ECOLOGIA BALKANICA
2015, Vol. 7, Issue 1 June 2015 pp. 29-38

Impacts of Climate Change on Droughts in Gilan Province, Iran

Ladan Kazemi Rad[1*], *Hosein Mohammadi*[2], *Vahid Teyfoori*[3]

1 - Academic center for education, culture & research, Rasht, IRAN
2 - Department of Geography, Tehran University, IRAN
3 - Statistics Governor of Gilan, IRAN
*Corresponding author: lkazemi_1980@yahoo.com

Abstract. Drought as a complex natural hazard is best characterized by multiple climatological and hydrological parameters and its assessment is important for planning and managing water resources. So understanding the history of drought in an area is essential like investigating the effects of drought. In this study at first climate parameters affecting the drought have downscaled by LARS-WG stochastic weather generator over Gilan province in Iran. After choosing a suitable model, the outputs were used for assessing the drought situation in the period of 2011-2030. Assessing the drought was done by TOPSIS method during 2 periods (present and future). After validation of the method, zoning the drought was performed by IDW method in GIS. Results showed that the expanse of situations with lower drought index will increase. Also we will expect more droughts in these regions for the future.

Keywords: Climate change, Drought, GCM model, LARS-WG, TOPSIS method, Gilan province.

Introduction

Observed changes in the climate due to increasing greenhouse-gas concentrations have made it essential to investigate these changes. The application of General Circulation Model (GCM) results is the most current method in use in climate change studies. Although GCMs are imperfect and uncertain, they are a key to understanding changes in climate. Output from GCMs requires application of various downscaling techniques (BARROW *et al*., 1996; BARDOSSY, 1997; WILBY *et al*., 1998; MEARNS *et al*., 1999; MURPHY, 1999; SALON *et al*., 2009). One of the downscaling techniques to create daily site-specific climate scenarios makes use of a stochastic weather generator (WILKS, 1992; BARROW & SEMENOV, 1995; WILKS & WILBY, 1999; SEMENOV, 2007). Recently, weather generators have been used in climate change studies to produce daily site-specific scenarios of future climate (WILKS, 1992; MEARNS *et al*., 1997; SEMENOV & BARROW, 1997). Two important reasons for using LARS-WG model include the provision of a means of simulating synthetic weather time-series with certain statistical properties which are long enough to be used in an assessment of risk in hydrological or agricultural applications and providing the means of extending the simulation of weather time-series to unobserved locations. It has been used in various studies, including the assessment of the impacts of climate change (BARROW & SEMENOV, 1995; SEMENOV & BARROW, 1997; WEISS *et al*., 2003; LAWLESS & SEMENOV, 2005; KHAN *et al*., 2006; SCIBEK & ALLEN, 2006; SEMENOV, 2007; SEMENOV & DOBLAS, 2007; DUBROVSKY, 1996).

Owing to the rise in water demand and looming climate change, recent years have

Union of Scientists in Bulgaria – Plovdiv
University of Plovdiv Publishing House

witnessed much focus on global drought scenarios. Droughts are recognized as an environmental disaster and occur in virtually all climatic zones. They are mostly related to the reduction in the amount of precipitation received over an extended period of time, such as a season or a year (WILHITE, 1992). They impact both surface and groundwater resources and can lead to reduced water supply, deteriorated water quality, crop failure, reduced range productivity, diminished power generation, disturbed riparian habitats, and suspended recreation activities, as well as affect a host of economic and social activities (RIEBSAME *et al*., 1991). They also affect water quality, as moderate climate fluctuations alter hydrologic regimes that have substantial effects on the lake chemistry (WEBSTER *et al*., 1996).

Generally, drought is a phenomenon which occurs in every area or country, with either arid or humid climate and in our country. In fact, Iran's natural conditions and its geographical location are so that we have always witnessed droughts and it can be said that some of the regions are often faced with the phenomenon (KARDAVANI, 2001). However there are definitions and models for measuring the qualitative and quantitative of this phenomenon but there is no real comprehensive model to have all climatic, hydrological, agricultural, social and so on conditions and be responsive to the needs.

MADM is a practical tool for selecting and ranking of a number of alternatives, its applications are numerous. In recent years, TOPSIS has been successfully applied to the areas of human resources management (CHEN & TZENG, 2004), transportation (JANIC, 2003), product design (KWONG & TAM, 2002), manufacturing (MILANI *et al*., 2005), water management (SRDJEVIC *et al*., 2004), quality control (YANG & CHOU, 2005), and location analysis (YOON & HWANG, 1985). In addition, the concept of TOPSIS has also been connected to multi-objective decision making (LAI, 1994) and group decision making (SHIH *et al*., 2001). The high flexibility of this concept is able to accommodate further extension to make better choices in various situations. This is the motivation of our study.

In this study at first changes in the climate variables are studied in Gilan, a Province in north of Iran. The output from two GCM models was compared with a stochastic weather generator, LARS-WG (Long Ashton Research Station Weather Generator) and suitable model used to produce a climate change scenario. Then TOPSIS method is used for determining and ranking of drought in the study area for 2 periods (present and future).

Materials and Methods

The study area is one of the 31 provinces of Iran. There is in the north of Iran and located in the South of Caspian Sea and has about 14000 kilometers in extent. Location of longitude is between 48 degrees 53 minutes and 50 degrees 34 minutes and latitude is between 36 degrees 34 minutes and 38 degrees 27 minutes, as shown in Fig.1. This area was selected to enable the researchers to collect data from a variety of climatic zones in the north of Iran (near the Caspian Sea). It has the best type of weather in Iran with a moderate and humid climate that is known as the moderate Caspian climate. The effective factors behind such a climate include the Alborz mountain range, direction of the mountains, the height of the area, and the Caspian Sea, vegetation surface, local winds, as well as the altitude and weather fronts. As a result of the above factors, three different climates exist in the region:

1. Plain moderate climate with an average annual rainfall amounts to 1200 or 1300 mm, decreasing to the east.

2. Mountainous climate which covers the high mountains and northern parts of the Alborz range. In the heights, the weather is cold mountainous and most of the precipitation is in the form of snow.

3. Semi-arid climate with the average annual rainfall stands at 500 mm and the average annual temperature is 18.2°C.

Firstly, the performance of the LARS-WG stochastic weather generator model was statistically evaluated by comparing the synthesized data with climatology period at

8 selected synoptic stations, based on 2 GCMs models (MPEH5, HADCM3) and 2 scenarios (A_2, B_1).

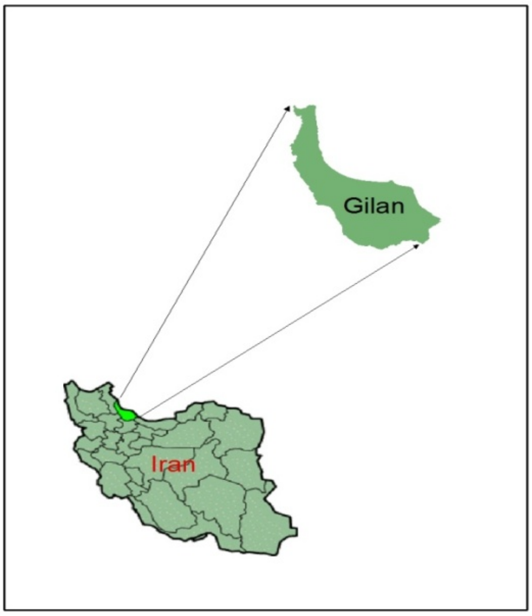

Fig. 1. Study area location

Name, latitude and longitude coordinates, as well as the elevation of the synoptic stations are shown in Table 1. After assessing LARS-WG ability in each station, it was performed for all 4 states (2 GCMs models based on 2 scenarios). Then the results were compared and the best model was chosen for predicting climatic parameters in the study area.

Table 1. Synoptic stations utilized in the study

Stations	Latitude (°N)	Longitude (°E)	Elevation (m)
Anzali	37° 29'	49° 27'	-23.6
Ardebil	38° 15'	48° 17'	1332
Astara	38° 22'	48° 51'	-21.1
Ghazvin	36° 15'	50° 3'	1279.2
Manjil	36° 44'	49° 25'	338.3
Ramsar	36° 54'	50° 4'	-20
Rasht	37° 19'	49° 37'	-8.6
Zanjan	36° 41'	48° 29'	1663

TOPSIS method is used for determining and ranking of drought in the study area. 7 Climatic Parameters consisting Precipitation in mm, Maximum and Minimum temperature in °C, Days with precipitation more than 0.1 mm (Number of wet days), Days with precipitation less than 0.1 mm (Number of dry days), Days with maximum temperature more than 30°C (Number of hot days), Days with minimum temperature equal or less than 0°C (Number of frost days) that are influencing on drought are used. Missing data are estimated by regression method and homogeneity of data is determined by Run-Test method. By using TOPSIS method and Excel software, droughts are identified and ranked in the study area for 2 periods (present and future). Then output data were compared with SIAP method. Finally, by using the interpolation method (IDW) in ArcGIS 9.3 software, zoning drought of study area is classified for 2 periods (present and future). Steps of operations can be expressed as followed:

1. Obtain performance data for 19 alternatives (Number of statistical years) over 7 criteria (Climatic Parameters). Raw measurements are usually standardized,

$$X = (X_{ij})n \times m \qquad (1)$$

2. Develop a set of importance weights wj, for each of the criteria.

$$\sum_{j=1}^{m} w_j = 1, \qquad j = 1,2,\ldots,m. \qquad (2)$$

Doing this section has 4 steps:

Step 1: Determining distribution of each climatic parameter.

$$p_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r} : \forall_{i,j} \qquad (3)$$

Step 2: Calculating Anthropy for expressing amount of uncertainty in this distribution.

$$E_j = -k\sum_{i=1}^{m}\left[p_{ij}.Ln(p_{ij})\right] : \forall_j \qquad k = \frac{1}{Ln \quad m} \qquad (4)$$

Step 3: Calculating uncertainty for each climatic parameter.

$$d = 1 - E_j : \forall_j \qquad (5)$$

Step 4: Calculating weight of climatic parameters.

$$W_j = \frac{d_j}{\sum_{j=1}^{n} d} : \forall_j \tag{6}$$

3. Multiplying matrix X (consisting 7 climatic parameters and 19 years) in the vector Wj (weight of each climatic parameter).

4. Assimilating climatic parameters: Increasing in 4 Climatic Parameters consisting maximum and minimum temperature, Number of dry days, Number of hot days and Number of frost days and also decreasing in 2 other factors consisting precipitation and Number of Wet days are causing drought. They are respectively negative and positive index. In positive indexes, data of each year is divided on maximum amount of parameter and they are divided on minimum amount of parameter in negative indexes.

5. Identify the ideal and nadir alternative A^+, A^- : (7) and (8)

$$A^+ = (v_1^+, v_2^+, \ldots, v_n^+) = \left\{ \left(\max_i \{v_{ij}\} \mid j \in B \right), \left(\min_i \{v_{ij}\} \mid j \in C \right) \right\},$$

$$A^- = (v_1^-, v_2^-, \ldots, v_n^-) = \left\{ \left(\min_i \{v_{ij}\} \mid j \in B \right), \left(\max_i \{v_{ij}\} \mid j \in C \right) \right\}.$$

6. Develop a distance measure over each criterion to both ideal (S_i^+) and nadir (S_i^-).

(9) and (10)

$$S_i^+ = \left\{ \sum_{j=1}^{m} \left(v_{ij} - v_j^+ \right)^2 \right\}^{0.5} ; \qquad i = 1, \ldots, n,$$

$$S_i^- = \left\{ \sum_{j=1}^{m} \left(v_{ij} - v_j^- \right)^2 \right\}^{0.5} ; \qquad i = 1, \ldots, n$$

7. For each alternative, determine a ratio Ti equal to the distance to the nadir divided by the sum of the distance to the nadir and the distance to the ideal,

$$T_i = \frac{S_i^-}{\left(S_i^+ + S_i^- \right)}; \qquad i = 1, \ldots, n. \tag{11}$$

8. Rank order alternatives by maximizing the ratio in Step 7. Ti =1 is shown maximum rank and Ti = 0 is shown minimum rank. Higher Ti represents more humid conditions and lower Ti represents less humid conditions.

9. Using Standard Index Annual precipitation (SIAP) method for comparison.

$$SIAP = \frac{P_i - \overline{P}}{SD} \tag{12}$$

Where SIAP is drought index, Pi is annual precipitation, $\overline{P}$ is mean of precipitation in period, and SD is standard deviation index of period.

Results and Discussion

Model validation is one of the most important steps of the entire process. The objective was to assess the performance of the model in simulating climate at the chosen site to determinate whether or not it is suitable for use. Firstly, LARS-WG model was performed based on the historical climate data obtained from 1992-2010 for verification of the model. A large number of years of simulated daily weather data were generated and were compared with observed data by using the t-test. The mean monthly correlation of the precipitation, minimum and maximum temperature and solar radiation were acceptable in 0.05 level of confidence.

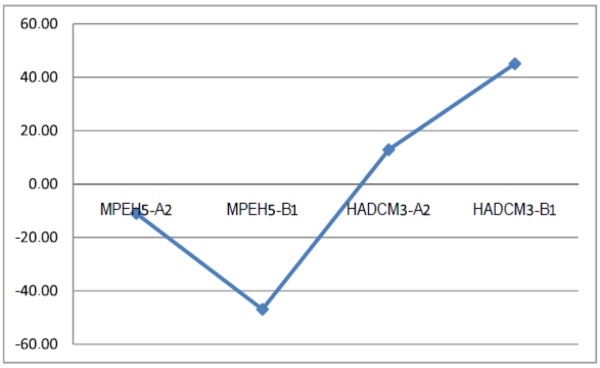

Fig. 2. Comparison between 2 models based on 2 scenarios

Then for selecting the suitable GCM model, LARS-WG stochastic weather generator model was performed for MPEH5 and HADCM3 models in A_2 and B_1 scenarios. As the Fig. 2 shows, between these 4 states, MPEH5 model based on A_2 scenario that has the least difference with the mean of models has selected and used for predicting the future climate.

The contribution of each climatic parameter in drought is different. So at first, it needs to determine weights for each of the criteria. Sum of the climatic parameters weight is equal to 1. Results are shown respectively in Table 2 and 3 for present and future period.

According to Table 4 and 5, distance of each year from ideal and nadir are determined for present and future period.

Results of calculating ratio Ti respectively are shown in Table 6 and 7 for present and future period.

At the end, by using the interpolation method (IDW) in ArcGIS 9.3 software, zoning drought of study area is done for 2 periods (present and future) that are shown in Fig. 3.

Table 2. Weight of climatic parameters in stations of study area (1992-2010).

Station	Precipitation	T min	T max	Wet days	Dry days	Hot days	Frost days
Anzali	0.0141	0.0015	0.0011	0.0045	0.0013	0.3616	0.6158
Ardebil	0.0705	0.2790	0.0126	0.0159	0.0018	0.5776	0.0426
Astara	0.0535	0.0056	0.0034	0.0197	0.0058	0.3737	0.5383
Ghazvin	0.4430	0.0580	0.0137	0.1902	0.0106	0.1019	0.1828
Manjil	0.1462	0.0034	0.0047	0.0972	0.0062	0.1265	0.6157
Ramsar	0.0450	0.0021	0.0010	0.0046	0.0009	0.3058	0.6406
Rasht	0.0865	0.0047	0.0026	0.0273	0.0079	0.1581	0.7131
Zanjan	0.3093	0.2806	0.0243	0.1126	0.0085	0.1596	0.1052

Table 3. Weight of climatic parameters in stations of study area (2011-2030).

Station	Precipitation	T min	T max	Wet days	Dry days	Hot days	Frost days
Anzali	0.0658	0.0060	0.0047	0.0361	0.0081	0.2360	0.6433
Ardebil	0.1683	0.4246	0.0220	0.0255	0.0018	0.3476	0.0101
Astara	0.2091	0.0176	0.0110	0.0685	0.0162	0.1274	0.5503
Ghazvin	0.6350	0.0558	0.0145	0.2122	0.0108	0.0096	0.0620
Manjil	0.1906	0.0050	0.0071	0.0453	0.0016	0.0182	0.7321
Ramsar	0.1708	0.0081	0.0040	0.0359	0.0062	0.0603	0.7148
Rasht	0.1421	0.0072	0.0040	0.0568	0.0097	0.0359	0.7444
Zanjan	0.4407	0.2958	0.0302	0.1132	0.0080	0.0775	0.0345

Table 4. Distance measure over each criterion to both ideal (S_i^+) and nadir (S_i^-)-(1992-2010).

	Anzali		Ardebil		Astara		Ghazvin		Manjil		Ramsar		Rasht		Zanjan	
S_i^+ , S_i^-	S_i^+	S_i^-	S_i^+	S_i^-	S_i^+	S_i^-	S_i^+	S_i^-	S_i^+	S_i^-	S_i^+	S_i^-	S_i^+	S_i^-	S_i^+	S_i^-
1992	0.04	0.14	0.01	0.07	0.03	0.04	0.01	0.02	0.03	0.05	0.14	0.04	0.07	0.01	0.01	0.02
1993	0.02	0.17	0.02	0.06	0.04	0.04	0.01	0.02	0.05	0.03	0.06	0.09	0.05	0.02	0.01	0.02
1994	0.03	0.16	0.01	0.08	0.04	0.04	0.00	0.02	0.04	0.04	0.04	0.11	0.03	0.04	0.01	0.02
1995	0.01	0.19	0.01	0.07	0.02	0.06	0.02	0.00	0.02	0.06	0.01	0.13	0.01	0.07	0.01	0.01
1996	0.01	0.19	0.03	0.05	0.02	0.05	0.00	0.02	0.03	0.05	0.02	0.13	0.03	0.04	0.01	0.01
1997	0.03	0.16	0.03	0.05	0.03	0.04	0.02	0.00	0.05	0.03	0.05	0.11	0.07	0.01	0.01	0.01
1998	0.04	0.16	0.03	0.05	0.02	0.05	0.01	0.01	0.03	0.05	0.04	0.11	0.05	0.02	0.01	0.01
1999	0.02	0.18	0.03	0.06	0.01	0.06	0.02	0.01	0.01	0.08	0.02	0.14	0.01	0.07	0.02	0.01
2000	0.03	0.18	0.04	0.04	0.02	0.05	0.01	0.01	0.02	0.06	0.02	0.13	0.02	0.05	0.01	0.01
2001	0.04	0.15	0.04	0.04	0.04	0.03	0.02	0.01	0.02	0.07	0.03	0.11	0.02	0.05	0.02	0.01
2002	0.03	0.18	0.04	0.04	0.02	0.05	0.01	0.01	0.03	0.05	0.01	0.14	0.04	0.03	0.01	0.01
2003	0.00	0.19	0.03	0.06	0.01	0.06	0.01	0.02	0.02	0.06	0.01	0.14	0.02	0.05	0.01	0.01
2004	0.01	0.19	0.03	0.06	0.02	0.05	0.01	0.01	0.01	0.07	0.02	0.14	0.01	0.06	0.01	0.01
2005	0.03	0.16	0.04	0.04	0.03	0.04	0.01	0.01	0.03	0.05	0.03	0.14	0.04	0.03	0.01	0.01
2006	0.03	0.17	0.06	0.02	0.03	0.05	0.01	0.02	0.05	0.03	0.03	0.13	0.03	0.04	0.01	0.01
2007	0.03	0.18	0.04	0.04	0.06	0.01	0.01	0.01	0.03	0.05	0.02	0.14	0.01	0.06	0.01	0.01
2008	0.18	0.03	0.03	0.05	0.02	0.06	0.02	0.00	0.08	0.00	0.11	0.05	0.07	0.01	0.02	0.01
2009	0.02	0.17	0.02	0.06	0.01	0.06	0.01	0.01	0.00	0.08	0.04	0.14	0.01	0.06	0.01	0.01
2010	0.06	0.18	0.08	0.00	0.04	0.04	0.01	0.02	0.01	0.07	0.02	0.14	0.01	0.07	0.02	0.01

Table 5. Distance measure over each criterion to both ideal (S_i^+) and nadir (S_i^-)-(2011-2030).

	Anzali		Ardebil		Astara		Ghazvin		Manjil		Ramsar		Rasht		Zanjan	
S_i^+ , S_i^-	S_i^+	S_i^-	S_i^+	S_i^-	S_i^+	S_i^-	S_i^+	S_i^-	S_i^+	S_i^-	S_i^+	S_i^-	S_i^+	S_i^-	S_i^+	S_i^-
2011	0.01	0.07	0.02	0.02	0.01	0.03	0.01	0.03	0.01	0.07	0.01	0.08	0.02	0.04	0.01	0.02
2012	0.01	0.07	0.01	0.03	0.01	0.03	0.00	0.03	0.01	0.06	0.02	0.06	0.00	0.06	0.02	0.01
2013	0.03	0.05	0.03	0.01	0.01	0.03	0.02	0.01	0.01	0.07	0.02	0.06	0.04	0.02	0.01	0.01
2014	0.02	0.05	0.02	0.02	0.02	0.02	0.03	0.01	0.05	0.03	0.01	0.08	0.06	0.00	0.01	0.01
2015	0.00	0.07	0.02	0.02	0.01	0.03	0.00	0.03	0.01	0.07	0.02	0.06	0.00	0.06	0.01	0.01
2016	0.01	0.07	0.02	0.02	0.01	0.03	0.02	0.01	0.04	0.03	0.06	0.02	0.03	0.03	0.01	0.01
2017	0.01	0.07	0.02	0.02	0.01	0.03	0.02	0.02	0.04	0.03	0.00	0.08	0.02	0.04	0.02	0.01
2018	0.01	0.07	0.03	0.01	0.01	0.03	0.01	0.02	0.03	0.05	0.03	0.05	0.03	0.03	0.02	0.01
2019	0.00	0.07	0.03	0.01	0.01	0.03	0.02	0.01	0.02	0.06	0.02	0.06	0.02	0.04	0.02	0.01
2020	0.02	0.05	0.02	0.02	0.03	0.00	0.02	0.02	0.01	0.06	0.02	0.06	0.02	0.04	0.01	0.02
2021	0.02	0.05	0.03	0.01	0.01	0.03	0.01	0.03	0.04	0.03	0.00	0.08	0.02	0.05	0.01	0.01
2022	0.00	0.07	0.03	0.01	0.00	0.03	0.02	0.01	0.01	0.06	0.02	0.06	0.03	0.04	0.01	0.02
2023	0.00	0.07	0.03	0.02	0.00	0.03	0.01	0.02	0.01	0.07	0.03	0.05	0.03	0.04	0.02	0.01
2024	0.07	0.01	0.04	0.01	0.01	0.03	0.01	0.03	0.04	0.03	0.02	0.06	0.05	0.02	0.01	0.01
2025	0.02	0.05	0.01	0.03	0.01	0.02	0.01	0.02	0.03	0.05	0.02	0.06	0.04	0.02	0.02	0.01
2026	0.01	0.07	0.01	0.03	0.02	0.02	0.03	0.01	0.01	0.07	0.02	0.06	0.03	0.03	0.00	0.02
2027	0.01	0.07	0.02	0.02	0.03	0.01	0.03	0.01	0.00	0.07	0.08	0.00	0.02	0.04	0.01	0.02
2028	0.01	0.07	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.07	0.02	0.06	0.00	0.06	0.02	0.01
2029	0.01	0.07	0.02	0.02	0.01	0.03	0.01	0.03	0.07	0.01	0.05	0.03	0.06	0.00	0.01	0.01
2030	0.01	0.07	0.02	0.02	0.01	0.03	0.03	0.00	0.05	0.02	0.02	0.06	0.03	0.04	0.02	0.01

Table 6. Ratio Ti for each alternative (1992-2010).

	Anzali	Ardebil	Astara	Ghazvin	Manjil	Ramsar	Rasht	Zanjan
1992	0.763	0.914	0.584	0.654	0.642	0.223	0.110	0.733
1993	0.881	0.753	0.463	0.653	0.375	0.572	0.324	0.708
1994	0.822	0.930	0.500	0.851	0.489	0.716	0.620	0.691
1995	0.955	0.895	0.752	0.200	0.786	0.903	0.905	0.465
1996	0.955	0.641	0.734	0.846	0.572	0.866	0.614	0.484
1997	0.866	0.574	0.558	0.193	0.419	0.693	0.121	0.485
1998	0.812	0.589	0.655	0.565	0.624	0.734	0.309	0.391
1999	0.890	0.675	0.837	0.315	0.878	0.869	0.904	0.263
2000	0.878	0.530	0.705	0.475	0.741	0.850	0.726	0.476
2001	0.792	0.493	0.449	0.287	0.815	0.769	0.765	0.227
2002	0.873	0.503	0.756	0.571	0.569	0.954	0.422	0.388
2003	0.985	0.692	0.819	0.753	0.780	0.933	0.693	0.507
2004	0.960	0.689	0.756	0.552	0.852	0.893	0.838	0.480
2005	0.822	0.548	0.596	0.414	0.657	0.831	0.465	0.412
2006	0.833	0.283	0.650	0.618	0.421	0.819	0.608	0.463
2007	0.878	0.552	0.136	0.554	0.573	0.879	0.824	0.626
2008	0.155	0.589	0.746	0.128	0.030	0.305	0.089	0.308
2009	0.904	0.752	0.863	0.484	0.944	0.768	0.878	0.481
2010	0.763	0.016	0.499	0.654	0.862	0.898	0.879	0.252

Table 7. Ratio Ti for each alternative (2011-2030).

	Anzali	Ardebil	Astara	Ghazvin	Manjil	Ramsar	Rasht	Zanjan
2011	0.925	0.562	0.717	0.775	0.884	0.923	0.665	0.594
2012	0.932	0.781	0.743	0.952	0.800	0.793	0.953	0.273
2013	0.635	0.296	0.716	0.293	0.907	0.792	0.336	0.529
2014	0.659	0.541	0.487	0.233	0.357	0.924	0.032	0.424
2015	0.975	0.520	0.797	0.968	0.881	0.795	0.936	0.477
2016	0.874	0.519	0.738	0.350	0.457	0.201	0.500	0.552
2017	0.925	0.389	0.735	0.455	0.460	0.951	0.667	0.302
2018	0.903	0.269	0.740	0.619	0.636	0.593	0.502	0.345
2019	0.996	0.336	0.849	0.339	0.786	0.801	0.663	0.354
2020	0.659	0.499	0.124	0.456	0.813	0.798	0.661	0.677
2021	0.668	0.208	0.749	0.732	0.451	0.988	0.752	0.444
2022	0.956	0.302	0.891	0.376	0.807	0.795	0.579	0.684
2023	0.946	0.452	0.883	0.670	0.932	0.597	0.584	0.274
2024	0.105	0.220	0.736	0.760	0.451	0.783	0.248	0.400
2025	0.665	0.727	0.588	0.675	0.643	0.776	0.334	0.329
2026	0.895	0.689	0.500	0.240	0.882	0.785	0.497	0.949
2027	0.840	0.532	0.236	0.203	0.954	0.031	0.665	0.683
2028	0.925	0.389	0.499	0.634	0.864	0.792	0.981	0.255
2029	0.930	0.470	0.853	0.854	0.082	0.401	0.044	0.525
2030	0.867	0.403	0.729	0.032	0.279	0.793	0.578	0.363

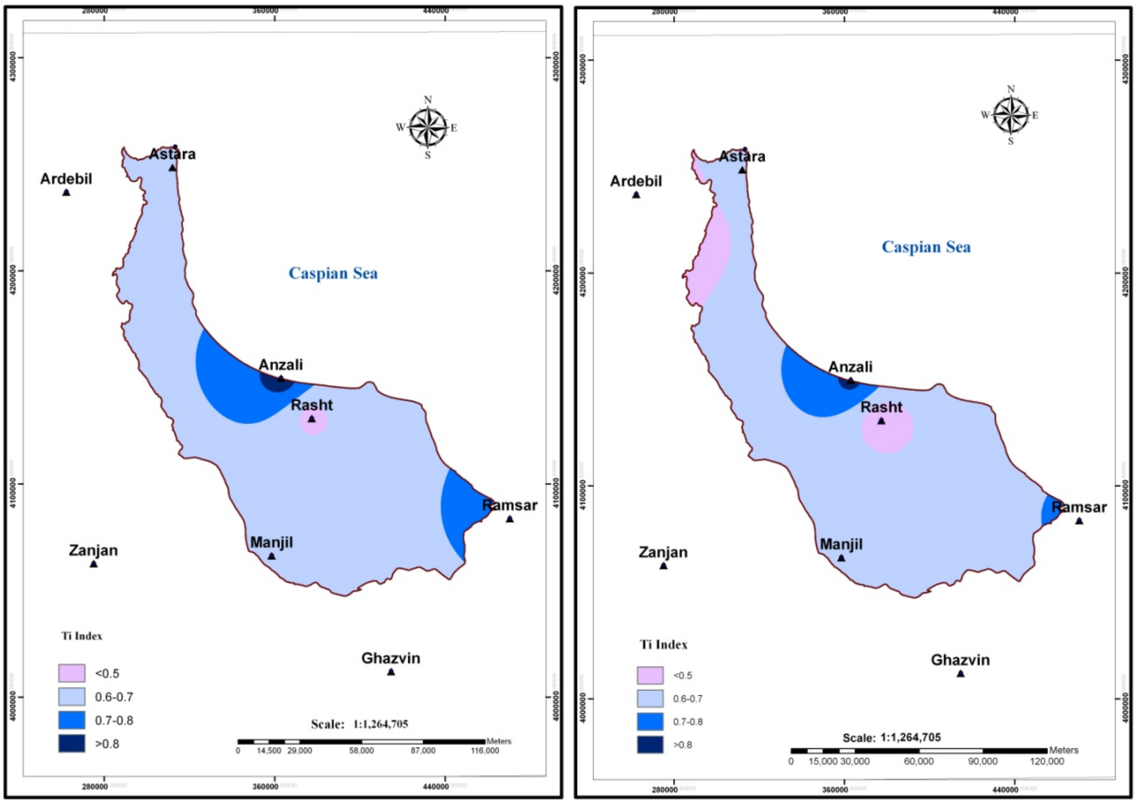

Fig. 3. Drought zoning by TOPSIS method for present (left) and future (right).

Conclusion

After all calculations, by t-test, the results of TOPSIS methods are compared with Standard Index Annual precipitation (SIAP) method. Results show that there is no significant differences between these two methods ($p \leq 0.05$). In the proposed method, systematic relationships between amounts of climatic parameters in different years is influence to determine drought and ranking it. In this method, we apply 7 climatic parameters, so it is more effective than other simple methods that only use one or two variables. Other ability of this method is ranking the drought. This method has more advantages than the SIAP and other methods. It minimizes the distance to the ideal alternative while maximizing the distance to the nadir. A relative advantage of this method is the ability to identify the best alternative quickly. It was found to perform almost as well as multiplicative additive weights and better than analytic hierarchy process in matching a base prediction model.

Comparison predicting period (2011-2030) with base period (1992-2010) show Ti index will decreased in the study area. Maps show the area of lower Ti index (<0.5) will increased in central parts of Rasht and western parts of Astara and Talesh in 2011 to 2030 period. It is expected that drought will increased in this period. In addition, area of higher Ti index (>0.7) will decreased in Anzali, Rezvanshahr, Masal, Somehsara and Roodsar. Though it is not expected drought, but wetness will decreased and it is alarm for these areas. In other areas, it is no changes in Ti index and it is from 0.6 to 0.7 in each period.

References

BARDOSSY A. 1997. Downscaling from GCMs to local climate through stochastic linkages. - *Journal of Environmental Management*, 49(1):7–17. DOI:10.1006/jema.1996.0112.

BARROW E., M. HULME, M.A. SEMENOV. 1996. Effect of using different methods in the construction of climate change scenarios: examples from Europe. - *Climate Research*, 7(3):195–211. DOI:10.3354/cr007195.

BARROW E.M., M.A. SEMENOV. 1995. Climate change scenarios with high spatial and temporal resolution for agricultural applications. - *Forestry*, 68:349–360. DOI:10.1093/forestry/68.4.349.

CHEN M.F., G.H. TZENG. 2004. Combining gray relation and TOPSIS concepts for selecting an expatriate host country. - *Mathematical and Computer Modelling*, 40: 1473–1490. DOI:10.1016/j.mcm.2005.01.006.

DUBROVSKY M. 1996. The stochastic generator of daily weather series for the crop growth model. - *Meteorologicke Zpravy*, 49: 97-105.

JANIC M. 2003. Multicriteria evaluation of high-speed rail, transrapid maglev, and air passenger transport in Europe. - *Transportation Planning and Technology*, 26 (6): 491–512. DOI:10.1080/0308106032000167373

KARDAVANI P. 2001. *Drought and the Ways to consecutive and comprehensive wet/dry-years periods of Confront It in Iran*. Vol. I. Tehran. Tehran University publications. 392 p.

KHAN M.S., P. COULIBLY, Y. DIBIKE. 2006. Uncertainty analysis of statistical downscaling methods using Canadian Global Climate Model predictors. - *Hydrology Processes*, 20(14): 3085–3104. DOI:10.1002/hyp.6084.

KWONG C.K., S.M. TAM. 2002. Case-based reasoning approach to concurrent design of low power transformers. - *Journal of Materials Processing Technology*, 128: 136–141. DOI:10.1016/S0924-0136(02)00440-5.

LAI Y.J. 1994. TOPSIS for MODM. - *European Journal of Operational Research*, 76(3): 486–500. DOI:10.1016/0377-2217(94)90282-8.

LAWLESS C., M.A. SEMENOV. 2005. Assessing lead time for predicting wheat growth using a crop simulation model. - *Agricultural and Forest Meteorology*, 135: 302-313. DOI:10.1016/j.agrformet.2006.01.002.

MEARNS L.O., I. BOGARDI, F. GIORGI, I. MATYASOVSKEY, M. PALESKI. 1999.

Comparison of climate change scenarios generated from regional climate model experiments and statistical downscaling. – *Journal of Geophysical Research*, 104: 6603–6621.

MEARNS L.O., C. ROSENZWEIG, R. GOLDBERG. 1997. Mean and variance change in climate scenarios: methods, agricultural applications, and measures of uncertainty. - *Climate Change*, 35(4):367–396. DOI:10.1023/A:1005358130291.

MILANI A.S., A. SHANIAN, R. MADOLIAT. 2005. The effect of normalization norms in multiple attribute decision making models: A case study in gear material selection. - *Structural Multidisciplinary Optimization*, 29 (4): 312–318. DOI:10.1007/s00158-004-0473-1.

MURPHY J. 1999. An evaluation of statistical and dynamical techniques for downscaling local climate. – *Journal of Climate,* 12(8): 2256–2284. DOI:10.1175/1520-0442(1999)012<2256:AEOSAD>2.0.CO;2

RIEBSAME W.E., S.A. CHANGNON, T.R. KARL. 1991. *Drought and Natural Resource Management in the United States: Impacts and Implications of the 1987–1989 Drought*. Westview Press. Boulder. CO. 174 p.

SALON S., G. COSSARINI, S. LIBRALATO, X. GAO, S. SOLIDORO, F. GIORGI. 2009. Downscaling experiment for the Venice lagoon. I. Validation of the present-day precipitation climatology. - *Climate Research,* 38:31–41. DOI:10.3354/cr00757.

SCIBEK J., D.M. ALLEN. 2006. Modelled impacts of predicted climate change on recharge and groundwater levels. - *Water Resource Research*, 42(11): W11405. DOI:10.1029/2005WR004742.

SEMENOV M.A., R.F.J. DOBLAS. 2007. Utility of dynamical seasonal forecasts in predicting crop yield. - *Climate Research*, 34(1): 71–81. DOI:10.3354/cr034071.

SEMENOV M.A. 2007. Development of high-resolution UKCIP02-based climate change scenarios in the UK. - *Agricultural and Forest Meteorology*, 144(1-2): 127-138. DOI:10.1016/j.agrformet.2007.02.003.

SEMENOV M.A., E.M. BARROW. 1997. Use of a stochastic weather generator in the development of climate change scenarios. - *Climatic Change*, 35(4):397–414. DOI:10.1023/A:1005342632279.

SHIH H.S., W.Y. LIN, E.S. LEE. 2001. Group decision making for TOPSIS, - In: *IFSA World Congress and 20th NAFIPS International Conference.* Vancouver, Canada, 5: 2712–2717.

SRDJEVIC B., Y.D.P. MEDEIROS, A.S. FARIA. 2004. An objective multi-criteria evaluation of water management scenarios. - *Water Resources Management* 18(1): 35–54. DOI:10.1023/B:WARM.0000015348.88832.52.

WEBSTER K.E., T.M. KRATZ, C.J. BOWSER, J.J. ADAGNUSON. 1996. The influence of landscape position on lake chemical responses to drought in Northern Wisconsin. – *Limnology and Oceanography,* 41(5): 977–984. DOI:10.4319/lo.1996.41.5.0977.

WEISS A., C.J. HAYS, J. WON. 2003 Assessing winter wheat responses to climate change scenarios: a simulation study in the U.S. Great Plains. - *Climate Change*, 58: 119–147. DOI:10.1023/A:1023499612729.

WILBY R.L., T.M.L. WIGLEY, D. CONWAY, P.D. JONES, B.C. HEWISTON, J. MAIN, D.S. WILKS. 1998. Statistical downscaling of general circulation model output: a comparison of methods. - *Water Resource Research*, 34(11): 2995–3008. DOI:10.1029/98WR02577.

WILHITE D.A. 1992. *Preparing for Drought: A Guidebook for Developing Countries*. Nebraska. Diane books publishing company. 78 p.

WILKS D.S., R.L. WILBY. 1999. The weather generation game: a review of stochastic weather models. – *Progress in Physical Geography*, 23(3): 329–357. DOI:10.1177/030913339902300302.

WILKS D.S. 1992. Adapting stochastic weather generation algorithms for climate changes studies. - *Climatic Change,* 22: 67–84. DOI:10.1007/BF00143344.

YANG T., P. CHOU. 2005. Solving a multiresponse simulation–optimization problem with discrete variables using a multi-attribute decision-making method. - *Mathematics and Computers in Simulation*, 68(1): 9–21. DOI:10.1016/j.matcom.2004.09.004

YOON K., C.L. HWANG. 1985. Manufacturing plant location analysis by multiple attribute decision making: Part I—single-plant strategy. - *International Journal of Production Research,* 23(2): 345–359. DOI:10.1080/00207548508904712.

Received: 20.12.2014
Accepted: 12.03.2015