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Abstract

Drought is the most important and destructive climate phenomenon which is usually o f importance in a regional scale. Therefore, this study offers a fuzzy-based hybrid inde x in order to analyze the regional drought in Abadan and khoramshahr, Khuzestan, Ira n. Influencing all aspects of human activity, drought does not have a comprehensive d efinition and an appropriate and general index to explore it. Consequently, in order to develop a model to evaluate and analyze drought, the fuzzy model has been used. The application of fuzzy logic to examine drought in Abadan-khoramshahr station demons trated that fuzzy logic enables us to examine drought more accurately and appropriatel y because it takes into account the type of product (wheat or dates) in calculating the p robability of drought. In furtherance of this aim, the fuzzy function related to the stand ardized Precipitation Index (SPI) and the standardized evapotranspiration index (SEI) have been combined and a new indicator called the standardized evapotranspiration an d Precipitation index (SEPI) was developed. In the final fuzzy model, 81 rules have be en utilized. In this study, the annual data of wheat and dates from 1994 to 2012 have b een utilized (sometimes 2013 data have been used), and on this basis, the results of the model revealed that severe and continued droughts have occurred in 1999, 2007 and 2 009 and the probability of drought for wheat and dates was 64.29 and 57.14 percent re spectively in this period.

Key Words: **Water Requirement, Probability of Drought, wheat, dates, SEPI.**

JEL Classification: **Q12, O13, R11, C15.**

1. Introduction

Agriculture as one of the most important sections of Iran's economy has a large contribution to GPP, non-oil exportation, and employment (Shams, 2005). Due to the huge population growth and the increased demand for agricultural and animal products, agriculture and animal husbandry have gained much more importance, and developing more efficient production procedures and supporting domestic producers has become more crucial (Enjolras et al, 2012). Moreover, agricultural activities have bilateral risks, affecting both producers' behavior and macro-agricultural policies. Among different risks involved in this section, some risks cannot be controlled and have a wide range of consequences, an important instance of which is drought (De Janvry et al, 2014). Drought is considered as a creeping phenomenon since a large part of its impact is not observed in a particular period; hence planning to reduce its damages is difficult. In comparison with other natural disasters, drought is greater with regard to severity, spread, human losses, economic damage, and long-term consequences, posing a serious threat to sustainable development (Leblois and Quirion, 2013).

Therefore, utilizing efficient methods to identify and forecast risk-producing factors in different sectors of agriculture (such as drought) can assist policy makers to adopt appropriate policies (Anton, 2013). The importance and function of calculating the risk of drought in Several areas have been dealt with in a wide range of studies, such as Kim et al (2013); Ramsay et al (2013); Gómez and Blanco (2012); Gil et al (2011); Altmana et al (2009); Waterbury and Mark (2008); Akcaoz and Ozkan (2005); Skees et al (2002) and Wright and Hewitt (1994) studies. Due to the climate conditions in Iran and the importance of agriculture sector in the prosperity of provinces, particularly those having revealed agriculture-related comparative advantages, the consequences of drought in the southern cities of Iran, and the strategic nature of wheat and dates in Abadan and Khoramshahr, investigating the probability of drought based on the type of products is of high importance.

2. Agriculture in Khuzestan

Khuzestan Province has an area of 67282 square kilometers and is located in the south -western of Iran. It has mild summers and cold winters in mountainous areas and has a semi-desert climate in foothills. Having access to open water in southern coasts and nu merous huge rivers, which have been the habitat of ancient Iranian tribes, is an import ant advantage of this province.

2.1. Abadan and Khoramshahr

Abadan has an area of 576 square kilometers and is located in the south-west of Khuz estan and across the Persian Gulf. After Ahwaz, Abadan is the second most important city of Khuzestan. The strategic importance of the Oil Refinery and having borders wi th Iraq make Abadan one of the most significant cities in Iran and the Middle East. Ab adan is located between the Persian Gulf and Arvand and Bahmanshir rivers and has a hot and humid climate. This city is among the low-rainfall areas and usually receives f leeting showers, and the type of soil in this city is quite appropriate for agriculture. M ost agricultural activities are devoted to cultivating and raising palm trees. The water o f Bahmanshir and Arvand rivers are used to irrigate these trees. Therefore, we should bear in mind that rainfall has utmost importance in the agricultural activities of this re gion, and hence water Shortage and drought severely damage that agricultural activitie s.

In the south-west of Khuzestan and has a dry and humid climate. Irrigation resources f or the farms of this city are Karun and Arvand rivers, and the farms located in the sout h and south-west of these rivers. Due to the special geographical position of Khorams hahr, it is potentially and actually capable of enhancing its agricultural activities. Whe at and dates are prominent products of this city which are both cultivated by means of irrigated farming. Due to high temperature and low rainfall in this region, like Abadan , the negative consequences of drought can do a serious damage to its farms and palm trees. Therefore, the ability to control agricultural risks in these two cities is of high i mportance.

2.2. Wheat

Wheat is one of the most salient agricultural products. In societies like Iran, wheat has crucial nutritious importance, and the social welfare of low and middle classes is heavi ly dependent on this product (Khousravipour et al, 2011). Like many other countries, wheat bread is people’s most basic daily food. Wheat is one of the most important agri cultural products in Khuzestan. Ten percent of the total amount of wheat produced in I ran is cultivated in this province (Hakimi, 2012).

Wheat is cultivated by means of rain-fed and irrigated methods. Research has shown t hat the amount of wheat produced through rain-fed method is directly related to the a mount and distribution of rainfall. Therefore, rainfall has a strong impact on wheat pro duction. This will increase the production risk particularly in Khuzestan facing the ris k of drought (Shamohammadi et al, 2005). Consequently, drought and adverse climate conditions bear a negative effect on wheat production. Hence, managing drought risks in wheat production is of prime importance, particularly in areas with a hot climate.

2.3. Dates

Dates, a tropical plant, is one of the oldest and most strategic agricultural products. C ontaining a lot of sugar, vitamins, and minerals, dates have great nutritious value. Date s are raised in arid and semi-arid areas having hot and long summers (Abdoullahi and Abedini, 2010). They are reaped from August to September. Based on global statistic s, Iran has the second largest cultivation area of dates in the world (Koshteh and Kama lian, 2004). Dates are the third most 'important horticultural products in Iran and is cul tivated in 13 provinces. With regard to the amount of production, Khuzestan stands thi rd in Iran (after Kerman and Bushehr). Although dates are generally raised in arid and semi-arid areas, palm trees need sufficient water to grow and production of high qualit y fruits. Therefore, increase in the temperature and decrease in relative humidity negat ively affects the performance of palm trees (Mohammadrezaei et al, 2009). Consequen tly, in order to utilizing maximum capacity of date's production, enough attention shou ld be devoted to water shortage, drought and their managements.

3. Drought Risk

Vulnerability to drought is a function of its nature, size, and severity. On the other han d, human beings cannot forecast many events properly. Therefore, there is always a de gree of uncertainty and a degree of inevitable risk (Hungsoo et al, 2013). Drought man agement has not experienced a huge progress in many parts of the world and many rea ctions to this phenomenon have been traditional. Drought risk management or the set of measures taken before the drought minimize the shock experienced during this phe nomenon. This issue has not been fully attended in developing countries (Blanco et al, 2013). Crisis management has become less valid; therefore, many governments try to gain more information about appropriate methods of risk management in order to miti gate the damages caused by drought and the negative consequences of possible drough ts in future (Anton et al, 2013).

3.1. Theoretical Foundations of Drought Management

Drought is a natural danger and a big disaster, posing many problems for countries. So me of the instances of the most severe droughts in the 20th century include the drough t in China in 1907, the Soviet Union in 1922, India in 1967 and Africa in 1975 (Kim e t al, 2011). Many factors contribute to the occurrence of drought in different parts of t he world; the common features of all of them are the potential amount of evapotranspi ration and the amount of rainfall which make the crops water requirement difficult. In addition, droughts pose numerous economic problems for farmers (Campbell et al., 20 11).

3.2. The Probability of Drought

Determining the time at which droughts start and end is difficult because this phenom enon is creeping and its consequences may hit an area over a period of time and contin ue for some time (Ward, 2014). Moreover, the negative effects of a drought in a wide area seem to be less than those of other natural disasters. On the other hand, more than 90 percent of Iran is located in arid areas with low water supplies, hence forecasting th e probability of droughts is an important concern of policy makers (Eyvasi et al, 2013) . Almost all areas in Iran are susceptible to the negative effects of drought. They const antly face drought. Central, western, and southwestern areas in Iran are more vulnerab le to drought because the amount of rainfall has been fluctuating over the past years. T herefore, forecasting the probability of the occurrence of drought can be quite benefici al for these regions.

3.3. Methods of Calculating the Probability

In order to identify drought and its negative environmental effects, many indexes such as rainfall, average temperature, soil humidity and evapotranspiration are considered. There are many variables involved in drought, so that there are different definitions po sed for this phenomenon. What is of prime importance is the role played by factors such as rainfall and evapotranspiration.

3.3.1. Standardized Precipitation Index (SPI)

This indicator, proposed by McKee et al. (1993) for the first time, is a powerful instrument to analyze rainfall-related data. This indicator is aimed at analyzing the amount of rainfall so that we can compare rainfall in different areas (Slahedin et al, 2014). We may calculate this indicator by comparing the aggregate amount of rainfall in a particular period of time in a particular region with the average rainfall in the same duration for all of the statistical periods. This indicator is measured for each particular region based on the long-term rainfall data, observing gamma distribution. The normalized SPI equation is as follows:

$$SPI = \frac{x_i - \bar{x}}{\sigma} \qquad (1)$$

In this equation, σ represents the standard deviation of rainfall, x is represents the amount of rainfall, and $\bar{x}$ is the average of accumulative rainfall (Alemaw and Kileshye-Onema, 2014).

3.3.2. Standardized Evapotranspiration Index (SEI)

This indicator's equation is as follows:

$$SPI = \frac{ET_i - \overline{ET}}{\sigma} \qquad (2)$$

In this equation, ET_i represents the evapotranspiration at i, $\overline{ET}$ represents the average amount of accumulative evapotranspiration, σ is the standard deviation of evapotranspiration (Labedzki and Kanecka-Geszke, 2009).

3.3.3. Standardized Evapotranspiration and Precipitation Index (SEPI)

The SEPI indicator has been introduced by Vicente- Serrano et al. (2010). According to fuzzy logic, this indicator is a combination of SPI and SEI and has all their features because the use of both of these variables is necessary to measure drought and neglect of either of them will negatively influence the results of the study (Sayari et al, 2013).

Table 1: The Classification of Drought based on SEPI

Description	Classification
Too Severe Drought	> 2
Severe Drought	1.5 to 1.99
Average Drought	1 to 1.49
Mild Drought	0.5 to 0.99
Normal	-0.49 to 0.49
Mild Wet Year	-0.99 to -0.5
Average Wet Year	-1.499 to -1
Severe Wet Year	-1.99 to -1.5
Too Severe Wet Year	< -2

Source: Vicente - Serrano et al. (2010)

In the calculation of SPI the only input is rainfall. Therefore, using SPI to analyze the severity of drought in arid areas, in which the differences in the temperature, evapotra nspiration are great, leads to a big error in the analysis of drought. Hence, the combina tion of the two indexes removes the above-mentioned limitations. After calculating SP I and SEI and using the classified linguistic variables and due to advantages of fuzzy l ogic in the combination of linguistic variables, SPI and SEI are combined based on fu zzy logic, and a combined indicator has created (Potop and Mozny, 2011).

Table 2: SPEI Values for Different Levels of Drought

Description	Classification	Description	Classification
Mild Wet Year (1)	0.5	Mild Drought (1)	-6
Mild Wet Year (2)	1	Mild Drought (2)	-5.5
Mild Wet Year (3)	1.5	Mild Drought (3)	-5
Average Wet Year (1)	2	Average Drought (1)	-4.5
Average Wet Year (2)	2.5	Average Drought (2)	-4
Average Wet Year (3)	3	Average Drought (3)	-3.5
Severe Wet Year (1)	3.5	Severe Drought (1)	-3
Severe Wet Year (2)	4	Severe Drought (2)	-2.5
Severe Wet Year (3)	4.5	Severe Drought (3)	-2
Too Severe Wet Year (1)	5	Too Severe Drought (1)	-1.5
Too Severe Wet Year (2)	5.5	Too Severe Drought (2)	-1
Too Severe Wet Year (3)	6	Too Severe Drought (3)	-0.5

❖ If SPEI equals zero, climate conditions are normal

Source: Vicente - Serrano et al. (2010)

3.3.4. Fuzzy Logic

Fuzzy logic was introduced in the framework of the fuzzy set theory proposed by Prof essor Lotfi Zadeh. Fuzzy logic includes three distinct stages, namely (1) fuzzy making stage, (2) accumulation stage, and (3) un-fuzzy making stage (Esfahanipour and Agha miri, 2010). All these stages occur in the framework of fuzzy inference systems. They are popular calculation frameworks based on fuzzy sets and "if-then" rules, which hav e successful applications in many domains such as economics, engineering, etc (Askar i Zadeh, 1965).

4. Empirical Results

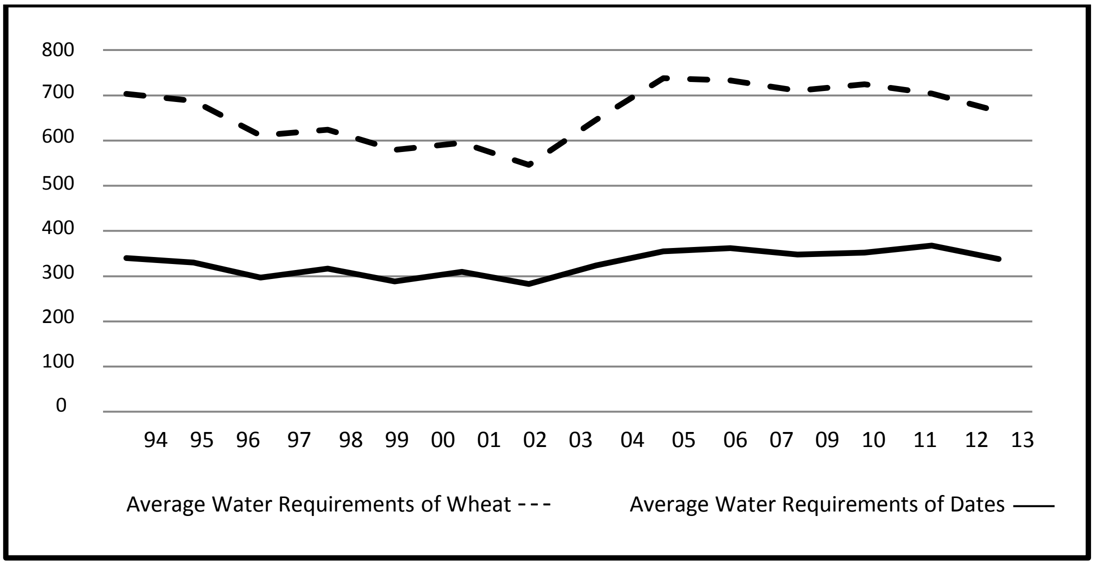
4.1. Drought and Its Relation with Net Water Requirement

There are four kinds of drought, namely metrological drought, hydrological drought, a gricultural drought, and socio - economic drought. In this research, we are mainly con cerned with agricultural drought. Therefore, it is necessary to propose a comprehensiv e definition of this type of drought at the beginning of this section. Agricultural droug ht takes place when the humidity stored in roots of the plants are not enough for those to survive between two rainfalls. It should be noted that even when the soil and the we ather contain humidity, the plants may be exposed to drought, which is caused by a su dden increase in the temperature. Accordingly, the drought risk for wheat and dates wi ll be different. Therefore, it is crucial to pay enough attention to sudden temperature c hanges affecting the degree of evapotranspiration in plants. Hence, there seems to be a significant and logical relationship between drought and net agronomic water require ment.

4.2. Comparing the Net Water Requirements of Wheat and Dates

The decrease of surface and underground water and rainfall in any regions can have a huge negative impact on agricultural activities. As a matter of fact, drought makes pla nts unable to satisfy their water requirements and this undermines their performance. Therefore, comparison of the wheat and date's net water requirements in the recent ye ars can offer us fresh insights about the drought risk of these two products. Efficient pl anning to tackle drought requires gaining information on net water requirements of pla nts. Due to the prime importance of wheat and dates for Khoramshahr and Abadan res pectively, we investigate the net water requirements of these two products (Figure.1).

Figure 1: Comparing the Net Water Requirements of Wheat and Dates



Source: the Finding of the Studies

In these two cities, a part of net agronomic water requirement are met by dint of rainfall that usually occurs in cold seasons during which the level of evapotranspiration is low and plants don't require any water. Therefore, Rain water can be added to underground and surface water. In warmer seasons of the year when the level of evapotranspiration goes up and plants request more water for their growth, a large part of water requirements are met by rainfall and a small part is satisfied through irrigation. In Khoramshahr, wheat is mainly irrigated by underground water, Karun River, and other sources of surface water. Palm trees in Abadan are also mainly irrigated by underground water, the tide of Arvand Rood, Karun, and, Bahmanshir, and other sources of surface water. Comparing the average net water requirement of wheat and dates between 1999 and 2013 reveals that the net water requirement of wheat is more than that of dates, and another reasonable and logical indication of the higher net water requirement of wheat is that the growth period of wheat is 220 days on average, while this period for dates is 120- 200 days on average.

4.3. Estimating the Probability of Drought Risk

4.3.1. Estimating the Standardized Precipitation Index (SPI)

According to the results of SPI, a large number of years in the period investigated in this study have been gripped with drought with varying degrees in different years. The important point is that drought was very severe in 1999, 2007, and 2009.

4.3.2. Estimating the Standardized Evapotranspiration Index (SEI)

The crucial importance of SEI lies in the fact that it provides a more pragmatic concept than what drought does. The degree of agricultural drought for different plants may vary in accordance with their features and this should be taken into account in the analysis. The results of drought analysis based on SEI reveals two basic points. The first point is that, as it was expected, the climate conditions for wheat and dates were not symmetrical in some years such as 2001 and 2004 and hence, the results of the indicator are not symmetrical. The second point is that the results of SEI are different from those of SPI, which is evident in light of the fact that calculation criteria of these two indexes are different. Therefore, relying on the results of each of the indicators separately will deviate the results of the analysis. Consequently, the dependency of the applied results based on the calculation of the probability of drought is unquestionable. In order to improve the precision of calculating the probability of drought, SEPI is introduced in the next section.

4.3.3. Estimating the Standardized Evapotranspiration and Precipitation Index (SEPI)

After determining all of the stages of fuzzy calculations and the fuzzy sets, the related computer program was designed in MATLAB software. On this basis, the input would be SPI and SEI values and the output would be SEPI values.

After determining the functions of SPI and SEI, a combination of the two indicators with different weights in accordance with the experts' views (the weight of rainfall is set as two times more than that of evapotranspiration), the fuzzy function of the levels of drought for SEPI were considered and the final fuzzy model was produced with 81 rules. Finally, in order to use the results of the fuzzy model, the final stage of this model, is the un-fuzzy making of the output, SEPI was determined for both wheat and dates. Then, the probability of drought was calculated for wheat and dates separately based on SEPI. The result of this analysis is demonstrated in Table 3.

Table 3: The Result of the separate SEPI probability for wheat and dates

Description	SPEI Probability of Wheat	SPEI Probability of Dates
Too Severe Drought	**7.14**	**7.14**
Severe Drought	**28.57**	**28.57**
Average Drought	**21.43**	**14.29**
Mild Drought	**7.14**	**7.14**
Normal	**0**	**0**
Mild Wet Year	**7.14**	**14.29**
Average Wet Year	**14.29**	**14.29**
Severe Wet Year	**14.29**	**14.29**
Too Severe Wet Year	**0**	**0**
Sum	**100**	**100**
Total probability of Drought	**64.29**	**57.14**
Total probability of Wet Year	**35.71**	**42.86**

Source: The Finding of the Study

Table 3 demonstrates the probability of different climates. In addition, the percentage of the aggregate probability of drought based on SEPI that equals the sum of probabili ties of very severe, severe, average, and mild drought is 64.29 percent for wheat and 5 7.14 percent for dates.

5. Conclusions

Most natural phenomena have elements that cannot be easily forecasted. Forecasting i s possible if some information about their past is available. An important instance of s uch phenomena is drought having hugely destructive consequences. On this basis, this study offers a fuzzy-based hybrid index in order to analyze the regional drought in Ab adan and khoramshahr, Khuzestan, Iran. Our Findings revealed that severe and contin ued droughts have occurred in 1999, 2007 and 2009 and the probability of drought for wheat and dates was 64.29 and 57.14 percent respectively in this period.

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