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ORIGINAL ARTICLE

Study of Summer Precipitation (rainy) Days Occurrence Probability in South Zagros using Markov Chain Model

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ABSTRACT
Precipitation shortfall and air drought especially in summer season are of the obvious features of Iranweather. However, identifying behavioral characteristics of precipitation occasionally occurring in some parts of south and south west of the country due to the impacts on the residents'life is necessary. In this survey , the probability of occurring the days with summer precipitation in south Zagros was studied using the network data resulted from the interpolation of daily precipitation statistics of 540 stations at a 51- years statistical period long(1961-2011) and markov chain technique . The mentioned statistics were arranged based on counting matrix of the mode change of precipitation days and the days with no precipitation and then the probability matrix of mode change calculated based on maximum likelihood method and through frequent orders of this matrix , the daily reliable probability of each drought mode and precipitation estimated . The summer precipitation occurrence probability over the zone of south Zagros has been estimated between 1 to 7 days. The reduction trend of area with increased precipitation occurrence probability and the centralized regions with more precipitations occurrence probability in south east of the zone have been paid attention so that from the east to the west of the zone , the probability of occurring rainy days is sharply reduced due to being far away from the focus of Iran summer monsoon and descended probability of having the outcomes resulted from their activity.
***Key words**: summer precipitation, Markov chain, occurrence probability, south Zagros.*

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INTRODUCTION

The shortfall of rainy days is considered as one of the intrinsic features of Iran weather. Being far away the path of moving western winds systems due to the extension of subtropical high pressure, being located of Iran on dry climatic belt , being neighbors with the world's vast deserts and special local position regarding low geographical latitude and increased angle of the sun radiation and receiving more heat in the summer cause the atmospheric precipitation in this season especially in more western parts of the country.

However, the occasional summer precipitation in south and south west of the country causes the damages to the residents and leaves inappropriate effects. For this reason , studying rainy days in the summer and calculating the probability percent of occurring this phenomenon in south Zagros as zonal is necessary from the view of recognizing the climate features of the summer precipitation in this zone , identifying the existent potential (from the view of precipitation) and planning to use resources resulted from these precipitations optimally and preventing their possible damages and harms.

Among the probability – statistical methods, Markov chain model has been seriously considered in atmospheric sciences over the recent year. Markov chain has made the solution of probability related to the processes easy using mathematical simple method such as matrices multiplication. Markov chain model has been extensively applied in different sciences such as meteorology, climatology, economic and industry. Cent Hiulan et al. [1] have calculated the possibility of weekly precipitation occurrence using

this method in order to plan the agriculture issues in Uttar Pradesh province in India and divided the weeks in wet and dry periods. Dash [2] studied the daily precipitation data from 2001 to 2010 in Odisha by first order Markov chain and calculated wet and dry days in order to manage agricultural water resources.

Asakreh[3] studied the frequency and continuous of rainy days in Tabriz through utilizing Markov chain technique and using daily precipitation statistic from 1951 to 2005 and estimated the probability of precipitation occurrence at each day to be%22.6 and the probability of its non- occurrence , %77.93 and also considered the highest probability of rainy days occurrence during the spring season especially May .Alijani et al. [4] studied the continuation ofthe frost days in Iran by using Maekov chain model for a 15-year period (1991-2005) from October to May in 58 stations of the country and concluded that the frost days occurrence in Iran involves the feature of Markov chain except the north and south areas of the country , meaning that the continuation of the frost days is not random but the occurrence of the frost day (days) depends on the climate conditions of the past days. Moreover, Asakreh [5] analyzed the probability of frequency and continuation of early and late frosts of Zanjan utilizing the statistics of minimum mean daily temperature in January and August and using Markov chain model and obtained the frost occurrence probability per day for January to be %3519 and for August , %375 .Asakreh & Mazini[6] calculated the probability of the days with precipitation and also the days with precipitation lower than 1mm in Golestan province and found that the local changes of dry days probability is not significant and with increasing the rainfall , the probability of dry day occurrence is reduced than that the areas with less rains and with respect to the increased precipitation in south regions of this province to its north regions the probability of dry days continuation in high- rain south regions is too low than that the similar days in low-rain north regions. Yazdan Panah et al.[7] in their research estimated the occurrence probability of 1 to 9 heat wave periods at the stations of Kerman province using Markov chain model and 20-year statistics of maximum daily temperature .Fooladmand [8] used Markov chain model to select suitable places of dry farming in Fars province and regarding that the probability of precipitation occurrence and regression period of different drought periods in November to January are low in the south Fars province and are increased toward the north and north west of the province ,the north and north west zones of Fars province are suitable zones for dry farming especially wheat. Lee [9] used Markov chain technique in order to forecast the summer seasonal precipitation in south east of U.S.A. Osman Yousef et al. [10] estimated the relationship between precipitation and the rate of growing the products in Mina farms in Nigeria so that based on this model , the government may prepare a long- term plan for the farmers .Edmasoet al.[11] used Markov chain model in order to analyze dry and wet weeks and analyzed weekly precipitation in the central valley region of Egypt for planning agriculture.

DATA AND METHODS

The zone under study (Fig .1) involves some parts of south and south west of Iran at eastern longitude from 40° 47 ′ to 56 ° 30 ′ and northern latitude from 26 ′ 30 ′to 33 ° including Koosestan , Kohgiluyeh and Boyer-Ahmad, Fars , Bushehr provinces and some parts of Hormozgn to the north of Hormoz strait with an area around 264208 km^2. From the view of roughness, the south west and south ranges of Zagros have been spread in this zone extended from the north to Zagros and from the west to Iraq and from the south side also extended from Koosestan plain and coasts of Persian Gulf to the north of Hormoz strait. The desired zone is benefited from the humidity resulted from these hydrological zone monsoon activities and sometimes utilized from precipitation due to vicinity to Persian Gulf, so that for a detailed study of these precipitations in this part of Iran , we have called it south Zagros.

Fig 1 . The position of under study zone in Iran

To study the probability of occurring the days with summer precipitation , the data of daily precipitation in summer season (July , August , September) of 540 stations with various statistical period long and maximally for 51 years was extracted and one T-shaped matrix at 540 × 93 perpared and regarded for the stations with no vacancy data . Therefore, 51 data matrices were obtained from 1961 to 2011. Since the statistical shortages may be resolved by the aid of interpolation methods, a map with a resolution of 7000m on Lambert conformal conic image system was provided using Kriging interpolation per day on the total 4743 summer days of the statistical period. The result of this practice was to fill the statistical gaps of the stations with statistical defect. On the other hand, the network data of summer precipitation with a common statistical period long and dimensions of 539 2 × 4743 with T-shaped arrays (the place on the lines and the time on the columns) were provided and used as the database for this survey. In addition, to minimize the errors resulted from interpolating; the values of %5 mm and less have been ignored.

A phenomena including drought, flood , precipitation with a definite amount , snowfall at a special time that their outcomes may not be determined before their occurring certainly are called random processes. Since the occurrence of the mentioned events depends on a variety of factors, small changes in each of these factors may change its nature to a high rate or even prevent its occurrence , Therefore , in different observations of these events and each similar event , various outcomes are resulted that their outcomes can't be determined definitely before their occurring . Based on the probability rules , some random phenomena have more chances to be occurred but the chance of occurring some of the other phenomena is lower . Markov chain is a mathematical method for modeling random phenomena [3]. Any outcome of random processes depending only on the outcome immediately before it is called random process or Markov feature. Accordingly, a random process that is true in Markov feature is called process or Markov chain. The chain indicates this fact that outcome is related to its immediate event before itself and not related to a prior event. In fact, in this trend , the possibility of occurring a climatic mode at time **t** depends on its condition at the prior time ,that is , t-1 . If a process is only related to a process prior to itself, it will be called the first approximation of Markova chain and if any process is related to two or three processes before themselves , it will be said the second and third approximation of Markov chain. In many of the random processes, the establishment of Markov chin feature may be not determined . In this cases, Markov feature is considered as an assumption. To use Markov chain in this survey, the following phases have been adopted, respectively:

1. The desired observations should be arranged as Markov chain and based on threshold ≤0.5 mm (without precipitation) and >0.5 (the days with rainfall).

2. At the second step, the frequency arrays of observations should be formed that it itself is a base of transfer probability array (the probability of change mode) .In frequency array of observations , the number of the modes are identified . Markov chains in this research follow a two – mode algorithm (occurrence and non- occurrence), so the probability of occurring an event or non- occurring an event are considered.

$$F = \begin{matrix} \\ D \\ W \end{matrix} \overset{\begin{matrix} D \end{matrix}}{\begin{bmatrix} n_{11} & n_{12} \\ n_{21} & n_{22} \end{bmatrix}}$$

The above frequency array of condition changing from a dry day to a dry day (D→D) is shown with n_{11} , from a dry day to a rainy day (D→W) with n_{12} , from a wet day to a dry day withn_{21} and from a rainy day to a rainy day (W→W) with n22.

3. At the next step , based on the information resulted from phase 2 , the transfer probability array is created . The way of performing this phase is related to the researchers′view . For this purpose , in this survey the maximum likelihood method has been applied as the most simplest method on probability estimation .

$$P = \begin{matrix} \\ D \\ W \end{matrix} \overset{\begin{matrix} D \end{matrix}}{\begin{bmatrix} \frac{n_{11}}{n_1} & \frac{n_{12}}{n_1} \\ \frac{n_{21}}{n_2} & \frac{n_{22}}{n_2} \end{bmatrix}} \Rightarrow P = \begin{matrix} \\ D \\ W \end{matrix} \overset{\begin{matrix} D \end{matrix}}{\begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix}}$$

The above matrices are random matrices because each of their array is non-negative and its total arrays per row is 1 ,so that the arrays of these matrices are corresponded with the probability of one – phase mode change .

4. All of the orders of probability matrix are also random and from a value onward by increasing the order, no change is made in probability matrix . In this mode , it is said that matrix has reached the stationary (reliability) . The probability of reliable mode shows that how much is the probability of occurring a rainy or dry day within a long time .Therefore ,in this phase , the probability of reliability for precipitation occurrence in summer season of south Zagros will be calculated .

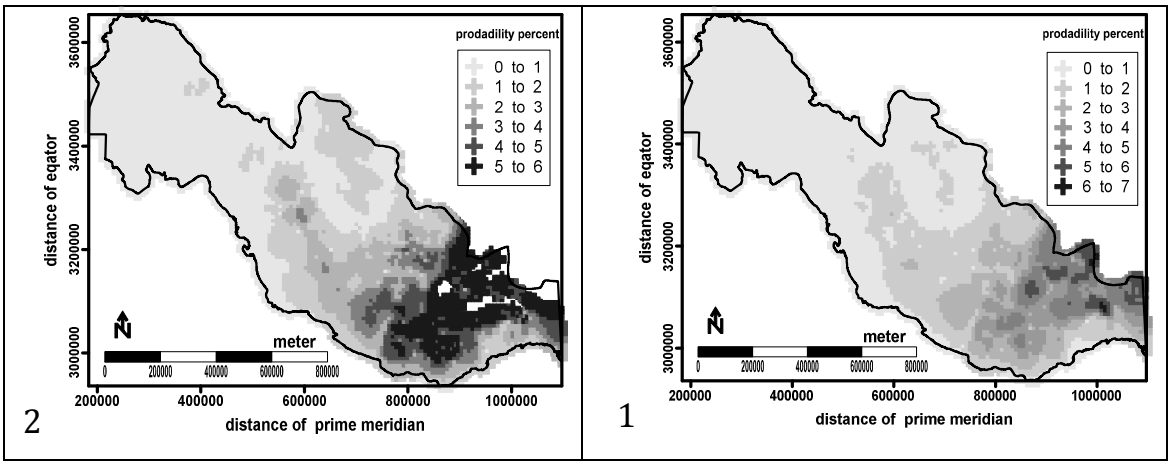
5.Preparation , interpretation and analysis of the maps are related to the summer precipitation occurrence probability in south Zagros.

RESULT AND DISCUSSION

In this survey aiming at detecting the probability of the summer precipitation occurrence in south Zagros , first order Markov chain technique has been applied . As seen in Fig.2, the probability of the summer precipitation occurrence has been estimated to be between 1 to 7 percent in different regions so that gray-colored cores show the maximum probability of 7% precipitation occurrence in south east and is corresponded with Hormozgan heights and the eastern regions of Fars province , while toward north west and coastal strip , the probability of precipitation occurrence is intensively decreased. The important points in this figure are the reduction trend of area with increased probability of precipitation occurrence as well as reduced precipitation slope from the south east half toward the north west so that the concentration of areas with more probability of precipitation occurrence is in the south east half and attached to the northern heights of Hormoz strait . This important matter indicates more utilization of this part of the zone from the summer precipitation of the south eastof Iran resulted from the vicinity with monsoons range beyond the strait of Hormoz and whatever the distance from the monsoon areas is increased , the probability of reaching the monsoons and involving the outcomes resulted from their activities that is the summer precipitation will be decreased. In sum , based on Tab.1 , in 49.4% of the zone area located mainly on coastal strip and from low height parts of Bushehr to north west parts located in Koozestan province , only 1 to 2 percent of precipitation occurrence probability are involved. In 21.2% of the zone, the probability is from 2 to 3 percent, in 13.6% of the areasfrom 3 to 4 percent , in 11.6% from 4 to 5 percent and only in 4% of the zones , there is 5 to 6 percent of the precipitation probability. Finally, the highest probability around 6 to 7 percent is also seen in 0.2% of the zone.

TabLE.1. The probability distribution of precipitation occurrence on the zone of south Zagros

Probability of occurrence (percent)		1-2	2-3	3-4	4-5	5-6	6-7
The area of each period (percent)	summer	49.4	21.2	13.6	11.6	4	0.2
	July	67.6	14.8	12.9	4.5	0.3	--
	august	40.8	25.3	12.2	11.3	10.4	--
	September	53	24.6	13.6	8.8	---	--



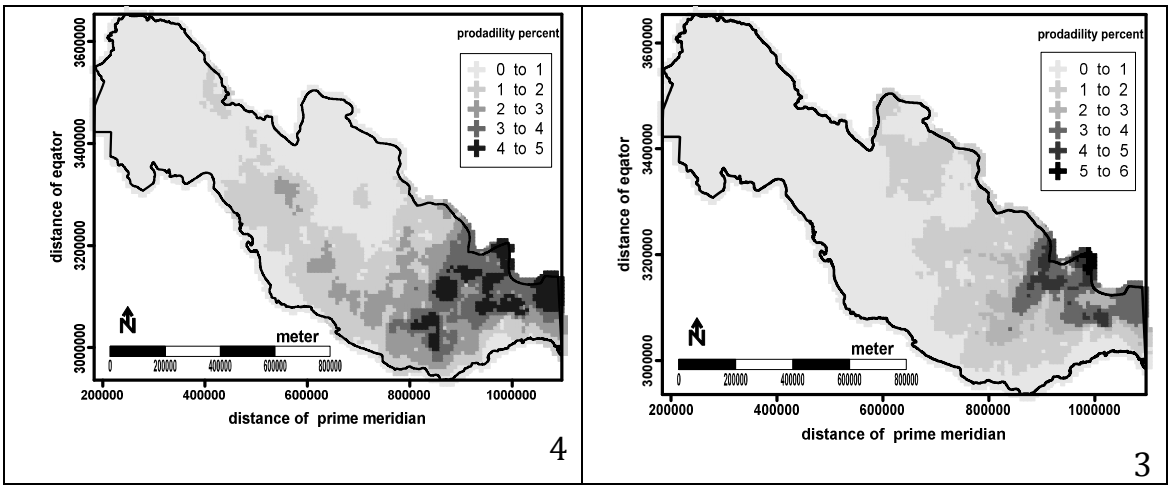


Fig.11-4. Local distribution of the probability percent of summer precipitation occurrence in south Zagros during the summer season : (1) July , (2)August ,(3) September.

July month

Fig.2 clearly shows that in July, firstly the probability of precipitation occurrence has been estimated to be 6% and secondly the maximum probability of precipitation occurrence between 5and 6 percent are located in smaller parts in Hormozgan and Fars covering about 0.3% of the zone area and the regions with low probability of precipitation occurrence are seen in a smaller zone only in Fars , Hormozgan and Kohgiluyeh and Boyer-Ahmad. For example, based on Tab. 1 , the most areas involving about 67.8% of the zone holds 1-2 percent of the probability for receiving the precipitation and 14.8% between 2-3 percent and the probability of 3-4 percent of precipitation at 12.9% and 4-5 percent of probability for rainy days also may be seen at 4.5% of south Zagros extension. In sum , the precipitation with low probability and with a smaller extension in this month than the other months of the summer season and more zones have a weaker probability.

August month

In August based on Fig.2 and Tab.1, about 40.8% of the least probability (1-2%) is seen so that the minimum probability observed at a smaller areas than the other months indicating the occurrence of more precipitations in a wider parts of the zone. As seen in the figure , the probability of more occurrences is extended toward coastal strip along the Zagros mountain range to the east of Koozestan. In general , at one fourth of the zone , there is the probability of 2-3% precipitations and at 12.2% , 4-5 percent of precipitations and finally the precipitation with 5-6% probability occurs in 10.4% of the zones. In sum , in this month the maximum probability occurs at more extensions and the minimum probability at a smaller zone than the other months.

September month

In September as seen in Fig.2 , the maximum cores are seen again in south east of the zone that is the west Hormozgan and east Fars. But , moving toward the south and west of maximum cores of precipitation occurrenceprobability is followed due to the more regressions of subtropical scanning high and its approximated departure from the south west borders of the country would provide a ground of rising abundant humidity resulted from evaporation of south coastal warm watersand also cause the precipitation occurrence probability as small but with a large extension.With respect to Tab.1 , in the final month of the summer , a few more than half areas of the zone (53%) , 1-2% rainy days have been estimated and around one fourth of the extension (24.6%) , around 2-3% and at 13.6% also 3-4% and the highest probability that is 4-5% is seen at 8.8% of south Zagros.

CONCLUSION

In this survey , Markov chain model was applied to study the probability of occurrence the summer rainy days in south Zagros and the calculations carried out on the generated zonal data of the daily precipitation with a 50-year period long. Based on the findings of this survey , at the heights of Hormozgan province and some parts of the east and south of Fars the probability of occurrence the summer rainy days is higher than the other parts. This important matter is due to more benefit of this part from the south east monsoon precipitation of Iran resulted from vicinity with monsoon range beyond the Hormoz strait. Whatever the distance from the monsoon regions is increased , the probability of reaching the monsoons and utilizing the outcomes resulted from their activity will be decreased. In July

, the precipitation with less probability and at a small extension than the other months of the summer is seen. In August , the occurrence of more precipitation and over a more wider parts of the zone is occurred and the probability of more occurrences with left-sided movement is extended toward the coastal strip as well as across the range of Zagros mountain to east Koozestan. In September, the maximum cores are seen in the north of western half of Hormozgan and east Fars. Due to more regressions of tropical high pressure system and its approximated departure from the western borders of the country , the ground of rising abundant humidity resulted from evaporation of south coastal warm waters is provided and also causes the precipitation occurrence probability as small but with a large extension. However, the precipitation occurrence probability is much higher in the south east parts than the North West. It is recommended that the findings of such this survey to be paid attention in planning regarding the intense shortage of fresh water in this part of the country in order to make more benefit from the water resources resulted from these precipitations and on the other hand, through identifying and forecasting the conditions coincided with these precipitations, the incidence of the possible damages can be prevented.

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