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ORIGINAL ARTICLE

GIS-Based Automated Landform Classification in Zagros mountain (case study: Grain mountain)

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ABSTRACT
The main objective of this study is to landform classification in Garin Mountain where located in Zagros mountain, Iran. In order to landform classification used Digital Elevation Models (DEMs) with 90 m resolution. In this study used semi-automated landform classification based on Topographic Position Index (TPI). By using TPI, the study area was classified into landform category. The input data for landform classification consist of: slope direction (Aspect), slope position, slope shape (planform curvature), topographic moisture index and stream power index. The classification results can be used in applications related to geology map of the study area. The result show that there are variety of landform in the study area and can used TPI for landform classification.
Keywords*: landform classification, Garin Mountain, Digital Elevation Models (DEMs), Topographic Position Index (TPI).*

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INTRODUCTION

Geomorphometrics consist of geometry, topography, and physical landforms of the Earths horizons, over time, and branches out from the disciplines of geomorphology, geomatics and geomorphometry. It is a response to the development of this GIS technology to gather and process DEM data (e.g. remote sensing, the Landsat program and photogrammetry). Geomorphometry provides a quantitative description of the shapes of landforms. According to Blaszczynski [1], landforms are defined as specific geomorphic features on the earth`s surface, ranging from large-scale features such as plains and mountain ranges to minor features such as individual hills and valleys. Geomorphometric properties have been measured by calculating the geometry of the landscape manually [2-4]. Recently, advances in computer technology, increased processing power, new spatial analytical methods and the increasing availability of digital elevation data have re-oriented geomorphometry [5].
Landform units can be carried using various approaches, including automated mapping of landforms [6-9], classification of morphometric parameters, filter techniques, cluster analysis and multivariate statistics [10-13].
The purpose in the study is landform classification by TPI in the Grain Mountain where located in Zagros Mountain, Iran.

MATERIALS AND METHODS

Case study
The study area is Zagros mountain in Iran. This area is located in 33^{o} 19′ 48″ to 34^{o} 56′ 24″- N and 47^{o} 03′ 36″ to 49^{o} 24′ 36″ E with an area of 15776.2 Km^2 (Figure 1 to figure 4).The highest elevation in this area is 3874 meters that is located in the South of the basin and lowest point is 1177 meters that located in the north of basin. Dataset for cases are originating from 1/25000 topographical elevation contours of 90 m vertical interval. Case study is in Zagros Mountains, Iran.
Landform classification
In the research used Topographic Position Index (TPI) for landform classification. TPI is the difference between the elevation at a cell and the average elevation in a neighborhood surrounding that cell. Negative values indicate the cell is lower while positive values indicate that the cell is higher than its

neighbors. TPI was developed in detail by Weiss [14]. TPI values provide a powerful means to classify the landscape into morphological classes [15]. Classifies of landform consist of "Canyons, Deeply Incised Streams", "Midslope Drainages, Shallow Valleys" and "Upland Drainages, Headwaters" all tended to have strongly negative planform curvature values, while "Local Ridges/Hills in Valleys", "Midslope Ridges, Small Hills in Plains"and "Mountain Tops, High Ridges"all tended to have strongly positive planform curvature values.

TPI values can calculate from two neighborhood sizes. A negative small-neighborhood TPI value and a positive large-neighborhood TPI value is likely to represent a small valley on a larger hilltop. Such a feature may reasonably be classified as an upland drainage. Conversely, a point with a positive small-neighborhood TPI value and a negative large-neighborhood TPI value likely represents a small hill or ridge in a larger valley [16] (Table 1 and Figure 5).

Table 1: Topographic Position Index (TPI) to define landform classes.

Classes	**Description**
Canyons, deeply incised streams	Small Neighborhood TPI: TPI ≤ -1 Large Neighborhood TPI: TPI ≤ -1
Midslope drainages, shallow valleys	Small Neighborhood TPI: TPI ≤ -1 Large Neighborhood TPI: -1 < TPI < 1
upland drainages, headwaters	Small Neighborhood TPI: TPI ≤ -1 Large Neighborhood TPI: TPI ≥ 1
U-shaped valleys	Small Neighborhood TPI: -1 < TPI < 1 Large Neighborhood TPI: TPI ≤ -1
Plains small	Neighborhood TPI: -1 < TPI < 1 Large Neighborhood TPI: -1 < TPI < 1 Slope ≤ 5°
Open slopes	Small Neighborhood TPI: -1 < TPI < 1 Large Neighborhood TPI: -1 < TPI < 1 Slope > 5°
Upper slopes, mesas	Small Neighborhood TPI: -1 < TPI < 1 Large Neighborhood TPI: TPI ≥ 1
Local ridges/hills in valleys	Small Neighborhood TPI: TPI ≥ 1 Large Neighborhood TPI: TPI ≤ -1
Midslope ridges, small hills in plains	Small Neighborhood TPI: TPI ≥ 1 Large Neighborhood TPI: -1 < TPI < 1
Mountain tops, high ridges	Small Neighborhood TPI: TPI ≥ 1 Large Neighborhood TPI: TPI ≥ 1

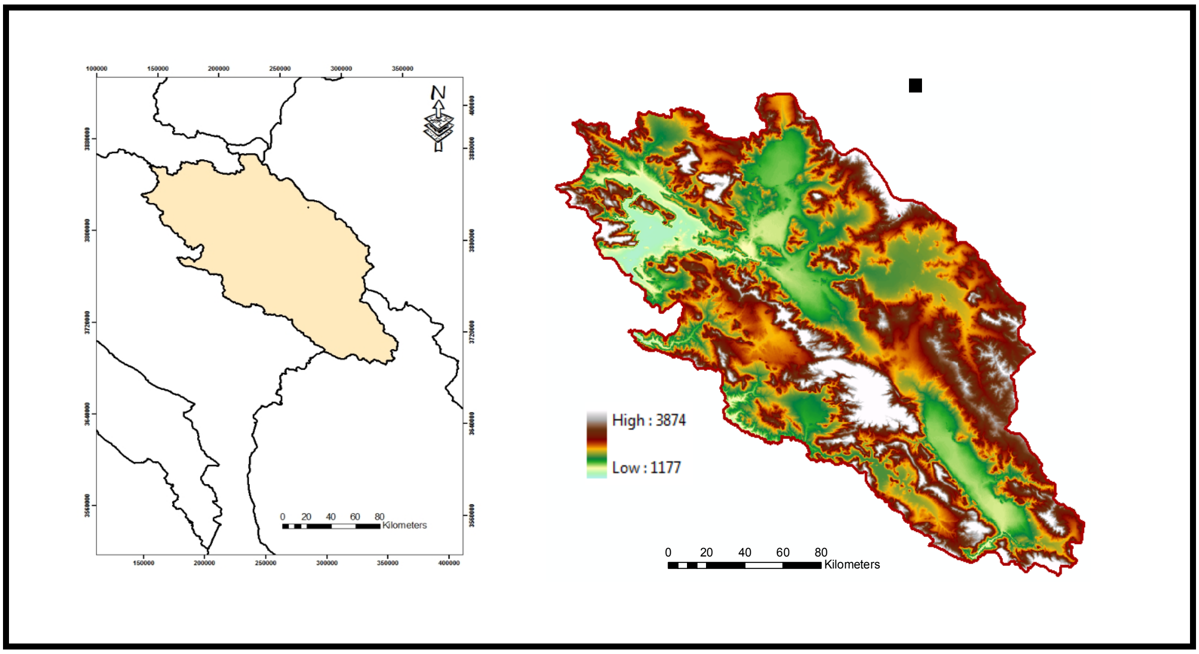


Figure 1. Location of study area

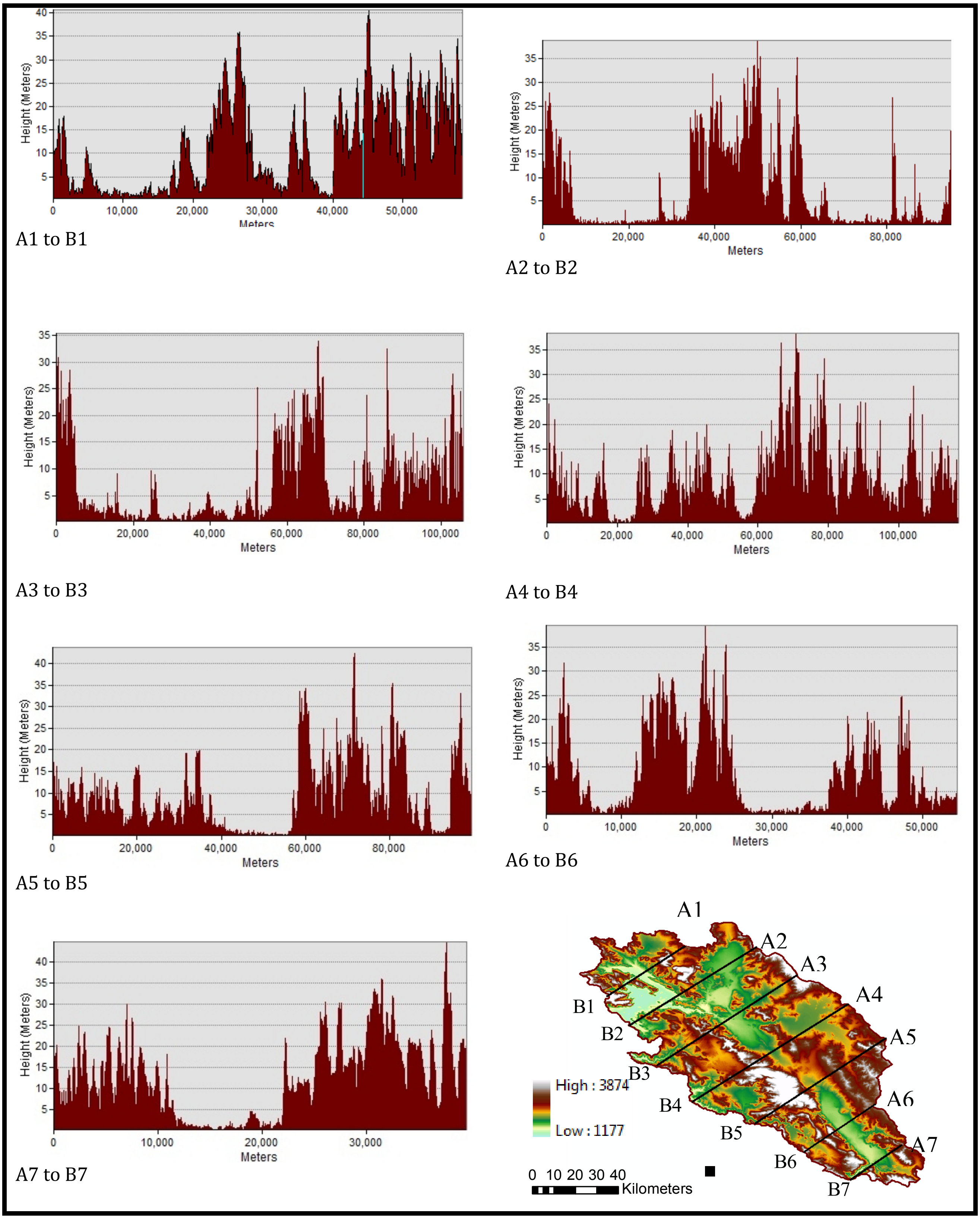


Figure 2: Cross-sections of watershed of Garin

Figure 3. Location of the study area

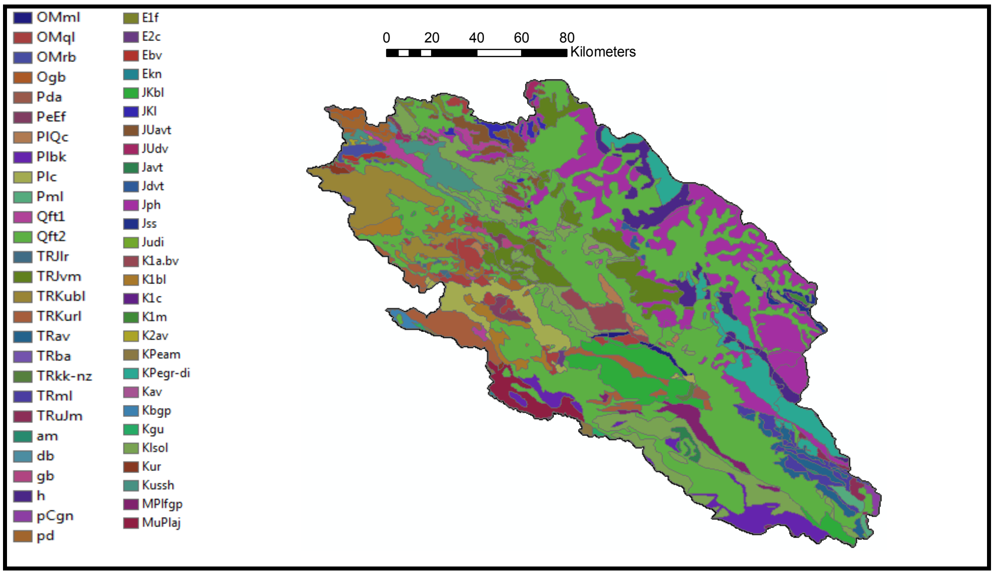
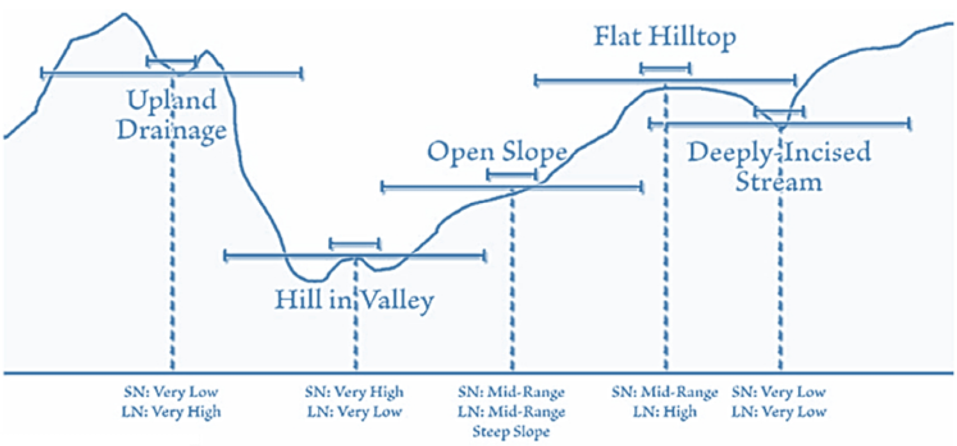


Figure 4. Geology map in the study area



SN: small neighborhood TPI
LN: large neighborhood TPI

Figure 5. Position of each class on topographic lines (Jenness, 2005)

RESULT AND DISSECTION

First of all, topographic attributes consist of: elevation (meters), slope (degree) aspect (degree), plan curvature, topographic wetness and stream power were prepared in the study area (Figure 6).Topographic wetness and stream power indices were used to quantify flow intensity and accumulation potential. Topographic wetness at a particular point on the landscape is the ratio between the catchment area contributing to that point and the slope at that point. Higher positive values are wetter and lower negative values are drier and values are calculated as:

Topographic Wetness Index (TWI) uses Flow Direction and Flow Accumulation rasters as inputs that following of Eq.1:

WI = Ln((“FLOWACC”*900) / Tan(“SLOPE”))

WI = wetness index output raster that will be created

a = area of each pixel in m² if 30m pixels are used (30m x 30m = 900m²)

FLOWACC = name of flow accumulation raster

SLOPE = name of slope raster

Then TPI value with 150, 250 and 450 m neighborhood were prepared that show in figure 7.

Also slope position classification generated from 150, 250 and 450 m neighborhoods was presented (Figure 8).

Finally, based on research of Weiss in 2001 landform classification were prepared that show in figure 9.

Relationship between landform classification and slope, DEM, curvature and topographic wetness in the study area show in Table 2:

For determination of landform classification accuracy in the study area used map of geology that relation between them show in Table 3 and Figure 10.

Codes of in figure 10 that is geology map show in Table 3.

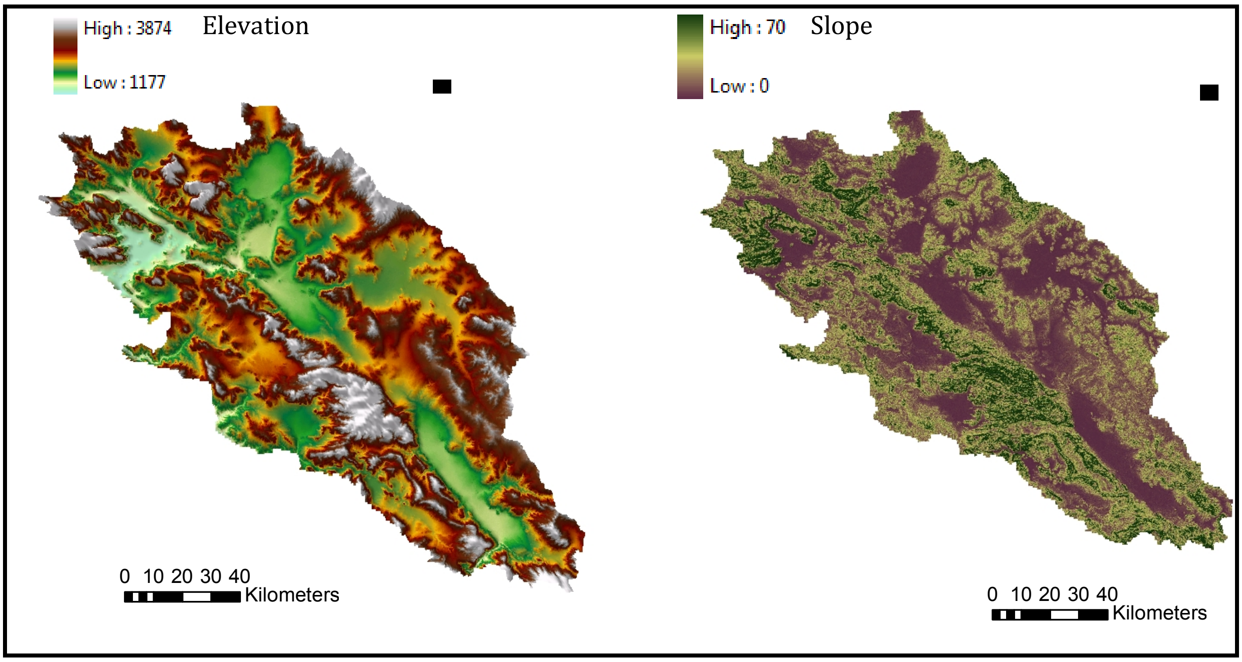
Table 2: relationship between landform classification and slope, DEM, curvature and topographic wetness in the study area

classes	Slope Mean ± (SD)	DEM	curvature	topographic wetness
Canyons, Deeply Incised Streams	16.34±8.98	2021.47±361.47	0.274±0.206	10.15±2.74
Midslope Drainages, Shallow Vallys	16.32±9.32	2006.04±341.89	0.206±0.152	8.67±2.16
Upland Drainages, Headwaters	27.47±10.75	2318.35±432.91	0.234±0.243	7.371±1.63
U-shaped Valleys	15.84±8.46	1982.85±348.63	0.094±0.102	9.08±2.57
Plains Small	7.58±7.59	1821.83±285.64	0.136±0.074	8.74±2.70
Open Slopes	10.24±9.05	1893.15±331.76	0.0081±0.158	8.78±2.68
Upper Slopes, Mesas	18.29±8.95	2163.902±331.76	-0.065±0.121	7.036±1.64
Local Ridges / Hills in Valleys	26.34±9.54	2140.82±419.602	-0.183±0.214	7.73±2.12
Midslope Ridges, Small Hills in Plains	15.71±8.82	1994.5±324.12	-0.186±0.133	7.44±1.85
Mountain Tops, High Ridges	16.74±9.22	2160.94±388.15	-0.288±0.222	7.02±1.61

Table 3: Description of geology map in the study area

code	Geological units	Description
1	Judi	Upper Jurassic diorite
2	Kbgp	Undivided Bangestan Group , mainly limestone and shale , Albian to Companian , comprising the following formations : Kazhdumi , Sarvak , Surgah and Ilam FORMATIONS)
3	TRuJm	Transitional zone composed of : phyllite with intercalations of crystalized limestone and acidic volcanics horizons
4	TRkk-nz	Thin to medium - bedded , dark grey dolomite ; thin - bedded dolomite , greenish shale and thin - bedded argillaceous limestone (KHANEHKAT AND NEYRIZ FORMATIONS)
5	Pml	Slightly metamorphosed fossiliferous (Fusulinid) limestone, locally crystaline limestone
6	TRav	Slightly metamorphosed andesite and andesitic tuff
7	K1c	Sandstone and conglomerate
8	PeEf	Sandstone , shale , limestone and volcanics
9	Jss	Sandstone
10	TRba	Red to light green conglomerate and microconglomerate with intercalations of sandstone and shale (Bagorog Fm .)
11	Ekn	Red conglomerate , sandstone and siltstone (KASHKAN FM.)
12	OMrb	Red Beds composed of , red conglomerate , sandstone , marl , gypsiferous marl and gypsum
13	Kur	Radiolarian chert and radiolarian shale
14	Plc	Polymictic conglomerate and sandstone
15	Jph	Phyllite, slate and meta-sandstone (Hamadan Phyllites)
16	TRJvm	Meta - volcanics , phyllites , slate and meta- limestone
17	Pda	Limestone , dolomite , dolomitic limestone and thick layers of anhydrite in alternation with dolomite in middle part (DALAN FM .)

18	K1m	Limestone , argillaceous limestone ; tile red sandstone and gypsiferous marl
19	gb	Layered and isotopic gabbros
20	Qft1	High level piedmont fan and valley terrces deposits
21	Klsol	Grey , thick - bedded to massive orbitolina limestone
22	JKbl	Grey , thick - bedded , o'olitic , fetid limestone
23	PlQc	Fluvial conglomerate
24	MPlfgp	FARS GROUP comprising the following formation : Gachsaran , Mishan and Aghajari
25	E1f	E1f
26	KPeam	Dark oliv - brown , low weathered siltstone and sandstone with local development of chert conglomerate and shelly limestone (AMIRAN FM .)
27	JKl	Crystalized limestone and calc- schist
28	h	Contact metamorphic rocks : two mica hornfelse ; cordierite hornfelse ; andalusite - sillimanite hornfelse and locally metamorphosed carbonate rocks (scarn)
29	Ebv	Andesite and basalt mainly with vesicular texture
30	am	Amphibolite
31	pd	Peridolites including dunite , harzburgite and serpentinite
32	pCgn	Migmatite , gneiss and granite - gneiss
33	OMql	Massive to thick - bedded reefal limestone
34	Plbk	Low weathering grey marls alternating with bands of more ressitant shelly limestone (MISHAN FM.)
35	Qft2	Low level piedmont fan and valley teraces deposite
36	KPegr-di	Late Cretaceouse - Early Paleocen granit to diorite intrusive rocks
37	db	Diabase
38	Kussh	Dark grey shale (Sanandaj shale)
39	E2c	Conglomerate and sandstone
40	TRKubl	Buff to grey , thick - bedded to massive , partly o'olitic limestone (Bisetun Limestone)
41	MuPlaj	Brown to grey , calcareous , feature - forming sandstone and low weathering , gypsum - veind , red marl and siltstone (AGHAJARI FM .)
42	Kgu	Bluish grey marl and shale with subordinate thin - bedded argillaceous -limestone (GURPI FM.)
43	K1a.bv	Andesitic and basaltic volvanic rocks



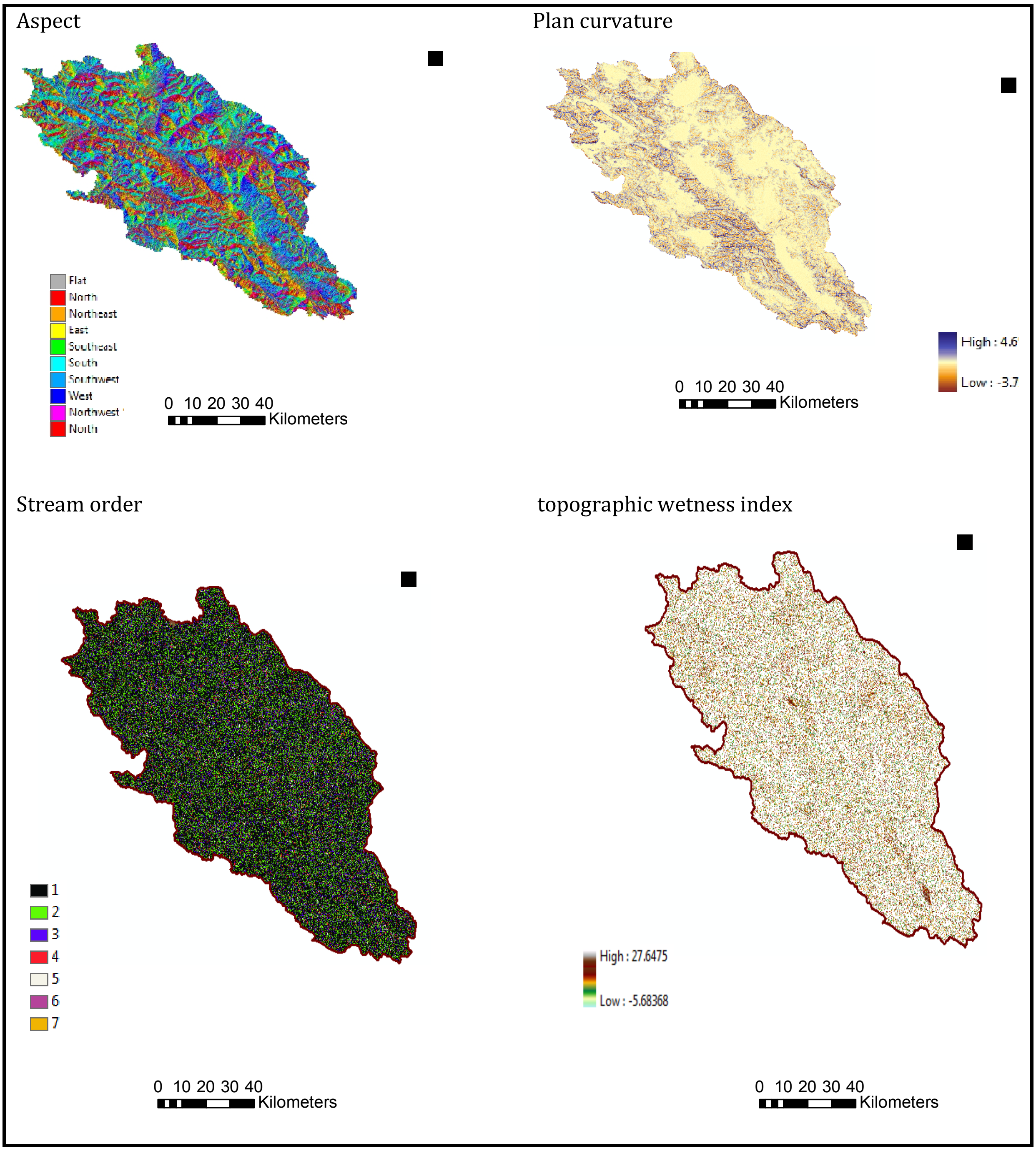


Figure 6. Topographic attributes: elevation (meters), slope (degree) aspect (degree), plan curvature, topographic wetness and stream power

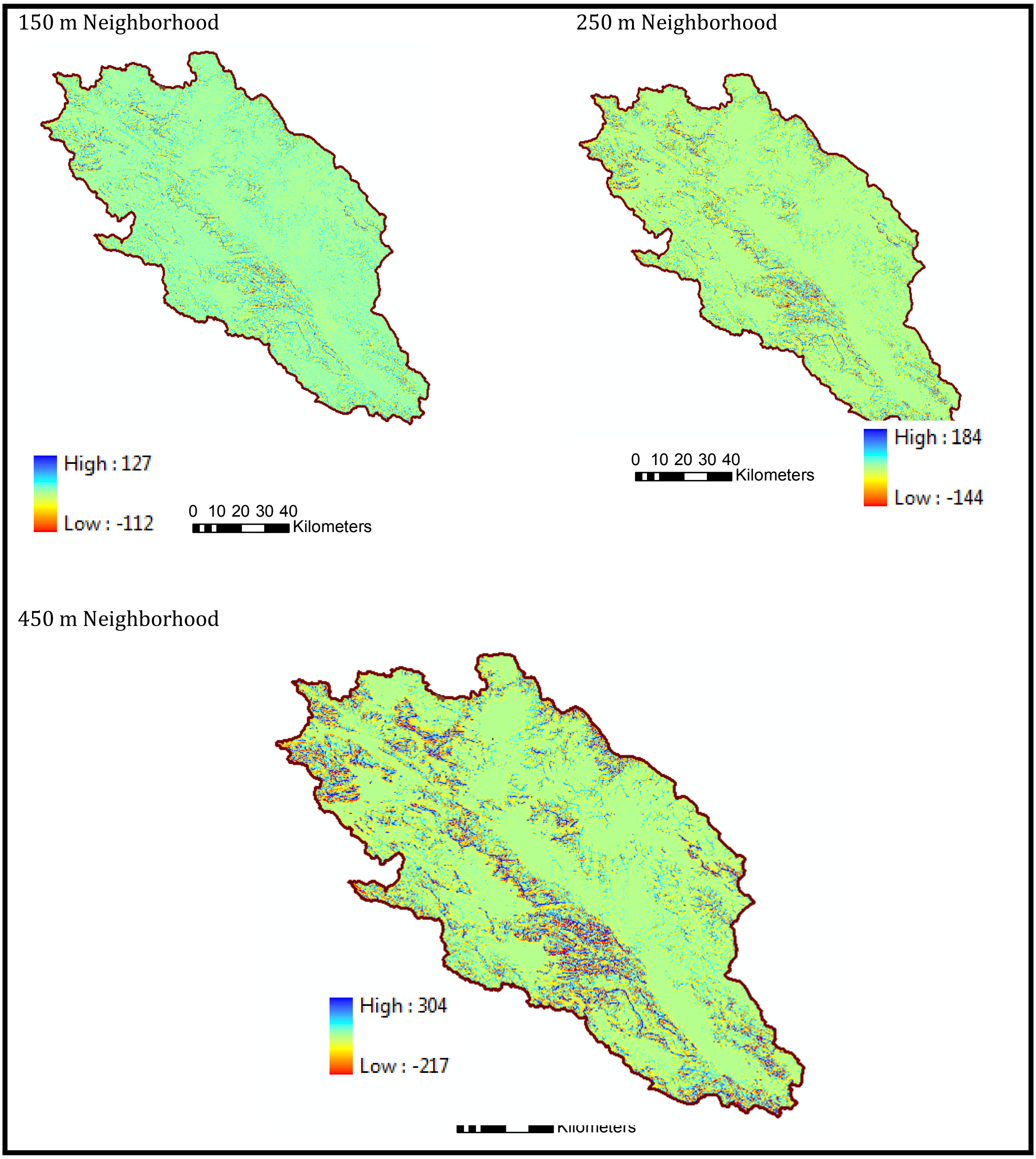


Figure 7. TPI using 3 different neighborhood sizes in the study area

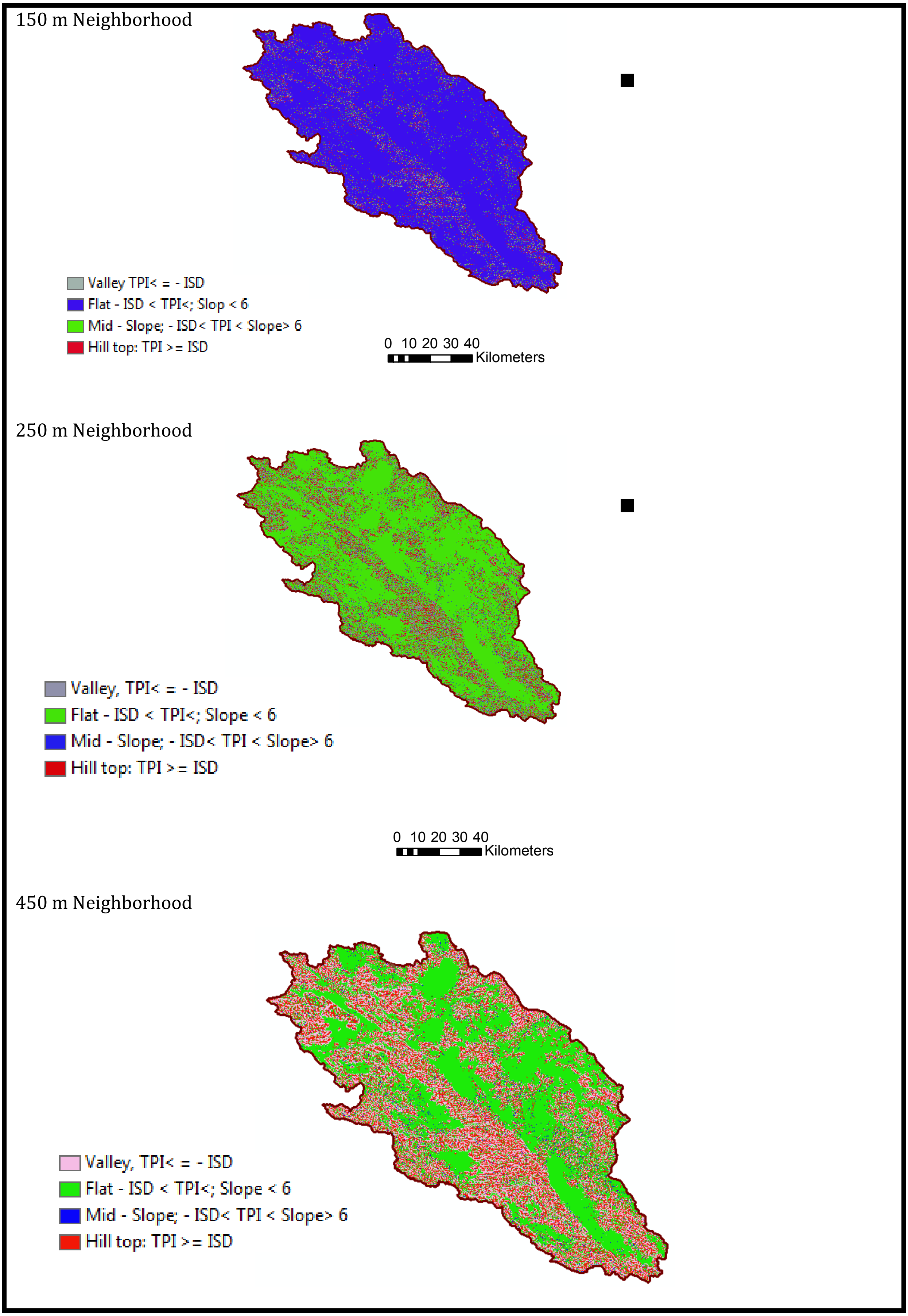


Figure 8. Slope classes using TPI from 3 neighborhood sizes in the study area

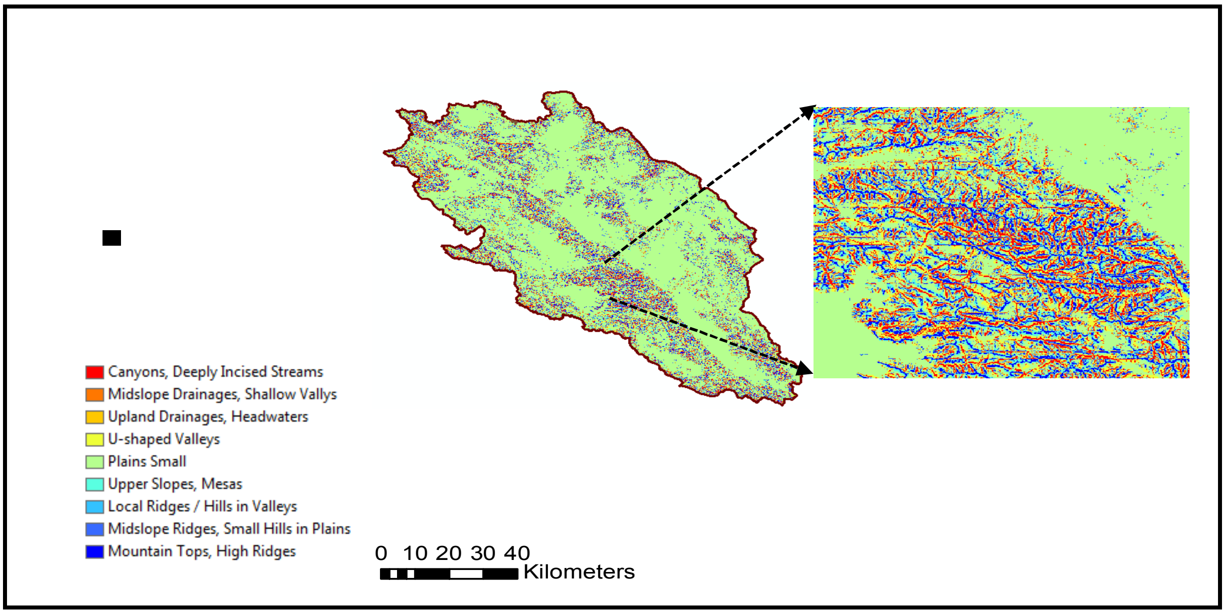
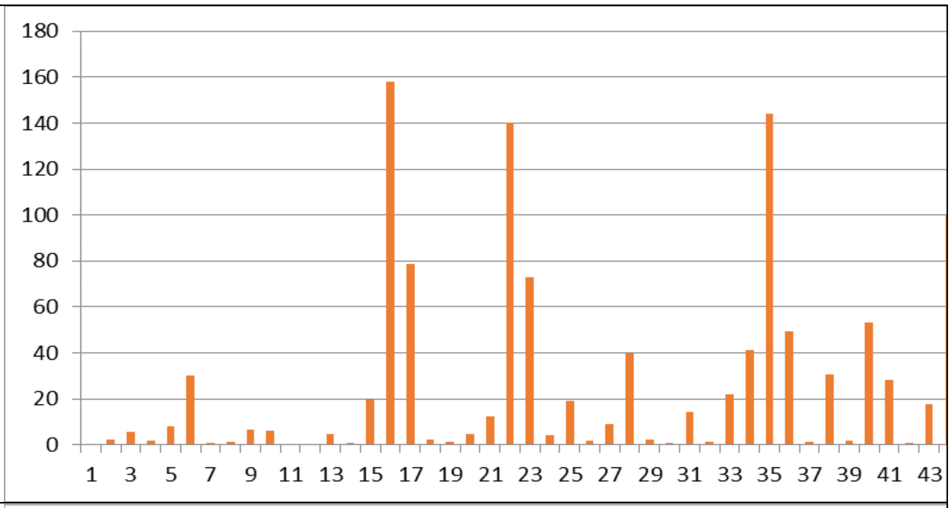


Figure 9. Landforms classification using Weiss (2001) classes

<table>
<tr><td>Canyons, Deeply Incised Streams</td><td>
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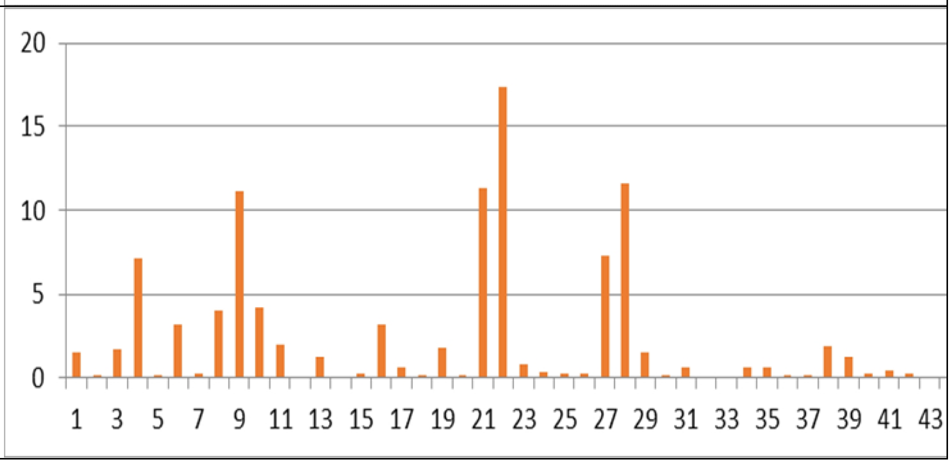
<tr><td>Midslope Drainages, Shallow Vallys</td><td>
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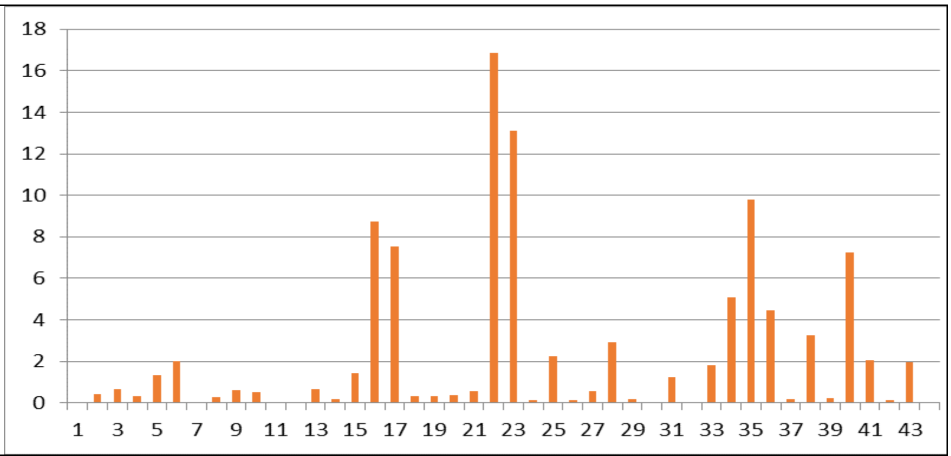
<tr><td>Upland Drainages, Headwaters</td><td>
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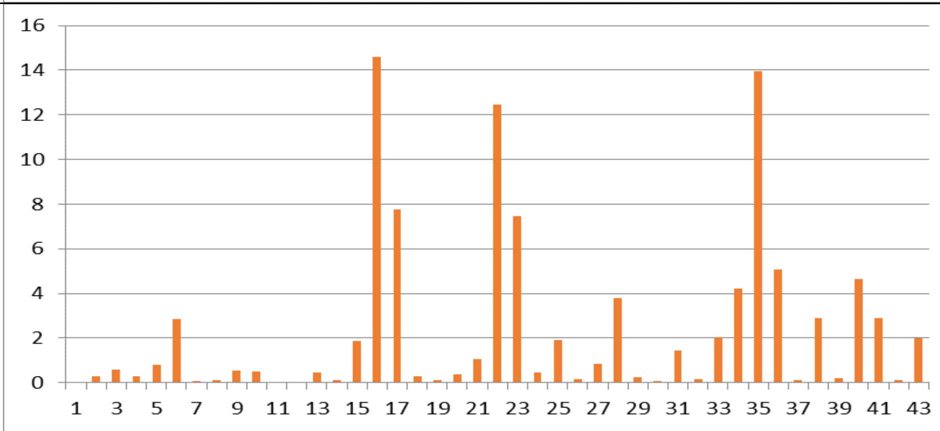
<tr><td>U-shaped Valleys</td><td>
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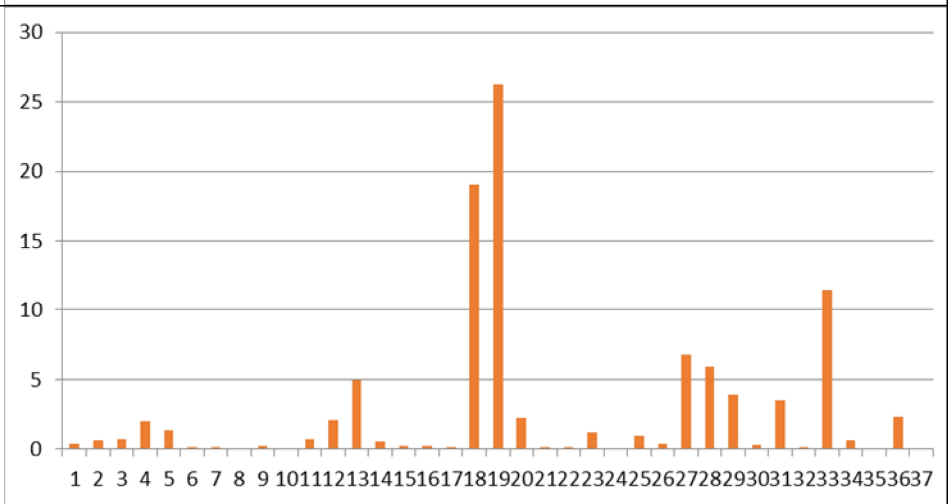
<tr><td>Plains Small</td><td>
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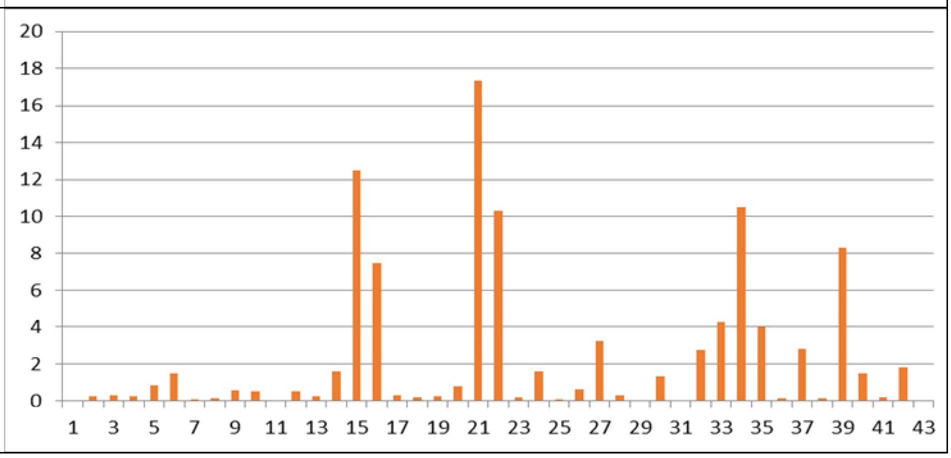
<tr><td>Open Slopes</td><td>
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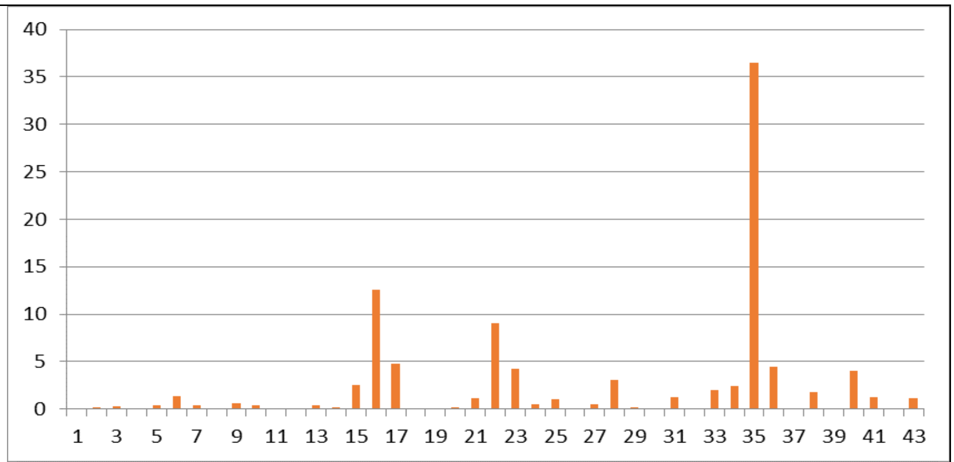
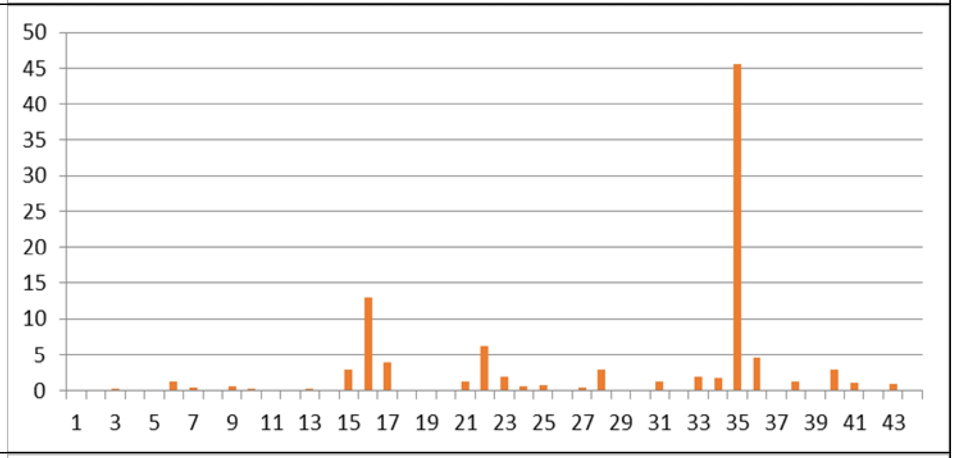
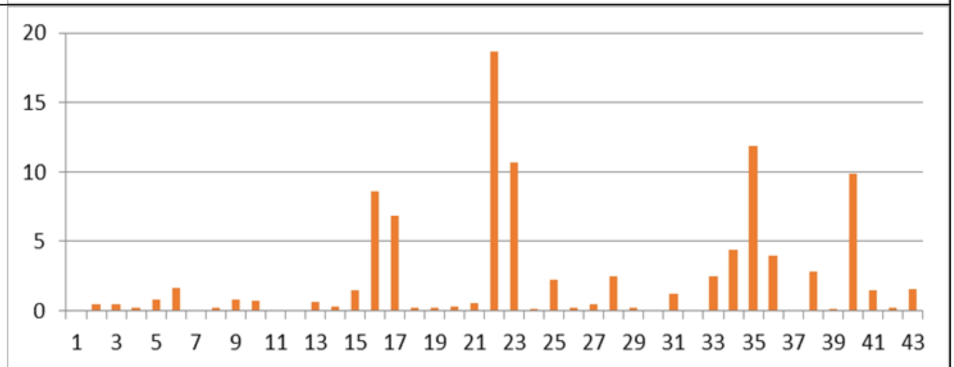
Upper Slopes, Mesas



Local Ridges / Hills in Valleys



Midslope Ridges, Small Hills in Plains



Mountain Tops, High Ridges

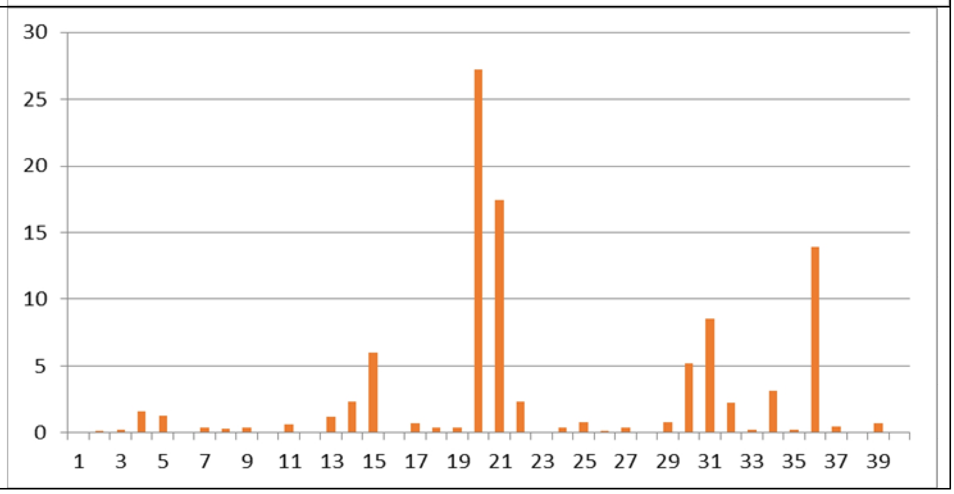


Figure 10. Relationship between landform and geology map in the study area

CONCLUSIONS

Geomorphologic analysis, combined with GIS and remote sensing techniques, are useful tools for landform classification. In this study, TPI was used to generate morphological types for a semi-automated derivation of landform elements according to Weiss [14]. Digital elevation models used as inputs data in the study area. The result show that TPI provides a powerful tool to describe topographic attributes of a study area and there are a relationship between landform map and geology map.

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