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Comparison of Landform Classifications of Elevation, Slope, Relief and Curvature with Topographic Position Index in South of Bojnoord

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ABSTRACT The aim of the study is the classification of landform based on elevation, slope, relief and curvature inputs (old method) and topographic position index (TPI) (new method) in the south of Bojnoord. The input data for the two methods is a digital elevation model (DEM). The results of topographic position index (TPI) model showed that most area of landform were covered by class 5 (plains small) and the lowest area of landform was covered with open slope (class 6) (< 0.1%). The results of landform classification using elevation, slope, relief and curvature showed that the upper terraces (shoulder) were located in the many parts of the study area (green color). Plateau (back slope) landform was located in center, some parts of the west and south of the study area. In general, with increasing slope and elevation different types of landforms occur. Thus slope, elevation, relief and curvature are effective in preparing the landform classification map. The comparison of the two methods showed that the TPI method was more accurate because the method revealed more details.

Key words: *Elevation, Topography, shoulder, plateau, back slope*

1 INTRODUCTION

Ecological evaluation is a critical step in process of sustainable development. These studies should be done as basic studies, a foundation for land use planning (Masoudi and Jokar, 2015). Topographic maps, aerial stereo photos, satellite imagery and digital elevation models (DEMs) are used as input data for landform classification. There are lots of studies which have used DEMs for mapping landforms (MacMillan *et al.*, 2000; Burrough *et al.*, 2000; Meybeck *et al.*, 2001; Schmidt and Hewitt, 2004; Saadat *et al.*, 2008). Some of the methods which tend to extract landforms from DEMs are classification of terrain parameters (Dikau, 1989; Dikau *et al.*, 1995), filter techniques (Sulebak *et al.*, 1997) and multivariate statistics (Adediran *et al.*, 2004). In most of these studies the landform is supposed as a unique topological unit with related structures, while in some other studies a landform is a set of simple parameters. This method uses some indexes, including the topographic wetness index (TWI) (Moore and Nieber, 1989), stream power index (SPI) (Moore *et al.*, 1993a), aggradation and degradation indices (Moore *et al.*, 1993b), thresholds (Dikau, 1989), multivariate

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descriptive statistics (Dikau,1989; Evans,1979), double ternary diagram classification (Crevenna *et al.,* 2005), discriminant analysis (Giles, 1998), fuzzy logic and unsupervised classification (Adediran *et al.,* 2004; Burrough *et al.,* 2000; Mokarram *et al.*, 2014), neural networks (Ehsani and Quiel, 2008) and using elevation, slope, relief and curvature as inputs for landform classification (Chabala *et al.,* 2013).

Topographic position index (TPI) measures the difference between elevation at the central point of a neighborhood and the average elevation around it within a predetermined radius (Gallant and Wilson, 2000; Weiss, 2001). There is also an old method which uses elevation, slope, and relief and curvature layers to produce a landform classification map.

The aim of the study is to compare landform classification using elevation, slope, relief and curvature and with topographic position index (TPI) in an area in south of Bojnoord, Iran. In fact, in order to landform classification, the common method (using elevation, slope, relief and curvature) was compared with new method (using only elevation) in this research. Also since Bojnoord has different kinds of topographic features and the watershed, it was selected as a case study. The methodology employed in this study is summarized in Figure 1.

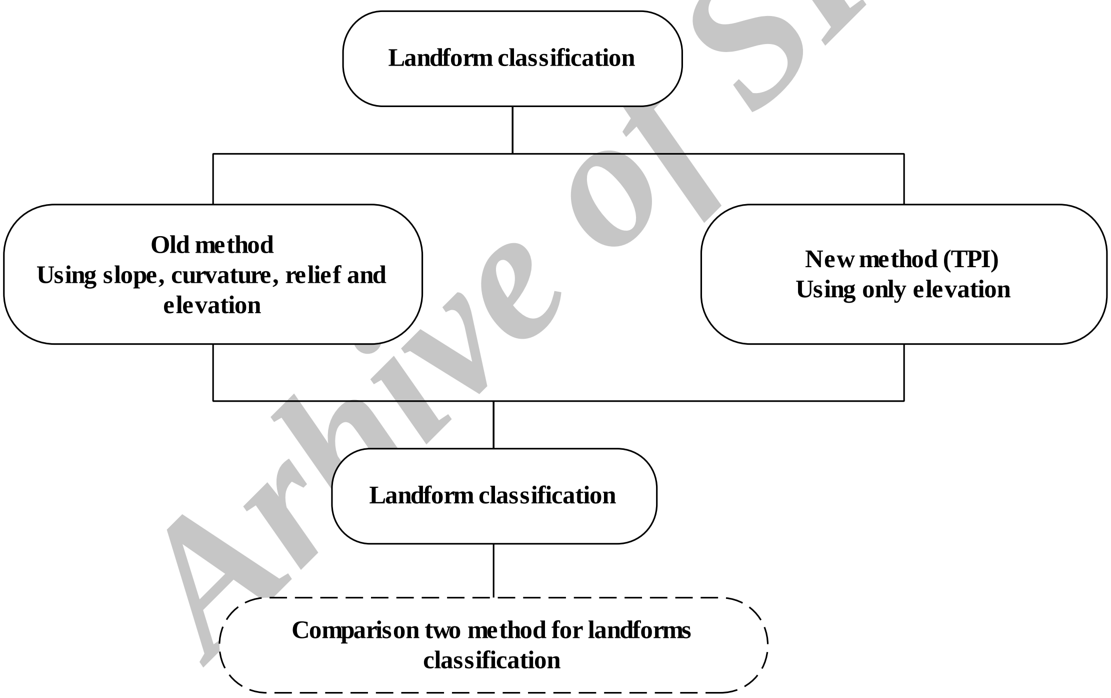


Figure 1 Flowchart for the methodologies of comparing landform classification with elevation, slope, relief and curvature and the topography position index

2 CASE STUDY

This study was done in south of Bojnoord (36° 03´- 37° 34´ N and 56° 33´ to 57° 36´ E) in northwest Iran (Figure 2), covering an area of about 2615 km^2. The average elevation of the study area ranges from 901 m to 1,422 m. For landform classification using old and new methods, (TPI) SRTM Digital Elevation Model (90 meters' spatial resolution) was used as input data. All of the calculations were done using Arc Map version 10.2.

3 MATERIALS AND METHODS

3.1 Landform classification using elevation, slope, relief and curvature (old method)

The landform map was generated by overlaying the reclassified four inputs that consist of elevation, slope, relief and curvature. This was done using the ESRI cell statistics tool, Cell Statistics, with the mean set as the overlay statistic. The equations are Eq. (1).

The output from the cell statistic tool was classified into five classes shown in Table 1.

$$\text{landform} = \text{CellStatistics}([\text{elevation}.\ \text{slope}.\ \text{relief}.\ \text{curvature}]) \quad (1)$$

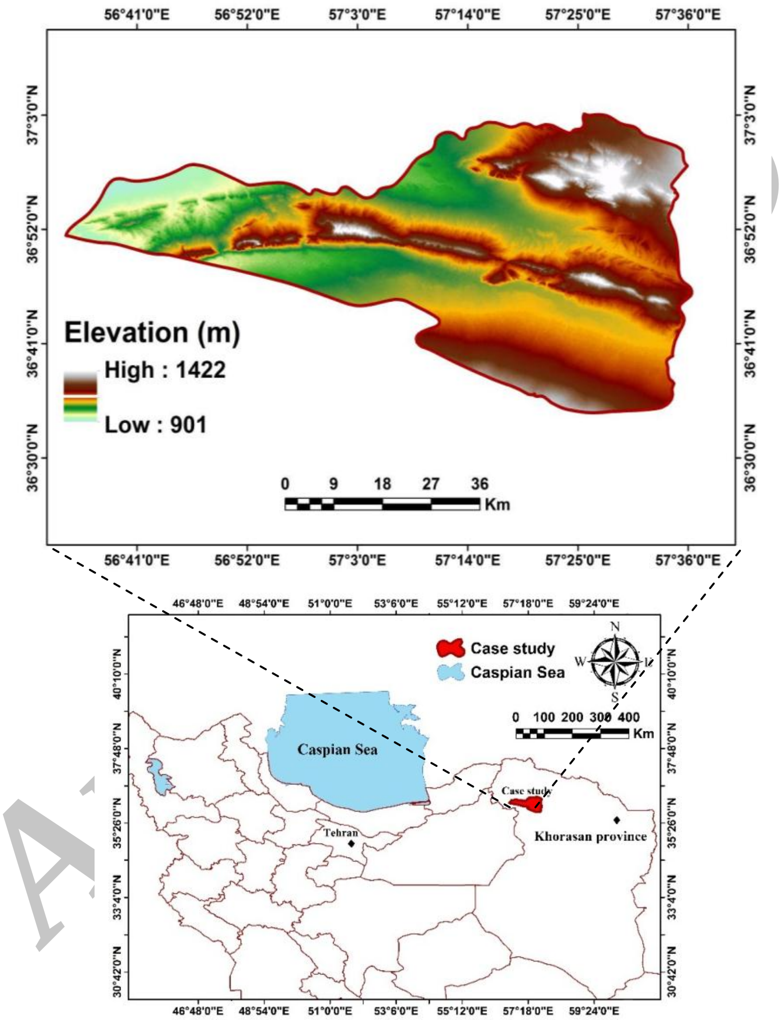


Figure 2 Location of the study area (DEM with spatial resolution of 90 m)

(Source: http://earthexplorer.usgs.gov/)

Table 1 Landform classes by elevation, slope, relief and curvature (Chabala *et al.*, 2013)

Class number	Type of landform	Description
1	Hills (summit)	upland land surfaces, slopes more than 12%, convex curvature, elevation more than 1180 m, relief intensity between 1180 and 1375 m.
2	Upper terraces (shoulder)	Slopes more than 8 up to 12%, concave curvatures, elevation more than 1180 m, relief between 1100 and 1180 m.
3	Plateau (back slope)	Upland areas, flat surfaces normally, the slopes more than 3 – 8%, flat curvatures, elevation between 1030 and 1180 m.
4	Dambos (foot slope)	Lowest elevation, slopes less than 1%, concave to flat curvatures, elevation between 976 and 1080 m, elevation between 976 and 1030 m.
5	Lowlands (toe slope)	low gradient, slopes more than 1 up to 3%, flat curvature, elevation between 976 and 1180 m.

Chabala *et al.* (2013) was followed for preparing the input data (elevation, slope, relief and curvature) and reclassifying them.

3.1.1 Elevation

A digital elevation model (DEM) is a major source for preparing an elevation map. The classified elevation and values are shown in Table 2. The classes represented respectively as level land, sloping land and steeply sloping land (Chabala *et al.,* 2013).

Table 2 Elevation classes (Chabala *et al.,* 2013)

Elevation classes	Range of elevation (m)
1	< 1080
2	1080- 1420
3	> 1420

3.1.2 Slope

Slope is one of the major inputs in landform classification methods that has been applied in many studies (e.g. Dobos *et al.,* 2005; Huting *et al.,* 2008; Saadat *et al.,* 2008; Barka *et al.,* 2011; Chabala *et al.,* 2013). Reclassified slope values in this work, expressed as percent (Table 3), was calculated following the Eq. (2) (Chabala *et al.,* 2013):

$$Slope\ (percent) = (dz/dx) * 100 \qquad (2)$$

where dz is change in height and dx is horizontal change.

Table 3 Slope classes (Chabala *et al.*, 2013)

Slope classes	Range of slope (percentage)
1	0-1
2	1-3
3	3-5
4	5-8
5	8-12
6	12-30
7	>30

3.1.3 Relief

Relief data represent the difference between the highest and lowest elevations in an area. Using the focal statistics tool the average value was calculated for each input cell location in a circular neighborhood with a radius of 6 cells. Five cells for a 90 m resolution DEM represented 990 m. The classified relief values are shown in Table 4.

Table 4 Relief Classes (Chabala *et al.*, 2013)

Relief classes	Range of relief
1	< 1030
2	1030 - 1100
3	1100 - 1180
4	> 1180

3.1.4 Curvature

Curvature is defined as the curves of a surface. This surface must be intersected with a plane surface but in a specified orientation (Thorne *et* *al*., 1987). Curvature value was calculated following the Eq. (3) (Wilson and Gallant, 2000):

$$C = Z_{xx}^2 + Z_{xy}^2 + Z_{yy}^2 \quad (3)$$

where z is elevation and C is curvature. The classified curvature values are shown in Table 5.

Table 5 Curvature classes (Chabala *et al*., 2013)

Curvature classes	Range of curvature (1/meter)
1	< - 0.095
2	- 0.095 – 0.140
3	> 0.140

3.2 Landform Classification Using Topographic Position Index (TPI)

TPI with higher values represent the locations with higher elevation than surroundings pixels. The lower values represent the valleys which are lower than surroundings. Values which are zero are flat areas or areas with a constant slope. TPI model is calculated using Eq. (4) (Weiss 2001).

$$TPI_i = T_0 - \frac{(\sum_{n-1} T_n)}{n} \quad (4)$$

Where T_0 elevation of the model point under evaluation, T_n elevation of grid and n the total number of surrounding points employed in the evaluation. According to Weiss "With combining TPI at small and large scales a variety of nested landforms could be distinguished (Table 6).

Table 6 Landform classification based on TPI .(Source: Weiss 2001: 9-13)

Classes	Description
Canyons, deeply incised streams	Small Neighbourhood : $Z_o \leq -1$ Large Neighbourhood : $Z_o \leq -1$
Midslope drainages, shallow valleys	Small Neighbourhood: $Z_o \leq -1$ Large Neighbourhood: $-1 < Z_o < 1$
Upland drainages, headwaters	Small Neighbourhood: $Z_o \leq -1$ Large Neighbourhood: $Z_o \geq 1$
U-shaped valleys	Small Neighbourhood: $-1 < Z_o < 1$ Large Neighbourhood: $Z_o \leq -1$
Plains small	Neighbourhood: $-1 < Z_o < 1$ Large Neighbourhood: $-1 < Z_o < 1$ Slope < 5°
Open slopes	Small Neighbourhood: $-1 < Z_o < 1$ Large Neighbourhood: $-1 < Z_o < 1$ Slope > 5°
Upper slopes, mesas	Small Neighbourhood: $-1 < Z_o < 1$ Large Neighbourhood: $Z_o \geq 1$
Local ridges/hills in valleys	Small Neighbourhood: $Z_o \geq 1$ Large Neighbourhood: $Z_o \leq -1$
Midslope ridges, small hills in plains	Small Neighbourhood: $Z_o \geq 1$ Large Neighbourhood: $-1 < Z_o < 1$
Mountain tops, high ridges	Small Neighbourhood: $Z_o \geq 1$ Large Neighbourhood: $Z_o \geq 1$

4 RESULTS and DISCUSSION

4.1 Landform classification using old method

For landform classification with old method, the elevation, slope, relief and curvature maps were prepared based on a digital elevation model (DEM). The 90m cell size, SRDM DEM was downloaded from USGS. According to Figure 3a, elevation is between 901m to 1,422m and according to Figure 3b slope values are 0 to 67.5 for the study area. The sheep slope is shown by the blue color in center and northwest of the study area. Relief (Figure 3c) is between 905m to 1,374.82m and the curvature values were between -1.39 to 1.51 (Figure 3d); the high curvature values were located in areas with high elevation showing a relationship between these two parameters.

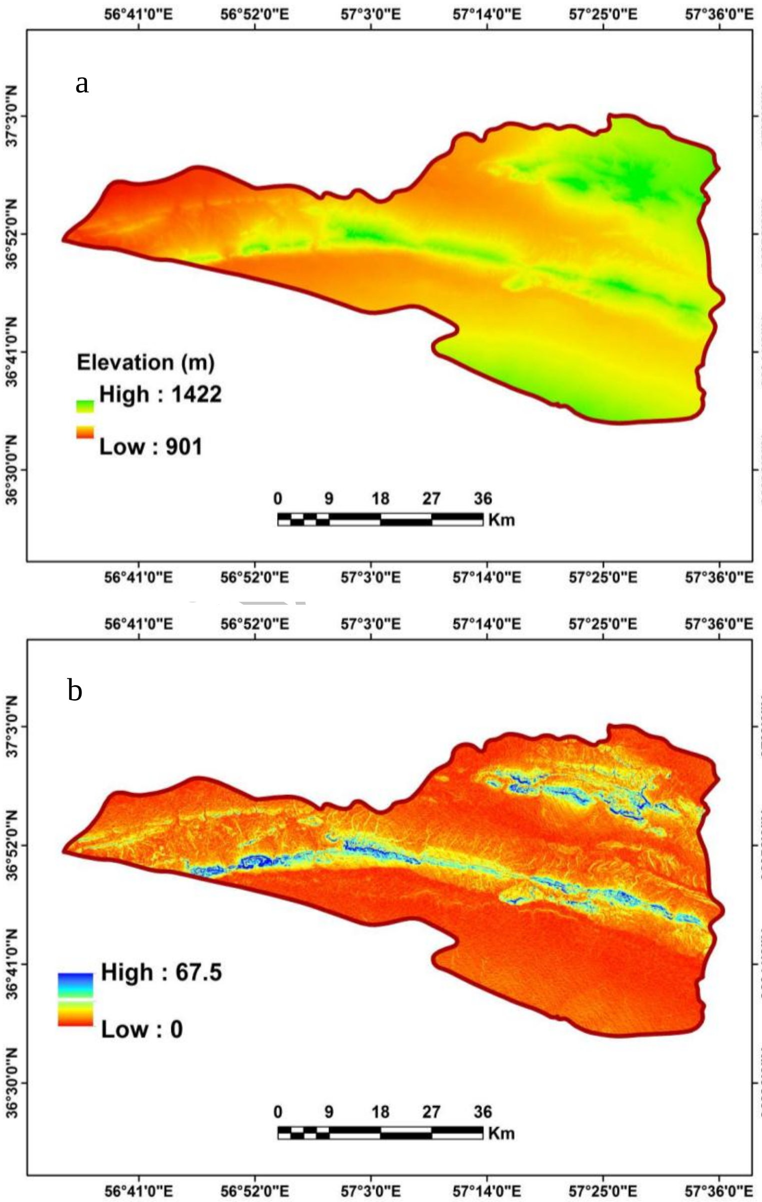


Figure 3 Input data for landform classification with old method. (a): elevation (b): slope (c): relief (d): curvature

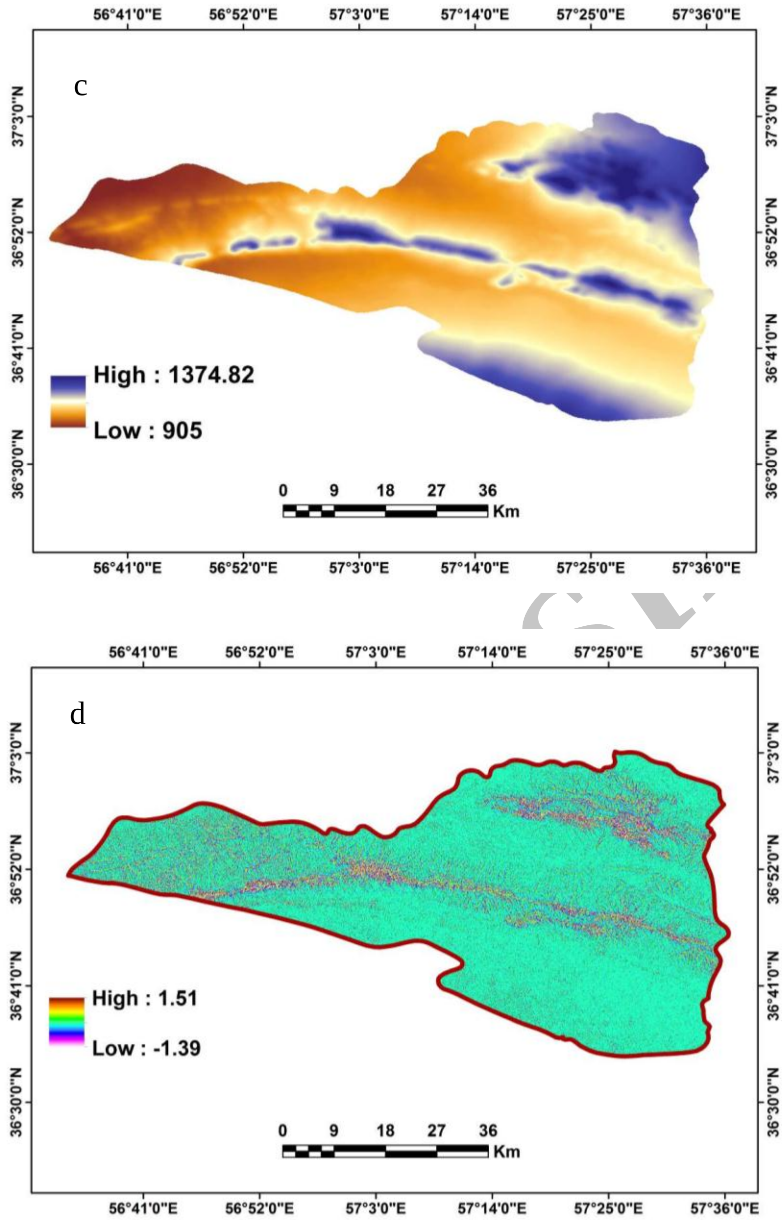


Figure 3 Continued

Based on Tables 2, 3, 4 and 5, the elevation, slope, relief and curvature maps were reclassified and were sorted from low values to high values. According to Figure 4, the center and northwest of the study area have the highest values, while other parts had low values. So, the landforms in two parts of the study area were different.

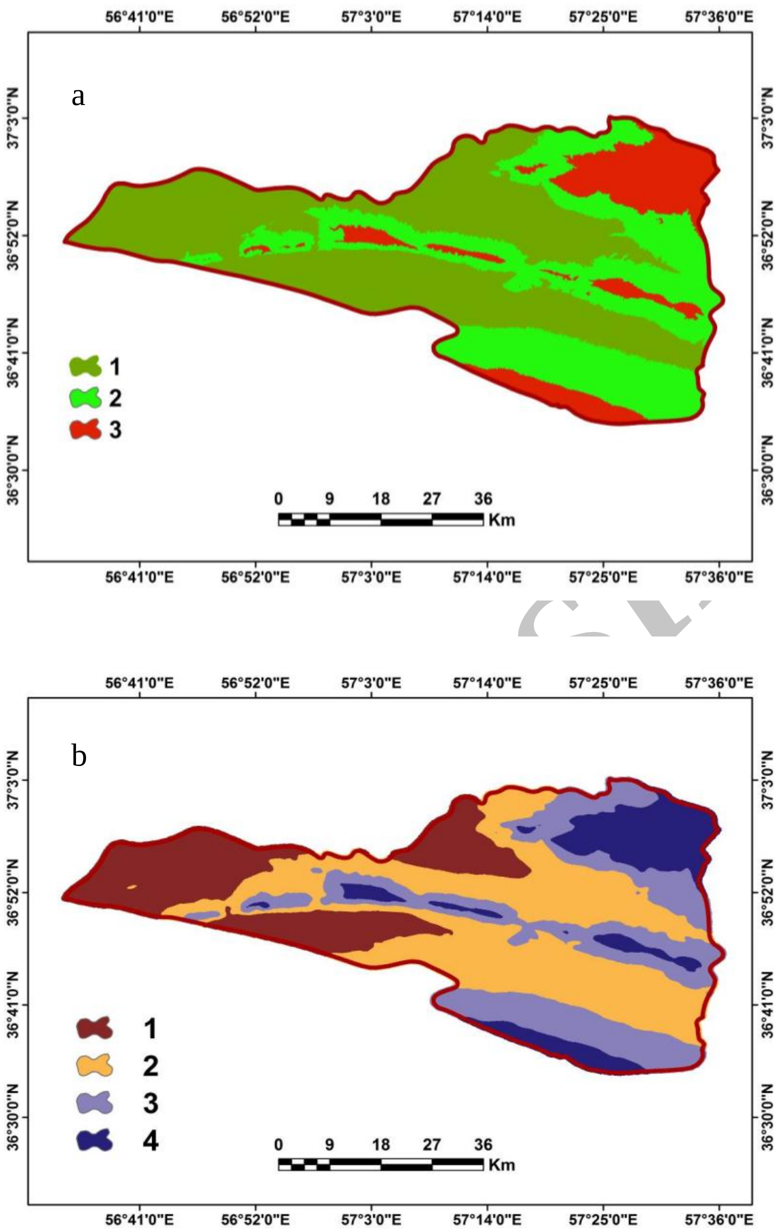
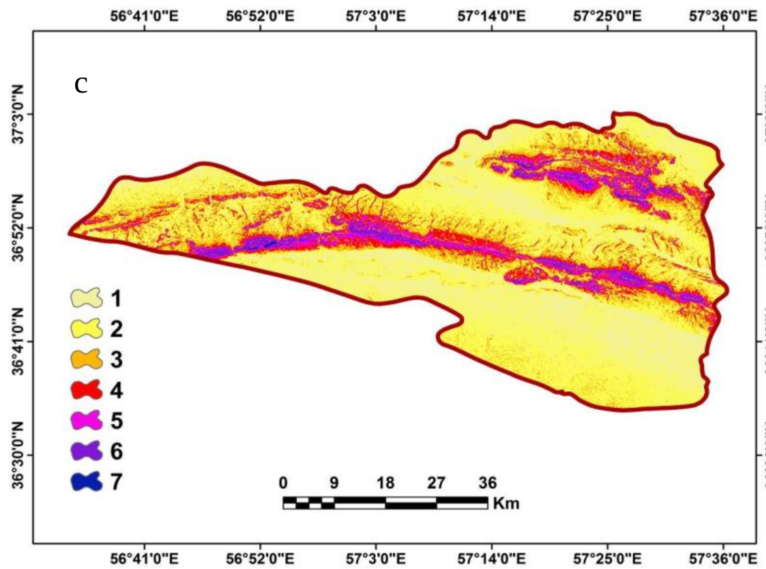


Figure 4 Reclassified maps of elevation (a), slope (b), relief (c) and curvature (d)



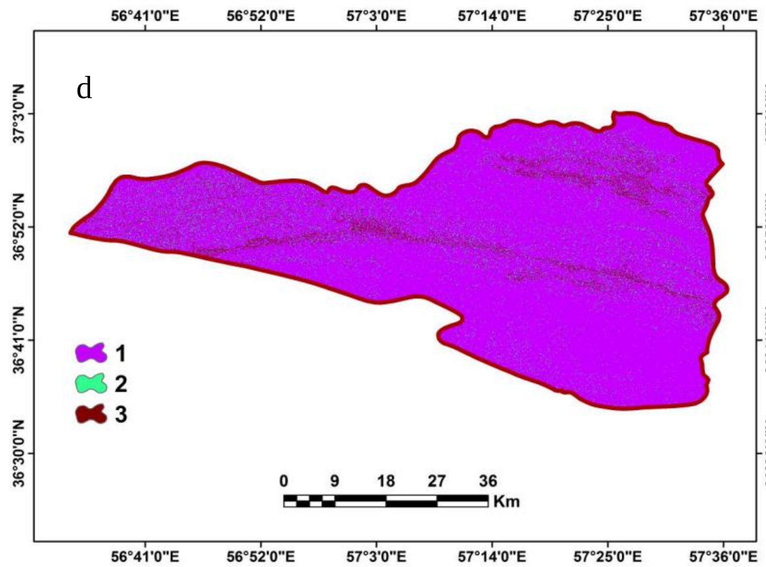


Figure 4 Continued

The landform classification maps were prepared using equation 1 and overlying the four layers of slope, elevation, relief and curvature (Figure 5).

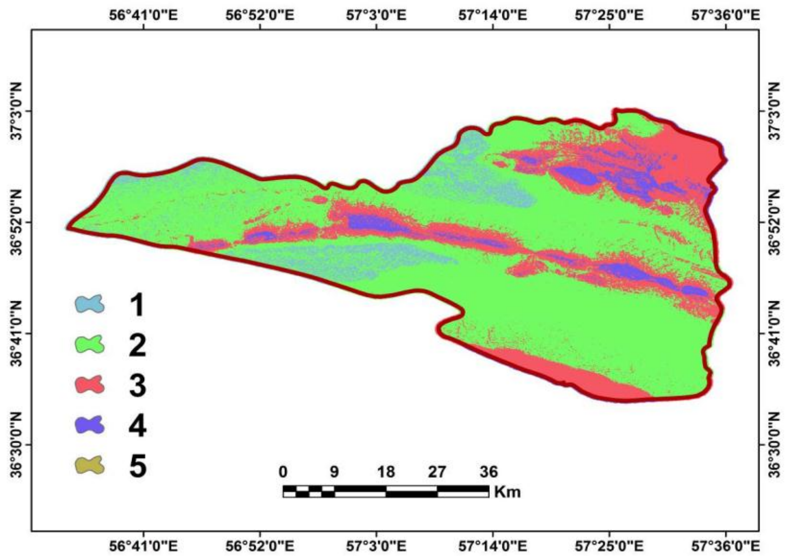


Figure 5 Landform map of the study area combining elevation, slope, relief and curvature

Based on Figures 3 and 4, the landform map for the study area consists of five classes: (1) hills (summit), (2) upper terraces (shoulder), (3) plateau (back slope), (4) dambos (foot slope), and (5) lowlands (toe slope). Landform of hills (summit) was in north, northwest and southeast of the study area. The upper terraces (shoulder) were located in many parts of the study area (green color). Plateau (back slope) landform was located in the central part, some parts of the west and the south. In general, different types of landform occur with increasing slope and elevation. The layers of slope, elevation, relief and curvature are effective layers for preparing the landform classification map. An area (%) comparison is performed for all landform classes and the results are shown in Figure 6.

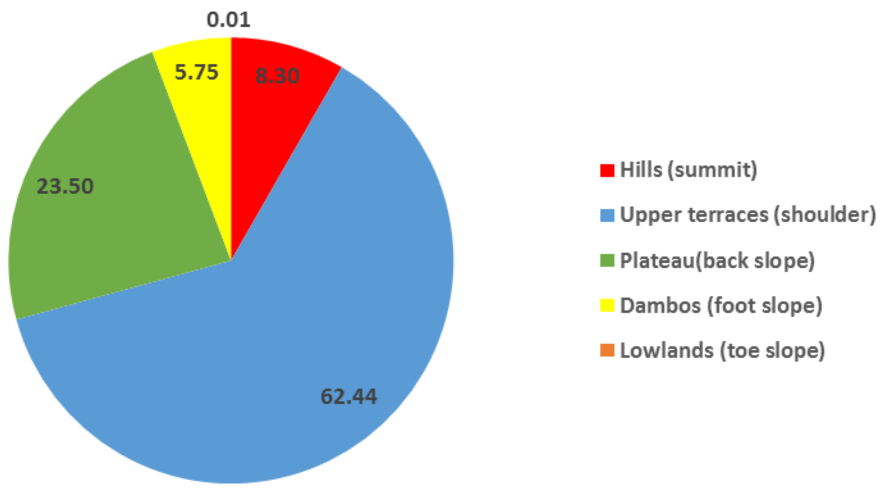


Figure 6 Percentage of the area covered by each landform classes

4.2 Landform Classification Using Topographic Position Index (TPI)

Using topographic position index (TPI), a landform classification map of the study area was generated. The TPI maps using small and large neighborhoods are shown in Figures 7a and 7b. TPI is between -28.2 to 62.84 and -41.42 to 117.07 for 3 and 11 cells for small and large neighborhoods, respectively. The classification has ten classes: high ridges, midslope ridges, upland drainage, upper slopes, open slopes, plains, valleys, local ridges, midslope drainage and streams (Figure 8).

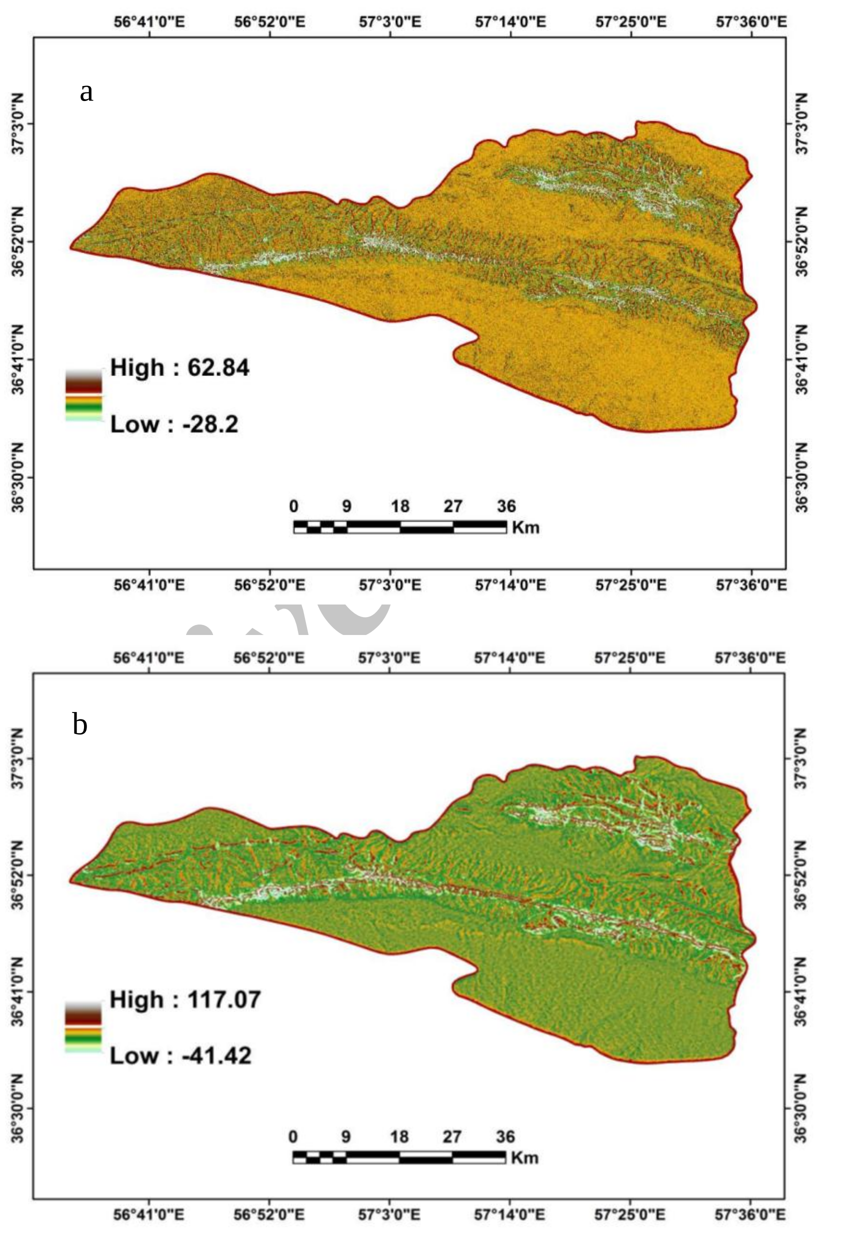


Figure 7 TPI maps generated using (a) small (3 cell) and (b) large (11 cell) neighborhoods

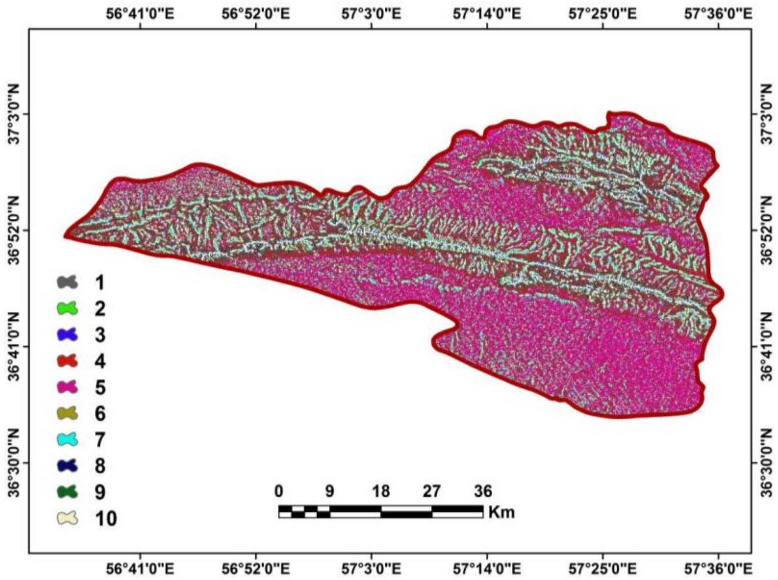


Figure 8 Landform classification using the TPI method

The results of the landform classification using the TPI method are shown in Figure 9 and indicated that most of the area are classed as plains small (small flat areas) with the least area being represented by open slope (< 0.1%).

So in the research determined that landform classification using topographic position index (TPI) is more accuracy than the preparing landform classification by elevation, slope, relief and curvature. In fact Topographic position index (TPI) measures the difference between elevation at the central point of a neighborhood and the average elevation neighbor it within a predetermined radius (Gallant and Wilson, 2000; Weiss, 2001).

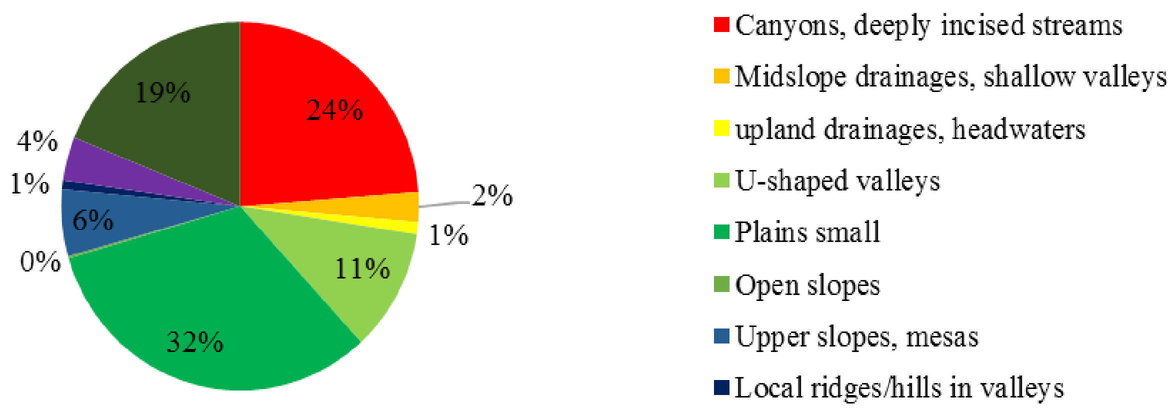


Figure 9 Percentage of study area covered by each landform class using the TPI method

5 CONCLUSION

This research has presented two landform classifications by using a combined classification based on elevation, slope, relief and curvature and the topographic position index (TPI). The input data for the two methods were based on a digital elevation model (DEM). The results of the landform classification using elevation, slope, relief and curvature show that the upper terraces (shoulder) were located in many parts of the study area while the plateau (back slope) landform was located in center and some parts of the west and south. In general, with increasing slope and elevation, different types of landforms occur. The parameters of slope, elevation, relief and curvature are effective in preparing a landform classification map. The results of topographic position index (TPI) showed that most area of landform was plain small (plain with low slope), while the lowest landform was open slope (< 0.1%). TPI method showed the largest numbers of landform classes and therefore likely to be more accurate at the local scale. In total, it is better to use new methods such as TPI for landform classification. TPI prepares landform map automatically and only uses DEM as input data. Based on the study area, each model could classify the landforms to a different number of classes.

6 REFERENCES

Adediran, A.O., Parcharidis, I., Poscolieri, M. and Pavlopoulos, K. Computer-assisted discrimination of morphological units on north-central Crete (Greece) by applying multivariate statistics to local relief gradients. Geomorphology, 2004; 58: 357-370.

Barka I., Vladovic, J. and Malis, F. Landform classification and its application in predictive mapping of soil and forest units. GIS Ostrava, 2011; 1: 23-26.

Burrough, P.A., Van Gaans, P.F.M. and MacMillan, R.A. high resolution landform classification using fuzzy-k means. Fuzzy Set. Syst., 2000; 113: 37-52.

Crevenna, A.B., Rodrı´guez, V.T., Sorani, V., Frame, D. and Ortiz, M.A. Geomorphometric analysis for characterizing landforms in Morelos State, Mexico. Geomorphology, 2005; 67: 407-422.

Dikau, R. The application of a digital relief model to landform analysis in geomorphology. In: Raper, J. (Ed.), Three-dimensional Applications in Geographical Information Systems. Taylor and Francis, London, 1989; 51-77.

Dikau, R., Brabb, E.E., Mark, R.K. and Pike, R.J. Morphometric landform analysis of New Mexico. Zeitschrift für Geomorphologie, N.F., Suppl.-Bd., 1995; 101: 109-126.

Dobos, E., Daroussin, J. and Montanarella, L. An SRTM-based procedure to delineate SOTER Terrain Units on 1:1 and 1:5 million scales. EUR 21571 EN, Office for Official Publications of the European Communities, Luxembourg. 2005; 55 P.

Ehsani, A.H. and Quiel, F. Application of self-organizing map and srtm data to characterize yardangs in the lut desert, Iran. Remote Sens. Environ., 2008; 112: 3284-3294.

Giles, P.T. Geomorphological signatures: classification of aggregated slope unit objects from digital elevation and remote sensing data. Earth Surf. Proc. Land., 1998; 23: 581-594.

Huting J.R.M., Dijkshoorn, J.A. and Van Engelen, V.W.P. GIS procedures for mapping SOTER landform for the LADA partner countries (Argentina, China, Cuba, Senegal and The Gambia, South Africa and Tunisia). ISRIC report 2008/04 and GLADA report 2008/02, ISRIC – World Soil Information and FAO, Wageningen, 35 P.

Chabala,L.M., Mulolwa, A. And Lungu, O. Landform classification for digital soil mapping in the Chongwe-Rufunsa area, Zambia. Agr. Forestry Fish. 2013; 2(4): 156-160.

Macmillan R., Pettapiece W., Nolan, S. and Goddard, T. A generic procedure automatically segmenting landforms into landform elements using DEMs, heuristic rules and fuzzy logic. Fuzzy Set. Syst., 2000; 113: 81-109.

Masoudi, M. and Jokar, P. Land-use planning using a quantitative model and geographic information system (GIS) in Shiraz Township, Iran. Ecopersia, 2015; 3(2): 959-974.

Meybeck, M., Green P. and Vorosmarty, C.J. A new typology for mountains and other relief classes: an application to global continental water resources and population distribution, mount. Res. Dev., 2001; 21: 34-45.

Mokarram M, Seif A and Sathyamoorthy D. Use of morphometric analysis and self-organizing maps for alluvial fan classification: case study on oshtorankooh altitudes, Iran. IOP Conference Series: Earth Env. Sci., 2014; 12 pp.

Moore, I.D., Gessler, P.E., Nielsen, G.A. and Peterson, G.A. Soil attribute prediction using terrain analysis. Soil Sci. Soc. Am. J., 1993a; 57: 443- 452.

Moore, I.D., Turner, A.K., Wilson, J.P., Jenson, S.K. and Band, L.E. GIS and land–surface–subsurface process modeling. In: Goodchild, M.F., Parks, B.O., Steyaert, L.T. (Eds.), Environmental Modeling with GIS. Oxford University Press, New York, 1993b; 196-230.

Moore, I.D. and Nieber, J.L. Landscape assessment of soil erosion and non-point source pollution. J. Minn. Acad. Sci., 1989; 55: 18- 24.

Saadat, H., Bonnell, R., Sharifi, F., Mehuys, G., Namdar, M. and Ale-Ebrahim, S. Landform classification from a digital elevation model and satellite imagery. Geomorphology, 2008; 100: 453-464.

Schmidt, J. and Hewitt, A. Fuzzy land element classification from DTMs based on geometry and terrain position. Geoderma, 2004; 121: 243-256.

Sulebak, J.R., Etzelmqller, B. and Sollid, J.L. Landscape regionalization by automatic classification of landform elements. Norsk Geogr. Tidsskr., 1997; 51(1): 35-45.

Weiss, A. Topographic positions and landforms analysis (conference poster). ESRI International User Conference. San Diego, CA, 2001; 9-13.

Wilson J.P and Gallant, J.C. Terrain analysis: principles and applications. John Wiley and Sons, Inc. Chichester, Canada, 2000; 479 pp.

مقایسه طبقه‌بندی لندفرم‌ها با استفاده از روش‌های قدیمی (استفاده از ارتفاع و شیب و انحناء) و شاخص موقعیت توپوگرافی (TPI) در جنوب بجنورد

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چکیدههدف از این مطالعه طبقه‌بندی لندفرم‌ها با استفاده از روش‌های قدیمی (استفاده از پارامترهایی مانند نقشه‌های ارتفاعی، شیب، پستی و بلخدی و انحناء) و شاخص موقعیت توپوگرافی (TPI) در منطقه جنوب بجنورد در ایران است. داده‌هایورودیبهدومدلبرایطبقه‌بندیلندفرمهامدلارتفاعیزمین (DEM) است. نتایجحاصل از مدل TPI نشان می‌دهد که بیش‌تر مناطق در طبقهدشت‌های کوچک طبقه‌بندی شده‌اند، در حالی که کم‌ترینمساحت لندفرم ها مربوط به شیب‌های باز (کمتر از یک درصد) است. نتایج استخراج شده از طبقه‌بندی با استفاده پارامترهای ارتفاع و شیبپستی و بلندی و انحناء نشان دهنده این امر است که تراس‌های بالایی در بسیاری از قسمت‌های منطقه مورد مطالعه یافت می‌شود در حالی که فلات‌ها (Plateau) در مرکز منطقه، برخی قسمت‌های شرق و جنوب منطقه مورد مطالعه دیده می‌شود. به طور کلی با افزایش شیب و ارتفاع تنوع لندفرم‌ها افزایش پیدا می‌کند. بنابراینشیب و ارتفاع برای تهیه نقشه‌های طبقه‌بندی لندفرم‌ها در روش قدیمی مناسب هستند. در نهایت نتایج حاصل از مقایسهدو مدل نشان دهنده این امر است که مدل TPI بسیار دقیق‌تر بوده و جزئیات بیش‌تری را نمایش می‌دهد.

کلمات کلیدی:لندفرم‌ها، روش قدیمی، مدل رقومیارتفاع،شاخص موقعیت توپوگرافی (TPI)، جنوب بجنورد