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Temporal–spatial analysis of drought and wet periods: case study of a wet region in Northwestern Iran (East Azerbaijan, West Azerbaijan, Ardebil and Zanjan provinces)

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Abstract

Northwest of Iran has plant, animal and environmental varieties because of its geographical location. Therefore, alternate weather may have irreparable outcomes in numerous environmental sectors. In the prevailing research, it was turned into consideration to investigate the droughts that with inside the northwestern vicinity of Iran all through a 30-yr statistical period (1987–2016) that occurred, the usage of the records of fifty-five synoptic, climatology and rain gauge stations was evaluated with inside the positioned area. Using the SPI in a 12-month period, 360 maps had been produced for drought severity and month-to-month droughts. Then, the maps had been transformed into records, and the calculations associated with its descriptive information consisting of the common center, well-known circle and ellipse had been calculated on 4236 cells. The consequences of the month-to-month evaluation of droughts and moist duration intensities all through 360 months confirmed that the chance of susceptible moist durations with inside the important elements and extreme droughts with inside the southern half of the vicinity is better than different situations. More extreme droughts arise on this vicinity.

Keywords Standard ellipse · Drought and wet periods · Northwest Iran · SPI · Average center

Introduction

Drought and moist intervals are climatic phenomena, which are not unusual place in Iran. For this reason, its miles are very critical to recognize the traits of those phenomena. Droughts are one of the perils whose detrimental results are a lot heavier than moist intervals and may purpose quite a few anxieties within side the place. With moist intervals arise all at once and the volume of its effect is not very large,

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the results of drought seem over an extended duration of time, and for the duration, a lot of its dimensions are hidden from the perspectives, and after the remittal of time, it has a terrible effect on exceptional parts, and its results may be understood. The weather of a place shows the climatic situation of that place over an extended time. However, alternate and variability are inherent capabilities of weather and feature periodic adjustments with inside the shape of oscillation. Many climatic fluctuations have regarded lightly and slowly; however, there have additionally been fluctuations that have now no longer proven a set duration; however, they may be predicted; this sort of fluctuations is known as unseasonal fluctuations. However, it could be stated that drought and wetness are some of the unseasonal fluctuations of the weather. The lifestyles of irregularities, whether or not terrible (drought) or positive (moist) in rainfall, have had powerful and detrimental results with inside the years of fruitful and coffee rainfall. In fact, the prevalence of wets and droughts is a sort of climatic crisis; however, the results of drought seem slowly and slowly over many years, so the damages because of this climatic phenomenon have a much wider depth and volume than wetness, due to the fact the results of moist intervals are instant and feature much less

volume. Studies with the aid of using scientists who include Hughes and Saunders (2002) in Europe, Ntale and gan (2003) in Africa, Kim and Byun (2009) in Asia and several different researchers display that drought is an international phenomenon. Since the prevalence of drought is related to a lower in rainfall, the opportunity of its prevalence in regions which are inherently confronted with water and precipitation deficiency will increase the danger of drought, so scientists have studied this phenomenon greater than wetness due to the significance of drought phenomenon, which may be cited as follows: Hughes and Saunders (2002). Using signs standardized precipitation index (SPI), they tested the prevalence and patience of drought for the duration of the twentieth century in Europe and confirmed that the maximum drought on a time scale of 12 months happened with a continuity of 2–6 months. Ntale and gan (2003) performed the usage of 3 SPI signs Bhalme–Mooley index (BMI) and Palmer drought severity index (PDSI) in East Africa; Soto et al. (2005) used the Standard Normal Index in Mexico; Tsakiris et al. (2007) used Reconnaissance Drought Index (RDI) and SPI in the regions of the rivers Morenos and Nestos in Greece; Balling Jr. Robert C, Gregory Balling et al. (2007) used indicators such as PDSI and evaluation of main additives with inside the Colorado River Basin; Vasiliades and Tzabiras (2008) used SPI in the Thessaly place, Greece, and tested the phenomenon of drought. Santos et al (2011) used the SPI frequency of droughts through the years 1910–2004 in Portugal; Choi et al. (2011), with inside the study, done the connection among droughts of East Asian summer time season and calm northern swings. In the latest decades, the growing significance of drought phenomenon has attracted the eye of government and scientists in Iran, which has additionally centered on offering several studies and forming seminars and conferences; for example, Razi et al. (2007) in Sistan and Baluchestan used well-known precipitation index and Markov chain and SPI .٩ Moradi et al. (2007) in Fars province used SPI signs; Yousefi et al. (2007) in Qazvin used Markov chain; Khosravi and Akbari (2009) in South Khorasan used SPI; Raziei et al. (2009) used spatial patterns and temporal variability of drought in western Iran; Modarres (2016) used extreme drought and flood events in Iran; Zarei (2019) done trend in spatial and temporal patterns of drought over south of Iran; Karimi et al (2019) used the prediction of meteorological drought using SPI and ARIMA model in the Karkheh River Basin, Iran; the phenomenon of drought has been investigated. Also, Moradi et al. (2007) analyzed meteorological drought features in Fars province. Droughts and wets are the inherent traits of weather and cannot save you then from occurring; however, the study expected and used the proper mesh traces and packages to decrease the feasible damages. Because of the significance of this issue, on this study, it turned into attempt to assess the drought and moist with inside the northwestern

place of Iran for the duration of 1966–2005 and the usage of the SPI and calculation of spatial distribution and imperative indices.

Materials and methods

In this study, fifty-five synoptic, climatology and rain gauge stations in 4 northwestern provinces of Iran (such as East Azerbaijan, West Azerbaijan, Ardebil and Zanjan provinces) and adjoining provinces with a minimal statistical historical past of two decades have been used; thus, the length of the statistical duration from 1966 to 2005 changed into consideration as the subsequent geographical coordinates: spatial distribution and elevation spectrum of the stations are utilized in Fig. 1. Most of the stations are placed with inside the peak variety of 1000–1500 m; the prevailing station facts cannot acquire correct data approximately and the climatic situations of the improved areas, due to the fact that the better stage of this station (Zinjnab) is placed at an altitude of 2100 m above sea stage.

$$N : 35°\quad 32'\quad 54'' \quad - \quad 39°\quad 46'\quad 18''$$

$$E : 44°\quad 02'\quad 19'' \quad - \quad 49°\quad 26'\quad 27''$$

However, the elevation variety of the vicinity reaches to 4877 m. Due to the dearth of factor facts at better altitudes, the use of legitimate geo-statistical strategies, the use of kriging interpolation approach because of the gold standard approach of interpolation, the present facts had been used and factor statistics transformed into zoning statistics. Kriging approach is one of the techniques of fact interpolation primarily based totally on their spatial versions and is one of the maximum appropriate techniques for estimating observations in regions without facts as a zone; this approach is an expressive, inert, linear estimator with minimal variance. In this approach, the estimation of passive values is performed primarily based totally on spatial modifications of sure values and their distances to the passive factor. In fact, a correct estimate is made with the minimal variance of the sure factors as compared to the passive factor (Asakereh, 2008, 27; Nafchi et al. 2021; Ostad-Ali-Askari et al. 2017a; Javadinejad, et al. 2019a; Ostad-Ali-Askari 2022a; Shayannejad et al. 2022; Ostad-Ali-Askari, 2022b;). The goal of this was to examine the opportunity of droughts and wetlands in northwestern Iran. For this purpose, a standardized precipitation index (SPI) was used. The standardized rainfall index is a way at the beginning utilized by climatologists to decide droughts. This index is primarily based totally most effective on precipitation and is a dimensionless quantity. The SPI is primarily based totally at the cumulative opportunity
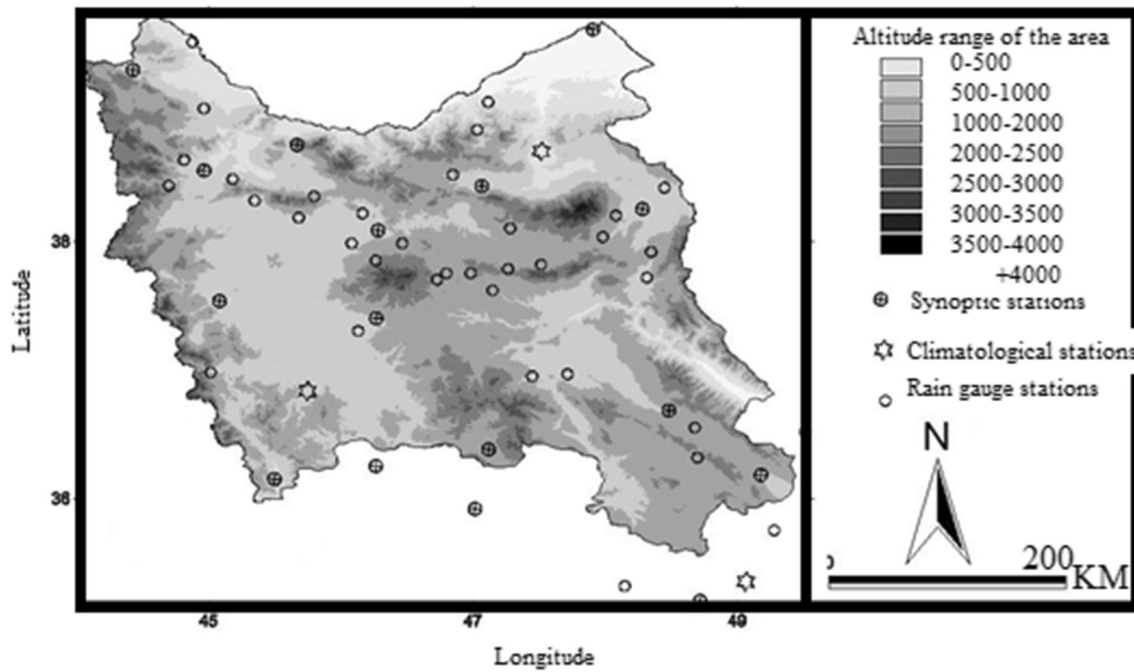
Fig. 1 Spatial distribution of stations with elevation distribution of northwestern region of Iran

Table 1 Classification of drought by SPI quantity and the probability of that happening (Edward and Mckee, 1997)

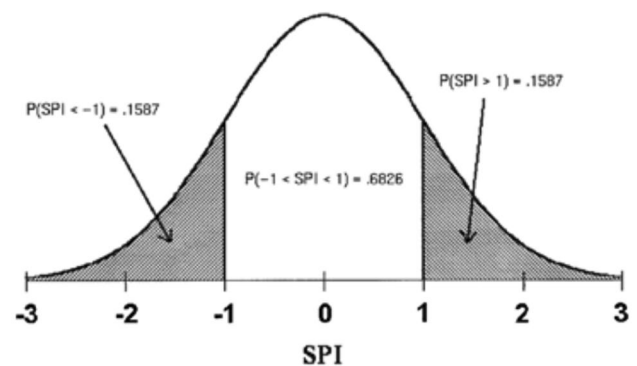| Probability%	Stage	SPI
2/3	Very intense wet	2 <
4/4	Intense wetness	(1/5)- (1/99)
9/2	Medium wetting	(1)- (1/49)
34/1	Poor wetness	(0)- (0/99)
34/1	Poor drought	(0)- (-0/99)
9/2	Moderate drought	(-1)- (-1/49)
4/4	Severe drought	(-1/5)- (-0/99)
2/3	Very severe drought	2->

Fig. 2 Probability of occurrence of standard normal distribution of SPI values (Edward and McKee, 1997)

of precipitation. Thus, first the facts are geared up with an opportunity distribution of gamma parameters after which transformed to a regular distribution. Gamma distribution is the nice distribution for becoming facts on this approach. It is a dimensionless quantitative index; this is calculated primarily based totally on the cumulative opportunity of precipitation. During steps, the facts are geared up with the parameter gamma opportunity distribution (the nice distribution for becoming the facts on this approach) and come to be a regular distribution. The category of drought uses the index with the aid of using (Edward and McKee in 1997) provided with inside the shape of Table 1 at the side of the opportunity of incidence of every of the drought intensities. Figure 2 indicates that after SPI values are geared up with a gamma distribution and the values SPI are transformed

to a regular distribution with a median of 0 and a variance of one.

In 1993, McKay et al. presented a classification of drought by SPI along with the probability of occurrence of each severity, as presented in Table 1. This table was the basis for determining drought periods with different severities.

Thus, the SPI values between (−0.99) and (0) as negative drought, the values between (−1.49) and (−1) as mild drought, etc. It changed into consideration. Then, the common month-to-month intensities of the calculated SPI values had been supplied as maps in Figs. 4 and 5. After calculating the common month-to-month values SPI and the corresponding

chance of incidence of every scenario, finally, to be able to offer an in-depth description in their area with inside the zone, descriptive information of every scenario, consisting of dispersion and tendency to middle indices, had been supplied via way of means of fashionable circle, fashionable ellipse and imply middle. By mapping the maps of the middle of gravity, the common month-to-month values SPI and chance factors of incidence of moist and drought phenomena may be identified by the spatial distinction in rainfall consumption and the chance of incidence of the preferred phenomena. In different words, it could be stated which a part of the location is much more likely to arise or excessive depth and which component is much less possibly to arise or severity. The middle of gravity may be completed via the following (Jay Lee, 2002, 55) as Eq. 1:

$$\overline{x}_{mc} = \frac{\Sigma_{i=1}^{n} xi}{n}, \overline{y}_{mc} = \frac{\Sigma_{i=1}^{n} yi}{n} \tag{1}$$

$\overline{x}_{mc}$ and $\overline{y}_{mc}$ are the coordinates that are center of the average, x_i and y_i are the coordinates of the point, n is the number of points. In calculating the average center, if the spatial average is weighed by a variable and presented with the values of a variable, better results can be obtained. Therefore, in this study, spatial values were used by weighted values and weighted mean center. The average is calculated through Eq. 2:

$$\overline{x}_{wmc} = \frac{\Sigma_{i=1}^{n} wixi}{n\Sigma_{i=1}^{n} wi}, \overline{y}_{wmc} = \frac{\Sigma_{i=1}^{n} wiyi}{n \Sigma_{i=1}^{n} wi} \tag{2}$$

The standard circle, like the standard deviation in classical statistics, indicates the dispersion (deviation) of the points around that are center of the average (J. Lee, 2002, 66; Eslamian et al. 2018a; Eslamian et al. 2018b; Nafchi et al. 2022; Javadinejad et al. 2018; Ostad-Ali-As 2022), the greater the dispersion of the set of points around the center of the average, the larger the standard distance. This standard distance is presented by considering the latitude and longitude X_i, Y_i of each cell in the zone for monthly values SPI and the probability of their occurrence calculated as the standard circle in the maps. Here, because monthly SPI values are considered for calculations, therefore, for each pixel, a weight of the area with the geographic coordinates of that pixel (longitude and latitude) is considered. In this study, since monthly values have been used to calculate the average center, therefore, weight for each pixel of the zone with a specific latitude and longitude is considered; if the values are in a region more than other regions, the average center is closer to that area as Eq. 3:

$$SD = \sqrt{\frac{\sum_{i=1}^{n} fi(xi - \overline{x}mc)^2 + \sum_{i=1}^{n} fi(yi - \overline{y}mc)^2}{\sum_{i=1}^{n} fi}} \tag{3}$$

Here $\overline{x}_{mc}$, $\overline{y}_{mc}$ are the center of the average distribution of points and the weight of points x_i, y_i. However, the set of positions of the points may have a directional deviation in terms of the occurring phenomena, in which the standard ellipse can show the directional deviation of the distribution of probability points. Any event in nature may have a certain orientation in terms of its occurrence location, and the standard ellipse can clearly reveal the directional deviation, or in other words, the orientation of that event by distributing probability points. In other words, the standard ellipse shows the extent of an event, where the major axis of the ellipse shows the maximum extent and distribution and the small axis shows the minimum distribution of the event in a region (J. Lee, 2002, 71; Ostad-Ali-Askari 2022d; Rabiei et al. 2022; Talebmorad et al. 2022; Vanani et al. 2022; Ghashghaie et al. 2022) in other words to divert the scattering points using the standard ellipse. In the ellipse, the extension of the main axis indicates the maximum scattering of the center of gravity (the maximum displacement of the center of gravity) and the sub-axis shows the path of minimum displacement. The major and minor axes of the ellipse in the Cartesian coordinate system are the same as the y, x axes, and the rotation angle of the ellipse is determined depending on the orientation of the event in the area. The two axes in the Cartesian coordinates are x and y axes, and the rotation angle has a certain value according to the geographical orientation of the distribution of points, the rotation angle, the angle between the north and the rotational axis y in the direction of the clockwise rotation. The steps to determine the standard deviation ellipse are as follows (J. Lee, 2002, 72; Fattahi Nafchi et al. 2022; Ostad-Ali-Askari 2022c; Abedi-Koupai et al. 2022; Kruse et al. 2018) as Eq. 4:

1- Calculate the coordinates of the average center $\overline{x}_{mc}$, $\overline{y}_{mc}$
2- Calculate coordinate transfer for each part of the distribution, P_i

$$x_i = x_i - x_{mc} \; y_i = y_i - y_{mc} \tag{4}$$

3- Calculate the rotation angle Θ according to the following relationship as Eqs. 5 and 6:

$$\tan\theta = \frac{\left(\Sigma_{i=1}^{n} x_i^2 - \Sigma_{i=1}^{n'} y_1^{2'}\right) + \sqrt{\left(\Sigma_{i=1}^{n} x_i^{n'} - \Sigma_{i=1}^{n'} y_1^{2'}\right) + 4\left(\Sigma_{i=1}^{n} x' - \Sigma_{i=1}^{n'} y'\right)^2}}{2\Sigma_{i=1}^{n} x_i' - \Sigma_{i=1}^{n'} y'} \tag{5}$$

$$x_i = x_i - x_{\mathrm{mc}} \ y_i = y_i - y_{\mathrm{mc}} \tag{6}$$

According to the angle Θ in the third step, it is possible to calculate the deviation along the axes x_i and y_i using the following formulas as Eqs. 7, 8:

$$\delta_x = \frac{\sqrt{\Sigma_{i=1}^{n}\left(x_i \cos\theta - y_i \sin\theta\right)^2}}{n} \tag{7}$$

$$\delta_y = \frac{\sqrt{\Sigma_{i=1}^{n}\left(x_i \sin\theta - y_i \cos\theta\right)^2}}{n} \tag{8}$$

Results and discussion

Study of the average drought situation in northwest of Iran

Because of the significance of drought incidence in the northwest of Iran, to research the common severity of its incidence with inside the quarter, the severity of drought (−2 to 0) with inside the quarter changed and calculated the usage of kriging interpolation approach calculated as a map in Fig. 3. Examining this map indicates that during an extensive region of northwest Iran, the incidence of droughts is of excessive depth, in order that with inside the south-relevant and particularly in Zanjan province, the incidence of mild-to-extreme droughts is of excessive depth. The northern has skilled much less depth than the southern. However, on this phase, there are separate regions with
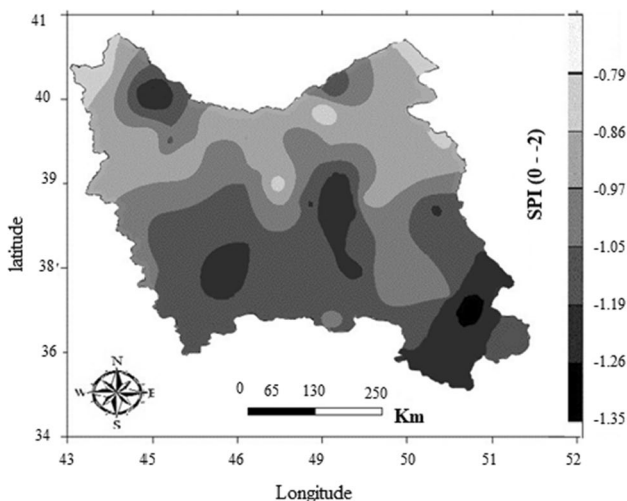

Fig. 3 Average severity of droughts in northwest of Iran

inside the northwestern a part of the studied region which are going through drought. Due to the truth that the cited phase is placed with inside the route of the western winds, because of the topography of the region, droughts are much more likely to arise in it.

Spatial analysis of average monthly values SPI

In order to research the severity of droughts with inside the northwestern vicinity of Iran, the common month-to-month values calculated with inside the shape of colored backgrounds are shown in Figs. 5 and 4. The consequences of the maps display that with inside the winter, the northern elements of the northwestern vicinity of Iran are extra tormented by drought, particularly with susceptible intensities. The southern elements of the northwestern vicinity of Iran have skilled moist situations because of receiving extra appropriate rainfall. In the spring, the western winds have now no longer left this vicinity but are energetic in it, so the moisture enters the northwest of Iran via the western winds. Also, because of the specific topographical situations of this vicinity, the sunny slopes are heated and the situations for slope convection are supplied within side the vicinity, and the range of wet and wet days with inside the vicinity increases. Therefore, within side of the spring, the depth of droughts with inside the northern elements of the vicinity decreases. The height prevalence of droughts with inside the vicinity is in April, and most effective Mughan plain, positioned with inside the northeast of the studied area, is an exception to this and reviews fewer wet days than the relaxation of the vicinity. In the ultimate month of spring, whilst the western winds are leaving the vicinity, the situations have changed, the range of wet days with inside the vicinity has decreased, and the southern elements of northwestern Iran are tormented by a susceptible drought. Figure 5 suggests that with the advent of the summer time season, the amount of rains and the range of wet days are much less than normal, and from the south to the north of the studied area, the drought turns into extra widespread, in order that inside months on the cease of summer time season and the primary month of autumn, a huge a part of the vicinity faces mild-to-extreme drought. A unique state of affairs is investigated with inside the vicinity of Meghan Plain positioned with inside the northeast of the vicinity, wherein the severity of drought is weaker on this season in contrast to different elements of the vicinity in overdue summer time season and early autumn. This may be because of the proximity to the northern nation-state of Iran and profiting from the humidity and excessive strain of Siberia, that is energetic with inside the north of Iran for the reason that cease of summer time season.

According to Fig. 5, through passing into summer time season from the southern a part of the location to the north, the volume of the regions tormented by drought and much less
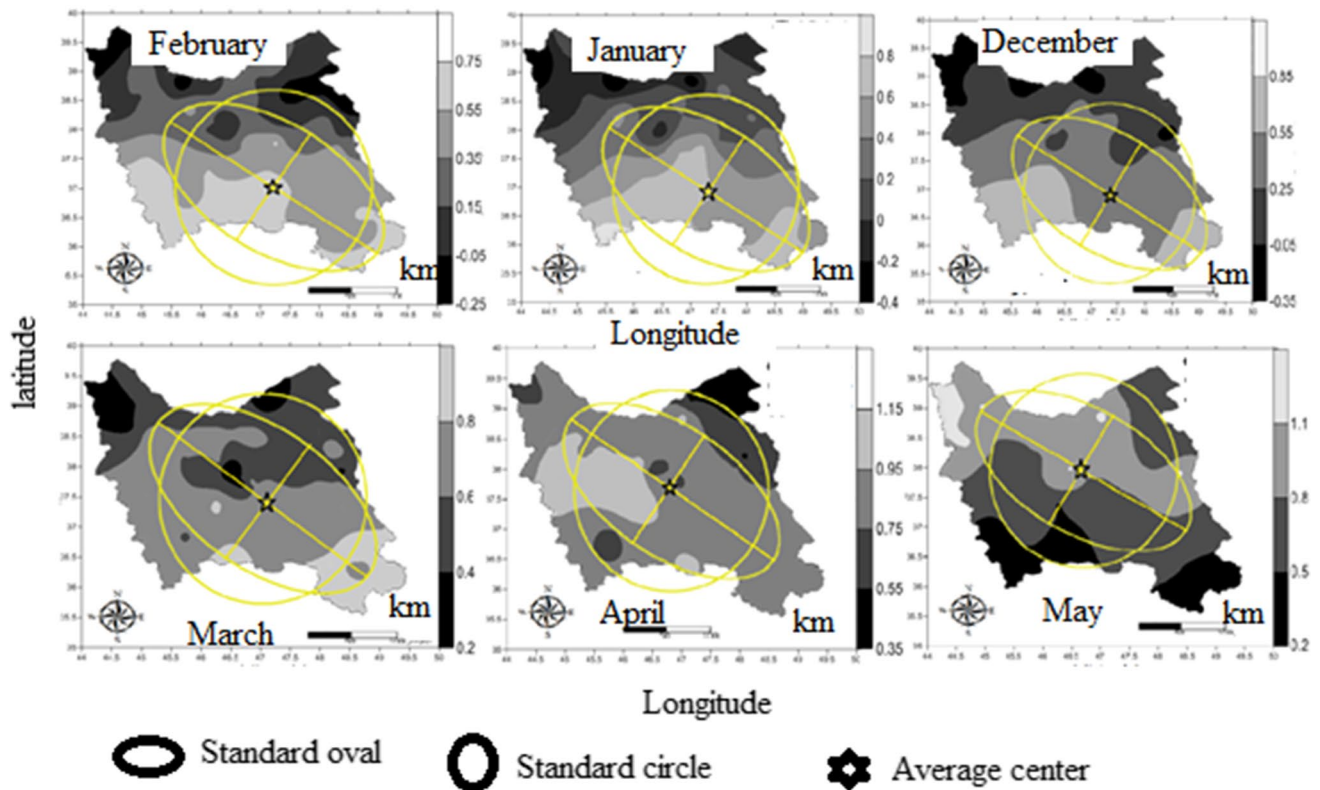
Fig. 4 Spatial distribution of monthly values SPI of winter and spring seasons and their distribution and central indices in northwest of Iran SPI. *Source*: Negarandegan

than everyday precipitation is added, in order that over the last months of summer time season and the primary month of autumn, a massive a part of the region is confronted with mild-to-excessive drought. In the meantime, the northeastern location (Mughan plain) has a unique state of affairs and indicates an image mode with a region. The incidence of droughts in the course of overdue summer time season and early autumn on this region is much less excessive than different components. However, in the course of the fall months, with the start of the appearance of western winds with inside the location and receiving suitable rainfall with inside the region, the incidence of moist regions has extended and the severity of droughts is regressive. They turned into no signal of rainfall and drought with inside the remaining month besides with inside the northwest corner. The common middle calculated for the region indicates that in the wintry weather months, the common values SPI are placed with inside the southern half, indicating the tendency of the common middle to the southern components to recognition greater at the severities of the incidence of wetness and negative droughts on this section. It may be visible that the usual circle and ellipse are maximum-tailored to every different in the course of the primary months of wintry weather; this variation shows greater consistency with inside the incidence of moist summers and vulnerable droughts with inside

the area, mainly with inside the southern half; however toward spring, the common middle of the southern half of movements toward the relevant northern components, this displacement with inside the middle indicates that because of the receiving of suitable and immoderate rainfall with inside the wide area, the depth of this displacement with inside the middle indicates that because of the proper and immoderate rainfall with inside the wide area, the depth of this displacement is observed. The incidence of droughts is likewise adjusted and in step with the amounts (Fig. 4) in the course of the spring months, vulnerable to mild fears are ruled with inside the region. However, with the addition of the usual ellipse, the spatial version of the relevant common increases. During the months of each wintry weather and spring, the most spatial displacement is the common middle with inside the northwest–southeast direction.

The small values of SPI and the immoderate proximity of the values of every cell from quarter to 0 in the course of the 3 months of July, August and September triggered the deviation of the statistics from the common middle to be very small values and the statistics to be focused across the common (attention round 0), so it changed into now no longer viable to calculate the usual circle and ellipse for the 3 months cited (Fig. 5). However, over the last months of autumn, the common middle regarded once more with inside the quarter and
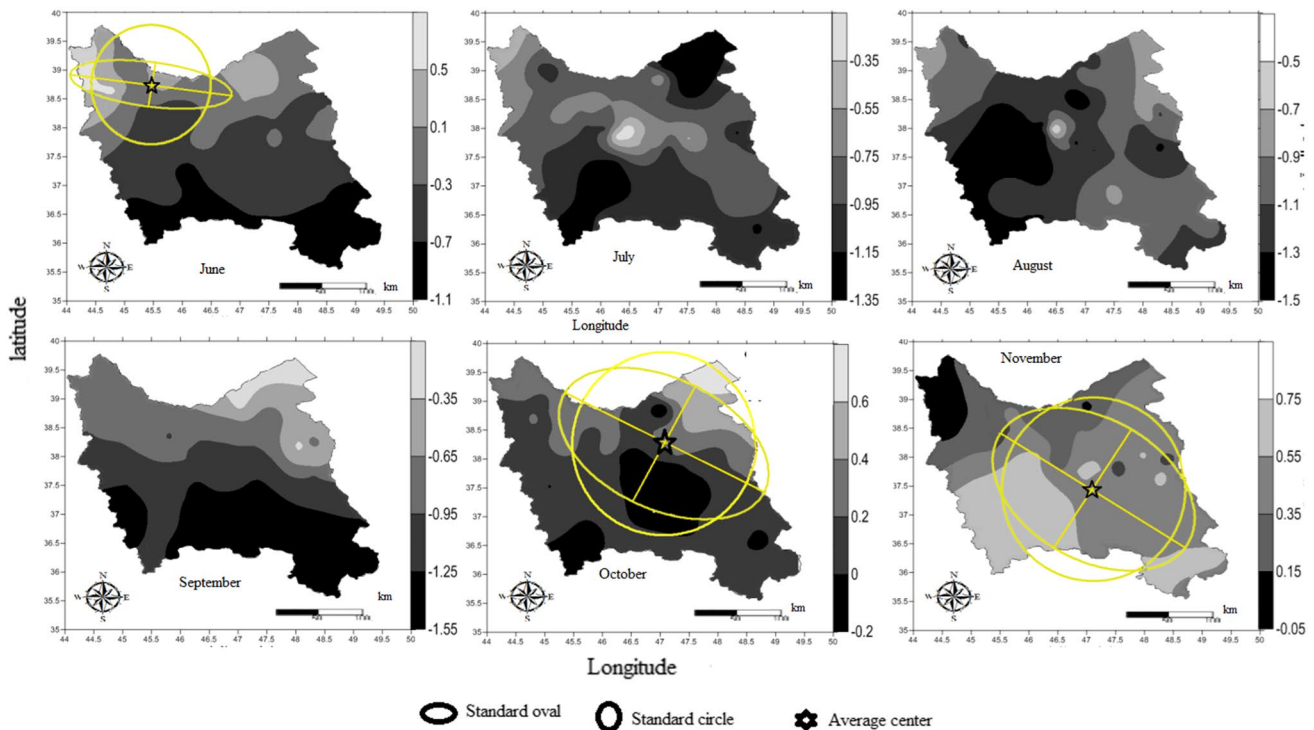
Fig. 5 Spatial distribution of monthly values SPI of summer and autumn and their distribution and central indices in northwest of Iran. *Source*: Negarandegan

the middle of gravity of drought-vulnerable wetness changed into positioned with inside the north of the location, in addition to enlargement of the distribution of statistics across the common, circle and widespread ellipse with inside the cited months confirmed extra reliability of the values with inside the regions beneath their control. During November, the middle of gravity has shifted to low latitudes, on the opposite hand, with growing rainfall in the course of this season with inside the location, the opportunity of vulnerable wetness occurring. There has additionally been extra. This is much more likely to arise with inside the Northwest location of Iran.

The possibility of severe drought and poor scarcity

As mentioned earlier, wet years and droughts with different intensities in the northwest of the country were investigated using standardized precipitation index (SPI). Since the studies showed the superiority of the probability of occurrence of weak wetness and severe drought in the zone, among the corresponding probabilities, descriptive statistics were presented only to express the characteristics of the probability of occurrence of these phenomena. In Fig. 6, the probability of occurrence, the mean center, circle and ellipse are depicted as the standard probability of poor wetness occurrence in northwestern Iran. Based on this form, the highest

probability of poor wetness occurs in the eastern-central and low-area parts of the northwestern part of the region. Matching the probability map of the occurrence of weak wetness with the elevation distribution map of the region indicates the probability of occurrence of this type of wetness from the eastern roughness orientation of the region. The probability of poor occurrence in the mentioned areas is between 47 and 51%. However, in the eastern and southern half with a skewed direction, the probability of occurrence is low compared to the eastern half and is about 34–47%, which is reduced to the northeast, northwest and southwest corners of the region and reaches to the minimum possible level.

The average center shows that on average, the highest probability of occurrence of weak wetness and its center of gravity are located in the eastern part of Mount Sahand. The standard circle shows the highest distribution of the probability of occurrence of this phenomenon in the central regions. In other words, in its scope, distribution is more likely to occur as a weak wetness. The main axis of the standard ellipse also indicates the maximum spatial displacement of the center of gravity in a particular metadata. According to Fig. 6, the maximum spatial displacement of the center of gravity is likely to occur in the northwest and southeast. This means that the average center is moved more in the mentioned direction. Further elongation of this ellipse indicates greater deviation and instability of the average

Fig. 6 Probability of weak wetness occurrence and the range of its central and dispersion indices in northwest of Iran
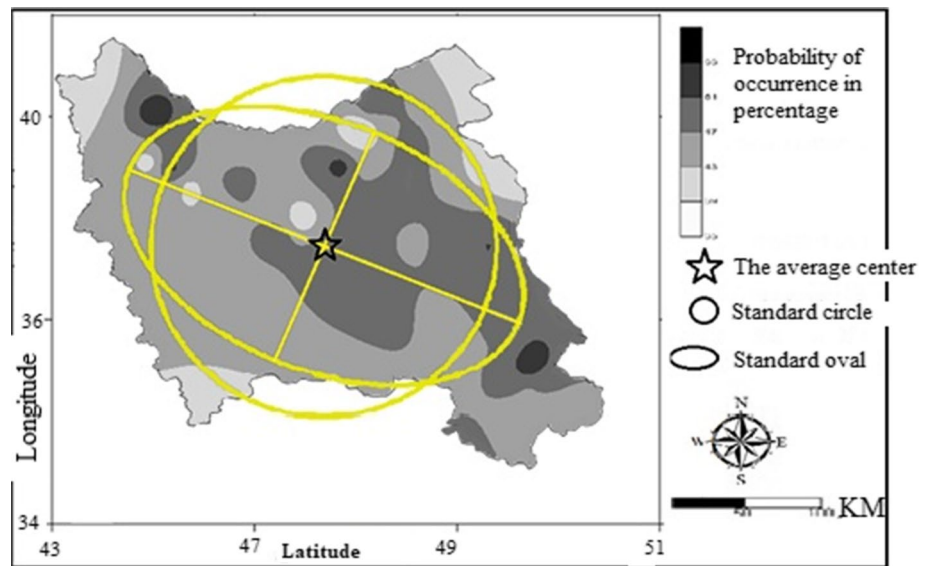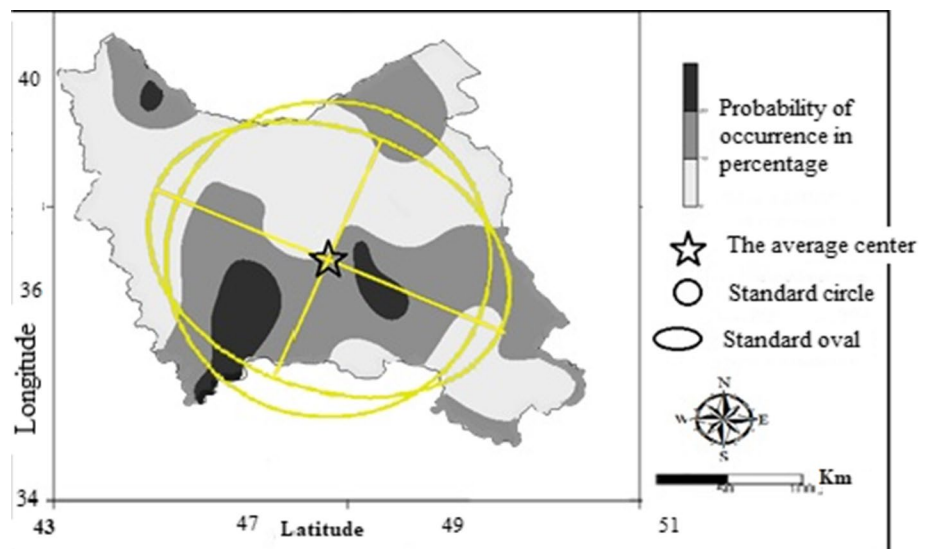

Fig. 7 Probability of severe drought and its distribution and central indices in northwest of Iran

center of probability of poor wetness. Figure 7 shows the spatial distribution of the probability of severe droughts. It can be seen that in a wide range of regions, especially in the southern half of the region, severe droughts are more likely (with the probability of occurrence of 20–30%), among which the most likely occurrence of these droughts is seen in the southwestern part.

However, the drawing of the average center and the standard circle shows that the highest probability of severe drought is located in the southeastern part of the Sahand Mountain. The center of the average and the standard circle

have shifted to lower latitudes relative to the weak wetness. In other words, the highest distribution is the probability of severe drought at lower latitudes. It should be noted that the standard circle and ellipse have a higher spatial serenity in severe drought than the probability of poor wetness because they are more adaptive to each other. On the other hand, the standard ellipse has less strain because the probability values are less deviant than the average. However, as with the probability of weak wet occurrence, the direction of the average center deviation has a direction northwest,

southeast. This indicates the maximum displacement of the center of gravity along the mentioned way.

Conclusions

In this study, we tried to investigate the situation of drought and wetness in the northwestern region of Iran using the index SPI. Monthly study of droughts and wetness with different intensities during 240 months shows inconsistencies and compliance with the probability of occurrence of severe droughts and wetness weaker years from normal probability distribution, and the percentage of probability of occurrence of weak wetness in eastern and central parts of the region and droughts in the southern half of the region is higher than other conditions. On the other hand, calculation of central indices and spatial distribution of each of the mentioned states also showed that spatial distribution of weak wetness in northern latitudes is more likely and the probability of severe droughts at lower latitudes is more evident; however, the probability of occurrence of severe droughts is more stable. Northwestern Iran is no exception and severe droughts in this part of Iran have a high probability of occurrence that the recurrence of this phenomenon can intensify the drought in the region over time and numerous negative effects on various sectors of the economy and agriculture and have an area environment; therefore, in this study, it is suggested that these phenomena be addressed from a synoptic perspective, because the occurrence of these phenomena is rooted in large-scale factors. It is also suggested to conduct more studies using advanced statistical techniques such as time series, spectral analysis and principal component analysis in the field of predicting the occurrence of droughts and wetlands in the region to do more accurate studies because it is the prediction of these phenomena that can. As a key to the esteemed officials in order to manage the crisis and deal with the side problems caused by the occurrence of these phenomena and master the critical situation, with proper and long-term planning and optimal use of water resources in the region and the use of new technologies and technologies for the use of runoff and water resources in the region, the harmful effects of drought in the region can be greatly reduced. In the meantime, the probability of severe drought occurrence is more stable in terms of the location. For doing so, we used standardized precipitation index in 12-month duration.

Declarations

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