FORECASTING DROUGHT BY MARKOV CHAIN (CASE STUDY : ARDAKAN CITY)

PREVISION DES SECHERESSES PAR LA CHAINE DE MARKOV (ETUDE DE CAS : ARDAKAN VILLE)

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ABSTRACT

Ardakan city is located in arid and semi-arid part of Iran. Occurrence of consecutive droughts during the last few years has shown that drought prediction is a subject that deserves more attention to be paid to. One way to achieve such goal is forecasting drought by Markov chain. in this study, agricultural and hydrological droughts have been predicted on the basis of analysis of 46 years of rainfall data of Aghda, Kharanagh and Ardakan synoptic stations. Standardized precipitation index was calculated in interval of 3 and 12 months. After obtaining drought severity classes using values obtained from SPI method, the first order of Markov model was found to fit well to the drought events. The following results were obtained from the study:

1. *With Increasing Interval of 3 to12 month, the probability of transition from a class to the same class are stronger.*
2. *Probability of transition from a very wet state to severe or extreme drought condition or vice versa is approximately zero in this area*
3. *In humid areas the monthly probability of wet years occurrence is high.*
4. *Almost all cases have a tendency to reach the normal state*

Key words: *Drought, SPI, Markov chain*

RESUME

La ville d'Ardakan est située dans la partie aride et semi-aride de l'Iran. La présence des sécheresses consécutives au cours des dernières années a montré que la prédiction de la sécheresse est un sujet qui mérite une attention. La prévision des sécheresses par la chaîne

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de Markov est l'un des moyens d'atteindre cet objectif. Dans ce rapport, on fait la prédiction des sécheresses hydrologiques et agricoles en analysant les données de la précipitation de 46 ans des stations synoptiques d'Aghda, de Kharanagh et d'Ardakan. L'indice normalisé de précipitation a été calculée dans l'intervalle de 3 et 12 mois. Après le recueil de classes de gravité de la sécheresse en utilisant les valeurs obtenues de la méthode SPI, la première commande de modèle de Markov a été retenue pour le phénomène de sécheresse. Suivent les résultats obtenus à partir de l'étude:

1. *Avec intervalle croissant de 3 à 12 mois, la probabilité de transition d'une classe à la même classe était plus forte.*
2. *Probabilité de transition d'un état très humide à l'état de sécheresse sévère ou extrême, ou vice versa est presque zéro dans ce domaine.*
3. *Dans les zones humides, la probabilité mensuelle des années humides est élevée.*
4. *Presque tous les cas ont tendance d'atteindre l'état normal.*

Mots clés : *Sécheresse, SPI, chaîne de Markov.*

1. INTRODUCTION

Yazd Province with average rainfall 106 mm is considered as one of the dry Regions. Therefore risk management should be used for handling of water resources and reducing drought damage. Markov chain model is one of the methods for data modeling and predicting drought. There are many researches in this field, for example, Alizadeh(2007) using Markov chain predicted drought in 2008 in Khorasan Razavi province. According to the results the probability of normal weather conditions in 2008 is higher. In this research, agricultural and hydrological drought in Ardakan,Yazd was predicted using Markov chain model.

Study area

Ardakan city is situated between 53^0 3' to 55^0 41' E and 32^0 3' to 33^0 12' N. Its climate is dry and hot. The mean annual temperature and precipitation is about 18.8^0C and 50 mm, respectively. February is the driest month and the highest monthly precipitation occurs in June.

2. MATERIALS AND METHODS

In order to predict droughtness using Markov chain models the following steps are involved:

1. Determining indicator Periods for each Synoptic station

At the first step, a common base Periods for each station should be considered. Therefore in each station (Aghda, Kharanagh and Ardakan) the rainfall data of a 46- year period were used as indicator Periods.

statistics Periods	Altitude (m)	Latitude	Longitude	Station
2009-1965	1104	32°19′ 32.32"	54°01′ 54.02"	Ardakan
2009-1965	1520	32°27′ 32.45"	54°45′ 54.75"	Kharanagh
2009-1965	1150	32°22′ 32.37"	53°38′ 53.63"	Aghda

2. Computation of the standard precipitation index (SPI):

This index indicates the probability of drought by means of the following formula:

$$Z = \frac{x_i - \overline{X}}{S}$$

where,

Z = Precipitation Standard Index

x_i = Rainfall amounts in Given year

$\overline{X}$ = Long-term average of Annual rainfall

S = Standard Deviation

SPI Index in periods of 3 and 12- month shows agricultural and hydrological drought respectively so in this study these indices was calculated. After that, by means of the following table the SPI values turn into the Drought severity classes.

Table 1. Classification scale for SPI values

Category	SPI Values
Extremely Wet	SPI>1.5
Moderately Wet	1<SPI<1.5
Near Normal	1<SPI<-1
Moderately Dry	-1<SPI<-1.5
Severely Dry	-1.5<SPI<-2
Extremely Dry	SPI<-2

Using Markov Chain

By Assuming that the first order model of Markov chain is fitted well to the drought events, the first order Markov chain model that have six state were selected. Each data in this matrix, Indicates the Transmission probability of a particular drought class to another class.

3. RESULTS

In the following Tables, the transition matrices of different locations are given:

Transition matrix(SPI=3 months) Kharanagh						
Pij	**1**	**2**	**3**	**4**	**5**	**6**
1	0.25	0.45	0.25	0.05	0	0
2	0.1429	0.119	0.7143	0.0238	0	0
3	0.0207	0.0648	0.8523	0.0466	0.0078	0.0078
4	0.027	0.0811	0.4324	0.3514	0.0811	0.027
5	0	0	0.5	0.375	0	0.125
6	0	0	0.25	0.125	0.25	0.375

Transition matrix(SPI=12 months) Kharanagh						
Pij	**1**	**2**	**3**	**4**	**5**	**6**
1	0.3077	0.3077	0.0769	0.2308	0.0769	0
2	0.0784	0.5294	0.3922	0	0	0
3	0.0055	0.0522	0.8901	0.044	0	0.0082
4	0.0682	0	0.3636	0.5	0.0227	0.0455
5	0	0	0.5	0.5	0	0
6	0	0	0.125	0.0625	0.125	0.6875

Transition matrix (SPI=3 months) Aghda						
Pij	**1**	**2**	**3**	**4**	**5**	**6**
1	0.125	0.375	0.25	0.25	0	0
2	0.0866	0.4567	0.4331	0.0236	0	0
3	0.0269	0.1852	0.7104	0.0572	0.0067	0.0135
4	0.0526	0.1579	0.5	0.1579	0.1316	0
5	0	0	0.5	0.4	0.1	0
6	0	0	0	0.4	0.4	0.2

transition matrix(SPI=12 months) Aghda						
Pij	**1**	**2**	**3**	**4**	**5**	**6**
1	0.7576	0.1212	0.0606	0.0606	0	0
2	0.122	0.4146	0.4634	0	0	0
3	0.0059	0.0592	0.8787	0.0325	0.0178	0.0059
4	0.0256	0.0256	0.359	0.4872	0.1026	0
5	0	0	0.1304	0.3043	0.3478	0.2174
6	0	0	0.1111	0	0.2778	0.6111

Transition matrix(SPI=3 months) ardakan						
Pij	**1**	**2**	**3**	**4**	**5**	**6**
1	0.24	0.24	0.32	0.2	0	0
2	0.0909	0.1591	0.7273	0.0227	0	0
3	0.0238	0.1935	0.7143	0.0387	0.0208	0.0089
4	0.0968	0.129	0.3871	0.1613	0.1613	0.0645
5	0	0	0.4667	0.3333	0.1333	0.0667
6	0	0	0.6667	0.1667	0.1667	0

transition matrix(SPI=12 months) ardakan						
Pij	**1**	**2**	**3**	**4**	**5**	**6**
1	0.2857	0.5238	0.0952	0.0952	0	0
2	0.1159	0.5797	0.3043	0	0	0
3	0.0153	0.055	0.8716	0.0336	0.0183	0.0061
4	0.0588	0	0.3235	0.4118	0.1471	0.0588
5	0	0	0.2174	0.2174	0.4348	0.1304
6	0	0	0.1667	0.1111	0.1111	0.6111

4. CONCLUSIONS

1. with Increasing Interval of 3 to12 month, the probability of transition from a given class to the same class is stronger.
2. The Probability of changing classes from very wet to severe or extreme drought condition or vice versa is approximately zero.

3. Almost all cases have a tendency to normal state.
4. if stations be placed in the more humid areas, the monthly Probability of drought occurrence (p^{44}) is greater.

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