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RESEARCH PAPER

Forecasting occur probability intense storm using Gumbel Distribution; Case study: Nahavand township

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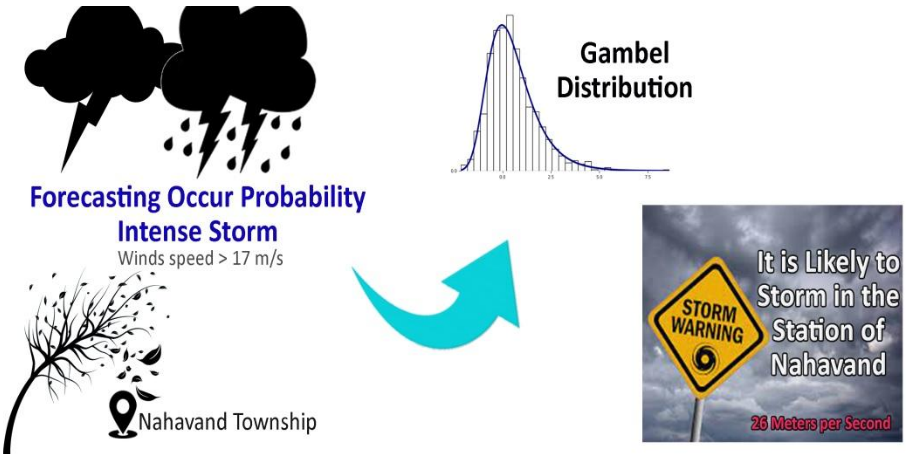
Highlights

- Natural disasters such as storms are not tangible that allocate about 30% share of 90% of natural disasters.
- Nahavand due to climatic characteristics and topography is an area stormy in Hamedan province.
- Types of distribution were applied using Smada software which best fit was for the Gumbel distribution.
- The maximum of thunderstorms of Hamedan province occurred in Nahavand station and most number of them is in the spring season.

Graphical Abstract



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Abstract

Natural disasters such as storm are not tangible that allocate about 30% share of 90% of natural disasters. This study aimed to forecast occur probability of intense storms using Gumbel distribution in Nahavand township based on 10 years, period from 1996 to 2005. Nahavand due to climatic characteristics and topography is an area stormy in Hamedan province and base on Nahavand station include the most occur storms in 2003 and 2004. In this study, Rainfall zoning of Hamedan province was done by geo statistic based on average rainfall 33 stations in Hamedan province and 10 stations from neighboring provinces. For indicating average speed and aspect of wind was used Wind rose. Using Wind rose software designed wind rose of autumn and winter moreover. Gumbel distribution was used for study statistically and predicting the incident probability of stormy and strong winds in Nahavand. To select days along with stormy and strong wind, winds with equal speed and more than 17 m/s and accepted by the Weather Meteorology Organization (WMO) are accounted as days by a stormy and strong wind. Also, applied types of distribution using Smada software which best fit was for the Gumbel distribution. Based on the Beaufort index in a return period of 5 years, with a speed of 26 m/s and more there is likely to storm in the station of Nahavand. On the other hand, the maximum of thunderstorms of Hamedan province occurred in Nahavand station and most number of them is in the spring season. If the storm continued causing great damage to agriculture, services, electricity and telephone lines, trees, and gardens, etc. Thus, for the environmental planning and safety of structures must consider the occurrence of this natural danger to decrease these disturbing effects.

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1. Introduction

All around the world disasters and hazards occur that always endanger human life and property. Among these disasters, the storm is one of the most dangerous that allocate about 30% share of 90% of natural disasters related to climatic factors and yearly enter irreparable damage in life and property (Hallström et al., 2015; Sarkki et al., 2016). In some areas of Iran occur incidence of storms by the speed of more than 100 kilometers in one hour occurred times (Baghbanan et al., 2020). High and severe storms are named storms whit different shapes and fast occurred in a short time and are usually associated with unstable weather. If the air unstable include of humidity is named Thunderstorm and if the air unstable is dry caused dust storm. Wind speed is vectoring quantity whit two items of intensity and aspect; the intensity of wind is calculated based on m/s, node/s, km/s, km/h, mil/h, etc. (Berkowitz and Balberg, 1993). The wind aspect calculated based on degrees and include of sixteen primary and secondary aspect, including the north, northeast, east, southeast, south, southwest, west, northwest, etc. respectively (Alizadeh-Choobari and Najafi, 2018). Wind forces greatly changing throughout the year and during the day (Zobeck, 1991). The main factor of wind causing is the pressure gradient between high and low-pressure points. When the wind speed is greater than a certain threshold, a storm occurred and started the destructive activity; for determining the contribution of strong winds and storms, knowing the characteristics of the wind (speed and aspect) in case study necessary.

Anyway, probability and intensity forecasts were subjectively determined based on the examination of several observed and forecast parameters in the case study, in a manner consistent with other Storm Prediction Center (SPC) severe weather forecast products (Vescio and Thompson, 2001). In the area, do not research, but have done some research on Nahavand wind patterns; Maryanaji et al., analyzed wind energy capacity in Nahavad township (Maryanaji et al., 2018); Rostami et al., researched about winds forecast synoptic patterns in Hamedan province (Rostami et al., 2014). Dargahian and Doostkamian, researched statistical analysis and predicting the incident probability of stormy and strong winds using analysis of a series of minor in the Sistan area (Dargahian and Doostkamian, 2021). Baghbanan et al., using synoptic maps indicated exist of low-pressure centers in different parts of Iran causing the occurrence of hurricanes in the northeast of Iran (Baghbanan et al., 2020). Akhzari and Haghighi, related main dust storms of western parts of Iranian originated from Iraq as one of the main sources of dust storms (Akhzari and Haghighi, 2015); The velocity of wind erosion has been increased in 2013 compared with 2003. Thunderstorms at all stations occurs in the spring season in the Hamedan province; in this season due to increase solar radiation energy along whit atmospheric humidity derived from evaporation, vegetation and thermodynamic transport system in the west and southwest of Iran, occurred the most number of storms in Nahavand city; the autumn season is the second viewpoint of storms occurrence. Therefore, this study aimed to forecast occur probability of intense storms using Gumbel distribution in Nahavand township based on 10 years, period from 1996 to 2005.

2. Materials and Methods

Nahavand township is located in Hamadan province, Iran (Fig. 1). This area has latitude 33º 39' 21'' to 34º 26' 40'' north and longitude 47º 52' 55'' to 48º 33' 9'' east with a minimum height of 1615 meters above sea level and maximum height from sea level is 2080 meters (mean height is 1850 meters above sea level). Diverse topographical and climatic conditions have led to high biological diversity in the west of Iran. In geomorphologic division, Nahavand city includes three physiographic sections: Alluvial Plain, Piedmont Plateau and Alluvial Fans. Nahavand Area is 1670 km^2 (Akhzari and Haghighi, 2015).

The maximum and minimum temperature of the study area in summer and winter is 43 °C and -32 °C, respectively. The average annual temperature is about 20 °C (Rostami et al., 2014); this region has a semi-arid climate, summers are fairly mild and winters are relatively cold. According to the regional meteorological center of Nahavand and the result of this study, the average annual rainfall is 425 mm. Fig. 2 indicated embrothermic graph for Nahavand in 1996-2005.

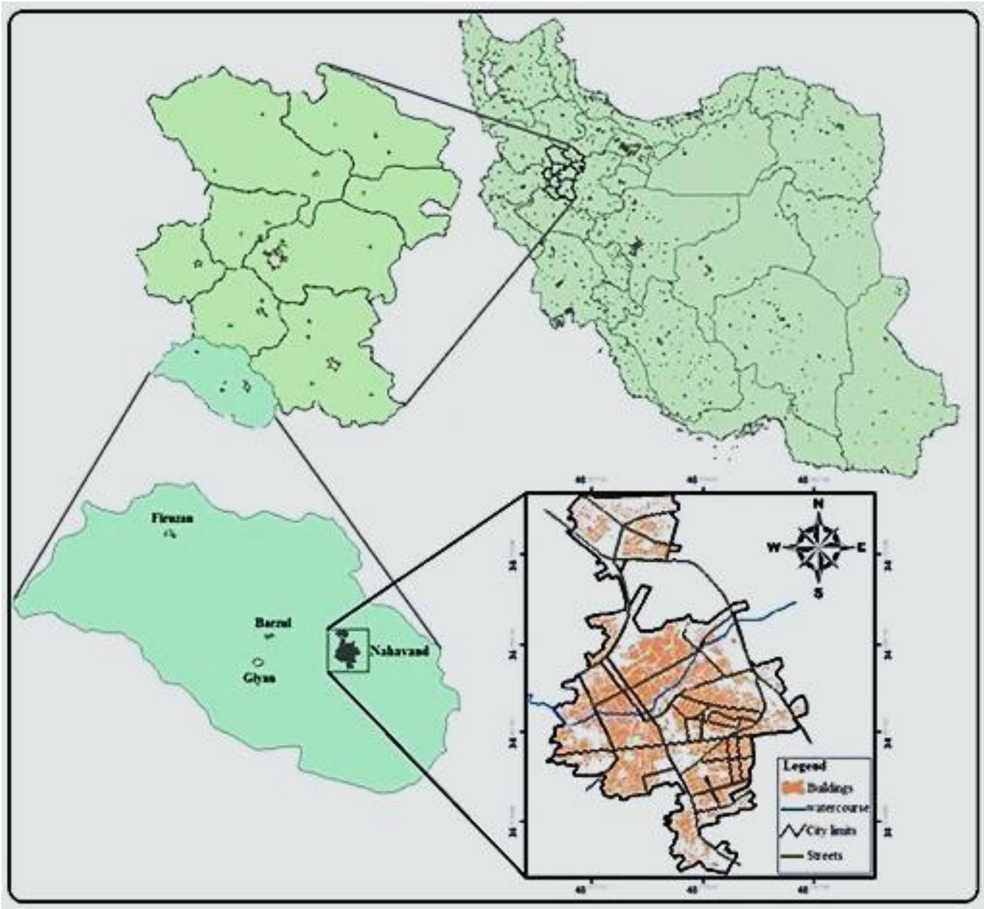

Fig. 1. Position of Nahavand city in Iran.

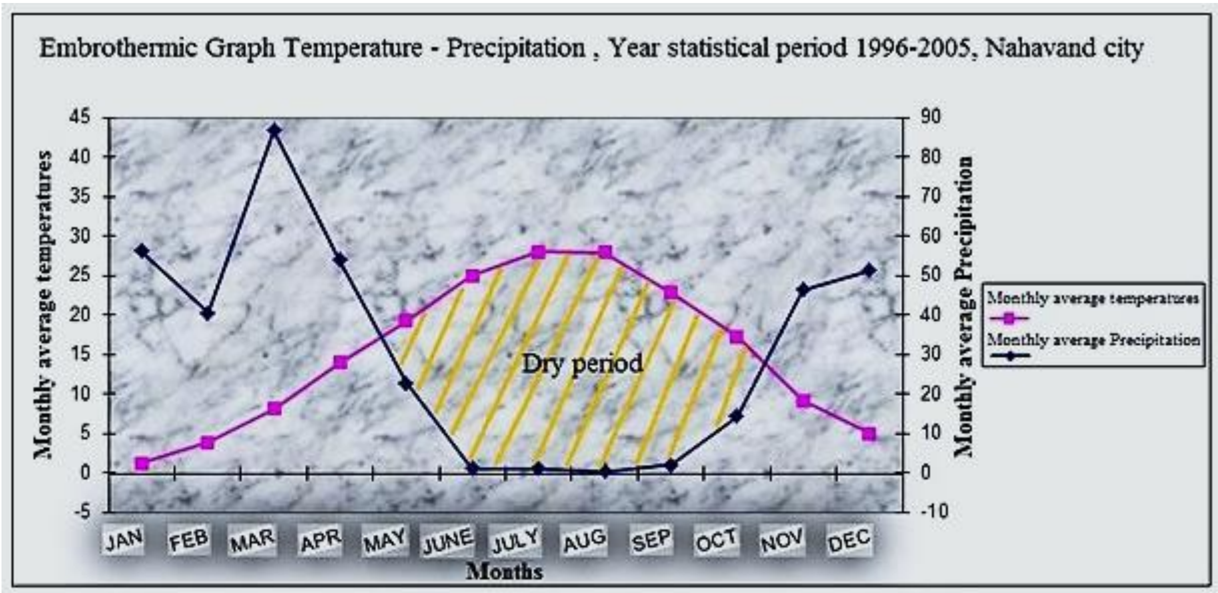

Fig. 2. Embrothermic graph.

In this research rainfall zoning of Hamedan province was done by geo statistic based on average rainfall 33 stations in Hamedan province and 10 stations out of Hamedan province (neighbor provinces). Regarded to for indicating average speed and aspect of wind used wind rose, in this study using wind rose software designed wind rose of autumn and winter moreover (Alizadeh-Choobari and Najafi, 2018). For study statistically and predicting the incident probability of stormy and strong winds in Nahavand used Gumbel distribution. To select days along with stormy and strong wind, winds with equal speed and more than 17 m/s (strong wind base on Beaufort scale) and accepted by Weather Meteorology Organization (WMO) is accounted as days by a stormy and strong wind. Based on the scale of Beaufort winds classification as follows (Table 1).

Table 1. Classification of winds based on scale of Beaufort (Dumitru and Gligor, 2017).

Beaufort Scale	Speed			Condition
	M/S	Mi/h	Knot	
0	0/5	1	1	Calm
1	0/5-1/5	1-3	1-3	Light air
2	2-3	4-7	4-6	Light breeze
3	3/5-5	8-12	7-10	Gentle breeze
4	5/5-8	13-`8	11-16	Moderate breeze
5	8/5-10/5	19-24	17-21	Fresh breeze
6	11-13/5	25-31	22-27	Strong breeze
7	14-16/5	32-38	28-33	Moderate gale
8	17-20	39-46	34-40	Fresh gale
9	20/5-23/5	47-54	41-47	Strong gale
10	24-27/5	55-63	48-55	Whole gale
11	28-31/5	64-72	56-63	Storm
12-17	>32	>72	>64	Hurrican

In this study were applied types of distribution using Smada software; Smada software is hydrological software include software statistically disturb 2.0 which was applied to the data types of distribution such as the normal distribution, log-normal distribution of two parameters and three parameters, Pearson type III and log Pearson type III and Gumbel distribution; the best fit was for the Gumbel distribution because the maximum overlap of Experimental curve and theoretical curve was related to Gumbel distribution (Klemeš, 1983; Lange and Sippel, 2020). Gumbel low applied for excessive data. Hurricane intensity is a random variable calculated by return period and probability (Morgan et al., 2011). Return period inverse than probability (Alizadeh-Choobari and Najafi, 2018); the relationship between return period (T year) and probability (P) is flowing (Equation 1).

$$T=1/P \tag{1}$$

For forecasting probability occur intense storms used Gumbel distribution whit return period 2, 3, 5, 10, 25, 50, 100, and 200 years. Controlled correctness of data; then using Gumbel table and equation 2 for analyses;

$$X=\mu+KS \tag{2}$$

(K) is Frequency coefficient and (S) is Standard deviation. At first winds by speed higher than base speed is selected and without attention to the year occurrence is ranked and accounted incident probability. Then in studying strong storms by certain return period and by using certain statistical (Rollo and Zdziarski, 2020); by considering all strong winds by speed more than base speed, an average occurrence at year is accounted and finally storm speed by certain return period and average speed of predicted storms is obtained. In most probability distributions are calculated the probability of occurrence, but although in Gumbel distribution considered the probability of lack occurrence (Fujita, 1955; Crimmins, 2006; Richardson et al., 2018).

3. Results and Discussion

The maximum annual rainfall in Hamedan province occurred in Nahavand about 600 mm; there are about 130 days in a year is glacial too. Although heavy cloudburst of rain in a few hours caused devastating flooding and killed 200 people of Nadavand in September 1939 (Rostami et al., 2014). Zonal statistics indicated highest average rainfall is 426 mm for Nahavand (Fig. 3).

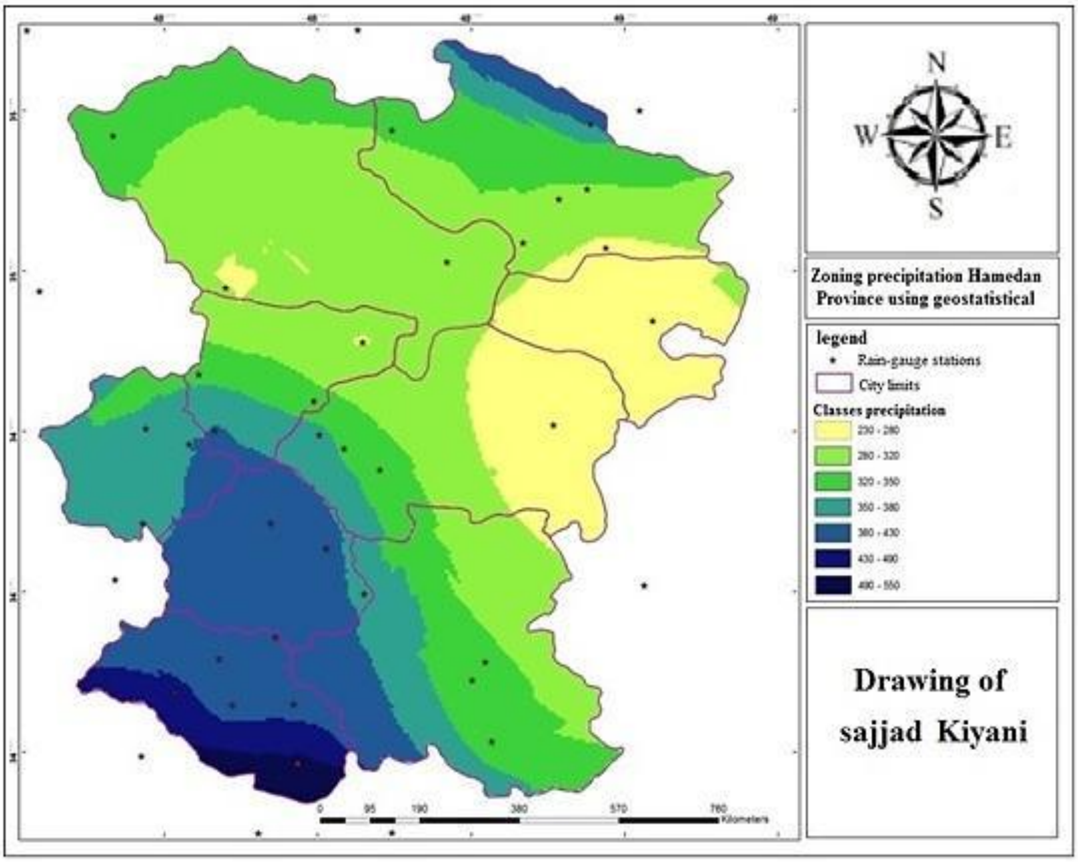

Fig. 3. Rainfall zoning by Geo statistics.

With regard to daily statistics of wind in Nahavad station from 1996 to 2005 calculated winds strongest occurred during each year (Table 2).

Table 2. Wind strongest occurred during 1996 to 2005.

Date of occurred	Wind aspect	Wind speed (m/s)
02/03/1996	190	12
10/01/1997	180	14
18/03/1998	220	15
26/11/1999	200	14
24/03/2000	140	25
24/09/2001	210	20
02/04/2002	110	18
26/03/2003	180	30
23/11/2004	210	25
16/12/2005	90	24

Nahavand due to climatic characteristics and topography is an area stormy in Hamedan province and base on Nahavand station include of the most occur storms in 2003 and 2004 whit speed of 30 m/s. About 8 days have been occur storms in each of these years. In Nahavand station strongest storms occurred in the spring season 35%, and autumn season 34%. The frequency of thunderstorms in spring season is 70 and 30% at day and night respectively; the frequency of thunderstorms in the autumn season is equivalent day and night. Thunderstorm increased during the day and decreased at night in Nahavand. Generally, during the day heating of ground and unstable conditions caused the formation of Hurricane and at night upside down. In this study using wind rose software designed Wind rose of autumn and winter (Fig. 4).

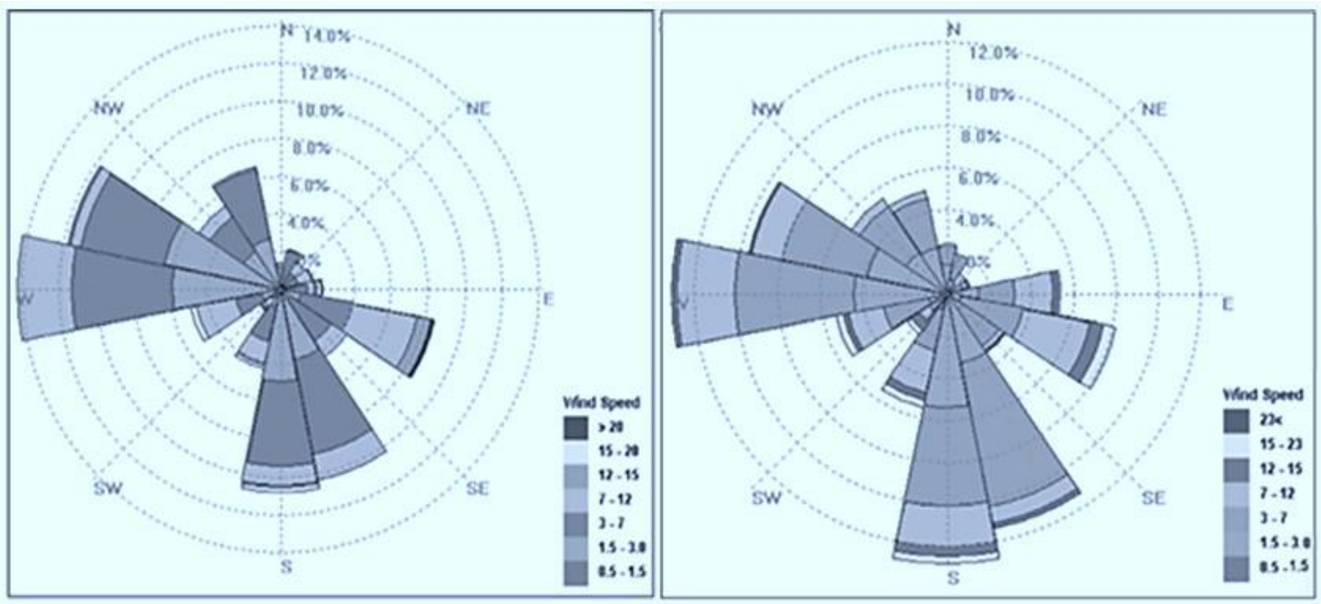

Fig. 4. Wind rose of autumn (left) and winter (right).

Results indicated west wind and wind south were dominant respectively and winds strongest was more than 30 m/s (108 km/h) blowing from southwest Nahavand township at winter season in 10 years, period 1996 to 2005. The best fit was for the Gumbel distribution because the maximum overlap of the experimental curve and theoretical curve was related to the Gumbel distribution (Fig. 5).

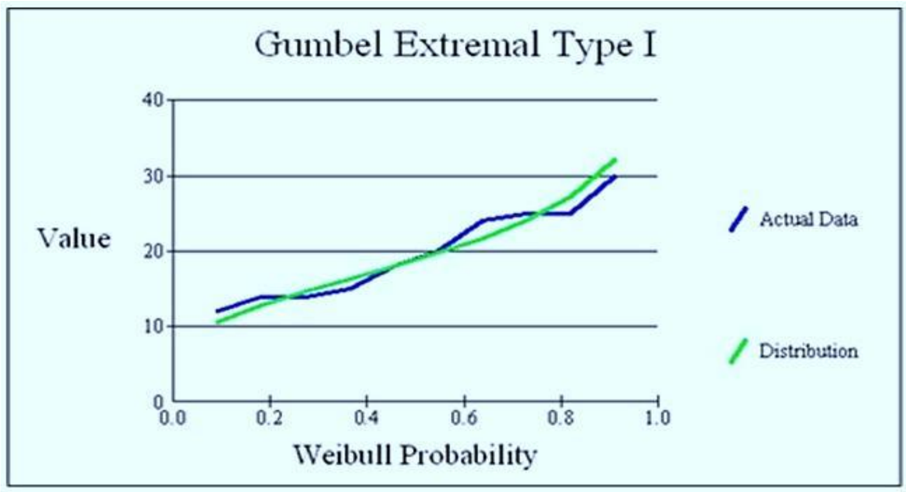

Fig. 5. Overlap of experimental curve and theoretical in Gumbel distribution.

For calculated occur probability of storms in different return, periods used Gumbel distribution; Table 3 indicated result. Predicting the probability of occurrence of storms by speed more than base that performed by analyzing and Gumbel distribution in return periods, has been shown that by probability near to 100% in return period of 200 years have been occurred storms by speed about 52 m/s (Bórawski et al., 2020; Coscarelli and Caloiero, 2012). Also predicted that in return period 50 years by probability 100% have been occurred storms by speed about 43 m/s. The probability of occurrence maximum speed in return period 5 years and above is 26 m/s and upper in Nahavand township.

Table 3. Occur probability of storms in different return period based on Gumbel distribution.

Occur probability	Return period	occur maximum (m/s)	Standard deviation
0.995	200	51.9399	3955.11
0.99	100	47.2679	9344.9
0.98	50	42.5789	4736.8
0.96	25	37.8550	0112.7
0.90	10	31.4873	0692.5
0.80	5	26.4476	5885.3
0.667	3	22.4451	5131.2
0.50	2	18.8357	7737.1

Although the maximum of thunderstorms of Hamedan province occurred in Nahavand station and most number of it is in the spring season; in this season due to increase solar radiation energy along whit atmospheric humidity derived from evaporation, vegetation and thermodynamic transport system in west and southwest of Iran, occurred the most number of storms in Nahavand city (Akhzari and Haghighi, 2015); Climatic characteristics and topography of Nahavand are effective too. Altitude ranges are from 1450 to 3600 meters which caused an increase of differential pressure between plains and mountains. The results of this study confirmed the findings of Dargahian and Doostkamian on statistical analysis and prediction of storm and strong winds (Dargahian and Doostkamian, 2021). The result of this study indicated in the spring season due to increase solar radiation energy along whit atmospheric humidity derived from evaporation, vegetation and thermodynamic transport system in west Iran, occurred the most number of storms in Nahavand city; The autumn season is the second viewpoint of storms occurrence.

Conclusions

Nahavand due to climatic characteristics and topography is an area stormy in Hamedan province and base on Nahavand station include the most occur storms in 2003 and 2004. The maximum of thunderstorms of Hamedan province occurred in Nahavand station and the most number of them is in the spring season. The occurrence probability of strong winds based on Beaufort index by speed more than 26 m/s in return period of 5 years are and above likely in the station of Nahavand approximately to 94% in return period of 5 years and above. If the storm continued causing great damage to agriculture, services, electricity and telephone lines, trees and gardens, etc. In the region; thus, environmental planning and safety of structures must consider the occurrence of this natural danger for decrease these disturbing effects.

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