University of Sistan and Baluchestan

Journal of Natural Environment Hazards

Print ISSN: 2676 - 4377 Online ISSN: 2676 - 4385

Homepage: https://jneh.usb.ac.ir

Performance evaluation of composite remote sensing indices in drought assessment (case study: Chaharmahal and Bakhtiari Province, Iran)

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Article Info

Article type:
Research Article

Article history:
Received: 13 September 2024
Revised: 14 November 2024
Accepted: 04 December 2024

Keywords:
Drought, Chaharmahal and Bakhtiari, Remote sensing composite drought indices, MODIS, CDI.

ABSTRACT

Drought is a significant natural disaster that requires monitoring to control and minimize its damages. In addition to climate-based drought indices, remote sensing drought monitoring indices are widely used today, especially in regions with limited climate data. These indices utilize satellite images and provide valuable information, resulting in relatively good performance. Furthermore, composite drought indicators are relatively new and multi-variable indices that combine remote sensing indicators for monitoring drought. Studies have shown that the effectiveness of these indicators can also be influenced by the study region. Given the importance of evaluating the performance of new methods in monitoring drought, this study compared the performance of a composite drought monitoring index, CDI, with the VCI, TCI, VHI, and PCI in Chaharmahal and Bakhtiari Province, Iran. CDI is a combination of VCI, TCI, and PCI. The values of the indices were compared with the SPI for the period of 2001-2020, with a time lag of 0 to 8 months by calculating the determination coefficient. For each index, the lag time that provided the highest R2 was identified. Precipitation data from 19 rain gauge stations in the study area were used to calculate the SPI on 3 and 6-month time scales. The results showed that the CDI presents by far the highest correlation with SPI values. The coefficient of determination for the VCI on a 6-month time scale with a 3-month time lag was on average 0.30. For the TCI, the average R2 is 0.50 in both the 3 and 6-month time scales without a time lag. The average R2 for the VHI on a 6-month time scale with a 2-month time lag was 0.41. The average coefficient of determination for the PCI index on a 3-month time scale without a time lag was just 0.32. The CDI index provided the best performance, with an average R2 of 0.73 in both the 3 and 6-month time scales without a time lag. While VCI, TCI, and PCI individually showed weak matching with the SPI, combining them into the CDI resulted in a significant correlation with the SPI.

Cite this article: Babaei, E., Asadi Zarch, M. A., Hosseini, S. Z., & Shahmoradi, S. (2025). Performance evaluation of composite remote sensing indices in drought assessment (case study: Chaharmahal and Bakhtiari Province, Iran). Journal of Natural Environmental Hazards, 14(43), 33-36. DOI: 10.22111/jneh.2024.49797.2067

Publisher: University of Sistan and Baluchestan

DOI: 10.22111/jneh.2024.49797.2067

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INTRODUCTION

Throughout history and across the globe, human life has always been vulnerable to various natural hazards, including those caused by climate processes. Among these hazards, drought is a significant and widespread concern. Estimating drought is crucial as a strategy for managing this natural phenomenon. Drought indicators are used to analyze drought quantitatively and qualitatively. The CDI index utilized in this research is based on three datasets developed by FAO. The study aimed to assess the effectiveness of remote sensing composite indices in detecting and estimating droughts.

According to a United Nations report, Iran has been facing consecutive droughts in recent years, leading to severe water shortages (Tabatabaii Zadeh et al., 2014). Chaharmahal and Bakhtiari province, despite their relatively small size in the country, holds approximately 10% of Iran's water resources, underscoring the importance of monitoring drought conditions in this region (Mohit Esfahani et al., 2020). Therefore, the study was conducted to evaluate the performance of composite remote sensing indices in identifying and estimating drought in the Chaharmahal and Bakhtiari regions. A review of the literature did not reveal any similar studies in the available resources.

DATA AND METHODS

Chaharmahal and Bakhtiari Province has an area of approximately 16,421 square kilometers, which from a topographic perspective includes a high mountainous area and various thermal climates. In this study, precipitation data from 19 rain gauge stations in Chaharmahal and Bakhtiari province during the statistical period from 2001 to 2020 were used to calculate the SPI index. McKee et al. (1993) proposed the SPI index to assess the meteorological drought in the state of Colorado, USA. Equations (1) to (5) were used to calculate the applied remote sensing indices including VCI, TCI, VHI, PCI, and CDI.

(1) (Kogan, 1995) $$VCI = \frac{NDVI_i - NDVI_{min}}{NDVI_{max} - NDVI_{min}} * 100$$

(2) (Zou et al., 2020) $$TCI = \frac{LST_{max} - LST_i}{LST_{max} - LST_{min}}$$

(3) (Kogan et al., 2004) $$VHI = 0.5(VCI) + 0.5(TCI)$$

(4) (Du et al., 2013) $$PCI = \frac{TRMM_i - TRMM_{min}}{TRMM_{max} - TRMM_{min}}$$

(5) (Al-Adaileh et al., 2019;) $$CDI_i = (W_{PCI} \times PCI_i) + (W_{TCI} \times TCI_i) + (W_{VCI} \times VCI_i)$$

In this study, the coefficient of determination between SPI and the remote sensing indices was calculated and examined at time scales of 3 and 6 months and with a time lag of 0 to 8 months.

RESULTS AND DISCUSSION

SPI was calculated using precipitation data from the study stations. The drought intensity values based on SPI for selected stations on an annual scale are shown in Figure 1. While the drought intensity values vary between different years at most stations, the overall trend of drought and wet periods is generally similar across stations. For instance, in 2008, most stations experienced some level of drought.

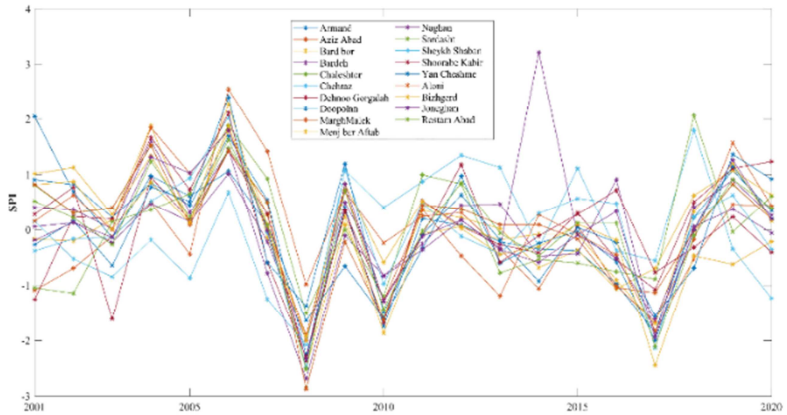

Figure 1: Annual SPI values for selected rain gauge stations in the study area

The determination of coefficient values was calculated between SPI and CDI. The R^2 values for the composite remote sensing data, without considering the time lag, were significantly higher than the R^2 values for CDI with a 6-month time lag. In conclusion, it can be inferred that CDI performs relatively well in monitoring drought in the study area. Arabi and Mohammadi (2021) also assessed the performance of PCI, TCI, VCI, and composite SDCI indices in Iran. The results indicated that the composite index had a higher correlation with SPEI compared to other remote sensing indices.

CONCLUSION

The study found that the CDI composite index outperformed the other indices analyzed. On average, the coefficient of determination for the VCI, PCI, VHI, and TCI indices was 0.30, 0.32, 0.41, and 0.5, respectively. In contrast, the CDI index had an average R^2 of 0.83. Therefore, when possible, using the CDI index for drought monitoring is recommended over the other remote sensing indices. The study suggests further comparison of the CDI index with other remote sensing composite indices to assess its performance.

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