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LINEAMENT ANALYSIS OF SULAIMANI MASTER PLAN AREA, KURDISTAN REGION, IRAQ

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Abstract

Modern technologies in the field of remote sensing and geographic information systems are used to process the available data to produce maps for lineaments types, distribution and lineaments density within the area of the master plan of Sulaimani city. Three scenes image of Spot satellite with panchromatic mode from date 12-2008 with ground resolution of 5 meter were selected for this analysis. Statically analysis of lineaments was taken in order to classify them according to their length and direction, also the general trend was found, then classification was done according to their density. For all analysis maps were produced by using Arc GIS program.

The results show four classes of lineaments according to their length short, linear, long and regional lineaments within NE-SW as a general direction within the study area. The distribution or the density of lineaments found to be 9.2 liners per km^2 where the numbers of lineaments is 4365, with total length up to 3801 km.

Most parts of the area fall between low density, density and high density classes where very low and very high density classes cover small areas relatively according to the density of the lineaments.

Introduction

The area under investigation is located in Sulaimani governorate, Kurdistan Region, NE of Iraq, it is located between longitude $45^0 12^- 00^=$ and $45^0\ 32^-\ 00^=$ E and between latitude $35^0\ 25^-\ 30^=$ and $35^0\ 40^-\ 00^=$ N, covering area estimated by 473 Km^2, Fig (1), with height ranging from 615.2m to 1651.92 m, above the sea level according to the DEM which has cell size 2 meters, Fig (2).

The area of study was located in the northern part of the Zagros Mountains, the north-northeastern part is characterized by the Iraqi Zagros Mountain belt with heights up to (3 600 m) above sea level.

Approximately, 20% of the total area is considered as a mountainous region, with high mountains such as Azmar and Goizha mountainous covered eastern part of the area, where Baranan ridge covered western part, and the plunge of Sulaimani anticline covered northern part of the area.

In this part of the study, the data of lineament was a geomorphology polyline shapefile generated by using ArcMap software. Three scenes from the same date 12/2008 of Spot satellite were processed in order to obtain a mosaic of images, geometrically correct, covering the all study.

The Spot images are panchromatic mode, with ground resolution of 5 meters. The Spot images are already georeferenced, and they are free of clouds and of very good quality.

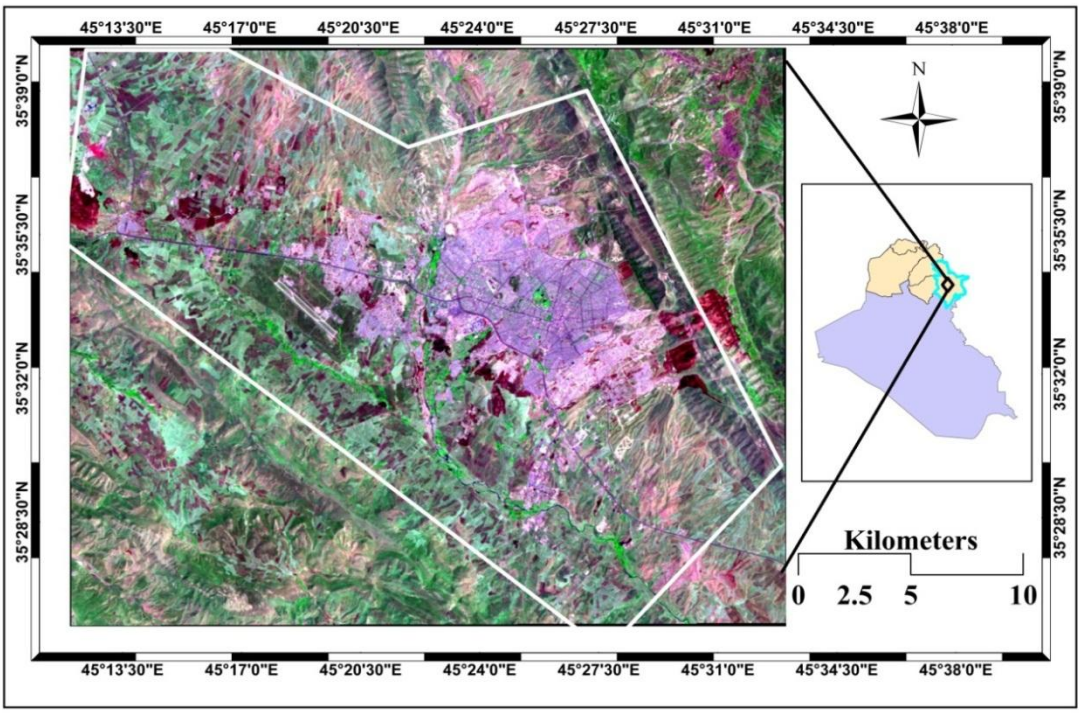

Figure-1: Satellite image shows the location of the study area.

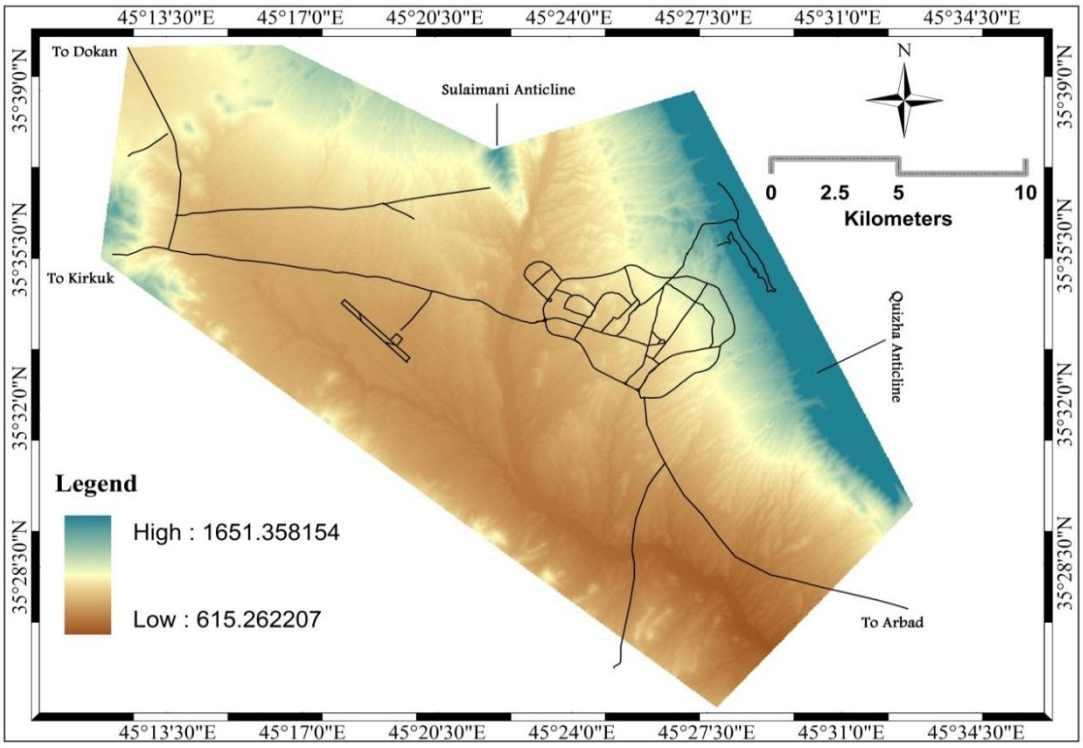

Figure-2: The DEM of the study area.

In this part of study, methodology includes two parts depending on the digital interpretation of satellite spot image. First part is the statically analysis of lineaments to classify them depending on their length and direction, while second part was attempt to classify them according to their concentration or density.

Regional Geological Setting

Tectonically, the study area is situated near the eastern margin of the High Folded Zone with small parts of the area located within the Imbricated Zone of Iraq (Jassim and Goff (2006). The study area represents part of the unstable platform of the Arabian plate. It is characterized by high mountain of elevation up to 1650m a.s.l. in the northeast and east part of the area. The trend of the folds and the strike of the strata are generally in NW-SE direction in accordance with the main trend of Zagros folds.

Generally, the studied area lies between High Zagros Reverse Fault (HZRF) and Zagros Mountain Front Fault (ZMFF) which make most of the studied area form part of the Zagros High Folded Zone, Figure (3), according to (Al-Qayim et al., 2012).

Structurally, the fundamental framework of the structure and stratigraphy of the study area is strongly influenced by the positioning of Iraq within the main tectonic units of northeast Arabian Plate. The Zagros Fold Thrust Belt (ZFTB) generally consists of foreland fold zone and thrust zone; the study area consists of a series of complex structures like Azmar, Goizha, Sulaimani and Baranan structures, Figure (4), the 3D image (DEM with Landsat Image) showing physical features of Sulaimani city within the area of master plan, (Bety, 2013).

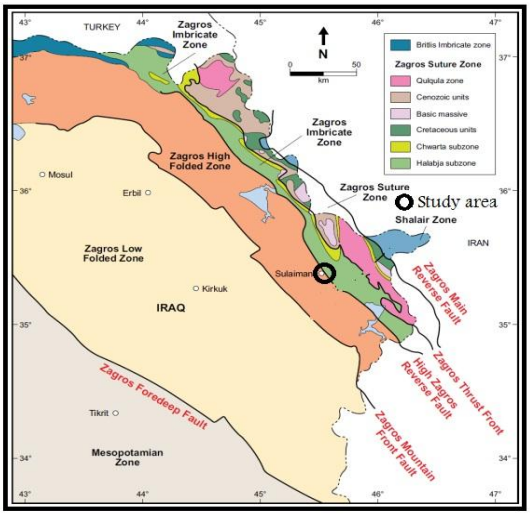

Figure 3

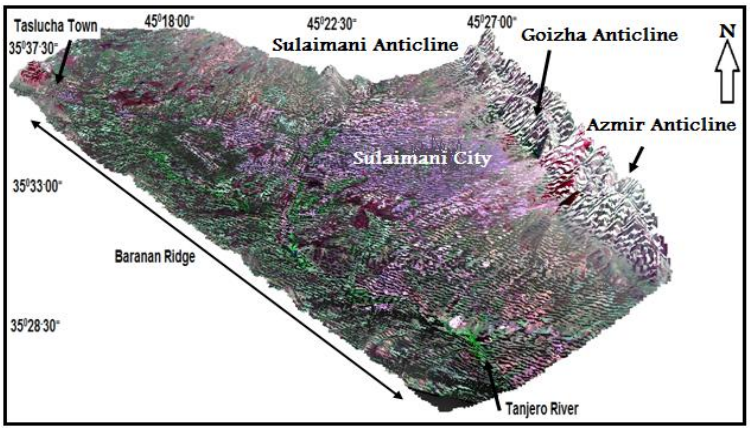

Figure 4

Figure-3: Tectonic subdivision and boundaries of NE Iraq (From Al-Qayim et al., 2012), Figure-4: The 3D image showing major physical features of Sulaimani city.

Stratigraphy, the area of study contains many stratigraphic units appeared as outcrop, ranging from Lower Cretaceous to Recent age, those formations are drawn in the geological map of the study area, (Figure: 5). Those formations from oldest to youngest are:

Balambo Formation (Valanginian-Turonion)

In the study area, this formation is the oldest exposed rocks at Azmar anticline and it is intensively deformed and consists of light gray well bedded limestone and marly limestone.

Kometan Formation (LateTuronian-Early Campanian)

Generally, the formation is well bedded, gray, fine grain limestone, and it is variably deformed, with well-marked striations, stylolites and fractures especially at the southwestern limb of Azmar anticline. The structural attitude of the beds in some cases is complicated and shows overturned or vertical with boudinage structures, (Al-Hakary, 2011).

Shiranish Formation (Campanian-Early Maastrichtian)

The formation is well exposed in the northeastern limb of the main Azmar Anticline. The formation is characterized by generally soft sediments of grayish green, marlstone and marly limestone. The formation bound the Azmar-Guaizha mountain foot slop.

Tanjero Formation (Middle to Late Maastrchtian)

The formation is composed mainly of alternation of sandstones, claystones, shale, and beds of conglomerates that have dark yellowish green and olive green colors with common lateral and vertical variation, see photo (2-4). The lower contact is gradational and conformable with the underlying Shiranish Formation (Karim and Surdashy, 2005). It is extensively exposed in the study area due to its high thickness and relatively soft lithologies and this is make it readily eroded by stream network of the area.

Kolosh Formation (Paleocene)

It is composed of grey calcareous shale, siltstone, sandstone and sandy limestone. In some cases, the thin bed of limestone occupies the upper part of the formation. Usually exposed in the slopes, below the cliffs of Sinjar Formation, as it appears in NW-W -SW part of study area along Baranan ridge. The formation along with Tanjero Formation forms topographically the lowest parts of the study area due to their soft sediments.

Sinjar Formation (Early Eocene)

The lithology of the formation is characterized by hard light gray, massive too thick bedded limestone of reef, fore reef, and lagoonal facies (Jassim and Goff, 2006). This formation occupies small part of the study area. It is exposed only in Baranan ridge.

Finally, The Quaternary sediments cover a large part of the study area, particularly in the west and east parts of the study area, and also occupy the lowland region. Quaternary deposits cover about 49.47 % of all the study area. Alluvial fans with fluvial deposits represent most of the quaternary deposits in the study area. The area and the percentage of the area for each formation that appear within study area are calculated digitally and the results are put in the Table (1).

Table-1: Show the Formation area and their percentage within study area

Formation Name	Area (km^2)	% of Total Area
Quaternary	234	49.47
Sinjar	7.5	1.58
Kolosh	43	9.1
Tanjero	127	26.85
Shiranish	13	2.75
Balambo and Kometan	37	7.86

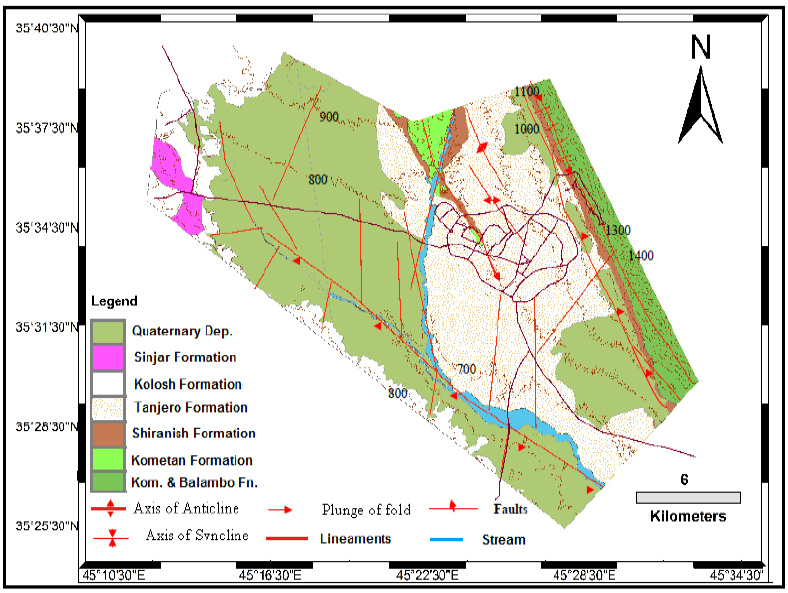

Figure-5: Geological map shows distribution of the formations in the study area.

Lineaments Classification

Lineaments can be defined as any linear features appear on remote sensing images which have structural origin, may be reflectance of fractures or manifestation of sub-surface fault appears in surface. In a geological point of view, the lineaments are usually indicated faults, major joints, or boundaries between stratigraphic formations. Lineaments can be derived from DEM and satellite image.

The analysis of lineaments were done by using PCI Geomatica software, Erdas software and also the results of some others studies which are related to the study area. Some of the lineaments like Baranan Backthrust Fault, High Zagros Reverse Fault (HZRF) and Chaqchaq and Sulaimany-Sitak Faults are mentioned in other previous studies as an important structural feature such as (Aziz et al, 2000; Ibrahim, 2009 and Al-Hakary, 2011).

Three scenes from the same date 12/2008 of Spot satellite were processed in order to obtain a mosaic of images, geometrically correct, covering all the area of Tanjero basin, (Figure: 6). Lineaments were extracted from Spot satellite image depending on new technical of remote sensing in order to get better results about all area of Tanjero basin, (Figure: 7).

The lineaments are classified, according to their length, into four classes, (Figure: 8), these classes are included in the final report of the hydro-geological study for the governorate of Sulaimani – around the central of the city (SGI, 2011) as they are:

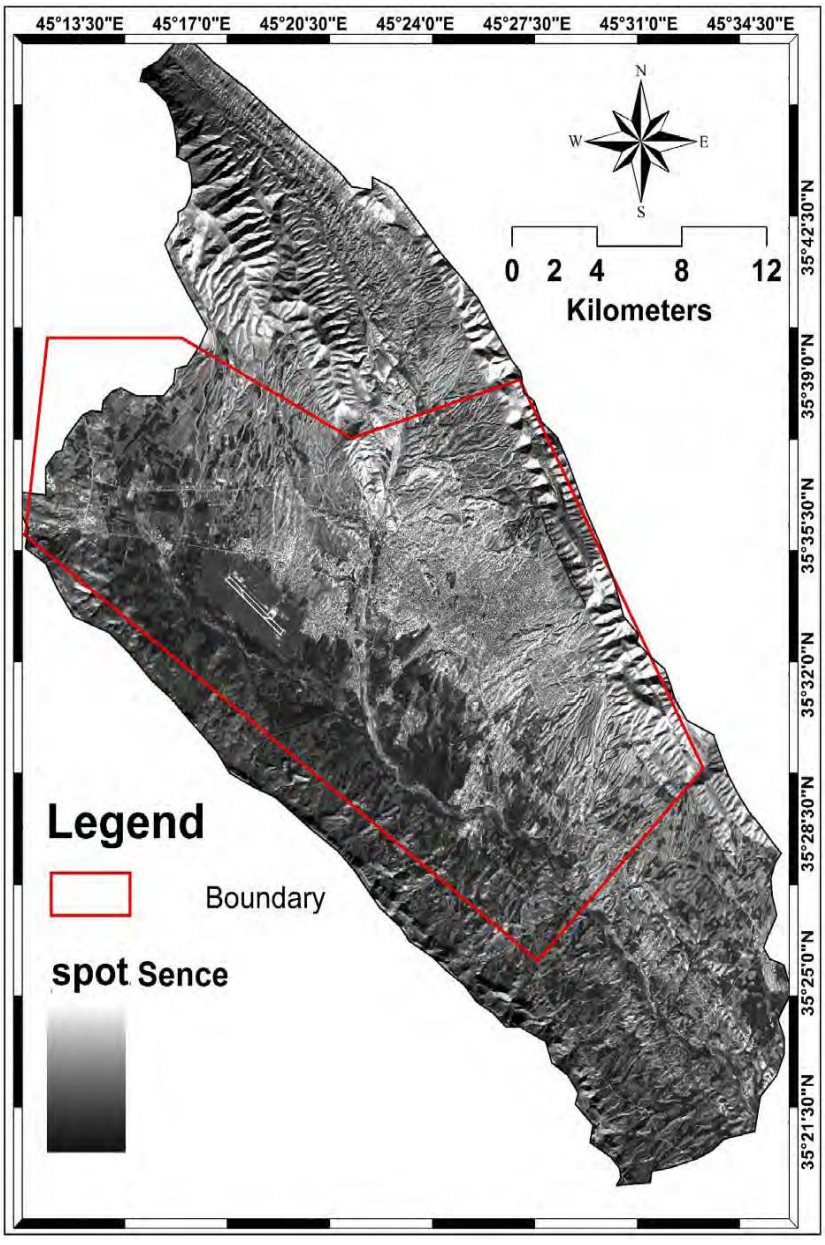

Figure-6: The panchromatic mode of Spot satellite image.

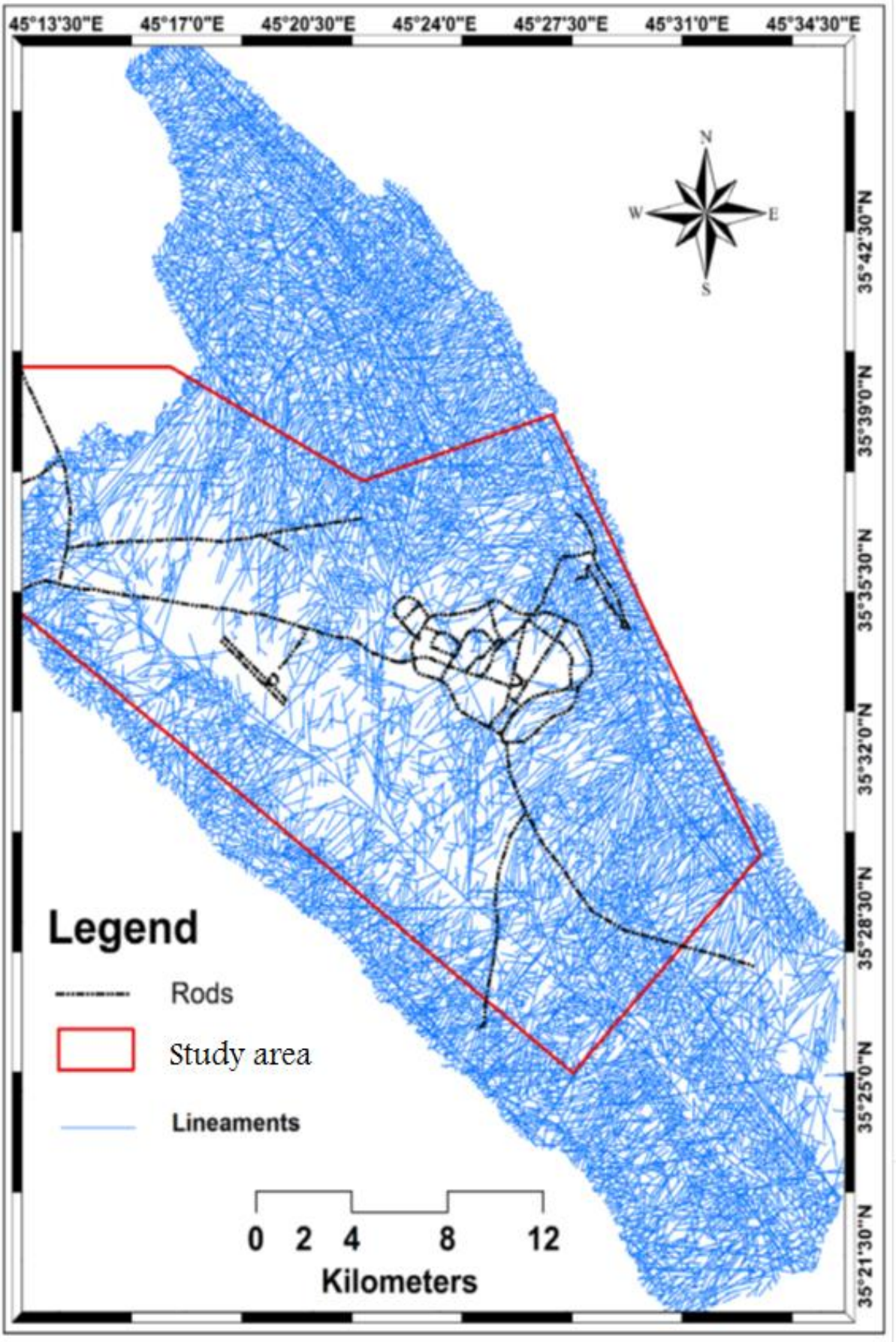

Figure-7: The lineaments extraction within Tanjero basin, after (SGI, 2011).

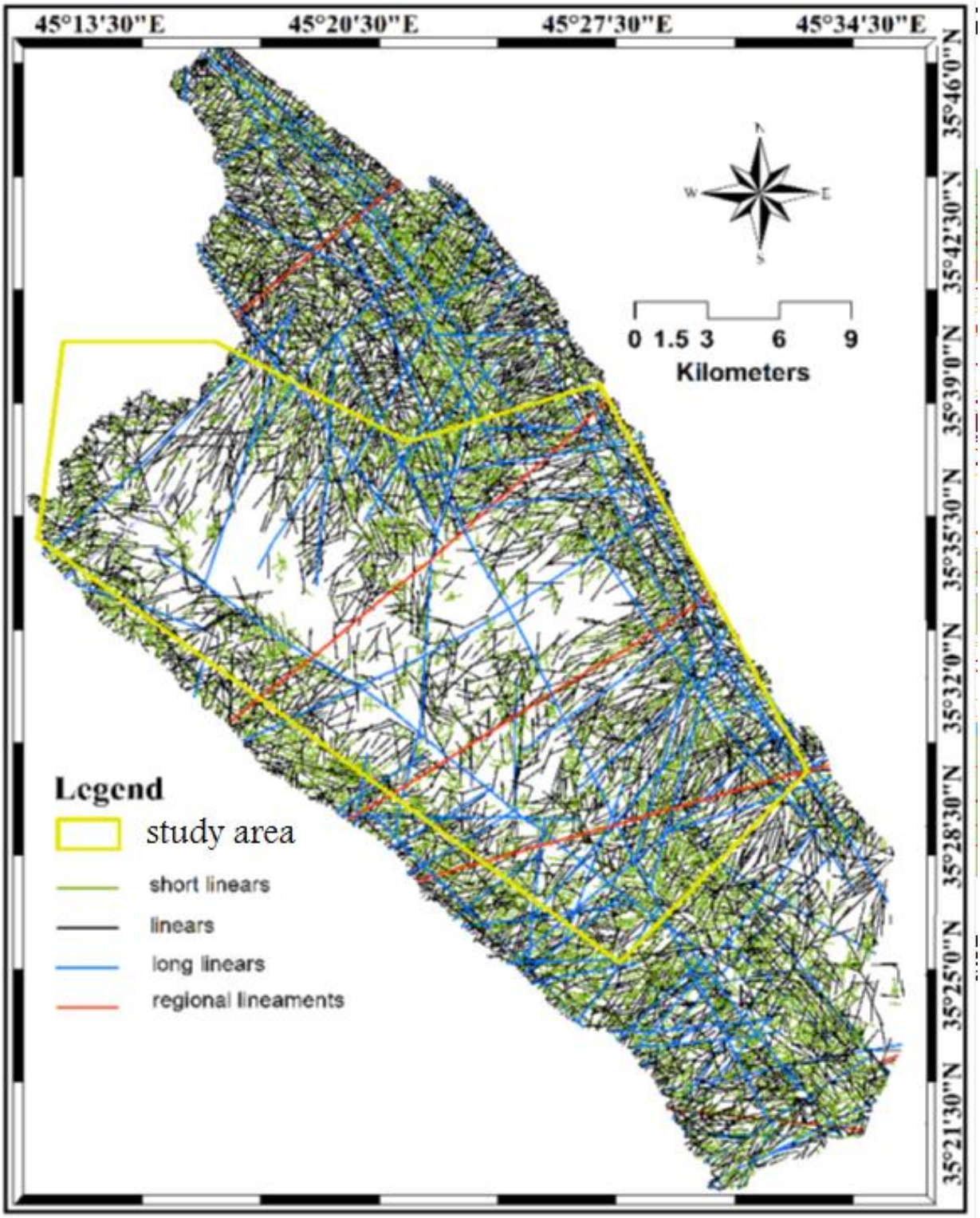

Figure-8: shows the classification of lineaments according to their length, after (SGI, 2011).

1- *Short lineaments*: They are those features that are shorter than 750 meters, referable to fracturing affecting the uppermost layer of rocks. Their recognition depends mostly upon the scale of the images employed and upon the quality of the outcrops, which clearly show the lithological, morphological and structural characteristics of the rocks.

2- Lineaments: This class includes the linear features comprised between 750 and 5000 meters. They are represented by recognized faults, fractures and stratigraphic joints, as well as by all other linear features outlined by morphology, vegetation, color boundaries, micro details and associations of them. At first sight,

this class appears to be the most frequent, in number, in the Tanjero basin area, except for the total field of the Sulaimani area, where the short lineaments are prevailing.

3- Long lineaments: This class contains the linear longer than 5000 meters. Their distribution appears to be quite uniform all over the study area; they include also features of stratigraphic origin, as related to lithologic changes within a formation, or to sharp contacts between different formations, as it is the case of the monoclines of the northernmost part of the area. The majority, however, is of structural origin, as important faults and major fracture lines. Some of these are parallel to fold axes. Therefore they should be tensional on anticlines and compressional on synclines.

4- Regional lineaments: They represent linear that have been traced by correlating several elements of different nature, but which show in the whole continuity referable to a single feature. They are characterized by a variable length, but always in the range of several tenths of kilometers. Some of these observed appear to continue outside the available images coverage area and therefore their real length could not be ascertained. Most likely they derive from regional studies carried out over areas much larger than the ones of this study. It is important to mention that just three regional lineaments are passing through the area of study. The classes of length within study area are shown in (Figure-9).

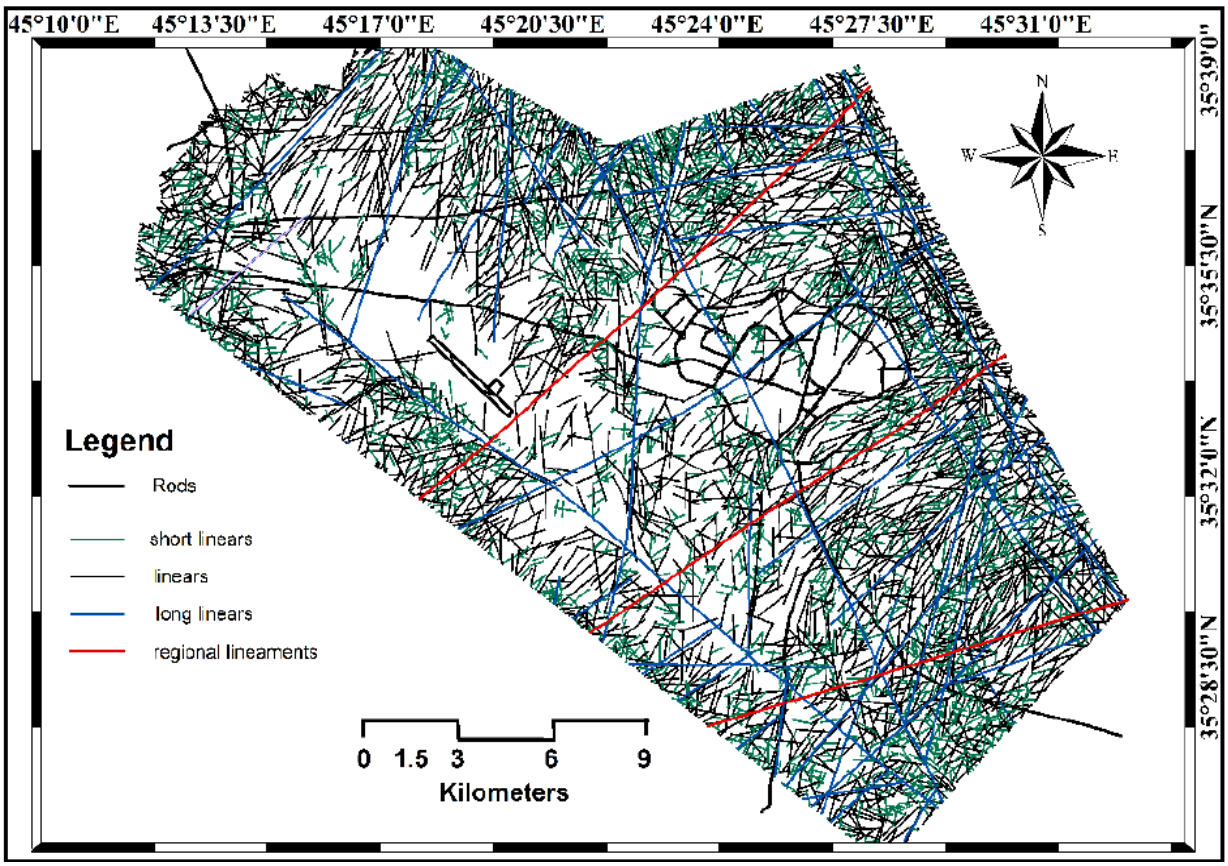

Figure-9: Classification of lineaments within study area.

ArcView 3.3 program is used to extract the rose diagrams which represent the frequency and length direction in different parts of the study area, the result was put in the (Figuer-10).

The rose diagrams show clearly that the percentage of numbers of lineaments increases toward NE direction, mainly ENE where it is less in NW direction. The high percentage of lengthy lineaments is oriented along the NW and E-W directions. In the Tertiary units of the Unstable Shelf, a quite uniform distribution in the frequency of numbers is noticed in the section included between NNE and E-W, while in the Mesozoic units, the distribution is more varied, with a peak along the ENE direction, as far as the lengths are concerned, the diagram of the Mesozoic units shows the same higher concentration in correspondence of

the directions between NNE and E-W and differs from the diagram of the Tertiary units, mainly for the presence of a peak between NNE and NE, (SGI, 2011).

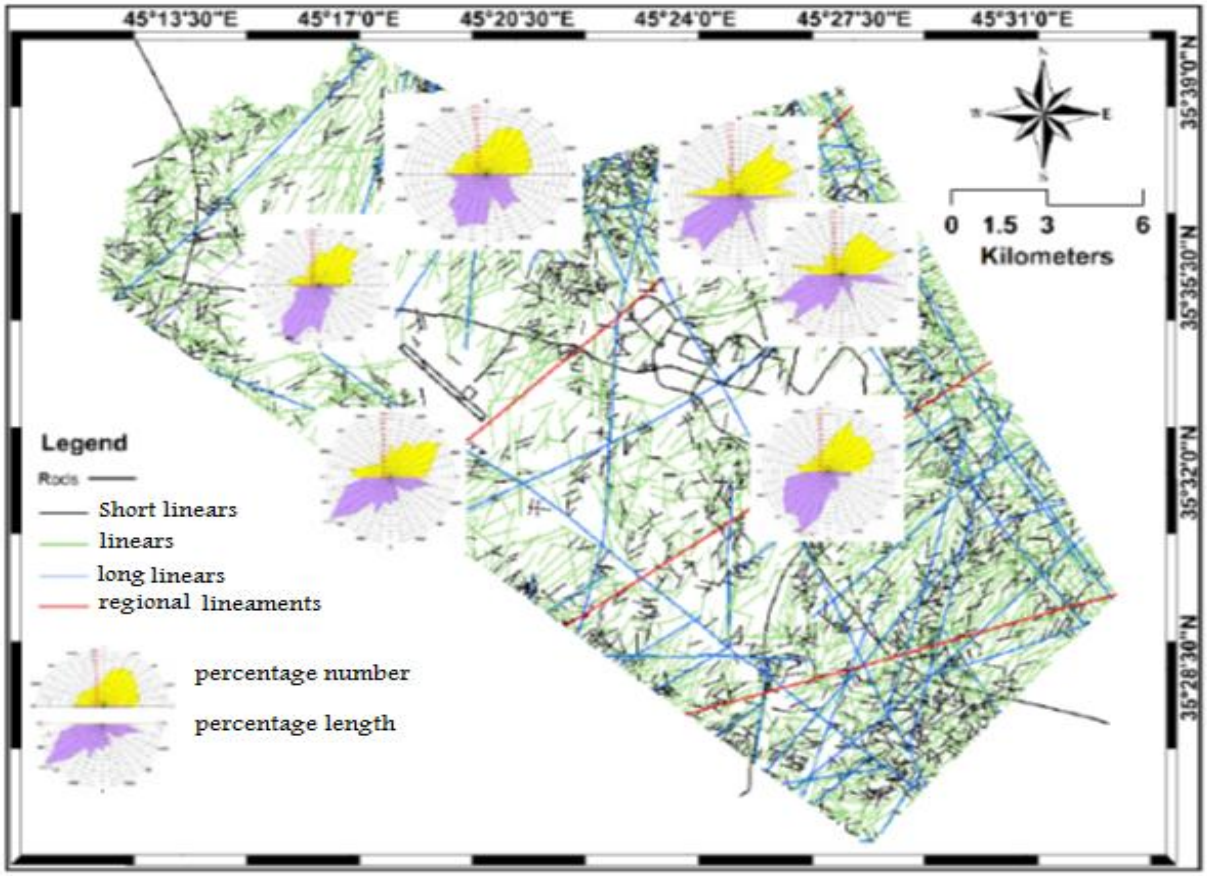

Figure-10: Rose diagrams represent lineaments frequency and length direction in study area.

Lineaments Density

The density of lineaments can be calculated by dividing the numbers of lineaments to the areas. It is found to be 9.2 liners per km2, where the numbers of lineaments is 4365, with total length up to 3801 km, so the average length is 0.87 km. (Gordon et al., 2004) think that the density of linear is sensitive to many factors like resolution of the data used, relief, and thickness of soil cover.

Based on the lineaments density, the study area is classified into five classes by using geometrical interval method from the program methods. Many methods were used in this study to produce the density map, but Kernel methods represent the best results, so it has been chosen for this study.

The count, maximum, minimum, mean, median and slandered deviations are calculated digitally in the classification statistics, the result of the distribution or the density of lineaments is shown by (Figuer-11).

By using the ArcMap program, shapefile is produced to calculate the areas of each class, and also the percentage of the area is calculated within the study area. The results are shown in the Table (2).

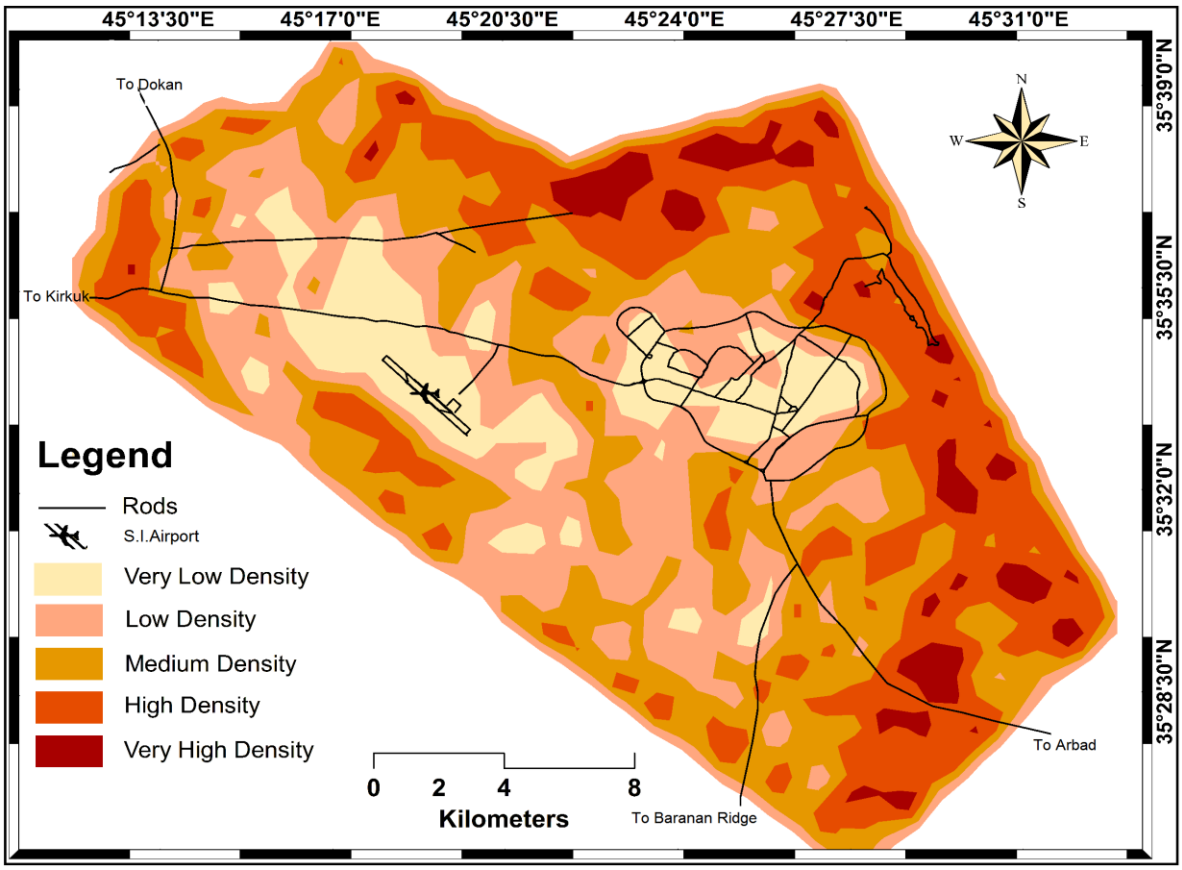

Figure-10: The Density map of lineaments in the study area.

Table-2: The area and percentage of the lineaments density classes.

The Class	Area in Km2	Percentage
Very Low Density	56.50	11.95
Low Density	128.75	27.23
Medium Density	149.18	31.55
High Density	118.20	25.00
Very High Density	20.11	04.25

Discussion of the results

It seems that most parts of the area fall between low density, density and high density classes where very low and very high density classes cover small areas relatively. Very high density cover most parts of mountain structural areas like Azmar, Goizha, and Sulaimani mountains. This is mainly indicated by the high intensity of deformation in that part and the brittle nature of its rocks.

The exposed bedding plans have been affected in the subdivision of classes, and for that very high density takes place with hard rock in the study area. Also it takes place with a small area of the Quaternary deposits too; this is mainly due to the surface channel within these deposits.

High and medium density classes covered many parts within the study area; it is distributed mainly within Tanjero and Shiranish formations, it takes place in some parts of the Quaternary deposits. Low and very low density cover mainly an area within middle parts of the study area; i.e. they cover Tanjero Formation and Quaternary deposits. Conceivably, the soft sediments natures of this part reduce lineament manifestation.

It is important to mention that lineaments are not significant from urbanization points of view; if they are stable, it is a necessity to make a combined observation between lineaments density map with seismic map of the area. Unfortunately the seismic data is not available for the study area to correlate and to evaluate lineament risk.

Compare the linear density with the density of drainage systems map, (Bety, 2013) shows clearly in some parts of the study areas a strong correlation between high density linear and medium to high density of drainage. Also the compare between slope map, (Bety, 2013) and lineament density map shows the gentle slope areas are covered by very low and low lineament density. On the other hand, the moderate and steep slope areas are covered mostly by the high and very high linear density.

Stratigraphically, the Kometan, Balambo and Sinjar formation exposure area shows mainly high and very high linear density, where Tanjero, Kolosh and Quaternary area shows distribution of very low, low and medium linear density. Finally, most parts of urbanization area are taking place over very low and low lineament density classes according to compare density linear map with urbanization map of the study area, (Bety, 2013).

Conclusions

1- Remote sensing and GIS technical was applied and provide ability in the analysis and the interpretation of special linear data relationships.
2- The lineament analysis shows that Spot satellite of the panchromatic mode with ground resolution of 5 meters gives better results as compared to the Landsat image with 30 m resolution.
3- According to the length, lineaments within the study area are classified into short lineaments, lineaments, long lineaments and regional lineaments.
4- The lineaments numbers are increasing mainly in ENE direction, where the dense of the linear is fewer toward NW. The high percentage of lengths oriented along the directions of NW and E-W.
5- Hard rocks formation exposures areas shown distribution of high and very high linear density, where soft materials area shows distribution of very low, low and medium linear density.

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