LAND DEGRADATION DETECTION USING GEO-INFORMATION TECHNOLOGY FOR SOME SITES IN IRAQ

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Abstract

This study aimed at monitoring, mapping, and assessing the land degradation in the upper Mesopotamian plain of Iraq. The country suffers severely due to land degradation and desertification problems, especially in its central and southern parts. Five vegetative, soil, and water indices related to land degradation were applied to two Landsat TM and ETM+ imageries to assess the extent of land degradation for the study area during the period from 1990 to 2000. A computerized land degradation severity assessment was adopted using ERMapper 7.1, Erdas Imagine 9.2, ArcView 3.3, and ArcGIS 9.1 environments to process, manage, and analysis the raster and thematic datasets. The indices used in this research are: The Normalized Difference Vegetation Index "NDVI", The Normalized Differential Water Index "NDWI", Tasseled Cap Transformation Wetness "TCW", and a new index proposed in this study that is the Normalized Differential Sand Dune Index "NDSDI". The results showed a clear deterioration in vegetative cover (2620.4 km^2), an increase of sand dune accumulations (1018.8 km^2), and a decrease in soil/vegetation wetness (1720.4 km^2), accounting for 12.9, 5.0, and 8.5 percent, respectively, of the total study area. In addition, a decrease in the water bodies area was detected (228.1 km^2). Sand dunes accumulations had increased in the total study area, with an annual increasing expansion rate of (10.2 km^2year^{-1}) during the ten years covered by the study. The land degradation risk in the study area has increased by 111% during the study period. The statistical analysis of the results indicated that the soil/vegetation wetness is the biggest influence in the process of land degradation in the study area. The high performance of the NDSDI is promising and effective for identifying the sand dunes accumulations in the area of study. This study finds reveals that most of the counties in the study area are exposed to a serious risk of land degradation and drought water bodies.

Keywords: Land degradation, Landsat, Remote sensing, GIS, NDSDI, Iraq.

Introduction

Land degradation is one of the most serious ecological problems in the world. It entails two interrelated, complex systems: the natural ecosystem and the human social system. Causes of land degradation are not only biophysical, but also socio-economic (marketing, income, human health, institutional support, poverty), undermining food production and political stability (UNCCD, 2004; and WMO, 2006). Desertification appears when land degradation becomes irreversible or when loss of total productivity reaches 50% to 66% (Katyal and Vlek, 2000). UNCED (1992) in Rio de Janeiro adopted this definition for desertification; desertification is land degradation in arid, half-arid and dry sub-humid areas, resulting from various factors, including climatic variations and human activities.

It is estimated that about one sixth of the world's population and one quarter of global terrestrial land is threatened by land degradation (UNCED. 1994). UNEP (2000) refers to land degradation as the diminution of current and/or potential capability of soils to produce quantities or qualities of goods or services as a result of one or more degradation processes.

Geoinformation technology (Remote Sensing 'RS', Geographic Information Systems 'GIS', and Global Positioning System 'GPS') and their integration are the basal and essential technical core of the system of geospace information science that play an important role for assessing and monitoring the environment and its components. Monitoring desertification and land changes over time is required in order to determine land condition trends: whether conditions are

becoming worse, better, or staying the same. Ideally, indicators of change should be quantitative, sensitive to small changes, few in number, and simple to measure. Finding indicators that are unambiguously related to certain land degradation process or to desertification in general is important.

Baugh et. al. (2006) quantitatively evaluated fourteen vegetation indices (VIs) using a Landsat TM dataset spanning 17 years over the San Luis Valley, Colorado, USA to find the best VI for use in sparsely vegetated arid regions. His results showed that ND VIoffset index is effective for use in the study regions. Remote sensing has long been recommended for its potential role to detect, map and monitor degradation problems with spatial and spectral resolution and for the detection of degraded areas including their spread effects with time (Sabins, 1987; and Sujatha et al., 2000).

Raina, et al. (1993) found in his study the cultivation of marginal areas and overgrazing of pastures have resulted in degradation of land. Accelerated wind erosion on sandy surfaces and water erosion on the shallow soils of piedmont areas are both common. Landsat Thematic Mapper sub-scenes have been used to map the type, extent and degree of degradation. In an area of over 5000 km^2, 42% was affected by wind erosion and 50% by accelerated water erosion. A quarter of the whole area needs urgent attention for soil conservation. Begzsuren (2007) studied the land degradation and desertification at Bulgan area, Mongolia using remote sensing technique. He applied many soil and vegetation indices in his study. His results showed that the land degradation in the study area increased from 1990 to 2005 and 94% of the area is considered to be degraded to varying degrees.

Iraq lies between latititude 29° 5' and 37° 15', and between longitude 38° 45' and 48° 45', comprising a total area of 437072 km^2. Over the whole area of the country there are five broad physiographic regions that can be distinguished: the Zagrous Mountains, the foot hills, the Jezireh, the Northern and Southern deserts, and the lower Mesopotamian plain (Buringh, 1960). In Iraq, the most typical and serious form of land degradation is desertification. In the west of the upper part of the Mesopotamia sand dunes accumulations and the drifting sands spread over large area in Salahaddin governorate. While there are wide areas in the middle and southern parts of the country infected by the soils salinization phenomenon, as well as to existing of the sand dunes and drifting sands.

In order to bring land degradation in the area effectively under control, severity of degradation and spatial distribution of degraded land have to be assessed realistically. Land degradation assessment requires identification and inclusion of various indicators of desertification, both natural and man-made.

The objectives of this study are:
1. Assess the land degradation severity and calculate land degradation risk in the ecologically vulnerable area in upper Mesopotamian plain of Iraq at County level using Geo-Information technology.
2. Develop a new index for monitoring, assessing, and mapping the Iraqi sand dunes accumulations, and assessment the sand dunes expansion rate in the study area, and then differentiate regional trends in land degradation.
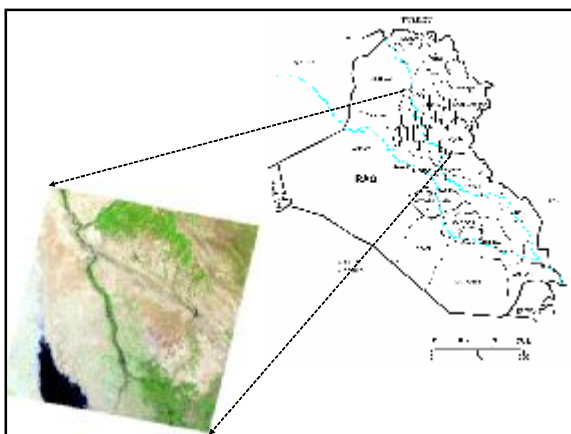
The Study Area

Because of the arid climate, water deficiency, soil erosion, and drifting sands, upper Mesopotamian plain of Iraq is confronted with several challenges and ecological degradation, so, it has been selected as the scope of this research. The study area suffers from land degradation and desertification problems, as well as to the existence of large areas of sand dunes accumulations in the east of Al-Daur and southwest of Tuz counties. The area is comprised of portions of seven counties situated in three different governorates. The counties in this study that belong to Salah Al-ddin governorate are: Samarra, Tikrit, Tuz, and Al-Daur. The counties that belong to Kirkuk governorate are: Daquq and Hawija, and the county that belongs to Diyala governorate is Khalis.

Physiographicaly, the study area Fig.(1) is located in the lower part of the foot hills and Jezireh regions, and in the upper part of the Mesopotamian plain. Annual rainfall in the

study area ranges between 100-250 mm, arriving primarily between October and April. The air temperature is characterized by great variation between day and night, as well as summer and winter, with maximum annual swings of up to 42-48 C^o (Ministry of Planning, 2002). The degree of bio-climatic aridity was defined by the ratio of the mean annual precipitation '*P'* to the mean annual potential evapotranspiration 'ETP' (Abrahams and Parsons, 1994). Thus the humidity index (P/PET) of the study areas ranges from 0.03–0.08, indicating a very dry environment Table.(1).

The study area is with a total area of 20,338.5 km^2, accounting 4.7% of the total area of Iraq. It extends between latitude N 33° 39' to N 35° 33', longitude E 42° 41' to 45° 07'. From the field observations and the satellite images it appeared that there are several types of sand dunes accumulations in the southern part of Tuz and in the northern part of Al-Daur counties. The sand dunes descended from the northwest to the southeast. The active dunes formed of small barchans and compound dunes. The mean height of the sand dunes ranges between 4-8 meters. Among the studied areas, Al-Daur and Tuz are the counties most dominated by aeolian landforms and sand dunes accumulations. The major environmental problems in the study areas are land degradation and sand dunes accumulations.

Fig.(1) : Location map of the study area in the Northern of middle part of Iraq and its ETM+ satellite image for the year of 2000.

Materials and Methods

1.Satellite Remote Sensing Data and Processing

The following Multi-temporal Landsat imageries (path 169, raw 36) were assembled for the study area, then preprocessed, processed, and analysed for this study: TM image (dated March 04, 1990) and ETM+ image (dated April 16, 2000).

1.1 Preprocessing

The pre-processing for the dataset included image registration, radiometric calibration, and radiometric normalisation. Rectification and registration of TM and ETM+ imageries were based on control points collected from vector files of the large and small rivers at the study area using fifty ground control points (GCP). The remotely sensed dataset were geometrically corrected in the datum WGS84 and projection UTM zone N38 using the first order (linear) of polynomial function and Nearest Neighbor rectification re-sampling, which was chosen in order to preserve the radiometry and spectral information in the imagery (Richards and Jia, 1999). Image to image registration was done in order to register the ETM+ image (dated 2000) with geocoded TM image dated 1990 (master image). The RMS error of the image-to-map was 0.40 to 0.45 pixel, while was 0.10 to 0.14 pixel with image to image registration.

The Landsat imageries were radiometric calibrated for sensor differences, converted into spectral radiance and normalized for illumination properties through differences in sun-elevation angle and sun–earth distance by recalculating the pixel values into at-satellite reflectance.

Table (1)
Mean annual precipitation and potential evapotranspiration of Tikrit county in the study area (Iraqi Meteorological Foundation. 2006. personal communication).

Location	Year	P	ETP	P/ETP	Aridity Index Class
		(mm)			
Tikrit	1989	246.6	2996	0.082	Arid zone
	1990	115.1	3870.5	0.030	Arid zone
	1999	109.4	3238	0.034	Arid zone
	2000	166.7	2762.4	0.060	Arid zone

2. Vegetation, Soil, and Water Indices

The geometrically rectified and radiometrically calibrated TM, ETM+ bands 1, 2, 3, 4, 5, and 7 were used to derive the studied indices. Satellite derived indices images were produced to portray surface changes.

2.1 The Normalized Difference Vegetation Index (NDVI)

Rouse et al. (1974) initially proposed the Normalized Difference Vegetation Index *"NDVI"*. The NDVI derived from the ratio of band 3 and band 4 in Landsat TM and ETM+ images data was applied for monitoring vegetation changes in the study area within the years of 1990 and 2000.

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

2.2 The Normalized Differential Water Index (NDWI)

The Normalized Differential Water Index *"NDWI"* was used to oversee the situation of the Water bodies in the study area. The ratio between Red and SWIR spectral region clearly enhanced water bodies to the brighter pixels (CPM, 2003).

$$NDWI = \frac{R - SWIR}{R + SWIR}$$

2.3 Normalized Differential Sand Dune Index (NDSDI)

The new index NDSDI is proposed and applied in this study for identify and highlighting the existence of the sand dune accumulations at the study area. The suggested index based on the normalized difference between the RED and the SWIR2 spectral values. This index is aimed at differentiating between sand dune accumulations, bare soils, and the other types of soils. A threshold was used in order to mask and extraction the sand dune accumulations in the processed image. Proposed the NDSDI has the form:

$$NDSDI = \frac{R - SWIR2}{R + SWIR2}$$

Where R is the reflectance of red (band3: 0.63-0.69 µm), and SWIR2 is the short wavelength infrared (band7: 2.08-2.35 µm) of the Landsat TM/ETM+ sensors. Taking into consideration the reflectance of different sand dune and drifting sand surfaces and vegetation, the difference between band R and SWIR2 in the NDSDI equation is designed to distinguish among the vegetated or water surface, sands, and bare soil; while the accumulation of the reflectance in the R, SWIR2 bands can discriminate the mineral and rock types; sensitive to soil and vegetation moisture content.

Threshold was applied based on field knowledge of sand dune accumulations and the visual interpretation. Selection an appropriate threshold value through visual comparison on the images with the aid of experience that gained during the field work is an important step to derive the different sand dunes accumulations in the study area. Valuesof the NDSDI is ranged between (-1≤ NDSDI ≤1); whereas the sand dunes accumulations and drifting sands often take values less than zero (< 0),while the vegetative cover takes values more than zero (> 0), and the water bodies take the highest values.

3. Data Transformation

3.1 Tasseled Cap Transformation Wetness (TCW)

The Tasseled Cap Transformation "TCT" was first introduced by Kauth and Thomas (1976) as a data transformation to be used with Landsat MSS data that provided valuable soil and vegetation information for agricultural assessments. Then TCT was update by Crist (1985) for use with Landsat TM data. TCT transforms the six Landsat TM (ETM+) bands into three indicators of known characteristics: soil brightness (TCB), vegetation greenness (TCG), and soil/vegetation wetness (TCW). Tasseled cap wetness TCW was used to determine the amount of moisture being held by the vegetation or soil, thus termed wetness (Crist, 1985). TCW applied to TM and ETM+ images of the study area using TCT algorithm with ERMapper 7.1

4. Land Degradation Detection Methods

In general, change detection involves the use of multitemporal data sets to quantitatively analyze the temporal effects of the phenomenon (Lu et al, 2004). Four aspects of change detection are important when monitoring naturally occurring phenomena: detecting the changes that have occurred, identifying the nature of the change, measuring the real extent of the change and assessing the spatial pattern of the change (RTO, 2007).

Land degradation is usually detected efficiently by remote sensing analysis. The change detection methods are grouped into seven categories: (1) algebra, (2) transformation, (3) classification, (4) advanced models, (5) Geographical Information System (GIS) approaches, (6) visual analysis, and (7) other approaches. (Lu et. Al, 2003).

Generally, there are two typical methods to realize the change detection. The first one is the post-classification comparison, aiming to uncover differences between the classified images of two different dates (Singh, 1989; and Weismiller et al., 1997). The second one which proposed by other authors is the image differencing to perform the detection (Jensen et al., 1982; and Lambin 1997). The image differencing was conducted to two Landsat TM and ETM+ images to detect the land cover changes in the study areas and complemented with visual comparison to distinguish and quantify the county-level change types.

In this study the post classification comparison were performed on the two feature images of NDVI and NDSDI for the year 1990 and 2000 in order to calculate the differences between them. On the other side, image differencing technique was used for NDWI and TCW images of the two years 1990 and 2000. The thresholds of NDWI and TCW differences were then used to develop a change map. The zones of positive, negative and no changes were determined by establishing a threshold value then applying a mask. According to this criterion the positive and negative change images were produced by ERMapper package as a raster dataset, and then converted to a GIS environment (ArcView 3.3) as ESRI shape files.

Locations were selected using a portable GPS device (Garmin) during field work to collect the ground truth and to perform the field checking for the obtained results. An accuracy assessment of the classification undertaken with used indices was done.

5. Land Degradation Severity Assessment

Realistic assessment of desertification severity relies, first and foremost, on the identification of pertinent indicators (Rubio and Bochet, 1998). Four indicators have been identified Table (2) as critical to assessment the desertification severity in the study area: vegetative cover, extent of drifting sand, desertification rate, and population pressure. The first two factors are prime indicators of the land degradation and directly derivable from satellite imagery. Population pressure and expansion rate of desertified land are indirect, and dynamic indices (Yansui et. al. 2003). The increase in population is one of the significant factors that influencing strongly, and leading to accelerated land degradation by creating a great pressure on the land and other natural resources. The threshold for each rank of a given indicator was set in accordance with the United Nations' indices for desertification assessment (UNEP, 1992), and with actual field observations.

6. Land Degradation Risk Index (LDI)

Land degradation risk LDI is indicative of the overall degree of the difficulty in rehabilitating degraded land in a given region for productive use. The vegetative cover and the sand dunes accumulation images were used for this assessment which derived both of them from Landsat TM and ETM+ imageries using NDVI and NDSDI algorithms, respectively. The higher value of LDI indicates a more severe level of land degradation. It is calculated using the following formula:

Land Degradation Risk Index (LDI) =

$$\sum_{i=1}^{n} P\, C_i^{-q}$$

where LDI ($0 \leq LDI \leq 1$) represents the risk of the land degradation in the county; Ci is the rank at which the land in an assessment unit has been degraded; P refers to the areal percentage of the land having a rank I, n stands for the number of indicator classes (four in this case); and q denotes the exponent of rank. Empirical values of 0.4, 0.25, and 0.15 were adopted for q after experimentation in this study for vegetation cover, drifting sand coverage, and annual desertification rates respectively. In order to study the temporal dynamics, the land degradation risk index was calculated for each county in the year of 1990 and 2000.

Table (2)
Indices and weights for factors used in the assessment of land degradation risk in the study area.

Indicator	Severity level				Weight
	I Severe	II High	III Medium	IV Low	
Vegetation cover (%)	<10	10-25	25-40	>40	0.40
Drifting sand coverage (%)	>65	15-65	5-15	<5	0.25
Annual desertification rate (%)	>5	2-5	1-2	<1	0.15
Population pressure (%)	>50	30-50	0-30	-30-0	0.20

7. Use of Geo-Information Technology

Geo-information technology was employed in this study for monitoring the land degradation in the study area. Algorithms of NDVI, NDWI, NDSDI, and TCW were utilised in the study in order to extract the feature raster file related to the vegetative cover, water bodies, sand dunes accumulations, and the soil/vegetation wetness. Then the raster files then were converted to Geotiff format in order to open them later in a GIS environment with ArcView GIS 3.3. By using ArcView; raster files were converted to vector (shape format) files, then the spatial database for vector files were built. Intersection by theme was done for each theme map with county's border theme to create a feature theme map for each county. Finally by field calculator; total area of extracted feature was computed.

8. Ancillary Data and Software Packages

County-level socio-economic, population census, meteorological data and software such as ERMapper ver 7.1 and Erdas Imagine ver 9.2 were used for the digital image processing and analysing. ArcView GIS ver 3.3 and ArcGIS 9.1 were used for analysing and presenting the results in a GIS environment. Statgraphics XV.I, NCSS-2007, and MS-Excel-2007 packages were utilized for the statistical analysis, calculations, and presenting of the results.

Results and Discussion

NDVI, NDSDI, NDWI, TCW, and LDI indices were computed and obtained for the multi-temporal Landsat TM and ETM+ images and tried to analyze the environmental changes

and assess the land degradation severity at the study area.

1. Assessment of Land Degradation Severity

Based on the NDVI, NDSDI, NDWI, and TCW indices images derived from Landsat TM and ETM+ remotely sensed dataset for the years 1990 and 2000, it appeared that the study area got a significant decline in the vegetative cover and a high increase in the sand dune accumulation, a decrease in the water bodies area, and a decrease in the soil moisture during the study period. The vegetation deterioration rate in the study area was 26.2 km^2Year^{-1}. The areal percentage of the vegetative cover decreased from 27.1 to 17.2% of the total study area, means it converted from medium vegetative degraded level (III) to highly vegetative degraded level (II) through ten years according to the UN indices

For desertification assessment. The vegetative degradation accompanied with an increase in the sand dune accumulation area from 2.5 to 5.0% from the whole study area, increasing from the low degraded (IV) to medium degraded level (III). Rate of sand dunes expansion during the ten years of study was 10.2 km^2Year^{-1}.

The decrease in the water bodies area was 228.1 km^2, while about 8.5% of total study area had a negative change in their soil/vegetation wetness, showing an expansion rate of 92.8 km^2Year^{-1} during the study period. Figs. (2, 3, 4, and 5) show the spatial distribution of the vegetative cover in the study area for the years 1990 and 2000, while Tables (3, 4, 5, and 6) provide related statistics.
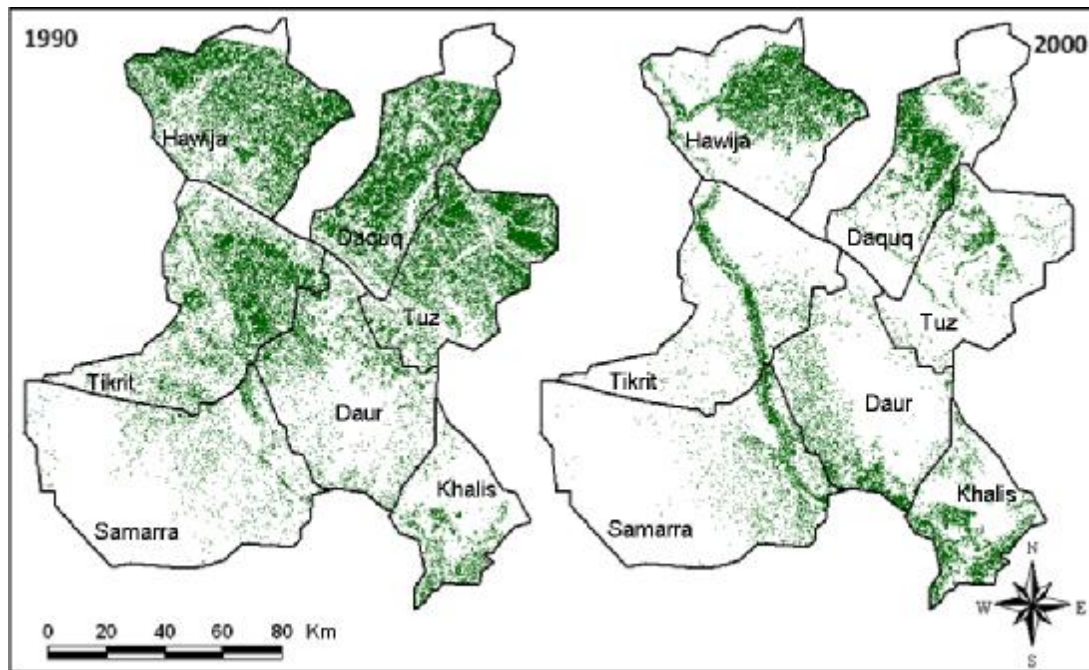
Fig.(2) : Spatial distribution of the vegetative cover extracted by NDVI in the study area for the years 1990 and 2000.

Table (3)
County-level vegetative cover extracted by NDVI results of the study area
for the period from 1990 to 2000.

County name	County area	1990		2000		2000-1990		Vegetation change rate
	km^2	km^2	%	km^2	%	km^2	%	km^2 Year^{-1}
Tuz	2555.9	1,114.2	43.6	227.9	8.9	-886.3	34.7	-88.6
Al-Daur	3063.3	462.7	15.1	368.9	12	-93.8	-3.1	-9.4
Hawija	2926.2	1,313.20	44.9	783.4	26.8	-529.8	18.1	-53.0
Khalis	1564.6	223.3	14.3	370.8	23.7	147.5	9.4	14.8
Daquq	2206.8	1,079.90	48.9	500.5	22.7	-579.4	26.3	-57.9
Samarra	4734.1	264.9	5.6	358.3	7.6	93.4	2.0	9.3
Tikrit	3287.6	1,047.50	31.9	275.5	8.4	-772.0	23.5	-77.2
Sum	20338.5	5,505.70	*27.1*	2885.3	*14.2*	2,620.40	*12.9*	**-262.0**
Average								**-26.2**
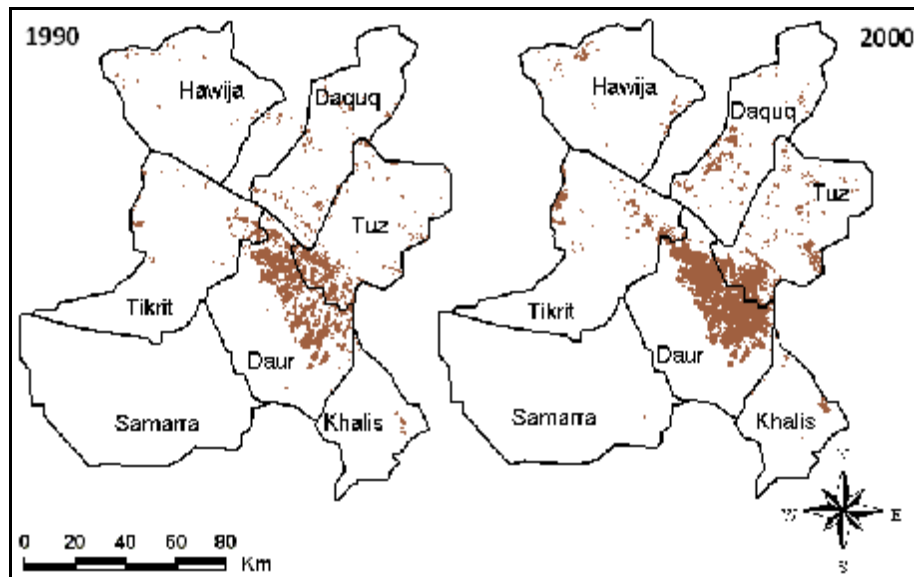
Fig.(3) : Spatial distribution of sand dune accumulations extracted by NDSDI in the study
area for the years 1990 and 2000.

Table (4)
*Sand dunes accumulations extracted by NDSDI in the study area at county-level
for the period from 1990 to 2000.*

County name	County area	1990		2000		2000-1990		Expansion rate
	km^2	km^2	%	km^2	%	km^2	%	km^2 Year^{-1}
Tuz	2555.9	139.9	5.5	592.1	23.2	452.2	17.7	45.2
Al-Daur	3063.3	282.0	9.2	713.0	23.3	431.0	14.1	43.1
Hawija	2926.2	15.9	0.5	20.5	0.7	4.7	0.2	0.5
Khalis	1564.6	3.1	0.2	10.8	0.7	7.7	0.5	0.8
Daquq	2206.8	36.3	1.6	39.9	1.8	3.6	0.2	0.4
Samarra	4734.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tikrit	3287.6	34.0	1.0	153.7	4.7	119.6	3.6	12.0
Sum	20338.5	511.2	*2.5*	1,530	*7.5*	1,018.8	*5.0*	102
Average								**10.2**

Table (5)
Water bodies surface area reduction during the period 1990 - 2000.

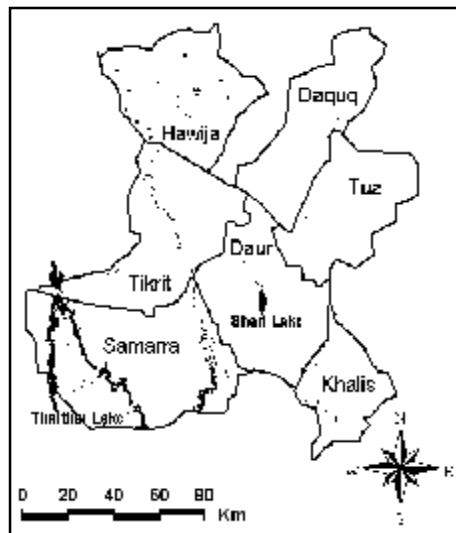| County name	Water body dryness area
	km^2
Tuz	0.225
Al-Daur	24.154
Hawija	7.503
Khalis	3.587
Daquq	0.136
Samarra	177.867
Tikrit	14.586
Sum	**228.1**

Fig.(4) : Water bodies decrease (rivers and lakes) at the study areas which extracted from the Landsat TM for 1990 and Landsat ETM+ for 2000.
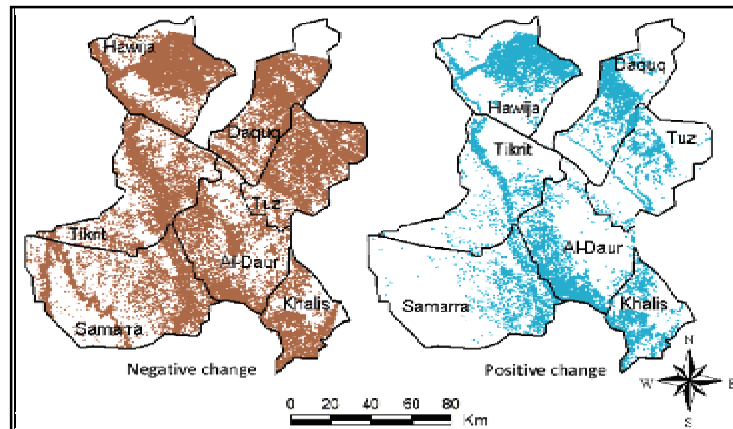

Fig.(5) : The Negative and positive changes of Tasseled Cap Wetness TCW indicator during the period 1990-2000.

Table (6)
County-level Tasseled Cap Wetness TCW results of the study area for the period from 1990 to 2000.

County Name	County area	TCW_pos		TCW_neg		No change		p-n	TCW Pos-rate	TCW Neg-rate
	km²	km²	%	km²	%	km²	%	%	km²Year⁻¹	km²Year⁻¹
Tuz	2555.9	119.9	4.7	608.2	23.8	1,827.9	71.5	-19.1	12.0	60.8
Al-Daur	3063.3	300.2	9.8	419.0	13.7	2,344.1	76.5	-3.9	30.0	41.9
Hawija	2926.2	411.1	14.0	465.9	15.9	2,049.2	70.0	-1.9	41.1	46.6
Khalis	1564.6	176.1	11.3	177.5	11.3	1,211.1	77.4	-0.1	17.6	17.7
Daquq	2206.8	255.6	11.6	429.2	19.4	1,522.0	69.0	-7.9	25.6	42.9
Samarra	4734.1	177.2	3.7	633.3	13.4	3,923.7	82.9	-9.6	17.7	63.3
Tikrit	3287.6	124.8	3.8	552.1	16.8	2,610.7	79.4	-13.0	12.5	55.2
Sum	20338.5	1,564.9	*7.7*	3,285.3	*16.2*	15,488.7	76.1	-55.5	156.5	328.4
Average									*15.7*	*92.8*

2. Spatial Distribution of Land Degradation

Tuz, Samarra, and Tikrit had lowest percentage of the vegetative cover among all studied counties during the study period. Three counties had a vegetative cover less than 10% in the year 2000, which is designated them as severely degraded level (I) land which accounting 44.9% of the total area of the study region (Tables (1, 2) and Fig.(2)). Al-Daur, Khalis, and Daquq suffered from the highly degraded level (II) land accounts for 33.6 % in areal proportion, and degradation has been caused mainly by sand dunes accumulations and vegetation deterioration. Hawija County had a medium degraded level (III) land, accounting 26.8% of the total study area.

In comparison between the vegetative cover area for each county during the two years 1990 and 2000, it observed a highly decrease in the vegetative cover in most of the studied counties. Tuz, Daquq, and Tikrit registered the worst situation and the highest decline Table (3) in the vegetative cover during the mentioned years. They were 34.7, 26.3, and 23.5% of the total area of each county, respectively.

It was found through the application of NDSDI for the sand dunes in the study area and its neighboring areas; it is effective and efficient in a isolate and highlight the presence of sand dunes and drifting sands. The NDSDI was specifically designed for using Landsat TM/ETM+ data sets. Obtained results of NDSDI gave a good impression and promising ability on its capability for identifying and highlighting the sand dune accumulations at the study area. The results indicated an obvious increase Table (4) of the sand dune accumulations at the study area during the ten year study period, especially in Tuz County, which got the highest increase in the sand dune accumulation area at the study region during the years from 1990 to 2000 that was 452.2 km^2, while Al-Daur County was at the second order, its increase was 431.0 km^2. Tuz and A-Daur were the highly degraded level according to the United Nations Indices of sand dune accumulations in the year 2000, while they were at medium degraded level in the year 1990. The sand dune accumulation situation changed strongly toward the worst during the ten years of study.

In recent years shrunk the amounts of water reaching Iraq through the Tigris and Euphrates rivers and their tributaries. That led to drought and reduced many areas of water bodies in Iraq, such as rivers, lakes and adversely affecting the cultivated areas and agricultural activities of the people and led to the degradation of many agricultural lands and then to the acceleration of desertification. As a result of above in the study area; Shari Lake dried up entirely while Tharthar Lake lost parts of its surface water by drought of 2-4 km depth of its beaches Fig.(4), while Little Zab and Al-Udhaim rivers had gained narrow in their flow.

Results of NDWI clarified a significant decrease in the area covered by water bodies during the study period from 1990 to 2000. Water bodies at Samara, Al-Daur, and Tikrit counties suffered significant loss in the areas covered by water. The measured reduction in water cover was 177.8, 24.1, and 14.5 km^2 in Samara, Al-Daur, and Tikrit counties, respectively. TCW results showed an increase in the negative change of the soil/vegetation wetness in the whole study area. Tuz and Tikrit counties had the biggest decrease in the soil moisture among the studied counties. They registered a decrease of 19.1 and 13.0% of the total area of two counties. Obliviously, the rate of land degradation has accelerated during the study period within the study region.

Although it is not possible to collect ground reference data for this type of study, a surrogate method was adopted, that is; a visual interpretation of the imagery at sample locations in situ. The estimated accuracy of the studied indices results for study area was 91.3%.

The population in the region increased during the ten years of study as well as to the decline in the water supplied by the rivers in the study area, since the discharges of the local rivers had decreased during the study period. One of the direct impacts of population growth is a decrease in the availability of arable lands, and increasing stress on the existing resources leading to rising of land degradation in the region.

3. Risk of Land Degradation

The Land Degradation Index LDI for the studied counties has been found to range from 0.96, 0.46, and 0.13 for Al-Daur, Tuz, and Hawija counties in the year 2000, while they were 0.19, 0.14, and 0.11 in the year 1990 for the same counties, respectively. As a percentage, these changes correspond to an increase in LDI of 352.6%, 228.5%, and 18.1%. Using the LDI as a summarization indication of the four land degradation indices shows that three counties which suffer the most due to desertification and land degradation are Al-Daur, Tuz, and Tikrit, with LDI values equal to 0.96, 0.46, and 0.39 respectively (see Fig.(7)). The LDI value of the whole area increased 111% during the ten years of study, reflecting the increasing in the vegetative deterioration and sand dune accumulations in the study area.
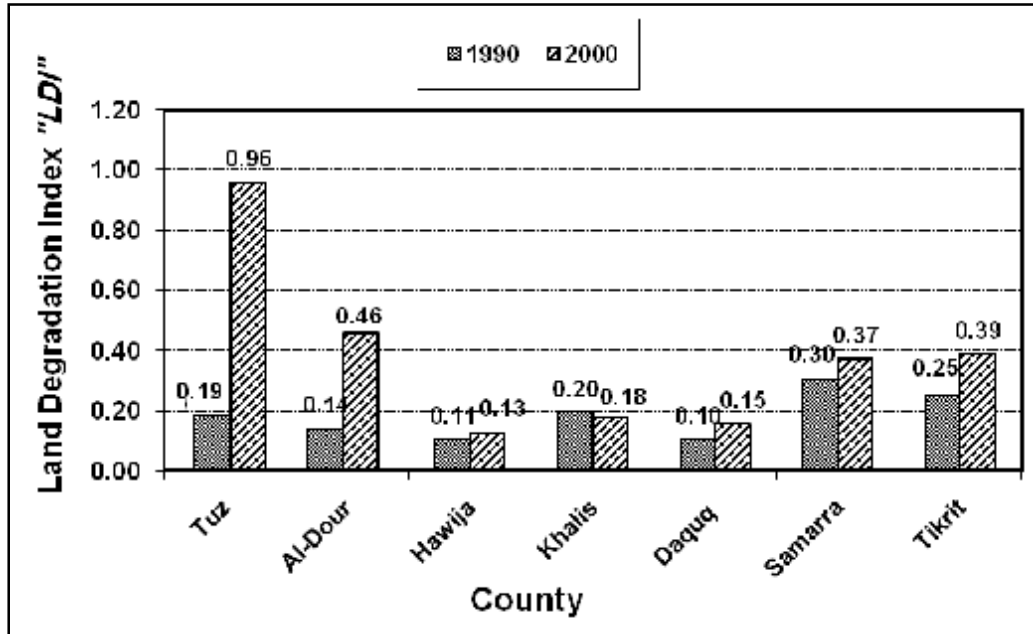

Fig.(6) : Land degradation risk index for the studied counties.

That desertification is linked to the conflicts among the concerns of human interest, increasing population pressure on limited natural resources and fragile ecosystem. Activities such as irrational exploitation of natural resources and poor management of land to a certain extent that lead to contribute to environmental destruction. The low mean of rainfall and declining river discharge in the region has led to pressure on the natural sources of rivers and other water bodies and then accelerated desertification.

Generally speaking, the results of this study indicated two counties; Tuz and Al-Daur, had the worst problems and at a high risk of land degradation and desertification among the studied counties during the ten years from 1990 to 2000.

4. Statistical Analysis for the Study Results

By the statistical analysis with Statgraphics XV.I and NCSS-2007 packages for the study results it appeared that there was a significant negative correlation (-0.83) between the Land degradation risk index LDI and the tasseled cap transformation wetness indicator TCW. Another significant positive correlation (0.77) was found between the NDVI and TCW, while the correlation between NDVI and LDI was significant negative (-0.71). Therefore, it is clear that the soil/vegetation wetness TCW had the strongest effect on the land degradation risk index LDI more than the vegetative index NDVI. That is logically; because there is no vegetation without water, so, the most effective factor on the land degradation acceleration in the study area is the deficiency of water in addition to

the socio-economic factors. Table (7) shows the correlation and the regression equation among the studies indices.

Table (7)
Correlation matrix and regression equations.

	LDI	TCW	NDVI
LDI	1	-0.83	-0.71
TCW	-0.83	1	0.77
NDVI	-0.71	0.77	1
Regression Equations			
LDI= - 0.0497- 0.0306 (TCW) r^2=84.1%			
LDI= 0.0709 – 0.0091 (NDVI) r^2=73.4%			
NDVI= 0.2256 + 1.7019 (TCW) r^2=79.4%			

Conclusions

Increasing land degradation lead to the acceleration of the sensitivity of the land surface to wind erosion and then to formation of dust storms which has negatively serious impact on the environment and public health.

The results of this study show clearly and unequivocally the state of land degradation and desertification experienced by the studied areas in the upper Mesopotamian plain of Iraq.

1. It highlighted the need to develop plans in short and long term to address the situation of land degradation and to combat desertification and loss of water bodies in most of the studied counties of the study area.

2. Overall results of the study indicated a general vegetation deterioration of 12.9 percent, an increase in the sand dune accumulation by 5.0 percent, a decrease in the wetted soil by 8.5 percent, as well as to the reduction in surface area of water bodies in the region by 228.1 km2. The land degradation risk in the study area has increased by 111% during the study period.

3. The results of the new index NDSDI for assessing, monitoring, and mapping the sand dune accumulations were promising and gave a good impression for its good capability in highlighting the sand dune accumulations in the study area.

4. The findings in this study have profound implications on how to reduce the severity of desertification risk in the study areas. In accordance with Fadhil (2002 and 2004) who indicated to the importance of soil conditioners, re-vegetation, and the afforestation for the fixation and stabilization of mobile sand dunes in Iraq and China. Zhu (1993) indicated to the plants should be grown and mechanical fences to control movement of sand should be set up to stabilize shifting sands.

5. The efforts should be directed to the improved irrigation situation would enhance farmland productivity, and hence reduce over-cultivation and grazing. If the reasonably water resource in the area could be adequately utilized through agricultural projects, it would be feasible to gradually re-vegetate the degraded lands.

6. Briefly, no single means can work effectively in isolation without the support. Coordinated efforts aimed to reducing and reversing desertification must given to the study area.

7. Rehabilitation endeavors should be directed to both areas of severely

degraded and also to the area that are not at high risk to lessen the overall of desertification.

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النباتي والتربة والمياه والتي لها صلة بتـدهور الأراضـي وطبقت لاثنين من صور القمر الصناعي لاندسـات TM و ETM+ لتقييم درجة تدهور الأراضي لمنطقـة الدراسـة خلال الفترة من 1990 إلى 2000. تم اعتماد نظام محوسب لتقدير شدة تدهور الأراضي بإسـتخدام حـزم برمجيـات ERMapper 7.1 و Erdas Imagine 9.2 و ArcView 3.3 و ArcGIS 9.1 لمعالجة وإدارة وتحليل البيانات النقطية والموضوعية. المؤشرات المسـتعملة فـي البحث هي مؤشر الغطـاء النبـاتي "NDVI" و مؤشـر المسـطحات المائيـة "NDWI" و مؤشـر Tasseled لرطوبة التربة/النبات "TCW" إضافة إلى المؤشر الجديد المقترح في هذا البحث والمسمى مؤشر الكثبـان الرمليـة والترب القاحلة "NDSDI". أوضحت نتائج البحث تدهورا واضحا في الغطاء النباتي (2620.4) كم^2 و زيـادة فـي تراكمات الكثبان الرملية (1018.8) كم^2 و إنخفاضـا فـي رطوبة التربة/النبات لمساحات (1720.4) كم^2 بما نسـبته 12.9 و 5.0 و8.5 بالمائة من المسـاحة الكليـة لمنطقـة الدراسة، على التوالي. أوضحت النتـائج أيضـا انخفاضـا وتقلصا في مساحات المسطحات المائية في المنطقة مقداره (228.1) كم^2. كما زادت مساحات انتشار الكثبان الرمليـة في المنطقة بمعدل إنتشار سنوي بلغ (10.2) كـم^2/ سـنة خلال عشر سنوات، وازداد خطر تدهور الأراضي بنسـبة 111% خلال الفترة نفسها. التحليـل الإحصـائي للنتـائج أوضح أن لنقص رطوبة التربة/النبات التأثير الأكبـر فـي عمليات تدهور الأراضي في منطقة الدراسـة. كـان الأداء المتميز للمؤشر الجديد "NDSDI" المقترح في هذا البحث واعدا وفعالا في تشخيص تراكمات الكثبان الرمليـة فـي منطقة الدراسة. يوضح هذا البحـث أن معظـم المنـاطق الواقعة في منطقة الدراسة معرضة لأخطار جدية في جفاف المسطحات المائية وتدهور الأراضي.

الخلاصة

هذا البحث يهدف إلى رصد و رسم الخرائط، وتقيـيم تدهور الأراضي في القسم الاعلى من سهل ما بين النهرين من العراق. العراق يعاني بشدة بسـبب مشـاكل تـدهور الأراضي والتصحر، وخاصـة فـي الأجـزاء الوسـطى والجنوبية من العراق. استعملت خمسة مؤشـرات للغطـاء