Analysis of Mega-landforms in Desert Environment Using Artificial Neural Network, Iran’s Lut and China’s Qaidam Deserts

Amir Houshang Ehsani, Marzieh Foroutan Pages 515-527

Introduction: Morphological segmentation of land surface is commonly used for land surface allocation in management and environmental sciences. The first step in assigning a piece of land to a specific application is to divide it into homogeneous morphological segments. Traditional field-based geomorphological mapping can be time consuming, costly, and challenging when large areas, particularly in remote areas where terrain is difficult to access and where the topography and landforms can be highly variable over short distances. Like other geomorphometric studies DEM is used as the basic input and SRTM DEM with 90 m resolution is actually suitable for mega landforms analysis. That is one of the most reliable elevation models worldwide.

Yardangs and ergs (sand dune fields) are exclusive landforms resulted from intensive wind erosion and deposition. They cover a large area in hyper-arid and arid regions near each other. Two typical examples of both these landforms can be found in Lut Desert of Iran and Qaidam Desert in China. This paper presents a new approach using Self Organizing Map (SOM) as unsupervised algorithm of artificial neural networks for analysis and characterization and finally comparison of yardangs and ergs in these two different and interesting deserts of Asia.

Material and methods: Lut Desert of Iran with an area about 80,000 km² is a lowland area of several large basins separated by low ridges located in provinces of Kerman, Khorasan, and Sistan. This desert depression contains several hundred meters of upper Pliocene to Pleistocene lacustrine silts over a basement of flat-lying Paleogene and esitic lavas and tuffs. Several Quaternary basalt flows occur near the Nayband fault on the western edge of the Lut. The eastern part of Dasht-e Lut is a low plateau covered with salt flats. This area consists of sand and it contains also some of the highest dunes of the world, about 300 m high. Western part of Lut desert is covered with strong diagonal lines resulting from wind erosion and episodic floods acting on the Neogene silts. Surface slope is ranged from 0 to 19°. The desert is characterized by a hyper-arid climate with an annual rainfall less than 10 mm mainly falling in winter. The prevailing wind known as “wind of 120 days” or Bad-i-sad-o-bist roz Systan blows from NNW–SSE direction and corresponds exactly to the direction of elongated yardangs.

Qaidam Basin, the third largest basin in China, is located in Qinghai Province, northeast of Qinghai-Tibet Plateru. The average altitude of the bottom of the basin is about 2,600 - 3,000 m. It is the highest basin in China. The wind regimes are characterized by a narrow range of wind directions and dominant wind directions of gradual change, changing from near northerly to northwesterly in the NW sector to near westerly in the SE sector. Longitudinal dunes occur in all major sand areas in the world. The yardangs of Qaidam are enormous, reaching up to 50 m high, and can clearly be observed on satellite images and often camouflage the trend of bedding in the sedimentary rocks on which they are carved.

Kohonen’s Self Organizing Map (SOM) is an unsupervised artificial neural network for clustering and visualization of the information that preserve the topological relationship of the input. It converts the nonlinear statistical relationships of high dimensional input data to low dimensional (usually two-dimensional) output grid. The SOM characteristics perform like learning ability, abstraction with topology preservation and visualisation can be utilized in complex tasks such as morphometric analysis and landform classification. Digital Elevation Model (DEM) is the basic input of all geomorphometric analysis. We have used the latest version of SRTM/X with 90 m resolution. The data are displayed in a geographic (Lat/Long) projection, with the WGS84 horizontal datum and the EGM96 vertical datum (figure 1). The SRTM 3 arc seconds data were re-projected to a 90 m UTM grid. Bivariate quadratic surfaces with moving window size of 5×5 were fitted to this DEM. The first derivative, slope steepness and the second derivatives minimum and maximum curvature and also cross-sectional curvatures were calculated as geomorphometric parameters used as input to the SOM. Final landform maps are evaluated using minimum quantization error and topography map.

Discussion of results and conclusion: All four areas (Lut Yardang region, Lut erg, Qaidam Yardang region, Qaidam erg) have been classified separately by 4 basic geomorphometric parameters (Slope, minimal
curvature, maximal curvature, and cross sectional curvature) with the most precise SOM classification of IDRISI application. We have also used a special Davies Bouldin Index (DBI) to find out the best number of classes in each area and for each set of landforms. Comparison between the classes shows that the number of classes in yardangs of Qaidam Desert is more than those of Lut. This is because of whale shape of yardangs in Qaidam and active geology and also two different levels of micro and mega yardangs. Another reason can be the existence of semi-strong winds in other directions different from the strong winds in overall direction of yardangs. The lithology of structures can also be effective in their variation. Nose slope in Qaidam yardangs is exactly in windward part of whale shape yardangs but because of Spindle shape form and the homogeneity of their width, it is not recognizable in Lut yardangs. Thus, three classes in Qaidam are the same as just one class in Lut. Slow slope corridor class in Qaidam and slow slope corridor in Lut are different in shape and percentage in both regions. Classification of ergs indicates that diversity in dune patterns and forms are much more in Lut desert in comparison with Qaidam. Nose slope class is about 30% in Lut and 12% in Qaidam. This shows much mature sand dunes in Lut. Erg classification has less quantization error relative to the errors in yardangs classification. This is indicative of a better classification (Table 1). More specific input data of geomorphometric parameters can lead to better classification in yardang regions but it seems that classification with these four parameters work well for the sand dune regions. Results of this research show the same number of classes in the ergs of the two regions (6 classes). But yardang region in Qaidam with 8 classes shows more complexities in comparison with Lut yardang area with 7 classes. The area in Lut has more uniform distributed classes. In addition, more detailed yardangs in Qaidam relative to more homogeneous yardangs in Lut lead to more complex classification in Qaidam. Effect of aspect (slope direction) in final classification of Qaidam made it more specific. The most significant reason of huge differences in yardang area of these two deserts is the lithology and topography of their bed. We can observe more similarities in erg area of the two regions. But more mature erg in Lut is the evidence of available sand source with different wind directions and it is a little bit more detailed than that in Qaidam. Percentage of Shoulder and Nose slope classes in the two regions is notable. These classes are related to wind direction and topography of bed rock. Finally, in this research Self Organizing Maps as an unsupervised algorithm proved effective and useful for semi-automatic analysis of desert landforms and comparison between same landforms in different regions.

Keywords: landform, Lut Desert, Qaidam in China, SOM, SRTM