Journal of Scientific Research and Development 2 (6): 306-315, 2015
Available online at www.jsrad.org
ISSN 1115-7569

Analysis of relation between Lake Urmia's area with meteorological and hydrological droughts using Landsat satellite images

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Abstract: Urmia Lake is one of the biggest super saturation of salt Lake of world which its sea level has severely dropped in recent years and its area has decreased, especially in south and south East regions. Many factors effect on these changing in long-term which included rainfall, temperature, the drought, human factors and sunspots. The purpose of present study was to investigate the effect of drought on reduction of Urmia Lake area in recent 45 years. In this study, standard precipitation index of SPI in 3, 6, 12, 24 and 48 scales was used to investigate the drought procedure. The satellite images of Urmia Lake from 1984 to 2012 were processed by remote sensory tests and required calculations were performed to obtain Lakes are. In addition, the lake changing procedures and the drought effects were investigated. The performed studies showed that Urmia lake area has reduced equal to %56 compared with its maximum area during statistical period of 1984 to 2012. Moreover, the relationships between drought procedure changing, level changes and annual volume of inflow to the lake with lake area changing were identified in present study.

Key words: Urmia Lake; Standardized index of SPI; Remote sensing; Runoff; Area

1. Introduction

Urmia Lake is the biggest and saltiest lake of Iran and is one of the biggest super saturation of salt lake of world, which is comparable with Great Salt Lake of America. Many researches have been performed on Urmia Lake in order to determine Lake Area reduction, climate changing, supplying resources of lake, the drought periods and lake level reduction. For example, Rahimi et al. (2005) have comprised a number of approaches about ground surface temperature estimation around drainage basin of Urmia Lake by utilizing from NOAA satellite images.

Dahesh et al. (2010) have investigated the effect of physical-chemistry factors on this lake with focusing on this point that this lake is in flowed by various resources. Since the area of this lake is decreasing, they have investigated lake procedure changing and its affecting by the drought. Rahimi Golenji et al. (2007) have analysed drought by Markova chain (Golenji et al., 2007).

In this study, the statistical period of 1977 to 2007 was used to drought analysing. Bahooshi et al. (2009) have investigated the effect of drought and its factors on Lake. In this study Standard precipitation index was used to calculate intensity, frequency, duration and the drought extent of Urmia lake basin (Siavash, 2009).

Plank et al (2009) have investigated 620 lakes of Minnesota region in their study. The have found a relationship between lake level changing and the drought in 1930 decade by utilizing from aerial photographs. They results showed that lake level changing procedure of this region follow from spatial distribution of water (Hassanzadeh et al., 2012). Hassanzadeh et al. (2012) have investigated the cause of Urmia lake reduction by dynamic methods and investigated the effects of climate changing, doms of region and precipitation reduction. Delju et al. (2013) have studied the climate changing in Urmia Lake basin and used static methods. The used data included minimum and maximum rate of warmth, precipitation and the number of rainy and snowy days. Fathian et al. (2014) have investigated the reasons of lake level reducing and hydrology and climate variables. According to mentioned studies about Urmia Lake and the problem of server reduction of lake level, especially in southern parts of lake, the study of the lake basin drought has been limited to investigating and analysing the drought or wet of condition of region. In addition the researches have emphasized on lake level changing procedure and the effect of drought and total inflows to lake. One of the matters in this regards which has been focused is the analysis of whole basin of Urmia lake and considering the SPI indexes of all stations existed in region in simultaneously form.

3. Methods and materials

In this section the research steps are provided:

3.1. Geographical location

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Urmia Lake is located in North West of Iran and Azerbaijan region. According to the last administrative divisions, it is the biggest water level in inside of country which is located between Eastern Azerbaijan and western Azerbaijan provinces. Urmia Lake is one of the six main basins of Iran with 32 billion cubic meters volume which is surrounded from North to Basin of Aras River, from East to Sephidrood river basin, from south to basins of Ghezel Ozen and Sirvan and from west to basin of water and some parts of Iran boundaries with Iraq and Turkey.

3.2. Finding the area of basin

It was needed to process the lake images, before performing any action on images. Since the complete image of lake existed in three parts and sometimes in four parts, the images were put together by ENVI software in order to complete the lake image. In this step, the lake boundary was extracted in highest from for all images by utilizing from a Shape file which was related to lake in a form that had the highest level of area in statistical period. The images obtained from Landsat satellite and Satellite site of NASA were processed by ENVI software. The following stages were done to find area:

- Downloading satellite images from NASA website related to Landsat satellite (include ETMT, MSS and TM) which the warmest month of water year (August) was selected due to the great volume of images for mentioned period (Yekom, 2004).
- Images correction
- Mosaicking images in each year (since the complete image of lack existed in 3 or 4 parts, the images were mosaics before doing any action).
- Creating ROI file in order to separate Lake Boundary (introducing ROI layer which software capture on main image and extract main image with the shape of new layer).
- Utilizing from K-Means classification method in order to identifying Lake Boundary which is shown in Fig. 1.

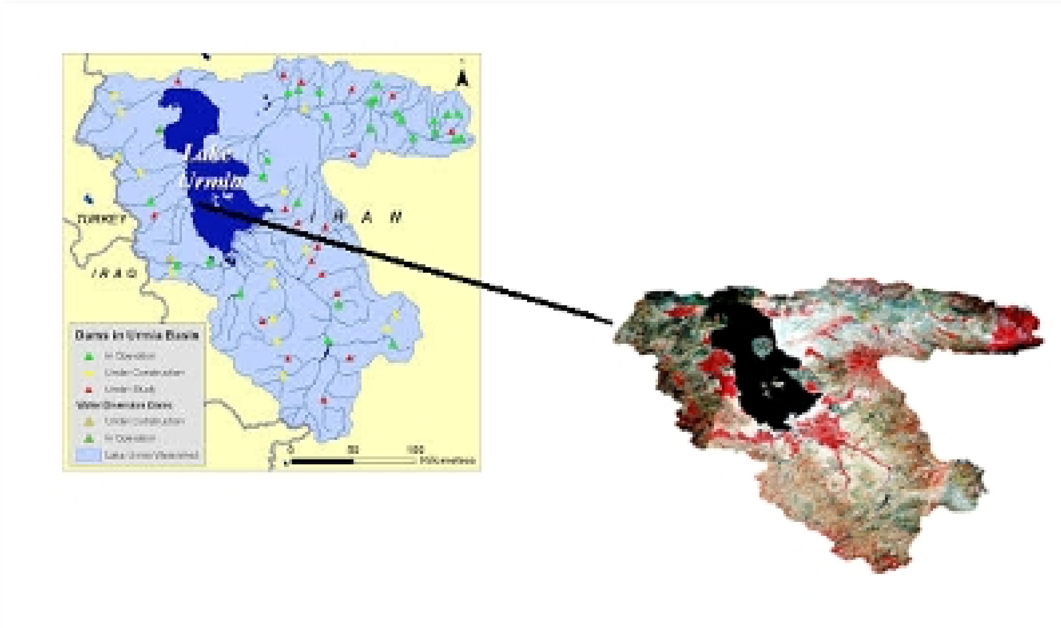

Fig. 1: Satellite images of Urmia Lake Basin created by combining the colors 4.3.2 (First Consulting Engineers, 1383) (Mckee et al., 1993)

3.3. Precipitation data

The precipitation data related to 33 synoptic and weather stations located in Urmia Lake basin during statistical periods of 1965-2008 were used in this study (Energy Ministry) (Mckee et al., 1993). In order to investigate the effect on main parameters of region climate, the stations were selected in a way that covered all area of basin. These stations are located in North, South, West and East of basin in distribution point of view and located in different distance from lake in distance point of view.

3.4. Calculating SPI

Mckee et al. have recommended Standard precipitation index (SPI) in order to short-term time scale of drought survey in 3 and 6 months scales to agriculture objects and long-term time scales of 12 , 24 and 48 months to hydrology objects (Hayes et al., 1999). Haze et al in the investigation of drought of 1996 showed that SPI index provides accepTable results, when the drought is developing (WRMC). Numerous indexes have provided for drought analysing which among them ISP is widely utilized. In SPI method , at first precipitation data which are recorded for a relative long period (usually 30 years) are fitted by Gama statistical distribution and then transferred to normalized distribution (with average equal to D and variance of 1). The read value of Z is the index value.

The data precipitation of 33 synoptic and weather stations located in Urmia lake basin in statistical period of 1965 to 2008 were used in present study (Energy Ministry) (Mckee et al., 1993). The SPI index was calculated by DIP software which is for calculating various types of drought. In this study, it is try to investigate SPI index in each of scale for three month of August, September and October in separate form, in addition to investigating the total SPI index of drought changing procedure of Urmia lake basin which is obtained by interpolation method. The reason of selecting these three desired month was the obtained images from satellite photographs which were related to August and also the unfavourable atmospheric condition such as the high level of cloudy condition. Therefore the SPI of all three month were investigated.

4. Presenting results

In this section, the SPI indexes of 333 under study stations are provided which calculated by interpolation method for whole of basin. The first part includes SPI results of whole of basin in under study statistical period (1965-2008) and in the scales of 3, 6, 12, 24 and 48 months. In second part, the important results of SPI for three under study month i.e. August, September and October are annually provided.

The calculated are of Urmia Lake from 1984 to 2012 is provided in third part and then the relationship between Urmia Lake area changing variables with total yearly inflow of Urmia Lake , level and annul precipitation were investigated.

4.1. General investigation of results

Urmia Lake basin was investigated for a 43 years period. It had normal condition in most months and had significant drought and wet condition is some years. The 48 month SPI in long-term showed the effect of drought on Lake and sea levels. Fig. 2 is the diagram of drought changing index (SPI) in 48 months scale.

As it can be seen, the number of month with normal condition was lower than other scales and the number of months with mean wet condition is higher. The number of months with server drought condition in higher than other scales. The longest drought period in 48 months scale had 47 month continuation which was started form June 1998 and continued to July 2002 and the basin had server drought during this dry period.

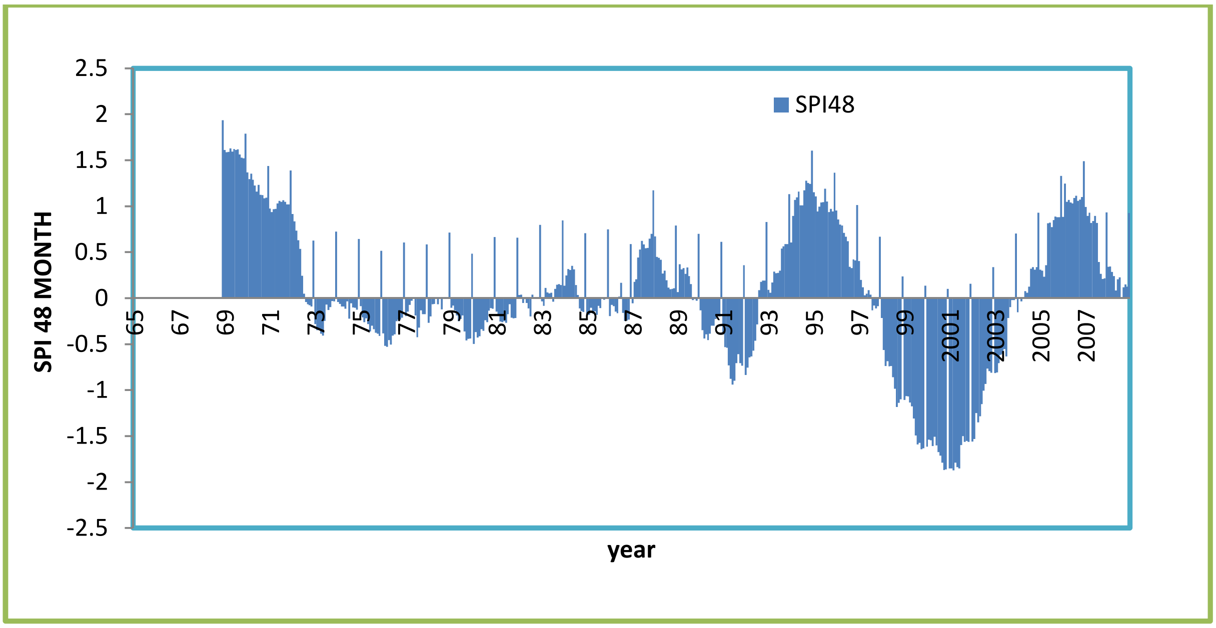

Fig. 2: The diagram of drought changing index SPI in scale 48-month

Table 1: Maximum and minimum values of SPI and the time of occurrence

Drought index SPI	Maximum value	Index type	year	month	Minimum value	Index type	year	month
SPI 3 Month	2.35	Highly severe wet year	2006	6	-3	Highly severe drought	2006	9
SPI 6 Month	2.27	Highly severe wet year	1967	7	-2.24	Highly severe drought	2006	11
SPI 12 Month	2.33	Highly severe wet year	1967	7	-1.95	severe drought	2006	11
SPI 24 Month	2.19	Highly severe wet year	1967	12	-1.9	severe drought	2007	11
SPI 48 Month	1.93	severe wet year	1967	12	-1.87	severe drought	2000	3

4.2. Investigating monthly results (August, September, October)

In this section , the SPI results in time scale of 48 months was yearly investigated for three months of August , September and October and their changing diagram was drawn and the basin condition was shortly investigated in a Table.

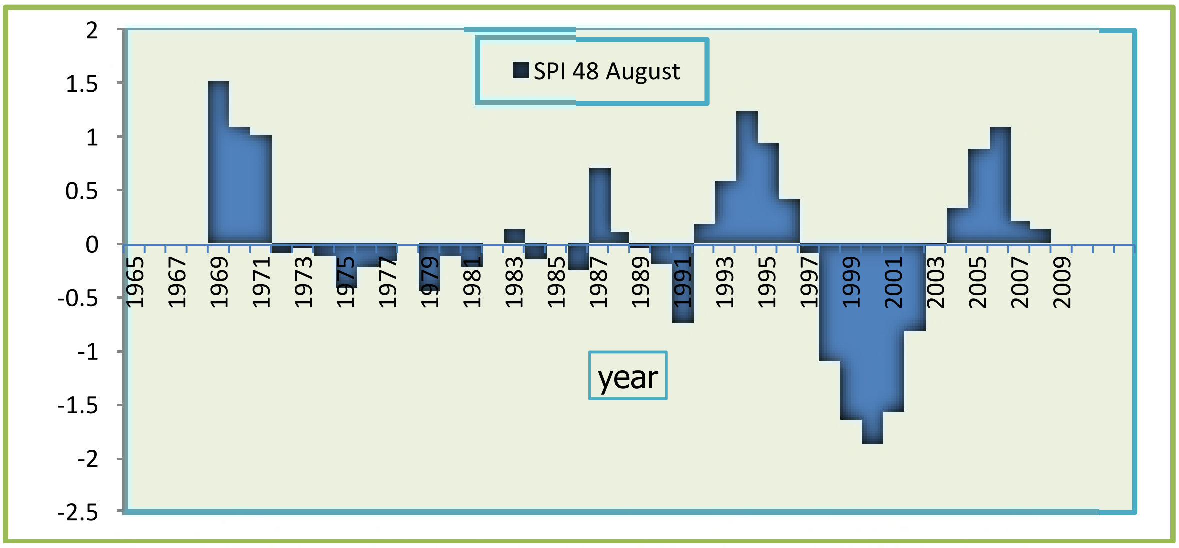

Fig. 3: The diagram of drought changing index SPI in scale 48 month related to August

Fig. 3 is the diagram of SPI changing for August in 8 month scale which showed that the basin was mostly normal in August similar to SPI of total mean of whole basin. The frequency of years in which had average drought and wet condition in August were higher than other, According to the long-term 48 months SPI.

The number of normal year in this scale were lower than other forms , the frequency of years with mean wet condition was higher than other forms and the number of years with mean drought condition was lower. In contrast, the number of years with server drought was higher than other under study scales in August. The longest drought period occurred in long-time 48 SPI scale started from 1998 to 2001 and the basin had severe drought in three years of this period. The most important changing of SPI in 48 months scale presented in Table 2.

Table 2: Maximum and minimum values of SPI and the time of occurrence

Drought index SPI	Maximum value	Index type	year	month	Minimum value	Index type	year	month
SPI 3 Month	1.23	Medium wet year	1977	11	-0.94	normal	2006	11
SPI 6 Month	1.66	Severe wet year	1967	11	-2.24	Highly severe drought	2006	11
SPI 12 Month	1.9	Severe wet year	1967	11	-1.95	severe drought	2006	11
SPI 24 Month	1.86	Severe wet year	1967	11	-1.9	severe drought	1994	11
SPI 48 Month	1.52	Severe wet year	1967	11	-1.86	severe drought	1999	11

As it was expected, the basin also had normal condition like SPI of total mean of basin. The frequency of years with mean wet and severe wet condition was higher in September. According to the long-term 48 months SPI scale, the number of years with normal condition was lower than others in this scale and in contrast, the number of years with server drought was higher in September. Generally, in long-term 48 months SPI scale, the values of basin indexes were higher than zero. Fig. (4) shows that the SPI index values of basin were higher than zero for all under study scales in September. The most important SPI changing in 3, 6, 12, 24 and 18 scales for September presented in Table (3).

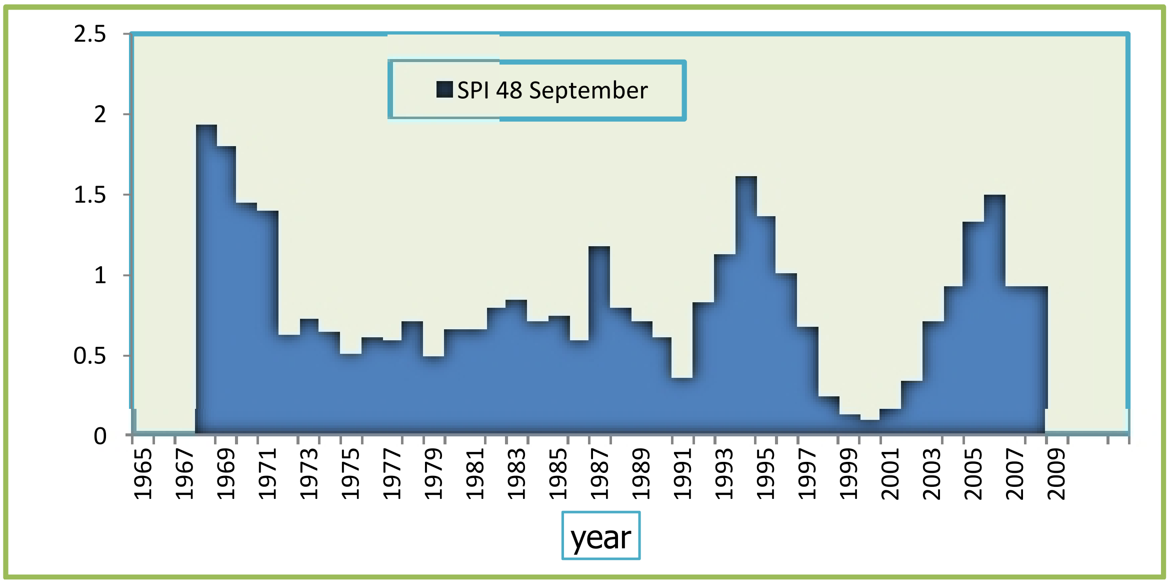

Fig. 4: The diagram of drought changing index SPI in scale 48-month related to September

Table 3: Maximum and minimum values of SPI and the time of occurrence

Drought index SPI	Maximum value	Index type	year	month	Minimum value	Index type	year	month
SPI 3 Month	1.49	Medium wet year	2007	12	-0.28	normal	1984	12
SPI 6 Month	1.2	Medium wet year	1967	12	-2.22	Highly severe drought	2006	12
SPI 12 Month	2.26	Highly Severe wet year	1967	12	0.07	normal	2006	11
SPI 24 Month	2.19	Highly Severe wet year	1967	12	0.07	normal	1998	12
SPI 48 Month	1.93	Severe wet year	1968	12	0.1	normal	2000	12

Fig. 5 shows the drought index (SPI) changing in 48 months scale for October which indicates that the SPI index values normal condition was lower others and the number of years with server drought was higher in October.

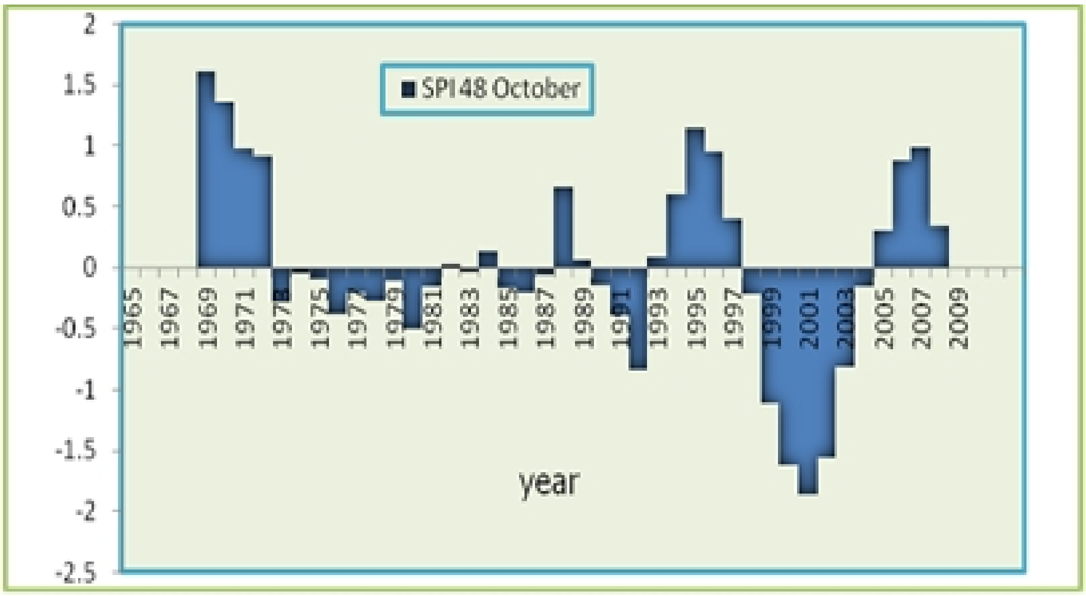

Fig. 5: The diagram of SPI drought index in 48 months scale related to October

The most important SPI changing related to drought in 3, 6, 12, 24 and 48 months scales for October presented in Table (4).

Table 4: Maximum and minimum values of SPI and the time of occurrence

Drought index SPI	Maximum value	Index type	year	month	Minimum value	Index type	year	month
SPI 3 Month	1.89	sever wet year	1982	1	-0.83	Normal	1978	1
SPI 6 Month	1.25	medium wet year	2004	12	-1.33	meduim drought	1368	12
SPI 12 Month	2.1	sever wet year	1969	1	-1.49	meduim drought	1998	1
SPI 24 Month	1.95	sever wet year	1969	1	-1.8	sever drought	1999	1
SPI 48 Month	1.61	sever wet year	1969	1	-1.85	severe drought	2000	1

According to Table 4, in the last of statistical period of October and the early of statistical period and in last years of period, the drought condition existed.

4.3. Urmia Lake area by Landsat Satellite photographs

In this section the area of Urmia basin was obtained by satellite photographs of TM, +ETM and MSS in statistical period of 1984-2012. According to the available images in NASA organization achieves, the images related to August were selected (the September and October months would have been selected, if there were not August images).

The diagram of Lake area changing was drawn which is presented in Fig. 6.

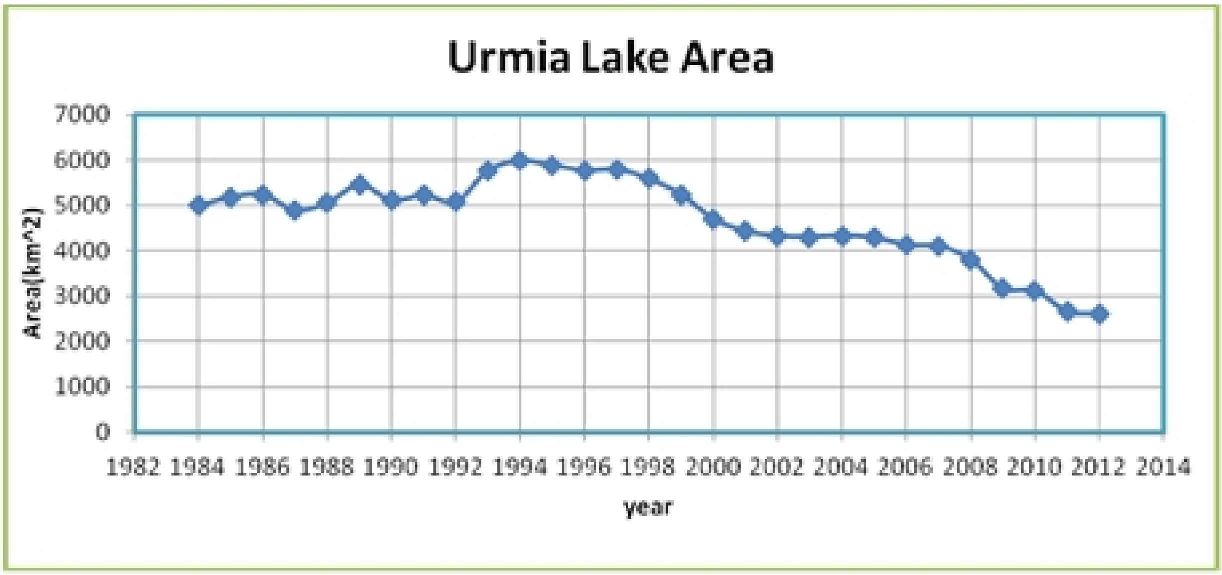

Fig. 6: The diagram of lake area changing during statistical period of 1986-2012

As it can be from Fig. 6, the procedure changing of lake was down procedure in these years, although the Lake area was significantly increased in middle of period. The greatest area was related to 1994-1995 with 5990 cubic kilometres and the lowest area was related to 2011-2012 with 2605 cubic kilometres. The reduction amount of area from highest to lowest was 56% which the highest level of area reduction occurred in South and East South parts. According to this Fig., the average of Urmia Lake area is 4694 cubic kilometres.

In this section , the relationship between Lake are changing for three months of August , September and October was investigated , relatively based on 48 months SPI changing. According to Fig. 7, the procedure changing of Urmia lake area and 48 months SPI in statistical period was in a way that Lake Area changing procedure was similar to 48 month SPI changing in 1992 to 1995 and generally it was not observed any other relationship between these two Procedures.

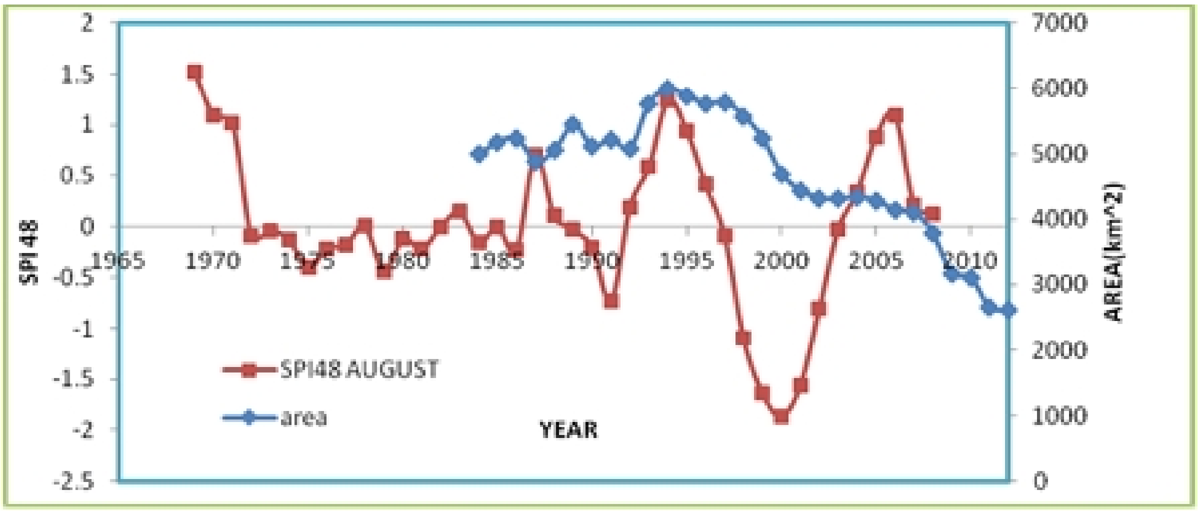

Fig. 7: The diagram of area changing compared with 48 months SPI related to August

According to Fig. 8 and Lake Area changing and 48 months SPI changing, there was not any relationship in this form and these two procedures were similar to each other only in 1992 to 1995 and the lake area has regularly decreased after 1995.

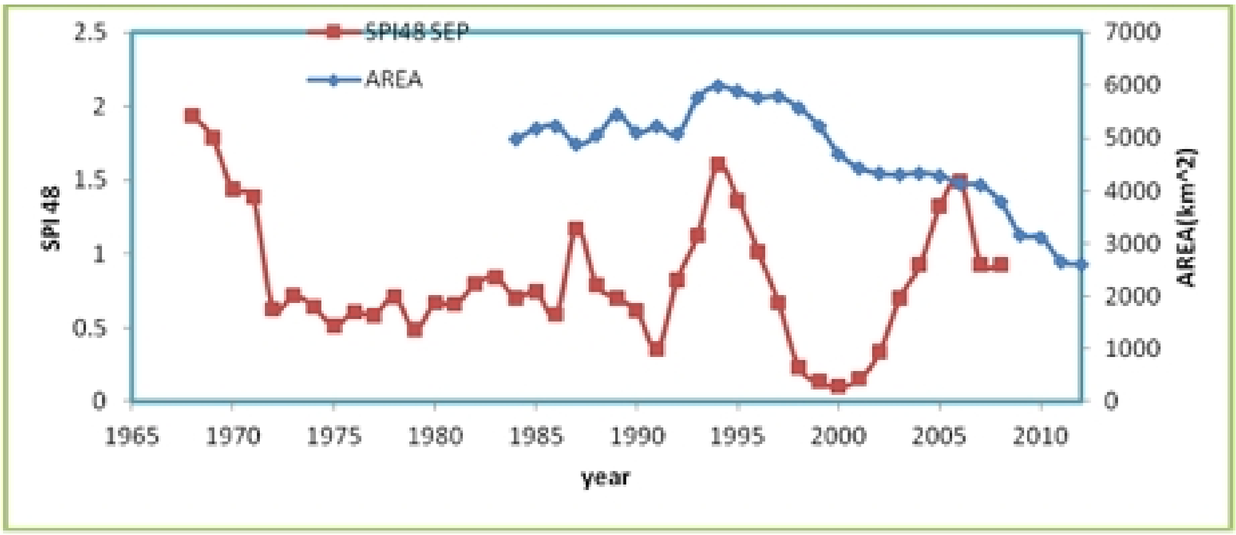

Fig. 8: The diagram of area changing compared with 48 months SPI related to September

According to Fig. 9 about Lake area procedure changing and 48 months SPI changing , it can be said that during statistical period of 1990-1992 the procedure changing of lack area and 48 months SPI were similar to each other October and No clear procedure occurred between area changing and 48 months SPI changing.

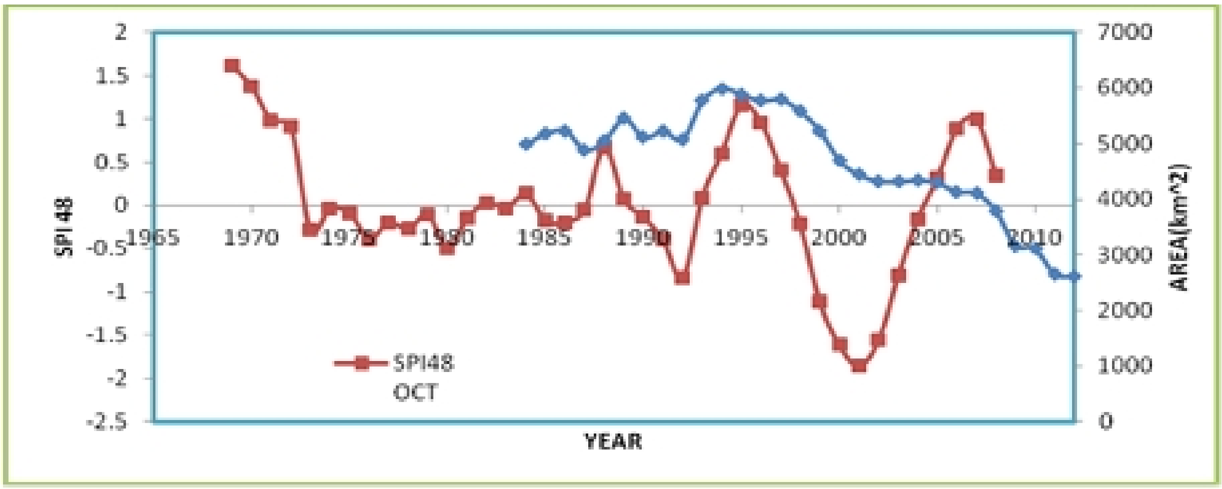

Fig. 9: the diagram of area changing compared with 48 months SPI related to October

4.4. The relationship between changing of total yearly inflows to Urmia Lake with 48 months SPI

The 48 months SPI is completely long-term and is used to investigate the effects of changing and swings of precipitation on large water storage and underground resources. As it can be seen from Fig. 10, the procedures of total yearly inflows to Urmia Lake and 48 months SPI is similar , but with difference that total inflows to Urmia Lake have occurred 4 years before 48 months SPI occurrence which is a normal matter , because 48 months SPI indicates hydrology condition of previous for years in same month. Fig. 10 is the diagram of total yearly inflows to Uriam Lake changing and 18 months SPI of August, September and October months.

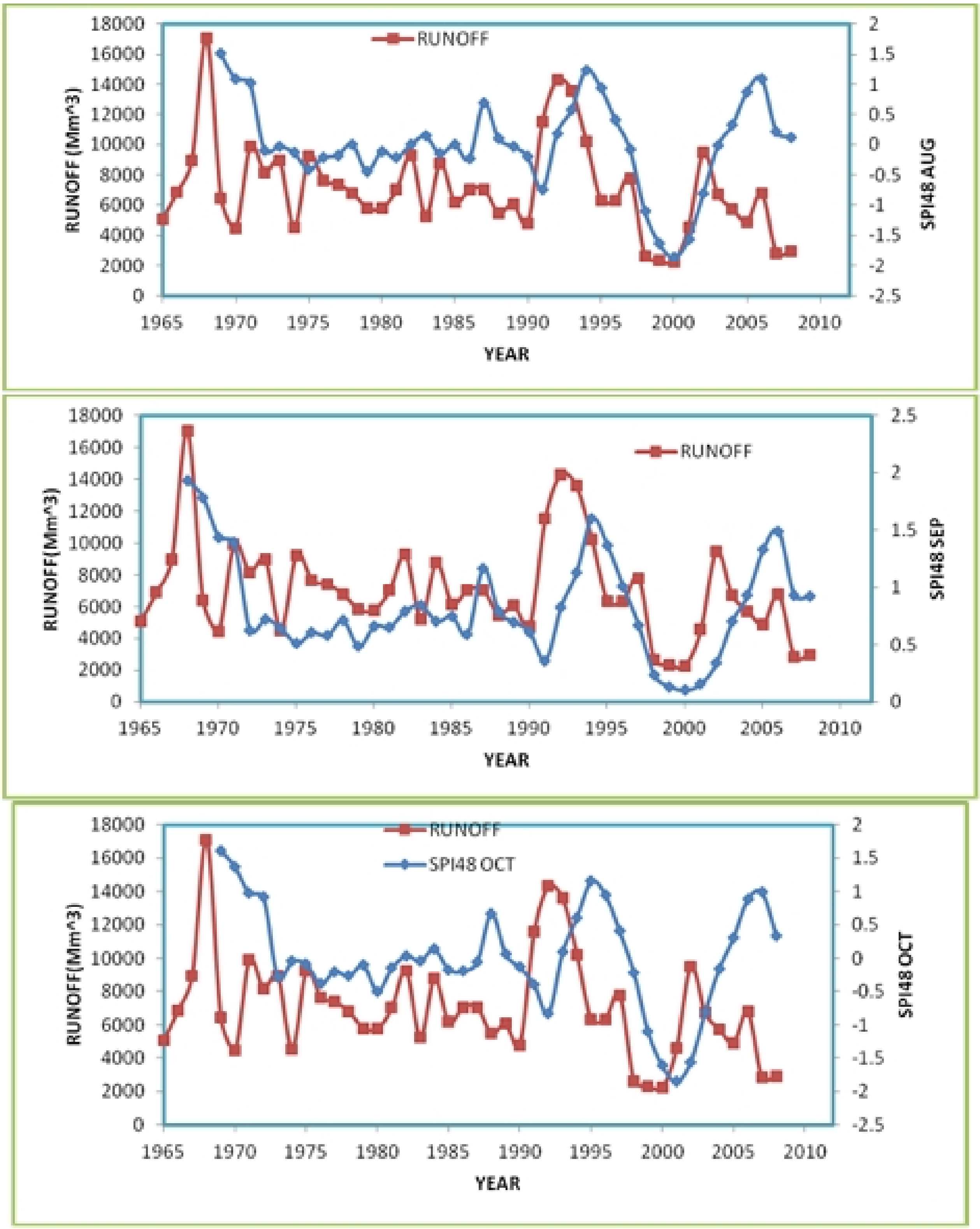

Fig. 10: The diagrams of changing of total inflow to Urmia Lake and 48 months SPI, 1) August, 2) September, 3)October

4.5. Investigating the procedure of total yearly inflows to Urmia Lake changing and Lake Area changing

Total yearly inflow to Urmia Lake is one of the Lake supplies resources, therefore its changing can be used to analysis Lake area.

Fig. 11 shows the changing of total yearly inflows to Urmia Lake procedure in under study statistical period and lake area during 1984 to 2012. It can be observed that from early of 1984 to 1994 affected by total yearly inflows and its area was decreased or increased by total yearly inflows increasing or reduction. It should be noted that the Lake area didn't change from 1986 to 1989 due to the fixed and no change procedure of total inflows procedure. In continue the area had decreasing procedure after 1995 and although the total inflows have increased in some years, but the area reduction likewise continued.

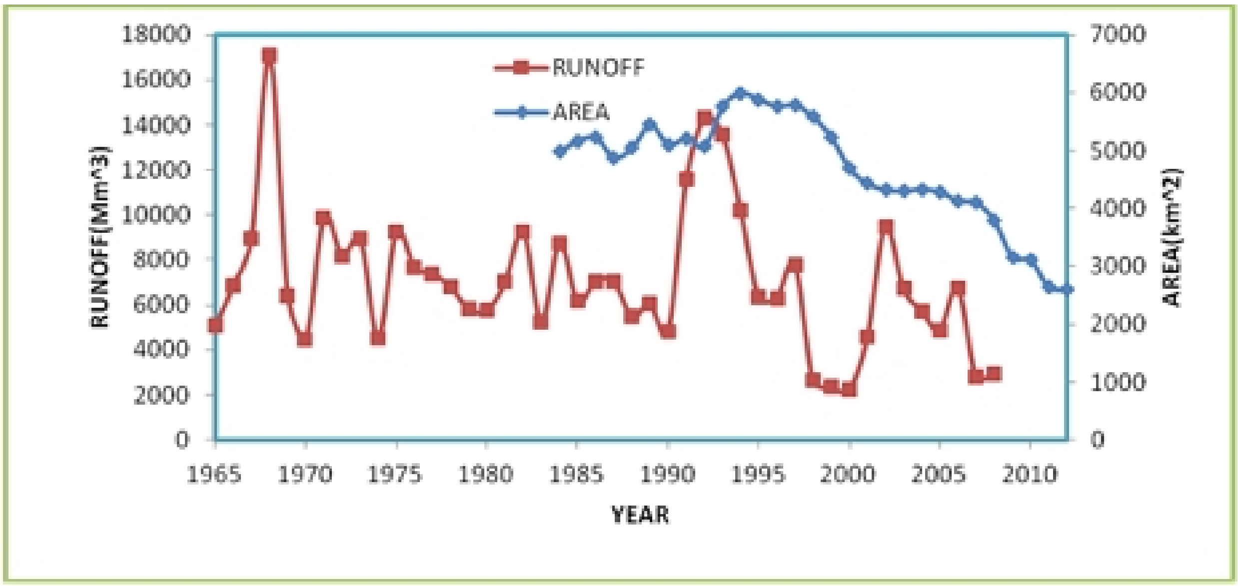

Fig. 11: The diagrams of changing of total inflow to Urmia Lake and Lake Area

4.5.1. Investigation of level changing and Lake Area

Fig. 12 shows the lake level changing procedure in statistical period of 1965-2012 and Lake Area in 1984-2012. According to Fig. 12, the changing procedure of area and level were similar and downing since 1995. They were relatively similar before 1995. In some years, the levels have affected area equal to 1 year. For example, the level had decreased in 1997 and the area decreased after a year.

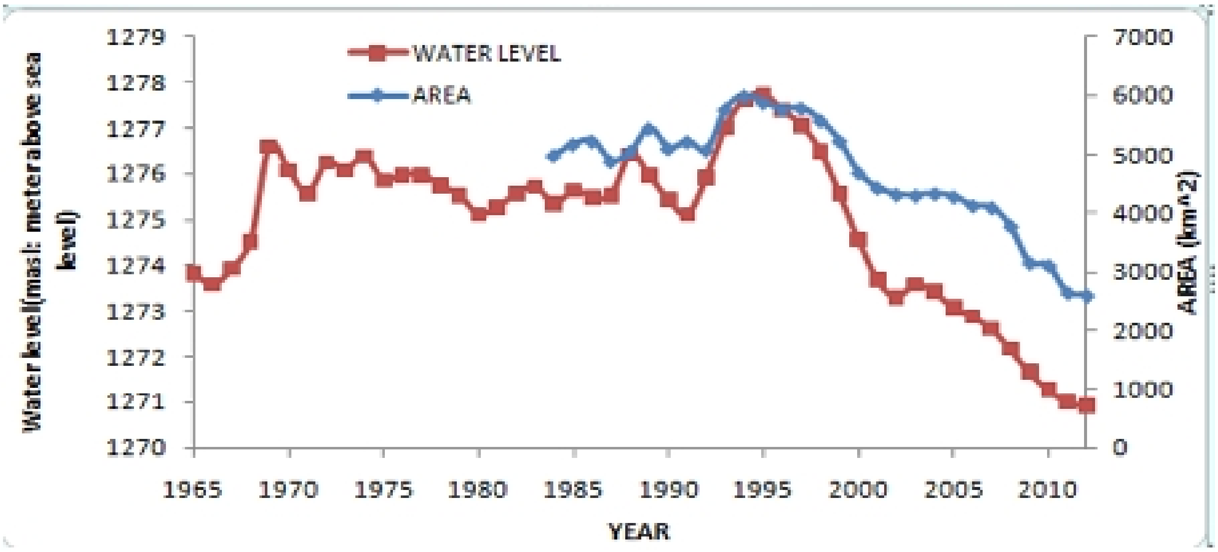

Fig. 12: The diagrams of level changing and Lake Area changing

5. Conclusion

Since Urmia lake has faced with severe reduction of level and area , especially in South and East South regions due to the different factors in recent years , therefore in this study the effect of drought procedure , level rate and runoff on the size of lake area were investigated and identified and presented on related diagrams and Tables. The following general results related to area changing, the volume rate of inflows, the volume rate of run off and their relationships with lake area have been provided:

- The results of studying SPI index in 3, 6, 12, 24 and 48 months scales and area procedure changing showed that drought don't have direct effect on lake area reduction and in fact, have indirect effect by the volume of inflows.
- About early of 1984 to 1994, the area was affected by total yearly inflows, in a way that the area has redacted or increased by total inflow increasing or reducing with 2 years delay. However, it should be noted that the area didn't change from 1986 to 1989 due to the fixed procedure of total inflow to lake. In continue, the lake area has reduced since 1995 and the total inflow changing didn't affect it. It means that the area has reduced even with the inflow increasing
- About the effect of lake level on area, it can be said that the area changing and level changing were similar to each other and downing since 1995, although these changing were not completely coincident before 1995.

6. Recommendations to future studies

In this section, the following recommendations provided to farther studies and developing results for different forms and proper predicting of Urmia lake condition based on performed investigations and obtained results:

- According to the performed investigations of this study, climate condition and drought don't have direct effect on lake area reduction and therefore other effective factors of Lake Urmia changing should be investigated and developed.
- Since the used photographs of this study belonged to 1984 until now, the older photographs should be investigated and processed in order to find proper way against Urmia Lake reduction.
- It is necessary to find proper relation to predict area based on effective parameters of is which are developable in long term statistical period.
- The drought condition and its effect on surface water resources in basins of Iran which are similar to Urmia Lake should be investigated in order to find similar procedure.

The water consuming in agricultural lands should be investigated based on production and provinces of basin separation and should be comprised with Lake Water shortage and its effect on area reduction should be investigated.

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