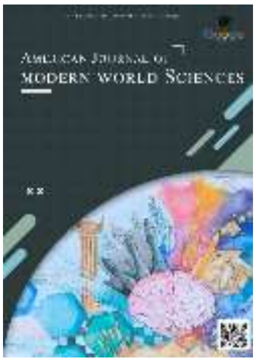

DEVELOPING A METHOD FOR DETERMINING THE IMPACT OF LAND SLOPE ON THE CONDITION OF FORESTED AREAS

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Abstract. *This study examines the influence of land slope and curvature on forest condition using GIS and remote sensing data. High-resolution digital elevation models were applied to analyze geomorphological parameters such as slope, aspect, curvature, hillshade, and wind exposure within the Egrisuv plot 3. The results show that concave slopes provide favorable conditions for forest development due to higher moisture retention, while convex slopes are characterized by lower vegetation density and increased ecological vulnerability. Northern and western aspects support denser forest cover compared to southern and eastern slopes. The proposed approach enables accurate assessment of forest condition and supports sustainable forest management and ecological planning.*

Keywords. *Land curvature; Slope; Aspect; Forest condition; GIS; Remote sensing; DEM; NDVI.*

Introduction

Curvature is a three-dimensional property of a two-dimensional surface that describes the morphology (shape) of a slope. In this way, the degrees and shapes of slope curvature are determined. Topographic structure and slope shape play a crucial role in the distribution of forests.

The influence of this parameter on forest formation is analyzed by examining changes in curvature types (concave, convex, flat), as well as surface water and sediment accumulation, slope degree, and aspect.

The morphological characteristics of the Earth's surface-particularly curvature and slope shape-directly affect forest development, density, and health. Curvature is a three-dimensional parameter that identifies the concave (inward-bent), convex (outward-bulging), or flat shapes of terrain, which in turn governs the movement of water and sediments along slopes. These geomorphic features directly influence ecological factors such as moisture distribution, solar radiation, wind exposure, and ultimately vegetation cover density.

Methods

By analyzing the topography of an area, we can determine under which natural conditions forests form and in which zones they weaken. This analysis was performed using high-resolution digital elevation data (DEM, DTM). Surface morphological traces are indicators of stable or dynamic geomorphic processes that play a decisive role in the formation of forest zones. For instance, concave slopes retain moisture and promote favorable forest development, while convex slopes dry quickly and negatively impact plant health.

In recent years, the advancement of LIDAR (Light Detection and Ranging) and other high-resolution remote sensing technologies has enabled widespread use of digital terrain models (DTM/DSM) with 0.5-1 meter accuracy for terrain analysis. Such resolution is especially critical for identifying small-scale geomorphic features-initiation zones of shallow landslides, micro-slopes for tree growth, moisture accumulation sites, and high erosion risk areas.

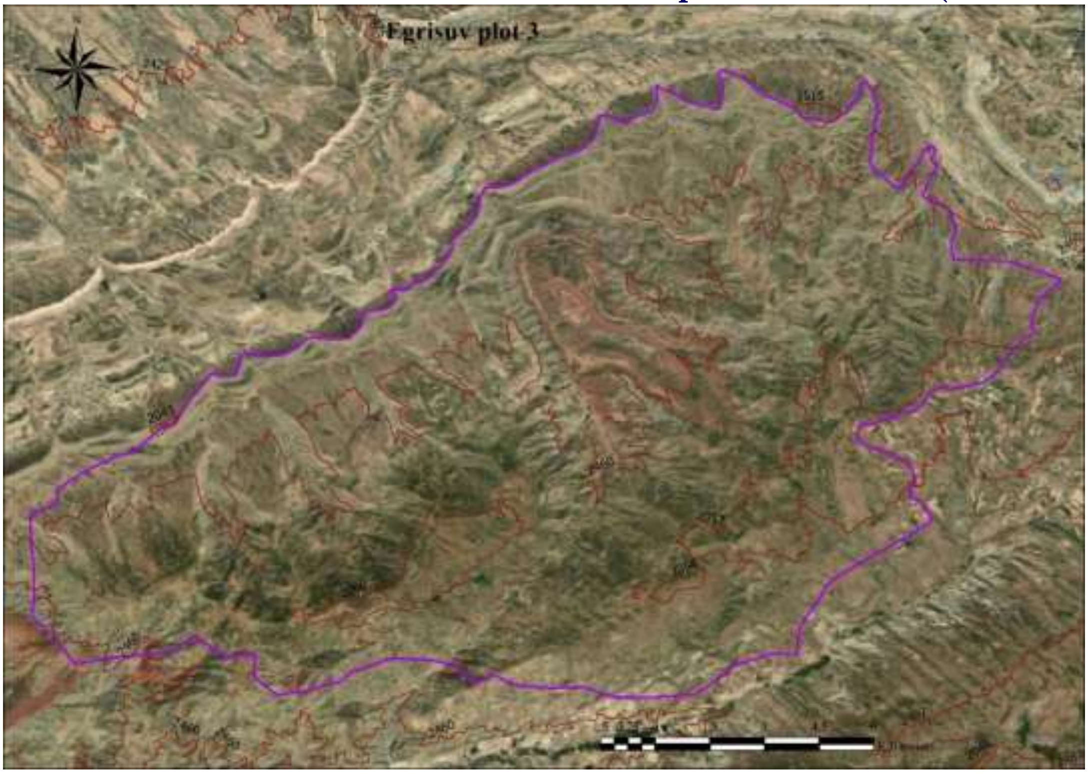

Figure 1. Basemap image of Egrisuv plot 3

The relief and elevation lines are shown on the map of the Egrisuv plot 3 based on satellite imagery. The pink line represents the boundary of the section, and the red contours represent elevations from 1615 m to 2487 m. The terrain is complex, the northern and western slopes are forested, and the southern and eastern parts are open and sparsely vegetated. This map will serve as a basis for geomorphological analysis and ecological planning.

In this figure below, a contour line at a height of 2000 meters of the Egrisuv plot 3 is selected, and its attribute data (ID: 2054) and coordinates (66.691324°E, 38.176017°N) are shown in the pop-up window. The contour lines are constructed at intervals of 500 meters, which is important for determining vertical changes in relief and distinguishing between mountainous and lowland zones.

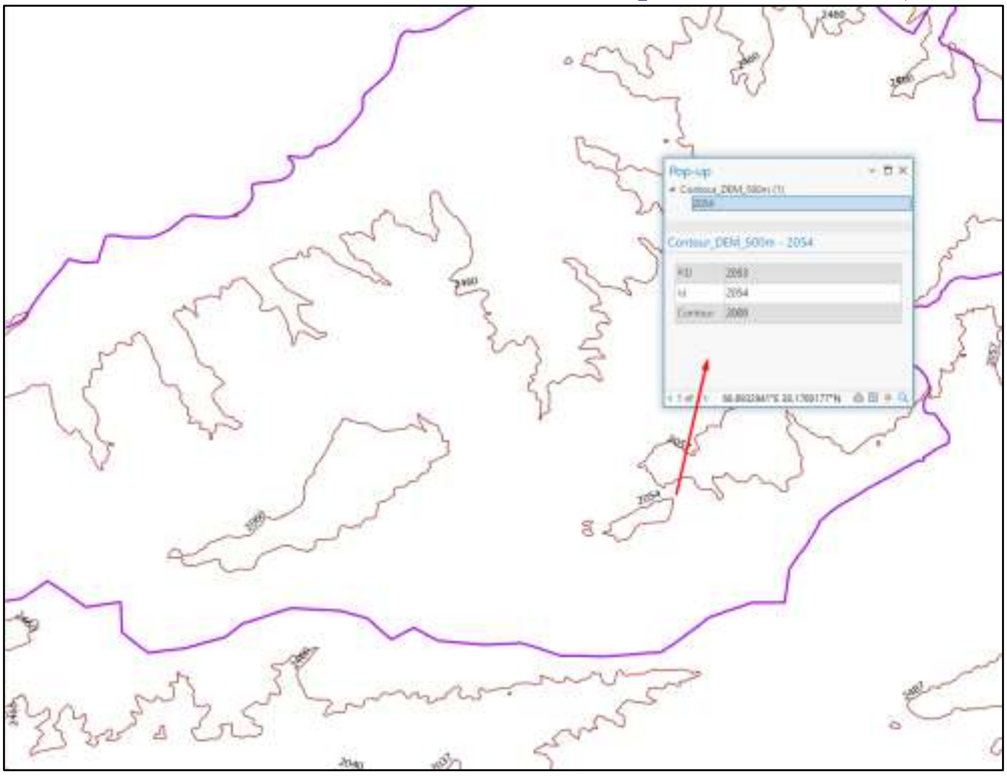

Figure 2. Creating contour lines by using Contour tool.

Results

In our study, the following stages were carried out in assessing the connection of forest zones with the relief:

The Aspect-slope function creates a raster layer that simultaneously shows the side and slope of the surface.

Aspect determines the downward direction of the maximum rate of value change from each pixel to its neighbors. The aspect can be represented as the direction of the slope. The values of the output raster will be the compass direction of the side represented by tone (color). Slope represents the rate of change of height, measured in degrees for each pixel of the digital elevation model (DEM). Slope represents the steepness of the surface and is symbolically represented by three classes indicated by color saturation (brightness).

Figure 3. Aspect and Slope symbols [46]

Aspect directions are represented by color, and slope by light.

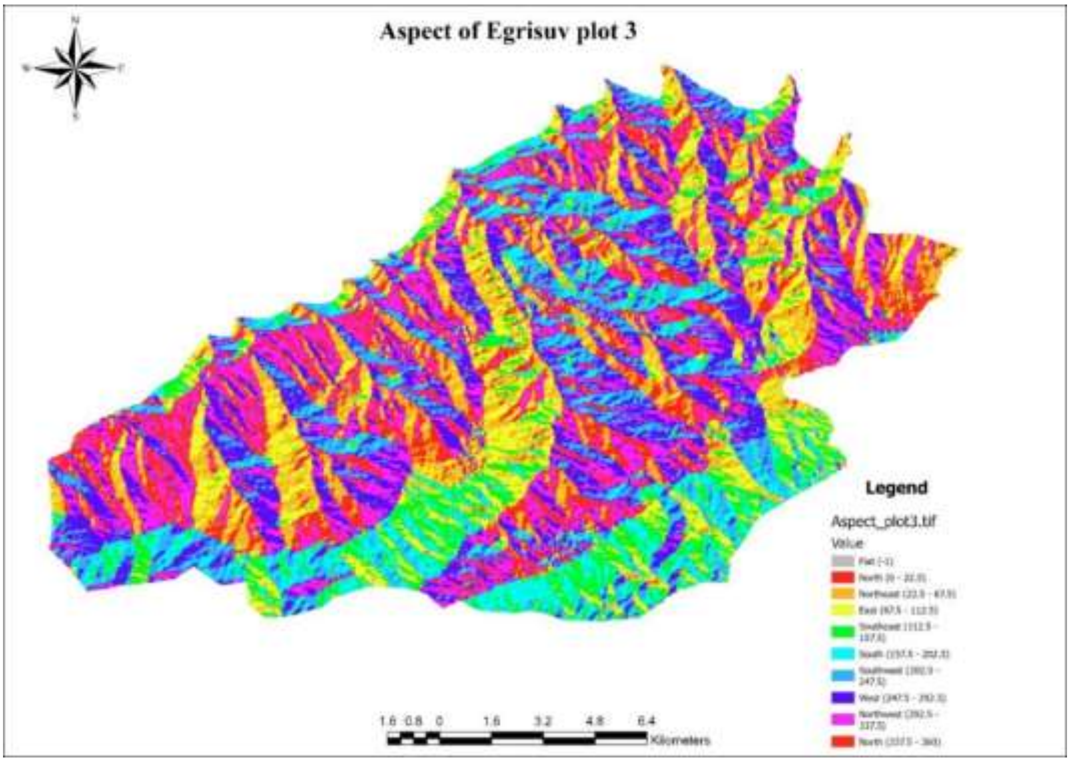

Figure 4. Aspect map of Egrisuv plot 3

The Egrisuv plot 3 has a complex terrain structure, where there are slopes and elevations of various directions. To assess the geomorphological and ecological features of this territory, an aspect map based on remote sensing technologies and a basemap map based on satellite imagery were studied. When studying both maps together, it becomes clear how climatic and topographic factors influence the distribution of vegetation.

On the aspect map, the slope directions are represented by different colors. Especially the northern (0-22.5° / 337.5-360°), northwestern (292.5°-337.5°) and western (247.5°-292.5°) slopes have cool, relatively humid conditions, and in these areas, more forest and vegetation cover is preserved. Red, pink, and blue zones are important in this case. On the contrary, the slopes facing south (157.5°-202.5°), southeast (112.5°-157.5°), and east (67.5°-112.5°) are exposed to intense sunlight, and vegetation is scarce or absent in these areas. This state is represented by green, light green, and yellow colors. Flat or flat areas are given in white and are mainly lowlands or valleys.

With the help of the updated basemap map, the data of this aspect are visually confirmed. On the map, the boundary of the plot is marked with a pink line, and the contour lines indicate the elevation level. For example, marked areas from 1615 m to 2043 m, 2060 m, 2460 m, and even 2487 m indicate the vertical variability of the terrain. A dense arrangement of contour lines indicates steep slopes, while a sparse one indicates slope zones.

According to satellite imagery, forests are mainly located on the northern, northwestern, and western slopes. In these areas, shady conditions, relative coolness, and long-term soil moisture preservation create favorable conditions for plants. Particularly dense vegetation is observed along the western and northwestern slopes. The southeastern and eastern slopes are open and vegetation is sparse, represented mainly by rocky or eroded areas.

The lowlands may be used for agriculture or as pastures. The reddish massifs in the central part are geologically layered, reflecting eroded rocks, indicating extremely sparse or lost vegetation.

In conclusion, the distribution of vegetation in the 3rd section of the Yegrisuv is directly related to such factors as relief shape, slope direction, and elevation. The northern and western directions are favorable for forests, while the southern and eastern slopes are ecologically vulnerable zones. This data will serve as an important basis for the restoration of degraded lands, forest protection, and ecological planning.

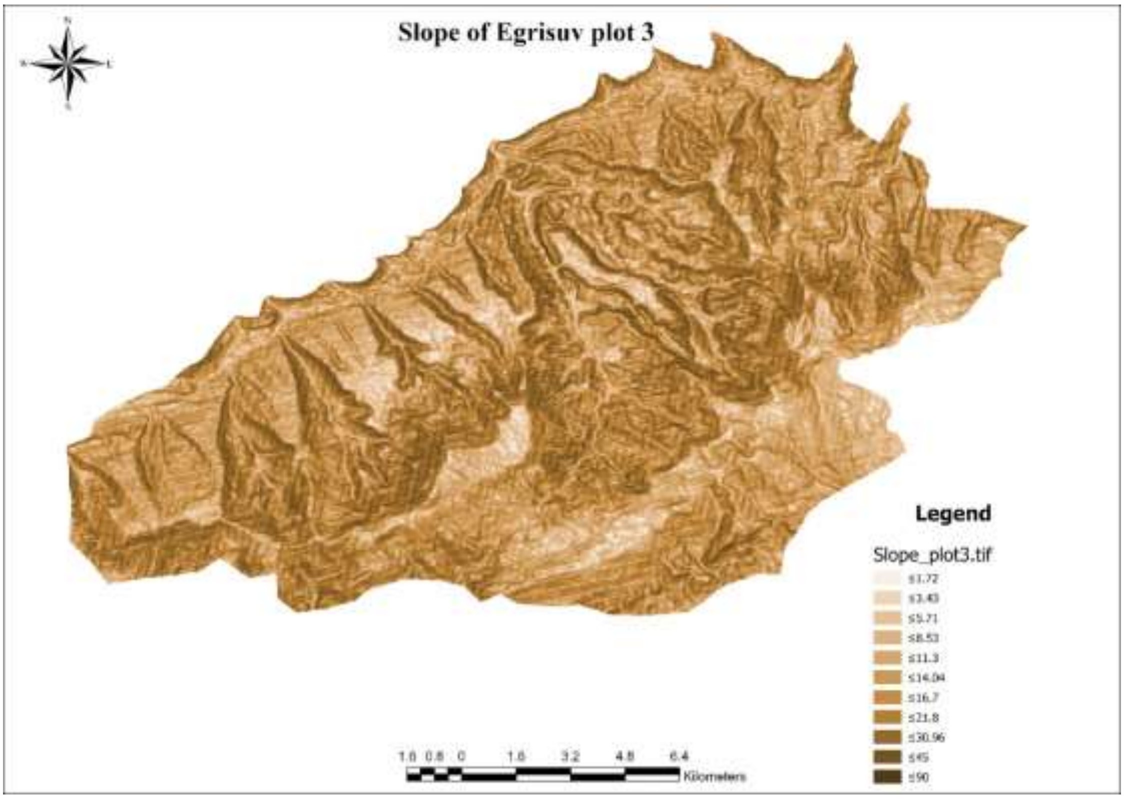

Figure 5. Slope map of Egrisuv plot 3

The map above is a slope map of the Egrisuv plot section 3, where the slope levels of the area are depicted in gradient colors, divided into 10 categories. The lightest slopes (<1.72°) are given in light tones, and the steepest slopes (≥50°) are given in dark brown. The map shows that the relief is complex and uneven: the slope level is high, especially in the central and southwestern parts, which means areas with a high risk of erosion. Low-slope valleys and plains are light-colored and considered suitable for agriculture. This map is an important source for land resource use, anti-erosion planning, and environmental monitoring.

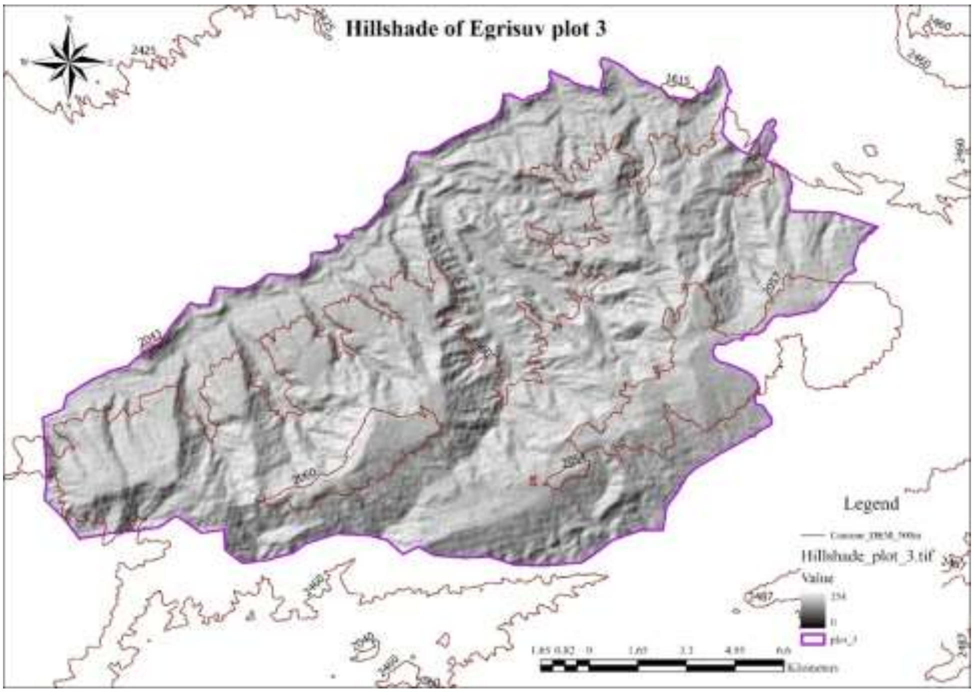

Figure 6. Hillshade map of Egrisuv plot 3

This map is a hillshade (shaded relief) map of the Egrisuv plot 3 section, which visually reflects the three-dimensional structure of the ground surface in the area. Hillshade is a map that models what shadows the terrain casts under sunlight, allowing for the precise representation of the depths and steepness of terrain forms and the directions of slopes. This map is mainly created based on DEM (Digital Altitude Model) and enhances information about the relief structure.

Key elements on the map:

Shadow effects: Bright areas are slopes where direct sunlight falls (for example, southwestern ones); areas with deep shadows are shaded northern or steep slopes with less sunlight.

The pink line indicates the exact boundary of plot 3. This line helps to determine the boundary with the landforms and landscape structure of the area.

Red contour lines are elevation isolines representing mountainous terrain ranging from 1615 m to 2043 m, 2460 m, and 2487 m. Areas with dense contour lines represent steep slopes, while areas with sparse contour lines represent steep slopes or flat surfaces.

Gradation values (legend): In the figure, the Hillshade values range from 0 to 254, with 0 denoting fully shaded areas and 254 denoting fully illuminated areas.

Geomorphological and ecological analysis:

The main advantage of the Hillshade map is that it shows relief forms in a "real" way. Mountain ranges, valleys, ravines, slopes, and lowlands are clearly distinguished. Use this map to:

It will be easier to identify watercourses and drainage systems;

Potential erosion zones (vertical and open slopes) are identified;

Understand the differences in vegetation distribution and microclimate in shaded areas;

It serves as an important analytical tool for forest restoration, land degradation control, and agroecological planning.

The hillshade map of the curved plot section 3 reflects the relief forms in a three-dimensional aesthetic view and facilitates landscape analysis. The elevation lines, the degree of shading, and the boundaries clearly indicate the mountainous and valley structure of the area. This map is used as an important source for monitoring, land management, environmental analysis, and forest management based on geoinformation systems.

Based on DEM, slope and curvature layers were formed;

For each type of curve, forest status indices (for example, NDVI) were analyzed using the zonal statistical method;

In concave zones, NDVI values are high, and forest density is well preserved, while in convex zones these values decrease.

And the flat zones showed average indicators.

It was also possible to determine the location of forests and their adaptation to natural and geographical conditions by combining the openness to the wind direction, the angle of sunlight (aspect), and the degree of slope.

Discussion

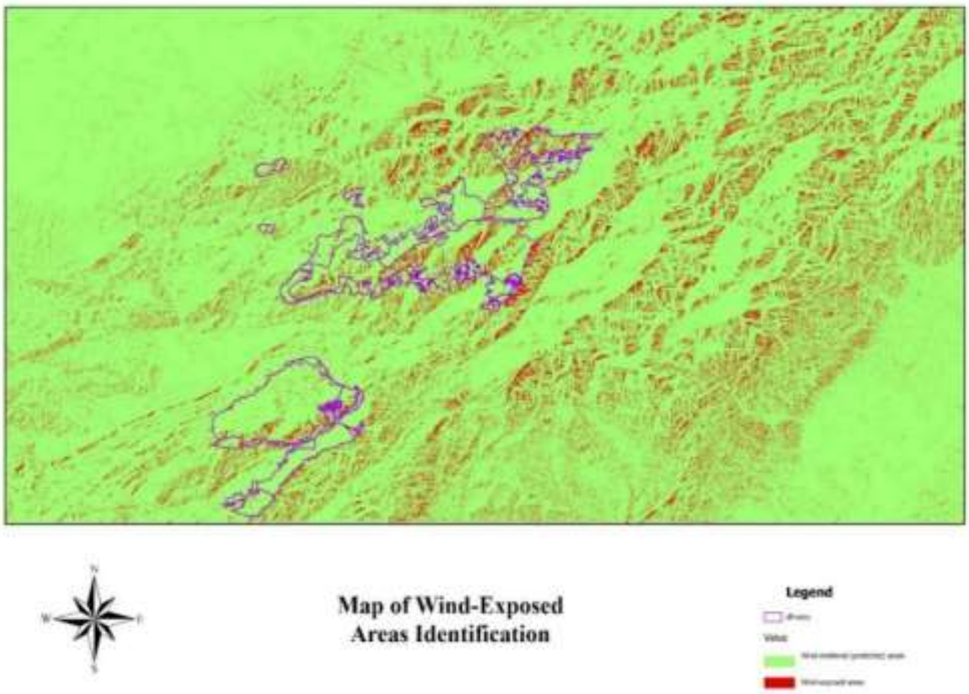

Figure 7. Map of the Process for Identifying Wind-Exposed Areas

This map illustrates the distribution of wind-exposed and wind-sheltered areas within the study region. The analysis was conducted by combining slope and aspect data derived from a digital elevation model

(DEM). For Dehkanabad district, the prevailing wind direction is considered to be southeast (SE), approximately 135° azimuth.

Map Elements:

- Red zones – Wind-exposed areas. These are areas facing the wind direction with a slope greater than 5°.
- Green zones – Wind-sheltered (protected) areas. These include areas not facing the wind direction or with flat slopes.

Purple contours – Represent the boundaries of the studied forest zones or monitoring sites.

Methodology:

To identify these zones, the following conditional formula was applied using the Raster Calculator tool in ArcGIS Pro:

$$Con\big((Abs(Aspect - 135) \leq 22.5) \,\&\, (Slope > 5), 1, 0\big) \quad (3.1)$$

As a result, two zones were created:

Value 1 – Wind-exposed zones

Value 0 – Wind-sheltered zones

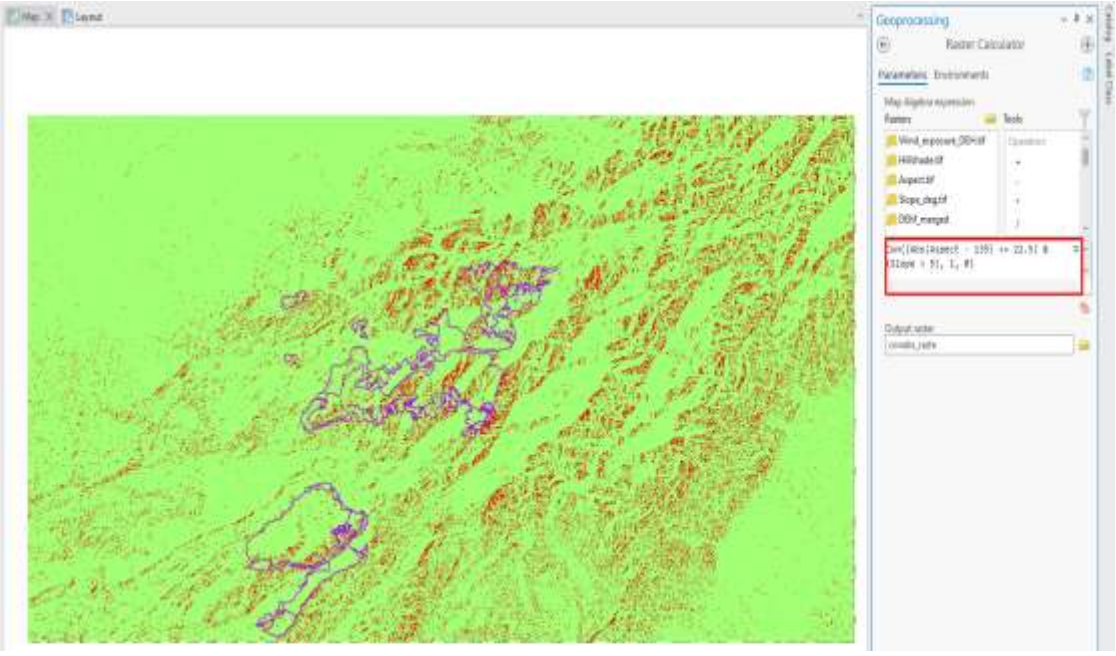

Figure 8. Raster-Based Identification of Wind-Exposed Areas Using Aspect and Slope Thresholds

Practical significance:

This map is intended for use in the following areas:

Forestry – Identifying zones hazardous for vegetation in open areas with strong winds;

Erosion risk assessment – Locating areas where soil erosion is likely due to wind exposure;

Ecological planning – Analyzing microclimatic conditions and improving landscape protection.

The proposed method for determining the impact of land curvature on forest condition is based on:

- High-resolution terrain analysis;
- A multi-parameter geomorphic model;
- And enables more reliable and fine-scale forest monitoring.

Thus, geomorphological parameters-especially curvature-can be considered key factors in assessing forest health and ecological behavior.

Conclusion

The study demonstrates that geomorphological factors, particularly land slope, aspect, and curvature, play a decisive role in the condition and spatial distribution of forested areas. The results confirm that concave terrain forms provide more favorable conditions for forest growth due to higher moisture retention and reduced erosion, whereas convex slopes are characterized by lower vegetation density and increased ecological vulnerability. Northern and western slope aspects support healthier and denser forest cover compared to southern and eastern slopes, which are more exposed to solar radiation and wind effects. The integrated GIS- and DEM-based approach proposed in this study enables accurate, fine-scale assessment of forest conditions and can be effectively applied in sustainable forest management, erosion risk mitigation, and ecological planning.

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