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Assessment of Climatic Drought and Its Economic Effects (Case Study: South Khorasan Province)

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Abstract. In this research Standardized Precipitation Index (SPI) in a period of 22 years (1990 to 2011) was used for zoning of climatic and agricultural drought in South Khorasan province, Iran. Rainfall data of six synoptic stations were collected and used for evaluation of meteorological drought. Also, reports of some local offices such as natural resources, agriculture, regional water and environment department were provided to study the effect of agricultural economic drought. At first, the elevation-precipitation regression of each period was obtained then this relationship was applied on Digital Evaluation Model (DEM) layer using ArcGIS 9.3 software. The result showed that the most severity droughts occurred in 2008, 2000, 2006 and 2011 respectively. In 2008 more than 66% of the study area were classified as extremely drought class. The result of agricultural drought showed that the total annual rangelands forage production of South Khorasan province that expected to be 625000 tons reduced to 250000 tons during period of 2007 to 2011. Also the agricultural production was faced with 45% reduction and caused rising poverty and unemployment, immigration from rural area to urban, in evacuated villages.

Key words: Zoning climate drought, Economical drought, SPI, ArcGIS 9.3, South Khorasan

Introduction

One of the natural aspects affected by climate is drought; such that decline or increase of climate influences causes this phenomenon appearance (Ershadi, 2007). Drought is one of natural hazards that have direct and indirect effects especially in semi arid and arid areas. This phenomenon occurring frequent is one of the most persistent and most natural disasters damaging from economical aspect (Jamali *et al*., 2002). The chief characteristic of a drought is a decrease of water availability in a particular period and over a particular area (Beran and Rodier, 1985). Wilhite and Glants (1985) classified drought into four categories including meteorological, hydrological, agricultural and economical drought. Drought events are usually explained by drought indicators, as variables that identify drought characteristics, i.e., the magnitude, duration, severity and spatial extent. In addition, over the years several indices have been proposed to detect and monitor droughts. As a common practice, drought indices are used to investigate occurrence and extent of drought events (Khalili *et al.,* 2011). One of the well known meteorological drought indices is the Standardized Precipitation Index (SPI), originally suggested by McKee *et al.* (1993). Some of the recent researches on drought evaluation include Edossa *et al.* (2010), Pandey *et al.* (2010), Vasiliades *et al.* (2010). In Iran, Barouti *et al.* (2009) used SPI index as one of the most common meteorological indices that is used for drought studies and drought analyze based on temporal scales of 6, 12 and 24 months and showed that SPI with timescales of higher than 12 months is most appropriate to study wet and dry periods but this index must be used cautiously in timescales 6 months and lower. Banivaheb and Alijani (2005) studied periods of drought and wet in Birjand area (case study in this article) from 1995 to 2000, using multivariate statistical methods predicted climate change. During the last decade the SPI has become very popular due to its low data requirements, (Tsakiris *et al.,* 2006).

Economic drought occurs, if water demand for production of economic goods be more than water supply, drought damages appear mainly as decrease of grassland yield, crop production especially dry land farming, agriculture water resources, ground water, surface water, increase of plant and animal pests, migration and etc., (Negaresh and Khosravi, 2000). Unfortunately most existing systems in Iran focus on drought damage after treatment, while in many other countries drought management strategies are based on damage prevention programs. Thus, rural producers will be able to manage drought with minimal loss using data system. Jahanbakhsh and Hooshyari (2007) stated that the influence of agricultural products and their sensitivity depends on the lack of rainfall, soil moisture and temperature. So that, some years agricultural products will be faced irreparable damage because of drought.

Droughts are the world's costliest natural disasters, causing an average $6–$8 billion in global damages annually and collectively affecting more people than any other form of natural disaster (Vasiliades and Athanasios, 2007). The economic consequences of water shortages are especially dire in countries and regions subject to irregular rainfall patterns. The occurrence of drought has been reported as the most important source of uncertainty in Australian agriculture. Despite the existence of vast inter year storage capacity; irrigators still face uncertain water supplies (Quiggin and Chambers, 2004). Unfortunately most existing systems in Iran focus on drought damage after treatment, while in many other countries drought management strategies are based on damage prevention programs. Thus, rural producers will be able to manage drought with minimal loss using data system.

Khalaji and Shaian Nejad (2002) used drought severity and duration and numerical analysis of rainfall to against water crisis in Shahrekord, Zabol and Zahedan regions, Iran. Their results showed that despite of two different climates there was a drought problem in both cases and people faced very losses in these areas. In order to determine the drought severity this phenomenon should be quantitative instead of qualitative and some indices must be introduced. McKee *et al.* (1993) developed SPI to determine and monitor drought and also to determine lack of rainfall for temporal scales of 3, 6, 12, 24 and 48 months. Barouti *et al.* (2009) used SPI as one of the most common meteorological indices that is used for drought studies and drought analyze based on temporal scales of 6, 12 and 24 months and showed that SPI with time scales of higher than 12 months is most appropriate to study wet and dry periods but this index must be used cautiously in timescales 6 months and lower.

Numerous and frequent droughts in South Khorasan have caused damage to sensitive and fragile ecosystem and finally immigration. So, in this investigation, it is assumed that SPI is one of the most appropriate indices in analyzing past drought. The main purpose of this study is to evaluate the climatic drought pattern in South Khorasan from 1990 to 2011 using SPI.

Materials and Methods

Study area

South Khorasan province, the Easternmost province of Iran, with 82864 km^2 located in 57° 46' to 60° 57' eastern longitudes and 30° 35' to 34° 14' northern latitudes. The province is border with Afghanistan at the east, from the north with Razavi Khorasan province, at the west to Yazd and Kerman provinces and from the south is neighbor with Sistan and Baluchistan province. According to the latest divisions, South Khorasan has 8 cities including Birjand, Qaen, Ferdows, Darmiyan, Sarayan, Sarbisheh and Nehbandan. The climate is dry and desert type and the average annual rainfall of the province is 150 mm. The maximum temperature of 44°C (Boshrooyeh) and the lowest recorded temperature of -21.5°C have been reported. It has a dry and arid climate but according to topography divided in 2 classes:

A: Dry and warm climate including plains, flat areas in center, west and south.

B: Dry and mild climate including highlands in north, north west and around Birjand. In this study the data of six stations: Birjand Khoor, Qaen, Nehbandan, Boshrooyeh, and Ferdos have been used (Fig. 1).

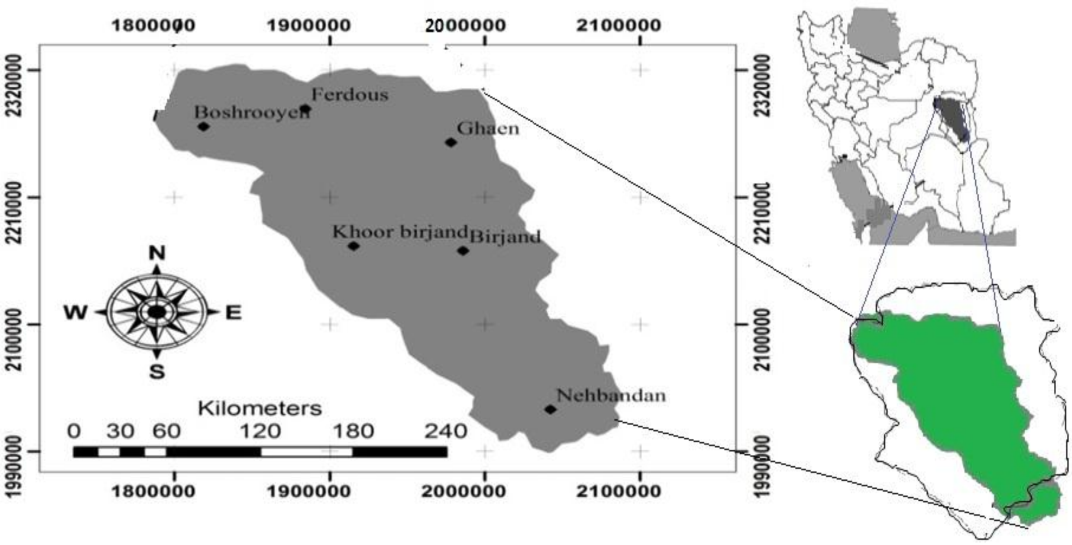

Fig. 1. Location of the studied stations

Meteorological drought

To calculate the SPI, a long-term precipitation record at the desired station was at first fitted to a probability distribution (e.g. gamma distribution), which is then transformed into a normal distribution so that the mean SPI is zero (McKee *et al.*, 1993, 1995; Edwards and McKee, 1997). The SPI may be computed with different time steps (e.g. 1, 3 and 24 months). Guttman (1998) showed that the use of SPI at longer time steps was not advisable as the sample size reduces even with originally long-term data sets. The use of different timescales allows the effects of a precipitation deficit on different water resource components (groundwater, reservoir storage, soil moisture, stream flow to be assessed. Positive SPI values indicate greater than mean precipitation and negative values indicate less than mean precipitation. The SPI may be used for monitoring both dry and wet conditions. The numeric interval of various classes of this index is shown in Table 1, that in order to droughts being more visible, number of classes has increased.

Table 1. Drought categorization values (Mckee *et al.*, 1993)

Class	SPI Values
Exceptionally wet	>2
Extremely wet	1.6 – 2
Severely wet	1.3 – 1.6
Moderately wet	0.8 – 1.3
Near normal	0.5 – 0.8
Normal	-0.5 – 0.5
Near normal	-0.8 – -0.5
Moderately dry	-1.3 – -0.8
Severely dry	-1.6 – -1.3
Extremely dry	-2 – -1.6
Exceptionally dry	<-2

Six stations located in the study area were selected in period of 1990 to 2011 (Table 2). Homogeneity test data (Ran Test method) was done to ensure the data quality and homogeneity of data sets; in required case, the data were corrected. Correlation method among stations was used to reconstruct the incomplete stations data. On the other hand, the data of stations with high correlation were used to reconstruct monthly data of incomplete stations.

Table 2. Latitude, longitude, elevation and average rainfall of meteorological stations

Station	Latitude	Longitude	Elevation (m)	Average Rainfall (mm)
Birjand	32° 52′ E	59° 12′ N	1491	155.65
Boshrooyeh	33° 54′ E	57° 27′ N	885	88.59
Ferdous	34° 1′ E	58° 10′ N	1293	135.05
Ghaen	33° 43′ E	59° 10′ N	1432	167.78
Nehbandan	31° 32′ E	60° 02′ N	1211	129.51
Khoor	32° 56′ E	58° 26′ N	1117	91.77

In order to obtain SPI, first precipitation map of each year was prepared by ArcGIS 9.3 software (Fig. 2). To do this, elevation-precipitation regression of each period was obtained using elevation and precipitation of meteorological stations, and then relationship between elevation and precipitation for each period was obtained in Excel software.

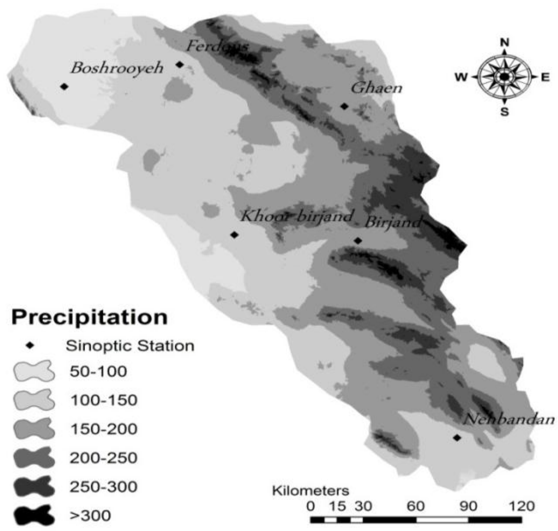

Fig. 2. Average precipitation of the study area (1990-2011)

Then in ArcGIS 9.3, DEM[2] map with precision of 30 m was inserted in this relation instead of elevation number 1 and precipitation map of each period was obtained. After obtaining precipitation map using ArcGIS 9.3, precipitation maps of each year was inserted in SPI equation instead of precipitation data. Finally, SPI map of each year was obtained by the map obtained from precipitation map of each year minus map of average precipitation of total period divided with map of standard deviation.

Economical drought

Reports of some organizations such as Natural Resources, Jihad- Keshavarzi (2012), the data of regional water (2012) and department of environment organization (2012) in South Khorasan were used to study of effect of agricultural (economical) drought.

Results

Meteorological drought

The SPI Averages in 6 study stations during 22 years has been shown in (Table 3). (Figs 3-6), show drought maps of the study area in 2000, 2006, 2008 and 2011 as example. The result showed that the most drought severity occurred in 2008 (Fig. 5), so that around 67% of study area included all station classified in extremely drought class; whereas 53.43% of area including just Birjand and Ghaen stations were classified in this class in 2000 (Fig. 3). (Fig. 5), shows that the study area just classified in extremely and severely classes and there was no medium and small class in 2008, while around 14% of the study area were classified in small and medium class in 2000.

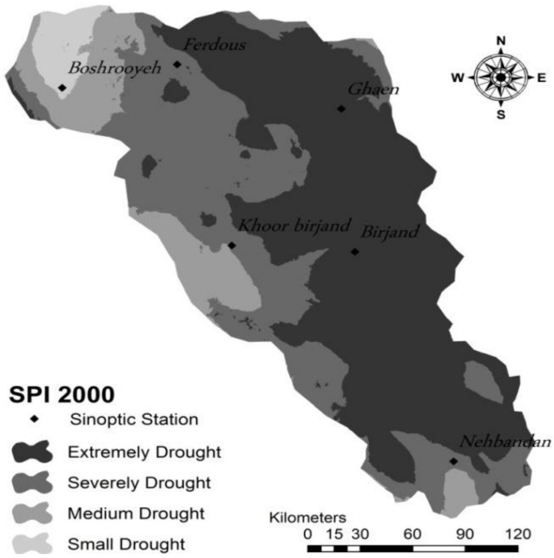

Fig. 3. Zoning map of annual drought in 2000

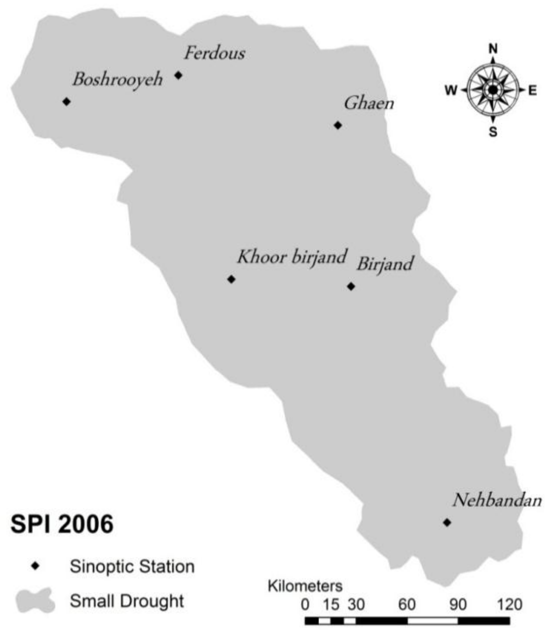

Fig. 4. Zoning map of annual drought in 2006

[2] . Digital Evaluation Model

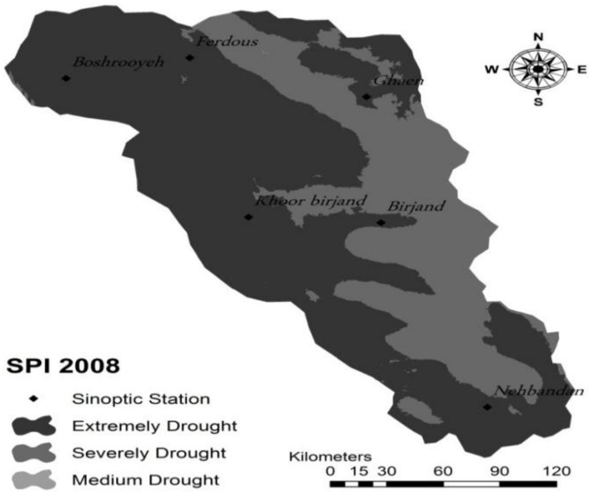

Fig. 5. Zoning map of annual drought in 2008

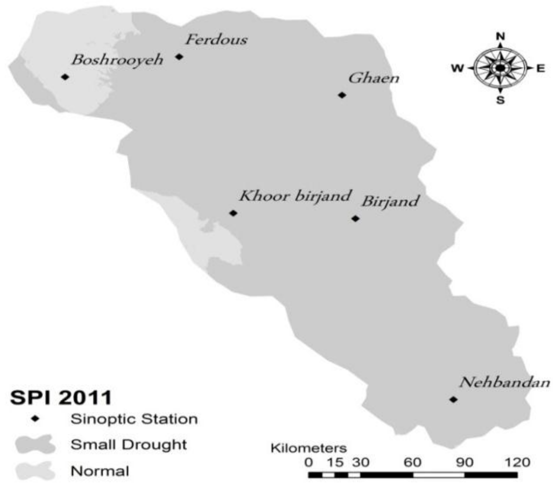

Fig. 6. Zoning map of annual drought in 2011

Table 3. Average of SPI in 6 stations during 22 years

Year	Ghaen	Birjand	Boshrooye	Ferdows	Khoor	Nehbandan
1990	0.38	0.57	0.55	0.37	0.19	-0.04
1991	1.30	0.51	3.02	1.07	1.21	2.42
1992	1.33	0.67	1.09	0.60	-0.61	0.03
1993	0.95	1.00	1.03	0.25	0.88	1.62
1994	-0.84	-0.68	-0.41	-0.41	-0.99	-0.75
1995	0.09	0.93	0.01	1.72	1.83	-0.28
1996	1.56	1.33	0.18	0.17	1.41	2.02
1997	-0.54	-0.40	-0.61	-0.95	-0.47	0.37
1998	1.85	1.15	0.21	2.88	1.48	-0.35
1999	0.89	-0.19	-0.09	0.76	-0.08	0.70
2000	-1.33	-1.38	-1.54	-1.44	-1.48	-0.51
2001	-1.14	-1.48	-0.72	-1.01	-1.24	-0.96
2002	-0.19	0.32	-0.88	-0.56	-0.32	-0.72
2003	-0.29	-0.17	0.62	0.21	0.55	-0.63
2004	-1.00	-1.25	0.90	0.008	-0.42	-1.00
2005	0.86	1.23	0.05	-0.33	0.69	0.88
2006	-1.13	-1.13	-0.77	-0.52	-0.94	-0.77
2007	-0.44	0.40	0.01	-0.27	0.03	0.17
2008	-1.33	-1.46	-1.38	-0.93	-1.16	-1.06
2009	-0.38	1.21	-0.21	-0.004	1.07	0.26
2010	-0.23	0.16	0.01	-0.56	-0.88	-1.04
2011	-0.38	-1.35	-1.08	-1.06	-0.74	-0.35

Economical drought

Severe drought has been one of the most important problems in South Khorasan province recently. Unprecedented drought and winds has caused increase and extend of desert area in South Khorasan resulting hopelessness among the people. Located near Lut desert and having dry weather South Khorasan province is affected by weather conditions. Average rainfall decrease has caused irreparable damage to the wildlife, Qanat, ground water resources, vegetation cover and animal in the last decade. Rainfall decrease has had adverse effects on flora and fauna species, so that some wild species like deer, goats and sheep are becoming extinct. Also because of drought natural springs in the study area has been dried. According to the report of regional water department due to increase of groundwater extraction and dug wells (36%) in drought years, groundwater quality and quantity have decreased. The experts of natural resources anticipate that with continuing this process all vegetation will be lost in the next few years. Although there are no official statistics about human and financial losses caused by drought, but losses caused by drought in the province is inevitable. Food shortage has caused entrance of wild animals like wolf to the farms, attack to domestic animal and so much damage to farmers. The rate of damage in 2007-2008 has been shown in (Table 4).

Table 4. Damages caused by drought, over grazing, wildlife attack to farms in South Khorasan province in 2007-2008 (millions Rials)

Row	City	Ghaen		Shaskuh and Esfaden Plain		Darmian		Damage Caused by Animals Attack
		Area (ha)	Damage	Area (ha)	Damage	Area (ha)	Damage	
1	Birjand	35000	21	-	-	-	-	300
2	Ghaen	-	-	111000	57	-	-	400
3	Darmian	-	-	-	-	8000	84	1600
Sum	162 m Rials							2300
Total	2462 m Rials							

Rainfall decrease and drought frequency has caused extreme poverty rangeland in the province and therefore herbivores and seed-eating species (domestic and wild animals) faced lack of food directly and indirectly. The reports of natural resources organization shows that the annual forage production that was 625000 tons in 2007 decreased to 250000 tons in 2011. On the other hand, the rangelands production of the province faced with 60% decrease in 2007-2011 Period. According to the report of Agriculture-Jahad organization (2012) that the agriculture crops has faced with 45% decrease has rising poverty and unemployment, immigration from rural to urban area, evacuated villages. Based on the report uninhabited villages had increased to 30% from 2005 to 2011.

Discussion and Conclusion

Population growth and improve living standards increase demand for water and competition among water consumers (drinking, agriculture, industry). Drought is a recurring phenomenon for example, Iran has experienced drought with different intensity in the recent two decades. According to the conducted researches, the direct effect of losses resulting from decrease of 1mm rainfall is around 98 billion Rials. Assuming that the difference of extracted water between wet and drought years are 13 billion m^3, the losses resulting reduced cultivation land is around 1274 billion Rials. The provinces of Isfahan, Kerman, Khuzestan and South Khorasan had face with the most losses due to drought in the last 10 years, (National Disaster Management Organization of Iran, 2011). In some southern African countries, policymakers finally appear to be displaying a greater awareness of the economy wide threat of drought. For example, the Zimbabwe government to deal with this phenomenon requiring action likes promotion of appropriate economic activities in specific agriculture area. Increasing production of small grains where these are the staple crops, construction of large- scale dams, establishment of permanent drought mitigation unit to plan and implement long-term drought mitigation recovery measures, (Benson and Edvard, 1998).

All people are familiar with the effects of drought and have touched that, but determining the drought severity and its evaluation is one of the most important issues that still unresolved. Drought is an imminent and unavoidable thereat in many areas of Iran. The result showed that the main losses in South Khorasan province are in the year when SPI has classified in extreme and sever class. Drought has affected on the study area as follow:

1. Immigration,
2. Loss of herbivore species due to poor nutrition,
3. Increase unemployment and poverty,
4. Reduction of agricultural crops and groundwater quality.

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بررسی خشکسالی اقلیمی و تأثیر اقتصادی آن (مطالعه موردی: استان خراسان جنوبی)

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چکیده. در پژوهش حاضر به منظور تعیین و پهنه‌بندی خشکسالی اقلیمی با استفاده از شاخص SPI در یک دوره ۲۲ ساله (۲۰۱۱-۱۹۹۰) از آمار بارندگی شش ایستگاه سینوپتیک خراسان‌جنوبی استفاده و جهت بررسی خشکسالی اقتصادی از گزارش‌های و آمار موجود در ادارات کل منابع طبیعی، جهادکشاورزی، آب منطقه‌ای و سازمان محیط زیست بهره‌گیری شد. به منظور دستیابی به مقدار خشکسالی ابتدا برای هر سال رابطه رگرسیونی بین مقدار بارش و ارتفاع ایستگاه‌ها بدست آمد، سپس این رابطه در محیط Arc map بر روی لایه DEM منطقه اعمال و در نهایت با استفاده از فرمول، نقشه‌های خشکسالی منطقه تهیه و پهنه‌بندی گردید. نتایج نشان داد که شدیدترین خشکسالی‌های اقلیمی به ترتیب در سال‌های ۲۰۰۸، ۲۰۰۰، ۲۰۰۶ و ۲۰۱۱ رخ داده است. بطوریکه در سال ۲۰۰۸ بالغ بر ۶۶٪ منطقه در طبقه خشکسالی شدید و در سال ۲۰۱۱ حدود ۹۰٪ منطقه در طبقه خشکسالی کم قرار گرفته است. نتایج حاصل از خشکسالی کشاورزی- اقتصادی نیز نشان داد که در سال‌های ۲۰۰۷ تا ۲۰۱۱ تولید سالانه علوفه مراتع استان (۶۲۵ هزار تن) ۶۰ درصد کاهش داشته که خسارتی معادل ۹۳۷۵۰۰ میلیون ریال به مراتع وارد شده است. همچنین در سال‌های ۲۰۰۹ تا ۲۰۱۰ محصولات کشاورزی منطقه با کاهش ۴۵ درصدی همراه بوده که باعث تخلیه بسیاری از روستاها و مهاجرت مردم به شهرهای اطراف، افزایش فقر و بیکاری، تلف شدن گونه‌های گیاهخوار به دلیل فقر غذایی و کاهش کیفیت آب‌های زیرزمینی شده است.

کلمات کلیدی: پهنه‌بندی خشکسالی اقلیمی، خشکسالی اقتصادی، SPI، ArcGIS 9.3، خراسان جنوبی