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Extraction of Geological Structural Lineaments in Northern Kuwait Using High Resolution Landsat 8 ETM+ Satellite Images and Edge Enhancement Techniques

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Abstract

Earth consists of hard rock layers where water is restricted to secondary permeability, and thus to fractures and the weather zones. Satellite images, aerial photographs and digital elevation models will give lineament information. Recent advances in digital image processing allow such lineament extraction to be accomplished in semi-automatic to fully automatic approaches. Precise delineation and mapping of geological structural lineaments is very much needed in Northern Kuwait in view of their close spatial association with subsurface tectonic fractures in oil fields at deep levels and groundwater fields (aquifers) at shallow depths. As such, high spatial resolution remote sensing multispectral image data (Landsat 8 ETM+ satellite) will be used delineate and map the lineaments. Lineaments are linear features which provide information about the underlying geological structure. Their analysis are widely considered in the location or sitting of suitable groundwater exploration sites since the water will tend to flow along the fracture zones. The major objective was to extract the lineaments in Northern Kuwait, with a view of using the analysis for groundwater exploration in the future to mitigate the requirement of groundwater in the area. The analysis was carried out using Band 5, 6 and 7 of Landsat 8 (OLI), which was processed using the edge enhancement filters available to extract the lineaments in the study area. These were then verified using manually digitized lineaments from a geological map partly covering the region and false color composites of the study area. The results showed that the semi-automatic extraction of lineaments can yield tangible results using optical imagery. However, the lineaments still require verification through comparison with known lineaments. Filters which are Sobel, Laplacian and Directional filtering of Band 5, 6 and 7 of Landsat 8 proved to be useful in visual identification and verification of lineaments.

Keywords: Landsat data, GIS, Lineaments, Geology, Arid region, Kuwait

Introduction

The surface features making up a lineament may be geomorphological, i.e. caused by relief or tonal, i.e. caused by contrast differences (Hung et al, 2005). Lineaments are linear features evident at land surface that are an expression of the underlying geological structure. It isa map able linear or curvilinear feature of a surface whose parts align in a straight or slightly curving relationship which may be caused by an existing fault or other line weakness. Analyses of lineaments in an area are a widely used method for ground water exploration since water naturally tends to be found near fracture zones (R. Maliva& T. Missimer, 2012).

The detection of lineaments from satellite imagery has been carried out successfully using a number of techniques including; applying Laplacian edge enhancement, High pass filter, and Sobel edge detector gradient filters, principal component analyses. (C. Ayday& E. Gumuluoglu, 2008)Applied gradient filtering and principal component analyses on band 7 of Landsat. First applied gradient filters in eight directions then applied principal component analysis on each band created from the filtering. It was concluded that principal component analysis using eight different gradient filtered bands was more effective than four major gradient filtered bands and recommended though that the methodology be tried and tested to the other areas for verification. There are two general methods of extracting lineaments from satellite imagery; the first involves manual digitizing of visually identified lineaments after image processing and the second is automated lineament extraction where the satellite image is subjected to semi-automated processing by specifying different parameters such as curve length, linking distance, kernel size. To extract required output from remote sensing data, a visual inspection of all the bands were carried out and selected the short-wave infrared band 5 to use in current analysis. This band was stretched to an output of 0 to255 and then an edge sharpening filter applied to it. The edge sharpened image was then used as an input for the lineament extraction, which applied edge detection, thresholding. Further noted that the algorithm of the semi-automated lineament extraction method does not work successfully in the identification of all the lineaments present in the area; it thus requires some verifications and also needs tobe applied with different remote sensing techniques such as radar images, different resolutions, and different geological environments. The current work did conclude however, that it is still a useful technique though expert knowledge is always required to evaluate the extracted lineaments.

Climate

The state of Kuwait is located in an arid region, where there is a wide range of variations in the temperature. Two climatic seasons are recognized: a long, hot, dusty summer extends from May to October; and a relatively short, pleasant winter that starts in November and ends in February. Marchand April are transitional between summer and winter. The prevailing wind directions affecting Kuwait are the northwesterly, locally known as ‘Shamal’, which is dry and cool in winter and hot in summer, and the southeasterly, locally known as ‘Kaus’, which is hot air in summer and humid in winter. Winds from other directions are less frequent and of shorter duration.

Physiography

The land surface of Kuwait is generally flat but occasionally interrupted by low hills, scarps, valleys of ephemeral streams and shallow, wide inland depressions. The altitude rises from sea level to about 300m in the southwestern part of Kuwait. The surface of Kuwait is covered by Quaternary sediments that include Pleistocene gravel and sand and Holocene sediments including marine. Physiographic divisions of Kuwait are shown in Figure1 (Khalaf et. al, 1984b). Al-Dibdibbagravel province occupies most of the northern sector of Kuwait and represents the southern extension of Al-Dibdibba gravel region of the southwestern desert of Iraq. This province is characterized by system alternative gravel capping ridges and long wide shallow valleys. The sand-flat province occupies the southern half of the country. It is very flat, featureless, except for some shallow depressions and small conical hills at Wara and Burgan with an average height of about 40m.Coastal hills are represented by JalAz-Zor hills in the north and Al-Ahmadi ridges and the small coastal ridges in the south. JalAz-Zor hills extend along the northern coast of Kuwait Bay, its local relief reaching about 120m at Al-Mutla. The Al-Ahmadi ridge parallels the southern coastline and rises to heights of about 110m above sea level.

The coast of Kuwait is of submerged lowland type, characterized by a flat coastal area, which varies in width and shape. These geomorphological variations are reflected on the variability of the coastal sedimentary environment. Khalaf et al. (1984) and Gunatilaka (1986) divided the coastal area of Kuwait into two main physiographic units, the northern coastal area and the southern coastal area. The northern coastal area extends from RasAjuza to the northern coastal border of the State. Thisincludes Kuwait Bay, Khor Al-Subbiyah and the coasts of Warba and Bubiyan Islands. The southern coastal area extends from RasAjuza to the southern coastal border of the State.

Study Area – Northern Kuwait

Kuwait is located in the Northern Arabian Peninsula and shares borders with Iraq on the north and Saudi Arabia on the south. On the east it has the Arabian Gulf which forms Kuwait's coastline. In addition, two major islands in the Arabian Gulf constitute as part of Kuwait and are known as Bubyan and Failaka. It hasa land area of approximately 26,000 sq. km, These structural elements are identified using seismic lines, seismic structure maps, stratigraphic data logs from oil wells, remote sensing/ imaging data (includinggravity, Landsat and borehole imagery data) as well as rocks from cores and outcrops (Carmen 1996).The fault related tectonic elements are seen shaping straight coastlines and headlands aligned with lineaments while the arches and anticlines coincide with the oil fields formed by structural entrapment (Figure6). Particularly noteworthy are north-south trending oilfields namely Burgan, Minagish and Sabriya
on Kuwait Arch, and the northwest-southeast trending oil fields namely Wafra and Umm Gudair. Another prominent trend is the northeast-southwest subsurface structural lineation's coinciding with JalAz-Zor, JalAl-Liyah, and the 3 headlands (Dasman, Al Salmiya and Mina Said) further down on the east coast. The shoreline length of the State of Kuwait is about 500 km. Kuwait lies on the northern tip of the Arabian Gulf, bordered by Kingdom of Saudi Arabia to the south and south-west; and the Iraqi Republic to the north and north west; it is between longitudes 46º 33' 10" E & 48º 33' 29" E and latitudes 28º 31' 29" N & 30º 6' 11" N. (Figure 2).

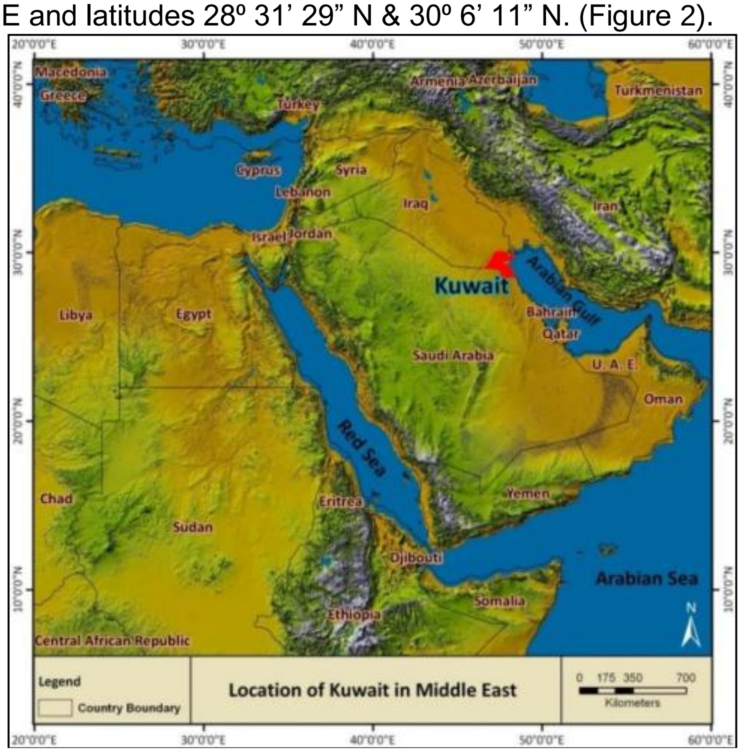

Figure 1: Location of Kuwait in Arabian Peninsula, Middle East Region

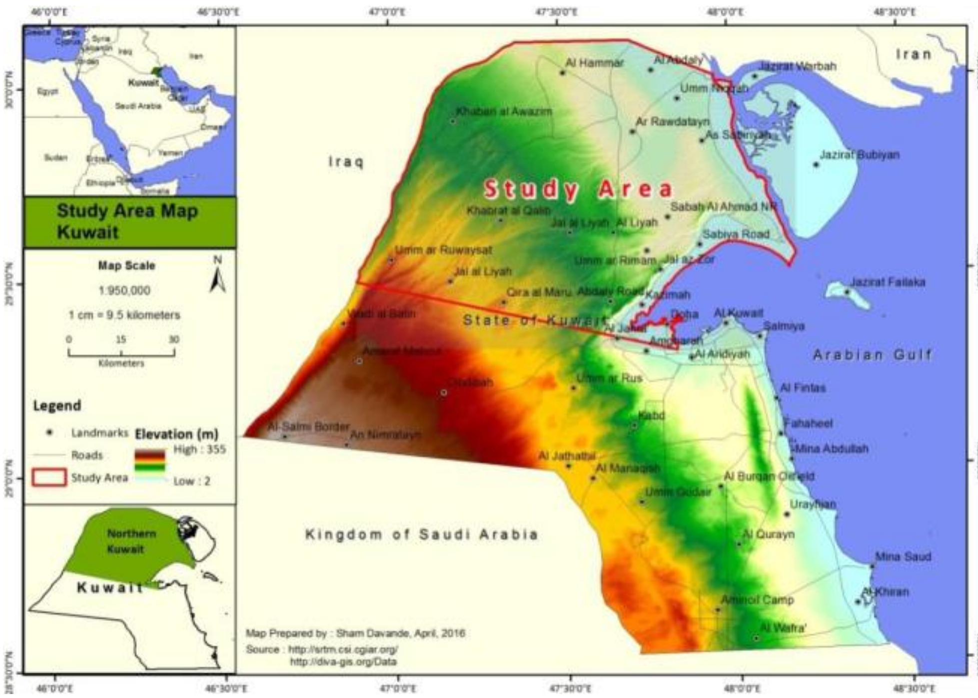

Figure 2: Location of Study Area in Kuwait.

Objectives

This study aims to evaluate the remote sensing data and its analysis to extract geological features called Lineaments using digital extraction techniques available. Mainly to prepare the lineament and fracture map of Kuwait surface outcrops using remote sensing techniques. The output needed field work and ground checks were undertaken on selected outcrops/ coastal exposures of Kuwait. The specific objectives of the project however will include:

1. To digitally extract lineament from available satellite images of the Northern part of Kuwait area.
2. To use edge enhancement techniques to identify, map lineaments and verify with existing geological lineament maps already published for Kuwait area.

Material and Methods

Input Data

Satellite Data Landsat 8 Enhanced Thematic Mapper (ETM) data acquired on **January, 2016**. Data was used for analyzing an area covering northern part of Kuwait, especially Northern Kuwait and nearby areas. A sub-scene covering approximately 36,822 square km was extracted as area of interest. Study area demarcated using Kuwait country coast was digitized along the visual extent appeared in satellite data and then the image clipped using this boundary which cover an area of 7077 square km as a **Study Area**. Landsat 8 data products are consistent with the all standard Level-1 (ortho-rectified) data products created using Landsat 1 to Landsat 7 data to the following specifications:

Processing	:Level 1 T- Terrain Corrected
Pixel Size	:OLI multispectral bands 1-7,9: 30-meters& PAN-15meters
Data Characteristics	:•GeoTIFF data format, •Cubic Convolution (CC) resampling
	: •Universal Transverse Mercator (UTM) map projection
	: • World Geodetic System (WGS) 84 datum, • 16-bit pixel values
Data Delivery	:.tar.gz compressed file via HTTP Download
File size	: Approximately 1 GB (compressed), approximately 2 GB

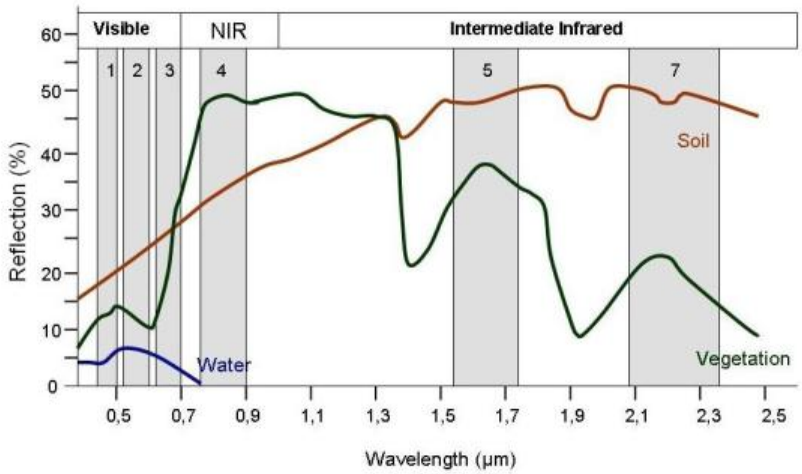

Figure 3: Spectral signatures of soil, vegetation and water, and spectral bands of LANDSAT 8.

Table 1: Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) Band details.

Band	Wavelength	Useful for mapping
Band 1 – coastal aerosol	0.43-0.45	coastal and aerosol studies
Band 2 – blue	0.45-0.51	Bathymetric mapping, distinguishing soil from vegetation and deciduous from coniferous vegetation
Band 3 – green	0.53-0.59	Emphasizes peak vegetation, which is useful for assessing plant vigor
Band 4 – red	0.64-0.67	Discriminates vegetation slopes
Band 5 - Near Infrared	085.-0.88	Emphasizes biomass content and shorelines
Band 6 - Short-wave Infrared (SWIR) 1	1.57-1.65	Discriminates moisture content of soil and vegetation; penetrates thin clouds
Band 7 - Short-wave Infrared (SWIR) 2	2.11-2.29	Improved moisture content of soil and vegetation and thin cloud penetration
Band 8 - Panchromatic	0.50-0.68	15 meter resolution, sharper image definition
Band 9 – Cirrus	1.36 -1.38	Improved detection of cirrus cloud contamination
Band 10 – TIRS 1	10.60 – 11.19	100m. res. Thermal mapping and estimated soil moisture
Band 11 – TIRS 2	11.5-12.51	100m.res.Improved thermal mapping and estimated soil moisture

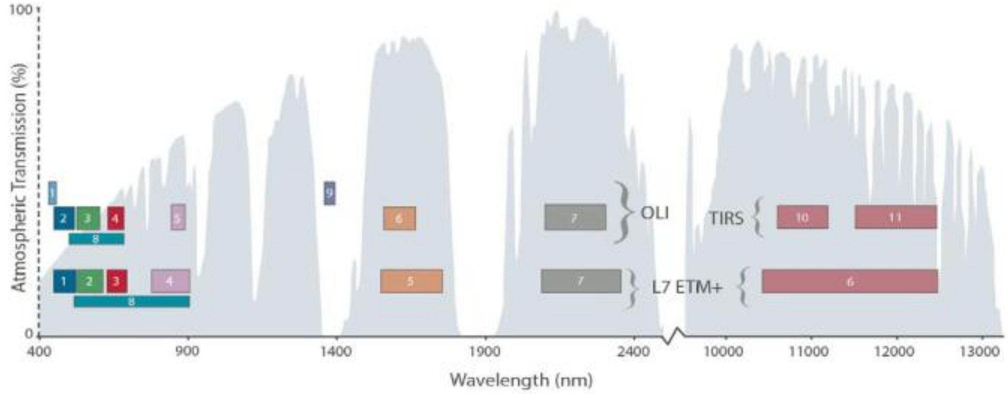

Figure 4: Comparison between LANDSAT7 ETM+ vs LANDSAT8 OLI Spectral signatures

Structural elements of Kuwait

The Structural elements of Kuwait (Figure 6) are seen on seismic lines, seismic structure maps, in oil field wells (stratigraphic data and logs), remote sensing/imaging data (including gravity, Landsat and borehole imagery) and in rocks (cores and outcrops). These elements range from structural arches, regional highs and lows, to megascale (anticlines and synclines, troughs, regional gradients), mesoscale(e.g. faults) and microscales (sedimentary structures, fractures and styloites). The following discussion presents some examples of structural elements to demonstrate the variety present in Kuwait with an emphasis on megascale tomesoscale features. Following map has been digitized and used as reference of lineaments in Kuwait

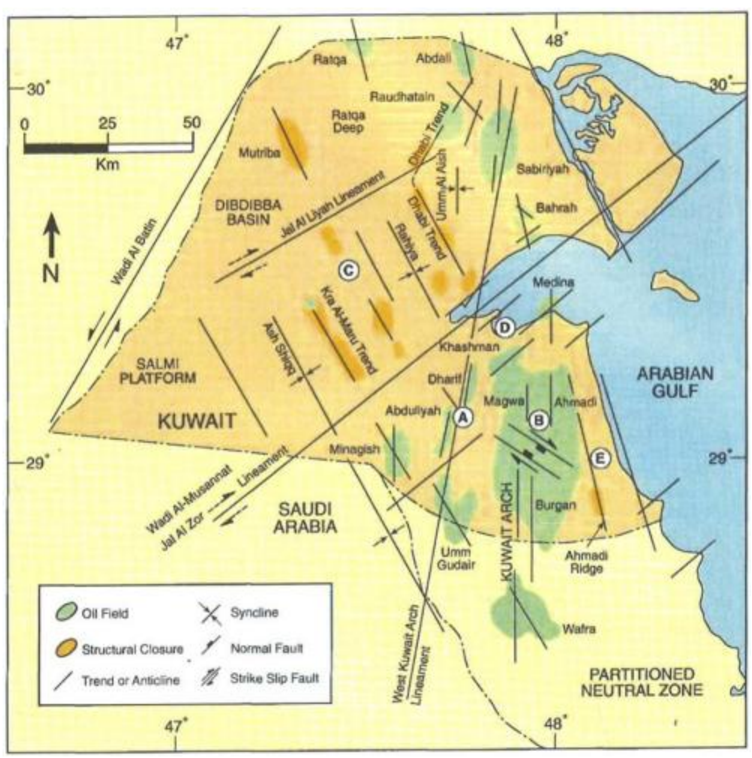

Figure 5: Structural elements of onshore Kuwait based on subsurface structures (Carmen, 1996)

Methods

Image Processing

Image processing is applied to compensate data errors and geometric distortions, to enhance and extract features related to thematic subjects being under investigation and to suppress redundant information. In this study, standard tools of image processing have been used for digital processing of the satellite data. Digital image processing was used to

- register the originally orbit oriented raster data over the UTM coordinates system
- Enhance and to extract features that indicate targets of interest in the data.

In this study, the digital image processing processes were conducted in the following steps:

Image Enhancement

Image enhancement is the modification of an image in order to alter its impact on the viewer (Sabins, 1987). Generally, image enhancement changes the original digital value and it should be carried out after geo-referencing. The purpose of image enhancement is to make the images more interpretable for specific applications. The general aim of image enhancement is to highlight features of thematic interest (lineament, rock and soil properties, etc.) and to suppress redundant information. Major tools applied for the enhancement of the satellite data were histogram analysis and contrast stretching, edge enhancement, Band Ratioing, RGB-Coding such as false color composite. Dataprocessing and image products, a number of processing techniques (Jensen, 1986 and Mather, 1987), the contrast of 11 bands data of the Landsat ETM+ imagery was digitally enhanced. The images of all bands were compared in term of contrast and geomorphological appearance of different types of surface geological features in the study area. The data has been processed / prepared as appropriate thematic maps for their direct / indirect introduction to the knowledge base lineament identification expert system. The derived thematic data is supporting to the mapping / extraction / identification of lineaments and lineament types.

Extraction of Lineaments

As discussed, there are two common methods for the extraction of lineaments from satellite images:

Visual extraction:

At which the user first starts with some image processing techniques to make edge enhancements, using the directional and non-directional filters such as the **Laplacian**, and **Sobel,** then the lineaments are digitized manually by the user.

Automatic extraction:

Various computer-aided methods for lineament extraction have been proposed. Most methods are based on edge filtering techniques. The most widely used software for the automatic lineament extraction is ERDAS, ENVI and PCI Geomatica. In this study, IdrisiSelva (demo version) software has been used for digital analysis and automatic extraction process. The algorithm consists of three stages:

Edge Detection

In the first stage, the Canny edge detection algorithm is applied to produce an edge strength image. The Canny edge detection algorithm has three sub steps. First, the input image is filtered with a Gaussian function whose radius is provided by the RADI (Filter Radius) parameter. Then, the gradient is computed from the filtered image. Finally, pixels whose gradient are not the local maximum are suppressed by setting the edge strength to 0.

Thresholding

In the second stage, the edge strength image is thresholded to obtain a binary image. Each ON pixel of the binary image represents an edge element. The threshold value is defined by the GTHR (Edge Gradient Threshold) parameter.

Curve Extraction

In the third stage, curves are extracted from the binary edge image. This step consists of several sub steps. First, a thinning algorithm is applied to the binary edge image to produce pixel-wide skeleton curves. Then, a sequence of pixels for each curve is extracted from the image. Any curve with a number of pixels less than the value of the LTHR (Curve Length Threshold) parameter is discarded from further processing. An extracted pixel curve is converted to vector form by fitting line segments to it. The resulting polyline is an approximation of the original pixel curve, where the maximum fitting error (distance between the two) is specified by the FTHR (Line Fitting Threshold) parameter. The final polylines are saved in a vector segment for further quality check with existing maps of lineaments available for Northern Kuwait regions.

Sobel Edge Detector

This study utilized Sobel operator which made up pair of 3×3 convolution kernels asshown in Figure 7. These kernels are designed to respond maximally to edges running vertically and horizontally relative to the pixel grid, one kernel for each of the two perpendicular orientations. The kernels can be applied separately to the input LANDSAT 8 ETM data, toproduce gradient components in raw and lines of image (call these Gx and Gy). These can then be combined together to find the absolute magnitude of the gradient at each point and the orientation of that gradient. Following Gonzalez and Woods (1992) the gradient magnitude is given by:

-1	0	+1
-2	0	+2
-1	0	+1

Horizontal

+1	+2	+1
0	0	0
-1	-2	-1

Vertical

Figure 6: Sobel kernel operator

LaplacianEdge Detector

According to Gonzalez and Woods (1992), the Laplacian is a 2-D isotropic measure of the2nd spatial derivative of an image. The Laplacian of an image highlights regions of rapid intensity change and is therefore often used for edge detection. The Laplacian is of ten applied to an image that has first been smoothed with something approximating a Gaussian Smoothing filter in order to reduce its sensitivity to noise. The operator normally takes a single gray level image as input and produces another gray-level image as output. Following Davies (1990), Gonzalez and Woods (1992), since the input LANDSAT 8 ETM image is represented as a set of discrete pixels, we have to find a discrete convolution kernel that can approximate the second derivatives in the definition of the Laplacian. Three commonly used small kernels are shown in Figure 8;

0	-1	0
-1	4	-1
0	-1	0

The Laplacian Operator

-1	-1	-1
-1	8	-1
-1	-1	-1

The Laplacian Operator
(include diagonals)

Figure 7: Three commonly Used Discrete Approximations to the Laplacian Algorithm

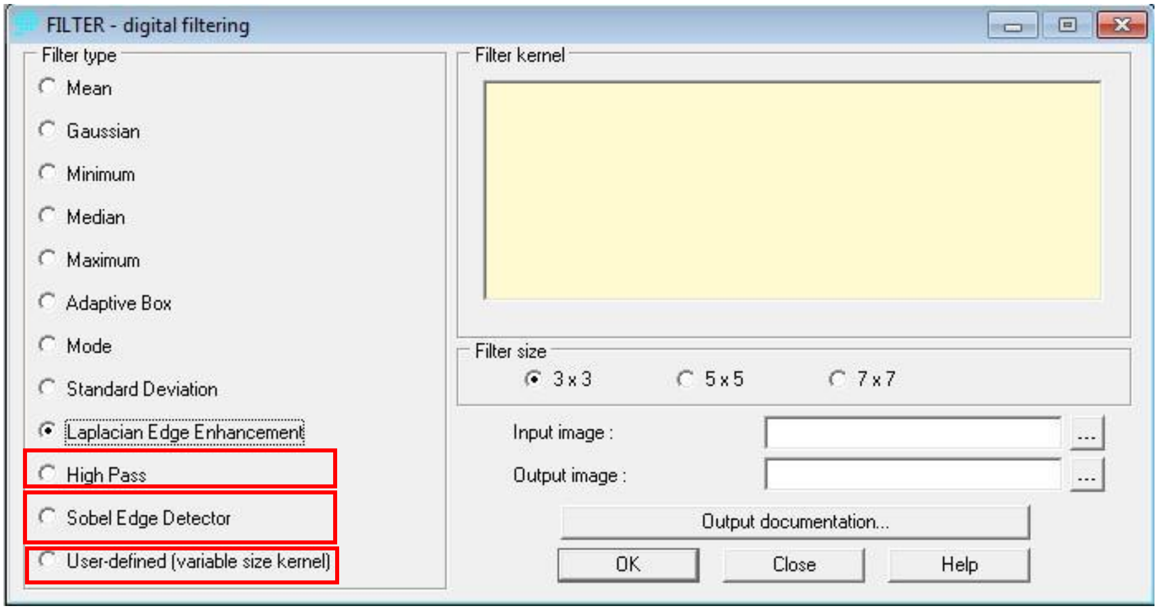

Figure 8: Image filtering algorithms used in Edge Enhancement from satellite image bands

Image Interpretations

A digital classification using LANDSAT 8 ETM+ data covering the visible, infrared and microwave regions of the spectrum was carried out to detect the major geological lineaments in the areas of Northern part of Kuwait. In order to have more than one source for the identification of lineaments, other datasets such as geological maps and DEM are used as reference datasets for the final lineament mapping. The term “lineament” is defined by O'Leary (1976) as "a mappable, simple or composite linear feature of a surface, and which differs distinctly from the patterns of adjacent features and presumably reflects a subsurface phenomenon". Other definitions of lineaments exist in the literature, such as “a linear topographic feature of regional extent that is believed to reflect crustal structure” (Hobbs, 1976) or “long, often subtle linear arrangements of various topographic, tonal and geological features”(Drury, 1987). Tectonic features can be indicated by anomalies in vegetation without any influence of topographic factors (Gustafsson, 1993). In thisstudy the definition of Lineaments is considered as the most appropriate, identifying the lineament as “a natural linear feature consisting of topographic (including straight stream segments), vegetation or soil tonal alignments that can be visible on aerial photos and expressed continuously or discontinuously over a certain distance”. Many lineaments are fracture zones where brittle deformation in the uppermost crust has taken place (Gustafsson, 1993). The surface expressions of lineaments can be either geomorphic features (due to relief) or tonal features (due to contrast difference) (Cortes et al., 1998). Lineaments are revealed in satellite images as linear topographic features caused by faults, fracture patterns, lithological boundaries or breaks within a uniform tserrain (O’Leary et al., 1976; Ollier, 1981; Panizza et al.,1987; Remo, 1999). Linear features between areas of contrasting tone or differences in moisture, vegetation, soil and rock characteristics consist mostly of tonal contrasts, indicating their possible structural origin.

The discrimination of lithologies and identification of lineaments in a satellite image data can be significant when the satellite image processing procedure use sthe selection of appropriate bands and RGB combinations. So it is necessary to examine which aspects are representative to lithological mapping by using satellite image data. Previous studies have predominantly been interested in the use of satellite imagery for mapping lithologies in low-relief arid regions, where easier discrimination is accomplished due to the lack of vegetation cover (e.g. Rowan,2003; Al Rawashdeh, 2006; Pena, 2006; Qari, 2008). This study focuses on arid region, such as Northern part of Kuwait, where vegetation cover will be totally absent. That characteristic aspect should be considered by aiming to vegetation suppression. Hence, the evaluation of image enhancement is expected to derive RGB combinations, to discriminate lithologies in aridregions. Some criteria for selecting the best bands and the RGB combinations(with regard to lithological and lineament information) have to be determined. The criteria for focusing on the bands or RGB combinations that highlight lithological information are summarized below:
The lithology can be discriminated by the use of Landsat ETM+ bands 4, 5 and 7. These bands highlight and emphasize the rock types, as well as linear features. Studies by Kenea (1997), Suzen (1998),Won-In &Charusiri (2003) and Pena (2006) utilized these bands in RGB combinations or band ratios for lithological mapping or lineament extraction.

Principal component Analysis (PCA)

Other studies in the past referred to lineament extraction, based on thecolour differences at the boundaries of contrasting lithological units by using components of PCA in RGB combinations (e.g. Novak &Soulakelis, 2000; Semere, S., and W., Ghebreab 2006). In this research these assumptions are evaluated asan alternative approach to discriminating lithologies. The components of the PCA products can be particularly useful in this research for enhancing and identifying the features that cannot be discriminated with typical RGB band combinations. Such approach can be useful, as mentioned above, when lithological discrimination is examined on a site-by-site basis, as outcrop lithologies can often be very variable. PCA output details containing eigen vector values vs satellite image bands in the form of matrix as shown below in Table 2.

Table 2: The eigenvectors of the principal component analysis (PCA) of satellite imagery bands

EigenMatrix	PC1	PC2	PC3	PC4	PC5	PC6
band_1	0.98869	-0.14492	-0.01173	-0.03205	-0.01151	-0.01406
band_2	0.99284	-0.11457	-0.01607	-0.01526	0.01668	0.01946
band_3	0.99788	-0.01211	0.03413	0.04210	-0.03351	0.00537
band_4	0.99809	-0.00549	0.03267	0.04117	0.03065	-0.00902
band_5	0.98013	0.12157	-0.15669	-0.00202	-0.00151	-0.00097
band_7	0.98396	0.14323	0.10064	-0.03435	0.00013	0.00084

Results

Image Processing

The satellite imagery used was subject to initial pre-processing stages before the application of further processing and analysis. One of the first steps was the creation of study area image from full mosaicked satellite data scenes and to isolate the Arabian Sea part from the land (Figure 10& 11). In addition, the satellite images acquired for this research were pre-georeferenced and transformed to the UTM 38N reference system. The stretching of the DNs to the full range of 256 (intensity levels of grey),reveals the difference between the two images; it can be observed that the stretched image has considerably more detailed information with contrast. This step was to ensure that the layer stack included sufficient information (via the band’shistogram) in order to produce a multispectral image.

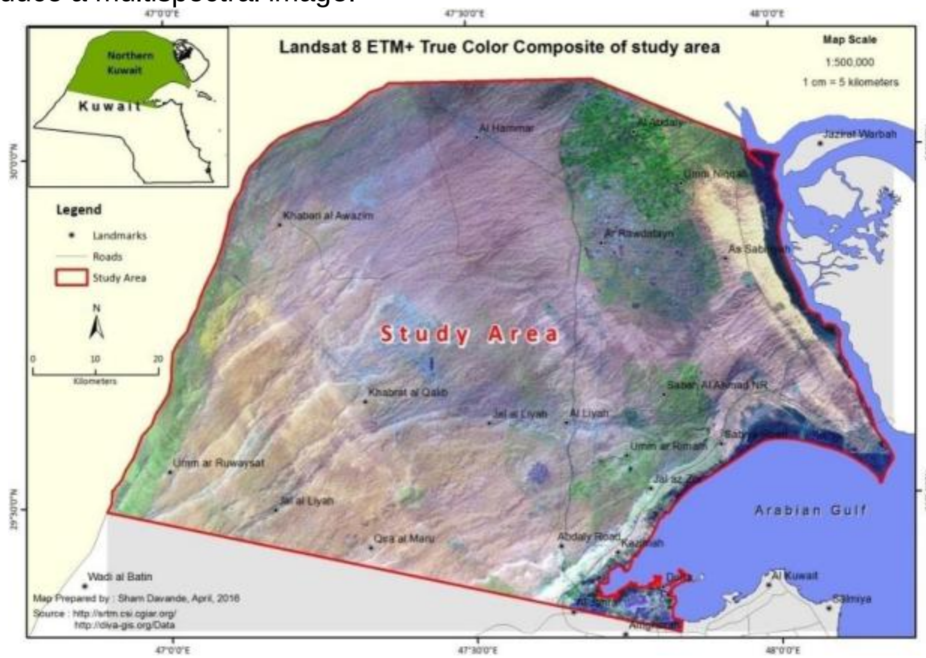

Figure 1: Landsat 8 ETM+ Satellite image band 157 composite of Study area

Image enhancement

The image enhancement of the satellite imagery was essential in order to produce better-quality images for visual interpretation. However, the image enhancement procedure improves and highlights better the visual interpretation of any characteristic features. Such enhanced images can be then used to extract information regarding the lithology, tectonics and geomorphology of the study area. The results of the image enhancement methods described in the methodology are presented below and output as shown in figure 12.

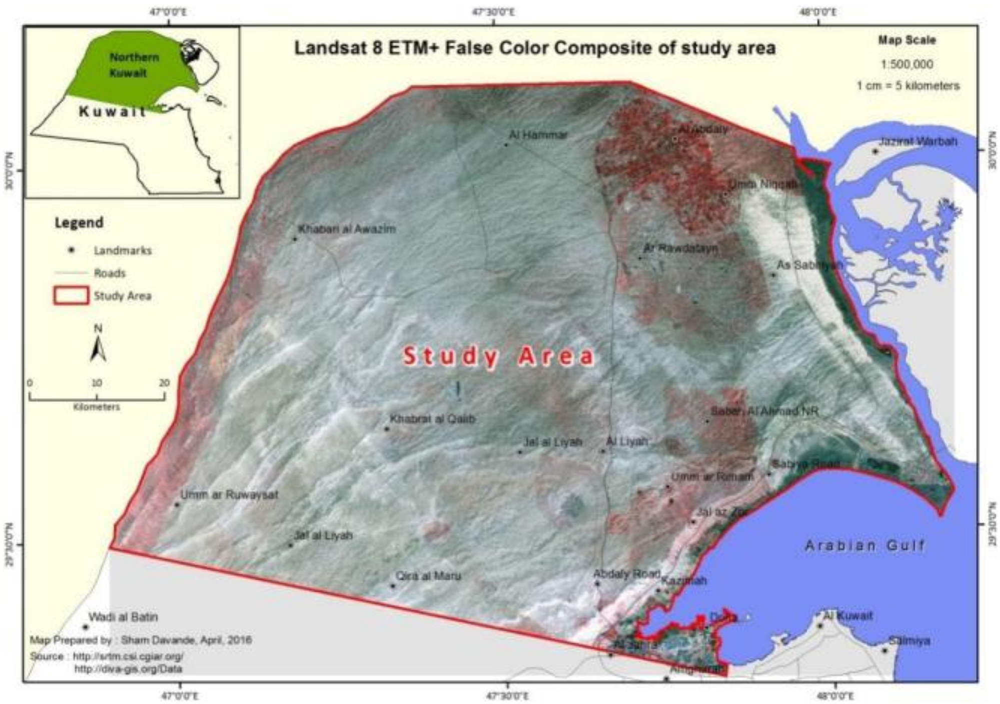

Figure 10: Landsat 8 ETM+ Satellite image band 345 composite of Study area

Principal Component Analysis

With regard to the principal component analysis (PCA) application for the Landsat 8 ETM+ satellite multispectral imagery, the following were calculated:

1. Covariance matrix
2. The factors of linear transformation (eigenvectors and eigenvalues, Table 2 and 3)

The covariance matrix is symmetrical. The values of the main diagonal express the dissemination per spectrum channel while their sum expresses the total dissemination that exists in the initial data (Table 2). In current study, the total calculated dissemination is 37951.491. The values of the correlation matrix (Table 2) imply a qualitative and quantitative correlation between the spectrum channels of visible (VIS) (bands 2, 4) and Short-wave IR(SWIR) (band 7) where values close to 1 are observed. The highest correlation(0.998) is observed in visible (VIS) bands 4 and 3, while the near-infrared (NIR)band 4 is differentiated from VIS bands, as well as from SWIR bands, with correlation values close to 0. The least correlated bands can highlight their differences and discriminate the lithology. This suggests that the degree of correspondence between the principal components and the initial bands are very useful.

The level of dissemination for each new component is determined from the eigenvalues (Table 3). For instance, the first principal component (PC1) has a dissemination value of 37216.256 while the total dissemination was (SUM) = 37951.491. It becomes clear that the higher percentage of the variance information is included mainly in the first two principal components (PC1 andPC2) (~99%).PCA output components as shown in figure 12 & 13 below.

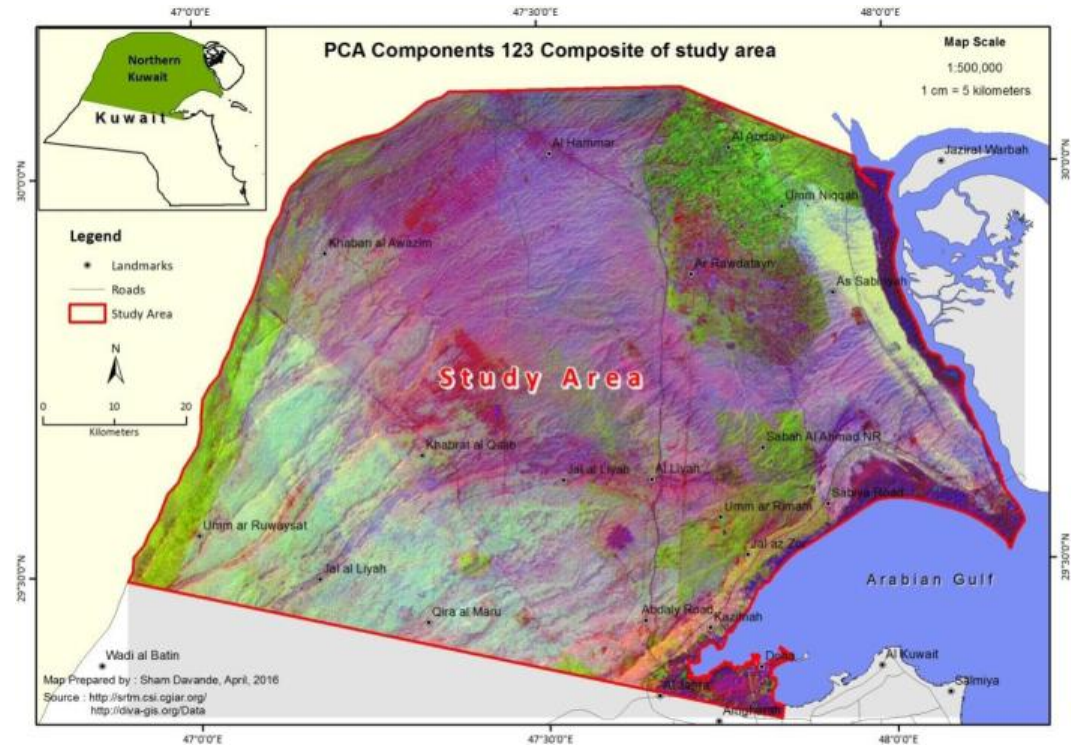

Figure 2: PCA components 123 composite of Study area

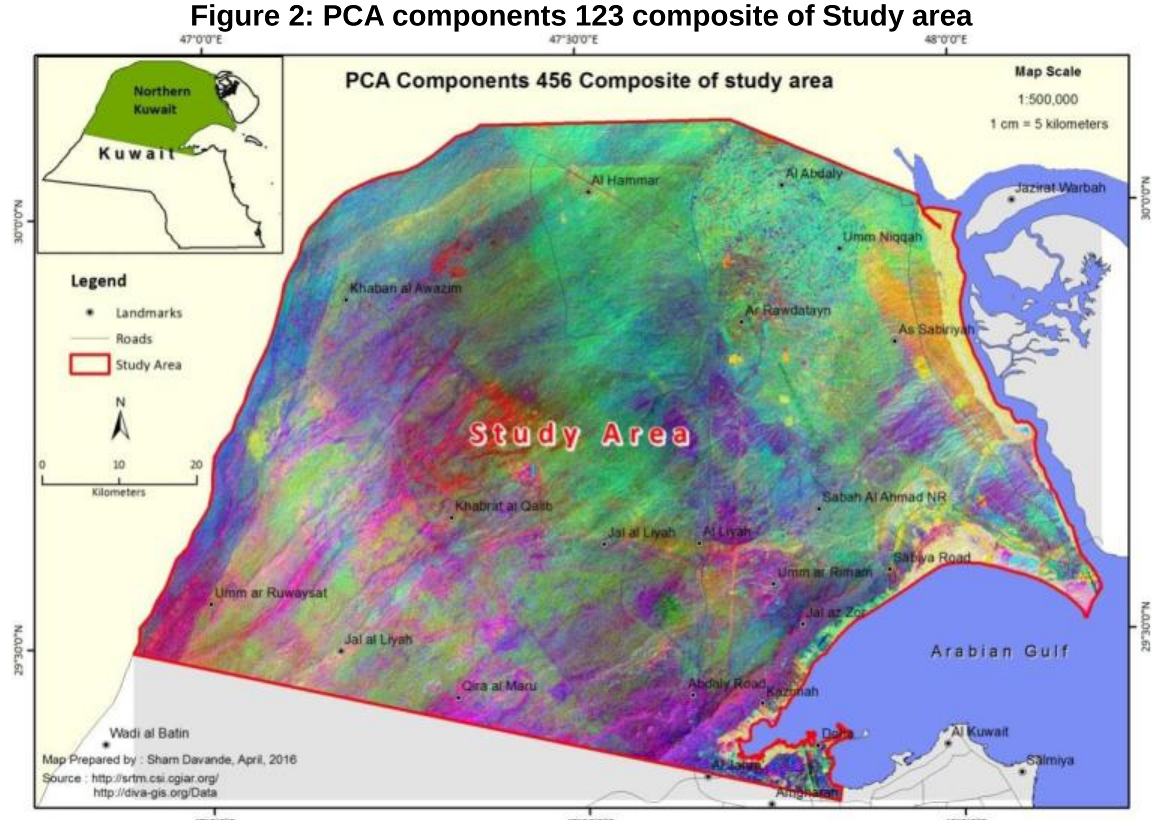

Figure 12: PCA components 456 composite of Study area

Extraction of Lineaments

The final lineaments were extracted from PCA band outputs by reclassifying the bands to 0 and 1 pixel values by thresholding. This reclassified output used in digitizing the alignment of lineaments as observed as a final lineament GIS layer. In ArcGIS 10.2 demo version, “Polar Plots and Circular Statistics” a free GIS extension tool was downloaded and installed in ArcGIS software (Jenness, J. 2014). Rose diagrams of lineaments were then created in this tool for comparison with the existing lineament map GIS layer prepared as one of reference layer for comparison (figure 15 & 16). The rose diagrams shows most of the lineaments present in Northern part of Kuwait are following direction of SW to SE lineaments, which imply the current tectonic regime (see figure14). In addition, these particular lineaments/faults seem to correspond to stream segments of second and third order, implying to the structural control of these stream segments by the current tectonic regime (figure 14).

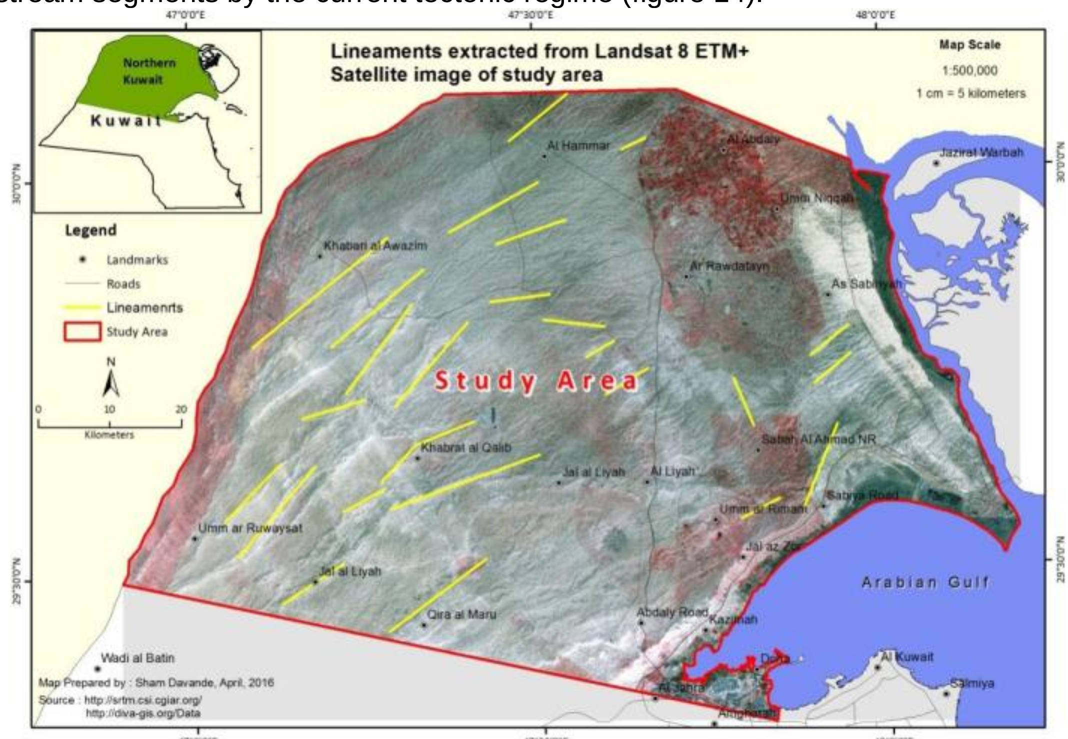

Figure 13: Lineaments extracted from Landsat 8 ETM + bands of Study area

Discussion

The stages that were applied in this research in order to discriminate the lithologies and to identify the lineaments of the studied area by using LANDSAT 8 ETM+ satellite datasets. The Structural Elements map published by KOC in year 1996is the only available dataset that provides information about the lithologies and faults of the study area. The Structural Elements map was based on fieldwork and the interpretation of aerial photos, so new technologies such as the multi-spectral satellite Earth observational data are potentially very useful for additional mapping. The Landsat 8 ETM+ image processing provided asemi-automated approach to lithological discrimination, with the outcome images being in addition used for the visual interpretation of lineaments. Band ratios from multispectral satellite images are commonly used for lithological mapping (e.g. Crippen, 1989; Ramadan et al., 2001;Teeuw et al., 2005). A feature of band ratios is the suppression of shadow in shaded relief, which can assist lithological discrimination. On the other hand, such procedures result in a poorer depiction of lineaments. Enhancement of tonal contrast differences, helping to highlight lineaments and to depict lithologies is provided. The procedure is based on criteria that offer isolation of spectral information, using PCA operations. Spectral information within each PCA's principal component decreases substantially for the components after PC1, with the later components being harder to visually interpret and containing progressively more speckle (e.g. Green et al., 1988). A major benefit of both PCA is that some of their components keep most of the spectral information, while suppressing the signal from vegetation cover. As a consequence, components of PCA and RGB combination image, such as PC1-PC2-PC3, can highlight lithological differences, on a site-by-site basis, more clearly than simple RGB combinations.

Conclusions

In order to achieve that target the study combines both Geographical Information Systems (GIS) and Remote Sensing (RS) digital satellite data (DEMs and multispectral satellite imagery), with factors such as fracture patterns and drainage basin morphological variations. The geology and the lineaments are of high scientific interest. Landsat 8 ETM+ imagery has higher spatial resolution (30 m) was providing us a powerful for lineament study and analysis especially in the arid area. The image enhancement was one of the useful tools to improve the interpretability or perception of information in images for human viewers, or to provide better input for automated image processing techniques, one of those edge enhancements is an edge sharpening enhancement technique for enhancing the edges in an image.

Lineaments corresponding to faults shown on the Carmen, 1996structural lineament map were mapped by analysis of satellite imagery and DEMs. A relatively large number of lineaments (~73% of total lineaments identified by satellite imagery analysis) indicated previously unrecorded faults. The classification of lineament/fault azimuths was particularly useful for evaluating the current tectonic status of the study region.

In current study, the different treatments applied to the Landsat 8 ETM+ images which we quote: geometric correction, spatial and radiometric enhancement, color composition, classification, PCA, Sobel, Laplacianand gradient filters and creating the new channels. These treatments provide information on the geological formations lithology and more detailed additional tectonics data. Indeed, we were able to map at the regional level the major lineaments network in order to give an idea about the distribution of different structural lineaments families in the study area. It is then distinguished single important group of the lineaments orientation: SW-SE, with the predominance of the first direction. This result agrees well with the comparison of structural elements maps by Carmen, 1996. The methodology developed in this study represents a low-cost alternative to satellite radarinterferometric analysis (InSAR) and differential GPS monitoring. Moreover, it is applicable in unapproachable areas of Kuwait desert regions where these expensive techniques have limited applicability.

It can be said that composite Landsat 8 ETM+ band 4, band 5and band 7 can be used to map the spatial lineament variations. It has been demonstrated that Sobel Edge Detector algorithm is appropriate algorithm for semi-automatic lineaments mapping. Integration between Sobel Edge Detector algorithm, DEM and its topographic derivatives like hill shade could be used as an excellent tool to understand variation of lineament density.

Recommendations

Main purpose of this work is to evaluate and to identify potential limitations (that may arise) and to propose some areas for future work (that can be considered). Although such considerations do not have a significant impact on the outcomes of current study, the improvement of its methodological framework can extend its applicability. This study relied solely on Band 7 of Landsat 8 EMT+ for the semi-automatic extraction of the lineaments.

The recommendation for Edge Enhancement studies can be listed as follows.

- Accuracy assessment in this study is based on the published map data which have different purposes and mapping scales. These differences, however, had aundesirable effect on the accuracy of the resultant map. For this reason field studies (ground truth studies) are suggested to be the best way to test the accuracy of the extracted lineaments.

- There is no standard on selection of the optimum band for manual lineament extraction. Therefore, it is recommended that the geologic, topographic properties and vegetation cover along drainages of the selected area should be taken in the consideration.
- Manual Lineament extraction is a user dependent process. The study made by the expert increases the reliability of the resultant map.

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