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Comparison of SIAP and TOPSIS model for drought assessment in Gilan province, Iran

Ladan Kazemi Rad[1*] and Hosein Mohammadi[2]

1- Ph.D Student, Department of Geography, Science and Research Branch, Islamic Azad University, Tehran, Iran

2- Prof., Department of Geography, Tehran University

***Corresponding author*:** Ladan Kazemi Rad

ABSTRACT: Droughts are recognized as an environmental disaster and have attracted the attention of environmentalists, ecologists, hydrologists, meteorologists, geologists and agricultural scientists. 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. In this research, by using TOPSIS method and seven climatic factors, droughts were identified and ranked in Gilan. Then output data were compared with SIAP method and finally, the study area is classified with proposed method.

***Keywords*:** Drought, Zoning, TOPSIS, SIAP, Gilan.

INTRODUCTION

Drought as a complex natural hazard is best characterized by multiple climatological and hydrological parameters and the assessment of it is important for planning and managing water resources [19]. Droughts occur in virtually all climatic zones, such as high as well as low rainfall areas and 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 [26].

Generally, drought is a phenomenon which occurs in every area or country, with either arid or humid climate. It is not a new or unknown phenomenon, 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 [8]. Even in northern of Iran that has wet climate, this phenomena has observed and exists many damages in agricultural economics and environmental landscapes [1].

Owing to the rise in water demand and looming climate change, recent years have witnessed much focus on global drought scenarios. So understanding the history of drought in the area is essential like investigating the effects of drought [24].

A number of different indices have been developed to quantify a drought, each with its own strengths and weaknesses. They include the Palmer drought severity index (PDSI) [17], rainfall anomaly index (RAI) [23], deciles [4], crop moisture index (CMI) [18], Bhalme and Mooly drought index (BMDI) [2], surface water supply index (SWSI) [20], national rainfall index (NRI) [5], standardized precipitation index (SPI) [12, 13], and reclamation drought index (RDI) [25]. The soil moisture drought index (SMDI) [6] and crop-specific drought index (CSDI) [15] appeared after CMI. Furthermore, CSDI is divided into a corn drought index (CDI) [14] and soybean drought index (SDI) [15], and vegetation condition index (VCI) [11].

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. The TOPSIS method was initially presented by Hwang and Yoon (1981). Although MADM is a practical tool for selection 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 [3], transportation [7], product design [9], manufacturing [16], water management [22], quality control [27], and location analysis [28]. In addition, the concept of TOPSIS has also been connected to multi-objective decision making [10] and group decision making [21]. 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.

MATERIALS AND METHODS

Study area

The study area is Gilan Province of Iran, which situated in the north of Iran and located in the South of Caspian Sea and has about 14044 kilometers extent area. 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 (Figure 1). It has the best type of weather and climate in Iran with a moderate and humid climate that is known as the moderate Caspian climate. The effective factors on such 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.

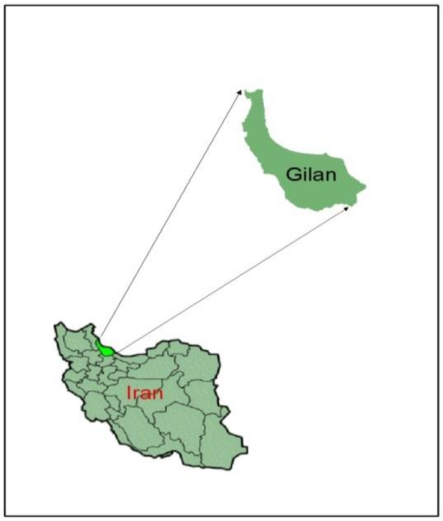

Figure 1. Study area location

Methods

TOPSIS method is used for determining and ranking of drought in the study area. 7 Climatic Parameters consisting Monthly total of precipitation in mm, Average of maximum and minimum temperature in ºC, The mean of days with precipitation more than 0.1 mm (numbers of Wet day), The mean of days with precipitation less than 0.1 mm (numbers of dry day), The mean of days with maximum temperature more than 30 ºC (numbers of hot day), The mean of days with minimum temperature equal or less than 0 ºC (numbers of frost day) that are influencing on drought are used. Name, latitude and longitude coordinates, as well as the elevation of the synoptic stations are shown in Table 1. Missing data are estimated by regression method and Homogeneity of data is determined by Run-Test method. By using TOPSIS method and Matlab software, droughts are identified and ranked in the study area. Then output data were compared with SIAP method and finally, the study area is classified with proposed method.

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

Steps of operations can be expressed as followed:

(1) Obtain performance data for 18 alternatives (Number of statistical years) over 7 criteria (Climatic Parameters). Raw measurements are usually standardized,

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

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

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

Doing this section has 4 steps:
Step1: Determining distribution of each climatic parameter.

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

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

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

Step3: Calculating uncertainty for each climatic parameter.

$$d = 1 - E_j : \forall_j$$

Step4: Calculating weight of climatic parameters.

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

(3) Multiplying matrix X (consisting 7 climatic parameters and 18 years) in the vector Wj (weight of each climatic parameter).
(4) Assimilating climatic parameters: Increasing in 4 Climatic Parameters consisting Average of maximum and minimum temperature, numbers of dry day, numbers of hot day and numbers of frost day and also decreasing in 2 other factors consisting Monthly total of precipitation and numbers of wet day 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^- :

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

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

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

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

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

(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,

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

(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.

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

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

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 1. Results are shown in Table 2:

Table 2. weight of climatic parameters in stations of study area

Station	precipitation	minimum temperature	maximum temperature	Wet day	dry day	hot day	frost day
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

According to table 3, distance of each year from ideal and nadir are determined

Table 3. 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

Results of calculating ratio Ti are shown in table 4

Table 4. ratio Ti for each alternative

	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

After all calculations, by t-test, the results of TOPSIS methods are compared with Standard Index Annual precipitation (SIAP) method. Results show there is no significant differences between these two methods ($p \leq 0/05$).

At the end, by using the interpolation method (IDW) in ArcGIS 9.3 software, zoning drought of study area is done (figure 1).

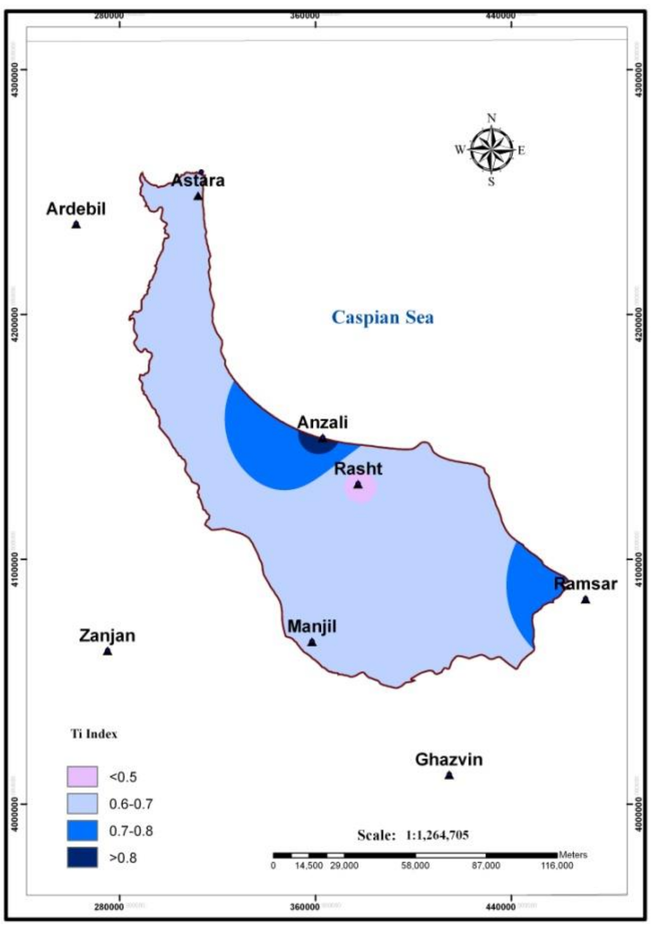

Figure 2. Drought zoning by TOPSIS method

CONCULSION

In the proposed method, systematic relationship 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.

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