Drought Risk Assessment In Iraq Using Remote Sensing And GIS Techniques

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Abstract
This paper aims to investigate the drought levels in Iraq using Remote Sensing and GIS Techniques. Meteorological and Agricultural droughts were calculated based on Standardized Precipitation Index (SPI) and Anomaly of Normalized Difference Vegetation Index (NDVI), respectively. The drought risk maps were prepared by calculating the classes frequency of droughts. Finally, a resultant risk map was obtained by integrating agriculture and meteorological drought risk maps. The results indicated that 14.4% area has Slight drought, 61.6% area face moderate risk, 23.2% area face severe risk and 0.8% area face very severe risk within the study area. It was evident from the study that northwest of Iraq is more prone to drought.

Keywords: Agricultural drought, Meteorological drought, NDVI, Standardized Precipitation Index (SPI).

تقييم مخاطر الجفاف في العراق باستخدام تقانات التحسس النائي ونظم المعلومات الجغرافية

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الخلاصة
تتناول الدراسة الحالية كشف الجفاف في العراق باستخدام تقانات التحسس النائي ونظم المعلومات الجغرافية. تم حساب الجفاف الانوائي والجفاف الزراعي بالاعتماد على دليل المطر القياسي وشذوذ دليل الاختلافات الخضرية الطبيعي على التوالي. تم إنشاء خرائط الجفاف بواسطة حساب تكرار أصناف الجفاف المختلفة, أخيرا تم الحصول على الخريطة النهائية للجفاف من خلال جمع خريطة الجفاف الانوائي والجفاف الزراعي . النتائج تظهر بان 14.4% من المساحة تعاني جفاف طفيف,61.1% تعاني جفافا متوسطا, 23.2 تعاني جفافا حادا و 0.8% تعاني جفافا حادا جدا. يمكن ملاحظة إن المناطق الشمالية غربية هي الأكثر عرضة للجفاف.

1. Introduction

Drought is a natural hazard that results from a deficiency of precipitation from expected or "normal", such that when it is extended over a season or longer period of time, the amount of precipitation is insufficient to meet the demands of human activities and the environment [1]. Drought is a regional phenomenon and its characteristics will vary from one climate regime to another [2]. The severity of drought is also difficult to determine. Drought is often perceived as a creeping hazard as it develops slowly and has a prolonged duration [3]. The climatic environment of uncertainty is one of the major threats in water resources management. Droughts are regional events and their occurrences are governed by regional climatic parameters like precipitation, evapotranspiration, temperature etc. So the characteristics and consequences of drought vary with respect to climatic regimes around the world.

There is a number of indicators for drought monitoring and assessment. Every indicator has its successes and limitations in drought detection. Meteorological drought indicators assimilate information on rainfall, stored soil moisture or water supply but they do not express much local spatial detail.

On the other hand, the derived drought indicators calculated from satellite-derived surface parameters have been widely used to study droughts. Normalized Difference Vegetation Index (NDVI), Vegetation Condition Index (VCI), and Temperature Condition Index (TCI) are some of the extensively used vegetation indices. With the advancements in remote sensing technology, the historical drought indices were over powered by the newly developed indices from remote sensing data that are considered to be real time. Remote sensing and GIS technique is increasingly being regarded as a useful drought detection technique, as evidenced by its use across many parts of the world (e.g. Gujarat, India) [4], Western and Central Kansas, and Borkhar District, Iran [5].

This study was carried out to detect drought in Iraq which covers a total area of 435052 Km^2. Drought is one of the important natural hazard events in this region. The major objectives of the study are to identify agricultural drought by remote sensing and GIS, to identify meteorological drought by SPI method and finally to assess drought of the study area by combining both agricultural and meteorological drought.

2. Data Acquisition

Data has been acquired mainly from two sources, firstly derived from satellite sources (AVHRR-NDVI) which was derived from data collected by the National Oceanic and Atmospheric Administration (NOAA) satellites see Figure (1). The 8 km NOAA–AVHRR data during the Rainy season October –May from 1980 to 2010 has been used.

Secondly the monthly mean rainfall obtained from ground meteorological station. Historical records of monthly rainfall data for the time period 1980-2010 were acquired from the Iraqi Meteorological Organization and Seismology (IMOS) and Ministry of Agriculture and Water Resources (Kurdistan Region). Long-term data were collected from 39 weather stations located at different regions of the country, see Figure (2).

For the purpose of this study, monthly NOAA-AVHRR Pathfinder NDVI images of 8 km by 8 km spatial resolution were used. These satellite images were radiometrically corrected however; geometric corrections had to be done. The area of interest (Iraq) was extracted from a set of images. Finally the data of study area were extracted and became ready for analysis .for this study, 240 seasonal NDVI images were analyzed and used as an input data for NDVI anomaly drought index.

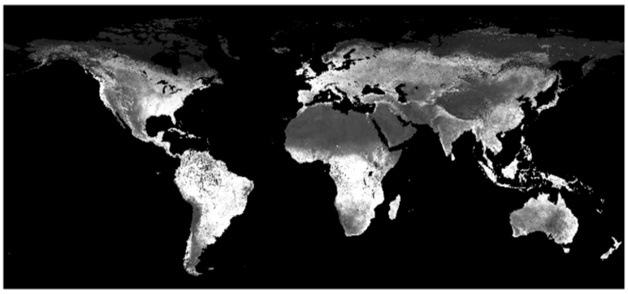

Figure 1- Global Distribution Of NDVI On April 15 1998.

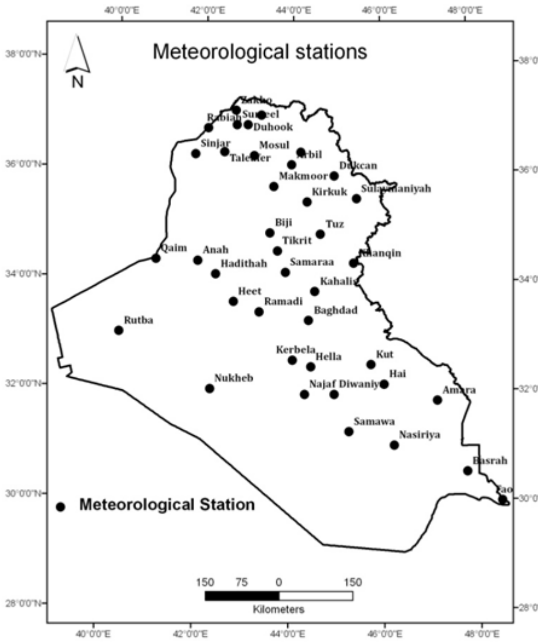

Figure 2- Meteorological Stations In Iraq.

3. The Standard Precipitation Index (SPI).

SPI is calculated by fitting gamma distribution function to given frequency distribution of precipitation totals for a given station, then the determined gamma distribution is transformed to a normal distribution with mean zero and variance of one The steps and equations to calculate SPI are as follows [6]:

(i) The precipitation data are calculated using the gamma probability density function which is defined as [7];

$$g(x) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta} \quad \text{for } x > 0 \qquad (1)$$

where $\alpha > 0$ is the shape parameter, $\beta > 0$ is a scale parameter and $x > 0$ is the amount of precipitation. $\Gamma(\alpha)$ defines the gamma function. α and β are parameters to be estimated for each station and for each time step of interest.

(ii) The maximum likelihood solutions are used to optimally estimate the gamma distribution parameters α and β [8]:

$$\hat{\alpha} = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right) \qquad (2)$$

$$\hat{\beta} = \frac{\bar{x}}{\hat{\alpha}} \qquad (3)$$

$$A = \ln(\bar{x}) - \frac{\sum \ln(x)}{n} \qquad (4)$$

and n is the number of precipitation observations. This allows the rainfall distribution at the station to be effectively represented by a mathematical cumulative probability function given by:

$$G(x) = \int_0^x g(x)\,dx = \frac{1}{\hat{\beta}^{\hat{\alpha}}\Gamma(\hat{\alpha})} \int_0^x x^{\hat{\alpha}-1} e^{-x/\hat{\beta}} dx \quad (5)$$

(iii) Since the gamma function is undefined for x = 0 and a precipitation distribution may contain zeros, the cumulative probability becomes:

$$H(x) = q + (1-q)\,G(x) \qquad (6)$$

where q is the probability of zero value. The cumulative probability H(x) is then transformed to the standard normal distribution to yield SPI [9].

4. Normal Difference Vegetation Index (NDVI)

NDVI was first suggested by Tuker (1979) as an index of vegetation health and density.

NDVI = (NIR-VIS) / (NIR+VIS) (7)

where, NIR and VIS are reflectance in the near infrared and visible band, respectively. Theoretically the NDVI values range is [-1, 1] but in practice it is within these limits.

The anomaly of NDVI has been calculated for a specific year using the mean, maximum value during the period 1980-2010 using the following equation [4]:

$$NDVI_{anomaly(i)} = \frac{NDVI_{max\,(i)} - \overline{NDVI}_{max}}{\overline{NDVI}_{max}} \times 100\ \% \qquad (8)$$

where, $NDVI_{anomaly(i)}$ is NDVI anomaly for ith year, NDVI max is maximum NDVI and $\overline{NDVI}_{max}$ is the average of maximum NDVI during the period of the study.

5. Result and Discussion

SPI and NDVI anomaly have been computed and it shows that when SPI is positive NDVI anomaly is also positive, and when SPI is negative NDVI anomaly is also negative, which states that SPI and NDVI anomaly could share a linear correlation up to certain accuracy extent, see Figure (3). The correlation coefficient between them is 0.86, Therefore, it can be said that a sort of relationship exist between SPI and NDVI anomaly.

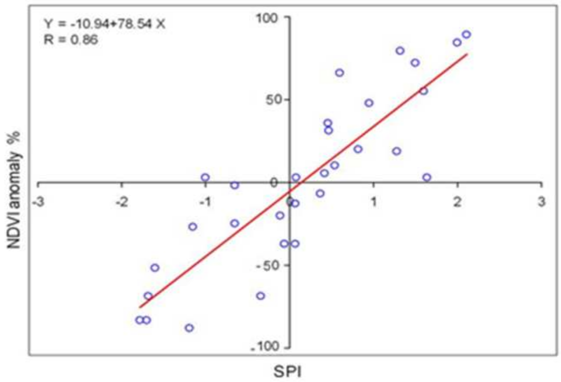

Figure 3- Relationship of SPI with NDVI anomaly.

The meteorological and agricultural drought risk maps have been prepared by integrating all drought frequency maps generated from the two drought indices, SPI, and NDVI anomaly. The maps in Figure (4) and Figure (5) show the frequency over the studied years for each risk level, they have been multiplied by weights according to the risk level, and a high weight of 0.5 was given to sever, 0.3 to moderate and 0.2 to slight risk to get drought risk maps. According to the result derived from the integration of all drought frequency maps, the area is classified into slight, moderate, severe and extreme drought risk zones.

Figure (6) shows the Meteorological and agricultural drought risk maps. The result of Meteorological drought map indicates that the percentage area affected by slight, moderate, severe and extreme agricultural drought risk encompasses 11.6%, 63.6%, 24% and 0.8% of the total area, respectively. The result of Agricultural drought map shows that the percentage area affected by slight, moderate, severe and extreme agricultural drought risk encompasses 12.7%, 32.3%, 41.3% and 13.7%, respectively, of the total geographical area of Iraq.

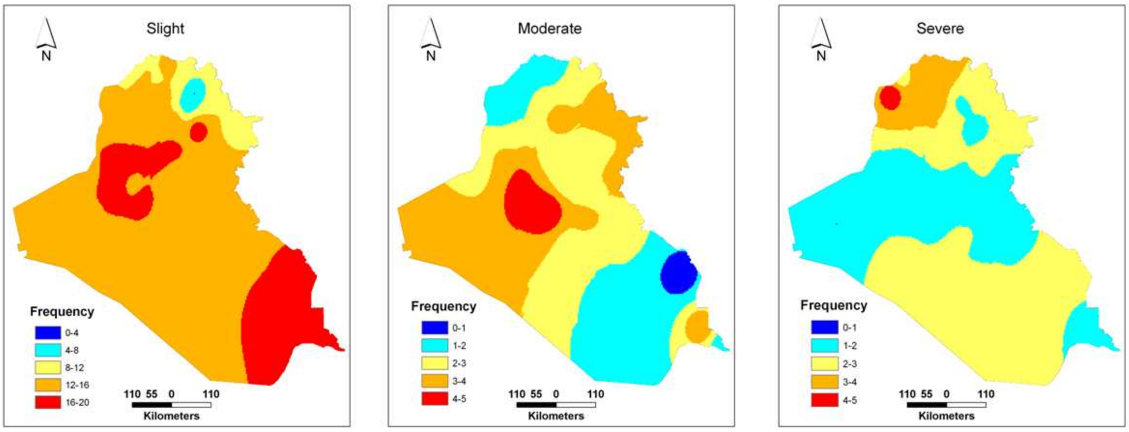

Figure 4- Frequency of Meteorological drought in three different

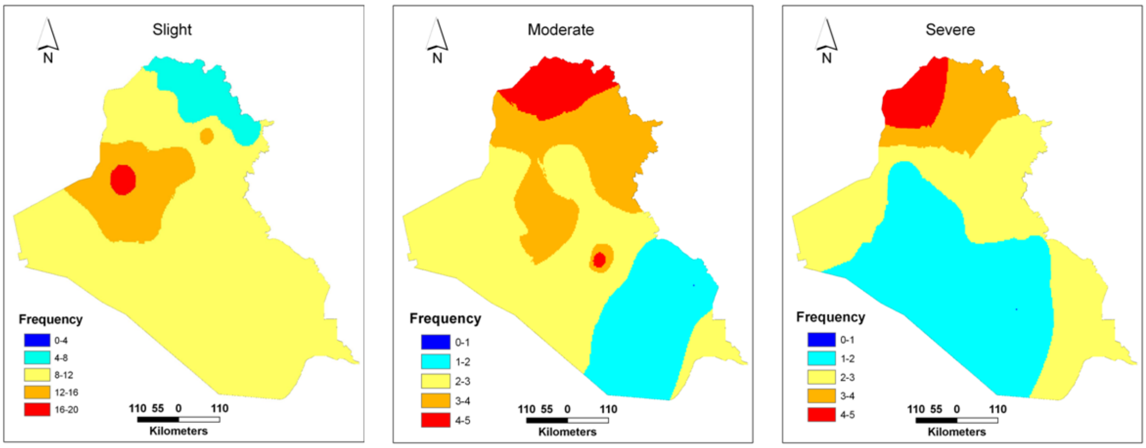

Figure 5- Frequency of Agriculture Drought in Three Different Severity Classes, Slight, Moderate

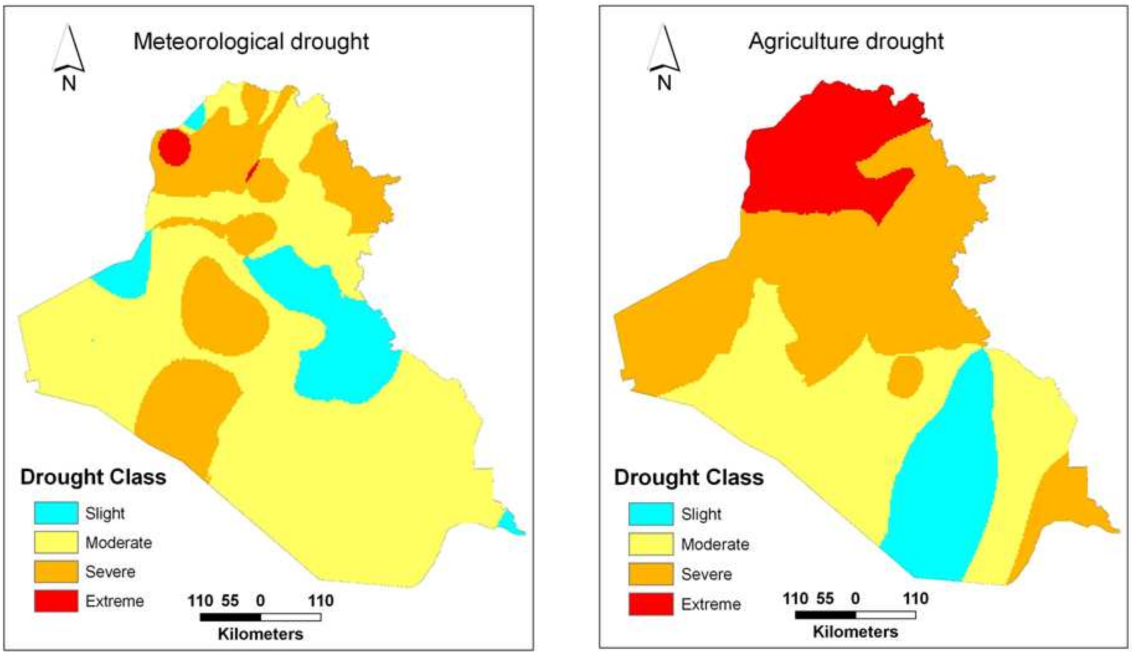

Figure 6- Meteorological and Agriculture Drought Risk

The final drought risk map, which has been obtained by integrating both the risk maps generated from agriculture and meteorological drought. These maps were integrated using ArcGIS 9.3. Figure (7) and Figure (8) shows the percentage area affected by the combined drought risk. Slight and moderate risk areas encompass 14.4% and 61.6% of the area. Severe and extreme risk prevails, nearly, 23.2% and 0.8% of total geographical area which comprises of districts that are major producers of wheat and barley; therefore a stress has to be given more on these districts when drought management plans are prepared.

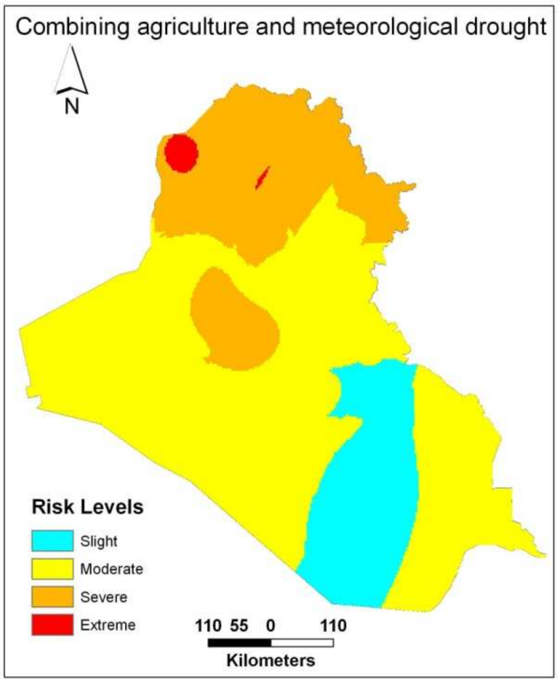

Figure 7- Drought Risk Areas By Combining Meteorological And Agriculture Drought Risk

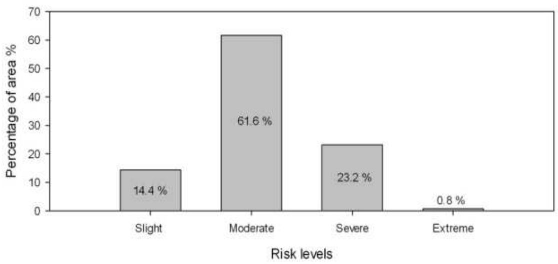

Figure 8- Total Percentage Of Area Facing A Combined Drought Risk

6. Conclusions

In this study, the agricultural and meteorological drought prone areas in Iraq have been identified using Remote Sensing and GIS. The drought risk areas have been assessed by integrating satellite image data and meteorological information. The role of satellite derived index for drought detection has been exemplified by integrating meteorological derived index called Standardized Precipitation Index. It is found that the NDVI anomaly is closely linked with SPI and proportions relationship exists between NDVI and SPI. The highest found correlation is 0.86. Results show that the northwest portion is facing high drought risk.

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