Develop a methodology for evaluation of the environmental sensitivity areas to desertification in the Maysan Province, Iraq

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Abstract
Systematic studies have been conducted in the present work to develop a methodology for evaluation of the environmental sensitivity areas to desertification. The area selected for the study is the Maysan Governorate which is located in the southern eastern part of Iraq. The methodology involves use of an integrated approach comprised of data generated from remote sensing assisted by population data, climatic factors, field survey and available previous studies. All data were classified and integrated in GIS environments to develop a model using a mathematical overlapping weights. This model is theoretically based on the relationship between a number of indicators directly related to the effect of desertification, namely Normalized Difference Vegetation Index (NDVI), Normalized difference Water index (NDWI), Salinity Index (SI), Eolin Mapping Index (EMI), population data and climate factors. Weights have been giving by expert's scientists for each indicator and within the class-specific index and classes with the help of ArcGIS and the Raster Calculator toolbox. Thus, a possible map of sensitivity areas to desertification in Maysan provenance desertification was obtained.
Based on the analysis of this map the entire area divided into five possible sensitive grades, which are highly sensitive, high, moderate, low and very low. It is noted that the area affected or highly sensitive to desertification is located in the north and west of the study area due to the presence of sand dunes and salinity, while desertification decreases towards the city center because of the increase in rainfall and abundant vegetation.

1. Introduction
In recent years many problems occurred in the environment due to the developments in human life. One of the most environmental problems is desertification [1]. [2] Suggest that desertification began several centuries ago and can be traced back to the mediaeval and even Neolithic period. Desertification means land degradation in arid, semi-arid and dry sub humid areas resulting from various factors including climate change and human activities [3] and [4]. Desertification in Iraq especially in the southern governorates has become a serious problem. Thus the identification of land affected by desertification is an important issue at present. Maysan governorate is one of the regions that suffer from the problem of desertification as it is one of agricultural areas and characterized by economic importance to the country. This region suffers also from the presence of sand dunes, water shortages, erosion and factors that affect soil productivity. The methods currently used for evaluation sensitive areas to desertification are mostly traditional and inaccurate, expensive and take long time. Hence, there is a need to find the new method to define sensitive areas to desertification in order to...
break down the problems and find a proper possible solutions. The present study has been taken up with an objective of develop a methodology to evaluate the environmentally sensitive areas to desertification in the Maysan governorate, southern Iraq using integrating Remote Sensing and Geographic Information System (GIS). GIS provided integrated information on different parameters that control the desertification factors. These techniques applied a lot in many studies related to desertification like [5], [6], [7], [8], [9], [10], [11] and [12].

2. Study Area

The study area is bounded by longitude 47° 05' 21.16'' E to 47° 40' 53.52'' E and latitudes 32° 03' 25.52 '' N to 32° 30' 30 '' N in zone 38N according to UTM projected coordinate system as shown in Figure (1). It is located 400 Km away from Baghdad on the bank of the Tigris river in the south eastern part of Iraq represents a commercial center for agricultural crops, fish, and cattle. It is linked to the Governorates of Basra and Wasit and to the Governorate of Thi Qar. The area of Maysan province constitutes 3.7% from the total area of Iraq's. Climate characteristics of this region such as high temperatures, low precipitation and a northwesterly winds prevailing have a direct and indirect effect on the characteristics of soil and water resources, which in turn effects on the spatial distribution of agriculture and livestock.

Figure 1. Location map of the study area

3. Methodology

A number of indices such as (NDVI), (NDWI) (SI) and (EMI) assist with the climate and population data have been used to develop a methodology for evaluation of the environmental sensitivity areas to desertification in the Maysan Province. Image processing software (ERDAS 13) is used to enhance digital satellite of Landsat TM, ETM and OLI images for interpretation of (NDVI), (NDWI) (SI) and (EMI) that effect to desertification phenomena. Climatic and Population data were collected and used as assistant and additional secondary data to analyses the factors causing desertification in the study area. Climatic data such as rainfall, wind speed, wind direction, temperature, evaporation, and relative humidity is collected from Amara meteorological station for the period 1989-2015. Spatial distributions map of these indices have been created using the inverse distance interpolation technique (IDW) and integrated in GIS environments. Weights have been giving by expert's scientists for each indicator and within the class-specific index and classes with the help of ArcGIS and the Raster Calculator toolbox.
3.1. Classifications of the generated indicator maps

Normalized Difference Vegetation Index (NDVI), Normalized difference Water index (NDWI), Salinity Index (SI) and Eolin Mapping Index (EMI) generated from Landsat TM, ETM+ and OLI have been classified using GIS (Arc GIS, version 9.1) to interpret the features that effect on desertification. Population data and Climatic elements such as relative humidity, wind speed, rain-fall, temperature and evaporation have also classified as shown in Figure (2 to 11). It has been observed that the vegetation and water bodies was found to be denser in the south, south-east and central part of the study area, with a clear decline and disappearance of complete agricultural areas in the north, north-east and western part of the study area. Sand dunes and salinity is very low in the south of the study area increasing towards the northeast and southwest. The highest rainfall was in the central of the study area decreasing to south-west of the study area. The lowest temperature in the centre of the study area increases to the south west northeast. The relative humidity is high in the south of the study area decreasing towards the north and southwest. The evaporation is increasing towards the northwest of the study area.

![Figure 2. NDVI classification](image)

![Figure 3. NDWI classification](image)
Figure 4. Sand dunes classification
Figure 5. Salinity classification
Figure 6. Rainfall classification
Figure 7. Temperature classification
3.2. A weights of the indicator (layers) related to the desertification phenomenon

After creating the layers of vegetation, water cover, salinity, sand dunes, climate and population, a questionnaire has been conducted to evaluating the environmental sensitivity areas of desertification in the study area. The questionnaire was distributed to five experts for giving a weight to the indicators related to the phenomenon of desertification. For example, water cover is play very important role to
the desertification, hence the better water cover means the desertification is less, so the relationship is reversed and lesser weight is given to this indicator and so for the rest of the indicators. Tables (1) to tables (10) show the results of weighting each parameter and according to weighting method, inter and intra-criterion weights calculated.

**Table 1. Weighting of Rain fall**

| Layer name | Weighting method | Rain fall level | Intra-criterion weight | Inter-criterion weight |
|------------|------------------|-----------------|------------------------|------------------------|
| Rain fall  | More Rain fall Lower weight | Very low 4 | 1.5 |
|            |                   | Low 3         |            |
|            |                   | Moderate 2   |            |
|            |                   | High 1       |            |

**Table 2. Weighting of temperature**

| Layer name | Weighting method | Temperature level | Intra-criterion weight | Inter-criterion weight |
|------------|------------------|-------------------|------------------------|------------------------|
| Temperature| More Temperature Higher Weight | Very low 0.8 | 0.8 |
|            |                   | Low 1.5          |            |
|            |                   | Moderate 3.2     |            |
|            |                   | High 4.5         |            |

**Table 3. Weighting Relative Humidity**

| Layer name | Weighting method | Relative Humidity level | Intra-criterion weight | Inter-criterion weight |
|------------|------------------|-------------------------|------------------------|------------------------|
| Relative Humidity | More Relative Humidity Lower Weight | Very low 3.9 | 0.4 |
|            |                   | Low 2.7                |            |
|            |                   | Moderate 2.1           |            |
|            |                   | High 1.3               |            |

**Table 4. Weighting of Evaporation**

| Layer name | Weighting method | Evaporation level | Intra-criterion weight | Inter-criterion weight |
|------------|------------------|-------------------|------------------------|------------------------|
| Evaporation | More Evaporation Higher Weight | Very low 1.2 | 0.5 |
|            |                   | Low 2.2           |            |
|            |                   | Moderate 2.7      |            |
|            |                   | High 3.9          |            |
### Table 5. Weighting Wind Speed

| Layer name | Weighting method    | Wind Speed level | Intra-criterion weight | Inter-criterion weight |
|------------|---------------------|------------------|------------------------|------------------------|
| Wind Speed | More Wind Speed     | Very low         | 0.8                    | 0.7                    |
|            | Higher Weight       | Low              | 1.5                    |                        |
|            |                     | Moderate         | 3.2                    |                        |
|            |                     | High             | 4.5                    |                        |

### Table 6. Weighting Population

| Layer name | Weighting method    | Population level | Intra-criterion weight | Inter-criterion weight |
|------------|---------------------|------------------|------------------------|------------------------|
| Population| More Population     | Very low         | 1.1                    | 0.9                    |
|           | higher weight       | Low              | 2                      |                        |
|           |                     | Moderate         | 3                      |                        |
|           |                     | High             | 3.9                    |                        |

### Table 7. Weighting of vegetation

| Layer name | Weighting method    | Vegetation level | Intra-criterion weight | Inter-criterion weight |
|------------|---------------------|------------------|------------------------|------------------------|
| Vegetation | More Vegetation     | Very low         | 4.7                    | 1.4                    |
|            | lesser weight       | Low              | 3.2                    |                        |
|            |                     | Moderate         | 1.6                    |                        |
|            |                     | High             | 0.5                    |                        |

### Table 8. Weighting Water

| Layer name | Weighting method    | Water level | Intra-criterion weight | Inter-criterion weight |
|------------|---------------------|-------------|------------------------|------------------------|
| Water      | More Water          | Very low    | 5                      | 1.7                    |
|            | Lesser Weight       | Low         | 2.7                    |                        |
|            |                     | Moderate    | 1.8                    |                        |
|            |                     | High        | 0.5                    |                        |
Table 9. Weighting of Salinity

| Layer name | Weighting method | Salinity level | Intra-criterion weight | Inter-criterion weight |
|------------|------------------|----------------|------------------------|------------------------|
| Salinity   | More Salinity Higher Weight | Very low | 0.3 | |
|            |                   | Low        | 1.5 | |
|            |                   | Moderate   | 2.8 | |
|            |                   | High       | 5.4 | |

Table 10. Weighting of sand dunes

| Layer name | Weighting method | Sand dunes level | Intra-criterion weight | Inter-criterion weight |
|------------|------------------|------------------|------------------------|------------------------|
| Sand dunes | More sand dunes Higher Weight | Very low | 0.7 | |
|            |                   | Low        | 1.9 | |
|            |                   | Moderate   | 2.8 | |
|            |                   | High       | 4.6 | |

4. Weighting analysis and preparation map of sensitivity areas to desertification

After obtaining the weights of all factors related to desertification depending on expert’s opinion, the geometric mean is applied. This step is necessary to find the average value for each weight and hence the variation in the difference opinions is solved. For example, the geometric mean is implemented to calculate the weight within the same criterion (very low-rainfall). The five values of the five experts are depended to determine their arithmetical mean as shown in equation (1). This step is applied for all classes of the factors:

\[ GM = \sqrt[5]{4 \times 4 \times 3.2 \times 5 \times 4} = 4 \]  

\[ (1) \]

Where: GM is the geometric mean

The next step, the layer of each factor is generated based on the new values. Then the final map for desertification is obtained. In order to prepare the desertification potential map, the equation in below is applied with the help of ArcGIS software and Raster Calculator toolbox [13]; [14]; [15]; and [16]

\[ DP = RR \times 1.5 + RT \times 0.8 + RH \times 0.4 + RE \times 0.5 + RS \times 0.7 + RP \times 0.9 + RV \times 1.4 + RW \times 1.7 + RSa \times 1 + RD \times 1.1 \]  

\[ (2) \]

Where:

\[ RR = \text{Raster- Rainfall Map}, \ RT = \text{Raster- Temperature Map}, \ RH = \text{Raster- Relative Humidity Map}, \ RE = \text{Raster- Evaporation Map}, \ RS = \text{Raster- Wind speed Map}, \ RP = \text{Raster- population Map}, \ RV = \text{Raster- Vegetation Map}, \ RW = \text{Raster- Water Map}, \ RSa = \text{Raster- Salinity Map}, \ RD = \text{Raster- Sand Dunes Map} \]

Integration of all the above layers has been used to generate the desertification map of the study area. The entire study area is divided into five zones vis-à-vis their desertification potential namely, very
The results showed that the area affected by desertification is located in the north and west of the study area due to the presence of sand dunes and salinity, while the desertification decreases in the center of the city due to rainfall and abundant vegetation and water.

Figure 12. Environmental Sensitivity Areas to Desertification map

5. Model Evaluation
The model developed was validated against the field survey conducted for the area under study. Field observations of selected areas of the study showed that the rate of sensitivity of desertification increases with presses of sand dunes and high salinity soils while decreasing as we approach the center of the studied area because the rains are abundant and vegetation abundant as well as the presence of water bodies. This gives us an indication that the proposed method of predicting desertification is a good method that can be applied elsewhere.
6. Conclusions
A new methodology have been develop in the present study to estimate the environmental sensitivity areas to desertification in Maysan provenance. A major steps were conducted to create a data base including desertification-related factors. Spatial distribution maps of those factors were created and integrated using GIS package based on weights given by experts who's specialized in the field of desertification which is played very important role in generation of environmental sensitivity areas to desertification map of the study area. An analysis of the map result confirms that the north and west of the study area is the highest sensitivity areas to desertification, while the low sensitivity areas to desertification observed in the center of the study area. The above studies have also demonstrated that GIS integration geographic database derived from remote sensing is a suitable approach for evaluating the environmental sensitivity areas to desertification in the study area.

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