Atiyah et al. Iraqi Journal of Science, 2023, Vol. 64, No. 3, pp: 1535-1544
DOI: 10.24996/ijs.2023.64.3.41

ISSN: 0067-2904

Spatiotemporal Drought Monitoring Using Remote Sensing Technique in Babel-Iraq

Hiba Akram Atiyah [1]*, Sajaa M. Khazael[2], Assel Qaddoori Makhool[1]

[1]*Civil Engineering Department, College Engineering, Al-Iraqia University, Baghdad, Iraq*
[2]*Civil Engineering Department, College Engineering, University of Thi-Qar, Thi-Qar, Iraq*

Received: 27/11/2021 Accepted: 18/8/2022 Published: 30/3/2023

Abstract

Drought is one of the most natural hazards that may harm human life and property under different weather and environmental conditions. This study used remote sensing data to monitor agricultural and meteorological drought in Babel Governorate. Drought maps were drawn using Landsat 8 images based on Normalized Difference Vegetation Index (NDVI) for 2015, 2018, and 2021. The meteorological drought was assessed using a standardized precipitation index (SPI 12) for the same years. The results showed that the SPI-12 indicated near-normal drought types in 2015 and 2018, whereas SPI values showed a lower value in 2021. Two drought categories were identified which were moderate drought and severe drought. The NDVI results showed that the vegetation area decreased in 2021 by 9 % in comparison to 2015. This result could help the government planners to develop and manage the drought impacts.

Keywords: Drought; GIS; NDVI; SPI; Babel.

مراقبة الجفاف الزماني المكاني باستخدام تقنية التحسس النائي في محافظة بابل

هبة أكرم عطية[1]*, سجى محسن خزعل [2], اسيل قدوري مكحول[1]

[1]قسم الهندسة المدنية، كلية الهندسة، الجامعة العراقية، بغداد، العراق
[2]قسم الهندسة المدنية، كلية الهندسة، جامعة ذي قار، ذي قار، العراق

الخلاصة

يعتبر الجفاف من أكثر الأخطار الطبيعية التي قد تضر بحياة الإنسان وممتلكاته في ظل الظروف الجوية والبيئية المختلفة. استخدمت هذه الدراسة بيانات الاستشعار عن بعد لرصد الجفاف الزراعي والجوي في محافظة بابل. تم رسم خرائط الجفاف باستخدام صور لاندسات 8 استنادًا إلى مؤشر الغطاء النباتي الفروق الطبيعي (NDVI) للأعوام 2015 و 2018 و 2021. تم تقييم الجفاف الجوي باستخدام مؤشر هطول الأمطار القياسي (SPI 12) لنفس السنوات. أظهرت النتائج أن SPI-12 أشار إلى أنواع جفاف شبه طبيعية في 2015 و 2018 ، بينما أظهرت قيم SPI قيمة أقل في عام 2021. تم تحديد فئتين من الجفاف وهما الجفاف المعتدل والجفاف الشديد. أظهرت نتائج مؤشر NDVI أن مساحة الغطاء النباتي انخفضت في عام 2021 بنسبة 9٪ مقارنة بعام 2015. وقد تساعد هذه النتيجة المخططين الحكوميين على تطوير وإدارة آثار الجفاف.

* Email hiba.akram@aliraqia.edu.iq

1. Introduction

Drought is one of the most complex but least understood all-natural hazards [1]. The increase in the world population, urbanization, climate changes, deforestation, and desertification pushed drought to reach dimensions threatening society, the environment, and countries. Droughts are closely related to the economy, health, psychology, and society's trade. Although drought is increasing globally, its impact has not been fully understood, and its effects have not been adequately evaluated. As a natural consequence, a precise definition of drought cannot be made. Drought is one of the most complex but least understood all-natural hazards [1]. The increase in the world population, urbanization, climate changes, deforestation, and desertification pushed drought to reach dimensions threatening society, the environment, and countries. Droughts are closely related to the economy, health, psychology, and society's trade. Although drought is increasing globally, its impact has not been fully understood, and its effects have not been adequately evaluated.

Drought leads to water shortage in some environmental activities and sectors. The drought impact depends on the relationship between precipitation deficiency and water demand, as deteriorating environmental conditions are likely to exacerbate drought. Inadequate drinking water and a lack of adequate sanitation in many areas will continue to pose a growing challenge to the Iraqi people if not dealt with sufficiently [1]. Drought has wide spatial dimensions and thus can have severe implications for an entire region's social and economic stability. It is not possible to avoid the drought. However, drought preparedness and management of its effects can be developed. The success of both depends, among other things, on how well droughts are identified and drought characteristics are quantified [2]

There are various indicators to monitor meteorological drought, for instance, Palmer Drought Severity Index, simple rainfall deviation from historical norms, and SPI [3]. Recently, SPI has been considered widely used among several indicators due to its computational simplicity and reliability [4]. The SPI estimates the drought in countries to help the governments enhance the capacity and performance in drought control. The SPI-3 (three months) is used for a short-term meteorological drought assessment. The SPI-6 (six months) is used for agricultural drought assessment. The SPI-12 (12 months) calculates the intermediate to long-term drought index, which applies to hydrological drought applications [5]. Drought studies for various purposes have been carried out in the world generally and Iraq especially, where meteorologists work in predicting rainfall, temperature, humidity, evaporation, etc. in terms of volumes regarding engineers of water resources, streams, groundwater, reservoirs, and lakes; in terms of agricultural plants. Economists have studied drought in terms of people's lives. In drought studies, it is necessary to know the length, volume, and interval of common dehydration recurrence. Consequently, it is necessary to identify drought characteristics, such as drought duration, severity, and area covered. Wilhite and Glantz [6] studied drought phenomenology and preparedness for drought, while McKee et al. [7] proposed the SPI to understand whether a lack of precipitation affects groundwater, soil moisture, and stream flow.

Chen et al. [8] used the monthly SPI time series to calculate the duration and severity of drought. Ionita et al. [9] analyzed the spatiotemporal droughts variability in Romania for five decades via a high-resolution dataset using SPI. Noureldeen et al.

[10] evaluated the spatiotemporal drought in Sahelian Countries from 1985 to 2015 using the ground station and remote sensing data by applying multi-indexes like SPI, SPEI, and VCI. The results showed that these indices are efficient for assessing the impact of agricultural drought on crop production in the Sahel and identifying areas most affected by drought. Karakani et al. [11] suggested an approach for identifying Sustained Vegetation Cover (SVC) in the Middle East to identify the connection between SVC and drought. They used Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI) in their investigations to filter zones of rich vegetation cover from poorly vegetated or non-vegetated regions of the Middle East. They found that the most severe meteorological drought occurred in 2008. Jianxin et al. [12] examine the future meteorological (SPI and SPEI), hydrological (SRI), and agricultural (SSI) drought under two warming scenarios (SSP2-4.5 and SSP5-8.5). Hameed et al. [13]compared the NVDA and NDVSI when measuring the vegetation coverage for the Baghdad province. Abdul-Hammed and Mahdi [14] use the NDVI to monitor the changes in the vegetation cover for Baghdad province. This study aims to map and monitor the drought in Babel province- Iraq using NDVI based on Landsat 8 for the agriculture drought and SPI based on rainfall data for mapping the metrological drought. The results of this study could help government planners to develop and manage the drought impacts.

2. The Methodology

2.1 Study Area

Babel province is one of the essential provinces of the Middle Euphrates of Iraq, south of Baghdad. It has nearly two million people as a population, according to an estimated report in 2014. The Babel lands are rising to about 35 m above sea level to the south. It is dominated by a desert climate characterized by low rainfall and high summer temperatures, which reach 50 m, and warm weather prevails in winter. The Babel province is bordered from the north by Baghdad province, from the west by Anbar and Karbala provinces to the east by Wasit province, then from the south by Najaf and Qadisiya provinces to form an area of (5119 km^2). It forms about 7.2% of the country's area, 444,35 km^2, Figure 1. Its population reached 2,217,4 people, according to an estimation report in 2018, which is 5.7% of the total population of Iraq, which numbered 38,308,000 people [15]. The province consists of four districts, Hilla, Al-Musayyab, Al-Mahaweel, and Al-Hashimiyah.

2.2 Dataset

Landsat-8 satellite images are considered one of the significant resources for agriculture applications. The Landsat 8 is an imagery satellite launched by the United States of America in 2013 that provides researchers with free images with multiple bands that are updated every two weeks. In this study, Landsat-8 images were used with a spatial resolution of 30 meters, as shown in Table 1.

Table 1: Landsat image specification

Path/Row	Date	Bands	Resolution (m)
168/37	3/2015	Multispectral	30
168/38	3/2015	Multispectral	30
168/37	3/2018	Multispectral	30
168/38	3/2018	Multispectral	30
168/37	3/2021	Multispectral	30
168/38	3/2021	Multispectral	30

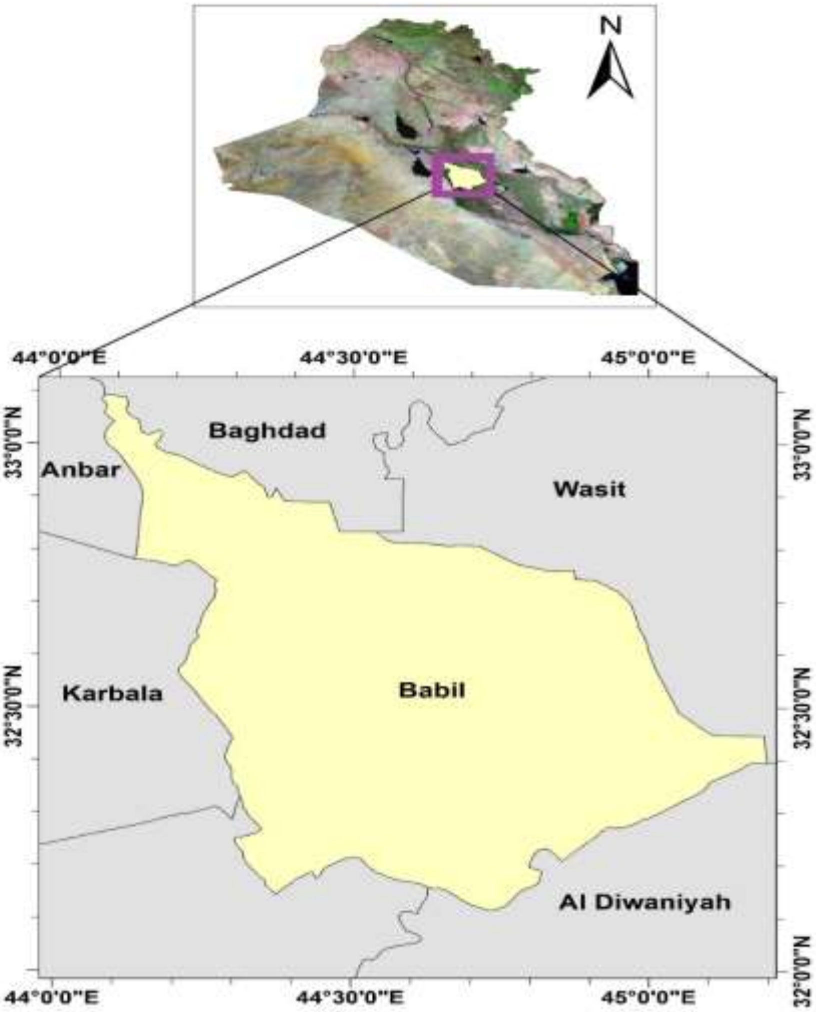

Figure 1: Map of the study area.

The SPI data can be calculated for any time scale for multiple monthly accumulation periods [16]. The SPI data were downloaded from European Drought Observatory (EDO) for five metrological stations to estimate the drought level. The metrological station coordinates are shown in Table 2.

Table 2: Metrological station coordinates for the study areas.

Name	Long	Lat
Al Hashimiyah	44.745776	32.155864
Al Hillah	44.352513	32.454874
Al Mahawil	44.453267	32.753883
Al Misiab	44.25176	32.552377
Mahmudiya	44.24526	32.857887

2.3 Normalized Difference Vegetation Index (NDVI)

The NDVI was proposed first in 1979 to estimate vegetation health and density [17], where it became the most commonly used vegetation index [18]. NDVI is based on the known plant's radiometric properties using visible and near-infrared radiation, Eq. (1).

$$NDVI = (\lambda NIR - \lambda RED) / (\lambda NIR + \lambda RED) \quad (1)$$

where λ_{NIR} is band 5 (for Landsat 8), and λ_{RED} is band 4 (for Landsat 8).

2.4 SPI Method

Since precipitation shows a significant variance in area and time, various drought indices based on precipitation conditions were used to determine drought, including a comparison between received rain and central slope measurements (average and median), also using dispersion measurements, standard deviation range, characteristics of wet-drought periods, in addition to using of precipitation limitations related to the sensitive levels of some known system's water necessities [19]. The SPI method has been used for observing droughts in recent years, which was invented by Mckee et al. [7], which is very easy to apply because it depends on the precipitation factor, which is flexible for measuring droughts of several duration.

Standardized precipitation series for any X1, X2…., Xn precipitation time series, Xi, is calculated using the equation 2:

$$X_i = \frac{X_{i-}\underline{X}}{S_x} \quad (2)$$

Where Xi represents the arithmetic average of the series and Sx represents the standard deviation of the series.

Different timeframes, such as 1, 3, 6, 9, 12, 24, and 48 months, were set to observe the general changes in indices while considering the effects of precipitation. Subjective reasoning, such as how long a deficiency in precipitation would take to create a visible effect on the usable water sources, was used to determine the timescales. For instance, while any decrease in the precipitation in any given month could affect soil moisture in a relatively short time (1-3 months), it takes a considerably long time to affect the underground waters and rivers (3-6 months) [20]. A negative value on a drought assessment using SPI values shows precipitation deficiencies or drought periods, while a positive value shows a surplus in precipitation. The researchers made individual drought classifications for different SPI ranges, Table 3. Drought intensity determination for various SPI ranges is vital for drought analysis and observation examinations. The SPI is a method that uses the precipitation data to determine the start, increase in intensity, and end of a drought in a region, meaning that it produces very beneficial results based on the precipitation data to produce the most critical variables of a drought: duration, magnitude, and intensity.

Table 3: The SPI drought categories [21]

SPI Value	Category
≥2	Extremely-wet
1.55-1.99	Very-wet
1.0-1.49	Moderately-wet
-0.99-0.99	Near-normal
-1.00--1.49	Moderately-dry
-1.5--1.99	Severely-dry
≤ -2	Extremely-dry

3. Results and Discussion

3.1 Agriculture Drought

The satellite images of Landsat-8 for April were used to compute the NDVI values for 2015, 2018, and 2021; Figure 2 shows the NDVI raster for the three studied years. The spatiotemporal analysis showed the change due to drought. For NDVI images, the brown color showed unhealthy and drought areas, whereas the green color showed healthy and wet vegetation areas [22] . Only positive values were taken in to count to classify the image. The vegetation data were extracted as shown in Figure 3, where each year's area and percentage for the vegetation class were calculated. The results showed that the vegetation area decreased in 2021 by 9 % more than in 2015, Table 4.

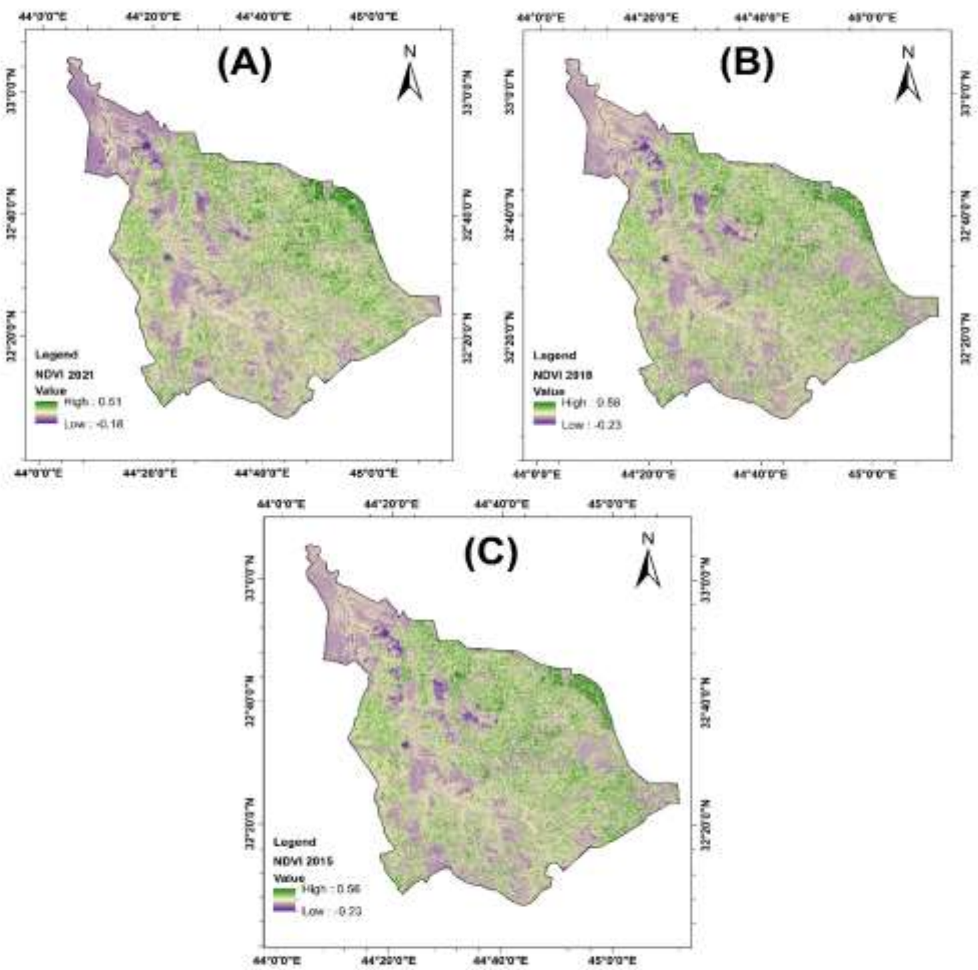

Figure 2: NDVI raster for the years (A) 2021; (B) 2018; and (C) 2015

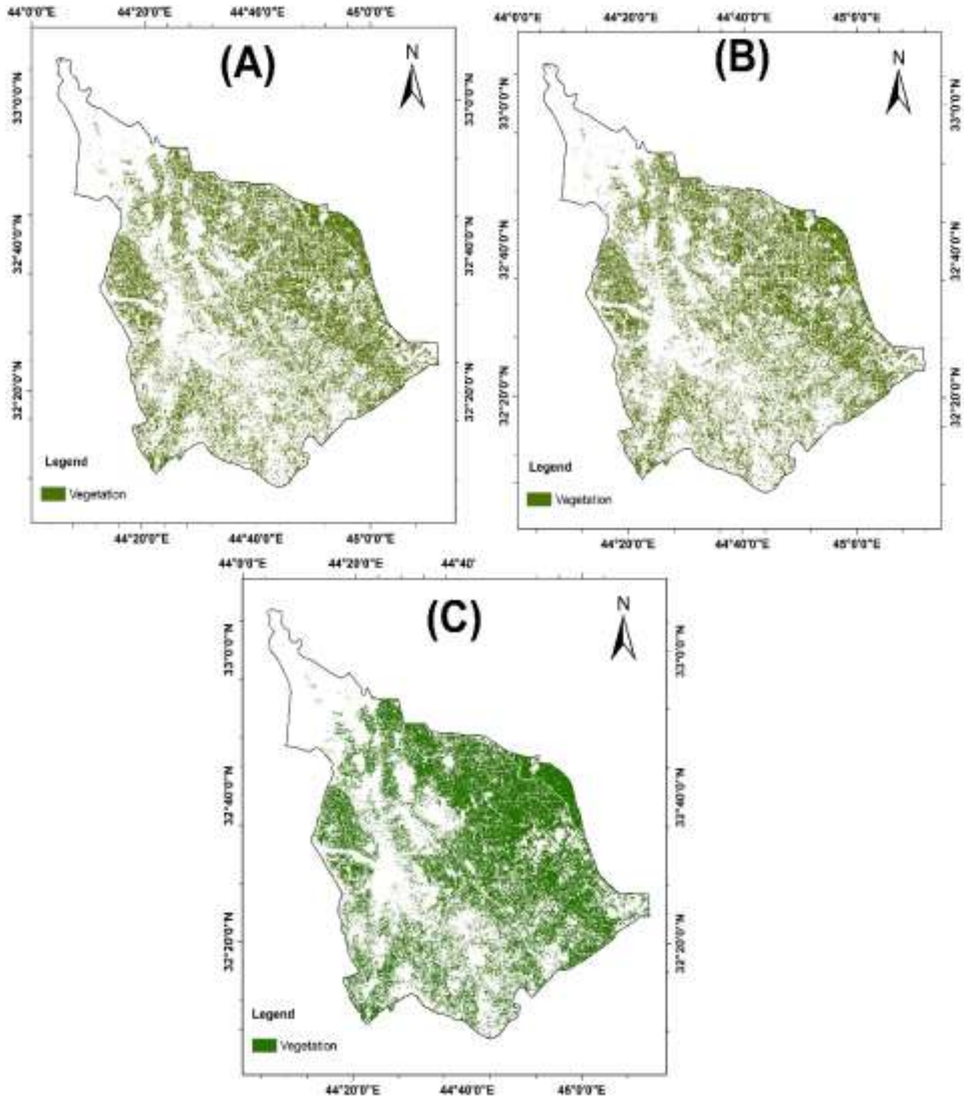

Figure 3: Extracted vegetation based on NDVI results, (A) 2021, (B) 2018, and (C) **2015.**

Table 4: The area and percentage of the vegetation class

Year	Area	Percentage
2021	**1667.9**	**31.3%**
2018	**2102.1**	**39.4%**
2015	**2176.1**	**40.8%**
Total Study Area	**5333 2**	

3.2Metrological Drought

The SPI data values for 2015, 2018, and 2021 were analyzed, then the data was used to identify the drought categories during 2015, 2018, and 2021 as shown in Figure 4. The SPI values showed a lower value in 2021, and two drought categories were identified: moderate drought and severe drought, whereas, in 2015 and 2018, SPI values were higher than 2021; according to the SPI typical rang, this value is considered near normal 2021, as shown in Table 5.

Table 5: The SPI value and drought categories for 2015, 2018, and 2021

Name	SPI 2015	Category	SPI 2018	Category	SPI 2021	Category
Al Hashimiyah	0.20	Near normal	0.198	Near normal	-1.19	Moderately dry
Al Hillah	0.42	Near normal	0.06	Near normal	-1.27	Moderately dry
Al Mahawil	0.33	Near normal	0.06	Near normal	-1.76	Severely Dry
Al Misiab	0.839	Near normal	0.039	Near normal	-1.88	Severely dry
Mahmudiya	0.34	Near normal	0.33	Near normal	-1.62	Severely dry

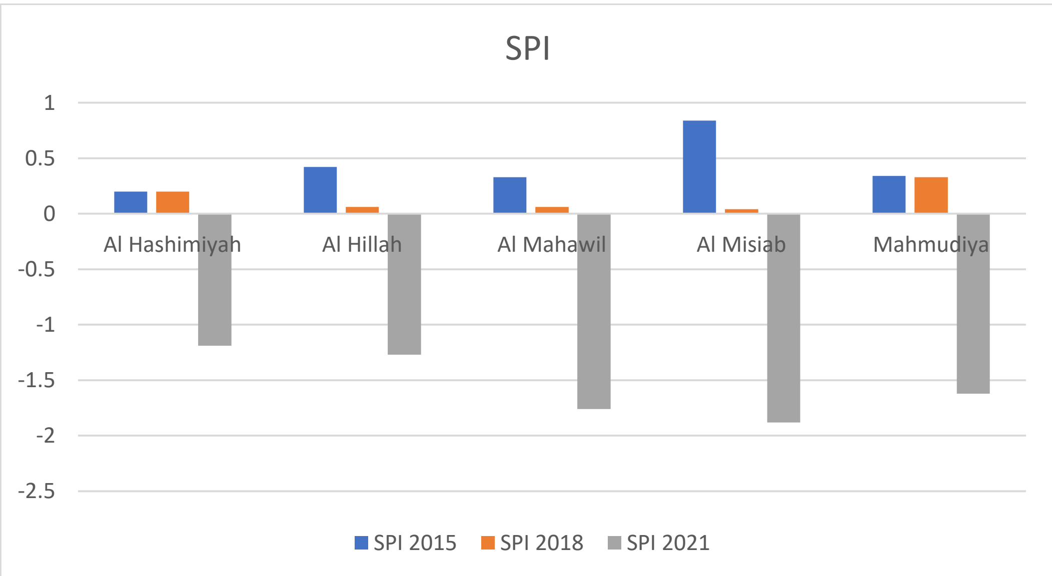

Figure 4: The SPI 12 values for the five stations for 2015, 2018, and 2021.

4. Conclusion

The study aimed to monitor the drought in Babel province/ Iraq using NDVI based on Landsat-8 for the agricultural drought and SPI based on rainfall data for mapping the metrological drought. Remote sensing data could be used successfully to improve drought monitoring. Due to climate change, weather patterns are changing daily; drought is widespread in the study area due to less rainfall and water scarcity. It could be noticed that there is a positive correlation between the metrological and agricultural drought in the study area. The SPI values in 2021 were negative in areas with less vegetation. The 12-month SPI results indicated drought of the near-normal type in 2015 and 2018, while in 2021, the lower SPI value was recorded at -1.88 in Al Misiab station, which refers to severely dry. Finally, after extracting the vegetation class, the percentage of area for the vegetation was calculated for each year to determine the change in vegetation cover. The results showed that the vegetation area decreased in 2021 by 9 % than 2015.

Conflict of Interest: The authors declare that they have no conflicts of interest.

References

[1] The United Nations Educational, Scientific, and Cultural Organization (UNESCO), Analysis Report, p. 28, 2013 .

[2] V. U. Smakhtin and . D. A. Hughes, "Review, automated estimation and analyses of drought indices in South Asia," International Water Management Institute, 2004 .

[3] M. N. Kumar, C. . S. Murthy, M. . V. R. Sesha Sai, and P. S. Roy, "Spatiotemporal analysis of meteorological drought variability in the Indian region using standardized precipitation index," *Meteorological Applications,* vol. 19, no. 2,pp. 256-264, 2012 .

[4] B. Lloyd-Hughes and M. A. Saunders, *International Journal of Climatology*, vol. 22, no. 13, pp. 1571-1592, 2002 .

[5] M. Vélez-Nicolás, a. García-López, V. Ruiz-Ortiz, S. Zazo and J.-L. Molina, "Precipitation Variability and Drought Assessment Using the SPI: Application to Long-Term Series in the Strait of Gibraltar Area.," *Water*, vol. 14, no. 6, p. 884, 2022 .

[6] D. A. Wilhite and M. . H. Glantz, "Understanding: the Drought Phenomenon: The Role of Definitions," *Water International*, vol. 10, no. 3, pp. 111-120, 1 1985 .

[7] T. .B. McKee, N. J. Doesken and . J. Kleist, "THE RELATIONSHIP OF DROUGHT FREQUENCY," *Proceedings of the 8th Conference on Applied Climatology*, pp. 179-183, 1993 .

[8] L. Chen. V. . P. Singh, S. Guo, A. K. Mishra and . J. Guo, "Drought analysis using copulas," *Journal of Hydrologic Engineering*, vol. 18, no. 7, pp. 797-808, 7 2013 .

[9] M. Ionita, P. Scholz and S. Chelcea, "Assessment of droughts in Romania using the Standardized Precipitation Index," *Natural Hazards,* vol. 81, no. 3, pp. 1483-1498, 2016 .

[10] N. Noureldeen. K. Mao, A. Mohmmed, Z. Yuan and . Y. Yang, "Spatiotemporal drought assessment over Sahelian countries from 1985 to 2015 ",*Journal of Meteorological Research*, vol. 34, no. 4, pp. 760-774, 9 2020 .

[11] E. G. Karakani, A. Malekian, S. Gholami, and . J. Liu, "Spatiotemporal monitoring and change detection of vegetation cover for drought management in the Middle East," *Theoretical and Applied Climatology*, vol. 144, no. 1, pp. 299-315, 2 2021 .

[12] J. Zeng, J. Li, X. Lu, Z. Wei, W. Shangguan, S. Zhang, Y. Dai, and S. Zhang, "Assessment of global meteorological, hydrological and agricultural drought under future warming based on CMIP6," *Atmospheric and Oceanic Science Letters*, vol. 15, no. 1, 2022 .

[13] R. S. Hameed, L. E. Georg and B. . H. Sayyid, "Modified Vegetation Detection Index Using Different-Spectral Signature," *Iraqi Journal of Science*, vol. 62, no. 11, 4208–4217, 11 2021 .

[14] A. N. Abdul-Hammed and A. S. Mahdi, "Monitoring Vegetation Area in Baghdad Using Normalized Difference Vegetation Index," *Iraqi Journal of Science*, vol. 63, no. 3, p. 1394–1401, 3 2022 .

[15] W. A. H. Sultan and D. S. Najja, "The Growth Variation of the Population of Babylon Province for the Period 1987 – 2018," *Journal of Al-Rafidain University College for Sciences,* issue 46, pp. 309-319, 2020 .

[16] N. B. Guttman, "Accepting the Standardized Precipitation Index: A calculation algorithm," *Journal of the American Water Resources Association*, vol. 35, no. 2, pp. 311-322, 12 1999 .

[17] C. J. Tucker, "Red and photographic infrared linear combinations for monitoring vegetation," *Remote Sensing of Environment*, vol. 8, no. 2, pp. 127-150, 5 1979 .

[18] J. J. R, *Introductory digital image processing: A remote sensing perspective, New Jersey: Prentice-Hall, Ed.02*, 1996 .

[19] S. Sırdaş and . Z. Şen, Meteorological drought modeling and application to Turkey, İstanbu: Istanbul Technical University, Graduate School of Science, Engineering and Technology, 2002 .

[20] G. Pamuk. M. Ozgurel and K. Topcuoglu, "Drought analysis of Aegean region by standardized precipitation index (SPI)," *The Journal of Ege University Faculty of Agriculture*, vol. 41, no. 1, pp. 99-106, 2004 .

[21] A. P. V. B. R. Nikam, A. Chouksey and S. P. Aggarwa, "Assessment and monitoring of agricultural droughts in Maharashtra using meteorological and remote sensing-based indices, isprs Ann. Photogramm," *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, vol. 4, no. 5, pp. 253-264, 2018 .

[22] I. Rousta, H. Olafsson, M. Moniruzzaman, H. Zhang , Y.-A. Liou, e. D. Mushore and A. Gupta, "Impacts of Drought on Vegetation Assessed by Vegetation Indices and Meteorological Factors in Afghanistan," *Remote Sensing*, vol. 12, no. 15, p. 2433, 2020.