CHANGE DETECTIONS IN MARSH AREAS, SOUTH IRAQ, USING REMOTE SENSING AND GIS APPLICATIONS

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ABSTRACT

The marshes of the southern part of Iraq are considered the most outstanding feature in the area. They are developed within the Mesopotamian Plain forming natural balance between the Tigris and Euphrates Rivers and Shat Al-Arab that leads to the Arabian Gulf.

The marshes that are locally called "Ahwar" have suffered from drying processes, since early eighties of the last century. During the late nineties, large parts were dried leaving barren salty (Sabkha) lands devoid of all types of life, especially those related to the large water bodies, beside human activities. Moreover, hydrological and climatic changes that clearly could be observed in the areas involved.

To detect the considerable changes, in land use and land cover, remote sensing techniques and GIS applications were used; among these are Landsat images in three different intervals: MSS in 1973, TM in 1990 and ETM in 2000. These were used in the changes detection method. Moreover, different digital image processing techniques that are available in ERDAS program were applied. Normalized Difference Vegetation Index (NDVI) was also used to recognize the vegetation cover. The classified images were converted to vector shape in GIS media in each class; the area of each class is determined as percentage from the total coverage area of the marshes.

The current study revealed that large changes took place between 1973 and 2000 in land cover and land use. The barren land is increased; while the water bodies are decreased drastically, consequently desertification is increased causing large environmental and hydrological changes that affected on the physical and chemical properties of the soil. The soil became unfertile and not suitable for agricultural purposes. The marsh areas were also abandoned by the local people due to the mentioned changes.

Since 2004, great efforts are carried on in the marsh areas to rehabilitate and reactivate the marshes. Therefore, considerable parts of the marshes have grown again; local people started to reconstruct their communities. Some types of birds, fishes and vegetation reappeared again. The coverage area of the marshes is about 50% of the original marsh areas, hitherto.

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**تحديد التغيرات في منطقة الأهوار، جنوب العراق
باستخدام تقنيات التحسس النائي ونظم المعلومات الجغرافية**

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المستخلص

تعتبر الأهوار في الجزء الجنوبي من العراق من أكثر الظواهر البارزة في المنطقة التي تكونت ضمن السهل الرسوبي مكونةً موازنةً طبيعية بين نهري دجلة والفرات وشط العرب المؤدي إلى الخليج العربي، ويطلق عليها محليا اسم (أهوار)، وقد عانى جزء كبير منها من التجفيف منذ بداية الثمانينيات من القرن الأخير مخلفةً اراضي السبخة والخالية من كل أنواع الحياة في المنطقة، وخاصة المياه إلى جانب النشاط البشري، بالإضافة إلى التغيرات المناخية والهيدرولوجية التي يمكن ملاحظتها في المنطقة.

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استخدمت في هذه الدراسة تقنيات التحسس النائي وتطبيقات نظم المعلومات الجغرافية (GIS) لتحديد التغيرات في غطاءات الأرض، لذلك استخدمت بيانات للقمر الصناعي Landsat لمتحسسات مختلفة ولفترات زمنية متباينة، MSS1973, TM 1990, ETM 2000 وإجراء عملية التصنيف الموجه باستخدام برنامج ERDAS 9.1 وتم تحويلها إلى صيغة المتجهات ضمن بيئة نظام المعلومات الجغرافية وحساب المساحة والنسبة المئوية لكل صنف، نسبةً إلى المساحة الكلية للأهوار.

تم في الدراسة الحالية ملاحظة التغير الكبير في المساحة بين عامي 1973 و 2000 تمثل بزيادة الأراضي الجرداء على حساب المسطحات المائية، ولذلك هناك زيادة في التصحر سببت تغيرات بيئية وهيدرولوجية كبيرة أثرت سلباً على الصفات الفيزيائية والكيميائية للتربة وأصبحت غير صالحة للزراعة وأدت بالتالي إلى هجرة سكانية شاملة. ولكن منذ عام 2004 يمكن ملاحظة الزيادة الملحوظة في مساحة الأهوار الرئيسية بعد عملية إحيائها بنسبة أكثر من 50%، مما أدى إلى عودة بعض السكان وظهور بعض النباتات والحيوانات والاسماك من جديد.

INTRODUCTION

The marshes of Southern Iraq, locally called "Ahwar", were originally covering considerable parts of the Mesopotamian Plain, developed along the Euphrates and Tigris Rivers. They were developed contemporaneously with the development of the flood plains of both rivers. The main marshes are Al-Hammar and Al-Huwaizah, the latter is partly fed by running streams from Iran (Fig.1). The total coverage area of the marshes was 35000 Km² (Buringh, 1960).

The marshes form flat areas; therefore, the level of inundation by water depends on the level of the water in the Tigris and Euphrates Rivers and the related seasonal changes, because the rivers do not have levees within the marsh areas (Yacoub *et al.*, 1985). The depth of the water is also variable in different parts, within the marshes. When the depth of the water is more than 2 m, then the water devoid of any vegetation and form small lakes of clear water. Otherwise, different types of natural vegetation grow in the marshes. Different types of fish and bird live in the marshes too, but the majority of these are of immigrant type. The local people live in small communities in slightly elevated and dry lands. They build their houses from reed; their main sources of living are fish and special type of oxen that are locally called "Jamoos".

The marshes were subjected to drying operations since the early eighties of the last century, due to oil exploration operations, as happened to the southern parts of Hor Al-Hammar and Hor Al-Huwaizah. Latter on, they became almost totally dried, since 1991, by converting and regulating the courses of the Tigris and Euphrates Rivers within the marshes. The drying operation led to drastic changes in the environment, the climate, creeping of the sand dunes towards ex-marsh areas, dryness of the land, increasing of Sabkhas, and absence of vegetation, fishes, and birds and of the migration of the local people.

The main aim of this study is to detect the drastic changes in the marsh areas and near surroundings that took place due to drying operations and the consequences on the environment. To fulfill the aim of this study, remote sensing techniques and GIS applications were used.

LOCATION

The marshes are located in the southern parts of Iraq; they are approximately bounded by the following coordinates (Fig.1):

Latitude	30º 00' 00"	32º 00' 00"
Longitude	46º 00' 00"	48º 00' 00"

The Iraqi marshes could be divided into three main types, depending on their geographical location and feeding source (Al-Khattab in Aqrawi, 1993), these are (Fig.2): **1)** Al-Hwaiza Marshes, **2)** Central Marshes and **3)** Al-Hammar Marshes**.**
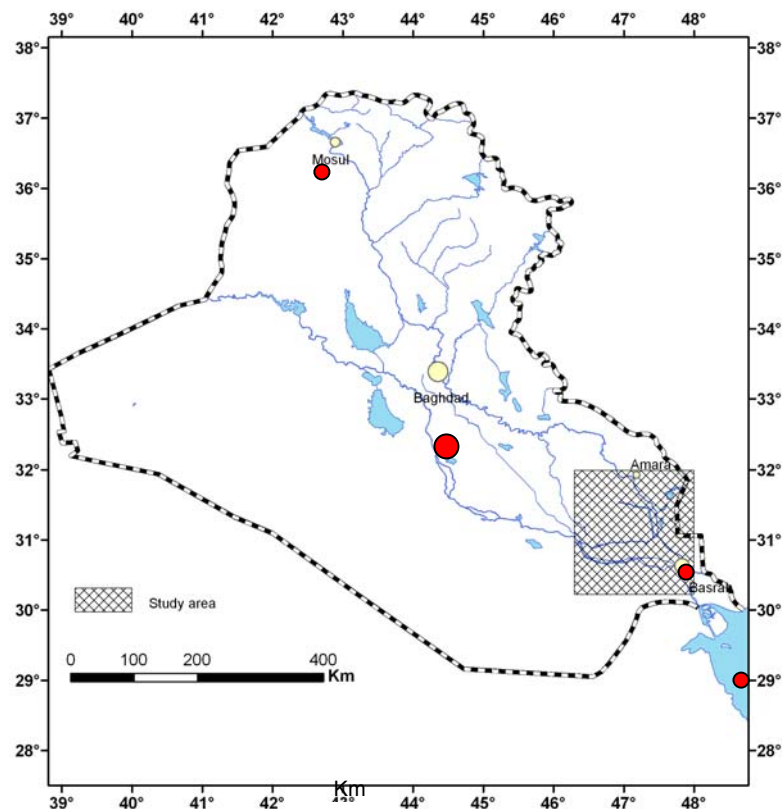
Fig.1: Location map of the study area

USED MATERIALS AND METHOD OF WORK

To achieve the aim of this study, the following materials were used:
- Landsat MSS, 1973
- Landsat TM, 1990
- Landsat ETM + 2000
- Geological maps of different scales and reports

Moreover, many GIS programs were used to get the changes detection in the marshes during the period of 1973 – 2000.

The carried out work includes three main stages, these are:

- **Preparatory Stage**, included collection of data, reviewing the previous works, such as theses, reports, published articles…etc.

- **Execution Stage,** included application of digital correction for the Landsat images to compile the required maps, using ERDAS IMAGINE 9 and changing the acquired data to GIS media. Field work was conducted to check the interpreted data and apply corrections to compile the final maps.

- **Final Stage,** included finalization of the acquired data to detect the environmental changes and land cover that have occurred in the marsh areas, using GIS applications.
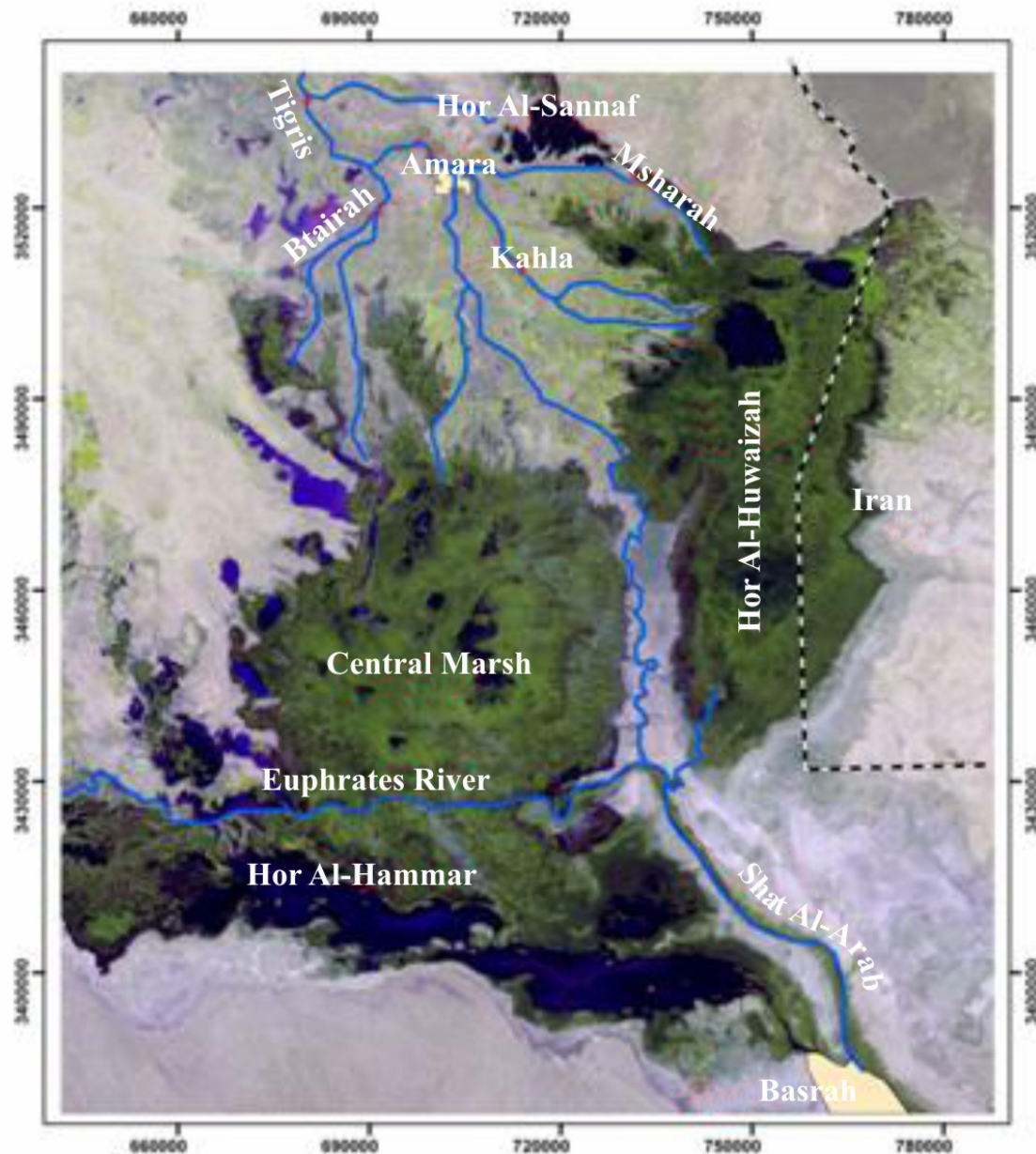
Fig.2: Landsat image of the Iraqi Marshes, 1973

PREVIOUS WORKS

The carried out works in the marsh areas concerning changes detection are very rare. However, the followings are the most relevant studies in the area:

- Buring (1960) studied the Iraqi soils and classified them; he also studied the flood plain levels and attributed their formation to the carried loads by Tigris and Euphrates Rivers.
- Yacoub *et al*. (1985) carried out systematic geological mapping for the southern part of the Mesopotamian Plain. They described the different geological and geomorphological units, including the marshes.
- Yacoub *et al*. (1981) carried out preliminary study of the Quaternary sediments of south Iraq

- Aqrawi (1993) studied the recent sediments in the marsh areas, the delta of the Tigris and Euphrates Rivers, as related to the oscillations in the sea level and tectonic activities, and their consequences on the sediments of the flood plain.

- UNEP (2001) conducted a study concerning the main marshes, included the consequences of the drying operations on the environment and the demographic distribution. The report concluded that the existing dams along the Tigris and the Euphrates Rivers have negative effect on the marshes and recommended that the down stream yield of the dams must ensure the continuity of the marshes.

- Rehabilitation Center of the Marshes (2006) conducted a study in Al-Huwaizah Marshes concerning the reactivation of the marsh's environment. The study included topographic survey, evaluation of the hydraulic system of the marshes, evaluation of the input and output water types in the marshes.

- Iraqi Ministries (2006) conducted a Total Management for the Water Resources in marsh areas. The study concluded that the maximum required quantity of water to sustain the marshes (in March) should be 2300×10^6 m^3, whilst the minimum required quantity of water to sustain the marshes (in August) should be 650×10^6 m^3.

GEOLOGICAL SETTING

The hereinafter mentioned geological data (Fig.3) are mainly acquired from Yacoub *et al.* (1985) and Yacoub (1995).

▪ Geomorphology

The marsh areas are located in the southern part of the Mesopotamian Plain. They comprise almost flat areas with very gentle slope that is about 4 cm/ Km, along Euphrates River and 8 cm/ Km, along Tigris River. Due to this very gentle slope, rivers have a meandering system with many distributaries that form lacustrine deltas. This natural system contributes in feeding of the marshes and it is one of the main factors that contributed in the development of the marshes. The main characteristic features are natural levees (in the northern parts) that are very poorly developed, depressions; some of which are filled with clean water; seasonally or annually, and others that have shallow water and change to marshes; when filled with vegetation.

▪ Stratigraphy

The marsh areas are totally covered by Quaternary sediments of fluvial origin, represented by the flood plain sediments of Tigris and Euphrates Rivers. The thickness of the sediments is about 120 m, near Amara city. They consist of silt and mud, rich in organic materials and very rarely calcareous.

▪ Structure and Tectonics

The marsh areas are located within the Unstable Shelf of the Arabian Platform (Al-Kadhimi *et al.*, 1996 and Fouad, 2010), while according to Jassim and Buday in Jassim and Goff (2006) they are located within the Stable Shelf. Many subsurface structures are developed within the area, they have N – S direction in the southern part, whereas in the central and northern parts they have NW – SE direction. Some lithological facial changes and acute meandering of the rivers may indicate the activity of these structures and development of Shat Al-Arab (Scott, 2005). The whole area is a large subsiding basin, which is continuously subsiding with a rate of subsidence amount that ranges from (− 0.4 to 1.4) cm/ 100 years, while the total subsidence ranges from (− 250 to ≥ 2000) m (Sissakian and Deikran, 1998).
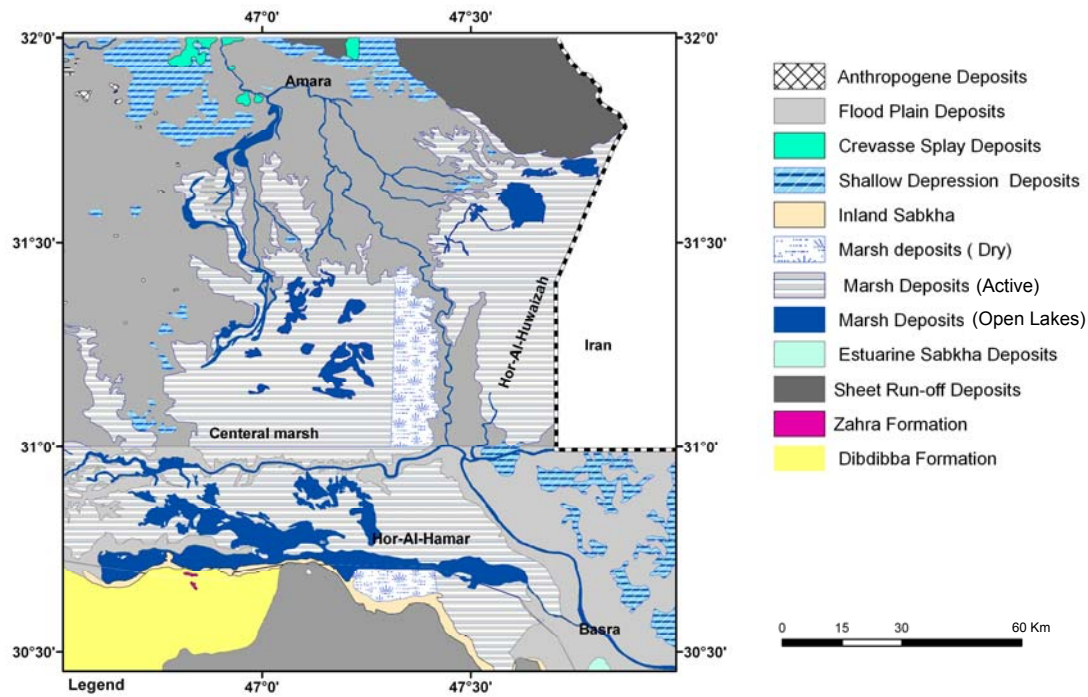
Fig.3: Geological Map of the study area (after Yacoub, 1995)

CHANGE DETECTIONS

To study the change detections, in the marsh areas that occurred due to drying operations between the early seventies of the last century and 2003, remote sensing techniques and GIS applications were carried out to achieve the aim of this study.

▪ **Remote Sensing Techniques**

Change detections were carried out to delineate the environmental changes in the marsh areas by using Landsat images of three different dates. It is recommended to use images of the same sensor with the same spatial resolution, spectral resolution and radiometric resolution accuracy, and equal wave length. Therefore, during selection of images for change detections study, the following parameters should be considered, otherwise the interpreted data will not be reliable (TCTP, 2007):
- Spatial Resolution
- Spectral Resolution
- Radiometric Resolution
- Temporal Resolution

Moreover, any used conventional method to detect the changes will show that the remote sensing techniques are more useful, because they are easily produced and used, beside the cost and duration differences in interpretation, as compared to the conventional methods. Many methods are available for change detections (TCTP, 2007), these are:
- Image Differencing
- Image Rationing
- Principal Component Analysis
- Normalized Difference Vegetation Index (NDVI)
- Tasseled Cap Transformation
- Temporal Classification Comparison

In this study, the Temporal Classification Comparison method was used, because it is the best, considering that the images used have different sensors, spatial resolution, and spectral resolution and wave lengths. Besides, the method depends mainly on the spectral signature (Table 1).

Table 1: Characteristics of the used Landsat images

Satellite	Sensor	Spectral Resolution (Wave length in um)	Spatial Resolution	Temporal Resolution
LANDSAT	MSS (Multispectral scanner system)	1:0.5 – 0.6 (B) 2:0.6 – 0.7 (G) 3:0.7 – 0.8 (R) 4:0.8 – 1. 1 (NIR)	60 m; 185 Km Swaths width	16 days
LANDSAT	TM Thematic Mapper	1: 0.45 – 0.515 (B) 2: 0.52 – 0.60 (G) 3: 0.63 – 0.69 (R) 4: 0.75 – 0.90 (NIR) 5: 1.55 – 1.75 (Mid-IR) 6: (thermal): 10.40 – 12.5 7: 2.09 – 2.35 (Mid-IR)	30m (visible, near and mid-IR): 120 m (thermal IR); 185 Km Swaths width	16 days
LANDSAT 7 (1, 2, 3, 6 are inactive)	ETM+ (Enhanced Thematic Mapper)	1: 0.45 – 0.515 (B) 2: 0.52 – 0.60 (G) 3: 0.63 – 0.69 (R) 4: 0.75 – 0.90 (NIR) 5: 1.55 – 1.75 (Mid-IR) 6: (thermal): 10.40 – 12.5 7: 2.09 – 2.35 (Mid-IR) 8: (pan): 0.52 – 0.90	30 m (visible, near and mid-IR): 15 m (panchromatic),60 m (thermal IR); 185 Km Swaths width	16 days

▪ **GIS Applications**

The classified digital images that were produced during the digital processing of the Landsat images stage were changed to vertical values within GIS media (Fig.4). This was carried out because it is more accurate and easy to determine the coverage area of each classified class, beside determination of its coverage percentage, as compared to the total area and of each classified digital image in the same date (Table 2). Moreover, it was represented by a histogram that can easily be followed-up (Fig.5).

Table 2: Coverage areas of the marshes during different years

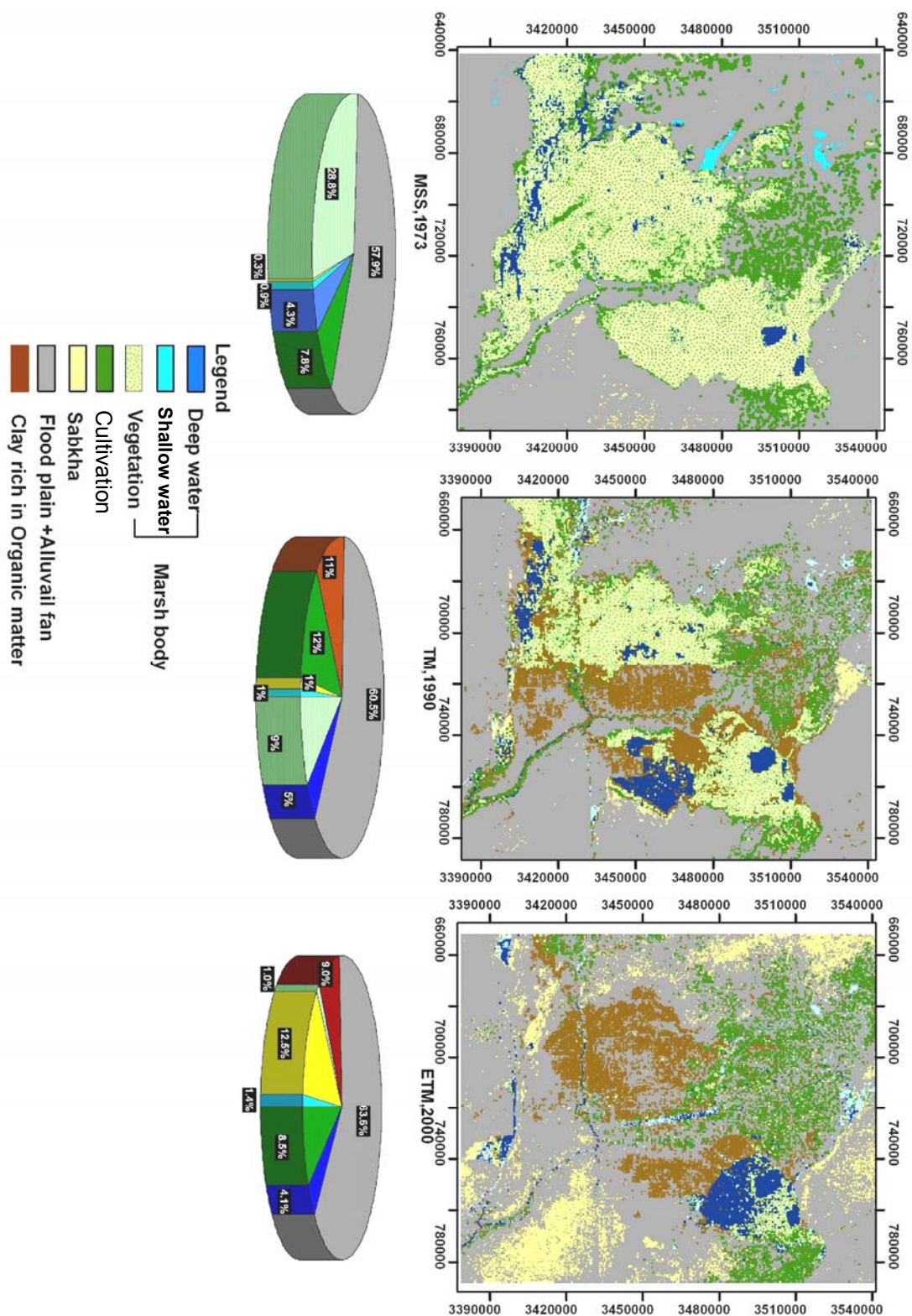| Class name	1973 (%)	1990 (%)	2000 (%)	Percentage Growth (%)
Shallow water	0.9	1	1.4	0.3
Vegetation	28.8	9	1	– 27.8
Deep water	4.3	5	4.1	– 0.2
Sabkha	0.3	1	12.5	12.2
Alluvial fan + Flood plain	57	60.5	63.5	6.5
Cultivated area	7.8	12	8.5	0.7
Clay rich in organic matter	–	11	9	– 2

Fig.4: Digital maps of the study area for three years with percentages diagrams

From reviewing the determined percentages (Table 2), the changes in the coverage areas can be seen for the period 1973 – 2000. It is very clear that there is an increase in barren areas and dry soils, which include the old flood plain and sabkhas. It is worth to mention that the increase in the areas covered with natural vegetation, in 1973, is accompanied with increase of areas of shallow marshes, which means the deep water areas were decreased. This means that the marshes, in the year 1973 were very densely covered by natural vegetation (reed and rushes), which had led to diminution of the water body due to the coverage by vegetation, therefore, the vegetation cover was increased.

To determine the changes in each class of the marshes environment and to detect the changes in the covered areas, before and after drying, relation curves were drawn (Fig.6) to represent the coverage area of each class with different durations. Reviewing these linear relations, the followings can be seen:

- Decrease in the areas of deep water marshes (Class No.1) about 0.3% during 1973 – 2000, but there is an increase in the year 1990, which is attributed to human activities in harvesting the natural vegetation from the south part of Al-Huwaizah Marsh. However, in the year 2000, these areas have, decreased again (Fig.7).
- Increase in the areas of shallow water marshes (Class No.2), due to decrease of the deep water marshes (Fig.8).
- Decrease in the areas of natural vegetation and water (Class No.3) (Fig.9), the latter is included within the marshes. This is due to the drying operations of the marshes and its consequences on the natural vegetation.
- Increase in the cultivated areas (Class No.4) (Fig.10) in the year 1990, because the local people involved by cultivation after the marshes were dried. But, these areas started to decrease due to the continuation of the drying operations, till the year 2000, and due to shallow water saline groundwater level that increased the salinity of the soil, the areas became unsuitable for cultivation. According to UNEP (2000), the local people started to emigrate from the marsh areas due to aforementioned reasons.
- Drastic increase in the sabkha areas (Class No.5) (Fig.11). According to UNEP (2000), 1000 Kg of salt were added to each hectare of land, due to the capillary action. Consequently, 3 million tons of salt is added yearly to the marsh areas.
- Increase in the areas of Barren lands (Class No.6), due to the drying operations and their consequences on the natural vegetation (reed and rushes) These barren lands include the old flood plain and alluvial fans in the northern and southern parts (Fig.12,). It is worth to mention, that many geomorphic units are grouped together, like the old flood plain and alluvial fans, because it is very difficult to differentiate them spectrally. This is due to high reflection of the flood plain, because it is highly eroded (barren) and has very smooth surface. Therefore, they are grouped with sabkhas and saliferous soil.
- Increase in the areas of organic soil (Class No.7) that started to develop in the year 1990, which marked the beginning of vast drying operations and caused by humification of the natural vegetation (reed), after drying of the marshes during 1973 – 2000. But, then, they started to decrease (Fig.13), because the organic soils became gradually barren and saliferous. Field check, showed that these areas were densely covered by natural vegetation, called locally "Talha".
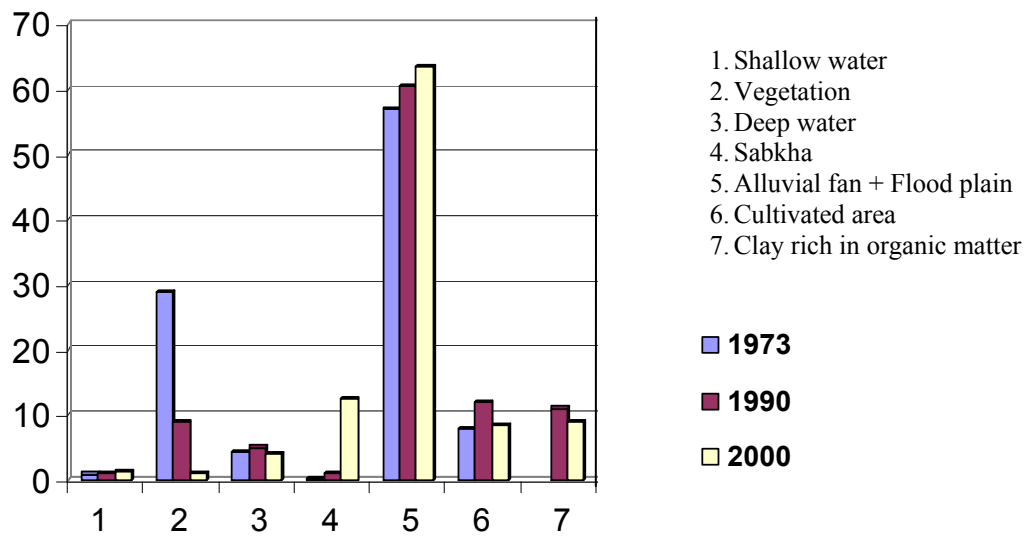
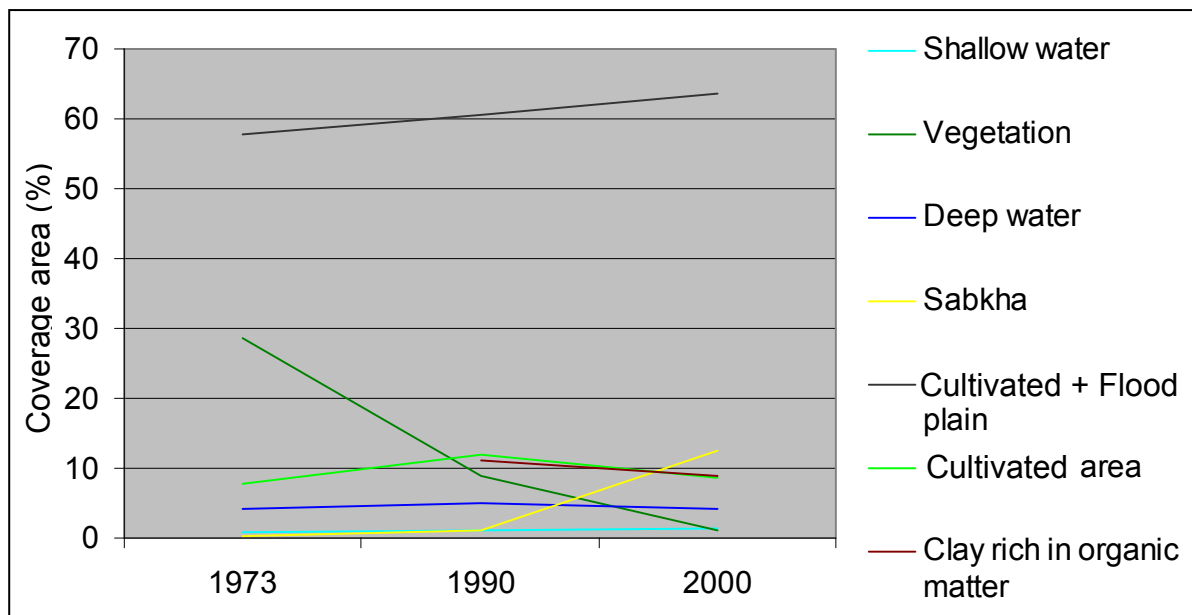Fig.5: Histograms of coverage areas for each class during three years

Fig.6: Linear relation between percentages of coverage areas and duration
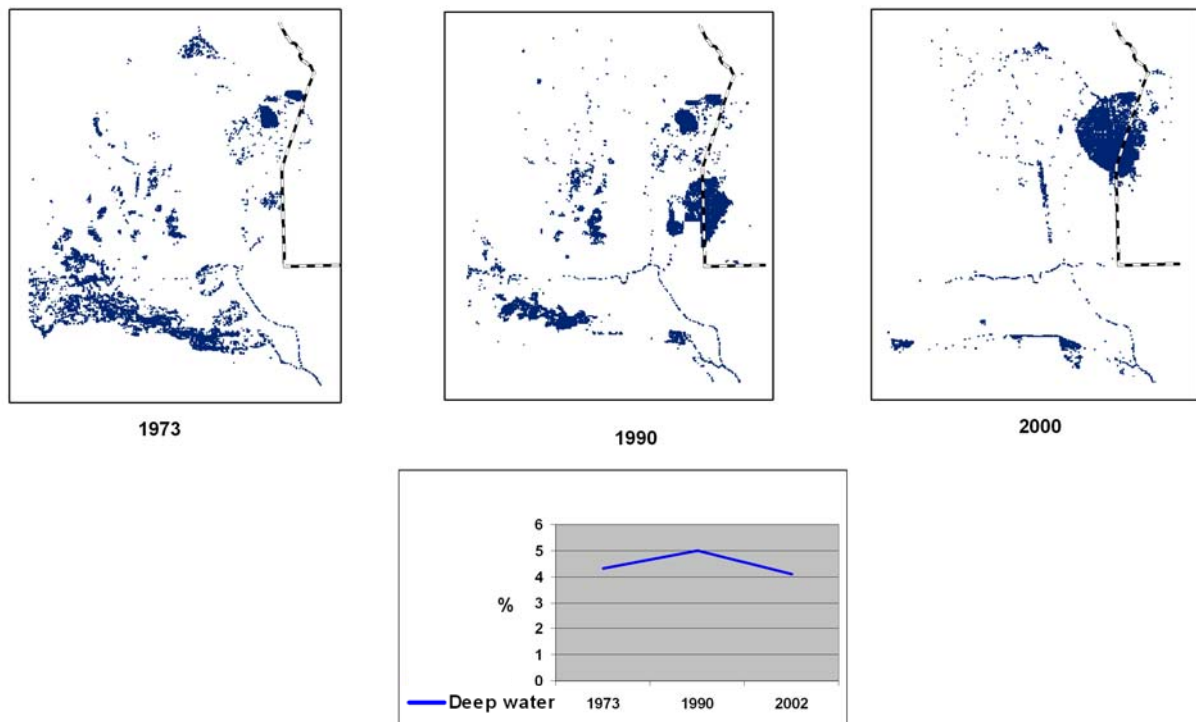
Fig.7: Digital map showing the changes in the coverage of **deep** water marsh areas
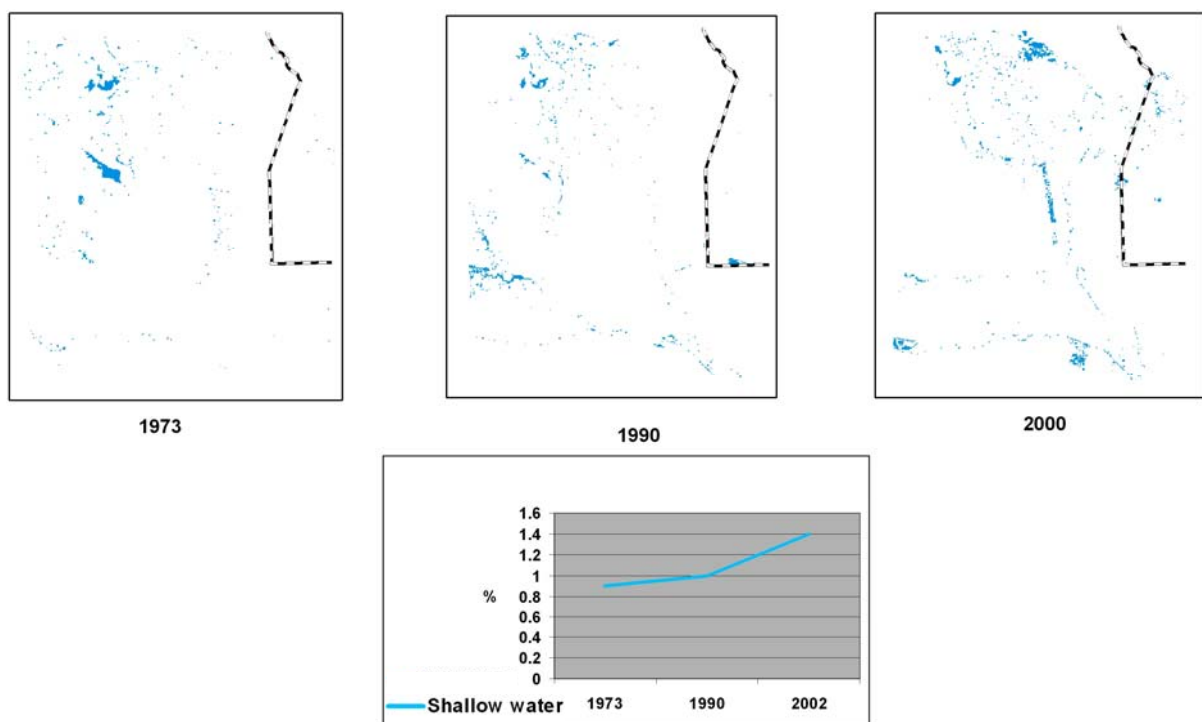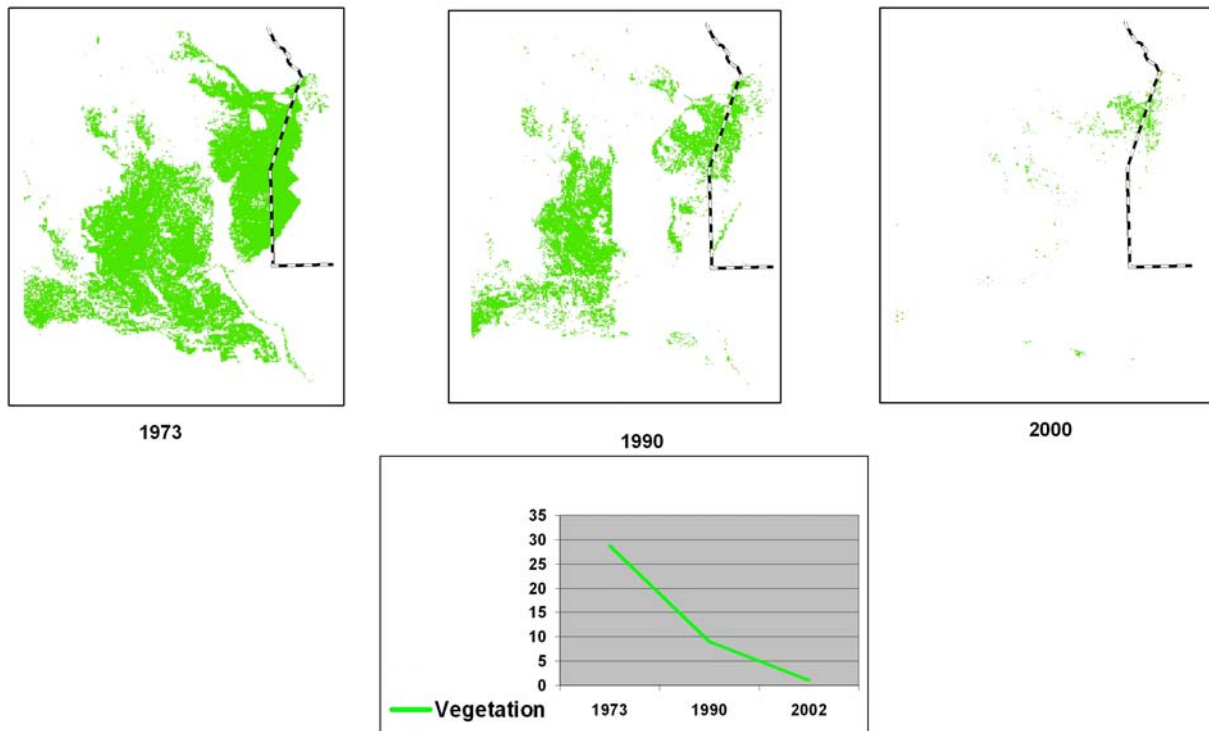(Class No.1) during the years 1973 – 2000, with linear relation diagram

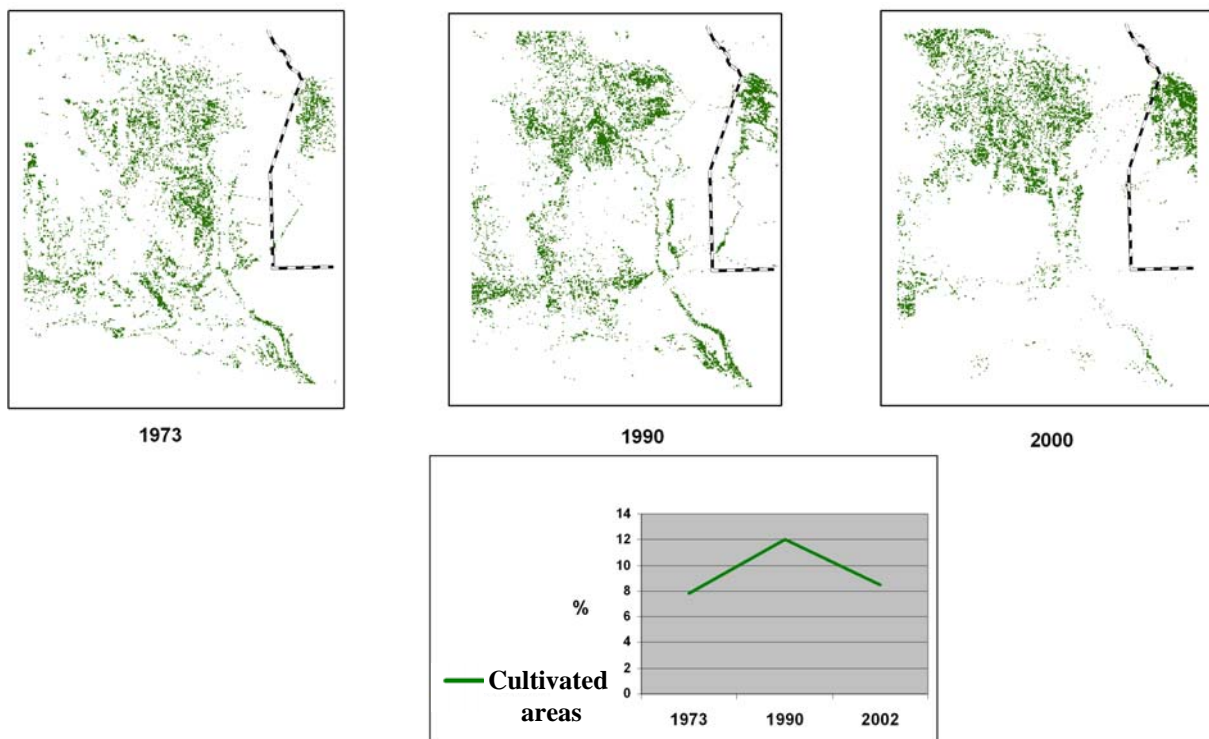Fig.8: Digital map showing the changes in the coverage of **shallow** water marsh areas
(Class No.2) during the years 1973 – 2000, with linear relation diagram

Fig.9: Digital map showing the changes in the coverage areas of natural vegetation in the marsh areas (Class No.3) during the years 1973 – 2000, with linear relation diagram

Fig.10: Digital map showing the changes in the coverage areas of irrigated and cultivated areas during the years 1973 – 2000, with linear relation diagram
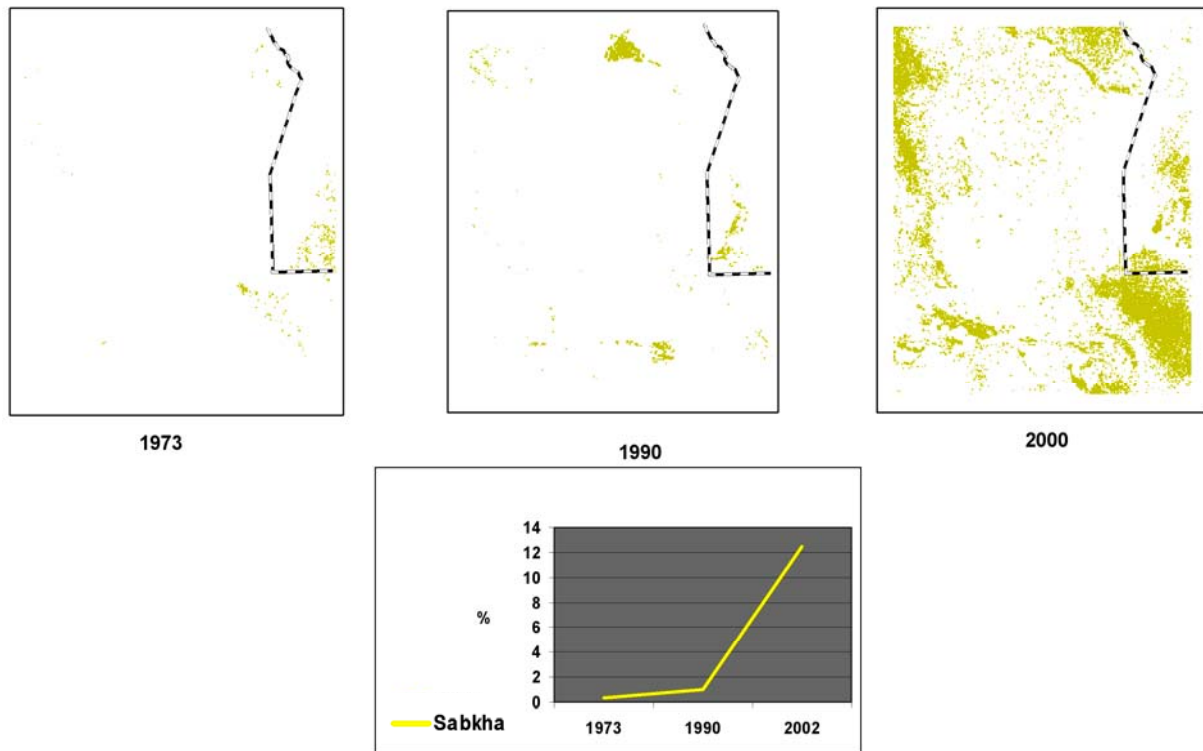
Fig.11: Digital map showing the changes in the coverage areas of sabkhas
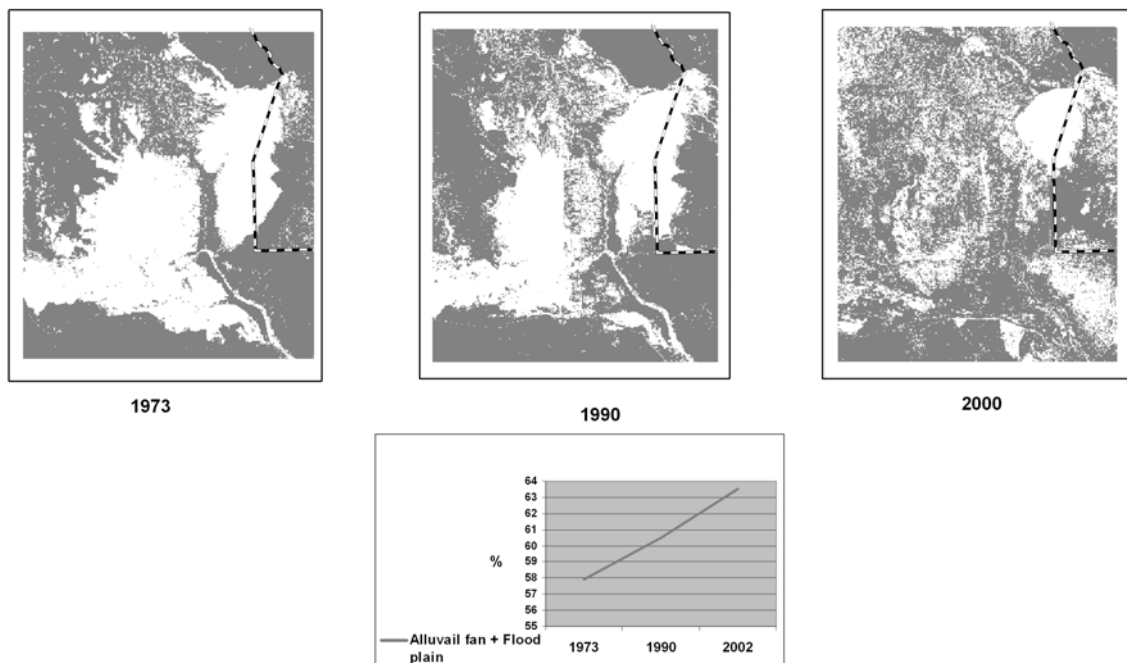(Class No.4) during the years 1973 – 2000, with linear relation diagram

Fig.12: Digital map showing the changes in the coverage areas of barren lands, which
includes the old flood plain and alluvial fans (Class No.5) during the years 1973 – 2000,
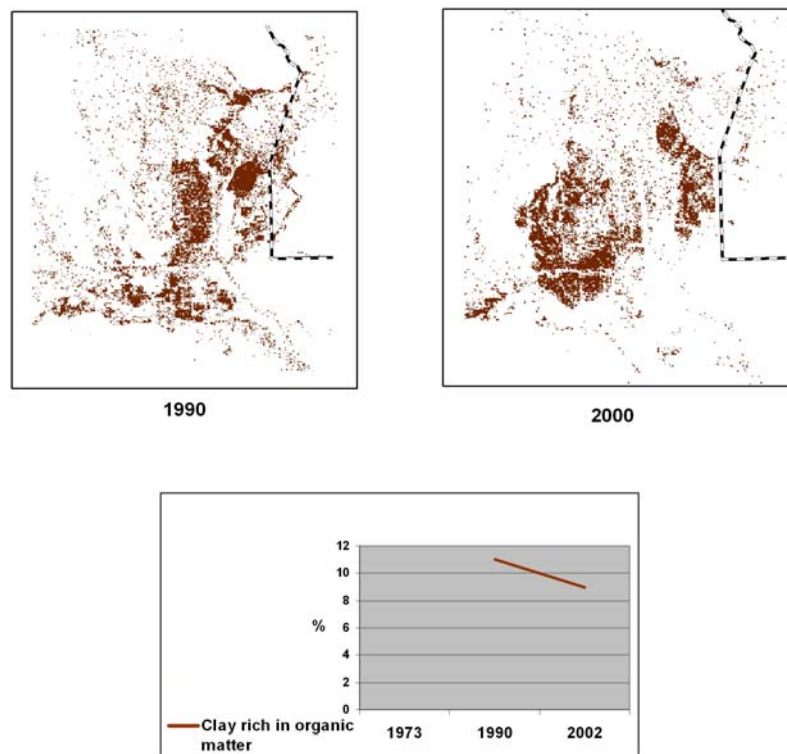with linear relation diagram

Fig.13: Digital map showing the changes in the coverage areas of organic soils (Class No.6) that appeared after the drying operations in the year 1990, with linear relation diagram

REHABILITATION OF THE MARSHES

Because Landsat images after the year 2003 are not available for this study to detect the changes after rehabilitation of the marshes, therefore data about the coverage areas is obtained from the Rehabilitation Center of the Marshes. The gathered data includes coverage areas of the marshes and natural vegetation during the years 2004 and 2005. These areas were compared with those of the year 1973 (before drying operations) and those of the year 2000 (after drying operations), and the percentage of the coverage areas was determined (Table 3) and plotted on linear relation diagram (Fig.14). Reviewing this data, it can be seen that more than 50% of the original marsh areas are regained in the Central Marshes and Hor Al-Hammar areas. Whereas, Hor Al-Huwaizah was not largely affected by the drying operations, because Al-Karkha River that flows from Iran feed the marsh (Maltby, 1994). However, after the year 1990 the drying influence started to prevail and 35% of this marsh was dried due to changing of the courses of Al-Mash'rah and Al-Kahl'a Rivers by mean of artificial channels and embankments (UNEP, 2001). These are the main distributaries of the Tigris River that feed Hor Al-Huwaizah.

In the Central Marshes, the coverage areas, after the drying operations, constituted 3% only, as compared to the original covered areas, whereas after the rehabilitation of the marshes, in the year 2005, only 24 % of their original areas were regained. This is mainly due to the presence of a large artificial channel (ex Al-A'z River), and also to the fact that the local people wouldn't leave their agricultural lands, after being cultivated.

Table 4: Coverage areas of the main marshes during different years

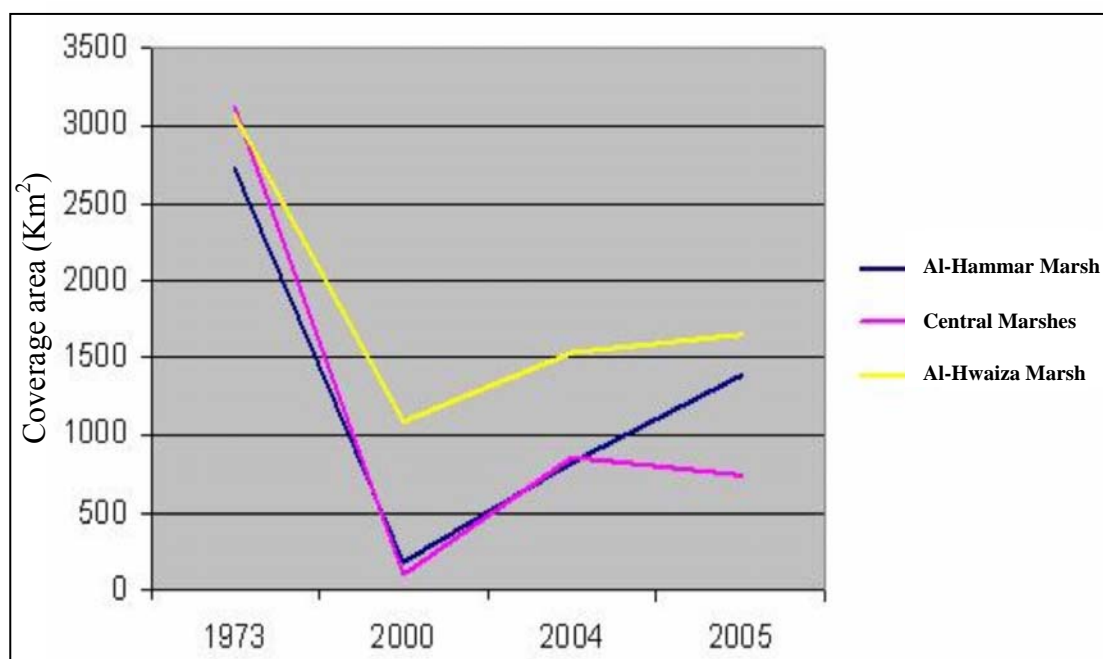| The area in 2005		The area in 2004, after rehabilitation operations		The area in 2000, after drying operations		Original marsh area (Km²) in 1973	Main marshes (Vegetation + water)
%	Km²	%	Km²	%	Km²		
51	1393	30	824	8	174	2729	Al-Hammar Marsh
24	854	21	741	3	98	3121	Central Marshes
54	1649	50	1540	35	1084	3076	Al-Hwaiza Marsh

Fig.14: Changes of the coverage areas of the main marshes during different years

HYDROLOGICAL CHANGES AND ENVIRONMENTAL IMPACT

The drying operations of the marshes caused severe changes in the soil and water properties that affected the water quality of the Tigris and Euphrates Rivers due to increase in the salt content. This pollution, which includes some chemical compounds of different sources, will be transferred to the Tigris and the Euphrates Rivers after rehabilitation of the marshes.

Due to drying of the marshes, increase of the evaporation and fluctuations of the daily temperatures caused increase of salt contents, especially that of sodium chloride in the upper parts of the soil. Moreover, the contamination of the irrigation water with that of the drainage has increased the total dissolved salts in the irrigation water, and the soil becomes polluted and unfavorable for agricultural purposes.

Most of the previous works referred to increase of different salts in the soils and water of the southern parts of the Central Marshes, because they represent the lowest parts, as deduced from DEM (Fig.15). In addition, the shallow groundwater is of very saline type. The soil and water are therefore contaminated and the contamination increases southwards (Fig.16). It is therefore, recommended to execute detailed studies on the sources of pollution in the dried marshes that will be rehabilitated, because their inundation by water will cause pollution of the Tigris and Euphrates Rivers. The amount of SO_4 in the water increased, also especially in the eastern parts of Al-Huwaizah Marsh, due to the flood that passes through gypsum bedrocks. This was observed in the collected soil samples during the field check (Fig.17). This also refers to the change in the environmental balance and the increase of pollution indicators, caused by hydrological changes.

The influence of the constructed hydrological structures in Turkey, Iran and Syria over Tigris, Euphrates, Karkha and Karoon Rivers, which form the main feeding sources of the Southern Marshes, are more destructive than the influence of the drying operations. Because 90% of the Tigris River and 80 % of the Euphrates River flow in the marshes before reaching Shatt Al-Arab (Kaite, 2006 in Al-Lami, 2008).

The distributaries of the Tigris River are the main sources for feeding the marshes north of Al-Qurna area, among them is the Bitera Channel that represents the largest distributary in the north of Amara, it lies 18 Km to the north. In the year 1979, the Bitera and Al-Areef regulators were constructed for irrigation uses. Both of them were blocked during the drying operations (CIRM, 2006). The Tigris River is bifurcated into two parts; the southern one is called the Tigris River, whereas the eastern one is called Al-Kahla'a Channel. Moreover, 19 Km south of Amara, another channel bifurcates from the eastern bank of the Tigris River called Al-Majar Al-Kabeer. South of Al-Majar Al-Kabeer town, this channel is divided into two parts; the western one is called Al-Adil with a length of 11 Km and the eastern one is called Al-Wadiyah with a length of 14 Km. All these channels are now oriented to flow in a big water channel, which was called Al-A'z River, and flows into the north of Qurna Marshes.

Along the left bank of the Tigris River, there are many distributaries such as Al-Mash'rah and Al-Kahla'a, in addition to the streams that flow from Iran, such as Al-Teeb and Duwaireej, these feed the Al-Huwaizah and Al-Sannaf Marshes (Fig.18). Al-Hammar Marsh, on the other hand is fed from the Euphrates River and Shatt Al-Arab, by water balance (Fig.19).

During drying operations, through the years 1986 – 1992 (Fig.19), all feeding sources were blocked. The discharge of Bitera and Al-Areef channels were decreased from 300 m^3/ sec to 100 m^3/ sec (CRIM, 2006).
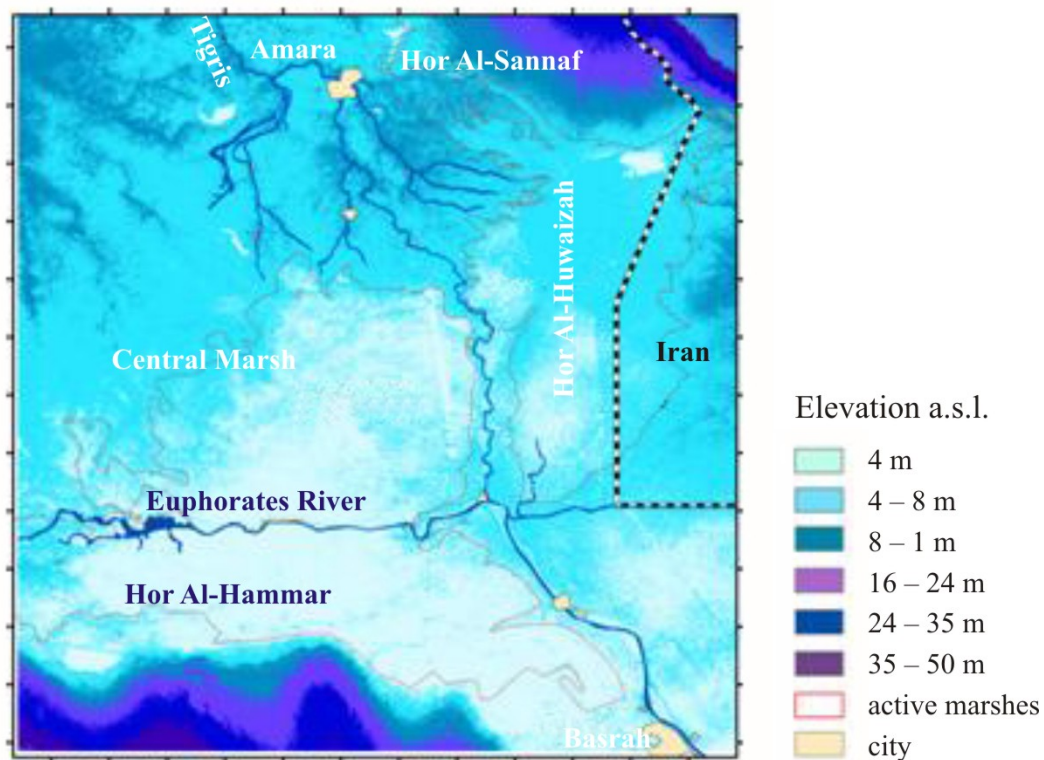
Fig.15: Digital image showing the height of the involved area
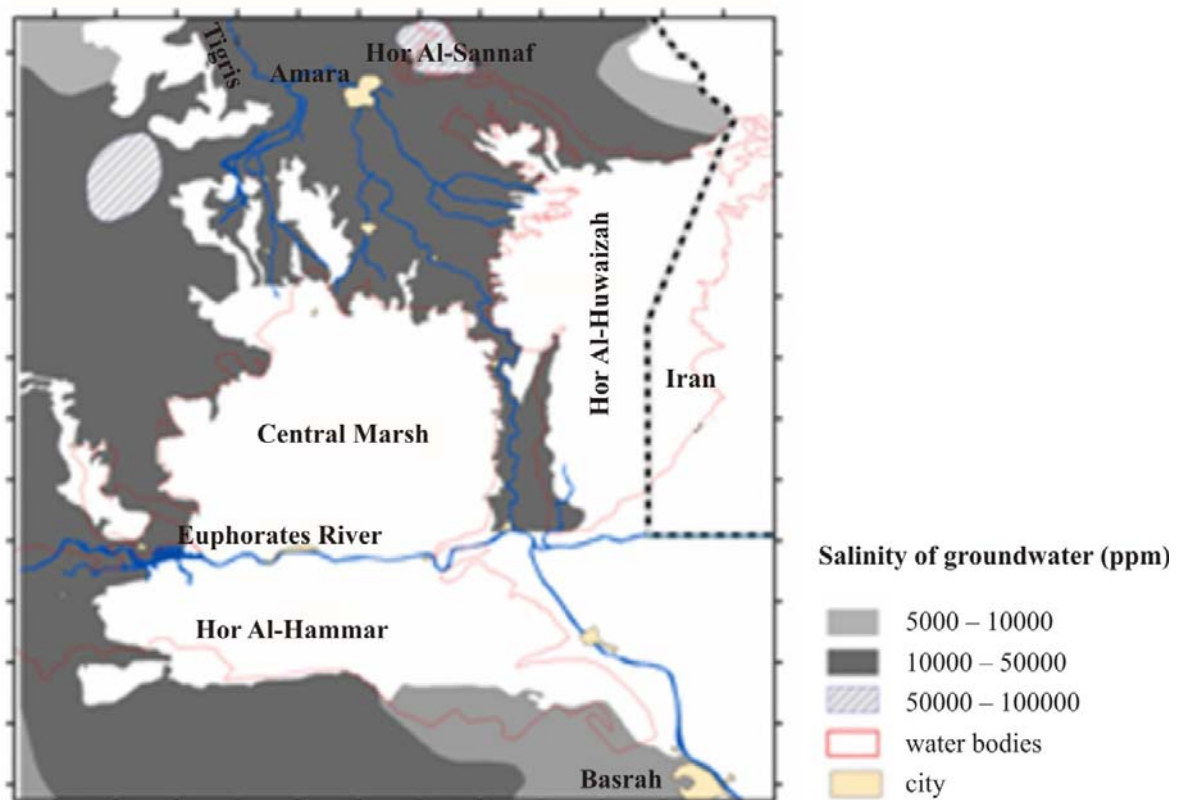(above sea level)

Fig.16: Distribution of the salinity in the groundwater
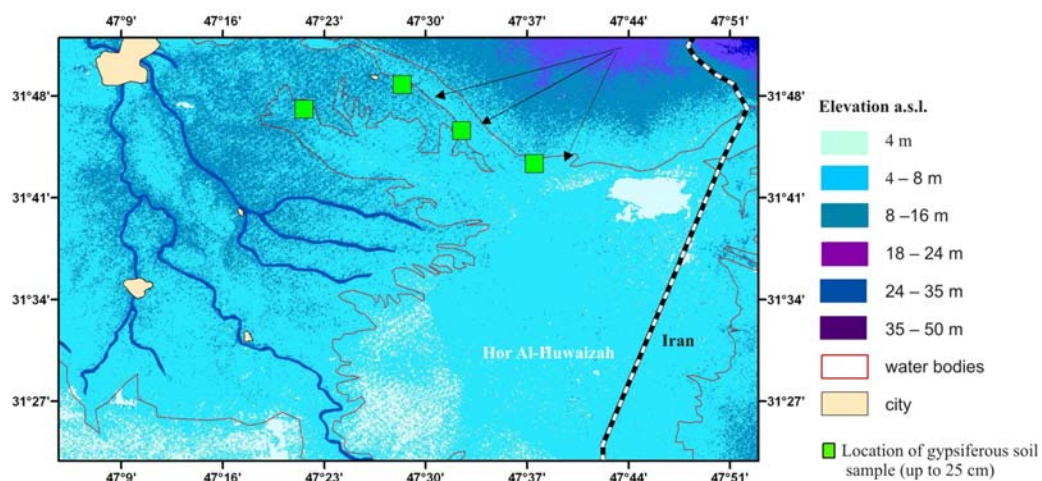
Fig.17: Digital image showing the height of the involved area,
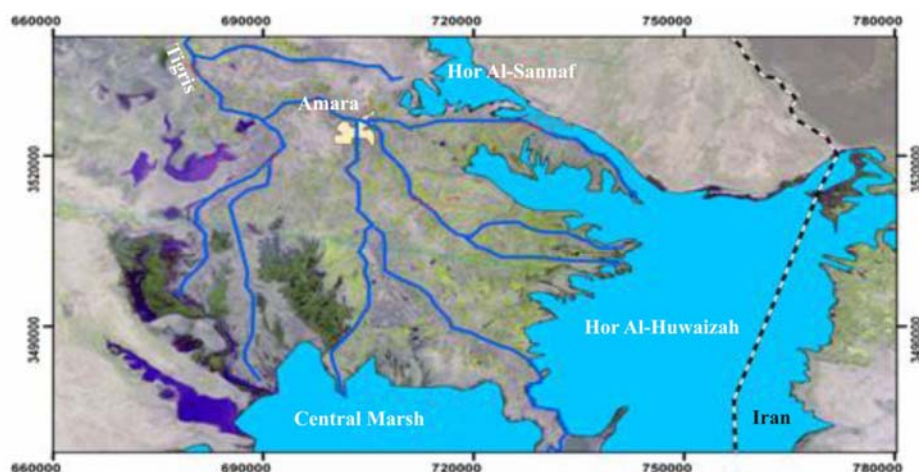with locations of gypsiferous soils

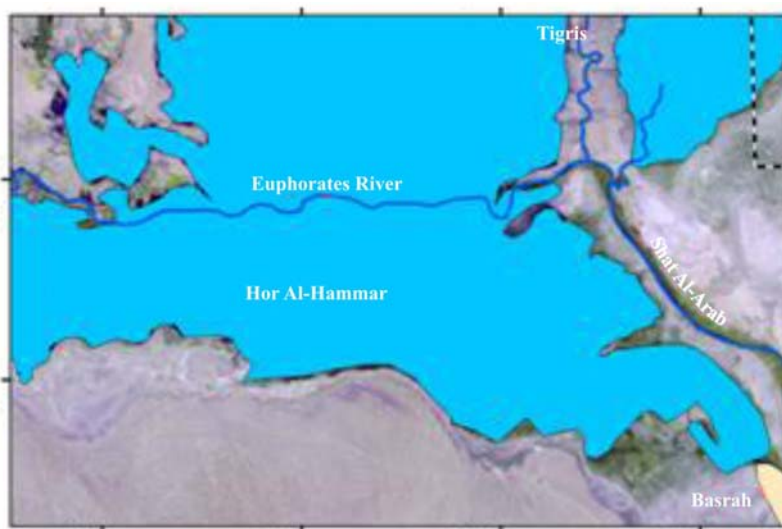Fig.18: Landsat image in 1973, note the feeding system of Al-Huwaizah Marsh

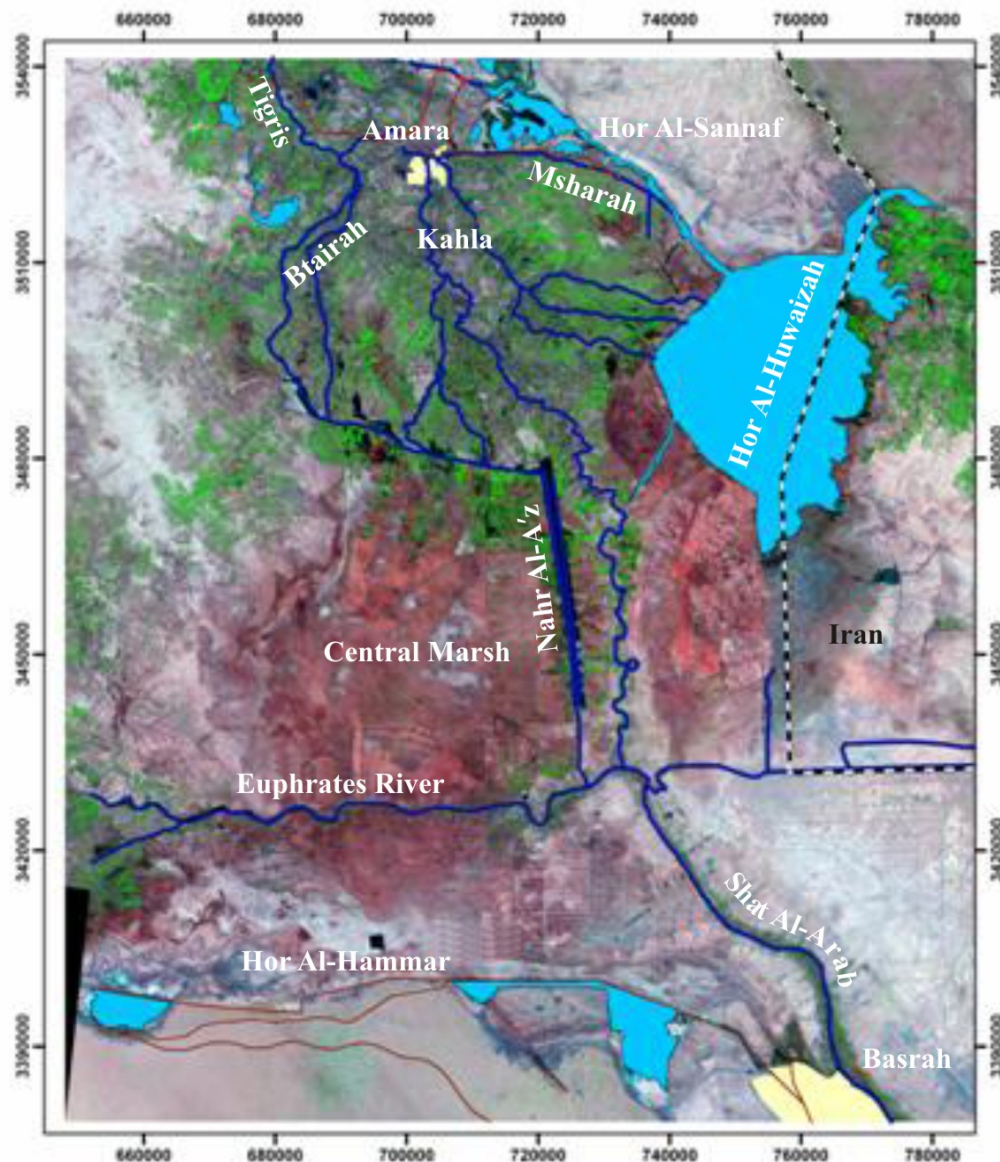Fig.19: Landsat image in 1973, feeding system of Al-Hammar Marsh westward

Fig.20: Landsat image in the year 2000, note the wet lands after the drying operations

The detected changes that occurred in the marshes during different stages can be seen in Fig. (21). MSS Landsat image shows the original extension of the marshes before the drying operations. The different stages can be observed from Fig. (21a, b and c) those are dated in the years 1973, 2000 and 2005, respectively. During the year 1973, the areas of all marshes in Iraq was 30 000 Km² that represents 4% of the total area of Iraq. The area started to decrease from 1976 due to the construction of dams in Turkey, Syria and Iraq; becoming (12000 – 15000) Km² that represents 50% of the original area (CRIM, 2006).

After the year 1986, when the drying operation started, the amount of the water in the Tigris Rivers and its distributaries decreased, and the discharge became insufficient for the demands of the local people. Moreover, the quality deteriorated and new vegetations started to grow that resists the saline water, consequently the environment was changed. Only small parts were not affected, because the feeding was from Iran, especially in the case of Al-Sannaf Marsh and parts of Al-Huwaizah Marsh; Besides parts of Al-Hammar Marsh near Basrah, was also not affected due to the activities in Shatt Al-Arab.
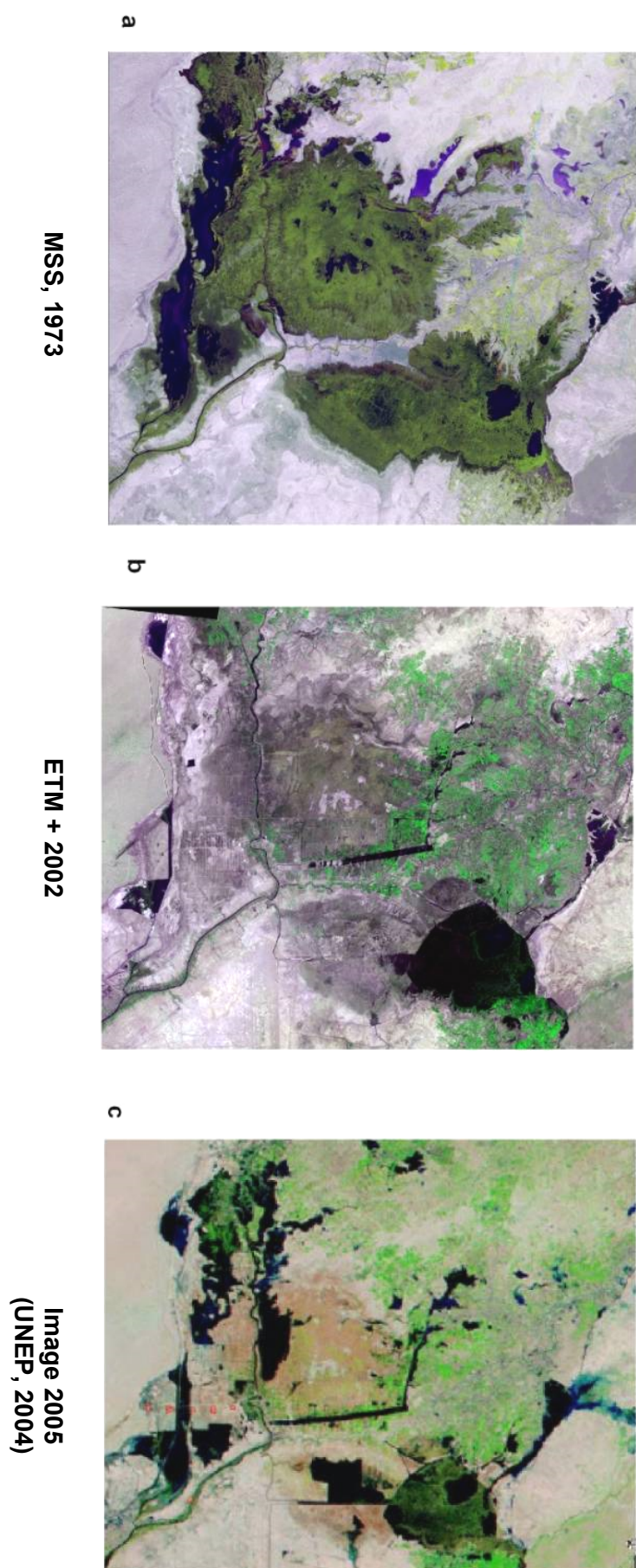
Fig.21: Landsat images of the studied area, before and after the drying operations
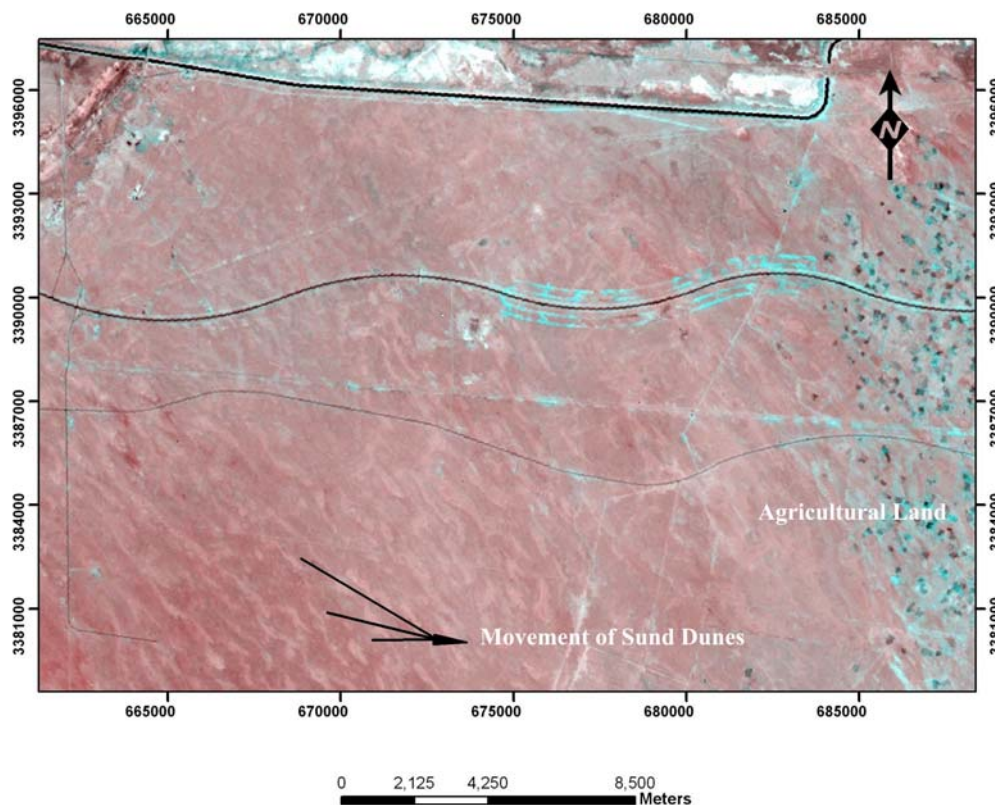
Fig.22: Landsat image showing desertification
due to creep of the Aeolian sands over the cultivated areas

The dried and re-inundated areas in the marshes can be observed in the Landsat images of different changes (Fig.21). The changes in hydraulic system can also be observed clearly from Landsat images. Moreover, Landsat image ETM also indicates the creep of Aeolian sands to the marsh areas and thus the related desertification (Fig.22), especially west of Basrah. As much, green areas are decreased, climatic and environmental changes have taken place too. Beside active soil erosion, the chemical and physical properties of the soil are also changed. The drying operations affected the top soil cover and changed it to unfavorable soil for agricultural purposes.

CONCLUSIONS
The followings could be concluded from this study
- The barren lands increased between the years 1973 – 2000, and thus the marsh areas decreased.
- The drying operations influenced the top soil properties, it became unfavorable for cultivation.
- The aeolian sands start creeping towards the dried marsh areas.
- The clear water marshes decreased about 0.3% from there original areas, between 1973 and 2000.
- The natural vegetation cover decreased, within the marsh areas.
- The cultivated areas increased after the drying operations in the year 1990, but they started to decrease after the year 2000, due to continuation of the drying operations.

- The drying operations led to immigration of the local people from the marsh areas.
- After rehabilitation, in the year 2005, the areas of Al-Huwaizah and Al-Hammar Marshes increased about 50% from the dried areas, whereas in the Central Marsh areas the increased area represents 24% only.
- The Central Marshes have the lowest elevations, as compared with other marshes; therefore they have the shallowest groundwater level and highest salt content.
- The drying operations caused increasing of SO_4 content and other salts in the soil.
- All detected changes in the marshes and related environment were due to human activities.

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