Bare Surfaces Analysis Within Ograzhden Mountain (Bulgarian Part)

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Abstract

The presence of bare surfaces is one of the main indicators for the degradation of natural ecosystems. The spread of bare surfaces and respectively the lack of vegetation cover is a serious threat to the sustainable development of complex environments such as mountains. The present study focuses on the spatial-temporal relationships of the bare surfaces with the local environment within the Bulgarian part of the small border mountain of Ograzhden. Based on temporal imageries from the Landsat 8 satellite, an analysis of the spatial distribution and tendencies in the development of bare surfaces has been made over a two-year period of time. Overall, the results of the research show a reduction in the total area of bare surfaces on the one hand and a slow environmental recovery on the other. Unfortunately, the positive changes are not ubiquitous, but describe only certain areas of the territory of interest.

Keywords: Ograzhden, Mountain, Bare Surfaces, Environment, Remote Sensing, Bulgarian

Introduction

Most common indicator for negative development of the natural environments is the presence of bare surfaces. In general, bare surfaces represent territories on Earth's surface not covered by vegetation. The term combines all territories occupied by bare soils and rock outcrops. Unfortunately it is one of the most important and typical land cover types all over the world. Generally, in the temperate regions the rapid development of this type of land cover often is a result of an adverse human impact on the environment, such as mineral exploration, deforestation, intensive cattle breeding and agriculture, etc.

Nowadays, remote sensing is one of the advanced tools for providing information of the spatial-temporal changes of the areas vulnerable to degradation, especially the mountain environments. Multitemporal data obtained from satellite images provide good geographical information for effectively managing of environmental processes within the mountain regions. Due to the difficult access to most mountain regions – difficult for physical and/or political reasons – remote sensing is often the only way for investigating large sections of the Earth's surface [1]. One of the most common applications of remote sensing is mapping and characterizing the surface cover. Manual and semi-automatic segmentation of optical images for vegetation, water, snow, rock, human objects, etc. can be based on panchromatic or color images. Multi-spectral remote sensing offers the opportunity for automatic classification of surface cover utilizing the variation in reflectivity with wavelength, which differs for most surface types [1, 2].

The present study investigates the spatial-temporal features of the bare surfaces within the Bulgarian part of Ograzhden Mountain. Using data from Landsat 8 satellite for a period of 2 years (08.08.2017 - 12.08.2019), a quantitative and qualitative assessment of the status and spatial distribution of the bare surfaces was made. The results of the study show positive trends, though not everywhere.

Study Area, Data and Working Methods

Study area

The object of present study is Bulgarian part of the small border mountain of Ograzhden (Fig.1) (41°57' - 41°39' N; 22°95' - 23°25' E). It is integral part of the Osogovo-Belasitsa mountain range and currently it is shared between Republik of Northern Macedonia (about 54%) and Republik of Bulgaria (about 46%). The total area of the Bulgarian part is 331 km^2 and has a length of 24 km and maximum width of 18 km. To the north it borders Maleshevo Mountain, to the south is the valley of the Strumeshnitsa River, which separates it from Belasitsa Mountain. To the east, the Struma River Valley separates it from Pirin Mountain. The western border coincides with the state border with Republik of Northern Macedonia. The highest point of Ograzhden Mountain - the Ograzhdanets peak (1748 m), is located on Northern Macedonian territory. Within the Bulgarian part, the highest point is Bilska chuka peak (1644 m), which is an important hydrographic knot. Other more well-known peaks are Markovi kladentsi peak (1523 m), Muratov peak (1398 m), Kukovski chukar peak (1233 m) [3], etc.

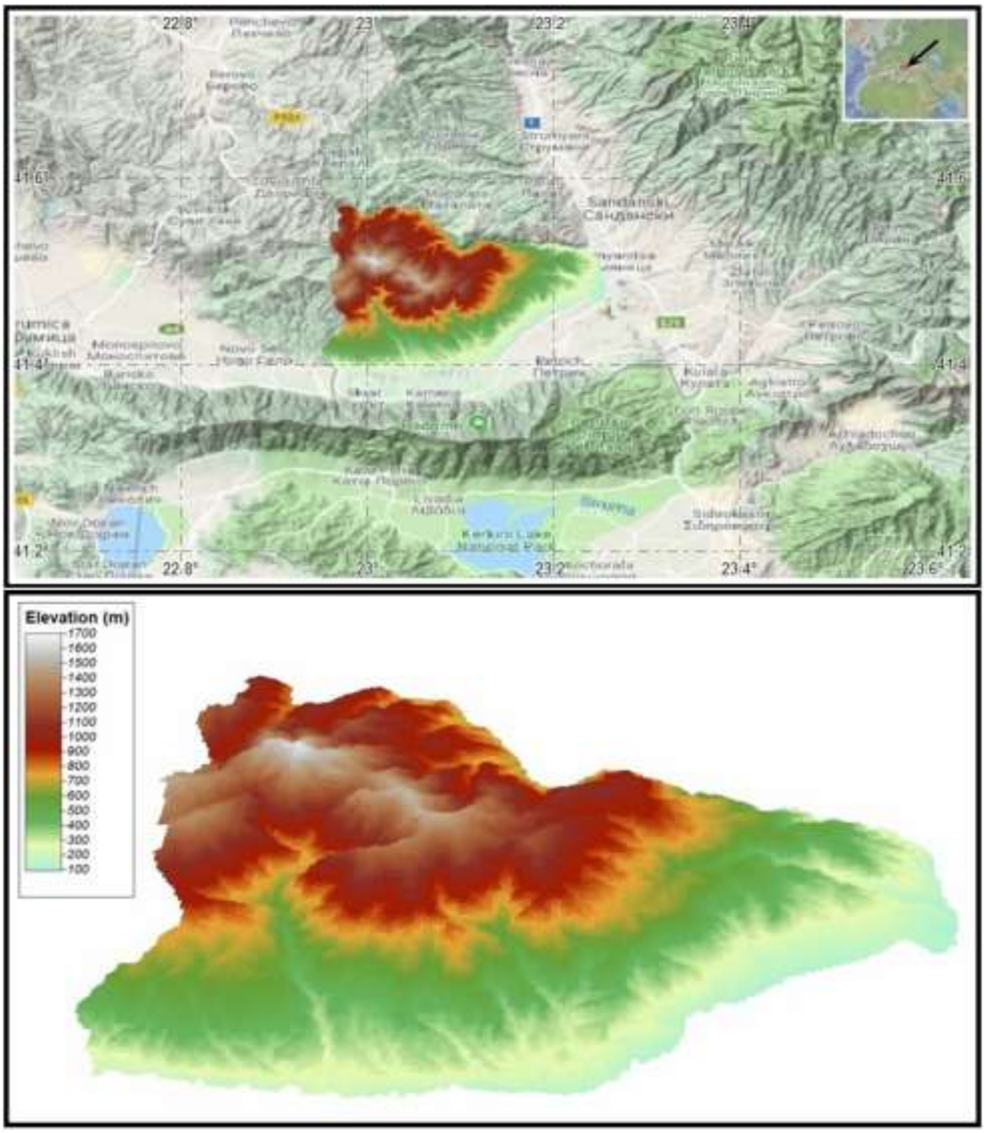

Fig.1: Geographical location and 3D view of the study area (Base map: Google Terrain).

Image Processing Method

Image processing methods transform the multispectral satellite data into images that enhance study features in contrast with the background [4]. Image fusion techniques deal with integration of complementary and redundant information from multiple images to create a composite image that contains a better description of the scene [5]. In the present study image processing techniques such as Band composite, Grid clustering and Change detection are applied. The band combination 5 (for Red) (wavelength 0,85-0,88 μm), 6 (for Green) (wavelength 1,57-1,65 μm) and 7 (for Blue) (wavelength 2,11-2,29 μm) allows differentiation of bare surfaces from vegetation. In the attached image (Fig.2), the bare surfaces are presented in a light blue colour and the vegetation in an orange colour. However, it is difficult to visually differentiate natural bare surfaces and the built-up areas in one image due to their high complexity and similarity of spectral response patterns, especially in a mixture of pixels with heterogeneous objects [6]. Within the surveyed area however, the settlements are very small and with a steadily decreasing population, so their total share of "bare surfaces" is minimal.

The vegetation and bare surfaces are extracted through unsupervised k-means clustering of grids, based on Hill-Climbing method [7]. The vegetation cover additionally was categorized into two classes – light (grass and individual shrubs) and heavy (closed forest and dense shrub vegetation) ones. Then, using change detection technique the spatial-temporal peculiarities of the extracted classes was analyzed.

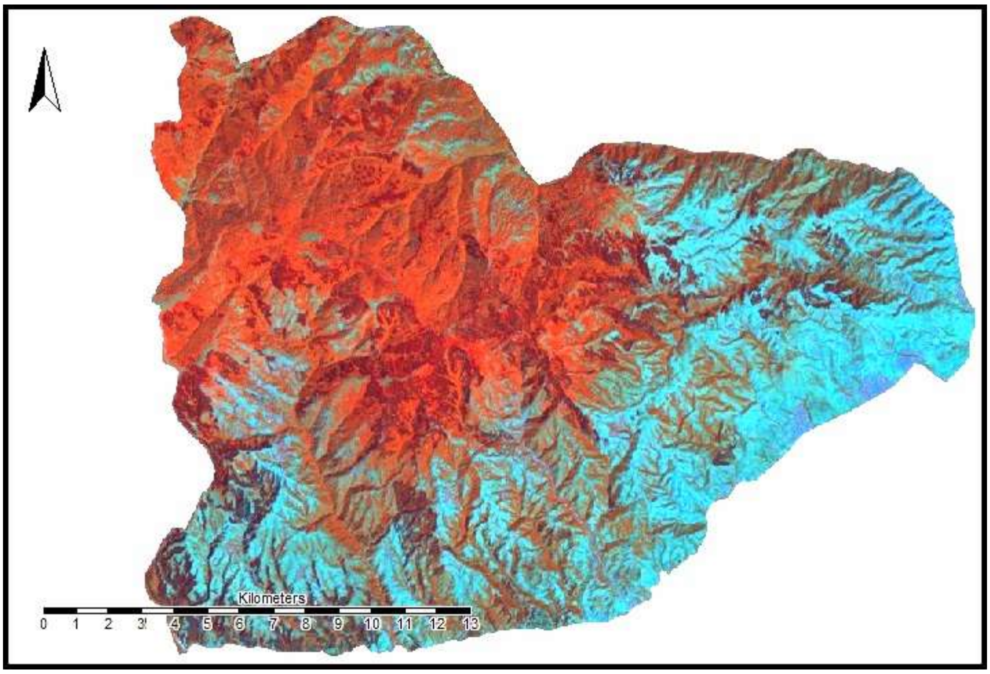

Fig.2: Composite image (bands 5, 6 and 7) of the study area. The bare surfaces are colored in light blue and vegetation is colored in orange.

Data and Software

The imagery data for the present study were acquired from Landsat 8 satellite using the United States Geological Survey (USGS) online interface, Earth Explorer (online available at https://earthexplorer.usgs.gov/). The imageries are available on a Universal Transverse Mercator (UTM) mapping grid at 30x30 m pixel size. The satellite data were acquired as zipped Georeferenced Tagged Image File Format (GeoTIFF) representing systematically terrain corrected data (L1T) for period of time 08.08.2017 and 12.08.2019.

The software used for processing and information extraction of imagery data are ArcGIS 10.1 and SAGA-GIS [8].

Results and Discussion

The results of the environmental monitoring of the bare surfaces within the study area for the period of time 08.08.2017 - 12.08.2019 show a reduction in their total area by 5% (Table 1). On the other hand, there is a restoration of the vegetation cover as a whole (+3%), especially the heavy one (+10%) (Table 2).

Table 1: Land Cover distribution within the study area for the period of time 08.08.2017 – 12.08.2019

	August 2017	**August 2019**

Land Cover	Area (km^2)	Area (ha)	Relative share (%)	Area (km^2)	Area (ha)	Relative share (%)
Vegetation	**239**	**23900**	**72,2**	**245,6**	**24566**	**74,4**
Heavy	*136*	*13600*	*41,1*	*150,4*	*15044*	*45,5*
Light	*103*	*10300*	*31,1*	*95,2*	*9522*	*28,9*
Bare surface	**92**	**9203**	**27,8**	**85,4**	**8538**	**25,6**

Table 2: Land Cover changes within the study area for the period of time 08.08.2017 – 12.08.2019

Land Cover transition	**Area (km^2)**	**Area (ha)**
Heavy vegetation >> Light vegetation	2,29	229
Bare surface >> Light vegetation	10,12	1012
Light vegetation >> Bare surface	3,48	348
Light vegetation >> Heavy vegetation	16,69	1669

In spatial terms, positive changes are not ubiquitous, but there is a rigorous geographical determination (Fig.3). Restoration of the vegetation cover is mainly related to the western parts of the study area. To the east, the situation is still unfavorable. Here the erosion processes are highly developed and give prerequisites for the occurrence of adverse hydro-climatic phenomena.

The intensive depopulation processes within the study area and the disappearance of cattle breeding in the last decades have contributed significantly to the positive trend. Unfortunately, in the eastern parts of the study area, the natural environment is so badly damaged thus special measures are needed to overcome the negative situation.

Conclusions

In the presented study an analysis of the condition of bare surfaces within the Bulgarian part of Ograzhden Mountain was made. Environmental monitoring using remote sensing has shown positive trends and reduced areas of bare surfaces. This fact, along with the increase in vegetation cover, is an indicator of environmental restoration. The vegetation cover and especially the forests are the main natural resource of mountain ecosystems such as Ograzhden Mountain. Its slow restoration in the medium to long term would reduce the negative impact of erosion processes (and probably some human influence) on these lands and guarantee the sustainable development of the local ecosystem.

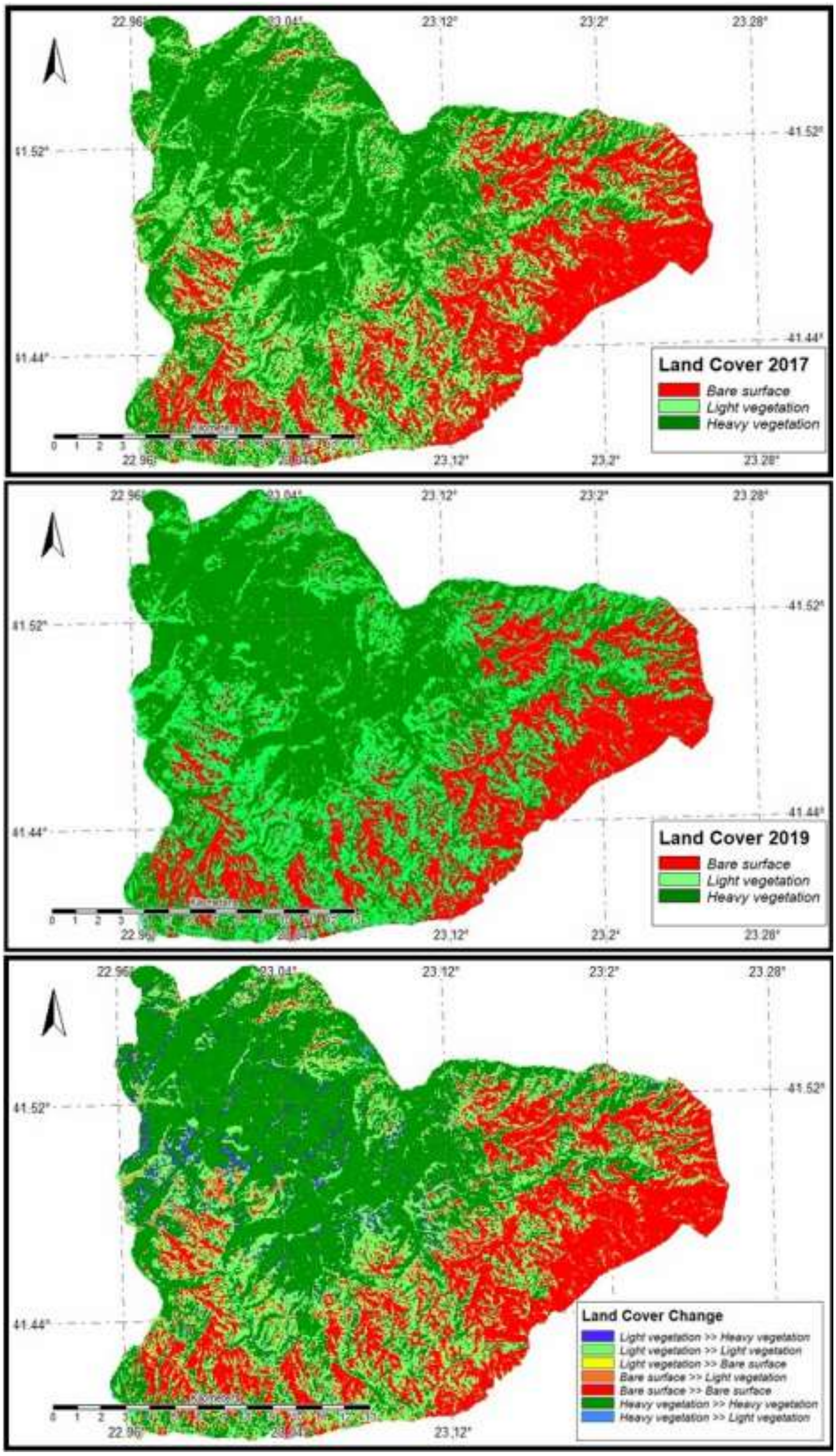

Fig.3: Spatial distribution of the Land Cover changes within the study area. From attached maps are visible the reduction of the total area of bare surfaces. Positive changes are geographically related to the western parts of the study area, while in the east the situation is still very bad.

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