ECOPERSIA. 2018;6(2):111-119

Zoning Drought with Standardized Precipitation Index and Reconnaissance Drought Index in Sistan and Baluchestan Province, Southeastern Iran

ARTICLE INFO

Article Type
Original Research

Authors
Nohtani M.* *PhD*,
Ajorlo M.[1] *PhD*,
Sarhadi M.[1] *MSc*

How to cite this article
Nohtani M, Ajorlo M, Sarhadi M. Zoning Drought with Standardized Precipitation Index and Reconnaissance Drought Index in Sistan and Baluchestan Province, Southeastern Iran. ECOPERSIA. 2018;6(2):111-119.

ABSTRACT

Aims Drought has become a main concern in Iran. The drought is posing a serious threat to life in Sistan and Baluchestan Province. This study aimed to evaluate the severity and extent of drought in Sistan and Baluchestan Province, Southeastern Iran.

Materials & Methods Standardized precipitation index (SPI) and reconnaissance drought index (RDI) were used to determine the severity, duration, and extent of drought in Sistan and Baluchestan Province. Seven synoptic stations located across the province with data period of 2001–2012 were used in monthly timescale. DrinC software was used to calculate SPI and RDI indices. Drought zoning maps were generated using ArcGIS software.

Findings Iranshahr and Saravan stations showed the most severe drought in 2003–2004 water year and Nikshahr station had the lowest drought severity in the same water year. The drought zoning maps indicated that the lowland areas and plains, especially in the southwestern part of the province and Iranshahr and Nikshahr stations, were vulnerable at the time of drought occurrence.

Conclusion Both drought indices behaved similarly, but the RDI index was more sensitive in a specific climate condition due to using potential evapotranspiration of reference crop. It can be recommended that the RDI index can be used as an appropriate indicator for drought monitoring in Sistan and Baluchestan Province.

Keywords DrinC Software; Drought Monitoring; Zoning Drought

CITATION LINKS

[1] Drought monitoring based on the SPI and RDI indices under climate change scenarios (Case study: Semi-arid areas of West Golestan province) [2] Regionalization of Urmia lake basin from the view of drought using factor analysis [3] Drought monitoring by Reconnaissance Drought Index (RDI) in Iran [4] The effect of PET method on Reconnaissance Drought Index (RDI) calculation [5] Comparative evaluation of four meteorological drought indices using the cluster analysis (Case study: Sistan and Baluchestan) [6] The study of drought indices SPI and RDI in a case study. 9th International Congress on Civil Engineering, Isfahan University of Technology [7] Determination of the most suitable geostatistics method for mapping of TDS and TH variations in groundwater, case study in Fassa county [8] Drought modeling and management using SPI and RDI indexes (Case study: Markazi province) [9] The role of evapotranspiration in meteorological drought monitoring in some climatic regions of the country [10] Evaluation and comparison of ordinary kriging and inverse distance weighting methods for prediction of spatial variability of some chemical parameters of Dhalai district, Tripura [11] An investigation on the Urmia Lake basin drought using RDI and SPI indices [12] Regional drought assessment based on the Reconnaissance Drought Index (RDI) [13] Ordinary kriging vs inverse distance weighting: Spatial interpolation of the sessile ommunity of Madagascar reef, Gulf of Mexico [14] Establishing a drought index incorporating evapotranspiration [15] Critical appraissal of meteorological drought indices: A case study on the Ananthapur district [16] Climatic classification of Sistan and Baluchestan province [17] Drought analysis in the Awash river basin, Ethiopia [18] A comparative study of some meteorological drought indices in some Iranian climatic samples [19] Monitoring the 1996 drought using the standardized precipitation index [20] DrinC: A software for drought analysis based on drought indices [21] Comparison of SPI and RDI in drought analysis in local scale with emphasizing on agricultural drought (Case study: Qazvin and Takestan)

*Department of Rangeland and Watershed Management, Faculty of Water & Soil, University of Zabol, Zabol, Iran
[1]Department of Rangeland and Watershed Management, Faculty of Water & Soil Faculty, University of Zabol, Zabol, Iran

Correspondence
Address: Department of Rangeland and Watershed Management, Faculty of Water & Soil, University of Zabol, Zabol, Iran.
Phone: +98 (911) 964 8185
Fax: -
m.nohtani@uoz.ac.ir

Article History
Received: November 12, 2017
Accepted: April 10, 2018
ePublished: June 26, 2018

Introduction

Drought is one of natural disasters that its occurrence is impossible to be prevented. The most important difference between drought and other natural disasters is that it starts gradually and then it affects neighboring areas in addition to the area where it occurred. The adverse effects of this phenomenon appear in all sectors such as water resources, agriculture, and environment gradually.[1, 2] Meteorological drought begins with a reduction in the amount of rainfall and changes in some atmospheric phenomena such as increasing air temperature, occurrence of strong winds, reducing the relative humidity, increasing sunshine hours, and decrease in cloud cover.

Drought indices are used to quantify and evaluate drought in different scales of time and space. To calculate these indices, availability of long-term hydroclimatic data is necessary.[3-5] Standardized precipitation index (SPI) is widely used for drought assessment throughout the world. However, the disadvantage of the SPI is that it is impossible to calculate it in months without precipitation records. This means that if some months in a given station has not precipitation, the SPI index is unable to analyze the data and determine wet and dry status in the whole course and also in that month.[1, 6] With consideration to the advantages of SPI index such as flexibility and usability in numerous time scales (short-term for agricultural purposes and long-term for spatial and hydrological purposes) in the micro and macro levels and suitability of index for the diagnosis of the onset of drought, monitoring, and prediction, rainfall variable alone cannot reflect the drought in areas with high temperatures and evapotranspiration.[1, 4] In recent studies, a relatively new index names reconnaissance drought index (RDI) has been introduced. The RDI advantages include being physical based, calculable for any periods of time, and the ability to communicate between hydrological and agricultural droughts.[1, 7] In general, the SPI index is used to measure hydrological and meteorological drought, while the RDI index is mainly used for evaluating agricultural drought because it uses potential evapotranspiration (PET) parameter in its formula (7).[8]

Numerous studies have reported the use of SPI and RDI indices in drought evaluation and zoning.[8-13] In Greece, the RDI and SPI indices were used for drought zoning in Mornos and Nestos river basins.[12, 14] The study reported that the RDI index was more sensitive in identifying drought compared with SPI index. In Iran, the performance of SPI and RDI indices on analysis of drought using precipitation and temperature data was evaluated in Qazvin and Takestan stations, Qazvin Province.[11] The study found that the RDI index compared with the SPI index was more sensitive to severe drought. The performance of the SPI and RDI indices in drought zoning was also assessed in Urmia Lake basin (data period of 1980–2010), northwestern Iran, and found that RDI was more sensitive in the assessment of severe and very severe droughts.[10] The management and zoning of drought using SPI and RDI indices were examined in Markazi Province, central Iran. For this purpose, data from 10 synoptic stations for 13 years (2000–2013) were used on monthly basis. Results indicated the vulnerability of lowland areas and plains to drought in Markazi Province.[8] In another study in Iran, the role of evapotranspiration in monitoring of drought was investigated in several climatic regions of Iran during 1962–2010 with SPI, RDI, and standardized precipitation evapotranspiration index (SPEI) using data of six synoptic stations including Ramsar, Hamadan, Shiraz, Sabzevar, Bandar Abbas, and Yazd.[9] Monthly data of meteorological parameters including rainfall, average temperature, minimum temperature, maximum temperature, relative humidity, sunshine, and wind speed were used. Results showed that there was no significant difference between SPI, RDI, and SPEI in wet regions, but the difference between the indices was clear in dry regions.[9] In India, drought indices of the SPI and RDI were studied in Anantapur district and found that these two indices characterize the drought condition properly.[15] The probability of slight drought in the region was estimated 99%.[15] It can be concluded that, in most of the research, a very high correspondence between the SPI and RDI indices has been founded, but in very dry conditions, the RDI index was more sensitive than the SPI index.

Sistan and Baluchestan Province has been severely subjected to drought in last decades due to being far from rainy systems route, locating in arid and desert zone, as well as proximity to other arid regions. Appropriate water resource management due to decrease in precipitation and increasing drought is needed to mitigate drought negative impacts in the province. Drought monitoring using drought indices, as one of the effective components of early warning system in natural disaster risk management, makes it possible to identify which areas of the province have been affected by drought. Given the fragile ecosystems of these areas in the province, planning and proper management of water resources should be done with regard to the possibilities and forecasting of drought occurrence. In this regard, the use of drought indices can better reveal the effects of drought on agriculture and water resources. According to the zoning maps, management practices and plans should be concentrated in places where drought is severe and its occurrence probability is higher.

To understand water crisis in Sistan and Baluchestan Province, the intensity of the drought as the most important factor in water crisis was investigated in this study. Therefore, the study aimed to use the SPI and RDI indices for evaluating the extent and severity of drought and also zoning of drought in Sistan and Baluchestan Province, Iran.

Materials and Methods

Study area

Sistan and Baluchestan Province with an area of about 181,785 km^2 is the largest province of Iran lying between 27°3' to 31°28' north latitude and 58°47' to 63°19' east longitude, southeastern Iran (Figure 1). Average annual rainfall and temperature are 139.8 mm and 22.6°C, respectively. High average temperatures and its low fluctuation are major characteristics of the climate in the province. Given the scarcity of rainfall and lack of snow resources, most of the rivers are temporary and seasonal.[6, 16]

Sistan plain which has been made of alluvial of the Hirmand River is located in northern part of the province. The plain, which is situated in the middle of the desert climate, receives rainfall <65 mm/year and annual evaporation is over 5000 mm/year. These conditions develop intense aridity and devastating drought in northern part of the province, especially, when the discharge of Hirmand River is decreased. Blowing of the 120-day wind from late spring to late summer intensifies unfavorable conditions in the northern part of the province. Southern regions of the province experience different climates due to the proximity to the Oman Sea and take advantage of the monsoon. Although limited groundwater resources are the only source of water supply in Baluchestan, life is completely depended on the Hirmand River flow in Sistan.[16]

Data sources

In this study, monthly temperature and precipitation data for seven synoptic stations located within the province for 2001–2012 were used (Figure 1 and Table 1).

SPI

The SPI index due to simplicity, flexibility, and ability to determine and monitor drought (because of the probabilistic analysis) has special position among water managers.[1, 17] The SPI is a z-score and represents an event departure from the mean, expressed in standard deviation units. The SPI is also a normalized index in time and space. This feature allows comparisons of SPI values among different locations.[17] This index is calculated based on the difference between precipitation and average precipitation for a specific timescale divided by the standard deviation of the series. Therefore, precipitation is the only factor that involves in the calculation of SPI (Equation 1).[18] This index compares the precipitation of areas

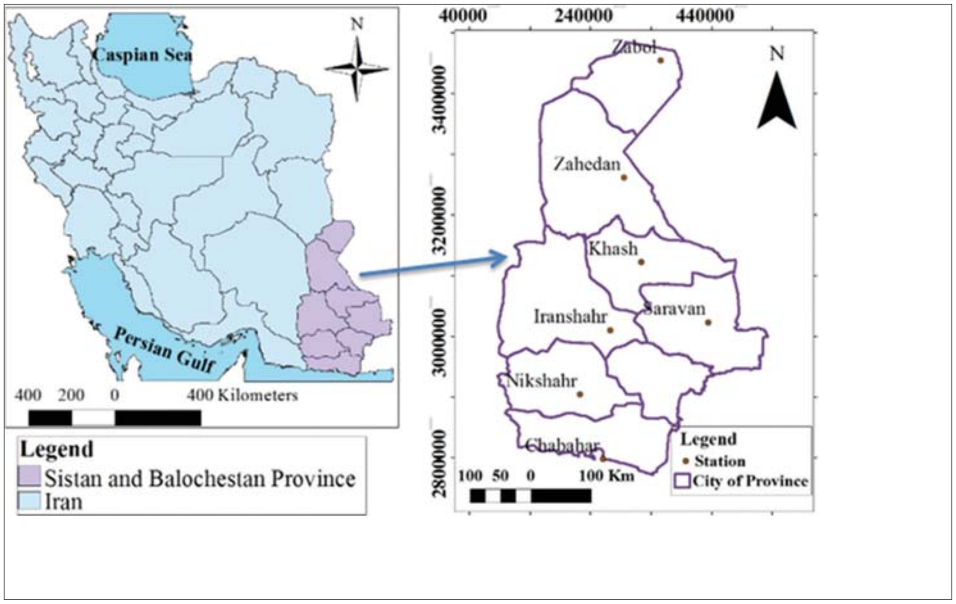

Figure 1: Location of the study area and synoptic stations in the province

Table 1: Geographical location of synoptic stations in Sistan and Baluchestan province (10)[14]

Station	Longitude	Latitude	Elevation (m)	Average temperature (°C)	Average rainfall (mm)	Climate type
Zabol	61°29'	31°13'	2.489	22.2	55.4	Hot and arid
Zahedan	60°53'	29°28'	9.1369	18.5	78.5	Semi-arid and hot temperate
Khash	61°12'	28°13'	1394	20.1	148.1	Semi-arid and hot temperate
Saravan	62°20'	27°20'	1195	22.2	107.3	Semi-arid and hot temperate
Iranshahr	60°42'	27°12'	1.591	26.8	111.9	Hot and arid
Nikshahr	60°13'	26°14'	510	27.9	173.6	Hot and arid desert
Chabahar	60°37'	25°17'	8	26.3	115.8	Hot and coastal desert

with different climatic conditions. According to this index, a drought event occurs when the SPI values reach -1 or less. The drought event is considered to terminate when the SPI value is positive [Table 2].[1, 19]

$$SPI=(P-P_0)/SD \qquad (1)$$

Where SPI is Standardized Precipitation Index, P is monthly or annual precipitation (mm), P_0 is mean monthly or annual precipitation (mm), and SD is the standard deviation of the series.

Reconnaissance drought index (RDI)

The RDI index was developed by Tsakiris and Vangelis.[1, 20] In the use of meteorological drought as criteria for evaluating water shortage a balance should be established

Table 2: Classification of SPI and RDI values

Drought classification	SPI and RDI values
Extremely wet	≥2
Very wet	1.5–1.99
Moderately wet	1.0–1.49
Near normal	−0.99–0.99
Moderate drought	−1.49–(−) 1.0
Severe drought	−1.99–(−) 1.5
Extreme drought	≤−2

SPI: Standardized precipitation index,
RDI: Reconnaissance drought index

between input and output of the model. Therefore, it is not possible to achieve proper assessment of the water balance using only precipitation as the input variable without output estimation. By this reasoning, the RDI employs evapotranspiration parameter in addition to precipitation in its equation. Many researchers believe that the RDI is a strong index for estimating drought[4] because it uses PET in addition to precipitation, so it can provide a more detailed answer in risk issues.[1, 10] The most important advantage of this index is that both water quantity and climatic factors are considered in drought assessment process. The calculation method of RDI is as follows:

Value of a_0 is calculated for each year (i) of the data period using Equation (2).

$$a_{\cdot}^{(i)} = \frac{\sum_{j=1}^{12} P_{ij}}{\sum_{j=1}^{12} ET_{ij}} \tag{2}$$

Where P is precipitation and ET is evapotranspiration at the j^{th} month of i year. The value of i will change from 1 to N (the number is the year, for which statistics are available).

The next step is to calculate normal RDI or RDIn for each year using Equation (3).

$$RDI_{\cdot}^{(i)} = \frac{a_{\cdot}^{(i)}}{a_{\cdot}} \tag{3}$$

For calculating standardized RDI (or RDIs), the annual values a_0 log is taken, called Yi (Equation 4).

Y_i=Ln a_0 (i) (4)

Then, the arithmetic mean and standard deviation of the numbers calculated and called σy_k and y_k, respectively. Finally, the standardized index of the RDI for each year is calculated by Equation (5).

$$RDI_s^{(i)} = \frac{y_k^i - \overline{yk}}{ó_{yk}} \tag{5}$$

In general, the RDI index uses two variables, i.e., rainfall and pPET and three steps include calculation of initial values, normalized RDI, and standardized RDI to determine drought. Standardized RDI can be compared with the SPI index. Classification thresholds of RDI and SPI indices are presented in Table 2.

Calculation of drought indices

These two indices were calculated using DrinC software (version 1.5) at 1 year intervals. The DrinC is a software for drought analysis based on drought indices which released in 2015. To calculate the RDI, monthly PET data were required which calculated using the Thornthwaite method in the software.[13]

Zoning drought

Two common models, i.e., Kriging and inverse distance weighting (IDW) were used to investigate geostatistically.[1] The Kriging, a geostatistical method, and IDW, as deterministic interpolation methods, have been used widely to predict many environmental variables.[13] Both models estimate values at unsampled locations based on the measurement at surrounding locations with certain assigned weights for each measurement.[10]

In this study, the best way to zoning drought indices was determined on the basis of mutual evaluation. The most important criteria for evaluating the estimations were root mean square error (RMSE) and mean error (ME) which calculated by Equations 6 and 7.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\hat{z}(u_i) - z(u_i)\right)^2} \tag{6}$$

$$ME = \frac{1}{n}\sum_{i=1}^{n}\left(\hat{z}(u_i) - z(u_i)\right) \tag{7}$$

Where n is the number of observations. Based on these criteria, the most appropriate method is the method with minimum RMSE and ME values close to zero as possible.[7] After determining the best method of interpolation, zoning maps and spatial distribution of two indices, i.e., the SPI and RDI were prepared in ArcMap for the province.

Findings

SPI and RDI drought indices

Drought in Sistan and Baluchestan Province was classified in three categories, i.e., moderately drought, severely drought, and extremely drought according to the outputs of drought indices calculation (Table 3). The most severe drought was occurred in Saravan and Iranshahr stations in 2003–2004 and the least severe drought was occurred in Nikshahr station in the same year. The SPI and RDI changes trend in Iranshahr station (with the most severe drought) and Nikshahr (the least severe drought) showed that the drought in 11 years was declining (Figure 2). The correlation coefficient (r) between SPI and RDI indices in these stations was 0.99, indicating high agreement between SPI and RDI indices at those two stations.

Evapotranspiration in Iranshahr station (the most severe drought) was much more than the Nikshahr station (the least severe drought) at the beginning of the period in question, but it has encountered with a significant decrease during 11 years and it was so close to evapotranspiration in Nikshahr station at the end of period (Figure 3).

Zoning the SPI and RDI indices

Interpolating of drought indices was carried out using two common geostatistical methods, i.e., Kriging and IDW. Validation results of the indices are presented in Table 4. In both indexes, IDW method had a lower error (the least RMSE), and it produced the most appropriate maps.

After calculation of drought indices and the best method of interpolation, a table

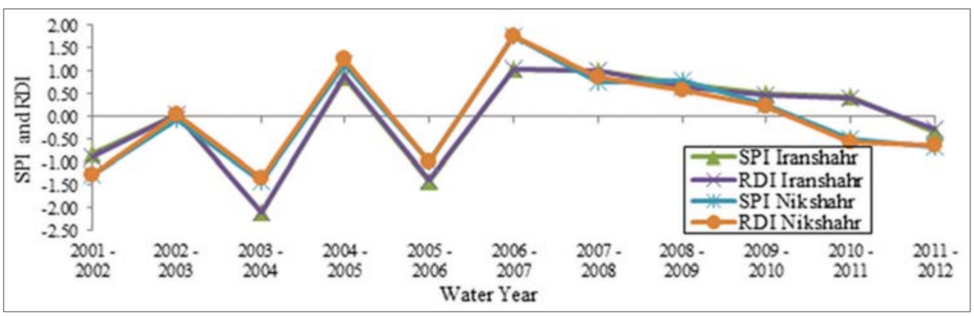

Figure 2: Changes of standardized precipitation index and reconnaissance drought index in Iranshahr and Nikshahr stations in 2001–2012

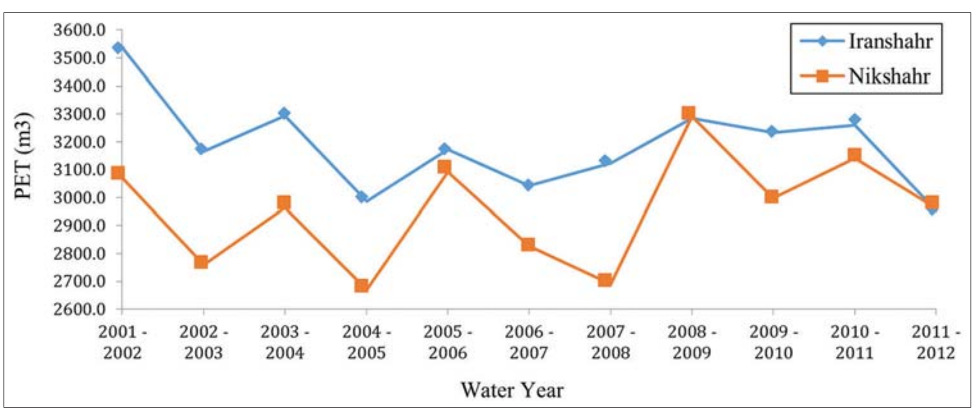

Figure 3: Potential evapotranspiration in Iranshahr and Nikshahr Stations in 2001–2012

Table 3: The highest SPI and RDI values calculated for each station in the study area

Station	SPI	RDI	Year	Drought classification
Zabol	−50.1	−51.1	2007–2008	Severely drought
Zahedan	−72.1	−73.1	2001–2002	Severely drought
Khash	−85.1	−83.1	2003–2004	Severely drought
Saravan	−10.2	−9.2	2003–2004	Extremely drought
Iranshahr	−10.2	−9.2	2003–2004	Extremely drought
Nikshahr	−40.1	−34.1	2003–2004	Moderately drought
Chabahar	−99.1	−2	2003–2004	Severely drought

SPI: Standardized precipitation index, RDI: Reconnaissance drought index

Table 4: Validation of drought indices in Sistan and Baluchestan province

Variable	Evaluation criteria	Kriging	IDW
SPI	ME	0.0048	−0.0181
	RMSE	0.3424	0.3145
RDI	ME	0.0011	−0.0145
	RMSE	0.3562	0.3321

SPI: Standardized precipitation index, RDI: Reconnaissance drought index, IDW: Inverse distance weighting, RMSE: Root mean square error, ME: Mean error

that contains the name of the station, UTM coordinates, and the highest values of SPI and RDI for each station was prepared. Then, the data were entered to the ArcGIS software, and zoning drought was conducted with IDW method for both SPI and RDI indices (Figure 4).

According to the zoning maps, Saravan and Iranshahr stations had the most severe drought in 2003–2004 water year and Nikshahr station had the lowest level of drought in the same year. The results of drought monitoring in studied stations indicated that drought was occurred in 2003–2004 in most parts of the province. Nikshahr station in 2003–2004 as well as Saravan and Iranshahr stations in 2003–2004 and 2005–2006 was affected by drought, but they were classified into normal and even wet classes in other years. Other stations also showed the different severity of drought.

In this study, the RDI value was lower than SPI values in severe droughts during a specific period. Finally, the SPI and RDI indices were calculated for seven meteorological stations in annual and monthly timescales at Sistan and Baluchestan Province in this study. The extreme values of the indices and their occurrence during the time period were also specified. The results of both indices in drought evaluation were almost identical in all stations and two indices were coincided. However, the RDI index was more sensitive in a specific climate because of using PET and reference crop parameters. The reason of mismatch of drought classes of the SPI and RDI in some years was because of the difference in annual evapotranspiration compared to the long-term mean. By increasing or decreasing of annual evapotranspiration rate compared to long-term mean, mismatch or difference of drought classes of both indices will be more.

Discussion

The present study aimed to use the SPI and RDI indices for evaluating the extent and severity of drought and also zoning of drought in Sistan and Baluchestan Province, Iran.

The SPI and RDI changes trend in Iranshahr station (with the most severe drought) and Nikshahr (the least severe drought) showed that the drought in 11 years was declining.

Since evapotranspiration has a key role in drought occurrence as well as in the RDI index, investigation of its temporal changes is important.[21] Evapotranspiration in Iranshahr station (the most severe drought) was much more than the Nikshahr station (the least severe drought) at the beginning of

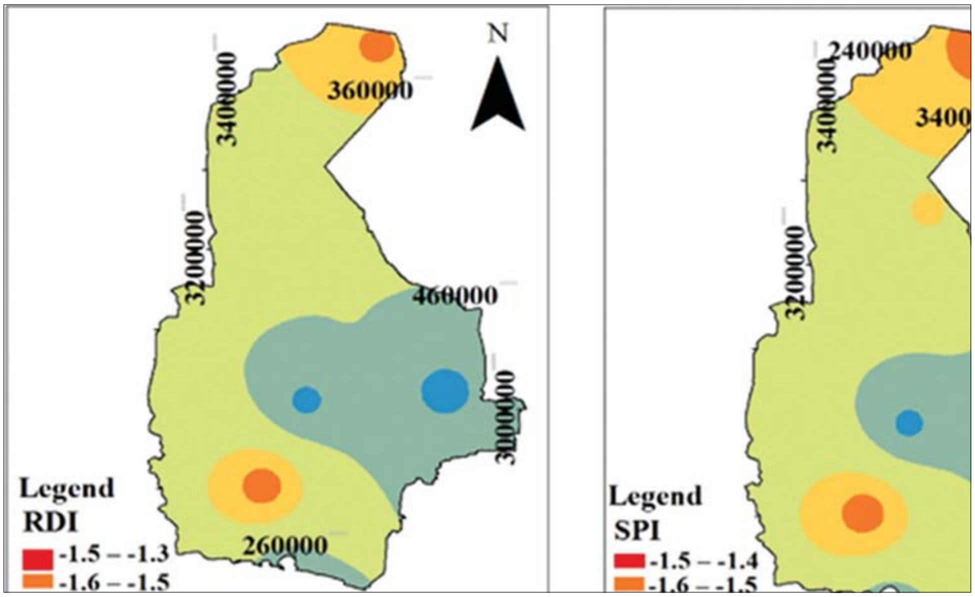

Figure 4: Zoning drought based on standardized precipitation index and reconnaissance drought index in Sistan and Baluchestan Province

the period in question, but it has encountered with a significant decrease during 11 years and it was so close to evapotranspiration in Nikshahr station at the end of period.

In this study, the RDI value was lower than SPI values in severe droughts during a specific period. This demonstrates the sensitivity of the RDI index to weather conditions. It means that the role of evapotranspiration in the drought studies cannot be ignored. This finding is consistent with the results of other studies.[6, 10-12] The SPI and RDI change trend in Iranshahr and Nikshahr stations showed that the drought trend was declining over 11 years.[6] The SPI and RDI indices showed the vulnerability of lowland areas and plains during drought in Sistan and Baluchestan Province.[8]

Conclusion

This study reports that the drought was occurred in most parts of Sistan and Baluchestan Province in 2003–2004. The most severe drought was occurred in Saravan and Iranshahr, and the least severe drought was occurred in Nikshahr station in 2003–2004. However, drought had declining trend in these stations during the period of study according to the SPI and RDI indices.

Zoning drought indicated that Sistan and Baluchestan Province has been suffering from drought during the period of study. However, drought severity varies in the province due to different climate types across the province. This study concludes that the RDI index is an appropriate index for drought evaluation in Sistan and Baluchestan Province.

Acknowledgments

Authors would like to express their gratitude to Vice-chancellor for Research and Technology, University of Zabol, for evaluation and approval of the proposal of this work.

Ethical Permissions

It is not necessary.

Conflicts of Interest

The authors state that there are no conflicts of interest.

Authors' Contributions

Each of the author contributed to the development of the paper.

Funding/Support

This research was funded by the University of Zabol, Iran (project code: 40–94).

References

1. Akbari M, Ownegh M, Asgari H, Sadoddin A, Khosravi H. Drought monitoring based on the SPI and RDI indices under climate change scenarios (Case study: Semi-arid areas of West Golestan province). Ecopersia. 2016;4(4):1585-602.
2. Ghorbani Aghdam M, Dinpazhuh Y, Fakheri Fard A, Darbandi S. Regionalization of Urmia lake basin from the view of drought using factor analysis. J Water Soil. 2012;26(5):1268-76. [Persian]
3. Asadi Zarch MA, Malekinezhad H, Mobin MH, Dastorani MT, Kousari MR. Drought monitoring by Reconnaissance Drought Index (RDI) in Iran. Water Resour Manag. 2011;25:3485.
4. Vangelis H, Tigkas D, Tsakiris G. The effect of PET method on Reconnaissance Drought Index (RDI) calculation. J Arid Environ. 2013;88:130-40.
5. Piri H, Abbaszadeh M, Rahdari V, Maleki S. Comparative evaluation of four meteorological drought indices using the cluster analysis (Case study: Sistan and Baluchestan). Water Eng. 2013;6(17):25-36. [Persian]
6. Mohammadi A, Azhdari Moghadam M. The study of drought indices SPI and RDI in a case study. 9th International Congress on Civil Engineering, Isfahan University of Technology. Isfahan: Isfahan University of Technology; 2012. [Persian].
7. Bahraini Motlagh M, Molaeinia MR, Soltani J, Jamshidi A. Determination of the most suitable geostatistics method for mapping of TDS and TH variations in groundwater, case study in Fassa county. 11th Global Irrigation Seminar and Evaporation Reduction. Kerman: Shahid Bahonar University of Kerman; 2012. [Persian]
8. Youssefi H, Nohegar A, Khosravi Z, Azizabadi Farahani M. Drought modeling and management using SPI and RDI indexes (Case study: Markazi province). Ecohydrology. 2015;2(3):337-44. [Persian]
9. Hatefi A, Mossaedi A, Jabbari Nooghabi M. The role of evapotranspiration in meteorological drought monitoring in some climatic regions of the country. J Water Soil Conserv. 2016;23(2):1-21. [Persian]
10. Reza SK, Sarkar D, Baruah U, Das TH. Evaluation and comparison of ordinary kriging and inverse distance weighting methods for prediction of spatial variability of some chemical parameters of Dhalai district, Tripura. Agropedology. 2010;20(1):38-48.
11. Shokoohi A, Morovati R. An investigation on the Urmia Lake basin drought using RDI and SPI indices. Watershed Eng Manag. 2014;6(3):232-46. [Persian]
12. Tsakiris G, Pangalou D, Vangelis H. Regional drought assessment based on the Reconnaissance Drought Index (RDI). Water Resour Manag. 2007;21(5):821-33.
13. Zarco-Perello S, Simões N. Ordinary kriging vs inverse distance weighting: Spatial interpolation of the sessile ommunity of Madagascar reef, Gulf of Mexico. PeerJ. 2017;5:e4078.
14. Tsakiris G, Vangelis H. Establishing a drought index incorporating evapotranspiration. Eur Water. 2005;9(10):3-11.
15. Mahesh Babu C. Critical appraissal of meteorological drought indices: A case study on the Ananthapur district. Int J Adv Res. 2016;4(3):1705-17.
16. Applied meteorology research center of Sistan and Baluchestan province (drought climatology group). Climatic classification of Sistan and Baluchestan province [Internet]. Zahedan: Meteorology Department of Sistan and Baluchestan Province; year? [Cited Year?, Day? Month?]. Available from: http://www.sbmet.ir/userfiles/uploads/climatesb.pdf.
17. Edossa DC, Babel MS, Guopta AD. Drought analysis in the Awash river basin, Ethiopia. Water Resour Manag. 2010;24(7):1441-60.
18. Bazrafshan J. A comparative study of some meteorological drought indices in some Iranian climatic samples [Dissertation]. Tehran: University of Tehran; 2002. [Persian].
19. Hayes MJ, Svoboda MD, Wilhite DA, Vanyarkho O. Monitoring the 1996 drought using the standardized precipitation index. Bull Am Meteorol Soc. 1999;80(3):429-38.
20. Tigkas D, Vangelis H, Tsakiris G. DrinC: A software for drought analysis based on drought indices. Earth Sci Info. 2015;8(3):697-709.
21. Shokoohi A. Comparison of SPI and RDI in drought analysis in local scale with emphasizing on agricultural drought (Case study: Qazvin and Takestan). Iran Irrig Water Eng. 2012;3(9):111-22. [Persian]