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Utilization of GIS Model Mapping to Detect Fault Segments in Mesopotamian Foredeep Basin

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Abstract:
The Mesopotamia Basin is widely recognized as a significant aggradation geomorphological entity, characterized by the dominance of fluvial, lacustrine, and aeolian landforms. The geographical scope of this study spans a specific region within the Mesopotamian Basin, specifically including Nasiriyah and Basrah located in the southern region of Iraq. It comprises a collection of Joint and fault systems that serve as indicators of various tectonic occurrences that have influenced the Arabian plate from the pre-Cambrian era up till the present day. The major goal of this model is to mapping and detects fault segments to get information about the large faults existing which is not recognized by prior work. A Geographic Information System (GIS) model was employed to create three digital layers, namely Lineament, drainage patterns, and lithological contact. These layers were established using several sources of information. The initial step of the GIS demonstration includes the input information, and the subsequent includes the selection of the equation for this model to specify the vulnerability of faulting segments in the research sector. Moderate to large lineaments (fault lines) were identified the results suggest an additional (26,15) new fault segment line numbers for the areas Nasiriyah and Basrah respectively which were not known by the fault map over the research sector, these fault lines reflect crustal structures (large length lineaments), as well as analysis lineaments from satellite images, enables obtaining a miscellany of terrain applications, such as the selection of landfill sites, determining terrain stability, dam sites, and many other applications

Keywords: *Drainage pattern, Fault lines, GIS Model, Lineament, and Lithological contact.*

INTRODUCTION

The study area under consideration encompasses a portion of the Mesopotamian Basin, specifically the regions of Nasiriyah and Basrah in southern Iraq. This area is characterized by a complex network of faults and joints within the larger Mesopotamia Basin. Historically, the term "Mesopotamia Basin" referred to the geographical expanse situated between the Euphrates and Tigris rivers. Basin holds great historical significance and is characterized by its flat topography, gently sloping from the northwest to the southeast towards the Arabian Gulf. The primary geological feature of the region consists of a diverse range of Quaternary deposits, with the northwestern section where occasional exposure of late Neogene sediments can be observed. It is worth mentioning that there is a significant presence of geomorphological features related to recent fluvial deposits in this particular area. These features include natural levees, river terraces, flood plains, and alluvial fans (Fouad, 2010).

Previous research has been undertaken on the study region by Al-Sakini (1993). The present study focused on the analysis of the courses of the Tigris and Euphrates Rivers, with the aim of assess the extent to which recent trajectories have been influenced by Neotectonic events. Furthermore, the researcher reached the concluded that the expansion of some subterranean anticlines resulted in the ongoing displacement of river channels, which often conform to the anticline rather than intersecting it.

Hassan and Galib (2004) A comprehensive geological survey was conducted on the Lissan area inside the Karbala-Najaf plateau. The findings of this study indicate that the area has been significantly influenced by the Abu-Jir fault zone. The topographic features in the area have been noted to be a result of the effects caused by the strike-slip motion. The Abu-Jir fault zone is a geological feature that is of significant interest and importance in the field of geology.

Abdul-Jabbar (2013) undertook a study to examine the tectonic characteristics of the Al-Thirthar, Al-Razzazah, and Al-Habbaniya depressions situated in the central region of Iraq. The findings of the investigation revealed the presence of three distinct classifications of lineaments. The initial group displayed a dominant alignment oriented in an E-W direction, perpendicular to the underlying extensional structures located under the three depressions. The orientation of the second group consistently exhibited a direction of N60°E-S60°, which was found to be perpendicular to the Prevailing orientation of the normal faults observed inside the extensional zone. The trend of the third group had a consistent N30°W orientation, which was observed to be parallel to the bulk of the normal faults detected within the extensional zone. According to Al-Saedi (2020), this study investigated the effects of fractures on the Euphrates River in the Mesopotamian basin. The presence of two unique types of fractures, specifically extension sets and shear fractures was confirmed in the location. Shear fractures may have developed under a stress regime exhibiting an approximate NW-SE (horizontal) alignment of the dominant primary stress axis. The presence of the vertical intermediate major stress axis suggests the existence of pre-existing fractures in the area. However, the two sets of fractures, which are oriented in an extensional direction and have almost horizontal beds in the stable shelf located to the west of the Euphrates River, are indicative of fractures that have occurred more recently. The utilization of GIS techniques in this work was motivated by their significant capacity for information presentation, map analysis, map drawing, and digital data display. These techniques are known for their extensive capabilities and flexibility, albeit requiring a substantial investment of time.

The major goal of this model is to mapping and detects fault segments to get information about the large faults existing which is not recognized by previous work. This is achieved by using many sources of data, including satellite imagery, various maps, and prior studies.

SITE DESCRIPTION

The Mesopotamia Basin is well recognized as a significant geomorphological unit characterized by extensive aggradation, primarily featuring fluvial, lacustrine, and Aeolian landforms. There are also estuarine and marine forms present in the study area, which is located in the southern region of Iraq, namely in the provinces of Nasiriyah and Basrah. The area exhibits gradual dips of strata with various geological formations, including Quaternary deposits, Dibdiba, Nfayl, and Dammam. Additionally, the study area encompasses irrigation projects. Figure (1) shows the location of the study area.

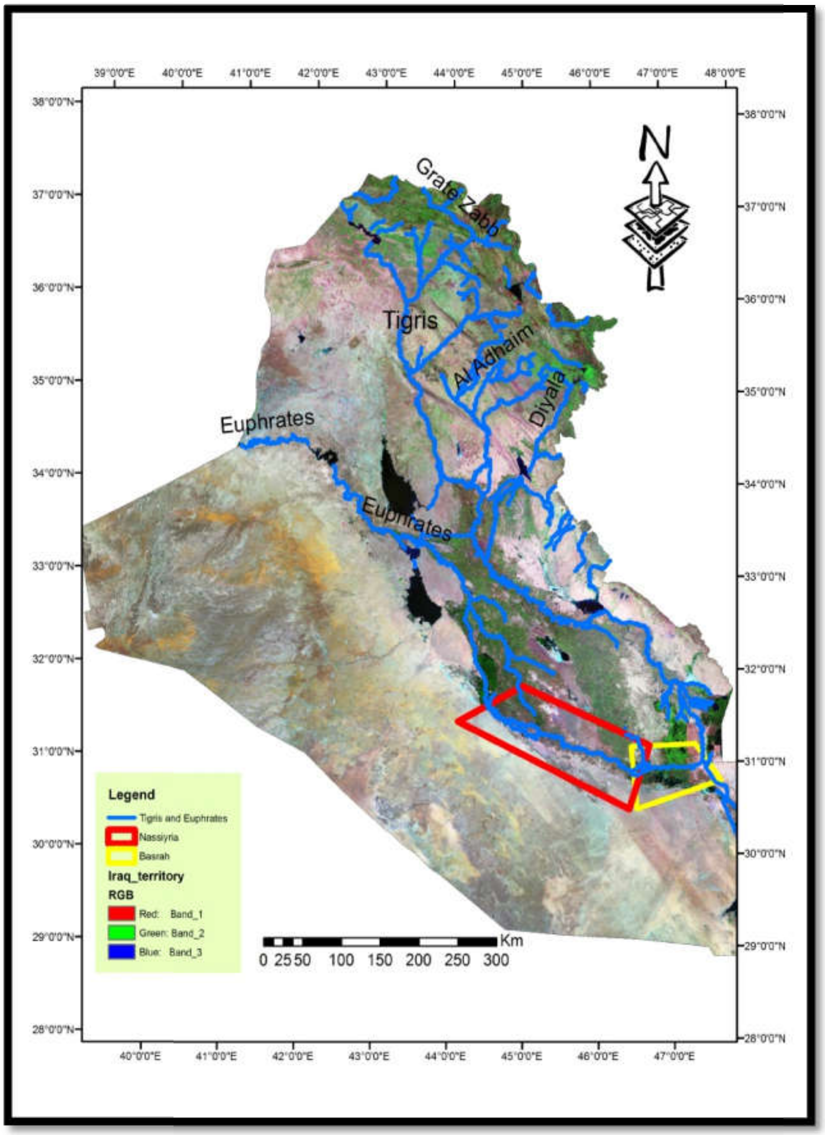

Figure 1: Location area of the study

MATERIALS AND METHODS

Methodology of the study

Present study as the flowchart. The present study is accompanied with a visual interpretation in the form of a flowchart present in Figure (2), which effectively demonstrates the approach that has been employed in conducting this research.

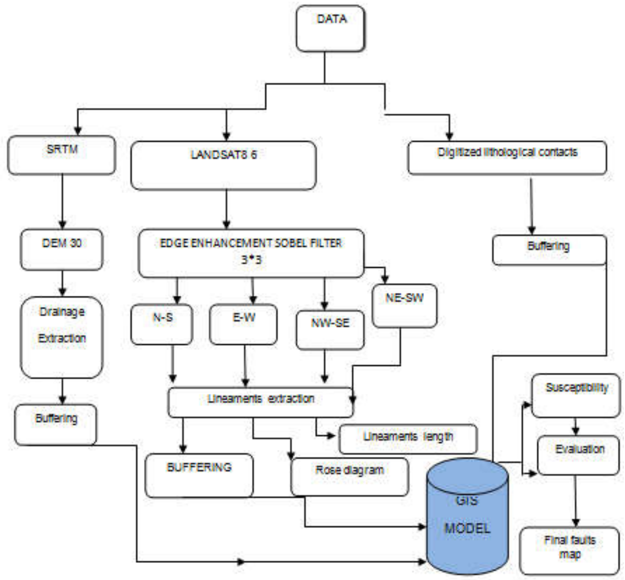

Figure 2: flow chart of the study

Lineament Extractions

The automatic lineament extraction is used, because of its advantage over visual extraction. Lineaments are separated from satellite images utilizing computerized extraction method, directional filtering of the image in N-S, NE-SW, E-WI, and NW-SE directions are preferred. Foursobel filters were due to increase the frequency and contrast in images as in figures (3) and (4).

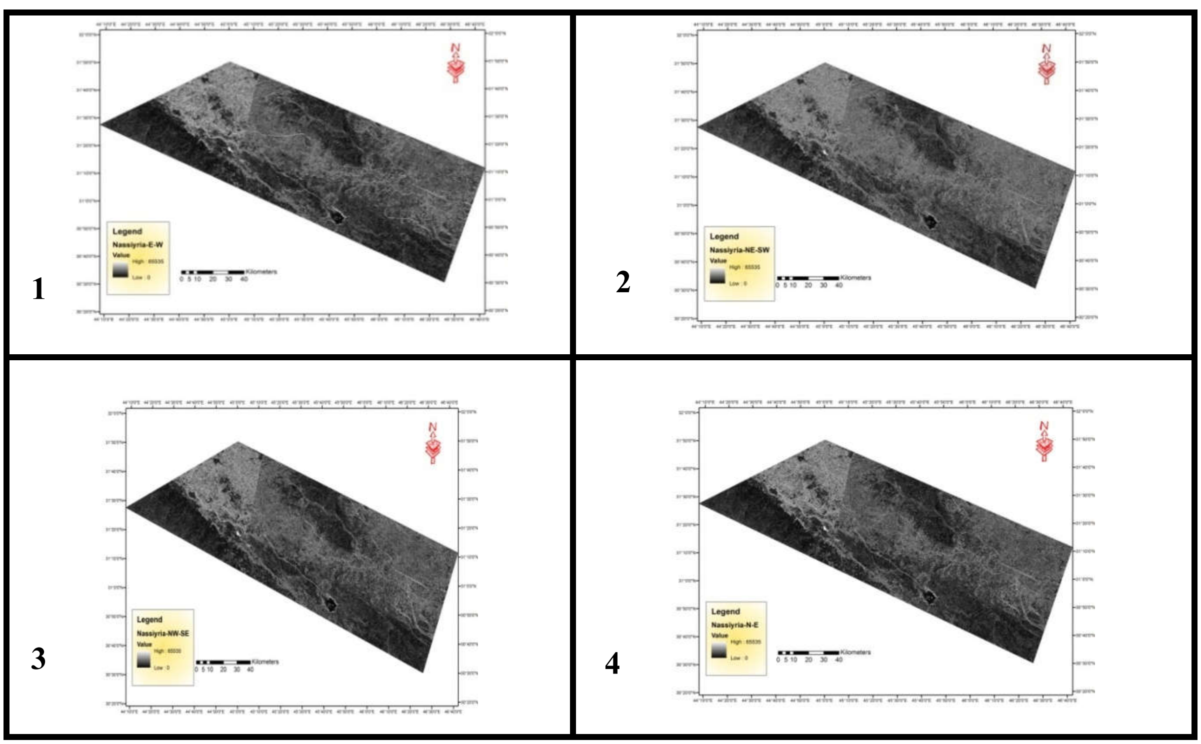

Figure 3 : Nasiriyahsobel directions (1) East-West, (2) NE-SW, (3) NW-SE, (4) North-South.

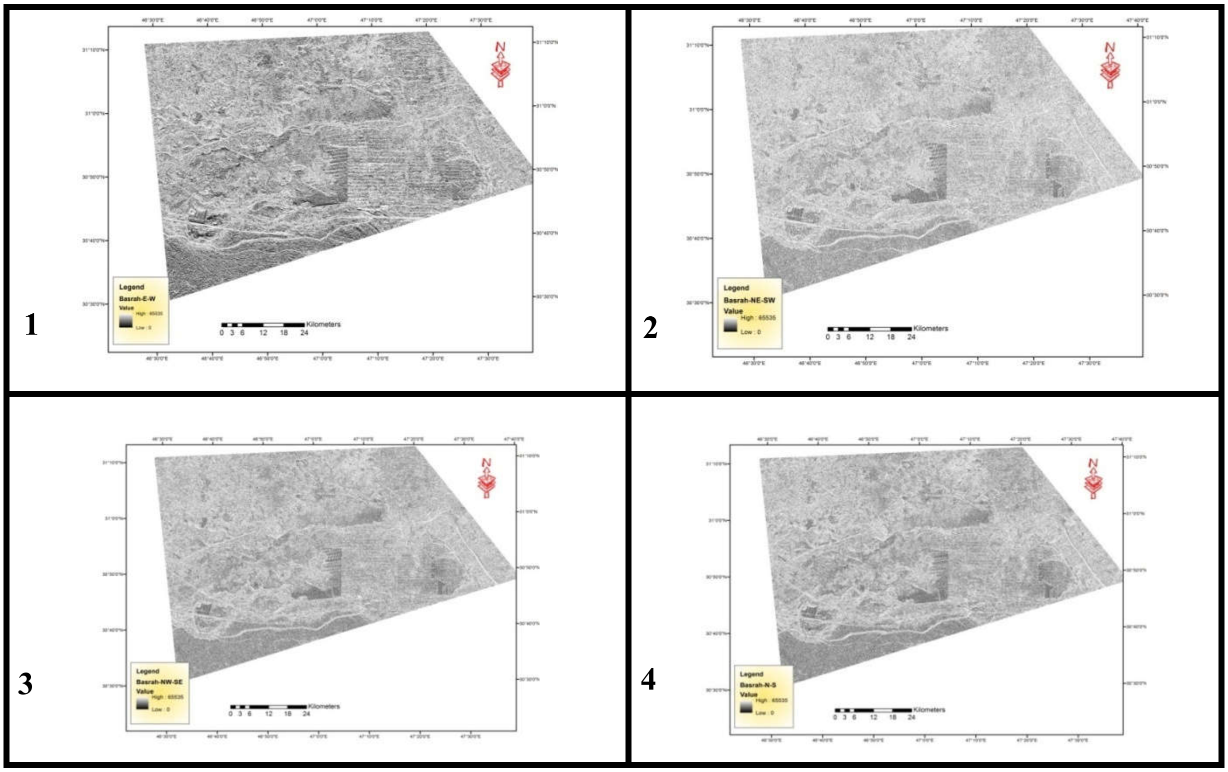

Figure 4: BasrahSobel directions (1) East-West, (2) NE-SW, (3) NW-SE, (4) North-South.

The automated lineament extraction operations are applied on Lands at 8 OLI, band 6 short wave infrared to extract geological formation rock fractures (lineaments). By using PCI geomatica software line option. Six parameters were used as in the table (1) in the automatic lineament extraction are described as follows, "RADI (filter iradius), GTHR (Gradient threshold), LTHR (length threshold), FTHR (Line fitting error threshold), ATHR (Angular difference threshold) and DTHR (Linking distance threshold)" (SARP, 2005).

Table1: Lineaments Parameters Automatic Extraction for Study Area

Areas	**Parameters**					
	RADI	GTHR	LTHR	FTHR	ATHR	DTHR
Nasiriyah	20	100	50	3	30	20
Basrah	20	100	40	3	30	20

After applying the parameters in study areas the lineaments are as follow: for Nasiriyah area which shows lineaments distribution as shown in figure (5).

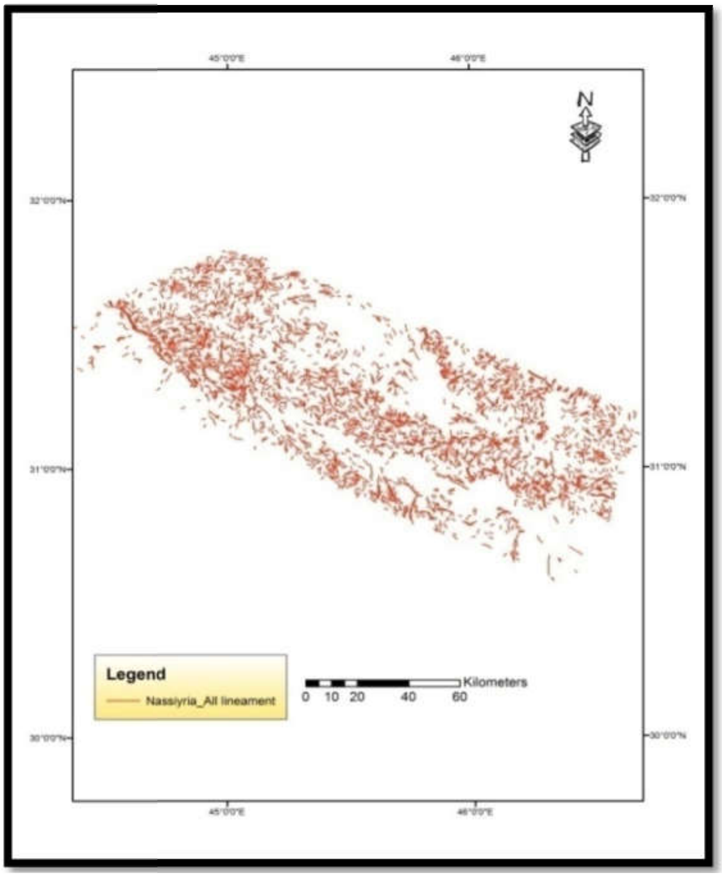

Figure 5: lineaments distribution in Nasiriyah area
With statistics (statistics of lineaments in Nasiriyahin the table 2).

Table 2: Basic Statistic of Lineaments in Nasiriyah area

Statistics	**Directions**				
	N-S	**NE-SW**	**E-W**	**NW-SE**	**All Directions**
Count	505	1144	538	1099	3286
Min. Length	1.5	1.5	1.5	1.5	1.5
Max. Length	10.4	7.3	8.9	13.9	13.9
Mean	2.1	2.1	2.1	2.3	2.2
Total length	1087	2515	1175	2534	7313

And Basrah as in figure (6). Which shows lineaments distribution.

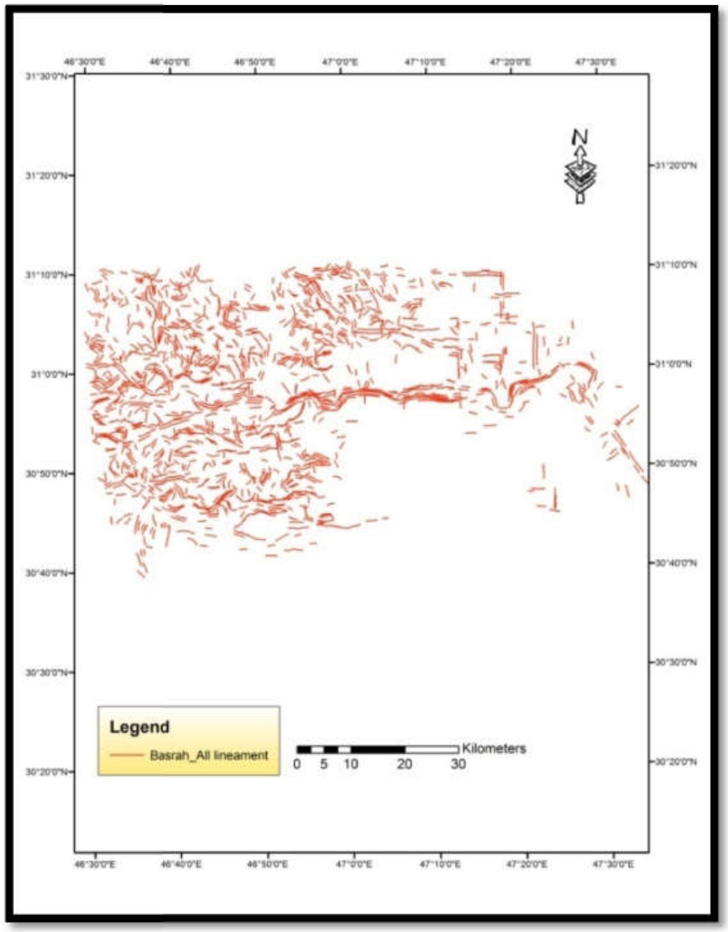

Figure 6: Lineaments Distribution in Basrah Area

With statistics (statistics of lineaments in Basrahin table 3).

Table3: Basic statistics of line-aments in Basrah area

Statistics	**Directions**				
	N-S	**NE-SW**	**E-W**	**NW-SE**	**All Directions**
Count	234	406	346	471	1457
Min.Length	1.2	1.2	1.2	1.2	1.2
Max.Length	11.3	6.8	9.7	20.4	20.4
Mean	1.9	1.9	2.1	1.9	1.9
Total length	456	787	730	919	2893

Lineaments Direction

The prevailing trend of lineament is indicative of the direction of the tectonic forces. However, rock types and their competence also affect the direction of linear features. Figure (7). Shows rose diagram in Nasiriyah area.

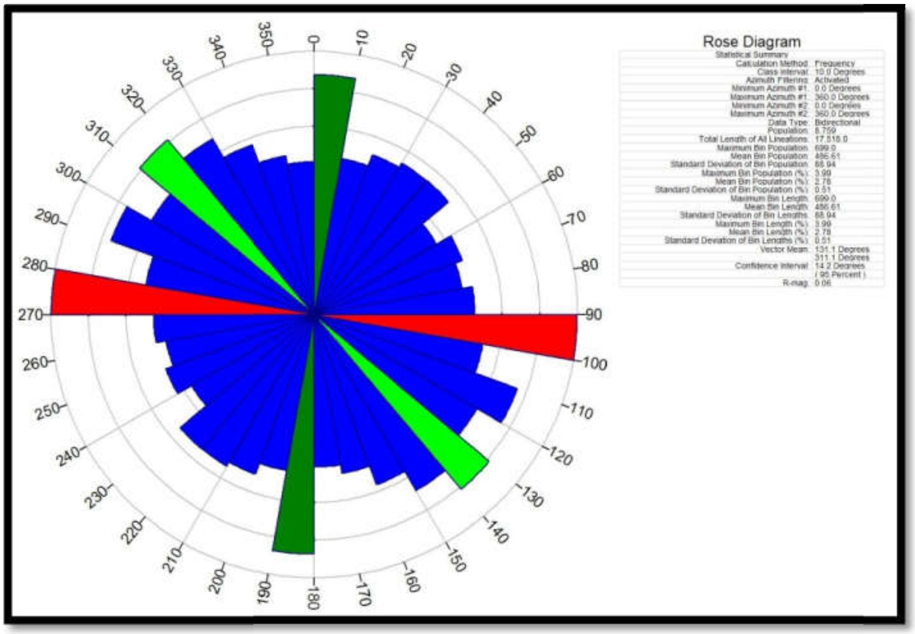

Figure 7: Nasiriyah Rose diagram

And for Basrah rose diagram as in figure (8).

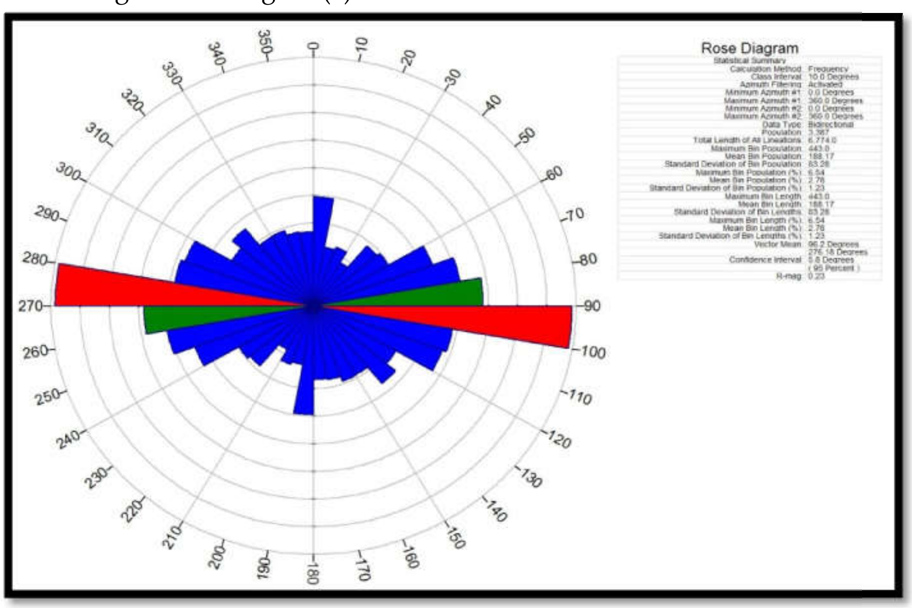

Figure 8: Basrah Rose diagram

Lithological Contacts

The lithological contacts layer of the research area was digitized (after Sissakian and Saeed, 2012) as in figure (9) which displays lithology of Nasiriyah area.

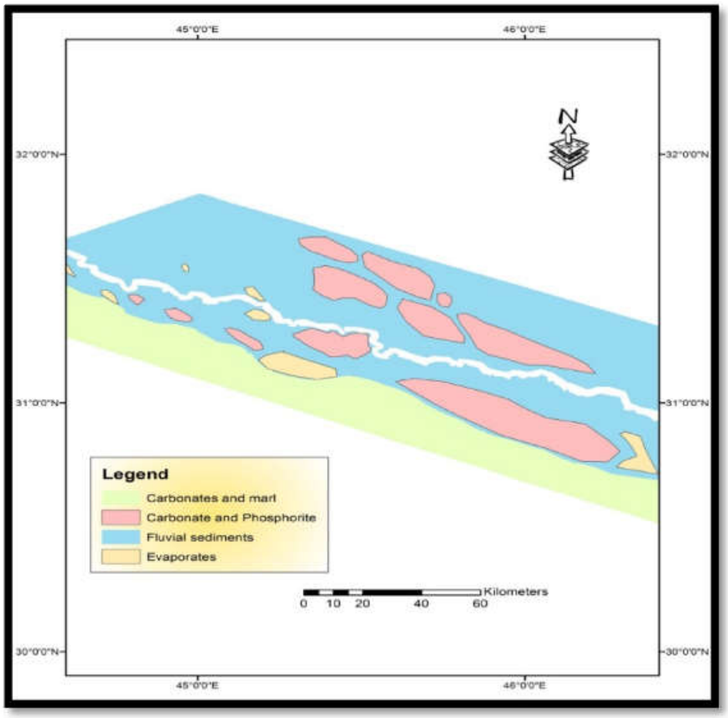

Figure 9: Nasiriyah area lithology

And for Basrah lithology as in figure (10)

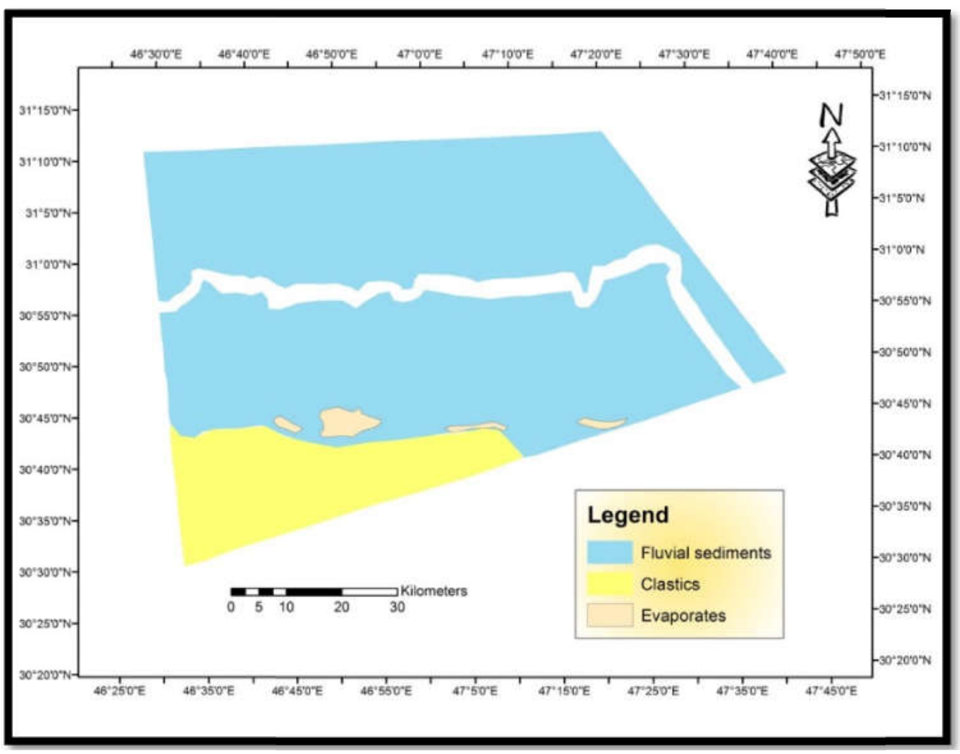

Figure 10: Basrah area lithology

Drainage pattern

The drainage network was obtained using SRTM radar images at a resolution of 30m. The DRAIN (Drainage Basin from Elevation Data) tool is utilized to identify the drainage networks, such as rivers and streams, inside the Digital Elevation Model (DEM). The resulting output data consists of lines that represent the rivers and streams in the area. According to Abdullah et al. (2010). The phenomenon of drainage into enclosed basins is mostly attributed to many geological processes, including tectonic movements, deposition of sediment by rivers or wind, erosion, and volcanic events. According to Ahmed and Al-Dousari (2013), The Nasiriyah region exhibits a dendritic drainage pattern, as depicted in Figure (11).

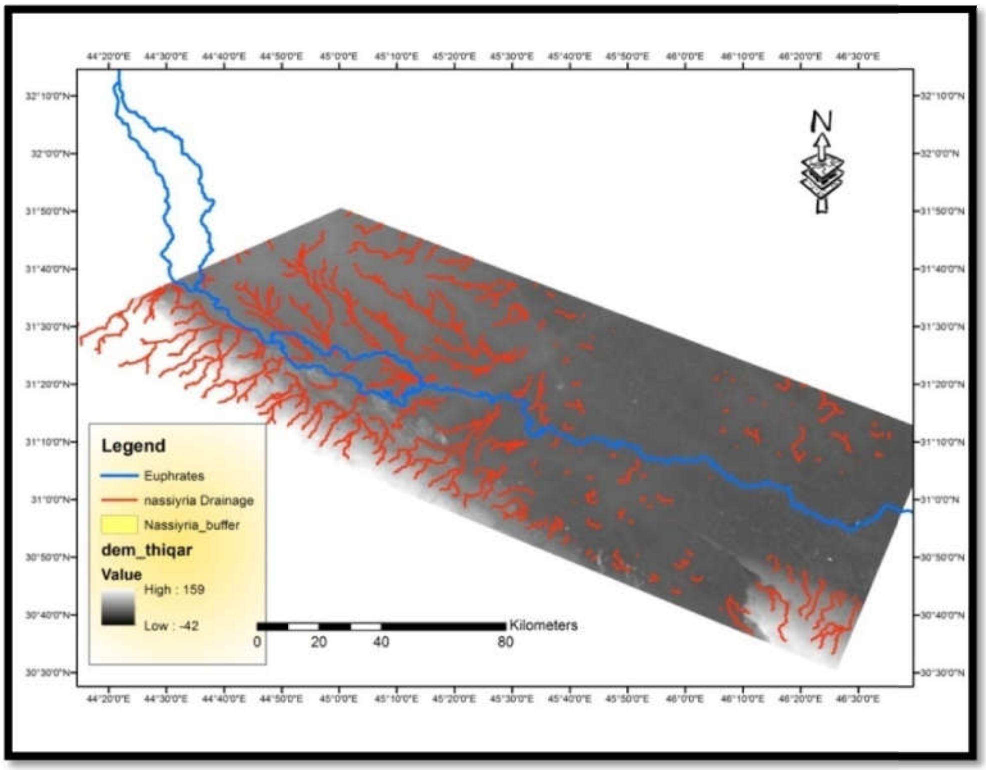

Figure 11: shows a dendritic type pattern in Nasiriyah area

And drainage pattern in Basrah area is annular type. As in figure (12).

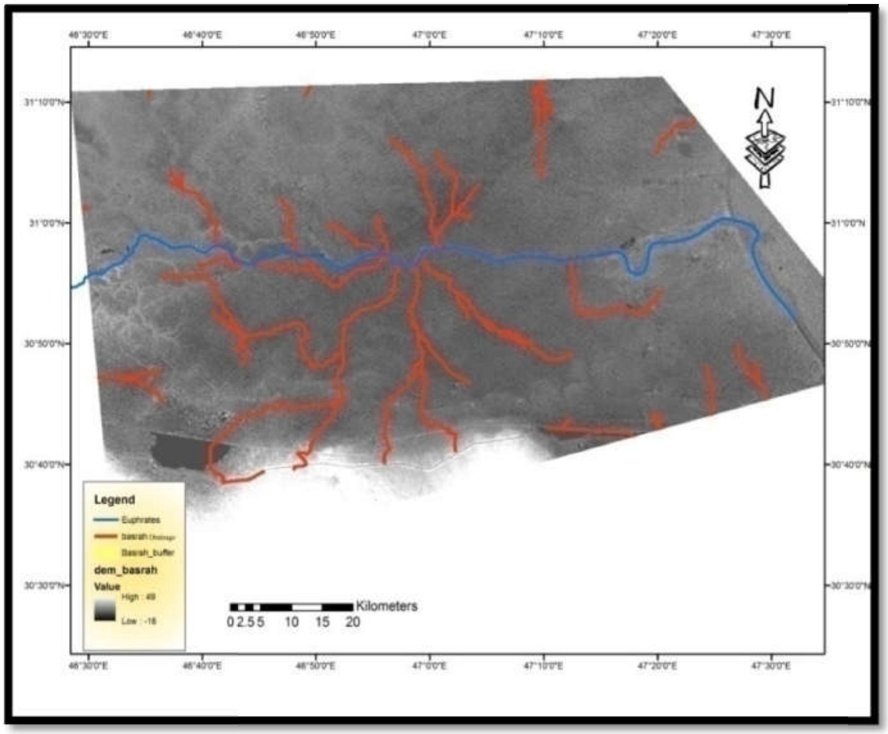

Figure 12: shows annular type pattern in Basrah area

RESULTS AND DISCUSSION

GIS Model

This work employed the union layer model, also known as spatial multi-layer analysis, to analyze thematic maps. The maps were aggregated, taking into account various criteria, and a fault susceptibility model was generated using a modified linear equation derived from the drastic model. In a study conducted by Aller in 1995, the equation utilized was as follows:

Potential map = LINW+LCTW+DRNW----- (1)

Where, LINW the lineament weight layer
LCTW the lithological contact weight layer and
DRNW is the drainage weight layer.

Table 4: Lineament's classification their characteristics after Saud, 2008

lineament	**length**	**Extent orientation**	**Dominant Geological control**
Large—scale Lineament (Long)	>10 km	Straight and Almost slightly curved	Regional tectonic forces resulting long faults
Moderate-scale Lineament (moderate)	1-10km	Straight and Partially curved	Almost due to faulting and sometimes to lithological contacts
Small – scale Lineament (short)	<1 km	Almost straight	Small-scale Faults and sometimes Local joints

The study adopted the classification of Saud, 2008 table (4), because it's proper for the study and highlight geological control and most important lineament length parameter due to detects fault segments.

After applying the equation no. (1) Overall the study area the results are got as in figure (13).Which displays the susceptibility map of Nasiriyah area.

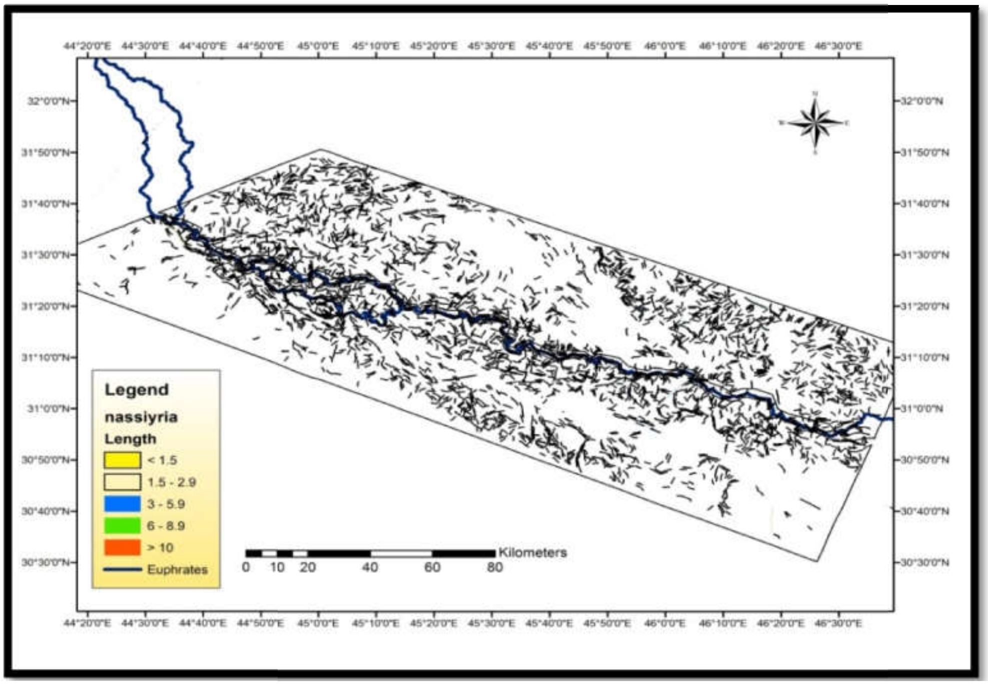

Figure 13: susceptibility map of Nasiriyah area

And statistics for Nasiriyha (lineaments length with geological control as in the table (5))

Table 5: Lineament length with geological control and structural type/Nasiriyha

Class	Length (km)	count	Geological control
1	≤1.5	6	Almost due to faulting and sometimes to lithological contacts
2	1.5-2.9	2834	Almost due to faulting and sometimes to lithological contacts
3	3-5.9	377	Almost due to faulting and sometimes to lithological contacts
4	6-8.9	19	Almost due to faulting and sometimes to lithological contacts
5	>10	4	Regional tectonic forces resulting long faults

And for Basrah susceptibility map shows in figure (14)

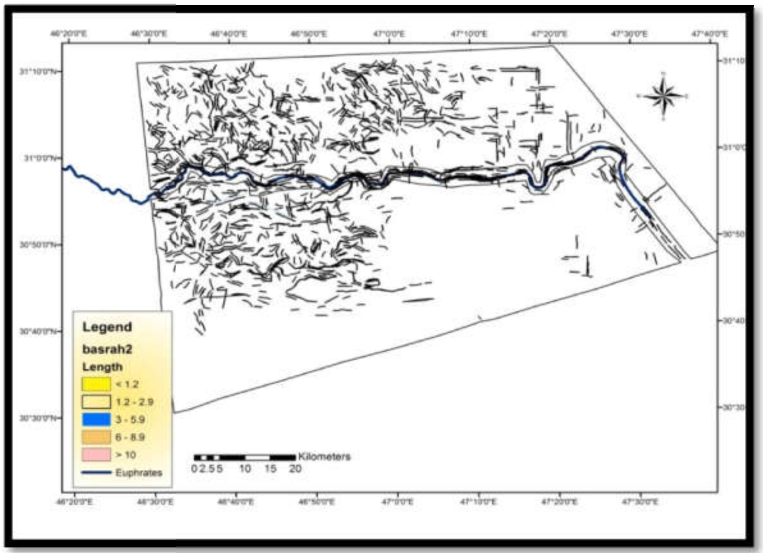

Figure 14: susceptibility map of Basrah area

And statistics for Basrah (lineament length with geological control in table (6))

Table 6: Lineaments length with geological control and structural type/Basrah

Class	Length(km)	count	Geological control
1	≤1.2	3	Almost due to faulting and sometimes to lithological contacts
2	1.2 -2.9	1218	Almost due to faulting and sometimes to lithological contacts
3	3-5.9	134	Almost due to faulting and sometimes to lithological contacts
4	6- 8.9	11	Almost due to faulting and sometimes to lithological contacts
5	>10	2	Regional tectonic forces resulting long faults

Assessment of the Susceptibility map

The assessment was made concerning the fault map (tectonic map), in the present study , Al-Kadhimi et al ,1996 tectonic map figure (15) , This detailed map illustrates the structural elements, such as folds and faults, through the utilization of geophysical methodologies. Additionally, it emphasizes the necessity of validating the model's accuracy.

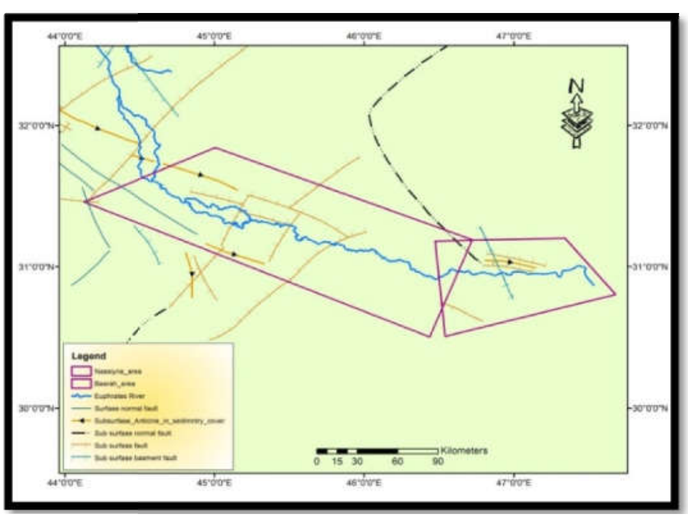

Figure 15: Tectonic map shows the main faults and folds in area (after Al-Kadhimi et al, 1996)

Saud,2008 mentioned short lineaments have more sets of directions even with the small areas while long lineament often follow specific orientations according to affecting tectonic forces. The study area reveals a range of different length, which is indicative of several geo-tectonic controls, mainly: the value of the tectonic forces, rock hardness, and consolidation, the geomorphic setting of terrain where the lineaments exist. In this analysis, we will compare the fault lines derived from the model with the fault lines depicted in Figure 15. Our attention will be on the moderate and large lineaments, as indicated in Table 4.The diagram presented in Figure 16 illustrates the visual representation of the data or concept being discussed. The presented visual displays the lineaments that have been taken from the susceptibility map pertaining to the Nasiriyha region

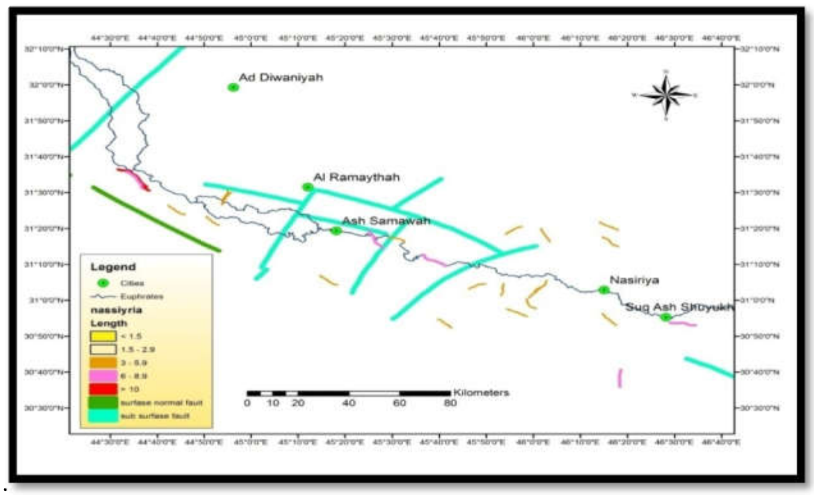

Figure 16: lineaments (faults lines) extracted from the susceptibility map Nasiriyha area (dark lines (green and cyan) represent Al-Kadhimi faults).

And for Basrah as in figure (17).

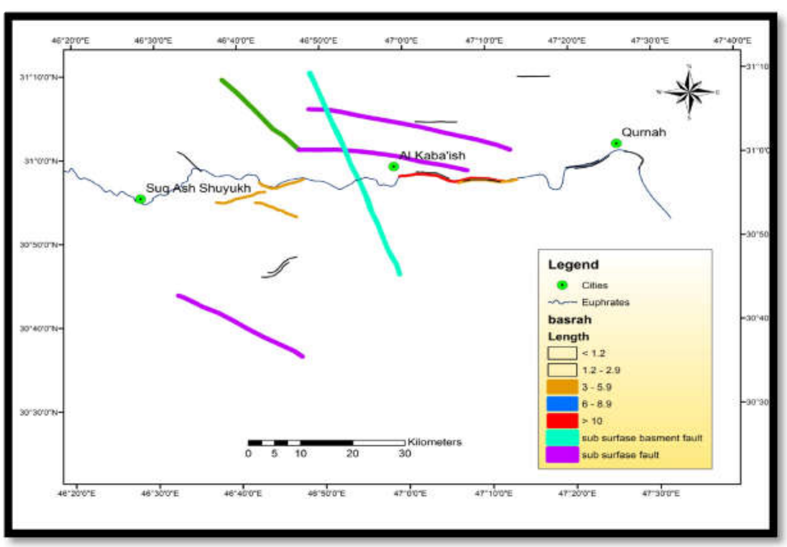

Figure 17: lineaments (faults lines) extracted from the susceptibility map Basrah area (dark lines (green and cyan) represent Al-Kadhimi faults).

CONCLUSIONS

The main conclusions listed as follow:

1-The results of automatic lineaments rose diagram that the direction of lineaments in Nasiriyha study area is in all directions but, the dominant lineaments trend is E-W and second trend is N-S and NW-SE (315) trend while in Basrah study area dominant lineaments trend is E-W.

2-The main type of rocks in the Nasiriyha and Basrah is soil (sediments) and the drainage pattern in the Nasiriyha area is dendritic whereas the drainage pattern in the Basrah area is annular. The observed drainage pattern in the studied area appears to be influenced by both structural and lithological factors. The correlation between fault lines and the distribution of drainage patterns, particularly in regard to third and fourth river orders within the region, is readily apparent.

3-The presence of moderate to large lineaments, commonly referred to as fault lines, has been observed in the study area. These fault lines do not correspond to any fault lines depicted in the tectonic map utilized in the research framework. It is possible that these newly identified fault lines, as indicated by the model employed in this study, represent surface manifestations of previously unknown fault locations within the research sector. This suggests that the implementation of the applicable model proved to be successful in identifying linear characteristics, such as fault lines, within the specified regions of interest. The findings suggest the inclusion of additional fault segments, specifically (26, 15), in the fault line numbers for the regions of Nasiriyha and Basrah. These segments were not previously identified in the fault map used for the study area. From satellite images, enables obtaining a miscellany of terrain applications, such as the selection of landfill sites, dam sites, and many other applications, but the most effective are those related with water resources management.

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