C – is the crop/vegetation management factor, used to the relative effectivness of soil and crop management systems in preventing soil loss (data source: Sentinel-2 Land use/ land cover (10 m).
P – is the practice support, it reflects the effects of practices that will reduce the amount and rate of the water runoff and thus reduce the amount of erosion.

Values obtained from literatures based on the farmers practices. According to the degree of erosion, the assessment was carried out in 5 categories (Table 1).

Vegetation changes are regularly monitored locally and globally using remote sensing. The received multispectral data are involved in research in the form of vegetation indices (NDVİ, EVİ, SAVİ, etc.) (Guha 2018; Li 2011). The Normalized Different Vegetation İndex (NDVİ) is mainly used. NDVI values range from -1 to 1.

Table 1. Soil erosion classification

Level	Soil loss (tons ha^{-1} $year^{-1}$)
Very low erosion	0 – 1
Low	1 – 5
Medium	5 – 10
High	10 – 50
Extreme	>50

Vegetation changes were analyzed through satellite images (LANDSAT 4-5; LANDSAT 8-9 OLİ/TİRS C2 L1) for the years 1990-2022. Coordinates of the center point of the image were 38°54'16.27"N, 46°41'39.66"E

The evaluation of the changes in the vegetation was carried out in 5 categories (Table 2):

Table 2. NDVI classification

NDVİ class	NDVİ value	The greenness level of the vegetation
1	<-0,03	non-vegetation area, open area, waterbody
2	-0,03-0,15	very low dense vegetation
3	0,15-0,25	low dense vegetation
4	0,26-0,35	moderately dense vegetation
5	>0,35	highly dense vegetation

3. Results

On the basis of the universal soil loss equation, soil erosion losses in the study area were calculated. (Table 3).

Table 3. Soil loss

Soil loss, tons, h/yr	Area, ha	Persentage of total, %
0 – 1	32602,89	46,51
1 – 5	6821,867	9,73
5 – 10	4709,621	6,72
10 – 50	16965,96	24,2
50 >	5691,568	8,12
Relative error	3307,271	4,72
Total	70099,177	100

According to the NDVI, the dynamics of the vegetation process by categories was studied, the areas of plots with stable and variable vegetation were calculated (Table 4).

Table 4. Direction of the vegetation process

Changes	Area, ha	Persentage of total, %
No veg.	37303,19	53,2
No veg - veg.	2762,847	3,9
Veg - no veg.	10838,05	15,5
Veg.	19195,09	27,4
Total	70099,177	100

4. Discussion

As a result of 30 years of occupation and 44 days of active war, the ecosystems of the study area were severely damaged, and the integrity of the ecosystem was violated. A soil loss map was developed for the assessment of erosion risk (Figure 2).

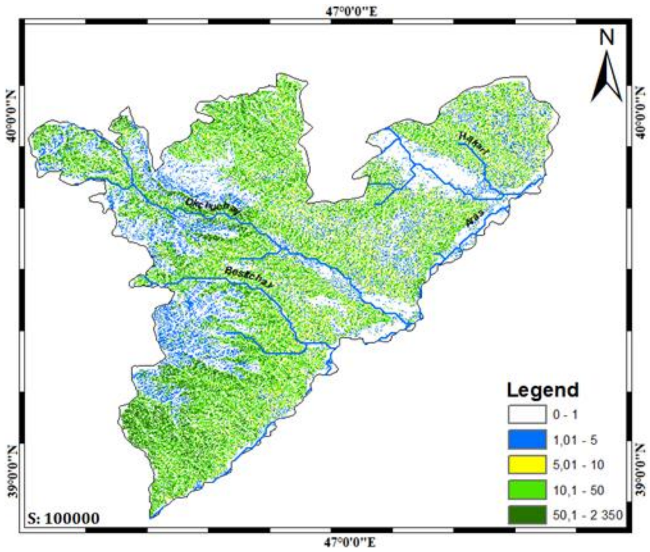

Figure 2. Soil loss equation map (2022)

The ecosystem of the region is sensitive and unstable to the influence of exodynamic processes. There was a serious degradation (physical, chemical and biological) of vegetation, which negatively affected the process of natural regeneration. The direction of transformation reflects a negative trend.

Based on the soil loss equation, it was determined that 43.76% (30,674.42 ha) of the research area has changed in a negative direction. This change was caused by the movement of military equipment, burying of mines, construction of defense fortifications, setting fires, cutting trees.

During the 30-year period of occupation, 10,838.05 hectares of forest area were cut down, and the process of natural regeneration took place on an area of 2762,847 hectares.

5. Conclusion

During the occupation, the area of heavily degraded territories increased by 14.55% (10202.76 ha) in 2022 compared to 1990 in the Zangilan administrative region, and the area of degraded territories at the background level decreased by 14.78% (10357.91 ha). Currently, work to restore the ecological balance should be carried out taking into account the balance between these two classes.

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