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RESEARCH OF THE RELIEF FACTORS OF THE PIRGULU RESERVE BASED ON SATELLITE IMAGES

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ABSTRACT

Using satellite images from the ASTER Terra sensor and Landsat 9, the properties of the relief of the Pirgulu Reserve around the Shamakhy Astrophysical Observatory were studied: NDVI, aspekt, slope, height above sea level and river courses. It was shown that the negative impact on the astroclimate increases from the eastern side and the inner territory of the Shamakhy Astrophysical Observatory.

Key words: Pirguli Nature Reserve, relief properties, anthropogenic impact, astroclimate.

1 INTRODUCTION

In thematic studies of the Earth's surface based on satellite imagery, a detailed characterization of the natural features of the surveyed area is essential (e.g., Ismailov 2023; Chandra Ghosh 2008; Dubovik et al. 2000). One of the primary features of interest is the relief of the area (e.g., Ismailov 2023, 2024a). Satellite imagery complements traditional ground-based methods for studying surface relief

For space-based studies of landscape features, it is important to combine optical and radar imagery. Processing optical satellite images involves several preliminary stages, including atmospheric correction methods that depend on the regional conditions and time of observation (e.g., Chandra Ghosh 2008; Dubovik et al. 2000).

Currently, a significant number of high- and ultra-high-resolution satellites provide radar data for constructing Digital Terrain Models (DTMs) https://asterweb.jpl.nasa.gov/gdem.asp. A Digital Elevation Model (DEM) is a three-dimensional representation of the Earth's surface given as an array of points with defined heights. DEMs capture the true surface relief, excluding vegetation, buildings, and other anthropogenic objects.

An important factor influencing the results of thematic satellite image analysis is the regional characteristics of the relief

GIS-Lab, Geoinformation Systems and Remote Sensing of the Earth. Available at: http://gis-lab.info/; Georeferencing in QGIS: https://gis-lab.info/qa/georef-qgis.html; Atmospheric correction using the DOS method: https://wiki.gis-lab.info/w/ (accessed DATE).Ismailov2023. In this work, satellite imagery is used to study the most indicative properties of the relief surrounding the Shamakhy Astrophysical Observatory, located within the Pirgulu Nature Reserve http://gis-lab.info/.

The Pirgulu State Nature Reserve was established in 1968 on a 1,521-hectare site at the eastern end of the Greater Caucasus Mountains, in the Shamakhy administrative district (e.g., SimpleMaps 2024). Its main objectives are to prevent erosion and atmospheric dust pollution, which adversely affect the activities of the Shamakhy Astrophysical Observatory, and to preserve the characteristic mountain-forest landscape of the region. This study investigates the methodological aspects of analysing the relief of the Pirgulu Reserve using the open-source Quantum GIS (QGIS) software (GIS-Lab 2024) in combination with multispectral satellite remote sensing imagery. A comprehensive assessment of the relief enables the derivation of robust conclusions regarding the landscape characteristics of the Pirgulu Reserve.

2 SELECTING SOURCE SATELLITE IMAGES

Fig. 1 shows the original raw satellite images used in this study. Images 1 and 2 were obtained from the Landsat 9 satellite, corresponding to the red (B4) and near-infrared channels of the Earth's surface, respectively https://landsat.gsfc.nasa.gov/ They illustrate the administrative boundaries of the Shamakhy district https://simplemaps.com/ and were used to calculate the NDVI vegetation index (Ismailov 2023). Fig. 1 also presents the Digital Elevation Model (DEM) of the study area, including the Pirgulu State Nature Reserve.

Information on terrain is essential for geoinformation projects based on Earth Remote Sensing (ERS) data. Digital Elevation Models provide accurate data on surface height, in-

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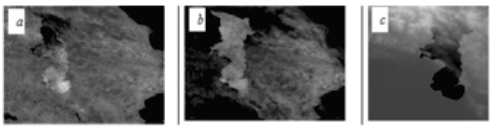

Figure 1. Satellite images: (1) LC09_L1TP_167032_20240826_20240826_02_T (2) LC09_L1TP_167032_20240826_20240826_02_T1_B5, (3) Digital Elevation Model (DEM).

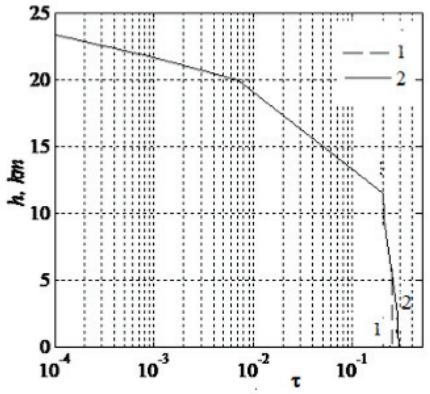

Figure 2. Vertical profiles of atmospheric optical thickness τ for Landsat 9 red (R, band 2) and near-infrared (NIR, band 1) channels

cluding buildings, vegetation, and other topographic features. Global DEMs are primarily constructed from stereoscopic optical and interferometric radar satellite data. In this work, we used the NASA ASTER GDEM (Global Digital Elevation Model) product derived from the ASTER sensor on the Terra satellite https://asterweb.jpl.nasa.gov/gdem.asp.

3 ANALYSIS OF RELIEF PROPERTIES

We consider the following properties of the relief of the Pirgulu Reserve: slope is an inclined section of the Earth's surface that is formed as a result of relief-forming processes; aspect is one of the morphometric characteristics of relief, characterizing the spatial orientation of an elementary slope of a hill, mountain or mountain range; height above sea level, absolute height is a linear measure of the potential difference at a point on the earth's surface and at the beginning of the height calculation (the starting point);

Figure 2. Vertical profiles of the optical thickness of the atmosphere for the R (2) and NIR (1) channels of Landsat 9. The normalized difference vegetation index (NDVI) is a widely used metric for quantifying the health and density of vegetation using sensor data. It is calculated from spectrometric data at two specific bands: red and near-infrared. The spectrometric data is usually sourced from remote sensors,

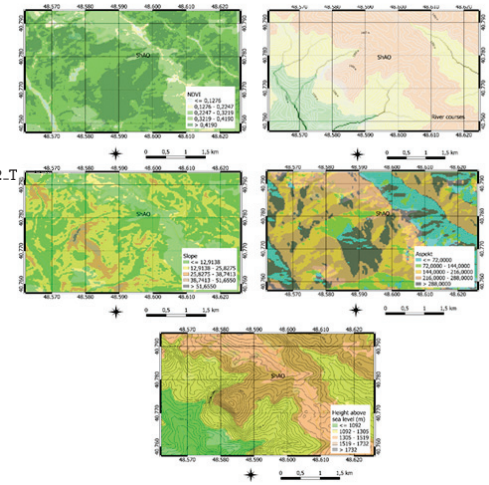

Figure 3. Fig. 3 Maps of relief factors

such as satellites; river courses is the bottom of a stream or river (bathymetry) and is confined within a channel, or the banks of the waterway; When calculating NDVI, preliminary processing of the red (R) (Fig. 1a) and infrared (NIR) (Fig. 2b) channels of Landsat-9 images was performed using the regional optical atmospheric model described by Ismailov (2023) and Ismailov (2024a) . Fig. 2 shows the vertical profiles of the optical thickness of the atmosphere τ as a function of altitude h for the red (R) and infrared (NIR) channels of Landsat 9. These data were used, respectively, for the atmospheric correction of images for the R (fig. 1a) and NIR (fig. 1b) channels of Landsat 9. In these figures, the vertical profiles differ significantly for the lower troposphere and the surface layer of the atmosphere.

Fig. 3 shows the mapping of the above-mentioned relief properties of the Pirgulu Reserve. Forest areas with high NDVI values > 0.4 are identified. At the same time, for the vicinity of highways, NDVI values > 0.4. This indicates the expansion of anthropogenic impacts around the roads and in the wider vicinity of the ShAO, which is associated with the expansion of the reserve areas allocated for tourist settlements and the construction of holiday homes. River channels are located mainly in the forested areas of the reserve. These channels stand out significantly to the east of the ShAO. The slopes of the reserve are more significant to the east and southeast of the location of the ShAO. In these directions, the areas of the southern sections of the reserve are significant and greatly decrease in altitude from the altitude level $h \approx 1.500$ km of the location of the ShAO. In general, the eastern and western sides of the reserve from the territory of the ShAO are significantly different. To the east of the ShAO there are significant forest zones with a strong decrease in the slope of the terrain. To the east there are less significant forest areas, with comparatively smaller differences in altitude. Anthropogenic impact is significant along the roads and to

the east of the ShAO territory and on its internal territory of the observatory.

REFERENCES

ASTER GDEM, 2024, ASTER Global Digital Elevation Map. Available at: https://asterweb.jpl.nasa.gov/gdem.asp (accessed DATE).

Chandra, A. M., Ghosh, S. K., 2008, Remote Sensing and Geographic Information Systems. Moscow: Tekhnosfera, 288 p.

Dubovik, O., Smirnov, A., Holben, B., et al., 2000, Accuracy assessments of aerosol optical properties retrieved from Aerosol Robotic Network (AERONET) sun and sky radiance measurements. *J. Geophys. Res.*, 105(D8), 9791–9806.

GIS-Lab, 2024, Geoinformation Systems and Remote Sensing of the Earth. Available at: http://gis-lab.info/; Georeferencing of data in QGIS: https://gis-lab.info/qa/georef-qgis.html; Atmospheric correction using the DOS method: https://wiki.gis-lab.info/w/ (accessed DATE).

Ismailov, F. I., 2023, Space Monitoring Based on Regional Space Images. LAP LAMBERT Academic Publishing, 130 p.

Ismailov, F. I., 2024a, Space monitoring on the territory of the Republic of Azerbaijan. *News Azerbaijan Natl. Acad. Sci., Ser. Phys. Tech. Math. Sci., Phys. Astron.*, No. 5, 103–111.

Ismailov, F. I., Dzhalilov, N. S., Humbatova, E. E., 2024b, About regional cosmic monitoring of snow cover in the south-eastern region of the Greater Caucasus. *Astron. J. Azerbaijan*, 19(1), 23–29.

NASA, 2024, Landsat 9 Bands. Available at: https://landsat.gsfc.nasa.gov/ (accessed DATE).

SimpleMaps, 2024, Free Azerbaijan GIS Map Files. Available at: https://simplemaps.com/gis/country/az (accessed DATE).