Assessment of the drought impacts on the vegetation cover over Iraqi lands

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Abstract. The current study was carried out on Iraqi lands, which is located between latitudes 29° 00′ to 37° 15′ N and longitudes 38° 45′ to 48° 25′ E and extended over an area of 436364 square kilometres. The study period is characterised by frequent drought conditions and scarcity of herbaceous crops for many years. The study aims to cast light on the impact of drought on vegetation cover using Standardised Precipitation Evapotranspiration Index (SPEI) and Normalised Difference Vegetation Index (NDVI) data. Required data are downloaded from Global SPEI database and Copernicus the Global Land Services. The spatial interpolation of the SPEI and NDVI are used for comparing drought conditions and the percentage of vegetation cover. The results point out to six years of dry conditions i.e., 1999, 2000, 2008, 2009, 2011 and 2012 during which most of Iraqi regions passed through moderate to extreme drought conditions with a significant decrease in vegetation cover. Measurement of the correlation coefficient marked moderate to very high correlation over areas where herbaceous crops are dominant, except areas in middle-south which show weak correlation due to dependence on irrigation process while southwestern parts due to the presence of sandy soil and north-eastern parts; because of dominance of wet-cold climatic conditions.

1. Introduction

Identifying natural vegetation from satellite imageries during the rainy season is considered as the most important evidence of dry and wet conditions in any area. The physiological response of the vegetation comes from the fact that the vegetation dynamics is sensitive to climate change and can be measured using threshold of NDVI greater than 0.2 gained from remote sensing satellites [1]. Productive plants use the energy of the red part of the spectrum and reflect the near infrared; therefore the Normalised Difference Vegetation Index (NDVI) has been used for showing the growth of vegetation [2, 3]. Spatial distribution of ecosystems and plant growth are constrained by water availability, solar radiation and temperature [2].

The influence of precipitation is not always correlated with vegetation cover activity, especially in high altitude area [4]. NDVI time series can be used for analysis and quantification of ecosystem changes from a local to global scale [5], and it is sensitive to ecosystem conditions [6]. The monthly NDVI show linear correlation with rainfall [7]. Vrieling, De Leeuw [8] have mentioned the application of many remote sensing data by using vegetation index like NDVI in phonological analysis of vegetation cover during the growing season. Becerra [9] inferred the vegetation in higher precipitation region are more resistant to drought when compared to vegetation in lower precipitation region, which are more sensible to water stress. Assessment of vegetation cover based on NDVI assumed to be affected by drought conditions [10, 11]. Contreras and Hunink [12] referred to the suitability of drought indices for drought monitoring and assessing their impact quantitatively. The capability to...
identify drought impact in a variety of systems was improved using Standardized Precipitation and Evapotranspiration Index (SPEI) as compared to Palmer Drought Severity Index (PDSI) or the Standardised precipitation index (SPI) [13, 14]. The SPEI provides the possibility of measuring the intensity, duration, as well as determining the beginning and end of periods of drought severity based on FAO-56 Penman-Monteith estimation of potential evapotranspiration [15]. The SPEI is similar to the Standardized Precipitation Index (SPI) but includes the role of temperature and precipitation in the calculation of drought [16].

The frequent and periodic drought conditions over Iraqi lands induced stresses on cultivation and natural vegetation cover. The current study aims to a) Evaluate drought conditions using Standardised Precipitation Evapotranspiration Index (SPEI) during rainy months based on data from Global SPEI database for selected grid points, b) Analyse the spatial and temporal variation in vegetation cover over Iraq using NDVI 1km Version 1 of data collected from Copernicus Global Land Services, and c) Using Thiessen polygons to compare the vegetation cover and drought conditions based on selected grid points.

2. Location of study area
Iraqi lands are covering an area of 436364 square kilometres and are located between latitudes 29° 00’ to 37° 15’ N and longitudes 38° 45’ to 48° 25’ E (figure 1). Topographically, they are divided into plain areas in central and southern parts with a plateau at the western region and toward the north and north-eastern the topography rises gradually from undulating land to mountain series with height reaching up to 3590 meters above sea level. The climate of the study area is characterised by periodic drought conditions inducing stresses on rainfed cultivation and herbaceous crops in most of Iraqi lands.

![Figure 1. Location map of study area and selected SPEI measurement points.](image)

3. Materials and method of analysis
In the current study SPEI and NDVI data are used to cast light on the spatial and temporal variation of drought and vegetation cover over Iraq during the years 1999 to 2014. SPEI data at 36 points are selected from available systematic grid points spaced with 0.5 degrees (≈ 55 kilometres) downloaded
from the Global SPEI database [15]. The SPEI points are used in drawing Thiessen polygons through ArcGIS spatial analyst interpolation toolbox. The SPEI data of 3 months accumulated period at each point are selected to calculate the average annual SPEI during rainy months in Iraq (December to May) using Microsoft Excel software. The average annual SPEI are illustrated on maps as agricultural drought conditions according to categories given in table 1.

Regarding the vegetation cover; NDVI data of one-kilometer resolution during the maximum growing period (Mid-March to mid-April) are downloaded as TIF images from Copernicus Global Land Services [17]. The NDVI images are classified into barren lands and vegetation cover using ArcGIS software and the resulting maps are used to calculate the percentage of vegetation cover area in each polygon. The impacts of drought are evaluated by calculating the correlation coefficient between average annual SPEI and percentage of vegetation cover area using Microsoft Excel software. The procedure of data collection and analysis is illustrated in figure 2.

**Table 1. Classification of drought categories [18]**

| No. | Intensity                  | SPEI Value     |
|-----|----------------------------|----------------|
| 1   | Extremely wet              | => 2           |
| 2   | Very wet                   | 1.50 to 1.99   |
| 3   | Moderately wet             | 1.00 to 1.49   |
| 4   | Mild wet (Near normal)     | 0.0 to 0.99    |
| 5   | Mild drought (Near normal) | 0.0 to -0.99   |
| 6   | Moderately drought         | -1.00 to -1.49 |
| 7   | Severely drought           | -1.5 to -2.00  |
| 8   | Extremely drought          | <= -2          |

4. Results
The results of spatiotemporal variation of average annual SPEI during rainy months and percentage of vegetation cover are calculated as shown in table 2. While the spatial distribution of average annual
SPEI and vegetation cover are plotted in figures 3 to 6. Whereas, the correlation coefficients between average annual SPEI and vegetation cover are given in table 2 and presented spatially in figure 7.

### Table 2. Explain the values of average annual SPEI, Percentage of vegetation cover and their correlation coefficients over Iraq during the period from 1999 to 2014.

| StNo | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|------|------|------|------|------|------|------|
|      | SPEI | Veg. (%) | SPEI | Veg. (%) | SPEI | Veg. (%) | SPEI | Veg. (%) | SPEI | Veg. (%) | SPEI | Veg. (%) |
| st.1 | -2   | 0     | -1.4 | 0     | 0.91 | 17.3   | -0.8 | 0     | -0.1 | 44.6   | 0.58 | 54.4   |
| st.3 | -1.8 | 0     | -1.6 | 0     | 0.77 | 41.6   | -0.8 | 0     | -0.1 | 18.8   | 0.46 | 30     |
| st.5 | -2   | 0.7   | -1.6 | 0.7   | 1.02 | 89.3   | -0.5 | 0.7   | 0.11 | 10.6   | 0.25 | 56.1   |
| st.10| -1.9 | 0     | -1.7 | 0     | 0.91 | 27.1   | -0.5 | 0     | 0     | 0.2    | 0.21 | 10.5   |
| st.11| -1.9 | 0.2   | -1.2 | 0.1   | 0.89 | 66.5   | -0.5 | 0.7   | 0.14 | 60.9   | 0.41 | 63.8   |
| st.12| -1.5 | 0     | -1.4 | 0     | 0.96 | 0      | -0.4 | 0     | -0.1 | 1      | -0    | 60     |
| st.14| -1.7 | 0     | -1.6 | 0     | 0.89 | 2.2    | -0.5 | 0.6   | 0.14 | 14.6   | 0.21 | 49.7   |
| st.15| -2   | 1.1   | -1.6 | 0.8   | 0.92 | 52.2   | -0.5 | 0.6   | -0.1 | 10.8   | 0.35 | 19.1   |
| st.16| -1.8 | 28.4  | 1    | 15.5  | 0.54 | 97.4   | 0.03 | 0.2   | 0.74 | 99.8   | 0.64 | 99.7   |
| st.17| -1.9 | 0     | -1.4 | 0     | 0.76 | 39.5   | -0.6 | 0     | -0.1 | 20.7   | 0.33 | 62.4   |
| st.18| -1.9 | 14.8  | -1.2 | 12.9  | 0.47 | 85.6   | -0.5 | 0.8   | 0.21 | 97.3   | 0.4  | 100    |
| st.19| -1.6 | 93.6  | -0.8 | 91.1  | 0.01 | 98.2   | 0.36 | 0.9   | 0.99 | 97     | 0.65 | 98.5   |
| st.20| -1.6 | 5     | -1.6 | 4.3   | 0.82 | 5.4    | -0.4 | 5.3   | -0.3 | 7.9    | 0.28 | 16.7   |
| st.21| -2   | 27.4  | -1.7 | 25    | 0.61 | 40.1   | -0.5 | 3.1   | -0.4 | 35.2   | 0.27 | 41.9   |
| st.22| -1.9 | 24.5  | -1.4 | 14.8  | 0.43 | 73.2   | -0.7 | 4.8   | -0.1 | 61.9   | 0.28 | 87.9   |
| st.23| -1.7 | 77.2  | -0.8 | 67.2  | 0.01 | 99.9   | 0.18 | 1.4   | 0.81 | 100    | 0.52 | 100    |
| st.24| -1.5 | 99.1  | -0.6 | 99.4  | -0.4 | 99.4   | 0.54 | 97.5  | 1.09 | 97.2   | 0.66 | 100    |
| st.26| -1   | 0     | -0.9 | 0     | 0.87 | 0      | -0.4 | 0     | -0.3 | 0      | 0.14 | 49.9   |
| st.27| -1.5 | 39.3  | -1.4 | 34.6  | 0.7  | 38.6   | -0.4 | 30.7  | -0.4 | 44.2   | 0.23 | 58     |
| st.28| -1.7 | 78.3  | -1.7 | 69.4  | 0.57 | 80.6   | -0.5 | 73.8  | -0.4 | 80.1   | 0.25 | 80.9   |
| st.30| -1.2 | 4.4   | -1   | 3.5   | 0.47 | 4.7    | -0.4 | 3.5   | -0.4 | 9.5    | 0.21 | 35.7   |
| st.31| -1.7 | 78.9  | -1.7 | 46.6  | 0.38 | 70.3   | -0.5 | 54.3  | -0.5 | 76     | 0.18 | 80.4   |
| st.32| -1.7 | 97.3  | -0.8 | 79.2  | -0.3 | 99.2   | 0.06 | 98.2  | 0.58 | 97.7   | 0.44 | 98.8   |
| st.33| -1.6 | 100   | -1   | 99.3  | -0.8 | 99.3   | 0.56 | 100   | 0.12 | 99     | -0    | 100    |
| st.34| -1.2 | 68    | -1   | 31.6  | 0.48 | 46     | -0.4 | 20.1  | -0.5 | 65.4   | 0.19 | 76.3   |
| st.35| -1.8 | 42.9  | -1.4 | 19.3  | 0    | 81.3   | -0.7 | 63.9  | -0.4 | 61.1   | 0.2   | 70.6   |
| st.36| -1.7 | 94    | -1   | 71.3  | -0.3 | 100    | -0.2 | 98.4  | 0.27 | 100    | 0.35 | 100    |
| st.37| -0.3 | 0     | -0.7 | 0     | 0.5  | 0      | -0.8 | 0     | -0.2 | 0      | 0.69 | 11.9   |
| st.39| -1.2 | 69.9  | -1.2 | 34.1  | 0.38 | 44.2   | -0.4 | 35.8  | -0.6 | 62.1   | 0.27 | 80.6   |
| st.41| -1.5 | 17.9  | -1.5 | 5.5   | 0.06 | 25     | -0.5 | 17.1  | -0.7 | 13.8   | 0.19 | 41.5   |
| st.42| -1.8 | 99.8  | -1.2 | 100   | -0.8 | 100    | 0.15 | 97.8  | -0.8 | 99.5   | -0.2 | 99.8   |
| st.43| -0.5 | 0.2   | -0.6 | 0     | 0.24 | 0.1    | -0.7 | 0     | -0.3 | 0      | 0.69 | 3      |
| st.44| -0.8 | 64.8  | -0.8 | 19.2  | 0.16 | 25.1   | -0.7 | 20.7  | -0.5 | 41.2   | 0.56 | 67.2   |
| st.46| -0.3 | 24.3  | -0.4 | 6.9   | -0.1 | 10.7   | -0.8 | 13.1  | -0.3 | 20.9   | 0.3  | 38.6   |
| StNo | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|------|------|------|------|------|------|------|
|      | SPEI (%) | SPEI (%) | SPEI (%) | SPEI (%) | SPEI (%) | SPEI (%) |
| st.1 | 1.90 | 17.3 | -0.5 | 6 | 0.04 | 15.5 | -1.3 | 2.4 | -1.5 | 8.2 | 0.65 | 35.1 |
| st.3 | 0.31 | 33 | -0.6 | 16.2 | 0.04 | 9.8 | -0.8 | 11.9 | -1.3 | 14.2 | 0.54 | 33.1 |
| st.5 | -0.2 | 1.6 | -0.1 | 2.8 | -0.8 | 31.2 | -1.4 | 1 | -0.9 | 2.7 | -0.1 | 12.4 |
| st.10 | -0.1 | 5.9 | -0.2 | 1.3 | -0.8 | 3.1 | -0.8 | 0.1 | -0.9 | 1.7 | -0.1 | 10.2 |
| st.11 | -0.8 | 10.3 | 0.19 | 18.5 | -0.9 | 6.1 | -2.1 | 0.1 | -1.3 | 0.9 | -0.2 | 1.6 |
| st.12 | 0.31 | 16.7 | -0.3 | 0.7 | -0.5 | 0.7 | -0.7 | 0.1 | -0.7 | 1.5 | -0.1 | 10.1 |
| st.14 | -0 | 36.3 | -0.2 | 10 | -0.7 | 12.9 | -0.9 | 7.1 | -1 | 16.8 | -0.1 | 40.5 |
| st.15 | -0.5 | 1.5 | -0.1 | 5.6 | -0.8 | 5.2 | -1.7 | 1 | -1.2 | 1.4 | -0.2 | 8.8 |
| st.16 | -1 | 95 | 0.22 | 91.1 | -0.9 | 74.8 | -2 | 5.3 | -1.3 | 23.4 | -0.2 | 73.6 |
| st.17 | -0.7 | 7.7 | 0.11 | 17.9 | -0.9 | 1.4 | -2.2 | 0 | -1.6 | 0 | -0.3 | 0.5 |
| st.18 | -0.8 | 85.1 | 0.13 | 85.9 | -0.8 | 37.2 | -2.3 | 13.8 | -1.7 | 14.6 | -0.4 | 22.6 |
| st.19 | -1.1 | 98.1 | 0.15 | 97.7 | -0.7 | 98.2 | -1.9 | 85.1 | -1.2 | 96 | -0.2 | 98.6 |
| st.20 | -0.4 | 7.9 | -0.2 | 6.2 | -0.6 | 6 | -1.2 | 5.5 | -1.4 | 6.2 | -0.4 | 8.6 |
| st.21 | -0.5 | 35.9 | -0.1 | 35.5 | -0.8 | 34.5 | -1.9 | 24.3 | -1.6 | 32.9 | -0.4 | 34.7 |
| st.22 | -0.7 | 59.2 | 0.08 | 57 | -0.8 | 49 | -2.3 | 25.1 | -1.8 | 28.4 | -0.5 | 45.2 |
| st.23 | -1 | 100 | 0.11 | 100 | -0.7 | 98.1 | -2.1 | 73.7 | -1.4 | 73.7 | -0.3 | 98.6 |
| st.24 | -1.1 | 100 | 0.1 | 100 | -0.4 | 100 | -1.8 | 99.7 | -1 | 99.7 | -0.2 | 100 |
| st.26 | 0.06 | 2.1 | -0.3 | 0.1 | -0.2 | 0 | -0.9 | 0 | -0.8 | 0 | -0.3 | 0 |
| st.27 | -0.3 | 44.5 | -0.2 | 41.1 | -0.5 | 41 | -1.3 | 40 | -1.3 | 40.2 | -0.4 | 43.2 |
| st.28 | -0.4 | 78.8 | -0.2 | 81.2 | -0.7 | 77.2 | -1.5 | 71.5 | -1.6 | 74.3 | -0.5 | 76.2 |
| st.30 | -0.1 | 6.5 | -0.2 | 5.3 | -0.3 | 5.3 | -1.2 | 3.2 | -1 | 4.9 | -0.3 | 7.4 |
| st.31 | -0.4 | 74.8 | -0.2 | 77.2 | -0.7 | 68.4 | -1.7 | 50.7 | -1.7 | 47.1 | -0.5 | 55.5 |
| st.32 | -0.8 | 98.8 | 0.08 | 98.7 | -0.5 | 99 | -2.2 | 76.1 | -1.7 | 86 | -0.4 | 99 |
| st.33 | -0.9 | 100 | -0 | 100 | -0.5 | 100 | -1.6 | 97.7 | -1.2 | 100 | 0.06 | 99 |
| st.34 | -0.2 | 68.2 | -0.2 | 69 | -0.4 | 72.2 | -1.4 | 51.6 | -1.3 | 57 | -0.4 | 55.2 |
| st.35 | -0.5 | 76.2 | -0.1 | 65.5 | -0.6 | 63.3 | -2.3 | 26.9 | -1.9 | 47.7 | -0.6 | 58.8 |
| st.36 | -0.7 | 99.9 | 0.02 | 99.7 | -0.5 | 99.7 | -2.3 | 52.2 | -1.8 | 91.3 | -0.5 | 99.7 |
| st.37 | 0.25 | 0.3 | -0.1 | 0 | 0.35 | 0 | -0.6 | 0 | -0.9 | 0 | -0.5 | 0 |
| st.39 | -0.2 | 74.5 | -0.2 | 76.5 | -0.4 | 74.8 | -1.6 | 62.6 | -1.5 | 59.1 | -0.5 | 69 |
| st.41 | -0.3 | 33.7 | -0.2 | 23 | -0.6 | 24 | -1.9 | 5.3 | -1.9 | 10 | -0.6 | 11.7 |
| st.42 | -0.6 | 99.8 | -0.1 | 99.8 | -0.8 | 99.8 | -1.9 | 99.8 | -1.8 | 100 | -0.3 | 100 |
| st.43 | 0.08 | 0.1 | 0.04 | 0.1 | 0.06 | 0 | -0.8 | 0 | -1.2 | 0 | -0.6 | 0 |
| st.44 | -0 | 65.7 | -0.1 | 69.3 | -0 | 69.3 | -1 | 50.7 | -1.4 | 48.2 | -0.6 | 48.7 |
| st.46 | 0.13 | 38.4 | 0.06 | 39.1 | 0.01 | 37.4 | -0.9 | 31.8 | -1.4 | 30.4 | -0.7 | 25.2 |
| st.47 | 0.03 | 51.2 | -0 | 42.9 | -0.1 | 42.4 | -1.2 | 23.7 | -1.8 | 27.7 | -0.7 | 31.6 |
| st.50 | 0.29 | 14.4 | -0.1 | 15.7 | 0.47 | 12.5 | -0.8 | 10.3 | -1.3 | 6.6 | -0.1 | 8.8 |
| StNo | 2011 SPEI | % Veg. | 2012 SPEI | % Veg. | 2013 SPEI | % Veg. | 2014 SPEI | % Veg. | Correlation coefficient (r) |
|------|-----------|-------|-----------|-------|-----------|-------|-----------|-------|--------------------------|
| st.1 | -0.6      | 17.3  | -1.6      | 0.1   | -0.6      | 40.4  | 0.27      | 63.7  | 0.68                     |
| st.3 | -0.4      | 26.6  | -1.8      | 1.4   | -1.0      | 29.5  | 0.4       | 56.1  | 0.79                     |
| st.5 | -0.9      | 3.5   | -1.4      | 1.6   | -0.2      | 14    | 0.1       | 60.1  | 0.70                     |
| st.10 | -0.5     | 6.4   | -2       | 0.0   | -0.8      | 8.3   | 0.34      | 14.0  | 0.73                     |
| st.11 | -1.7     | 1.0   | -0.6     | 0.8   | 0.49      | 2.7   | -0.4      | 5.2   | 0.67                     |
| st.12 | -0.4     | 3.7   | -1.4     | 0.0   | -1.3      | 11.5  | 0.15      | 13.4  | 0.26                     |
| st.14 | -0.5     | 23.5  | -1.9     | 0.2   | -1.0      | 35.4  | 0.24      | 27.1  | 0.44                     |
| st.15 | -1.0     | 2.7   | -1.6     | 1.1   | -0.2      | 7.4   | 0.08      | 10.9  | 0.73                     |
| st.16 | -1.4     | 47.5  | 0.03     | 25.7  | 0.79      | 77.2  | -0.8      | 92.8  | 0.70                     |
| st.17 | -1.7     | 0.7   | -1.2     | 0.0   | 0.32      | 2.8   | -0.3      | 4.7   | 0.65                     |
| st.18 | -1.6     | 25.1  | -0.9     | 14.8  | 0.51      | 65.5  | -0.5      | 44.1  | 0.81                     |
| st.19 | -0.8     | 97.4  | -0.6     | 94.7  | 0.84      | 98.6  | -1.0      | 98.5  | 0.59                     |
| st.20 | -0.6     | 7.5   | -2.0     | 5.5   | -0.7      | 9.5   | 0.07      | 14.3  | 0.51                     |
| st.21 | -1.1     | 32.8  | -2.1     | 28.9  | -0.2      | 48.2  | 0        | 59.1  | 0.72                     |
| st.22 | -1.7     | 37.7  | -1.4     | 30.1  | 0.32      | 71    | -0.4      | 82.2  | 0.87                     |
| st.23 | -1       | 98.9  | -0.9     | 80.8  | 0.72      | 100   | -0.9      | 99.4  | 0.69                     |
| st.24 | -0.3     | 98.2  | -0.9     | 98.5  | 0.8       | 99.7  | -1.2      | 99.7  | -0.35                    |
| st.26 | -0.3     | 0.1   | -1.0     | 0.0   | -1.4      | 0.3   | -0.3      | 19.7  | 0.30                     |
| st.27 | -0.6     | 39.9  | -1.8     | 36.6  | -0.8      | 44.9  | -0.1      | 49.7  | 0.45                     |
| st.28 | -0.7     | 75.7  | -2.3     | 69.4  | -0.5      | 84.6  | 0.08      | 85.6  | 0.76                     |
| st.30 | -0.5     | 4.4   | -1.3     | 4.1   | -1.1      | 8.1   | -0.3      | 11.2  | 0.44                     |
| st.31 | -0.9     | 65.7  | -2.4     | 60.0  | -0.5      | 82.9  | 0.05      | 87.1  | 0.59                     |
| st.32 | -1       | 97.1  | -1.8     | 92.5  | 0.57      | 99    | -0.7      | 98.7  | 0.61                     |
| st.33 | -0.6     | 99    | -0.9     | 99.7  | 0.6       | 100   | -0.9      | 100   | 0.25                     |
| st.34 | -0.6     | 44    | -1.5     | 40.4  | -0.9      | 70.2  | -0.2      | 81.7  | 0.26                     |
| st.35 | -1.4     | 49.4  | -2.1     | 29.4  | 0.08      | 81.1  | -0.2      | 93.7  | 0.86                     |
| st.36 | -1.1     | 93.1  | -2.2     | 83.2  | 0.44      | 99.9  | -0.5      | 99.9  | 0.70                     |
| st.37 | -0.5     | 0.0   | -0.6     | 0.0   | -1.3      | 0.0   | -0.1      | 3.2   | 0.51                     |
| st.39 | -0.7     | 63    | -1.9     | 50.7  | -0.7      | 74.8  | -0.2      | 84.3  | 0.31                     |
| st.41 | -0.9     | 12.1  | -2.6     | 4.4   | -0.4      | 22.3  | 0         | 31.6  | 0.83                     |
| st.42 | -0.9     | 99.5  | -1.8     | 99.5  | 0.38      | 99.8  | -0.5      | 100   | -0.29                    |
| st.43 | -0.6     | 0.0   | -0.9     | 0.0   | -1.2      | 0.0   | -0.1      | 0.6   | 0.61                     |
| st.44 | -0.7     | 44.4  | -1.3     | 33.4  | -0.9      | 62    | -0.1      | 75.1  | 0.37                     |
| st.46 | -0.8     | 22.1  | -1       | 22    | -0.9      | 32.1  | -0.1      | 35.8  | 0.29                     |
| st.47 | -1       | 34.4  | -1.9     | 25.7  | -0.5      | 43.9  | -0.1      | 59.9  | 0.72                     |
| st.50 | -0.5     | 6.9   | -0.9     | 6.0   | -0.7      | 8.2   | 0.15      | 8.2   | 0.54                     |
5. Discussion

According to the average annual SPEI and corresponding variations in vegetation cover, Iraqi lands passed through drought conditions which varied from moderate wet to extreme drought and can be categorized in four groups i.e., mild drought to moderate wet, near normal, near normal to extreme drought and mild wet to moderate drought conditions.

5.1. Mild drought to moderate wet

During 2001 as shown in figures 3-a and 3-b the conditions tended to be mild to moderate wet and this clearly appears in the increase of vegetation cover in the western and northwestern parts of Iraq. While in 2003 as shown in figures 3-c and 3-d the wet conditions are restricted to the northern and northwestern regions of Iraq, so the vegetation cover in these areas increased in a scattered manner.

5.2 Near normal conditions (Mild drought to mild wet)

The near normal drought conditions prevailed in Iraq during the years 2002, 2004, 2006, 2007 and 2010 (figure 4-a to 4-j). 2002 was characterized by a tendency to mild dry conditions in most of Iraq and effective decrease in herbaceous crops, except northern parts that passed under mild wet and recognized by dense vegetation cover. While, during 2004 the conditions were prone to mild wet, that is expressed by a significant increase in the herbaceous crops, especially in the northwestern and western parts of Iraq. Whereas, during 2006, 2007 and 2010 the mild drought is relatively predominant with a decrease in herbaceous crops in the northwestern and western parts of Iraq.

5.3. Near normal to extreme drought conditions

The near normal to severe drought conditions predominated over Iraq during the years 1999, 2000, and 2011, while the years 2008, 2009 and 2012 the climate prone to extreme drought conditions over most of Iraqi lands (figures 5-a to 5-l). The drought conditions are reflected negatively on the vegetation cover and herbaceous crops at most areas of Iraq except the northern and north-eastern parts of Iraq, which are not recognized by wet cold climate conditions along growing seasons and not affected even in prevailing drought conditions.

5.4. Mild wet to moderate drought conditions

Although, during the years 2005, 2013 and 2014 (figures 6-a, b, c, d and f); the areas in extreme north and southwestern parts tend to moderate drought conditions, but near-normal conditions dominated the remaining parts, with an increase in the herbaceous crops as identified significantly over western parts of Iraq.

Figure 3. Spatial variation of average annual SPEI and vegetation cover during Mild drought to moderate wet conditions.
Figure 4. Spatial variation of average annual SPEI and vegetation cover during near normal conditions (Mild drought–mild wet).
Figure 5. Spatial variation of average annual SPEI and vegetation cover during near normal to extreme drought conditions.

Figure 6. Spatial variation of average annual SPEI and vegetation cover during mild wet to moderate drought conditions.
5.5. Analysis of correlation coefficient

Analysis of the correlation coefficient results shown in table 2 and figure 7, identify that Iraqi lands, which mainly depend on rain show a high to very high correlation between average annual SPEI and density of vegetation cover with r-value ranging from 0.5 to 0.87, these are located in upper middle parts and northwestern parts of Iraq. While the areas in middle southern parts along the banks of Tigris and Euphrates rivers show moderate to weak correlation, because the area depends mostly on irrigation. whereas, area at st12 and st26 show weak correlation; that is because the area is covered mostly by sand sheet soil, which does not preserve the water in the root zone with high infiltration of water to deeper zones. While the area located in the far northeast of Iraq at st24, st33 and st42 identified by weak to negative correlation, because of their climatic conditions of prevailing high humidity and low temperatures with high mountainous topography and normally covered by forests and orchards.

6. Conclusions

The final results show that the climate and their impacts on vegetation cover over Iraqi lands identified in four groups of drought conditions and near normal conditions are the dominant cases, except six years of severe to extremely droughts that are recognized during the years 1999, 2000, 2008, 2009, 2011 and 2012. The compression of drought conditions with vegetation cover is significantly identified in the areas where rainfed and herbaceous crops are dominant, especially in western and northwestern parts of Iraq. Whereas, the areas around the riverbanks and that covered by irrigation projects show difficulty in recording the impacts of climate conditions on vegetation cover. Besides that, the mountainous area in northeastern parts of Iraq, which are characterized by cold and wet climate conditions along most of the seasons are also impossible to detect a correlation between drought conditions and vegetation cover, because of the area covered by forest and orchards fields along the year. The measurement of the correlation coefficient between average annual SPEI and percentage of vegetation cover shows moderate to very high correlation with r values ranging between 0.5 to 0.87 in most of the Iraqi parts. While the areas in south and west of Iraq dominated by sandy soils of high infiltration capability and the presence of irrigation projects show weak correlations. Also, the mountainous areas in northeastern of Iraq show a negative correlation between drought conditions and vegetation cover.

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