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Automated classification of landform, Z. R. B in Iran

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Abstract

This paper introduces an automated classification system of landform based on the SRTM image analysis. First, several data layers were produced from the Shuttle Radar Topography Mission (SRTM), including elevation, slope gradient, profile curvature and plan curvature. Next, homogenous objects were identified through image classification by the eCognision and the GIS software. Using a relative classification model, the object primitives were categorized as landform elements, made both on the objects' altitudinal position and the surface shape. To date, the slope aspect has not been considered in classification. The classification has seven classes: peaks and toe slopes (outlined by the degree of dominance or the altitudinal position), steep slopes and flat/gentle slopes (expressed by slope gradients), shoulders and negative contacts (based on profile curvatures), head slopes, side slopes and nose slopes (defined by plan curvatures). Flexible fuzzy membership functions were used to define classes. Results were identified by the SRTM, and classification options were used to assess output landform maps. In this paper, classification of landform map was identified for Zayandeh Rood Basin (Z. R. B), Iran. The methodology presents aspects of landscapes that are useful to get additional information for geomorphological and landscape studies. Its main advantage is movability, considering that only relative positions to adjacent objects and relative values are employed. The methodology introduced in this paper can be used almost for any application, where relationships between topographic features and other components of landscapes are to be assessed.

Keywords: landform, classification, terrain analysis; SRTM

1. Introduction

Landforms are result of endogenic and exogenic on earth surface that appear as geomorphological features. Several studies have explored how to make geomorphological maps and review developing methods.

The CSIRO land research (Australian), ITC classification, regional survey classifications and the Military Engineering Experimental Establishment (MEXE) were made at Oxford and used in the field in Swaziland, Kenya and Uganda. The USSR methods aimed at developing land or terrain classification through different terms for recognizing land units, and mainly assumed the code of a hierarchical landscape classification**.** The typical method to include relief units in a landscape evaluation is to define them using stereo aerial photographs or through field surveys. The results are influenced by interpreter's subjective decisions, and it is fairly time-consuming; therefore, it is neither reproducible nor transparent.

A study compared geomorphological mapping systems, including a Polish system (established by Klimaszewski), a Hungarian system (the Institut für der Ungarischen Akademie der Wissenschaften), French system (generated by Tricart), and a Soviet system by Bashenina (Gilewska, 1967). Map contour lines were used in all the mapping systems to define the relief (Marcus, 2006). Salomé et al. (1982) and Marcus (2006) designated the key differences among 6 geomorphological mapping systems (1:50, 000) developed by 6 different designers (a Belgian system, the ITC geomorphological mapping system, a French system, a Swiss system, a Polish system, and the ok Unified Key). The Belgian map was formulated based on the morphometry/morphography. A complete geomorphological description of the landscape was presented by the ITC system. The French system offered hydrography, lithology (type and resistance), genesis/processes and geomorphological map geological structure. The geomorphological map was presented by the Polish system, and the main landform classification was based on the difference between their exogenic and endogenic genesis. The Swiss system offered the geomorphology into either depositional or erosional forms. However, the IGU Unified Key concentrated more on the slopes.

The first map that described the landscape was developed in Babylon c. 4500 years ago (Marcus, 2006). Hachure method showed the 18th century reliefs, while the 19th century maps were developed using the contour lines methods. Landscape maps were generated with full explanation in the early 20th c. During 1920s and 1930s, several efforts were made to develop geomorphological maps. Following the World War II, European countries including Poland, France, and Russia tried to develop several official maps. In 1956, Congress of the International Geographical Union (IGU) provided two concepts of geomorphological map production in Rio de Janeiro. Detailed geomorphological maps were determined in 1960, with 1:10, 000 and 1:100, 000 scale broad pictures of Genesis, morphometry, morphography, and age prospects, showing lithology-specific symbols, features of colored symbols, and legends.

Many landform mappings have been made over the past decade using the digital tools and automatic classification, such as the DEM based on the geomorphometry (Paron & Vargas, 2007). Geomorphometry derives primary and secondary topographical attribute from the landform classification techniques, automatic classification (non-supervision and supervision) and the DEM. Manual method has been employed for geomorphological measurement in the last few decades (Drăguț et al., 2006;

Hammond, 1954) The GIS has been used as incorporate technique to analyze data (Drăguţ, et al., 2006) for exploring the spatial and non-spatial relationships among spatial objects and to analyze data as more compound landscape (Marcus. G, 2006). The digital elevation data are used in the GIS, which are easily accessible. Moreover, results of landforms classification are time-saving and more accurate (Marcus, 2006), but often some essential qualitative aspects are ignored because the method is purely quantitative.

In Iran, a geomrphological map was presented based on the manual method by lithology, topographical map, arial photo and satellite image (Ahmadi, 2006). The classification geomoprphological map was based on the geomorphological unites, types and faces. Geomorphological map methods are influenced by the development of technology. Slope morphology can be used for classification landform mapping. Drăguţ and Blaschke (2006) used the DEM data for classification landform map, based on the slope morphology. Accordingly, digital elevation tools, such as the DEM, can be used in large scales to save time and money. In this study DEM will be used for classification landform map.

According to (Marcus, G., et al, 2006) a geomorphological map should contain information on morphometry, morphography, hydrography, lithology, structure, age, and process/genesis. The landform formation category is established by classification landform. Oscar Peschel primarily classified the surface features and compared their morphology in 1867-70. An anatomy method, known as the vergleichende Erdkunde, was introduced to physical geography. The genetic approach was adopted by Davis and Mc Gee (1884-1888) to classify the landform. The approach included the following sub-sections: (1) volcanism, (2) gradation (erosion and deposition), (3) deformation, (4) glaciations, (5) alternation, and (6) wind action. A classification of landforms was presented based on the characteristic topographic forms (Gillbert, 1876), related to faulting and folding. The classification landform for geomorphological map in 1990s was based on the dissimilarity between their exogenic and endogenic, geological structure, hydrology, lithology, process and genesis (Marcus, 2006). Saadat et al. (2009) categorized landform according to pediment plain, river alluvial plain, gravely talus fan, upper terraces and gravely river fan plateau, mountain, hill and river terraces by the following parameters: aspect, slope, concavity, and convexity. Since the 20th century, classification of landform was altered through the emerging technology. The majority of methods were automat classification using the eCognition Software, RS and GIS (Drăguţ, Thomas Blaschke 2006). Slope attributes are important elements for many classification processes of landform based on slope attribute. Slopes are categorized as teo slope, slope gradient, peak, negative slope, shoulder, steep slope, head slope, side slope, flat/gentle slope, plane curvature and nose slope with profile curvature, altitude and an extra layer with relative altitude values (Drăguţ, Thomas Blaschke 2006). Some researchers have established automate classification methods (Barbanente et al., 1992) to find features in micro scale (Drăguţ, Thomas Blaschke 2006).

Table 1 Shows different parameters of geomorphological map that are used in different times. Despite the significance of surface' slope morphology, few researches have used slope parameters. According to the literature, the geomorphological map system in Netherland classified the landscape elements based on the combined slope angle and length into eight relief classes. The IGU committee used a slope classification divided into six gradient categories at 2, 5, 15, 35, and 55. The ITC systems employed some information on the slope to divide the landforms into gradient classes. The Alpine geomorphology research group (AGRG) used a simple slope classification system based on the slope height (b10 m or N10 m). The British morphology maps used a subdivision slope into concave and convex breaks.

Table 1: Literature review of the geomorphological map by (DEM) digital elevation model

Author	**Map**	**Martial**	**Parameters**
EVA A. U. SAHLIN and NEIL F. GLASSER 2008	1:10 000 scale geomorphological map	color aerial Photographs (scale 1:10000)and_eld investigations of landform/sediment associations. Digital Elevation Models (horizontal resolution 5 m, vertical resolution 1 m)	Morphology (appearance, shape), morphometric (size), morphogenesis (origin) and soil cover (substrate)
Janusz Badura, Bogusaw Przybylski, 2005	Nontectonic studies and analyses of glacial landforms of the Lower Silesia and Gniezno Pomerania regions.	DEM	morphology
Lucian Drăguț, Thomas Blaschke 2006	classification system of landform peaks and toe slopes (defined by the altitudinal position or the degree of dominance), steep slopes and flat/gentle slopes (defined by slope gradients), shoulders and negative contacts (defined by profile curvatures), head slopes, side slopes and nose slopes (defined by plan curvatures).	Digital Terrain Models (DTM)	Elevation, profile curvature, plan curvature and slope gradient. Second, relatively homogenous objects
Amy L. Kernich1 & Colin Pain, A. L. K. C, 2003	Geomorphological map	Landsat TM data, ASTER data, airborne gamma-ray radiometric data, a Digital Elevation Model (DEM), aerial photographs, and ground regolith sampling.	Landform units, geomorphic units

Yeong Bae Seong, et al, 2009	Glacial landforms	Satellite imagery. In addition, topographic maps (1:25, 000 and 1:50, 000) Satellite imagery consisted of Landsat ETM+ data acquired on October 17, 1999 and ASTER Multispectral imagery data acquired on August 12, 2000. All multispectral data were orthorectified to account for relief distortion. Topographic information was also utilized to generate landform maps. A digital elevation model (DEM) derived from ASTER data was generated to facilitate morphological characterization of the topography and landform features.	
Bishop, MA, (2009)	Volcanic (and other) landforms	Spatial statistical modeling of landform and SRTM	A generic classification
International Institute for Aerial Survey and Earth Sciences (ITC)	Geomorphological map	Arial photo, field work	

In the last decade, in spite of the importance of slope gradient in morphology and slope stability assessment, only a few geomorphological maps include characteristics of slope. In this research, the automated classification method was used for classification of landform based on the slope, elevation and aspect. According to the previous studies, a variety of parameters have been used for the geomorphological mapping. The slope attribute is an important parameter and some researchers have pointed out that it should be considered for classification of landform mapping (British geomorphological maps, 1990; Drăguț et al., 2006; Saadat et al., 2009).

2. Study Area

Z. R. B is a rectangle with its longer side stretching from North-Western to South-Eastern. The highest part of basin is located in the West and South-Western regions which embraces the eastern slope of Zagros heights. The lowest part is the Govkhooni marsh which is located in the east of basin.

Regarding elevation in the study area, Zayandeh Rood Basin has two distinctive parts. One of them is the high and mountainous areas in Zagros which slopes in the West and South-Western of basin, and the other is the extensive plains in the middle of the basin. (Marani. M. Barzani & O S Khairulmaini, 2013)

The topography of Z. R. B has been divided into several categories. The first section of the elevation is in the western part of the basin. The trend of mountains is in the northern and south and the topographical system is deferent from the eastern part of Z. R. B. The second elevation system basin is approximately in the middle part of the basin which stretches northwest to southeast with an approximate distance of about a hundred kilometers. The third elevations of the basin are hills and complex shapes of domes. The highest elevation is located in the south-western. The fourth elevation of the basin are scattered across in the middle of the plains. The fifth system height, low altitude areas and plains are part of the basin. The Z. R. B height is reduced from west to east. So that, the lowest part of the basin, namely in the eastern most point to the altitude of marshes in Gavkhoni reaches about 800 meters.

Figure1: location of Z. R. B in Iran (Marani. M. B. & Khairulmaini, O. S. 2013)

3. Methodology

3. 1 Classification Landform mapping by SRTM DEM

In this research, classification landform map was developed based on the slope morphology by the automate classification land form method. This stage of the research had two phases:

Classification landform map was provided by layers, such as the elevation, profile curvature, plan curvature and slope gradient. For mapping classification landform, the DEM (Digital Elevation Model) was used. For the first step, several data layers were produced from the SRTM data, including the elevation, profile curvature, plan curvature, slope aspect and slope gradient in the GIS environment. The layers were transferred to the eCognition Professional 8. 0 (Definiens Imaging, GmbH, Munchen, Germany) to segmented objects of the DEM image (object has equal pixels in raster images). Segmentation analysis in the software was done in two stages: 1. segmentation of the area based on the elevation in three classes of high land, mid land and low land and 2. classification of each segmented area (high land, mid land and low land) based on the slope gradient in seven classes, including the peak, toe slope, nose slope, head slope, nose slope, shoulder and negative slope (Fig1).

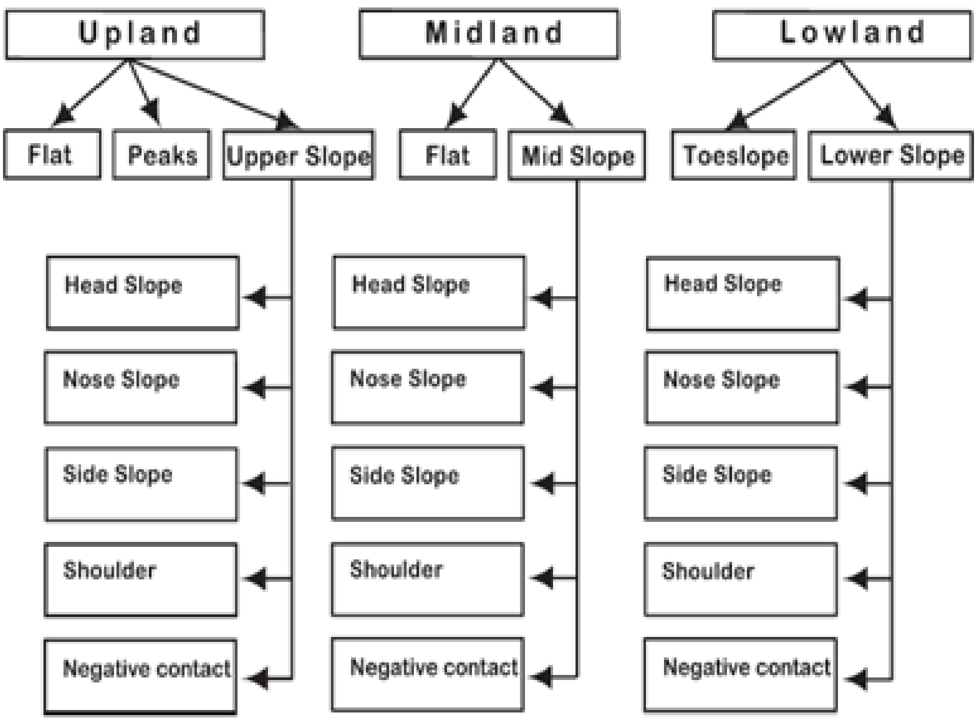

Figure 2: Shows Class hierarchy of classification landform, which are clarified based on altitude and slope morphology (Lucian D, Thomas B, 2006)

The results of classification landform for the Z. R. B are presented in the form of vector maps based on the slope morphology. In fact, classification landform based on the slope morphology is subset of classification land obtained from the map based on the elevation.

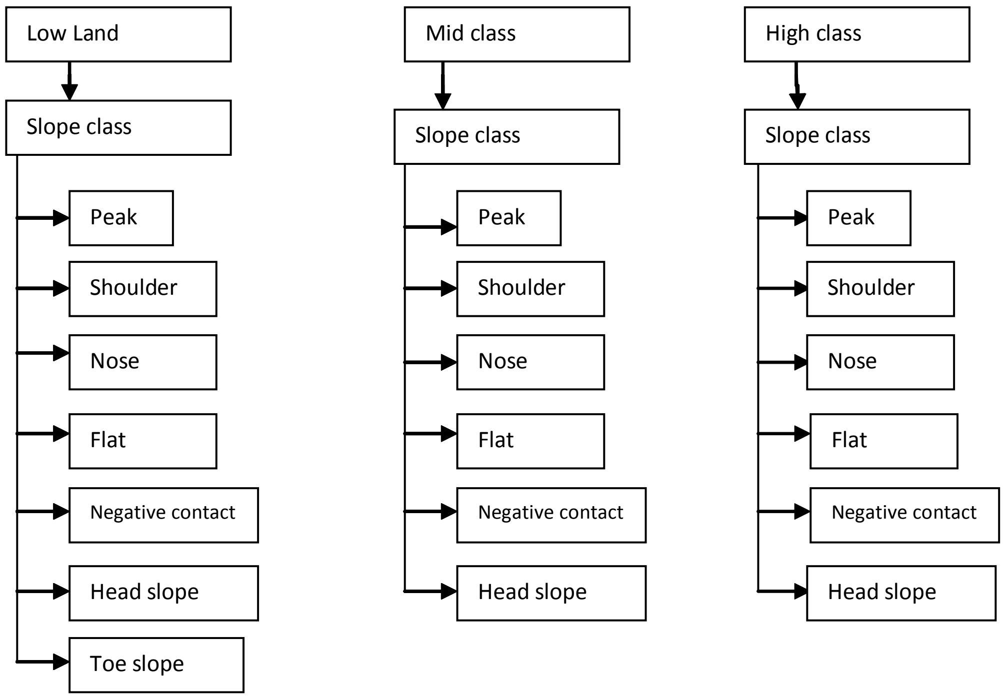

Figure 3: Shows classification landform based on slope morphology

4. Results and Discussion

4. 1 Classification landform map based on elevation

The altitude landforms were classified in three classes. The classification was based on high land, mid land and low land (fig. 3). According to the classification landform, the low land is made up of the largest part of the Z. R. B with 26152. 11 km^2 and low elevation >2000. This part is located on central, east and northeast of the Z. R. B. Mid land that covers a minimum area of 6932. 59 km^2 and elevation is between 2000-3000. High land of the Z. R. B is located on the west and northwest of Z. R. B with 8574. 56 km^2 and high elevation (<3000) (Table 2).

Table 2: Shows altitude classification landform area

Landform classes	Area/km^2	Area%	Elevation
Low class	26152. 11	62. 77	>2000
Mid class	6932. 59	16. 64	2000-3000
High class	8574. 56	20. 58	<3000
Total:	41659. 27		

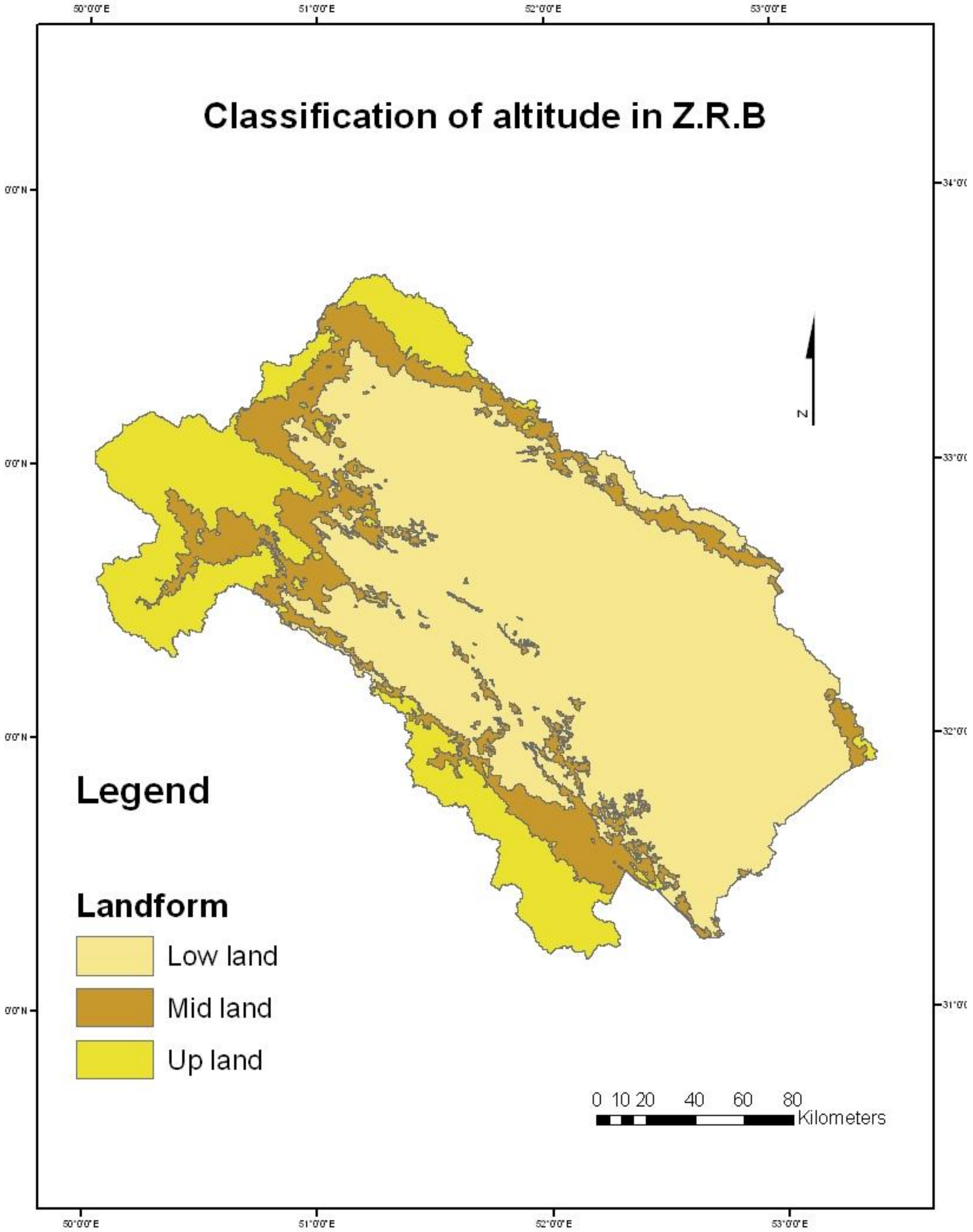

Figure 4: Shows classified altitude landform which is in three classes (high land, mid land and low land)

4. 2 Classification landform map based on slope morphology

Landform maps are classified based on elevation. There are different slope gradients in each class of altitude landform. Each class of altitude landform is classified based on the slope morphology (Fig 4). The landform maps include head slope, peak, toe slope, flat, negative slop, shoulder, and nose slope. The results showed three classes of altitude landforms based on slope morphology, including the high land, the mid-land and the low land.

The area of landform classes is calculated in the Arc Map, as shown in Table 3. A high percentage of the slope class area includes the nose slope. The lowest slope was 49. 46 km^2, covering 0. 0029 % of the whole area. The toe slope area was 6226 km^2 and 0. 376 % was located on low land of altitude landform.

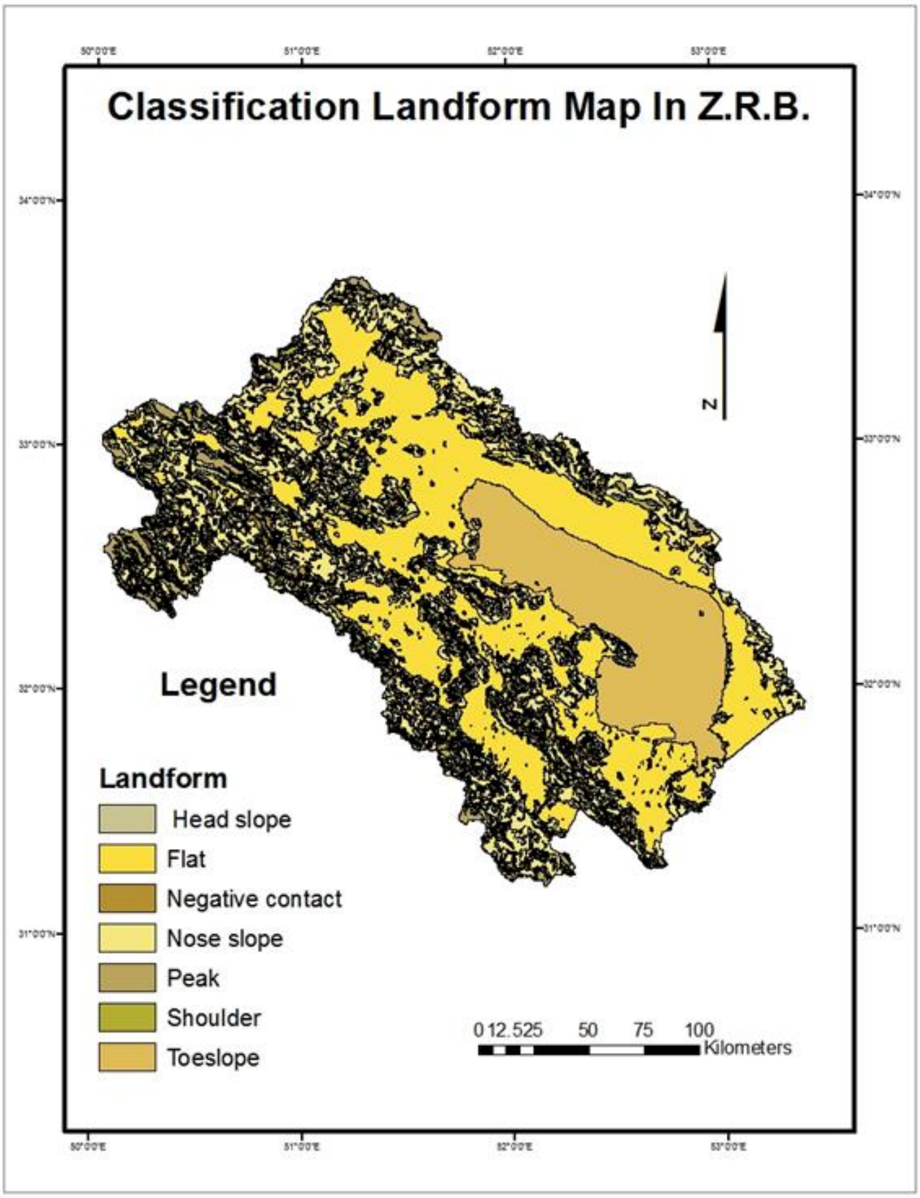

Figure 5: Shows classified landform based on slope morphology

Table 3. Classification of attribute landform classes of Z. R. B

Landform	Area	Area%	Slope	Elevation
Head slope	49. 46	0. 0029	<2	<2000
Flat	18309. 77	1. 107	>2	>2000
Negative contact	12963. 47	0. 78	>35	<2500
Nose slope	1552603. 22	93. 93	1-2	>2500
Peak	29362. 95	1. 77	<35	<3000
Shoulder	39596. 12	2. 39	<2	<2300
Toeslope	6226	0. 376	>1	>1500
Total	1652885. 03			

5. Conclusion

Previews of the geomorphological maps are based on the geomorphological faices, type feature and unite feature, which are largely manual. In this research, the automate classification method (Lucian D, Thomas B, (2006) was used. First, the classified landform map was based on the altitude parameters, which was shown in three classes of elevation landform (high land, mid land and low land). Each class is based on the slope morphology that involved the classes (flat & gentle slope, toe slope, peak, side slope, negative contact, shoulder). The range of Z. R. B's slope gradient was 0-40. In another analysis by Lucian D et al., (2006), they found that one peak was in the high land class, while in this research, the peaks were also found in the low land area. Advantage of this method is at meso to micro scale that can cover large area. Studies of the landform based on the slope morphology are significantly related to the hazard management and human activities.

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