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RESEARCH PAPER

Investigation and zoning of atmospheric hazards in Kermanshah province in the west of Iran

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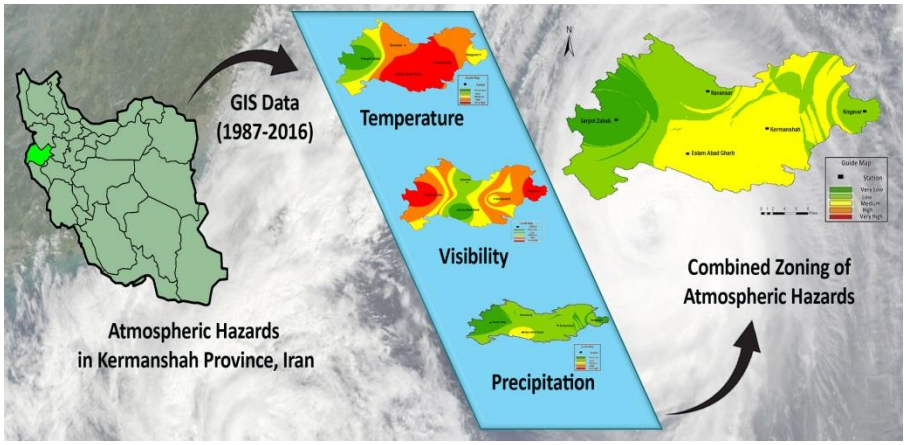
Highlights

- Atmospheric hazards were classified in Kermanshah province located in the west of Iran.
- The center and southern parts were with the riskiest areas.
- Both increasing visibility hazards from the south and the center to the west and to the east.
- Precipitation and temperature hazards decreased from the south to the west and to the east.

Graphical Abstract



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Abstract

The main purpose of this article was to zone atmospheric hazards in Kermanshah province. For this purpose, data were used from the meteorological organization of the province on a daily and monthly scale for a period of 30 years (1987-2016). Thirteen important atmospheric hazards were surveyed within the province. In general, the phenomena studied in the form of two main methods and the occurrence frequency maps were prepared for each of the hazards using the Geographic Information System (GIS) separately. Then, by considering the degree of similarities and differences, the 13 mentioned atmospheric hazards were classified into three main categories as: temperature, visibility and precipitation hazards, and a spatial zoning map were prepared for each category. Finally, by combining the results of all data, a comprehensive map of atmospheric hazards was prepared in the study area. The results of investigation showed the center and southern parts of Kermanshah province with the riskiest areas, while the western parts were with the lowest hazards due to the frequency of occurrences. The spatial pattern for the occurrence of the hazards indicates an increasing trend of visibility hazards from the south and the center to the west and to the east of the province. While for precipitation and temperature hazards, the occurrence of hazards decreased from the south to the west and to the east of province.

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1. Introduction

Any atmospheric phenomenon that causes the weakening and destruction of economic, social and physical capabilities such as financial and human damage and the destruction of infrastructure and economic resources is defined as atmospheric disasters. This phenomenon has multidimensional effects and has attracted by scientists and also politicians. Therefore, due to the importance of the subject, to know them can provide scientific solutions to deal with it. Each of the atmospheric elements alone can carry important atmospheric hazards such as: heat waves and heatstroke, strong winds, dust storms, heavy rainfall, hail and frost and frost. But most of the loss of life and property is based on combined atmospheric phenomena and their secondary hazards. The situation of Iran has been worrying both in terms of earthquakes and changes in precipitation, temperature and the resulting phenomena. However, Kermanshah province is exposed to wet Mediterranean fronts that cause snow and rain in dealing with the Zagros highlands (Faramarzi et al., 2022).

In a study to investigate the limit values of precipitation, using daily precipitation data of 27 synoptic stations with reliable and coverable data of normal standard period 1961-1990 was used. For this reason different parameters such as: maximum daily precipitation indices, maximum 5 consecutive days precipitation, simple intensity index precipitation, number of days with precipitation equal to or more than 10, 20 and 25 mm, were calculated and the trend of their changes were studied for practical purposes (Bannayan et al., 2011).

The investigation of changes in heavy snowfall in the northwestern region of the Iran country showed that in terms of the ratio of heavy snowfall for 5 snowy months of the year, Ardabil with 90% and Maragheh with only 41% had the highest and lowest ratios, respectively (Rahimi et al., 2019).

Parts of Iran, such as the northwest of the country, are occasionally affected by the phenomenon of frost and very low temperatures, along with strong winds, which can have adverse effects on human health and living organisms and plants. Therefore, in a study, the calculation of chill wind index was investigated as one of the important indicators of body comfort and recognition and presentation of synoptic patterns related to this index for northwestern Iran (Safarianzengir et al., 2020).

Atmospheric hazards were zoned in Khorasans province located in the northeastern of Iran. For this purpose, data from the meteorological organization was used on a daily and monthly scale for 17 synoptic meteorological stations in the three provinces of North Khorasan, Razavi Khorasan and South Khorasan for a 38-year period (1971-2008). In this study,13 important atmospheric hazards were studied. The results of investigation showed that the mountainous parts of North Khorasan were among the most hazardous areas in terms of frequency of occurrences, while the western and the southern parts of Khorasan was in the lowest hazard (Mofidi et al., 2013).

A study was conducted to determine the effects of rainfall changes on flooding of the Ravand river catchment area in Islamabad-e-Gharb region located in Kermanshah province. The results showed that the values of rainfall in the study area was decreased, but the intensity of rainfall and flooding were increased due to different human and natural factors (Dhital and Kayastha, 2013).

A study under the trend of the number of icy days in the most parts of Iran showed that the trend of the number of icy days were decreased in the northwest, low and flat areas of the southern, the central and the eastern regions of Iran. Only a very small percentage of Zagros and Alborz mountains have a positive trend. Also, the most negative and positive frosty days were obtained in January March respectively (Pitcher et al., 2016).

Climatic zoning of atmospheric hazards took place in northwestern Iran. For this purpose, the data including average, minimum and maximum temperature and daily and monthly precipitation for thirteen synoptic meteorological stations were used in the three provinces of East Azerbaijan, West Azerbaijan and Ardabil for a period of 26 years (1990-2015). In this study, ten important atmospheric hazards were examined. Then, frequency occurrence maps were prepared for each of the hazards using GIS separately. The results showed that in all investigated area, the center and the west parts were the most hazardous areas in terms of frequency occurrence of hazards (Hafezi Moghaddas and Hajizadeh Namaghi, 2011).

Vulnerability to drought among the cities of Golestan province by three components of (exposure, sensitivity and adaptability) identified and by three components and data related to indicators were collected. The results showed that in the dimension exposure to Bandar-e-Gaz, Bandar-e-Turkmen and Aqqala ranked first to third, respectively, and were exposed to drought. Azadshahr, Galikesh and Bandar-e-Turkmen counties were ranked first to third most drought sensitive, respectively. Morover, Gomishan, Galikesh and Maravhatpeh cities were the most adapted regions to drought, respectively (Nasrollahi et al., 2018).

On the other hand, because of Kermanshah province suffers a lot of economic losses (especially in agriculture) as a result of various weather hazards such as drought, frost, hail, dust storms, etc. every year. Moreover, accurate knowledge of areas with high potential for atmospheric hazards can provide appropriate and valuable information to prevent or control the above-mentioned disasters. Therefore, the present study aims to provide a comprehensive zoning of occurrence of atmospheric hazards in Kermanshah province while examining each of the atmospheric hazards in the region separately (Zargaran Khouzani and Gharineh, 2021).

2. Materials and methods

2.1. Study of area

In this study, Kermanshah province was considered with an area of 25008 square kilometers, between 33° 40′ to 35° 18′ minutes north latitude and 45° 24′ to 48° 7′ east longitude, which is from north to Kurdistan province, from south to Lorestan and Ilam provinces, from east to Hamedan province, and from west to Iraq with more than 330 km of common border with this country. The average rainfall of the province is approximately 450 mm. Based on de Domarton climate classification, the province's climate was divided into four climatic groups as: dry, Mediterranean, semi-arid and humid. Fig. 1 shows the location of Kermanshah province in the country and its relevant cities.

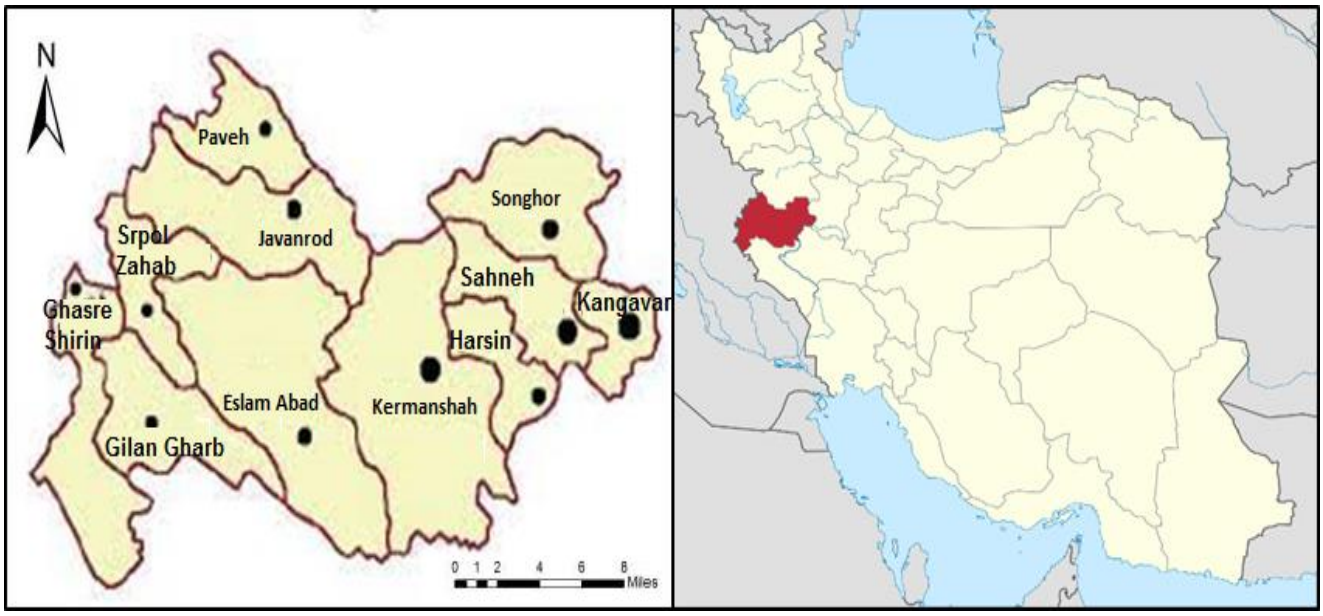

Fig. 1. Location of Kermanshah province and related cities in the country.

2.2. Methods

For this research, different meteorological data including precipitation, minimum, maximum and average temperature, wind direction and wind speed, visibility and weather conditions were used. The above data were received on a daily and monthly scale from the Meteorological Organization of Kermanshah province for 5 main synoptic stations with long-term statistics data in Kermanshah province and were used for a period of thirty years (1987-2016). Table 1 shows the details of the different stations used in this research.

Table 1. Details of the used stations.

No	Location of Station	Geographical attributes		
		Longitude	Latitude	Altitude
1	Kermanshah	47.15	34.35	1318
2	Islamabad-e-Gharb	46.47	34.12	1349
3	Sarpol-e- Zahab	45.87	34.45	545
4	Kangavar	47.98	34.5	1468
5	Ravansar	46.65	34.72	1380

The research method in this article step by step were as follow:

A) Atmospheric hazards for the region were determined in the first step based on existing records, previous reports and surveys, and in the second step based on the processing performed on meteorological station data. Studies indicated 13 cases of weather hazards for Kermanshah province, which were:

1) Drought (moderate and severe), 2) Heavy rainfall, 3) Moderate rainfall, 4) Hail, 5) Heavy snowfall, 6) Thunderstorm, 7) Dusty days, 8) Dust storm, 9) Fog, 10) Wind chill, 11) Blizzard, 12) Heat waves, 13) Frost.

B) After determining the types of atmospheric hazards in the region, in order to extract the occurrence frequency of each hazard, one of the following two methods was performed:

1) Using certain meteorological codes that have been determined by the World Meteorological Organization for each of the phenomena and represent different atmospheric phenomena, including atmospheric hazards. The mentioned codes could be extracted from the weather condition data prepared by the Meteorological Organization of the country in 3 hours. In this regard, the 3-hour data file of Kermanshah Meteorological Organization for 5 synoptic meteorological stations in the region and during 30-year statistical period were used to determine different hazards such as hail, heavy snowfall, thunderstorms, fog, dusty days, dust storms and blizzards. The occurrence frequency of 7 atmospheric hazards was extracted by hourly atmospheric monitoring data.

2) For some atmospheric hazards such as frost, drought, heavy rainfall, heat waves and hurricanes, separate and special study methods were designed to be able to properly indicate the occurrence of this phenomenon. The method of calculating this category of atmospheric hazards is presented in Table 2.

Precipitation hazards were as: heavy rainfall, light rainfall, heavy snowfall, hail, thunderstorms and drought (severe drought and moderate drought) that the result combination of those hazards was presented as a zoning map of precipitation hazards. Temperature hazards were as: frost, blizzard and heat waves. Visual hazards: fog, blizzard, dusty days, dust storms.

In the last stage of the research, the final hazard map of Kermanshah province was prepared by integrating information related to all atmospheric hazards. In this stage, information related to all atmospheric hazards in five classes and with equal valuation was used to produce the final map. It should be mentioned that the hazard of blizzard was not observed in Kermanshah province despite the mental image.

After extracting the annual occurrence frequency data for each of the above-mentioned hazards, frequency occurrence maps were prepared for each hazard by using the GIS separately. Two methods of interpolation, IDW (Inverse Distance Weighted) and Kriging, were tested on the data, but at the end, no significant difference was observed in the results of those two interpolation methods. Finally, the IDW method was selected and used for interpolation.

For all different hazards (input information layers) to have equal weight and value in zoning of atmospheric hazards, from the beginning, the frequency of occurrence of all hazards was classified into five categories as: very low, low, medium, high and very high. At the same time, in order to summarize and obtain a comprehensive view of the occurrence and distribution of atmospheric hazards in Kermanshah province, the types of studied hazards were classified into three main categories of atmospheric hazards, including precipitation hazards, temperature hazards and visibility hazards.

Table 2. Calculation methods or detection limits for types of atmospheric hazards.

Hazards		Method
Precipitation	Drought Hail	SPI index was used to calculate the drought and its amount was calculated according to the following equation using monthly rainfall data. In this study, 12-month SPI was used. $SPI = \frac{P_{ik} - P_i}{\sigma_i}$ σi = standard deviation of the data of the ith station Pik = precipitation values for the 1st station and the kth observation Pi = average precipitation of ith station
		Codes 27 and 87 - 88 - 90 - 93 - 94 - 96 - 99
	Heavy snowfall	Codes 73 -74 -75
	Thunderstorm	Codes 92-93 - 94 - 95 - 96 - 97 - 98 - 99
	Heavy rainfall and moderate rainfall	Heavy and moderate rainfall were extracted based on the percentage threshold method (Mofidi et al., 2013) and daily rainfall data for a period of 30 years (1987-2016). First, for each station, the threshold values of heavy rainfall and moderate rainfall were determined based on 5% and 10% of the average annual rainfall of that station. Then an average threshold was obtained for the whole of Kermanshah province. The amount of heavy rainfall and moderate rainfall in Kermanshah province were 22.17 and 44.35 mm, respectively.
Temperature	Frost	Minimum daily temperature data from October to May were used and zero temperature and lower were considered.
	Heat waves	Daily maximum temperature data were used during the statistical period of 30 years (1987-2016). The long-term average of maximum temperature was calculated for each month and each station. According to the definition of the World Meteorological Organization, if the maximum temperature at the station was 5 C° above the long-term maximum temperature of that month for 5 consecutive days, it was considered as a heat wave (Glickman, 2000; Fritch, 2002). For this part of the research, hot period data (April to October) were used.
	Wind chill	Wind chill was calculated based on the following equation and using daily minimum temperature data for 30 statistical years (1987-2016). Wind chill: 35.74 + .6215T- 35.75(V^.16) + .4275T(V^.16) T = wind speed per mph V = air temperature based on Fahrenheit degree Then, from the wind chill temperature rating table (Osuzowski and Blostein, 2005) wind chill was extracted for each station. Calculations were performed for the cold months (October-April). In this study, the degree of wind chill was not considered and only the days with wind chill were separated from other days.
Visual	Dust storm	Codes 6 to 9 and 30 to 35 with a horizontal view of less than 1000 meters
	Dusty days	Data were used from days with dust of the country's meteorological organization (codes 5-6-7-8-9)
	Fog	Codes 40 - 41 - 42 - 43 - 44 - 45 - 46 - 47 - 48 - 49
	Blizzard	Codes 38-39 70 to 73 (light, medium, heavy snowfall) plus a wind speed of 56 km/h or more, with a horizontal visibility of less than 400 meters for at least 3 hours (Brankick, 1997-Schwartz, 2002-Schwartz, 2005) which according to the conditions of the region, less than 1000 meters have been used in this research.

3. Results and Discussion

3.1. Entrepreneurship potential of Kermanshah agricultural sector zoning of precipitation hazards

Precipitation hazards were as: heavy rainfall, light rainfall, heavy snowfall, thunderstorms, hail and drought (moderate drought and severe drought). The general characteristics of precipitation hazards are summarized in Fig. 2. As this figure shows, the southern part of the province was with the highest occurrence of precipitation hazards. In other words, the southern regions of Kermanshah province was the most dangerous areas in terms of precipitation and related hazards. At the same time, as we move from the southern region to the east and to the west of the province, this category of risks was decreases. The center and the north of the province was in the second row of this risk.

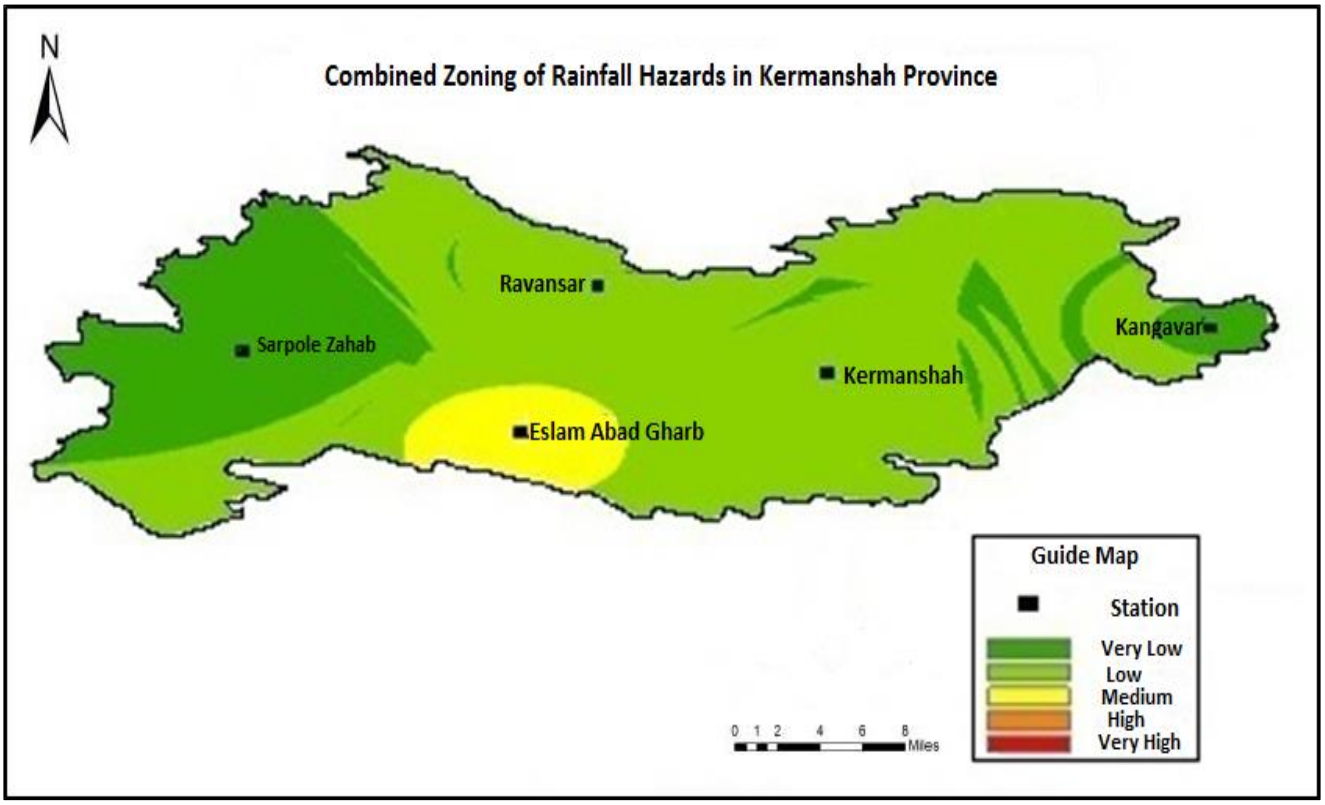

Fig. 2. Precipitation hazards in the study area.

Although the occurrence of this hazard (precipitation) not occur in the high and very high class in Kermanshah province, but Islamabad-e-Gharb station was in the middle class as the most dangerous station. Because of two reason which Islamabad-e-Gharb is exposed to the rainy currents of the western Mediterranean and also its complex topographic conditions. Kermanshah and Ravansar stations were in the second (low) position and Sarpol-e-Zahab and Kangavar stations were in the very low category of this risk.

3.2. Zoning of visual hazards

A combination of the three hazards of dusty days, dust storms and fog. The results of the survey are shown in Fig. 3. The highest frequency of visual hazards was observed in the east and the west of Kermanshah province. Kangavar station due to the high number of foggy and dusty days and Sarpol-e-Zahab station due to the high number of days with dust storms were the highest occurrence in the zoning of atmospheric visibility hazards. In general, the eastern and the western parts of the study area are in the category of very high visual hazards most at risk. As Fig. 3 shows, that the lowest and low to medium visual hazards condition were found in the centers of the southern parts, including Islamabad-e-Gharb station, and the northern and the central parts of province.

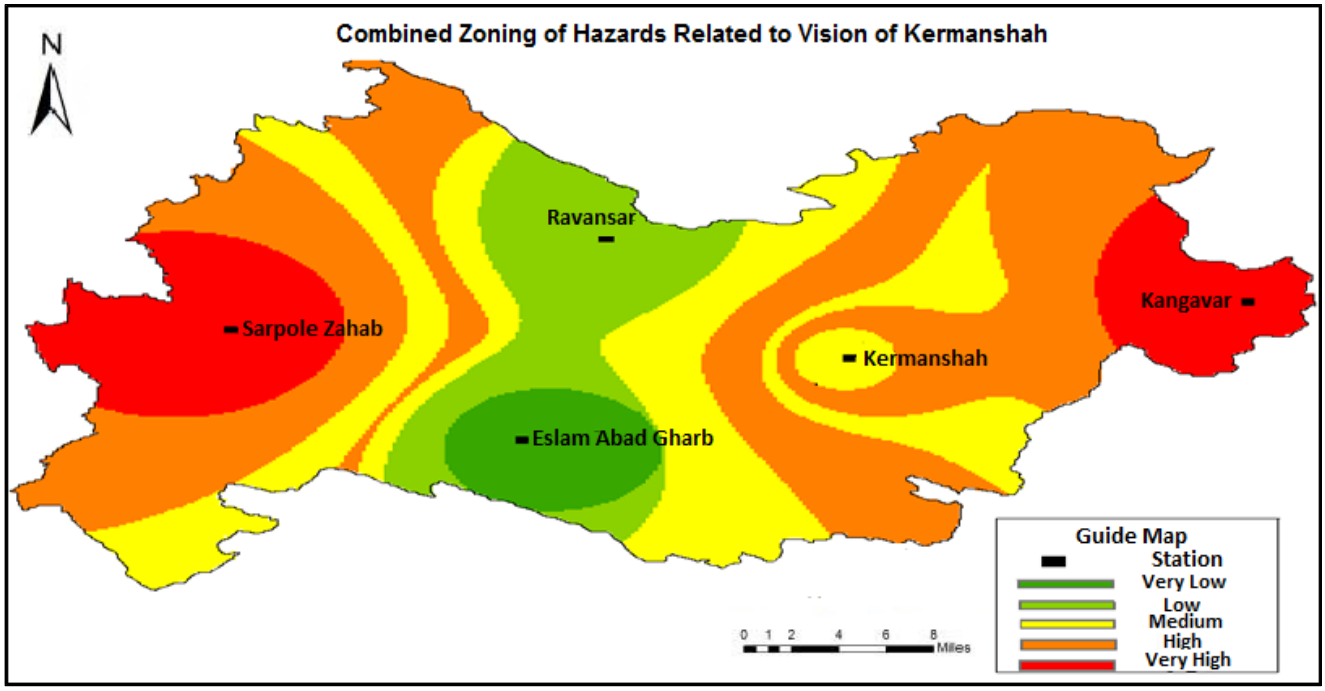

Fig. 3. Visual hazardous in the study area.

3.3. Zoning of temperature hazards

The temperature hazard zoning map consists of a combination of three hazards as: frost, chill wind and heat waves. Fig. 4 shows the temperature hazards of Kermanshah province. Temperature-related atmosphere hazards in the south and center and a small part of the north of the province have reached its maximum frequency and are the most dangerous conditions. Moreover, Islamabad-e-Gharb and Kermanshah stations were in the highest occurrence of this type of hazards. In contrast, the western regions of province were with the lowest temperature hazards. Fig. 4 shows that Sarpol-e-Zahab station was one of the places with the lowest occurrence of temperature hazards. Also, Kangavar station was in the moderate temperature hazard condition. At the same time, temperature hazards with high frequency was observed in Ravansar station located in the northeast of the province.

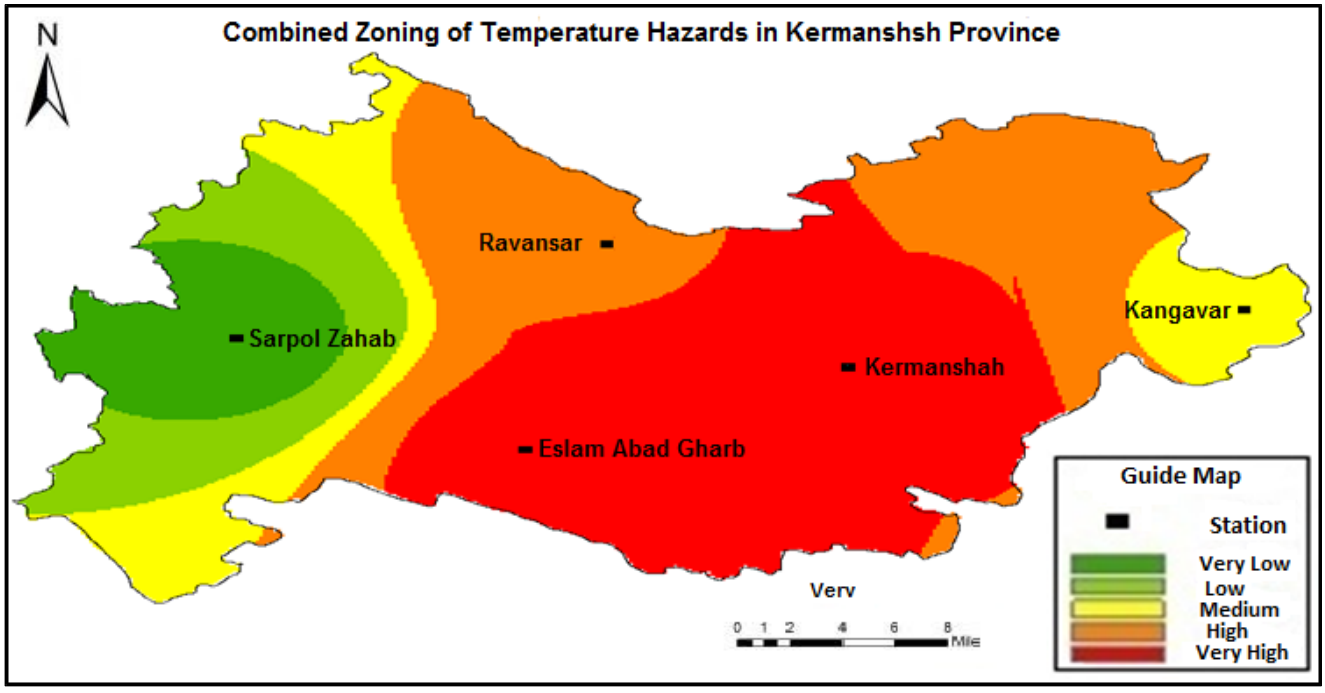

Fig. 4. Zoning of temperature hazards in the study area.

3.4. Combination of atmospheric hazards zoning

Fig. 5 was prepared from the combination of all atmospheric hazards and shows the final zoning of atmospheric hazards in Kermanshah province. By examining the combined zoning map of atmospheric hazards, some areas were not very high class in terms of the atmospheric hazard's occurrence. But some of the central and the southern regions of the province were considered as the most dangerous areas in Kermanshah province. Although, those places were in the middle class in terms of frequency of occurrence, an overview of precipitation hazard, visibility hazards, and temperature hazards map (Figs. 2, 3, and 4). As the investigation results, Kermanshah and Islamabad-e-Gharb stations were in the highest risk and in the middle category in terms of frequency. Moreover, those mentioned stations having complex topographic conditions, and also exposed to rainy currents of the western Mediterranean. The western parts of the province also experience the lowest occurrence of hazards. Sarpol-e-Zahab station was with the lowest frequency of atmospheric hazards and in a very low category. Due to its location and being far from moisture sources only some visibility hazards and temperature hazards could be absorbed. Moreover, the stations of Ravansar and Kangavard stations were with a low occurrence of atmospheric hazards frequency.

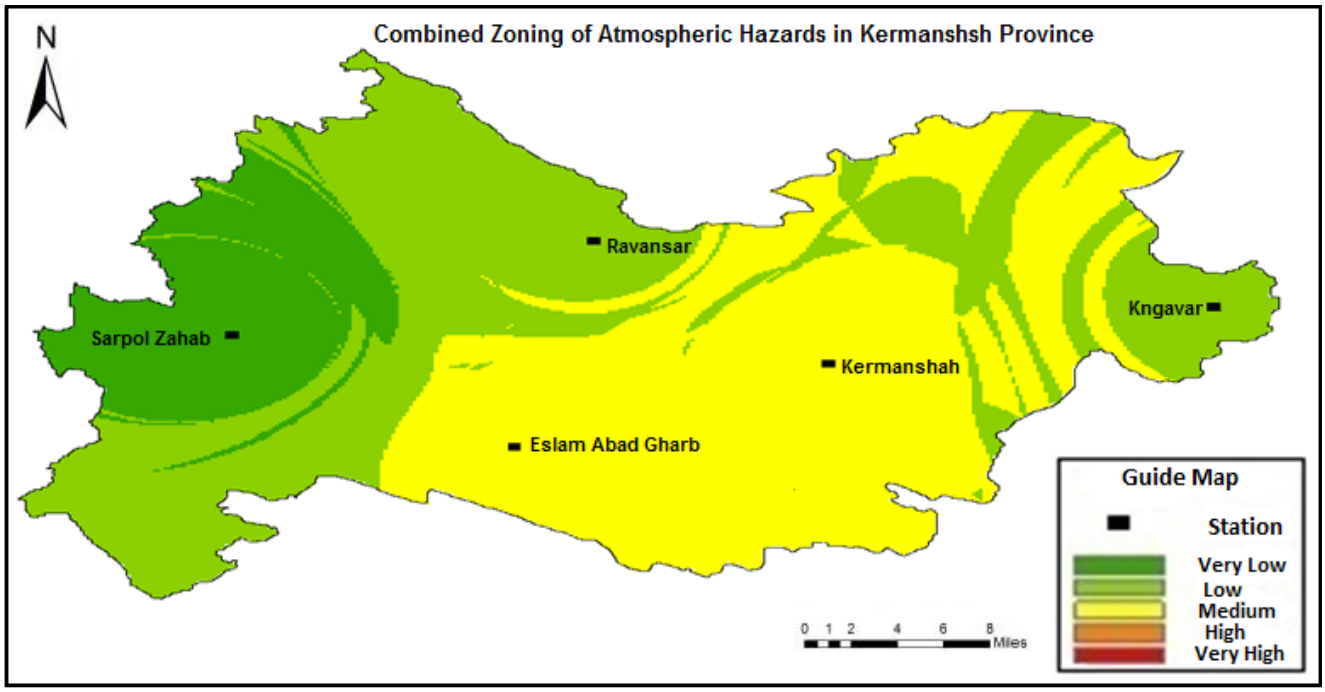

Fig. 5. Combined zoning of atmospheric hazards in the Kermanshah Province.

4. Conclusions

Thirteen atmospheric hazards were studied in the Kermanshah province located in the west of Iran in order to determine the potential occurrence of atmospheric hazards. According to the study, the following general results were obtained:

Some parts of the center and the south of the province (being in the middle rank) were considered to be the most dangerous area in Kermanshah province in terms of the occurrence frequency of various hazards. Also, some parts of the western regions had the lowest occurrence of hazards and were considered as the safest area. Besides, some parts of the north and the east of the province experience few conditions of hazards occurrence. Frost, chill wind, days with dust and moderate rainfall were shown the highest frequency of occurrence among the 13 studied atmospheric hazards. In addition, the lowest occurrence of hazards was related to very severe drought and severe drought, respectively. The highest occurrence of droughts was as moderate drought. The highest and lowest rate of rainfall were observed in the northern and in the eastern part of the province respectively. The highest and the lowest amount of heavy rainfall were found in Ranvansar and Kangavar stations respectively.

In the study of atmospheric hazards with three main categories (precipitation hazards, visibility hazards, and temperature hazards), the results indicated that the highest occurrence was belong to precipitation hazards that observed in the south of Kermanshah province, and rainfall hazards was reduced from the south to the east and to the west. The research findings showed that a large part of Kermanshah province experiences high temperature hazards. Islamabad-e-Gharb and Kermanshah stations have the highest rate of these hazards. To the west of the province, the occurrence of these hazards decreased and the eastern parts of the province were in the middle class of this hazard. The results also showed that the visibility hazards in the east and west of the province were in the highest concentration and frequency, and Kangavar and Sarpol-e-Zahab stations experience the highest occurrence of these hazards. The occurrence of visibility hazards was reduced in the south and the center of the province. Finally, it was suggested that all government agencies in Kermanshah province must use the practical results of this study before carrying out any desired infrastructure projects, to prevent any possible loss of life and property due to weather hazards.

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