MONITORING OF AEOLIAN DEPOSITS AND ENVIRONMENTAL CHANGES DETECTION OF ALI AL-GHARBI AREA, SOUTH EAST IRAQ, USING REMOTE SENSING AND GIS TECHNIQUES

Younus I. Al-Saady[1], Manal M. Al-Obaydi[1] and Mousa A. Ahmed[1]

ABSTRACT

Ali Al-Gharbi area is located in the eastern part of the Mesopotamia Plain. It covers 6569.9 Km^2 and falls within the arid climate region. Most parts of the study area are covered by Quaternary sediments. Pre-quaternary rocks are represented by Mukdadiya and Bai Hassan formations, which are exposed in the eastern part of the study area. It is suffering from land degradation due to sand creep. Haphazard irrigation habits led to an increase of saline soil under arid environmental conditions.

Supervised classification using Maximum Likelihood technique was carried out on the ETM 2002 and TM 1990 images in addition to image indices applications. ERDAS Imagine 9.1 was used for preparation and processing of the data and ArcGIS 9.3 was used for final layout of the maps. Depending on the results of supervised classification and image indices applications of Land Use Land Cover (LULC) classes, different land degradation types and environmental changes detection, between two dates are determined.

The Field checking was conducted to verify the supervised classification results. It includes determination of check points using GPS, description of the surface features, soil and sediments, supported by taking photos.

The supervised classification results distinguished the following classes: Barren Land, Water, Wetland, Vegetated Land and Agricultural Land Non-Vegetated (Idle and Cultivated land). The Barren Land class is divided into three sub-classes: Mixed Barren Land, Sand Dunes and Salt Flats. Distinguishing between dry barren land and salt flat also between aeolian sediments types: like sand dunes, sand sheets and some areas which are covered by aeolian sediments are difficult because there are mixed pixels between these units according to spectral resolution of available ETM and TM data.

The classification accuracy of both ETM 2002 and TM 1990 images data was examined and showed good accuracy results. They have showed 92% accuracy for ETM 2002 image with Kappa (K^) coefficient 0.8448 and 90.22% accuracy for TM 1990 image with Kappa (K^) coefficient 0.8260.

The main problems in the study area are erosion of dry soil, salinization of agricultural land, rising of dust storms and active sand dunes. All these factors have contributed in the increasing of desertification phenomenon.

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[1] Senior Geologist, Iraq Geological Survey, P.O. Box 986, Baghdad, Iraq

مراقبة الترسبات الريحية وتحديد التغيرات البيئية لمنطقة علي الغربي،
جنوب شرق العراق، باستخدام تقنيات التحسس النائي
ونظم المعلومات الجغرافية

يونس ابراهيم الساعدي، منال محمد العبيدي، موسى عبد اللطيف احمد

المستخلص

تقع منطقة علي الغربي في الجزء الشرقي من السهل الرسوبي وتبلغ مساحتها 6569.9 كم²، المناخ السائد في المنطقة هو المناخ الجاف. معظم أجزاء منطقة الدراسة مغطاة بترسبات العصر الرباعي مع وجود بعض الصخور العائدة لتكويني المقدادية وباي حسن التي تتكشف في الجزء الشرقي من منطقة الدراسة عند الحدود العراقية – الإيرانية. تعاني منطقة الدراسة من تدهور عام للأراضي نتيجة لزحف الكثبان الرملية وأساليب الإرواء القديمة والظروف المناخية الجافة.

تضمنت الدراسة الحالية إجراء تصنيف موجه لمرئيتين فضائيتين الأولى نوع TM ملتقطة في عام 1990 والثانية نوع ETM ملتقطة في العام 2002 إضافة الى استخدام قسمة الحزم. استخدم برنامج ERDAS 9.1 لتهيئة ومعالجة بيانات المرئية الفضائية وإجراء التصنيف الموجه، أما برنامج ArcGIS 9.3 فقد استخدم لإعداد الخرائط بالشكل النهائي. اعتمادا على نتائج التصنيف الموجه وقسمة الحزم تم تحديد وحدات غطاء واستخدامات الأرض لكلا المرئيتين وتحديد التغيرات البيئية لمساحة وحدات غطاء واستخدام الأرض من خلال حساب المساحات ومراقبة الترسبات الريحية.

نفذ العمل الحقلي لتدقيق نتائج التصنيف الموجه، التقاط الصور الحقلية، تحديد نقاط ضبط أرضية وتوثيق الملاحظات لكل محطة تدقيق. تم إجراء مقارنة بين أسلوبي التصنيف الموجه وقسمة الحزم في تحديد أنواع التدهور البيئي وتحديد التغيرات البيئية في وحدات غطاء واستخدامات الأرض.

شملت وحدات استخدامات الأرض والغطاء الأرضي التي تم تمييزها من التصنيف الموجه: الماء، النباتات، الأراضي الرطبة، الأراضي الزراعية المعطلة والمحروثة، الأراضي المغطاة بالترسبات الريحية والسباخ، حيث ميزت معظم الأصناف بصورة جيدة بينما التمييز بين الأراضي الجافة والأراضي الحاوية على محتوى ملحي واطىء لايخلو من بعض المشاكل اعتمادا على هذا النوع من البيانات. أظهرت النتائج دقة تصنيف جيدة لكلا المرئيتين حيث كانت 92% مع معامل كابا 0.8448 لمرئية ETM 2002 و 90.22% مع معامل كابا 0.8260 لمرئية TM 1990. أهم المشاكل الرئيسية في منطقة الدراسة هي تعرية الترب الجافة، تملح الأراضي الزراعية، العواصف الترابية والكثبان النشطة وجميع نتائجها تساهم في زيادة التصحر.

INTRODUCTION

The study area has important environmental and economic impact since it includes huge oil fields such as Al-Buzurgan and vast agriculture lands. Tigris River and its branches in addition to Al-Teeb River represent the main water resources, beside the surface water bodies like Al-Sa'diya marsh. These resources have important environmental impact on preservation of the environment and wildlife.

In fact, the ignoring of the study area in the last decade led to decadent of a huge area, because of unsuitable irrigation systems and absence of plans to monitor and control desertification and aeolian attention, like sand dunes and sand sheets. Moreover, huge areas changed from suitable agricultural lands to salt lands and sabkha, especially the eastern part of the study area.

In the present study, Landsat satellite data are utilized to determine the desertification extent and environmental changes detection, in addition to field checking. The climatic conditions and deterioration of natural resources are the main reasons that lead to desertification phenomenon. The desertification phenomenon in Iraq has increased rapidly and much efforts have been devoted to define and study its causes and impacts. The main aims of the present study are to identify and characterize the desertification phenomenon, reviewing the factors of its main causes, determination of LULC classes, detecting and

monitoring LULC change detection for different periods in arid environment and discussing its results and studying the various spectral indices in mapping of land degradation units.

▪ **Location**

Ali Al-Gharbi area covers the eastern part of the central sector of the Mesopotamia Plain. It covers an area of 6569.9 Km^2. The eastern boundary of the study area represents the Iraqi − Iranian international borders (Hemrine Mountains) from east, (Fig.1). It is limited by the coordinates: Longitude 46° 30' – 48° 00' and Latitude 32° 00' – 33° 00'.
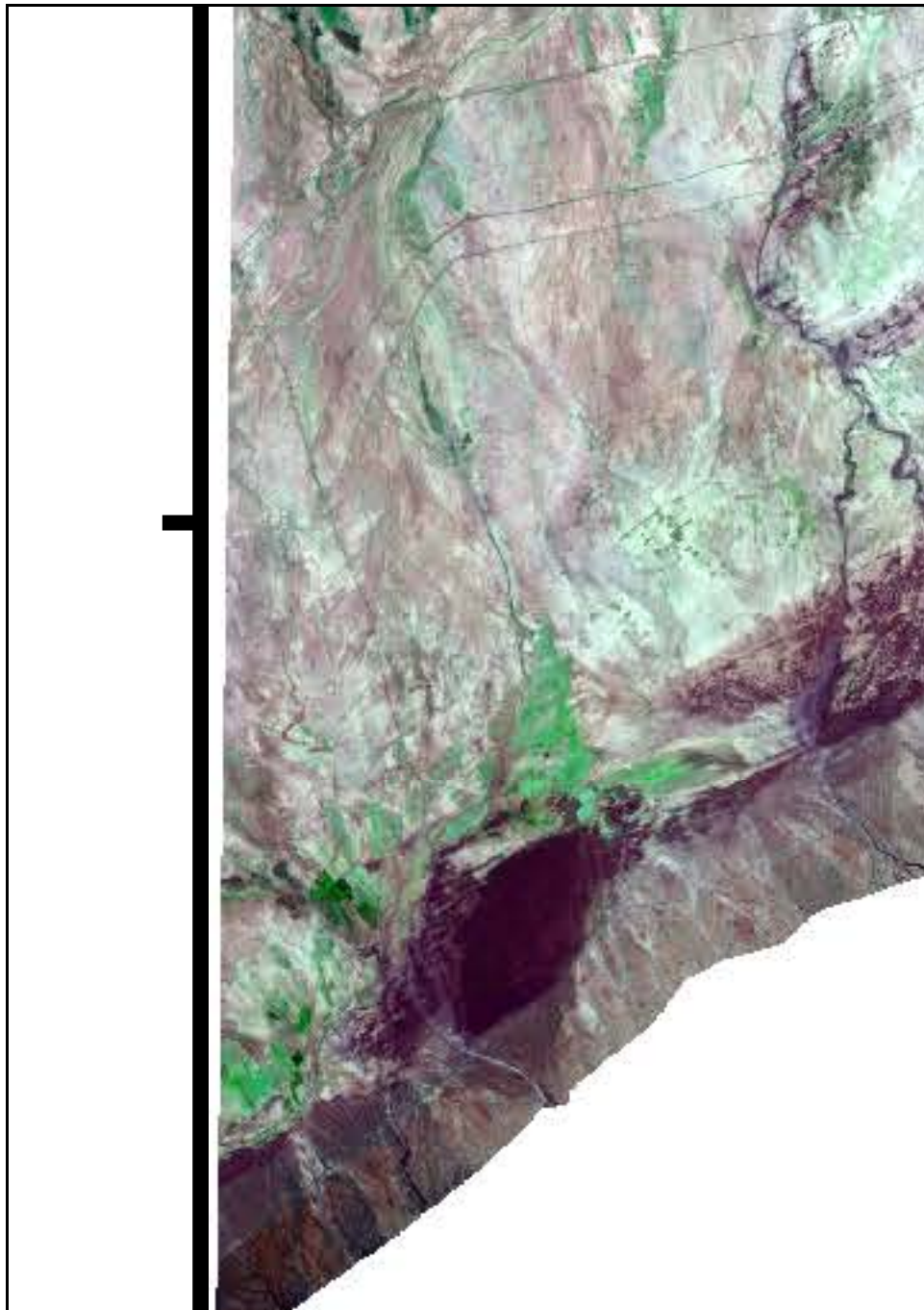

Fig.1: Location map of the study area

▪ **Previous Works**

The most significant works concerning the study area are:

1. Hassan (2009) executed sedimentological study of aeolian sediments east of Missan Governorate.
2. Barwary *et al*. (1993) compiled the regional geological map of Ali Al-Gharbi Quadrangle, sheet NI-38-16, scale 1:250 000.
3. Hassan (1985) studied the regional photo geological and geomorphological mapping of Mandali, Badra, Zurbatiyah, Sheikh Faris and Al-Teeb areas.
4. Domas (1983) studied the geology of Karbala − Kut − Ali Al-Gharbi area (the central sector) as a part of the Mesopotamia Plain project.
5. Krasny (1982) studied the hydrogeology of Kut – Ali Al-Gharbi – Al-Teeb area.

▪ **Topography**

The topography of the area is hilly in the northeastern and eastern parts; it extends along the Iraqi – Iranian boarders with an elevation reaches up to 270 m (a.s.l.). The topography gradually descends to less than 5 m (a.s.l.) in the central and southwestern parts of the study area, according to digital elevation data. The area is categorized into ten elevation ranges (Fig.2). Various types of relief features and geomorphological forms occur such as floodplains, alluvial fans, sand dunes, cultivated fields, hills, seasonal and permanent marshes.
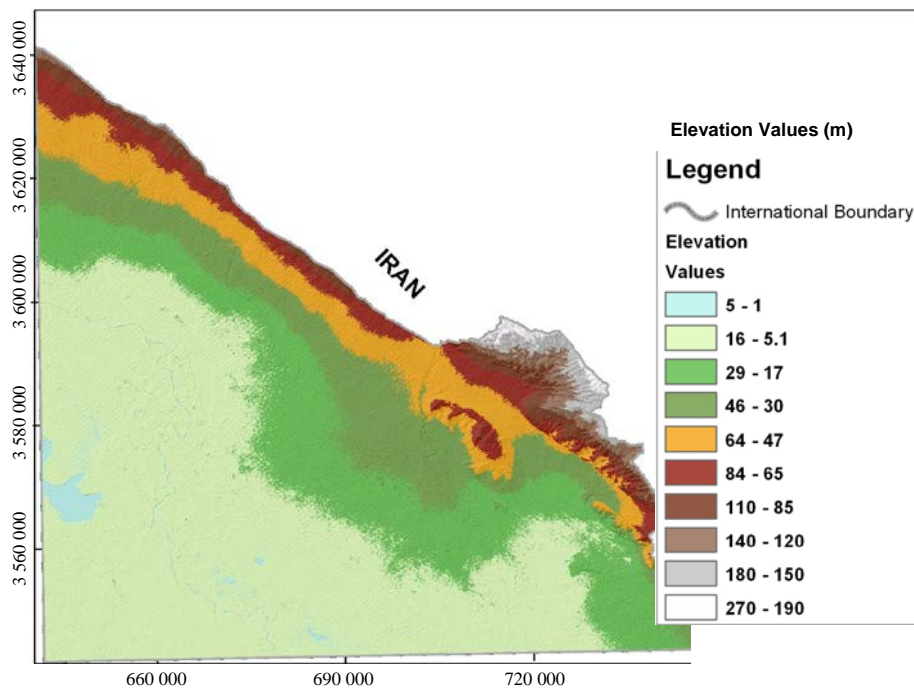

Fig.2: Elevation zones of the study area (in meter)

▪ **Climate**

The climate of the study area is characterized by seasonal variations through the year, long hot summer with occasional dust storms and short winter with limited and seasonal rainfall. The Meteorological data are collected from Amara meteorological station (I.M.O., 2003), which is located southeast of the study area, during the period (1980 – 2000). The maximum temperature reaches up to 48 °C in summer season. There is a large disparity in the average of

relative humidity between summer and winter seasons where the maximum average of the relative humidity reaches up to 86% in January, and the minimum relative humidity is 15%. The rainfall data for two periods (1980 − 1990) and (1991 − 2000) show that the rainfall period is from November to April, while the dry period is from May to September. The maximum monthly wind speed average during the period (1980 – 2000) was 9.8 m/sec in June, while the minimum was 1.6 m/sec in January. The wind direction is primarily from the northwest and some wind reversals occur chiefly during winter. The monthly averages of evaporation, in the study area range between 47 mm in January to 708.6 mm in July. The climate of the study area can be classified, according to Peltier (1950), as an arid region depending on the mean annual rainfall 211.8 mm and mean annual temperature 25 °C, as shown in Fig. (3).
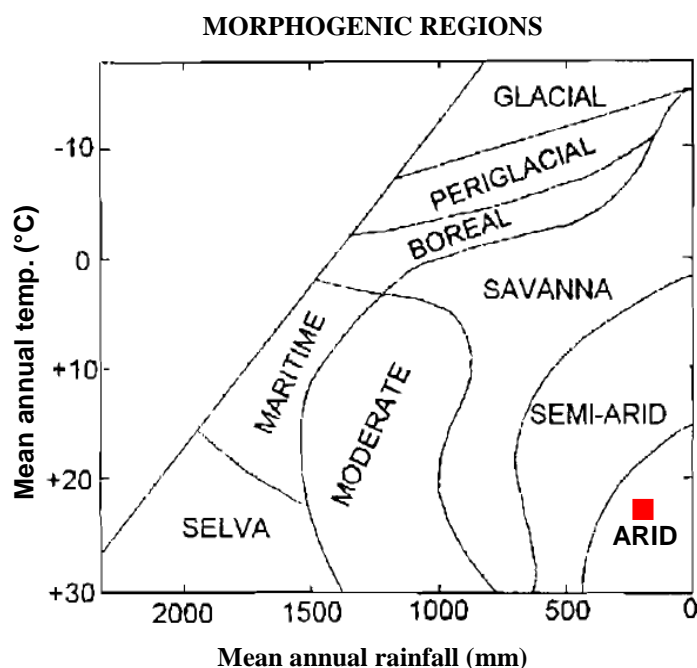
MORPHOGENIC REGIONS

Fig.3: Climatic boundaries of the morphogenetic regions (Peltier, 1950)

GEOLOGICAL SETTING
▪ Structural Geology
Structurally, the main parts of the study area lie within the Mesopotamia Foredeep and the other parts lie within the Low Folded Zone of the Zagros Fold − Thrust Belt. The Mesopotamia Foredeep is a flat terrain in general, nevertheless it contains several structures include faults, folds and diapiric structures that are almost entirely concealed beneath the Quaternary sediments (Fouad, 2010).

▪ Stratigraphy
More than 95% of the study area is covered by different types of Quaternary sediments. The sediments were differentiated, according to their origins and geomorphological processes (Fig.4). Into: **Alluvial fan sediments,** form a strip alongside the foothill of Himreen Mountain on the eastern margin of the study area (Yacoub, 2011). **Fluvial sediments** include sheet run off sediments which make a wide strip spreads (10 − 40) Km between the alluvial fans and the Tigris flood plain. **Flood plain sediments** represent a connected chain starting by crevasse splay sediments through natural levees up to the flood plain sediments and marshes. Ephemeral valleys are developed in the alluvial fan units. **Depressions fill sediments** are

accumulated in shallow depressions of different areal extents. Aeolian sediments, anthropogenic sediments and sabkha are developed in different parts of the study area. **Pre-Quaternary sediments** are exposed to the east and south east of Al-Teeb town (Barwary *et al.*, 1993). They have been compiled from aerial photographs interpretation and represented by undifferentiated Mukdadiya and Bai Hassan formations, due to their interface characters, as consequent, they are considered as one geological formation (Hassan, 1985).
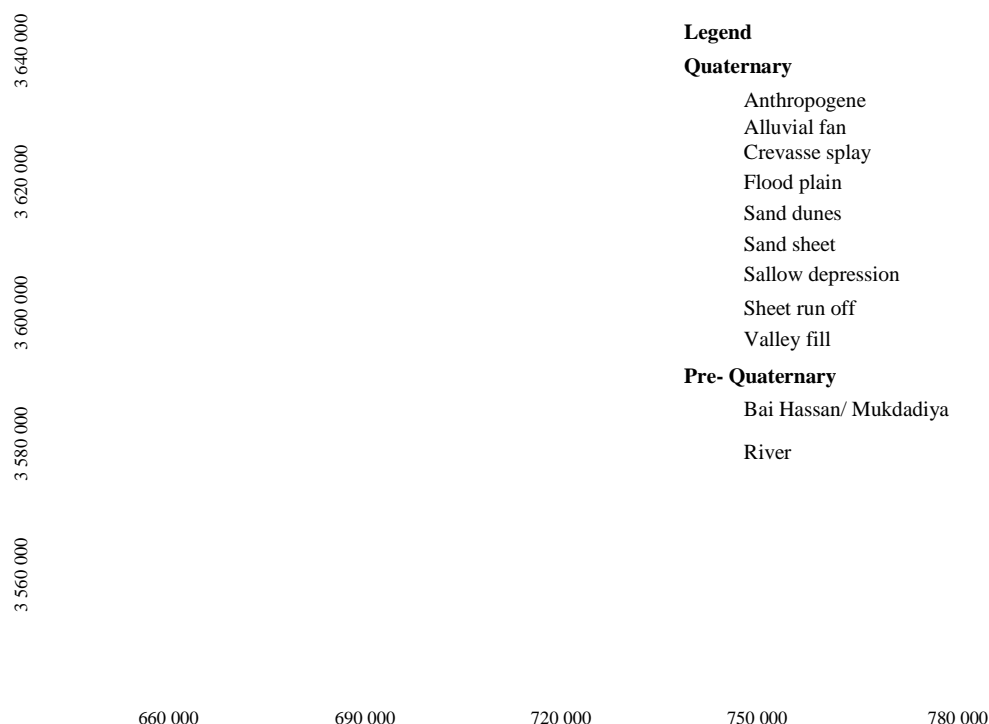
Legend

Quaternary

    Anthropogene
    Alluvial fan
    Crevasse splay
    Flood plain
    Sand dunes
    Sand sheet
    Sallow depression
    Sheet run off
    Valley fill

Pre- Quaternary

    Bai Hassan/ Mukdadiya

    River

Fig.4: Geological map of the study area (after Barwary *et al.*, 1993)

METHODOLOGY

    Landsat satellite images were used during two periods. These are: Landsat-ETM (Enhanced Thematic Mapper during 2002) (Fig.5) and Landsat-TM (Thematic Mapper during 1990) (Fig.6). ERDAS Imagine software version 9.1 was used for data preparation, data analysis for digital image processing, including a supervised classification, interpretation and change detection image of image. ArcGIS 9.3 was used for analyzing and then to layout the classification results. The field checking has been conducted to verify the classification and to collect field data and soil samples using Garmin (eTrex) Vista handheld GPS.

    The supervised classification is used in the present study to monitor and determine the desertification like salinization and aeolian sediments extent and to prepare LULC maps of the map area. Field checking was carried out during 2010 to verify and describe the main classes.

    The LULC map was produced as a result of applying the supervised classification method on the Landsat Satellite Images ETM 2002 and TM 1990 and the acquired results are illustrated in Figs. (7 and 8). The accuracy assessment was performed for both classification images. The obtained results are 92% accuracy with Kappa (K^) coefficient 0.8448 for ETM 2002 image and 90.22% accuracy with Kappa (K^) coefficient 0.8260 for TM 1990 image.

▪ **Land Use Land Cover Map**

The produced LULC map is dominated by Barren Land (the main class in the map area), moreover the class Barren Land is divided into three sub-classes (Mixed Barren Land, Sand Dunes and Salt Flats). The followed procedure to derive LULC maps in the present study is modified after Anderson *et al*. (1976). Main classes of LULC map are Urban and Built-up Land, Water, Wetland, Agricultural Land Non-Vegetated and Vegetated Land, which are classified according to Level I, while Barren Land is classified according to Level II into three sub-classes, which are Salt Flats, Sand Dunes and Mixed Barren Land. These categories are described hereinafter:
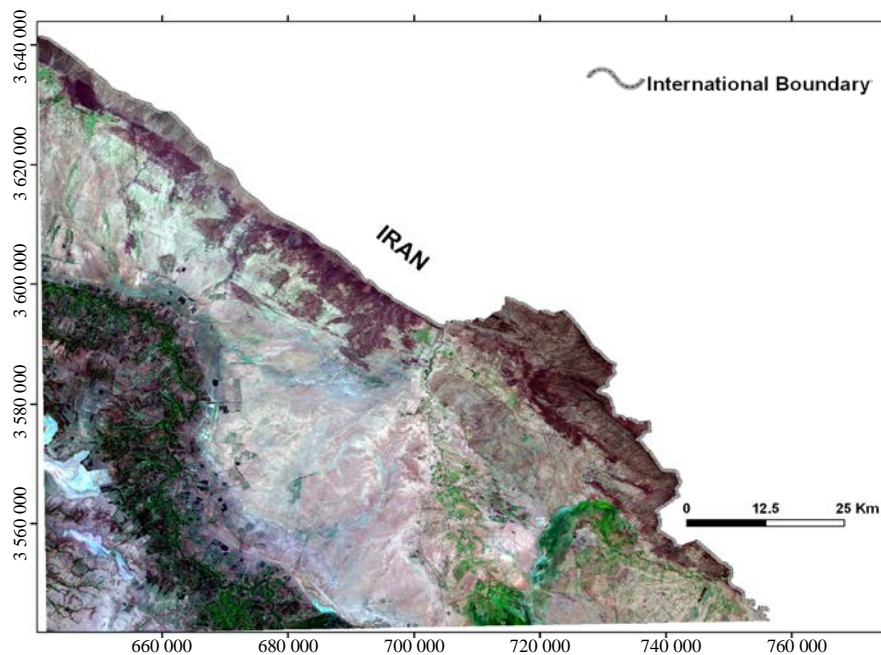

Fig.5: Satellite ETM 2002 image RGB 742 of the study area
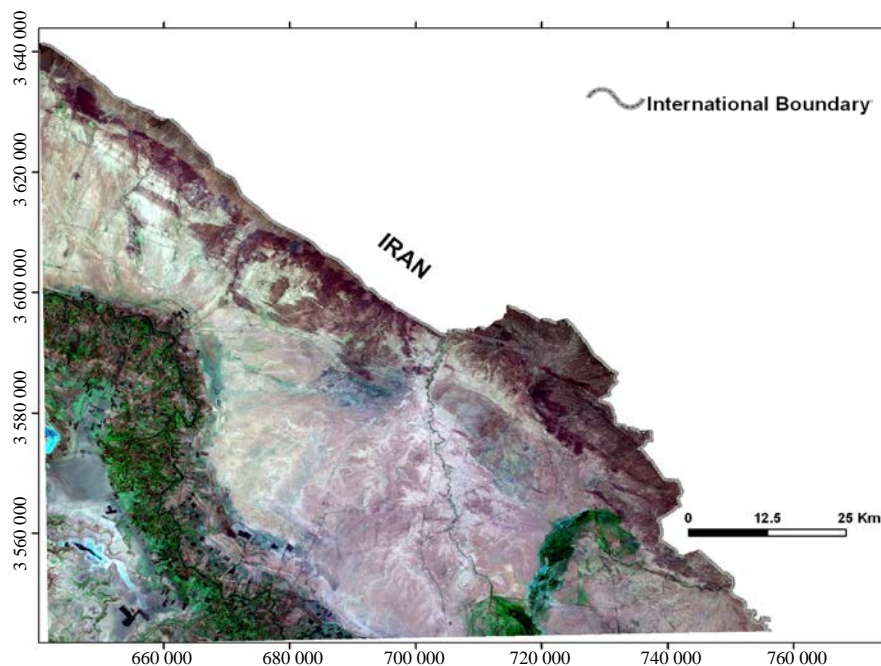
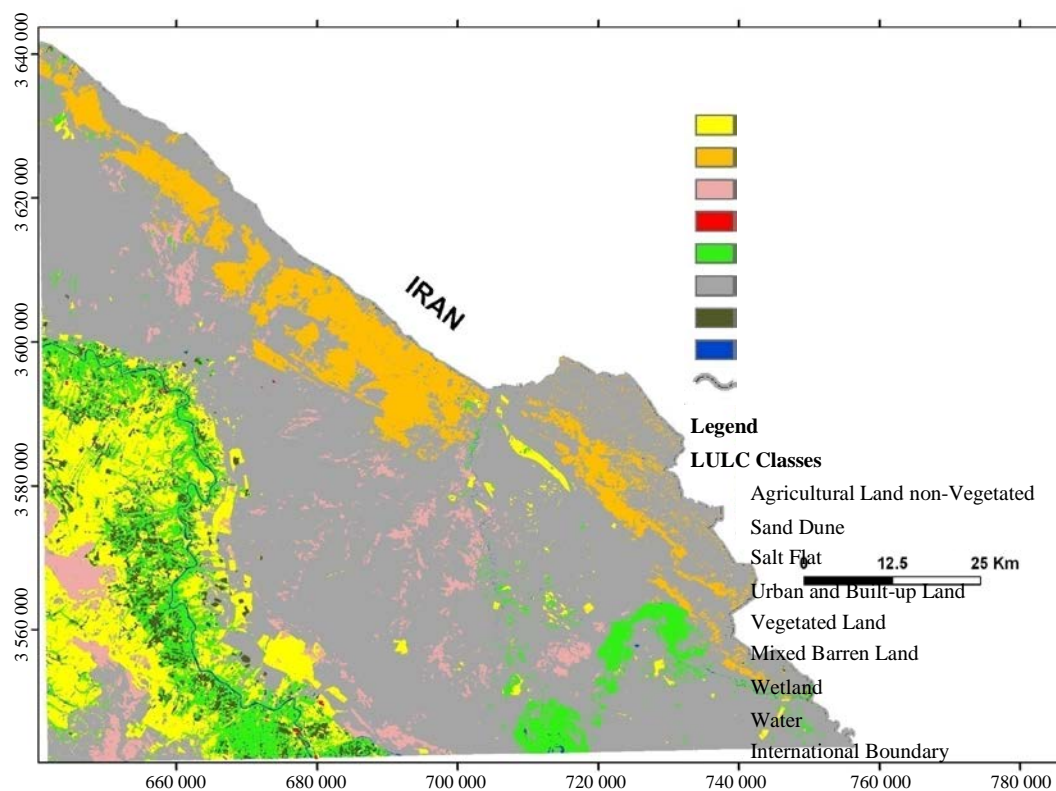

Fig.6: Satellite TM 1990 image RGB 742 of the study area

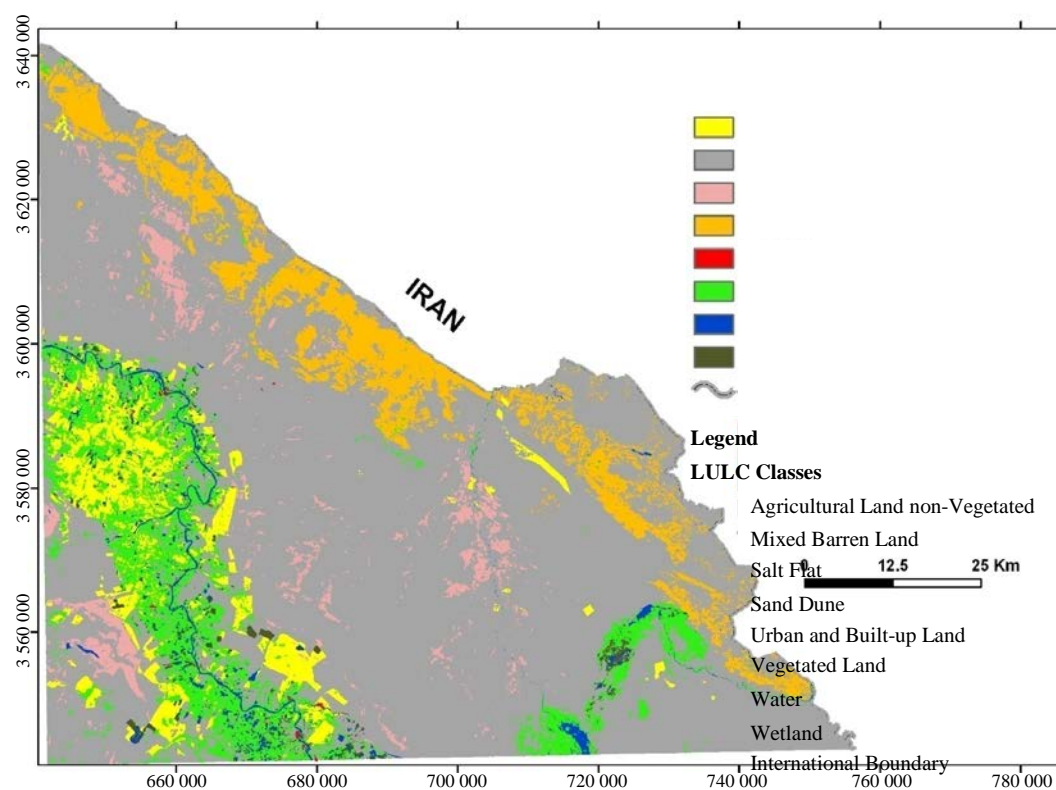Fig.7: LULC Classification of Landsat ETM 2002 image

Fig.8: LULC Classification of Landsat TM 1990

─ **Urban and Built-up Land Class:** Urban or Built-up Land comprises areas of intensive use with much of the land being covered by structures, included in this category which are: cities, towns, villages, strip developments along highways, transportation, power transmission lines, communication facilities, and areas such as those occupied by mills, shopping centers, industrial and commercial complexes, and institutions that may, in some instances, be isolated from urban areas (Fig.9) (Anderson *et al.*, 1976).

There is no huge urbanization in the study area, which cannot be clearly distinguished by the Landsat satellite images, due to low spatial resolution of adopted images and because most of the villages are built up by clay. Most of the Urban and Built-up Lands are represented by small villages and scattered houses distributed on the major parts of the study area. The Urban Land was added from another data (HIC, 2004), therefore, the change detection of this class is uncounted through present study. The Urban and Built-up Land cover 5.45 Km^2 with a percentage of 0.08%, as shown in Tables (1 and 2). The pie chart (Figs.10 and 11) show the percentage of this class. The individual scattered houses in the study area are uncounted within this percentage.

Fig.9: Urban and Built-up Land (eastward Kumait town)

Table 1: LULC classification results of ETM 2002 and TM 1990 images

| Satellite Image Type		ETM 2002		TM 1990	
Class Name		**Area (Km^2)**	**Area%**	**Area (Km^2)**	**Area%**
Barren Land	Mixed Barren Land Class	4097.58	62.37	4529.44	68.94
	Sand Dunes Class	568.77	8.66	576.12	8.77
	Salt Flats Class	281.59	4.29	230.49	3.51
Total Barren Land		4947.94	75.31	5332.05	81.22
Agricultural Land non-Vegetated Class		799.07	12.16	407.49	6.21
Vegetated Land Class		607.49	9.25	669.38	10.19
Wetland Class		182.13	2.77	64.71	0.98
Water Class		27.91	0.42	86.84	1.32
Urban and Built-up Class		5.45	0.08	5.45	0.08
Total		6569.9	100.00	6569.9	100.0
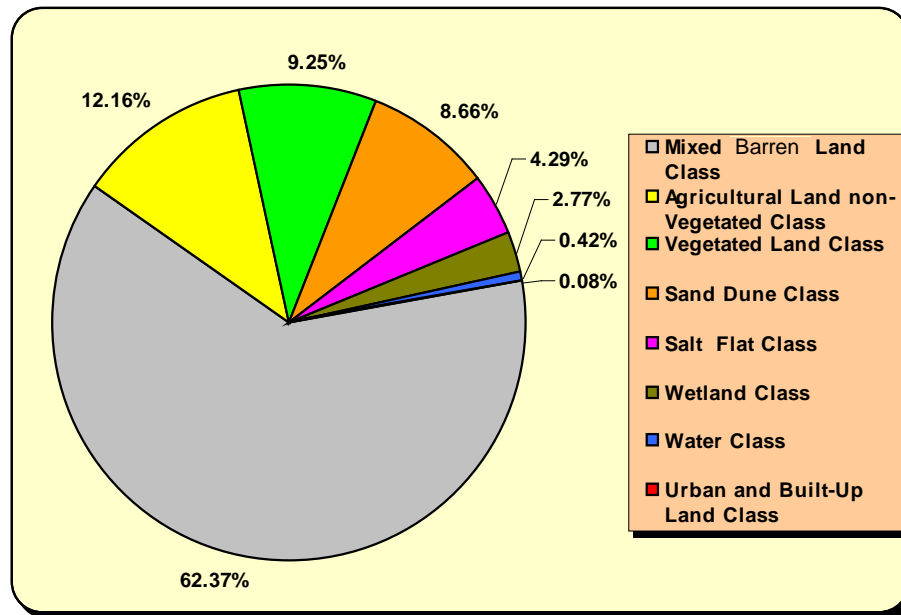
Fig.10: LULC classes in ETM 2002 image
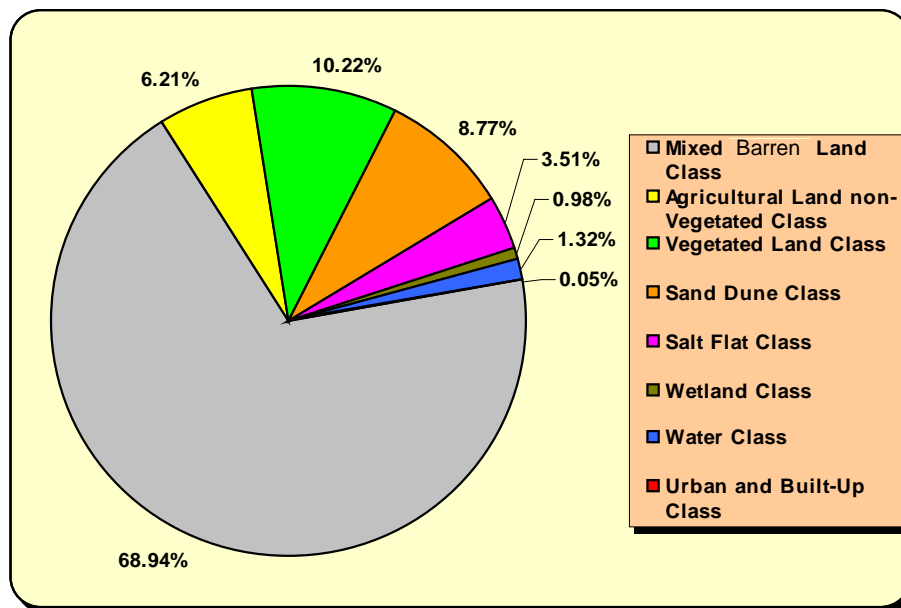
Fig.11: LULC classes in TM 1990 image

‒ **Water Class:** The available water resources in the study area are surface water, which involve Tigris River, as a sustainable river (Fig.12), and two seasonal rivers Al-Teeb and Khar Khar Rivers (Fig.13). They are active during rainfall season in addition to some seasonal valleys flow and some hand-dug wells. However, there is a shortage of water supply in the eastern parts of the study area, as a result of building dams particularly inside the Iranian territory; therefore, the decrease in the amount of water supply represents the main risk on local communities. The Water class occupies an area of 27.91 Km^2, with a percentage of 0.42% in ETM 2002 and 86.84 Km^2 with a percentage of 1.32% in TM 1990, respectively, as shown in Tables (1) and Figs. (10 and 11).

Fig.12: Tigris River
(nearby Ali Al-Gharbi city)

Fig.13: Al-Teeb River
(nearby Iranian border)

─ **Wetland Class:** There are two types of Wetlands in the study area. The first type is the natural marshes represented by eastern part of Hor Al-Sa'diya, northern parts of   Hor Al-Dujailah and Hor Al-Sannaf, they were dried during the acquisition date of ETM 2002 and TM 1990 images, except Hor Al-Sannaf, which receives water from Al-Teeb and Khar Khar Rivers (Fig.14). Hor Al-Sa'diya was filled by water during the period of field checking (Fig.15). The second type of Wetlands was formed as a result of human activity represented by the irrigated agricultural lands, but when flooded by water they will take the same reflectance of Wetland in satellite images, however, they can be classified using visual interpretation. The wetland class occupies an area of 182.13 Km^2 with a percentage of 2.77% in ETM 2002, and 64.1 Km^2 with a percentage of 0.98% in TM 1990, as shown in Tables (1) and Figs. (10 and 11).

Fig.14: Northern part of Hor Al-Sannaf

Fig.15: Hor Al-Sa'diya

─ **Agricultural Land non-Vegetated Class:** There are three types of Agricultural Land non-Vegetated in the study area, these are Harvested Cropland (Fig.16), Cultivated Land and Idle Cropland, which is left as a result of the bad use of irrigation system and the overuse of water in irrigation (Fig.17). Crops in this class are typically wheat and barley. Land covers of these types are commonly located adjacent to Tigris River. The Agricultural Land non-Vegetated class occupies 799.07 Km^2 with a percentage of 12.16% in ETM image 2002, and 407.69 Km^2 with a percentage of 6.21% in TM image, as shown in Tables (1) and Figs. (10 and 11).

Fig.16: Harvested Land
(nearby Ali Al-Sharqi)

Fig.17: Idle Cropland
(north Ali Al-Gharbi town)

─ **Vegetated Land Class:** Vegetated Land includes all vegetation cover, which grow naturally or by human activities like agricultural land. The agriculture lands in the study area are based mainly on the grain yield production and, to a lesser extent, on corn in the lowland adjacent to Tigris River. These lands are irrigated by net irrigation canals whereas, the relatively higher lands depend on rainfall. As a result of the irregular rainfall in the highland, the agricultural productivity is very low. In addition to the aforementioned vegetations, reeds, sedges also occur as small communities, which grow in swamps and beside the banks of the rivers (Fig.18). Shrubs mostly comprised herbaceous plant species that are mainly less than one meter in height. They are distributed as scattered plants or small communities on the majority parts of the study area (Fig.19). The class Vegetated Land occupies 607.49 Km^2 with a percentage of 9.25% in ETM image 2002, and 671.38 Km^2 with a percentage of 10.22% in TM image1990 as shown in Table (1) and Figs. (10 and 11).

Fig.18: Reeds and Sedges
(nearby Sayyid Aqul village)

Fig.19: Shrubs
(nearby Khar Khar River)

▪ **Barren Land Class**

The total area of Barren Land covers 4947.94 Km^2 in ETM image 2002 and 5336.05 Km^2 in TM image 1990. The percentage of Barren Land is 75.31% in ETM 2002 and 81.22% in TM 1990, as shown in Figs. (20 and 21). This percentage represents a good indicator for land degradation extent and the actual size of the desertification problem. Subcategories of Barren Land in the study area include Mixed Barren Land, Salt Flat and Sand Dune, each one of these sub-categories is described hereinafter:
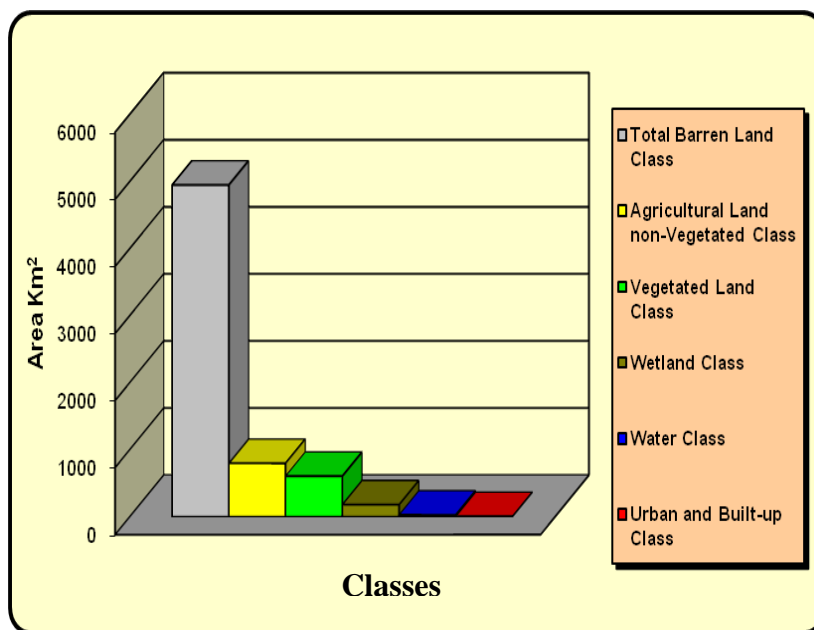

Fig.20: The percentage of total Barren Land as compared
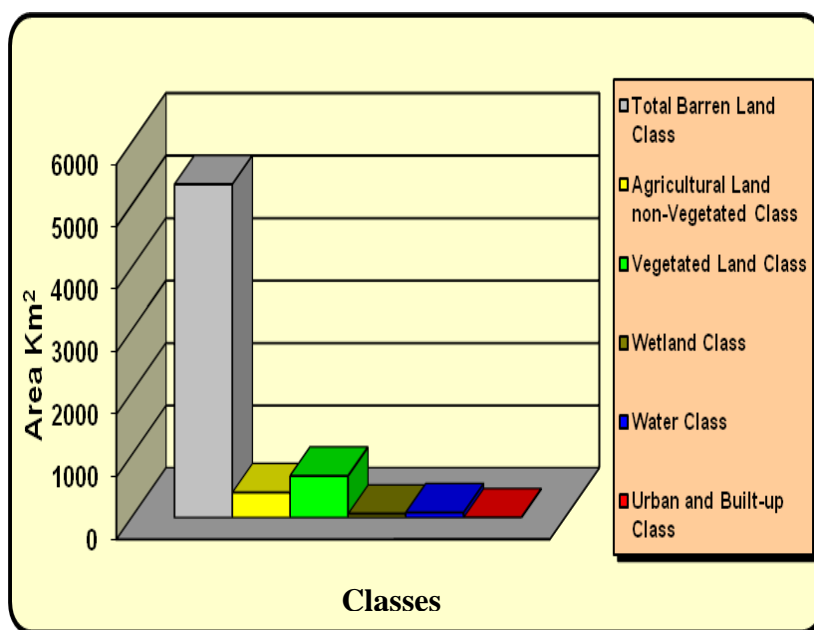with the other LULC classes in ETM 2002 image

Fig.21: The percentage of Barren Land class as compared
with other LULC classes in TM 1990 image

─ **Mixed Barren Land:** The Mixed Barren Land in the eastern part of the study area is represented by weathered and eroded materials of sand, silt and clay, with residual gravels (Fig.22A and B). These sediments belong to Bai Hassan and Mukdadiya formations. Whereas the majority of this class is represented by different Quaternary sediments, which have a wide extension in the study area. It is classified on the basis of spectral reflectance and field checking, which involve different types of sub environments like flood plain, sheet run off, slope sediments, alluvial fans and valley terraces.

Field checking of the Mixed Barren Land showed different types of sediments, which can be demonstrated depending on recent environment sediments, variation of soil texture from place to another, soil moisture, salt content and degree of consolidation. Most parts of the study area are characterized by mud flats (Fig.23A); with different degrees of salt and moisture contents (Fig.23B). Mixed Barren Land covers 4097.58 Km^2 in ETM image 2002 and 4529.44 Km^2 in TM image 1990, as shown in Tables (1). The percentage of Mixed Barren Land occupies more than 62.37% of the study area in ETM 2002 image while in TM 1990 image it occupies more than 68.94% and then represents the main land cover class; as shown in Figs. (26 and 27).

A- Gravel quarry
(nearby Al-Teeb Bridge)

B- Gravel sediments
(nearby Al-Teeb Bridge)

Fig.22A and B: Mixed Barren Land Gravelly sediments

A- Mud flat
(northeast Ali Al-Gharbi)

B- Salt and moisture contents
(northeast Ali Al-Gharbi)

Fig.23A and B: Mixed Barren Land

‒ **Mixed Salt Flat:** There are wide areas of interference (mixed area) between Mixed Barren Land and Salt Flat class were added to Mixed Barren Land class in LULC classification. Whereas, the distinction of the Salt Flat area with high accuracy requires high spectral resolution data. The distribution of the interface areas occur adjacent to the Salt Flat class area or in contact with these two classes. The Mixed Salt Flat occupies 668.02 Km^2 in ETM 2002 and 623.18 Km^2 in TM 1990 images. Table (2) and Figs. (24 and 25) show the distribution of these areas.

Table 2: Mixed Salt Flat of ETM 2002 and TM 1990 images

Class name	Image date	Area (Km^2)	Area%
Mixed Salt Flat	**ETM 2002**	668.02	10.17
	TM 1990	623.18	9.48

‒ **Salt Flat (Sabkha):** Salts tend to concentrate on the soil surface in low lands and dry areas, which are previously irrigated. As salinity increases, more salts will appear on the soil surface. Naturally, most of the salt-affected areas are saline due to human activities, which increase the salinization hazard. The results of this study indicate that the Landsat ETM image 2002 and TM image 1990 can be used to determine salt flat areas, which are characterized by high reflectance, due to their high salt content and salt efflorescence on the soil surface, but with low accuracy.

However, the authors believe, that the available data are insufficient to distinguish between barren land (Fig.28) and low salt flat (Fig.29), most probably attributed to low spectral resolution of the satellite data. It is also noticed that there is a big interference between dry barren land and low salt flat (Sabkha), because both of them have high spectral reflection. The field observation revealed that some flat barren lands are mantled by very thin veneer of salt; this may caused the aforementioned interference. The Sabkha in the study area has developed rapidly through the last years (Fig.30).

Salinization occurs on irrigated land under arid conditions, when salts are added by irrigation water and not washed away by rainfall. In addition to the effect of some other factors; such as the groundwater level which is near to the surface during most time of the year a thing which led to the accumulation of salt curst on the surface, in addition, the salt curst is formed on the surface of dry marshes in the study area. Salty marsh areas with limited living plant covers are located in the eastern part of Hor Al-Sa'diya and the northern part of Hor Al-Dujailah. The variation of physical properties of salty soils affect the variation of reflectance of this class such as the moisture content, which represents an important factor (Fig.31).

The salt flat covers area is 281.59 Km^2 in ETM 2002 image and 230.49 Km^2 in TM 1990 image, as shown in Table (1). The percentage of this class occupies 4.29% of the study area, in ETM 2002 image, while in TM 1990 it occupies 3.51%, as shown in Figs. (26 and 27). These percentages represent the pure sabkha, whereas the areas that have an interference between a very thin film of salt, on the surface of the soil or a dry bare soil without vegetation, which cannot be totally separated by a supervised classification, therefore they were added to the Mixed Barren Land as it was mentioned before.
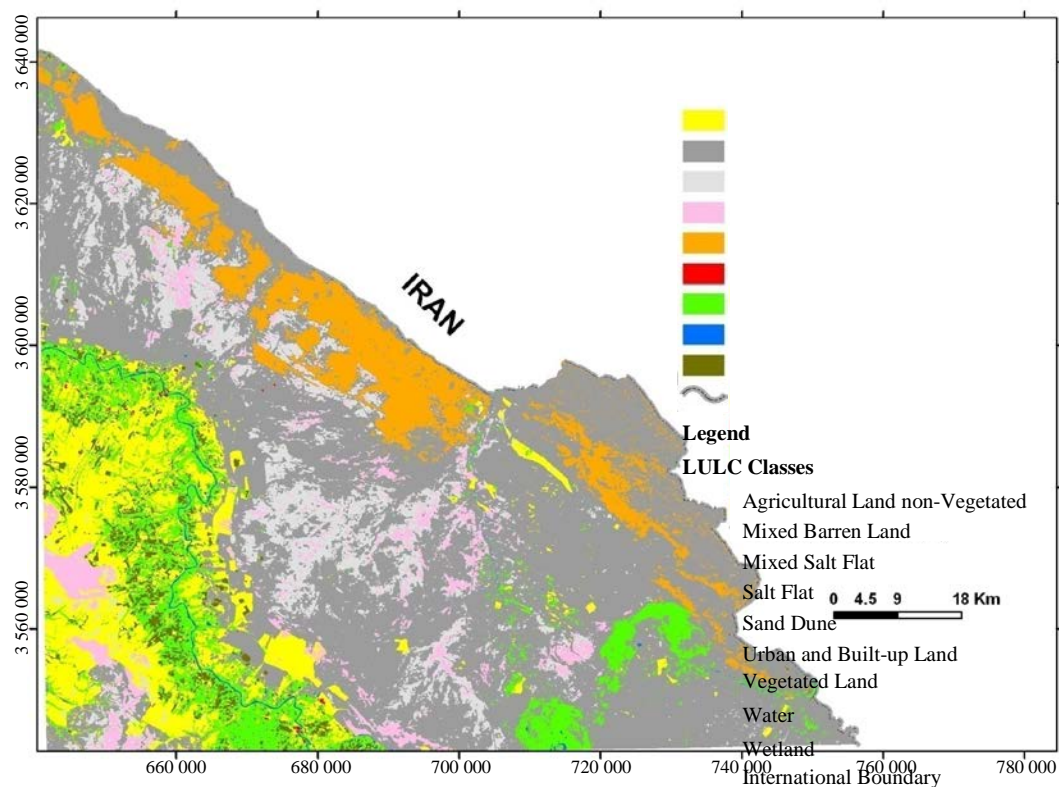
Fig.24: LULC Map showing the distribution of Mixed Salt Flat
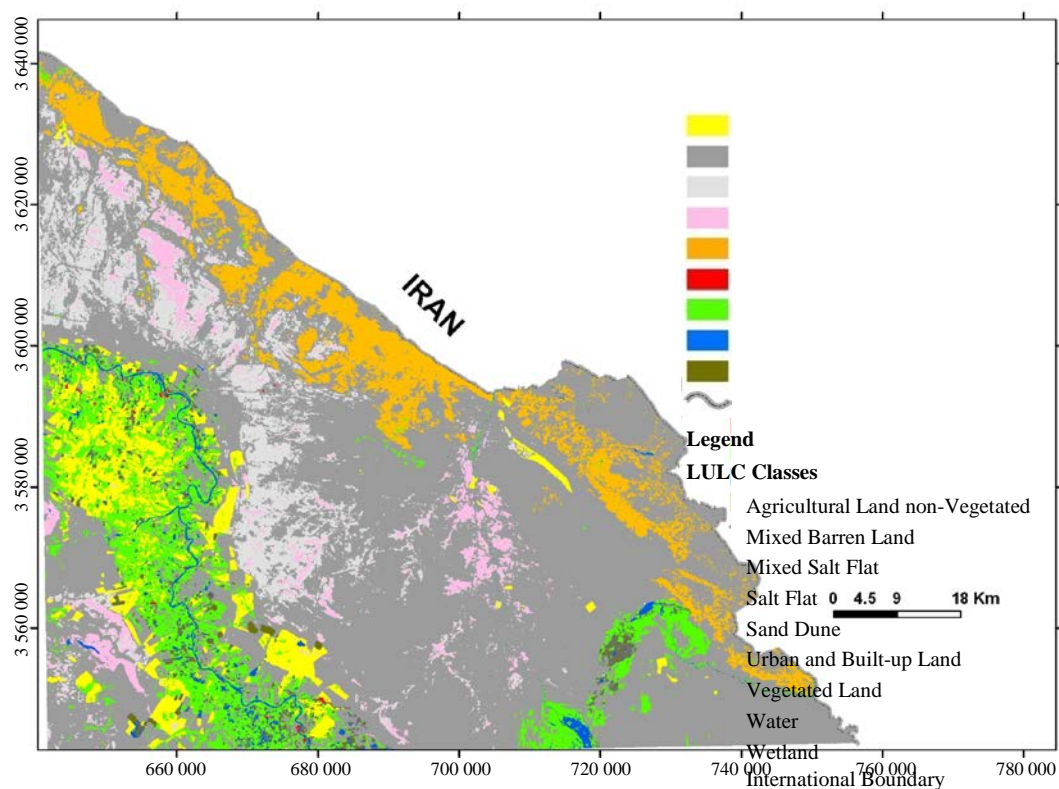(Landsat ETM 2002 image)

Fig.25: LULC Map showing the distribution of Mixed Salt Flat
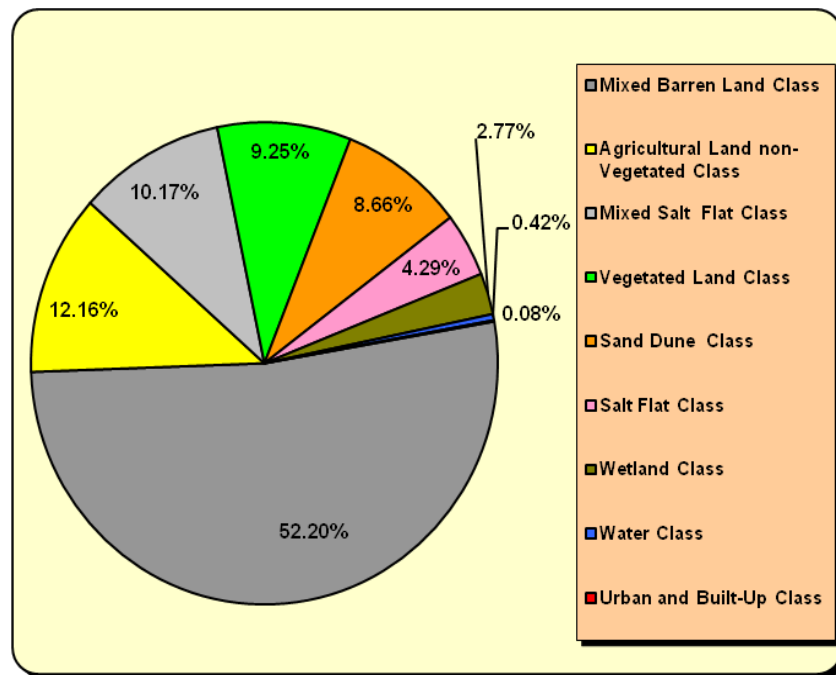(Landsat TM 1990 image)

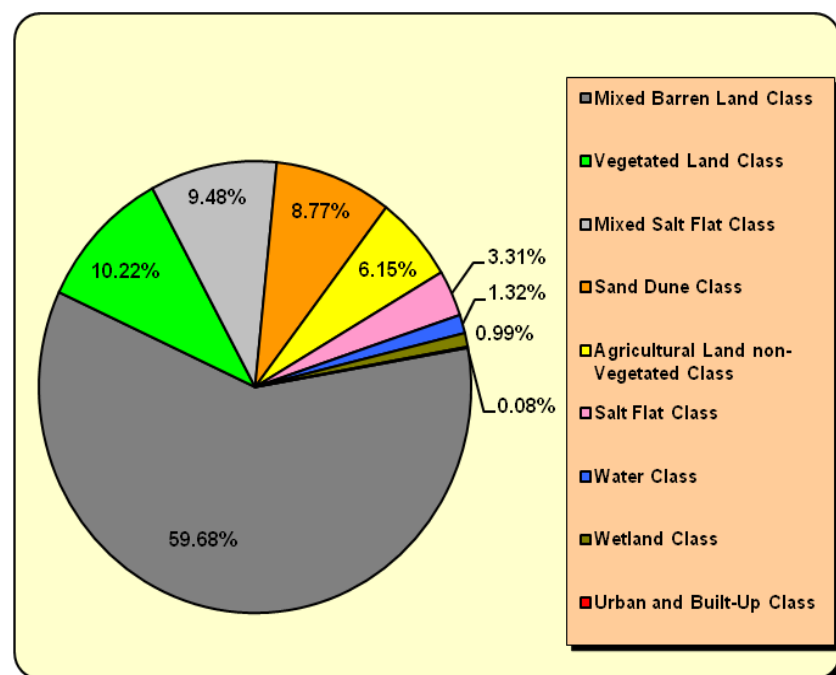Fig.26: Percentage of LULC classes with mixed salt flat of
ETM 2002 image

Fig.27: Percentage of LULC classes with mixed salt flat of
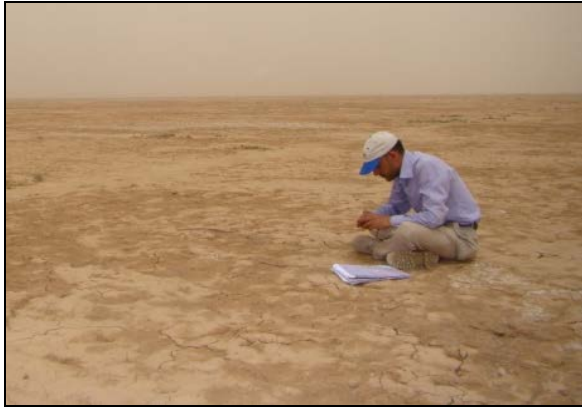TM 1990 image

Fig.28: Dry barren land
(NE Ali Al-Gharbi city)

Fig.29: Low salt flat
(NE Ali Al-Gharbi city)

Fig.30: Salt flat (Sabkha)
(NE Ali Al-Gharbi city)

Fig.31: Moist salt flat
(near Hor Al-Dujailah)

– **Sand Dunes:** The study area is characterized by two broad morphological units of aeolian sediments which can be subdivided into two types: **1) Sand dunes**, which form a relatively high relief and extend in NW − SE trend, **2) Sand sheet**, which covers a low relief. Sand sheets and Nabkhas occur in the middle part of the study area (Fig.32). Sand dunes can be clearly recognized in the satellite images with sparse or non-vegetation. Barchan and transverse dunes were formed along the Iraqi – Iranian border covering vast areas (Figs.33A and B).

Fig.32: Nabkha (near Chlat village)

A) Sand dunes (NE Khar Khar River)   **B)** Barchan dunes (NE Khar Khar River)

Fig.33A and B: Sand dunes

The area covered by sand in ETM image 2002 is 568.77 Km^2 with a percentage of 8.66% and in TM image 1990 it is 576.12 Km^2 with a percentage of 8.77%; as shown in Table (1). Figures (20 and 21) show the percentage of this class in ETM 2002 and in TM 1990 images.

▪ **Morphology of Aeolian Sediments**

In general, the primary determinant of dune forms in any given area is the nature of the wind regime of that area. Most dunes classification schemes are based primarily on the direction and intensity of the winds carrying the sand. Several studies identify wind regime and wind power as the most important physical factors in determining the mobility of dunes (Fryberger and Dean, 1979).

The wind parameters include wind velocity (above the threshold required to keep sand in saltation) and directionality (Noam *et al*., 2009), as sand mobility is a function of wind power related to the cube of the wind speed above the threshold speed (Bagnold, 1941). In addition to the other factors that have a great effect on the formation of sand dunes, like abundance of sand, the presence or absence of vegetation, topography, the nature of surface material and the dominant grains sizes of the sand which are contributing factors and must be taken into consideration (Fryberger and Ahlbramdt, 1979).

The morphology of the described sand dunes types depends on the shape and distribution of the dunes. A complex wind regime exists currently in the study area. The north – west winds are dominant and the south – east winds, although subordinate, play a role in shaping the sand dunes. The complex wind regime has produced a variety of dune types which include transverse (or barchanoid), reversing, parabolic, barchan and windblown dunes (Andrews, 1981). Merk (1960) described these complex transverse dunes as consisting of large primary dunes also called transverse dunes that have slip faces on the east, formed by winds blowing from the west, and smaller sharply defined secondary dunes that have slip faces on the west were shaped by winds blowing from east to west. Through the saddle on the crest, this wind direction in the northern part of the area drifted sand high onto alluvial fans and adjacent low land.

▪ **Types of Sand Dunes**

In the study area, simple and compound dune types (active types) are common. The simple type is represented by the barchan dunes, which are very common. The barchanoid ridges represent the compound dune type, which are less common. Nabkhas and sand shadows represent the fixed dune types, which are less common, and their occurrences are variable from place to another. Detailed descriptions for these types are represented hereinafter:

─ **Barchanoid Ridges and Barchan Dunes:** The barchanoid ridges and barchan dunes are observed in the field checking with a variation in distribution and density from place to place. Barchan dune is a free transverse dune with a crescent plan-shape in which the crescent opens downwind (Steven *et al*., 2002).

The simple form of barchans is an individual crescent feature; most of them are formed on the pre-Quaternary and Quaternary sediments and extend along the international Iraqi – Iranian borders as a strip within the study area. They display a wide range of sizes from great widths to few meters (Fig.34). Generally, dunes trend from NW to SE, which reflects the dominant prevailing wind direction influence. Some of the dunes in the southeastern part of the study area are typically orientated in the opposite directions, affected by southeastern wind and can be called reversing dunes (Fig.35). Most of the sand dunes along the Iraqi – Iranian international borders are still active in movement and have a long-term negative impact on the agricultural land, oil extraction companies, human health and roads (Fig.36).
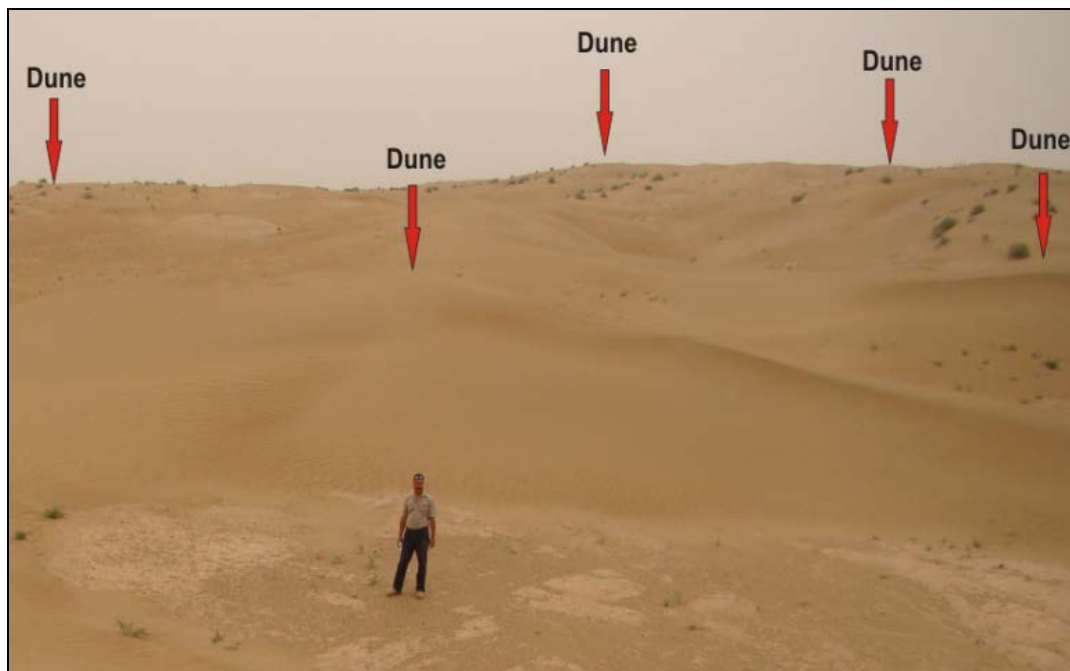

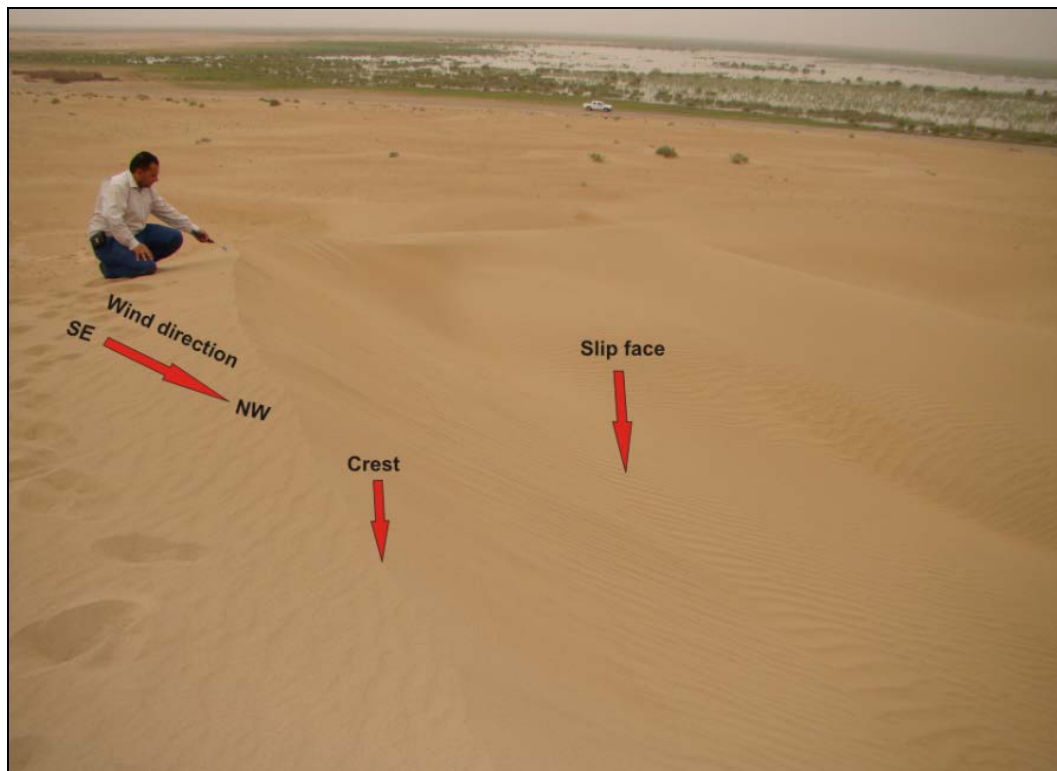Fig.34: Sand dunes with different sizes (NE Khar Khar River)
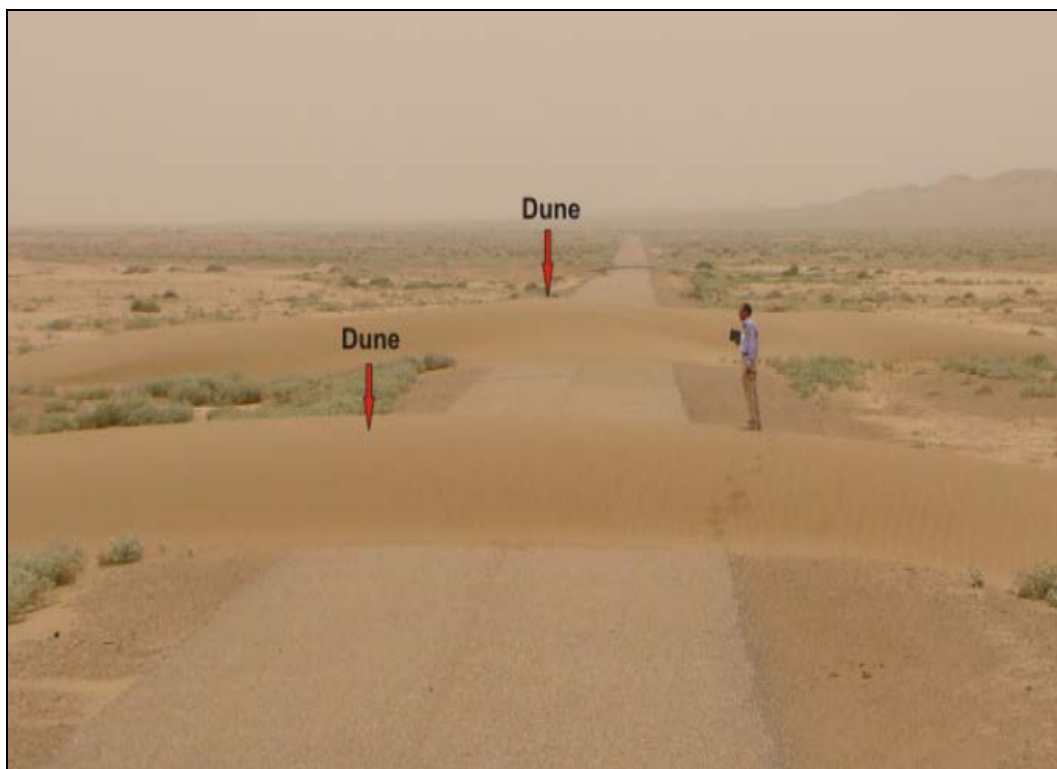
Fig.35: Reversing barchan dunes (nearby Hor Dwaireej)

Fig.36: Longitudinal sand dunes cut off the road (east Tulul A's Sur)

− **Sand Sheets and Nabkha:** Sand sheets (Zibars) are coarse-grained bed forms of low relief with no slip faces. Their surfaces consist exclusively of wind ripples and local shadow. They are regular, wave-like undulations lying at right-angles to the prevailing wind direction. The size of ripples increases with increasing particle size, but they typically range from about (10 − 300) mm in height and are typically spaced a few centimeters to tens of meters (Livingstone and Warren, 1996). This type of sand accumulation exists as scattered patches in different areas close to interdune area, as shown in Fig. (37).

Nabkha or nebkha, is an Arabic term given to mounds of wind-borne sediment (sand, silt of palletized clay) that have accumulated to a height of some meters around shrubs or other types of vegetation. The concentration of nabkha dunes is observed east of Ali Al-Gharbi district (Fig.38), and continues towards SE along Iraqi – Iranian border in front of Hemrin anticline, distributed over a wide area. The length of these aeolian sediments reaches to 3 m, with a height ranges from (0.5 − 1.4) m and a width reaches, in some places, to 2 m. The sand shadow sediments occur as tongues or ridges of fine-grained sand accumulated as small patches, in the terminology of Bagnold (1941), such accumulations are termed as sand shadows (Fig.39).

Fig.37: Wind ripples (NE Khar Khar River)

Fig.38: Sand sheets, sand shadow and Nabkha dunes (near Al-Jany police post)

Fig.39: Sand shadow sediments as tongues (near Al-Jany police post)

− **Fixed Dunes** (**Stabilized Sand Dunes):** Fixed dunes may be fixed by vegetation or by human activities, which have little or no movement. The fixed dunes are distributed in the middle of the northwestern part of the study area. Those dunes are covered by clayey layer to

fix them, in addition to farming some types of vegetation that have the ability to tolerate hard environmental conditions. Fixed dunes are noticed scattered within the areas as nabkha. Nabkha are distributed within scattered flats, which are covered by grasses during periods of precipitation (Fig.40). There are many attempts to fix sand dunes, sand sheets and nebkha by using clayey bed cover and planting, these attempts have succeeded in some places but they were threatened to fall down in other places. The clayey layer is crashed or destroyed in some places as a result of its thin thickness and the absence of maintenance work in addition to the severe climate conditions (Fig.41).
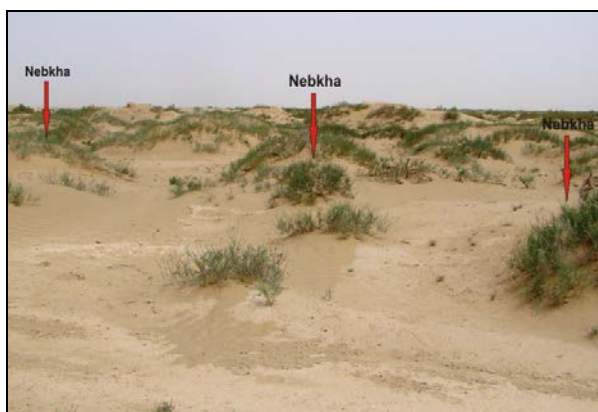

Fig.40: Nabkhas covered by grasses
(SW Al-Jany police post)

Fig.41: Nabkhas covered by artificial clay
layer (SW Al-Jany police post)

IMAGE INDICES AND CHANGE DETECTION
▪ Image Indices

Indices are used to create output images by mathematically combining the DN values of different bands. The following indices are applied in the present study:

─ **Normalized Difference Vegetation Index (NDVI):** Vegetation indices derived from satellite data are one of the primary sources of information for operational monitoring of the earth vegetative cover (Gilabert *et al*., 2002). Vegetation indices combine reflectance measurements from different portions of the electromagnetic spectrum to provide information about vegetation cover on the ground (Campbell, 1996). NDVI is an effective indicator to show the surface coverage condition of vegetation and it is computed as:

$$NDVI = \frac{NIR - R}{NIR + R}$$

Where: NIR = near infrared band (band 4 in TM and ETM data satellite images)
R = red band (band 3 in TM and ETM data in Landsat satellite images)

The TM 1990 and ETM 2002 images data were applied for monitoring vegetation changes in the study area. The distribution of vegetation covers, which is extracted from NDVI of two images, is shown in Figs. (42 and 43). Table (3) shows the area which is occupied by vegetation in two acquisition dates. The vegetation cover is decreased in ETM 2002 as compared with TM 1990 images. The variation in the occurrence of vegetation cover along both banks of Al-Teeb River is mainly related to the amount of water that flow from Iranian territory.
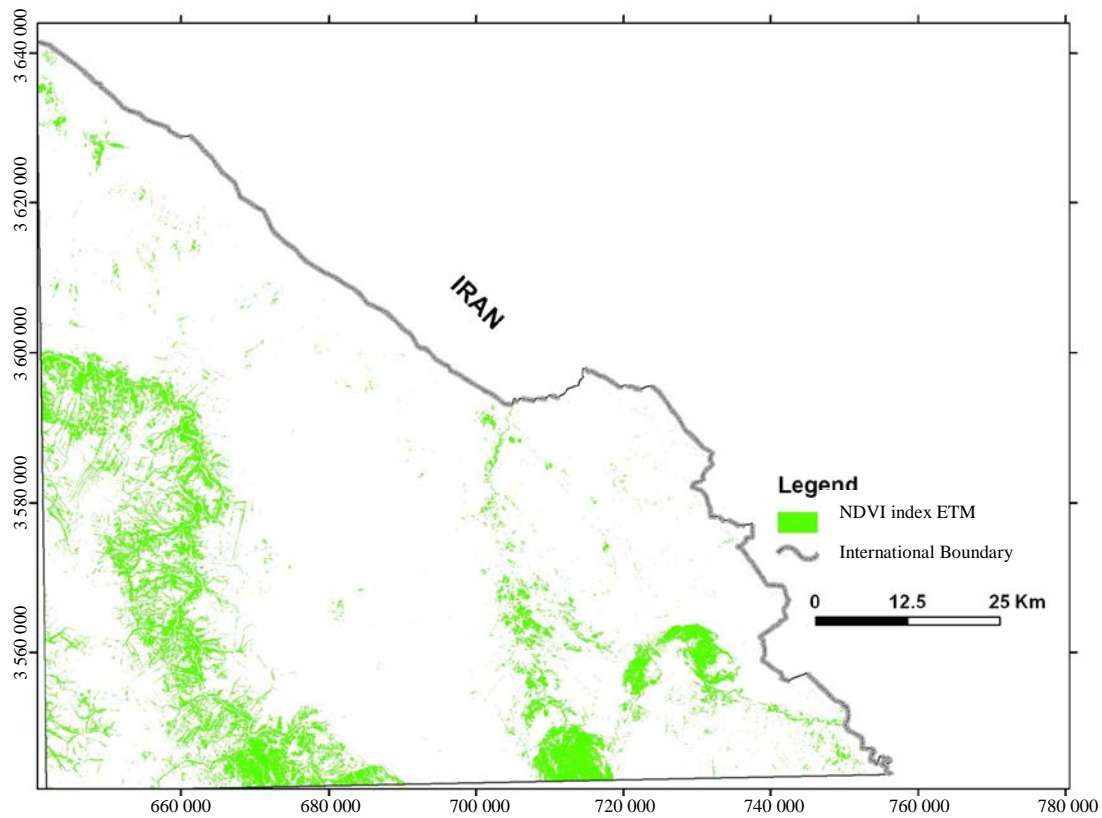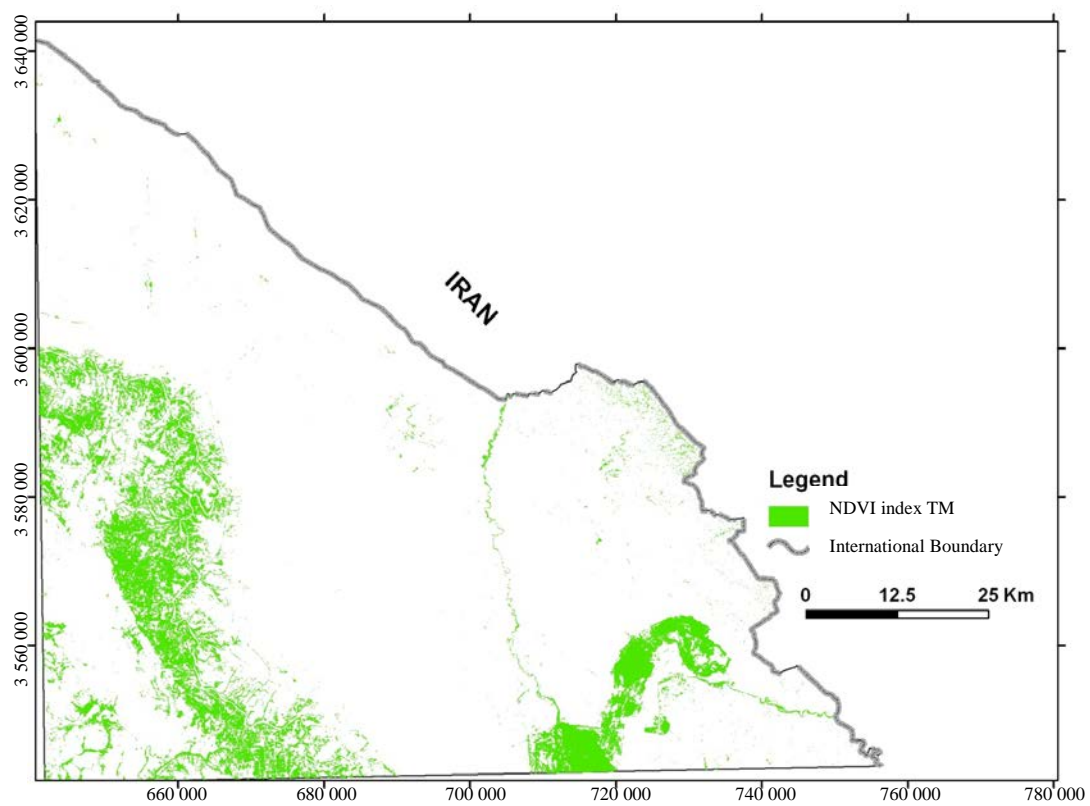
Fig.42: NDVI of ETM 2002 image

Fig.43: NDVI of TM 1990 image

Table 3: Image indices of TM 1990 and ETM 2002 images

Date / Images Indices	Area (Km²)	
	TM 1990 image	ETM 2002 image
NDVI	651.55	626.88
AMI	579.37	569.92
SI	217.84	291.75
NDWI	160.23	218.00

─ Normalized Differential Water Index (NDWI): The Normalized Differential Water Index was used to oversee the situation of water in the study area. Water index was computed by the summation of NIR and SWIR and divided by two (Al-Jaf and Al-Saady, 2009) as shown in the equation below.

$$NDWI = \frac{NIR + SWIR}{2}$$

Where: SWIR = short wave infrared band

The spectral region clearly enhanced water bodies to the brighter pixels or lowest value of this index represented the surface water. The areas covered by water is equal to 160.23 Km² in TM 1990 image and 218 Km² ETM 2002 image, the increase in water class in ETM 2002 image mainly belongs to the increase in the size of water body of northern part of Hor Al-Sannaf and the accumulation of water drained from the agricultural land in the low relief land area as the eastern part of Al-Sa'diya marsh which is characterized by a saline water, as shown in Table (3). The distribution of the surface water in two images is explained in Figs. (44 and 45).

─ Aeolian Mapping Index (AMI): The wind erosion in the study area was analyzed and evaluated using Aeolian Mapping Index (AMI). AMI is a simple model, which has been developed to generate an image that emphasized areas with low vegetation density and high soils reflectance.

The image product shows various shades of yellow color indicating levels of low vegetation density and high soils reflectance, and serves as a guide to estimate the relative level of erosion potential/vulnerability by wind. TM 1990 and ETM 2002 images are used respectively to generate the aeolian mapping Index (AMI).

The AMI index used the red and near-infrared (R/NIR) spectral bands from the Landsat images to generate an image that emphasizes areas with low percentage cover/density and/or high surface-soil reflectance. The near-infrared and red bands along with the ratio of the red to near-infrared bands (NIR, R and R/NIR) are used as the red, green and blue (RGB) components to make color composite (Khairy, 2007).

The covered areas by aeolian sediments are 579.37 Km^2 in TM 1990 image and 569.92 Km^2 in ETM 2002 image as shown in Table (3). The distribution of aeolian sediment in two images is explained in Figs. (46 and 47). The decrease of the area covered by aeolian sediments is due to the efforts that were carried out by the desertification combat office, whereas there are many efforts which have been carried out to restrict it such as covering it by clay and a forestation.
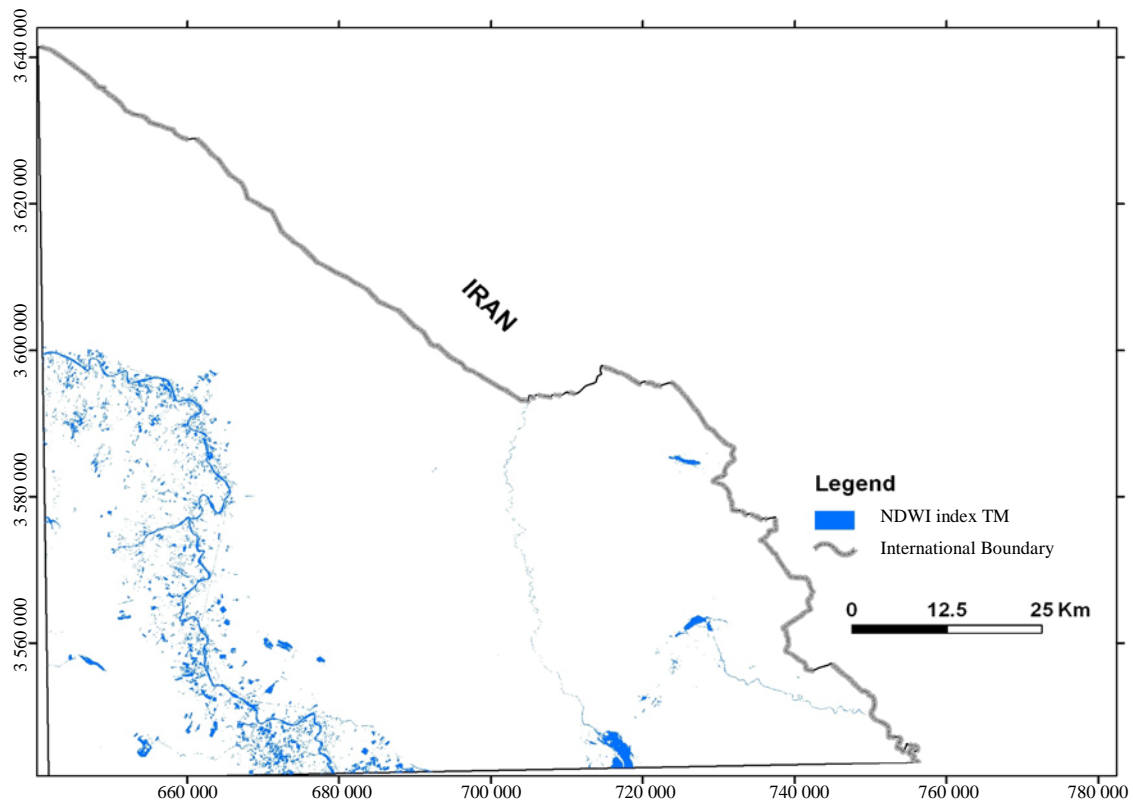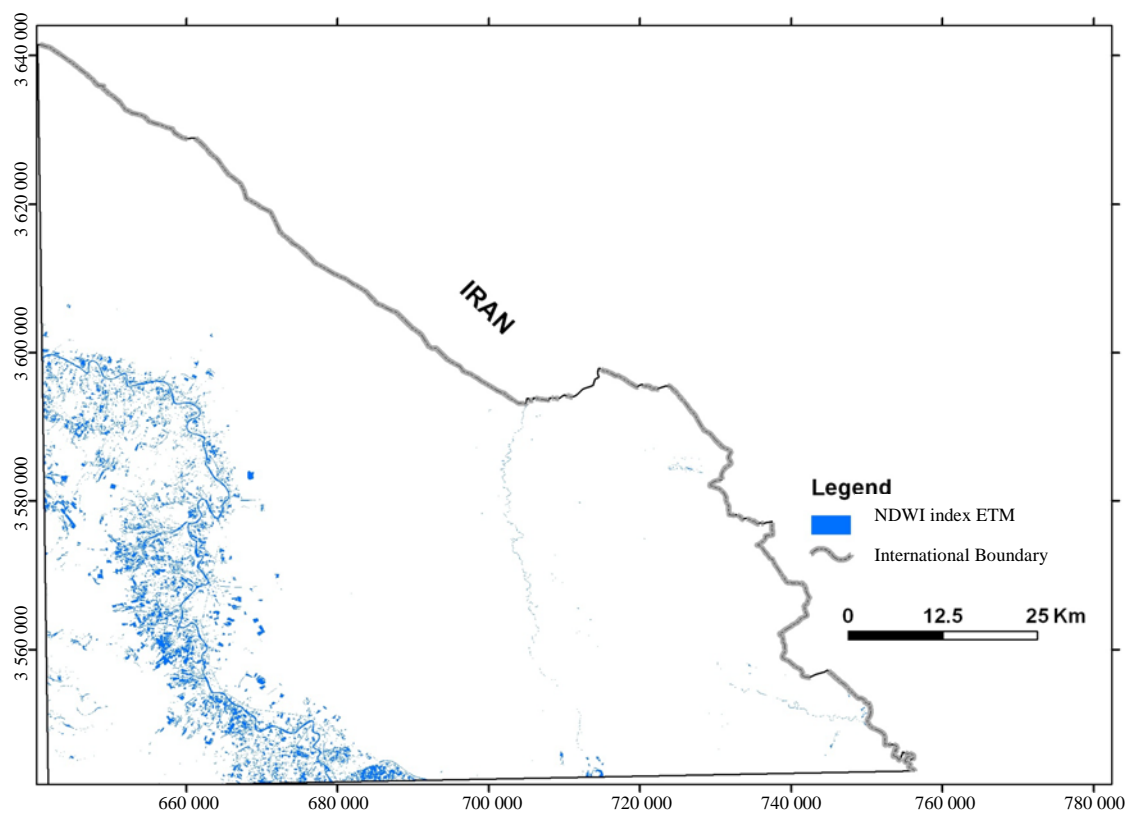
Fig.44: NDWI of ETM 2002 image
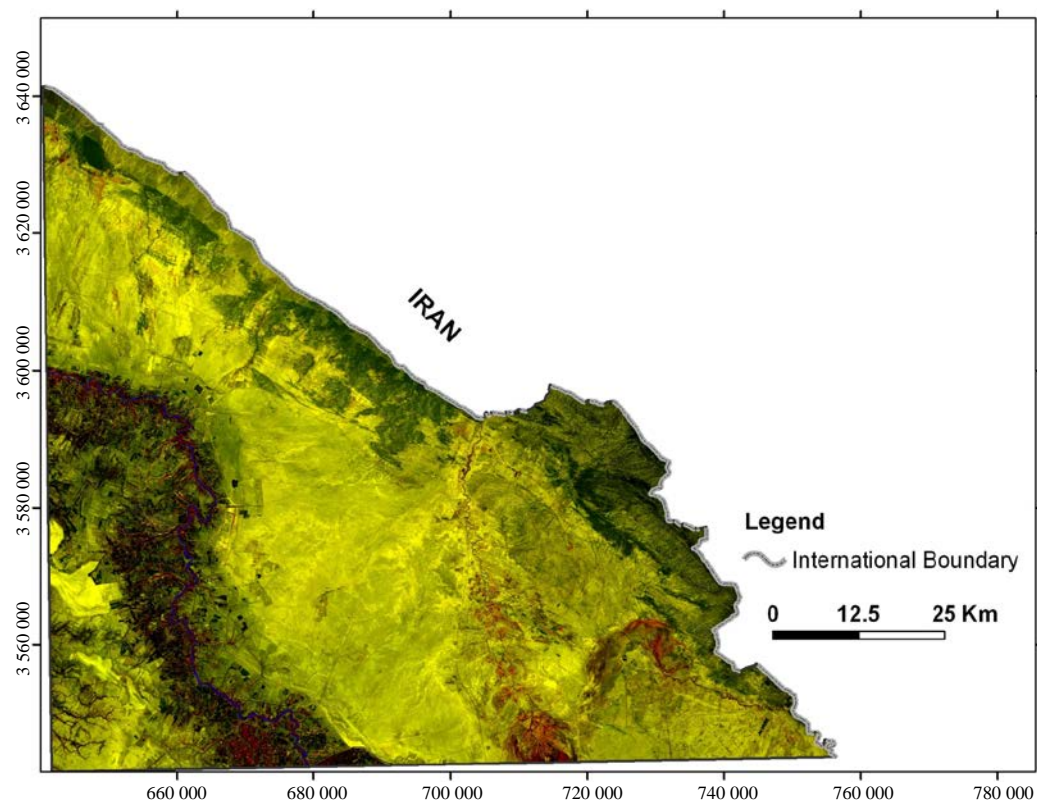

Fig.45: NDWI of TM 1990 image
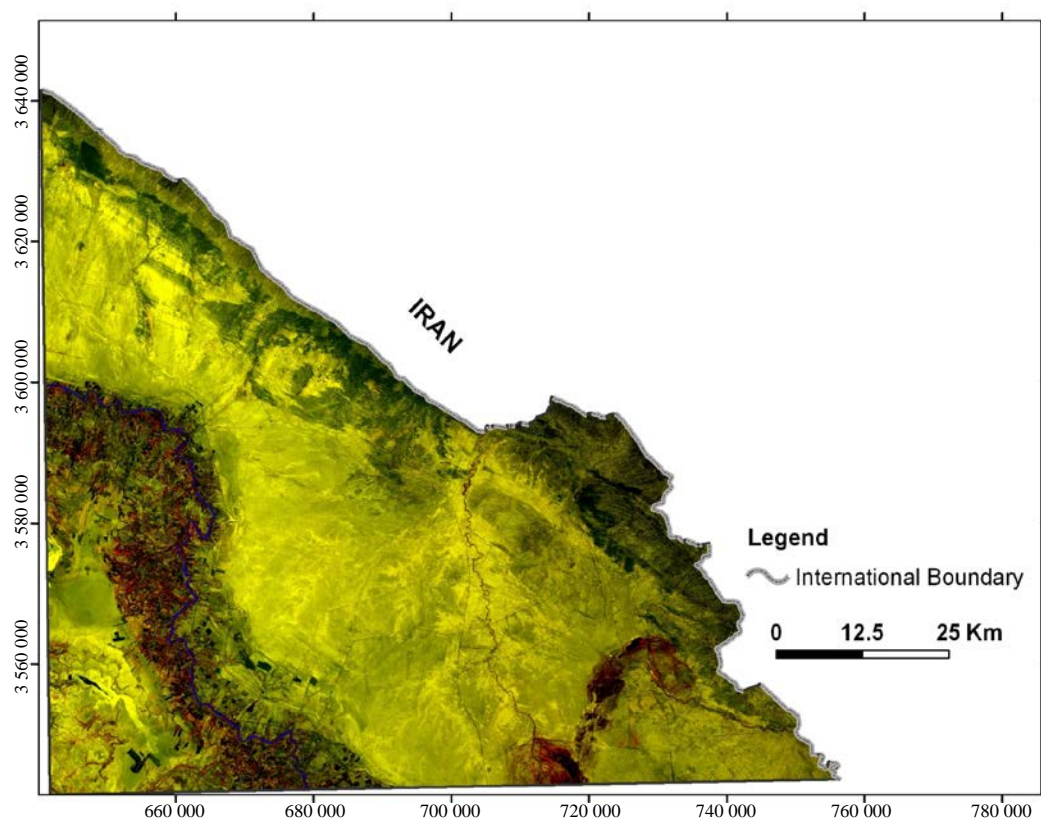
Fig.46: AMI of ETM 2002 image

Fig.47: AMI of TM 1990 image

─ **Salinity Index (SI):** Salinity Index showed that there is a possibility to detect the salinity by using the ETM 2002 and TM 1990 images. The equation of Salinity Index (Al-Jaf and Al-Saady, 2009), as mentioned below, was used to determine the saline soils in the study area using remote sensing data:

$$S\,I = \frac{Green + \mathrm{Re}\,d}{2}$$

The higher spectral reflection represents high saline soil. The areas covered by saline soil equal to 217.84 Km^2 in TM 1990 image and 291.75 Km^2 in ETM 2002 image as shown in Table (3). The results of saline soil distribution in TM 1990 and ETM 2002 images are shown in Figs. (48 and 49).

▪ **Change Detection**
In the current study, post classification comparison and change vector analysis were used to determine the change detection in aeolian sediment movements and LULC map area according to the results of the supervised classification and image indices. The accuracy of this change detection method depends on the resolution of two dates image classifications. The change detection statistics illustrate the change of each class feature by pixels and by percentages within the study area.

─ **Change Detection of Image Classification:** Post classification comparison was used to produce a detailed tabulation of changes between the two classified images. The TM image 1990 classified map was input as an initial state and the ETM 2002 classified map was input as a final stage. The result shows the changes of land use from the initial state into the final stage.

According to the change detection result (Table 4 and Fig.50) from 1990 to 2002, soil class has decreased to 432.23 Km^2, whereas Agriculture Land Non-Vegetated has increased to 391.23 Km^2 within this period. The decrease of soil class in ETM 2002 image can be considered as a good indicator for more reclamation of agricultural lands and the increase of the farming activities. On the contrary, this improvement is encountered by the increase in Agriculture Land Non-Vegetated (idle land) as a result of deterioration in irrigation system, and decrease of governmental support, in addition to an increase of salt level in soil. Whereas, salt flat class has increased to 51.08 Km^2 as an indicator to deterioration and water bodies have decreased to 58.93Km^2. The increase and decrease of each LULC category are shown in Table (4).

─ **Analysis of Land Degradation Risk:** Natural factors and human activities have played a role in the process of land degradation. The environmental limitations, such as aridity (rare precipitation), limited water resources and water overuse, represent the main causes of desertification. Most of the study area has a high potential risk of land degradation. However, the areas with high potential risks of land degradation have increased significantly from 1990 to 2002.
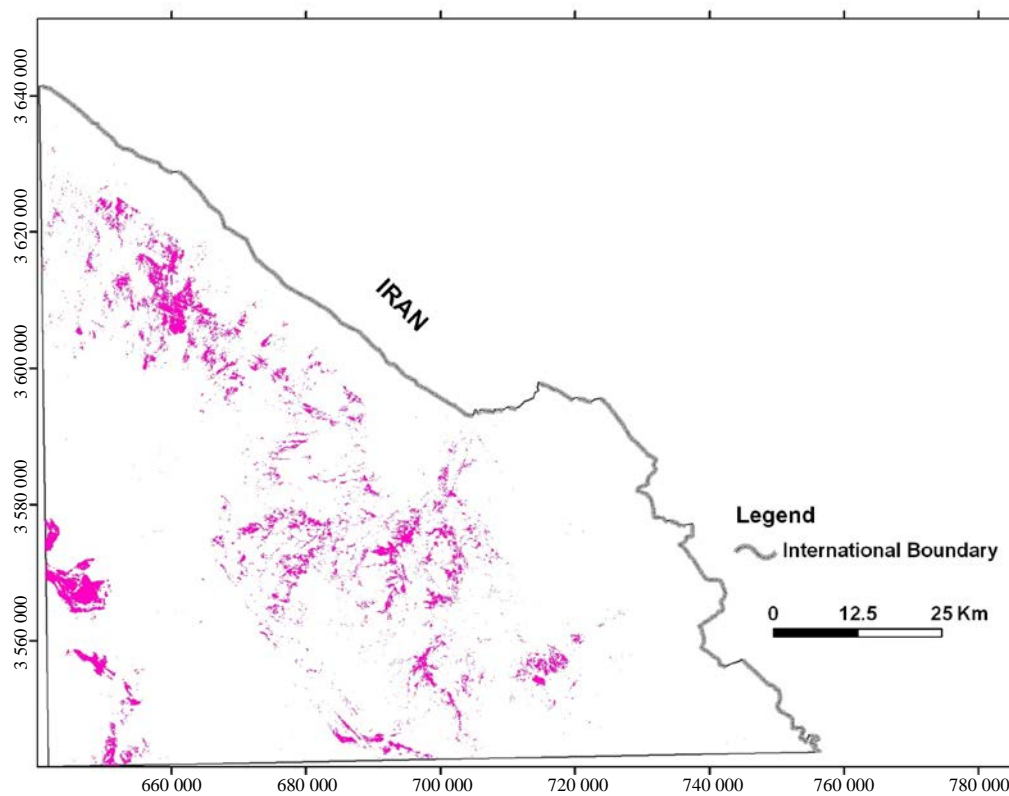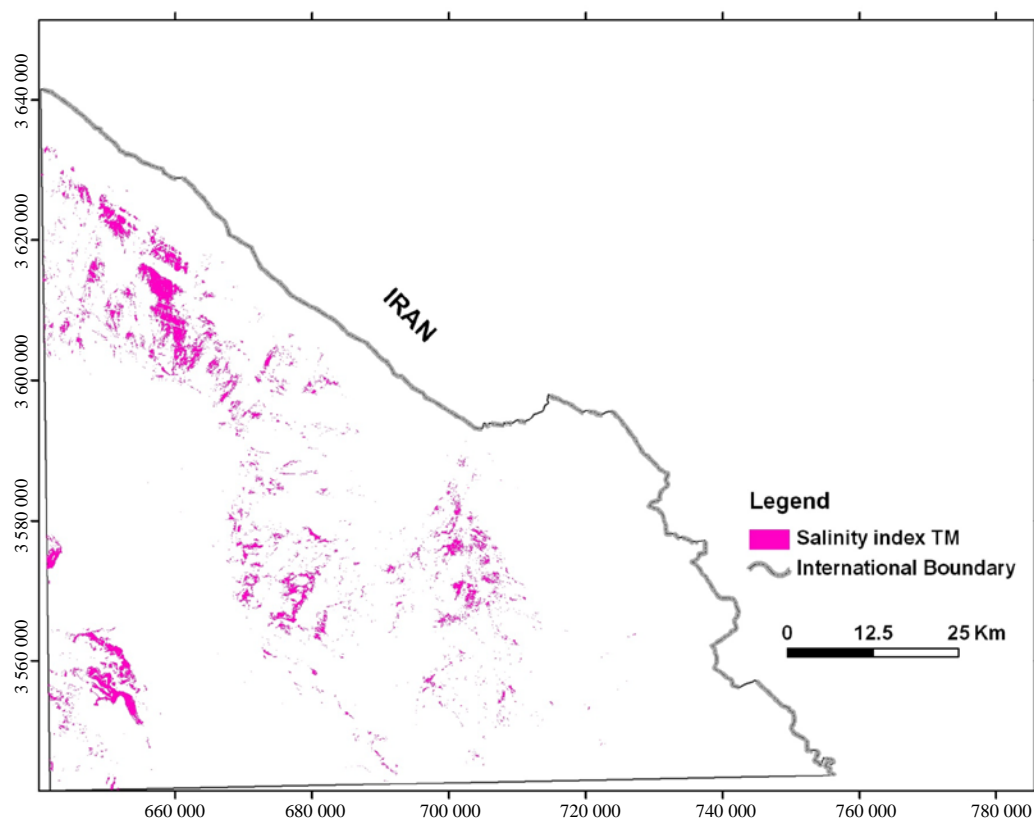
Fig.48: Salinity index (SI) of ETM 2002 image

Fig.49: Salinity index (SI) of TM 1990 image

Table 4: Change detection results of ETM 2002 minus TM 1990 images

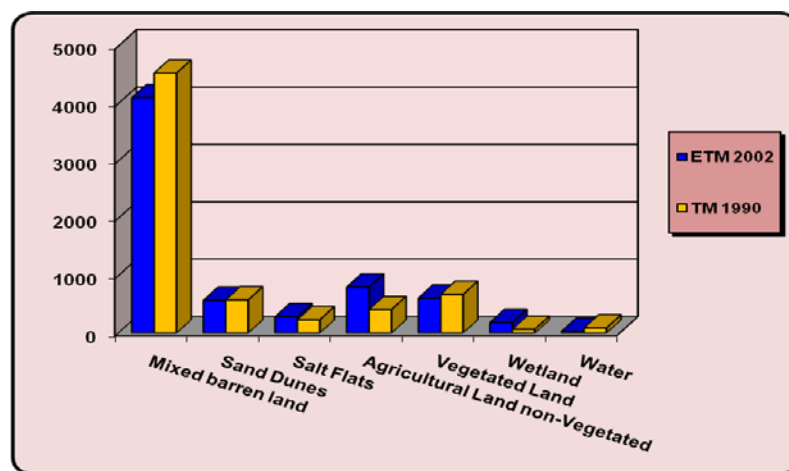| Class Name	Area (Km^2)	Area%
Mixed Barren Land	– 432.33	– 6.55
Sand Dunes	– 7.32	– 0.11
Salt Flats	+ 51.08	+ 0.78
Barren Land	– 388.57	– 5.88
Agricultural Land non-Vegetated	+ 391.23	+ 5.96
Vegetated Land	– 63.92	– 0.97
Wetland	+ 117.33	+ 1.79
Water	– 58.93	– 0.90
+ Refers to an increase in the class area, – Refers to a decrease in the class area		

Fig.50: Change detection results of ETM 2002 minus TM 1990 images

The overusing of the agriculture land makes the farming conditions poor, because of salinization and then increasing the risks of land degradation. The decrease in the sand dunes and other aeolian sediments (Table 4) comes as a result of the effort to fix these sediments in the middle of the area, but these effort focus on the product of erosion activity while most of these sediments come from degradation of pre-Quaternary sediments of formations in the eastern part of study area.

CONCLUSIONS

In this study, LULC changes and land degradation were determined and assessed using Landsat satellite imagery. The present study indicates that the land use changes led to the degradation of large areas of soil between TM 1990 to ETM 2002 images. The main problems that are explained in Landsat satellite images are: **1)** The separation between dry barren land and salt flat, whereas, there is a big interface between the two land cover classes. **2)** The inability to determine the urban and built up areas due to the low spatial resolutions of these data and the limitation of the urbanized areas which are occupied by urban. **3)** The limited ability of these data to distinguish between sand dunes and some flat terrain, which are covered by aeolian sediments because they have the same reflectance therefore, the separation depends on the visual interpretation. The fourth problem is the inability to distinguish between different types of vegetations. For these reasons, we advise to use high spatial and spectral data for detailed studies.

The variation in the percentages of classes between two acquisition dates of satellite images belong to natural and anthropogenic factors. The natural factors represented by climatic variable changes like rainfall, which led to variation in the amount of water and vegetation cover and also soil water content. The anthropogenic factors are represented mainly by variation in the vegetated and agricultural non-vegetated land and consequently affect the area of barren land.

Soil salinity caused by natural or human-induced processes is a major environmental hazard, which led to the reduction of the crop production as salinity levels increase, whereas the plant must spend more energy to take up more saline water from the same soil water content. The unsuitable irrigated systems represent the main problem for land degradation.The continuation of aeolian deposits progressive in spite of the efforts exerted to stop it related with the way and place, which was choosing to fix this problem. Most of these efforts deal with the result of dunes extended in the central part of the study area, thus covered by clay or farmed by some grasses.

From the results of this study, it can be concluded that the main source of aeolian deposits in the study area is the erosion of sediments and the exposed older geological formations which have high content of sandy silty material. Therefore, the best way to treat or restrict the creep of aeolian deposits is by fixing these deposits at the source, or fixing the main cause of the problem.

RECOMMENDATIONS

Landsat TM and ETM were used to detect the changes of LULC and to identify the land degradation in the study area to improve LULC classification and to detection the land degradation. From our analysis, it could be observed that a large amount of soil was degraded.

Salinization is one of the main reasons for soil degradation; thus, the improvement of soils would be an effective way to prevent land degradation. Promoting a forestation activity in the study area could contribute in the limitation of desertification. Forestation activities could be applied in the study area by the governmental organizations. In addition, wetlands have an important role in the environment. The restoration and improvement of natural water storage can also contribute in increasing the vegetation. Therefore, more wetland areas could serve as protection against land degradation. Afforesting and enhancing the discharge water system from agricultural land can reduce erosion and degradation of top soil. The main environmental principles for reducing land degradation are to maximize vegetation by exerting vegetation strips adjacent to sand dunes along the international border to reduce the speed and volumes of sediment transport from highlands over the soil to prevent erosion and prevent accumulation of aeolian sediments. These recommendations can be put in some topics as follow:

1. There is a necessity to construct a net of discharge canal for the discharge of the excessive water that release from irrigation, this could avoid the water of Tigris River from being polluted.
2. Prevention of uncontrolled disposal of waste in the nearby rivers.
3. Prevention of uncontrolled disposal of solid wastes and creating of infrastructures for environmentally-safe solid waste disposal.
4. Using new methods for irrigation such as the dropping system.

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About the Authors

Mr. Younus I. Al-Saady graduated from University of Baghdad in 1998 with B.Sc. degree in Geology, and M.Sc. in Geochemistry in 2008. He joined GEOSURV in 2001 and currently is Ph.D. student. He has 16 documented reports in GEOSURV library and 4 published articles in different geological aspects. His major fields of interest are Environmental Geochemistry, Remote Sensing and GIS studies, Regional Geology, Land Use, Land Cover and Geomorphological maps.
e-mail: younusalsaady@yahoo.com
Mailing address: Iraq geological survey, P.O. Box 986, Baghdad, Iraq.

Mrs. Manal M. Al-Obaydi graduated from University of Baghdad in 2001 with B.Sc. degree in Geology, and M.Sc. in Heavy Mineral in 2008. She joined GEOSURV in 2001. She has 3 documented reports in GEOSURV library. Her major fields of interest are remote sensing and GIS studies, regional geology, Land Use and Land Cover maps.
Mailing address: Iraq geological survey, P.O. Box 986, Baghdad, Iraq.

Mr. Mousa Abdulateef Ahmed graduated from University of Baghdad in 1991 with B.Sc. degree in Geology. He joined GEOSURV in 2000 and currently is M.Sc. student. He has 13 documented reports in GEOSURV library and 8 published articles in different geological aspects. His major fields of interest are Remote Sensing and GIS studies, Environmental studies, Regional Geology, Land Use, Land Cover and Geomorphological studies.
e-mail: mousageo@yahoo.com
Mailing address: Iraq geological survey, P.O. Box 986, Baghdad, Iraq.