Journal of Human, Environment, and Health Promotion. 2019; 5(1): 1- 8

Journal of Human, Environment, and Health Promotion

Journal homepage: www.zums.ac.ir/jhehp

The Validation of the Thermal Regions in Iran with an Emphasis on the Identification of the Climatic Cycles

Mustafa Solgimoghaddam [a] | Younes Khosravi [a*] | Hossein Asakereh [b] | Mehdi Doostkamian [b]

[a] *Department of Environmental Science, School of Science, University of Zanjan, Iran.*
[b] *Department of Geography, School of Humanities, University of Zanjan, Iran.*

***Corresponding author:** Younes Khosravi
Department of Environmental Science, School of Science, University of Zanjan, Iran. Postal code: 4537138791.
E-mail address: khosravi@znu.ac.ir

ARTICLE INFO

Article type:
Original article

Article history:
Received December 12, 2018
Revised January 21, 2019
Accepted March 4, 2019

DOI: 10.29252/jhehp.5.1.1

Keywords:
Cluster analysis
Discriminant analysis
Silhouette index (SI)
Principal component analysis
Spectral analysis

ABSTRACT

Background: The present study aimed to validate the thermal regions in Iran with an emphasis on the identification of the climatic cycles during the recent half-century.
Methods: Data on daily temperature were extracted for 383 synoptic stations of Iran Meteorological Organization. For the zoning of the temperatures of Iran, multivariate statistical techniques (cluster analysis and discriminant analysis) were applied. In addition, the verification of the areas that were identified by cluster analysis and discriminant analysis was performed using the silhouette analysis.
Results: Discriminant analysis and silhouette analysis could properly identify the thermal regions in Iran, and this claim was confirmed with 2% error. Moreover, the spectral analysis of the thermal regions indicated that the temperature of Iran in the first and second regions had a medium-term cycle or an occasional short-term cycle, while fluctuations were observed in the third and fourth regions, as well as 2-5-year short-term cycles.
Conclusion: According to the results, the temperature of Iran was affected by several factors in some regions with variable patterns, so that diverse short-term, long-term, and medium-term cycles were dominant in the thermal regions in Iran.

1. Introduction

Temperature is a key index used in climate studies, as well as a major determinant of other climate elements. Evidently, temperature largely influences environmental planning and could be considered a key element in climate systems, the changes in which may modify the weather conditions in every area [1].

Therefore, changes in the temperature of every location exert marked impacts on ecosystems [2, 3]. Climate change is considered to be a major environmental challenge in the current era. Some of the deleterious effects of climate change include the expansion of deserts and desertification, severe reduction of groundwater sources, unstable Ecological conditions, drying of wetlands, retrogression of lakes, and destruction of renewable natural resources [4-6]. Furthermore, temperature plays a pivotal role in zoning and climatic classification; therefore, climatic zoning is a prominent aspect of climate research regarding the identification of the geographical regions that are similar in terms of climate and their separation based on the heterogeneous spaces. The main purpose of statistical classifications is to maximize the intra-group congruence and out-group heterogeneity of the groups. In other words, climatic regions should have maximum similarity and internal congruence, as well as the maximum differences with each other [7].

How to cite: Solgimoghaddam M, Khosravi Y, Asakereh H, Doostkamian M. The Validation of the Thermal Regions in Iran with an Emphasis on the Identification of the Climatic Cycles. *J Hum Environ Health Promot*. 2019; 5(1): 1-8.

Recently, climate research using multivariate analysis, especially cluster analysis, has been on the rise on the national and international scale. For instance, the study by Ryerson et al. (2013) [8] was focused on the zoning of the climatic areas in California (USA) using multivariate methods. In addition, Tarasova et al. (2007) have specified six classifications for daily and seasonal ozone using the data of ground-level ozone during 1990-2004 in an extra-tropical area, as well as cumulative hierarchical cluster analysis [9]. In another research, Bravo Cabrera et al. (2010) identified two precipitation classifications in Mexico using hierarchical cluster analysis and the data of 35-40 years of precipitation collected from 349 Mexican stations [10]. On the same note, Zhou et al. (2009) [11], recognized two climatic areas and three hydrothermal regions in the arable area of Mormobiji (Australia) using cluster analysis and geographical information system (GIS) based on the long-term statistics of four climatic variables, including mean annual precipitation, mean annual evapotranspiration, mean annual growth degree days, and mean daily temperature. In China, Lau et al. (2007) focused on the coefficient of energy efficiency in structural design and energy consumption using cluster analysis based on the solar radiation data, as well as the statistics of 123 stations, for the classification of the sun rate, recognizing five climatic areas. Their findings were factual and in proper congruence [12].

Several studies in Iran have been focused on the classification and segmentation of climates using multivariate statistical techniques [13-16]. Since multivariate statistical methods have numerous applications in determining the climate of various regions and considering the lack of studies regarding climate classification using the cluster analysis, discriminant analysis, and silhouette index in Iran, the present study aimed to use cluster analysis, discriminant analysis, and silhouette index for the zoning of the climate in Iran.

2. Materials and Methods

The present study aimed to investigate and determine the behavioral pattern of temperature trends within a 50-year period (1961-2010). To this end, data on the mean annual temperature of this period were obtained from 383 meteorological stations in Iran. The data were obtained through the interpolating of the values during 1972-2011 regarding daily temperature. The applied data had the spatial resolution of 15×15 kilometers and were produced in the lambert conformal conic projection, arranged in the form of a matrix of 7,187×18,183 with S alignment (times in rows and places in columns) (Figure 1). After the preparation of the databases for the temperature zoning of Iran, cluster analysis was carried out, and discriminant analysis and silhouette index were used to validate the results of the cluster analysis.

2.1. Silhouette Index

Silhouette validity index is defined based on the mean distance of each cluster sample with the other samples in the same cluster, as well as the mean distance of the samples in the other clusters with a specific cluster.

Accordingly, the dispersion and correlation of each cluster were determined, and the maximum value of the index was used to determine the optimal number of the clusters [17], as follows:

$$\boldsymbol{S(i)} = \frac{\left(\boldsymbol{b(i)} - \boldsymbol{a(i)}\right)}{\boldsymbol{max}\,\{\boldsymbol{b(i)}, \boldsymbol{a(i)}\}} \quad (1)$$

Where a (i) represents the non-similarity of a specific sample with the other samples in a cluster, and b (i) shows the non-similarity of a specific sample to the other samples in another cluster (the nearest clusters). The silhouette index rate was estimated to be within the range of 1 to -1. If the index was equal to 1, it indicated that clustering was not performed accurately. If the index value was close to zero, the samples could be attributed to a closer cluster, and the distance of the sample with the two clusters was equal. If the index was equal to -1, it indicated that the clustering was not performed accurately.

2.2. Discriminant Function Analysis (DFA)

Discriminant function analysis (DFA; detection function) was used to assess the accuracy of the clustering. DFA was applied when the number of the clusters was known. In fact, DFA is a test for the accurate diagnosis of clustering. DFA automatically selects the first function that separates the groups. Following that, the second function is selected, which is not associated with the first function. This process continues until the maximum number of the functions is obtained based on the number of the independent variables and classes of the dependent variable. In other words, DFA is an approach for the classification of variables into distinct groups. The overall objective of DFA is to develop a linear combination of the variables that are used for clustering. In the present study, the linear combination of the variables was as follows [18]:

$$\mathrm{l} = \mathrm{B_1X_1} + \mathrm{B_2X_2} \ldots \mathrm{B_PX_P} \quad (2)$$

The obtained l value determined the assignment of a sample to a specific group, while X_1, X_2, and X_P represent the group of the obtained measurements for each of the selected changes. In addition, B_1, B_2, and B_p were similar to the B coefficients in regression. Therefore, it could be stated that DFA is similar to multivariate linear regression, with the difference that in linear regression, the dependent variable is at the relative distance, while in diagnostic analysis, the scale of the dependent nominal variable is two-dimensional or multi-dimensional.

After the identification of the thermal regions in Iran in order to extract the temperature cycles [18], the cell with the highest diffraction and highest correlation with the other cells simultaneously was selected as the representative of the studied area using principal component analysis (PCA). Following that, spectral analysis was performed on each representative cycle, and each area was identified.

Spectral analysis is a size of the variance distribution along all the wavelengths of a time series. In fact, the spectral analysis technique involves the analysis of the variance of a time series.

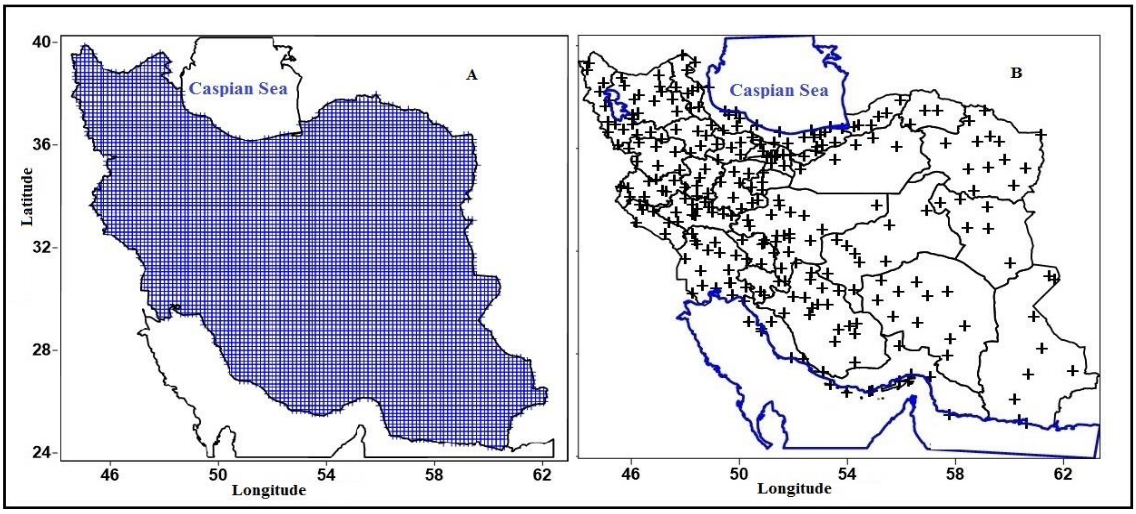

Figure 1: Spatial distribution of the studied synoptic stations (A), temperature network data

In spectral analysis, the time series is transferred into frequency functions as a period function with amplitude and frequency, where the frequency indicates the time scale (cycles per second), and the amplitude indicates the amount of the variance in the time scale. Therefore, every single wave is extracted in this technique, and the contribution of the wave in the total variance is determined. Finally, every single wave is assessed in terms of statistical significance. In general, the following steps are performed in order to extract cycles using spectral analysis:

2.3. Converting Time series to frequency

In order to convert the time series into frequency and calculate the harmonics, two parameters must be initially calculated using the following equation [19]:

$$a_i = \frac{2}{n}\sum_{t=1}^{n} X_t \cos\left(\frac{2\pi q}{n}t\right)$$
$$q = 1, 2, \dots, \frac{n}{2} \qquad (3)$$

$$b_i = \frac{2}{n}\sum_{t=1}^{n} X_t \sin\left(\frac{2\pi q}{n}t\right)$$
t=1, 2,...,n (4)

Where q is the number of the harmonics (compatibles). In even and odd series, there are instruments as the values of q = n/2 and q = (n-1)/2, respectively.

The variance of each frequency (wavelength) was also calculated using the following equation:

$$I(f_i) = \frac{n}{2}(a_i^2 + b_i^2) \qquad (5)$$

2.4. Significance Test of the Spectrum

In the present study, the test of significance was performed in three steps, including the calculation of the mean spectrum ($\bar{S}$), calculation of the first order self-correlation for the observations (time series of data) (r_1), and calculation of the spectrum for a random series with specifications ($\bar{S}$), and (r1) of the available series using the following equation:

$$\hat{I}(f) = \bar{s}\left[\frac{1 - r_1^2}{1 + r_1^2 - 2r_1\cos\left(\frac{\pi \times i}{q}\right)}\right]$$
$$i = 1, 2, \dots, q \qquad (6)$$

Correspondingly, a spectrum that is achieved with the profile ($\bar{S}$) and (r_1) has no trend and cycle, indicating the initial testing of the interval confidence (generally 95%) for each spectrum (frequencies). Accordingly, each of the time series outside the interval confidence shows that the cycles are significant. To this end, χ^2 was used in the present study, and the degree of freedom was obtained using the following equation:

$$df = \frac{2n - \frac{q}{2}}{q} \qquad (7)$$

Based on the calculated degree of freedom and 95% confidence level, the values in the table were used, and the significance level was calculated using the following equation:

$$\mathrm{sig}\hat{I}(f) = \frac{\chi^2}{df} \times \hat{I}(f) \qquad (8)$$

Accordingly, the cycles with the variance of $I(f) \rangle \hat{I}(f)$ were considered significant.

3. Results and Discussion

The analysis of variance and mean differences test were applied after cluster analysis in order to determine the proper number of the clusters. As a result, four thermal regions were identified, including cold areas (areas with low temperatures), areas with moderate temperatures, extremely warm areas (areas with very high temperatures), and warm areas. In order to validate the identified areas by cluster analysis, DFA and silhouette index were used. The description of the properties of each area is presented in Tables 1 and 2. Figures 2 and 3 depict the thermal regions of Iran as identified by each of the three methods.

3.1. Cold Areas (areas with high temperatures)

The cold areas based on the cluster analysis, DFA, and silhouette index were estimated at 12.66, 15.31, and respectively, which represented the minimum areas in the studied region. The mean temperature in these areas based on the cluster analysis, DFA, and silhouette index was determined to be 11.42 °C, 11.68 °C, and 11.42 °C, respectively (Table 1). Since the mean temperature of the cold area based on the silhouette index was equal to the mean value obtained by the cluster analysis, the identified areas were confirmed. In addition, the exact climate zoning based on the cluster analysis method includes the northwestern and western regions of the country. These areas were East Azerbaijan, West Azerbaijan, Zanjan, Kurdistan, Hamedan, and Arak, while some regions in Tehran, Zagros, and the northeast of the country were disseminated throughout this climatic area (Figure 2).

The cold areas based on the cluster analysis coincided with the cold areas obtained by the DFA and silhouette index. In these regions, the cold areas in Iran were identified based on the DFA and silhouette analysis, so that even in the silhouette index, which is more stringent, no suspicious spots were detected in these areas. The descriptive specifications of the cold areas based on the DFA and cluster analysis are presented in Table 2.

Table 1: Percentage of coverage and the average of thermal regions of Iran

Area	CA		DFA		SI	
	Area (%)	Average	Area (%)	Average	Area (%)	Average
Cold area or an area with cold temperatures	12.66	11.42	15.31	11.68	12.66	11.42
Moderate thermal region	29.76	14.86	28.78	15.16	28.66	15.11
Area of very warm	21.17	24.40	20.96	24.43	21.37	24.51
Temperature	36.45	19.06	34.97	19.18	37.15	19.22
Warm area	12.66	11.42	15.31	11.68	12.66	11.42

Table 2: Descriptive characteristics of the cold area and the area of very warm temperatures

Parameter	CA	DFA	CA	DFA
	Cold area or an area with cold temperatures	Cold area or an area with cold temperatures	Area of very warm temperature	Area of very warm temperature
Mean	11.42606	11.68562	24.40568	24.43249
Median	11.54238	11.79458	24.48969	24.5019
Mod	8.650994	8.650994	21.69439	21.73644
Std	0.864521	0.970259	1.4439	1.425718
CV	7.566224	8.303017	5.916245	5.835335
Variance	0.747397	0.941402	2.084846	2.032671
Maximum	12.6881	13.14774	27.05677	27.05677
Minimum	8.650994	8.650994	21.69439	21.73644
Skewness	-0.81573	-0.64828	-0.15047	-0.14717
Kurtosis	3.382677	3.045753	1.948	1.951875
Variation of range	4.037107	4.496748	5.36238	5.320325
First quarter	10.8971	11.0723	23.22103	23.26817
Second quarter	11.54238	11.79458	24.48969	24.5019
Third quarter	12.08955	12.48098	25.58889	25.59994

According to the central indices (mean, median, and mode), there was a large gap in these areas, indicating that the cold zone temperature had non-normal distribution, and the high temperatures had significant fluctuations. According to the information in Table 2, the high coefficients of the variations in the cold areas were 7.56 and 8.30 based on the DFA and cluster analysis, respectively. Therefore, it could be inferred that these areas had more frequent fluctuations and changes in the climate. The possible reasons for the high values of the variance and standard deviation in the identified cold areas could be the fact that the northwestern and western areas of the country are affected by air masses during the year, as well as the effects of altitudes, inequalities, and latitude, and the presence of variable atmospheric currents and widths. Additionally, the skewness value was observed to be negative in both the analyses in the cold area, indicating that the frequency of the values that were above the average was higher compared to the frequency of the values that were below the average in these areas.

3.2. Moderately Thermal Regions

Geographically, moderately thermal regions were identified in the northeast, northern strip, the Caspian Sea coast, Zagros Mountains, and central parts of Iran (Figure 2). In this regard, the scopes covered by the cluster analysis, DFA, and silhouette analysis were estimated at 29.76, 28.78, and of the entire regions in Iran, respectively. Meanwhile, the mean temperature in the identified areas by the cluster analysis, DFA, and silhouette index was estimated at 14.86 °C, 15.16 °C, and 15.11 °C, respectively (Table 1).

Comparison of the central indices (mean, median, and mode) of the moderately thermal regions in cluster analysis indicated that these regions had non-normal distribution, and their temperature had significant fluctuations due to the lack of uniformity and consistency in the obtained values of the central indices of these areas (Table 2). Moreover, the validation index silhouette for the identification of the areas with moderate temperature in the studied zone indicated that the identified zones in this analysis were mostly matched with the identified zones in the cluster analysis and DFA, which confirmed the accurate identification of the moderately thermal regions in Iran.

In the present study, the high levels of the variance and coefficient of variation (7.46 and 6.79, respectively) of the areas with moderate temperature represented significant fluctuations and instability of the temperature. These identified climatic areas were disseminated within large geographical regions with various environmental and atmospheric characteristics. From a climatic perspective, these areas do not have congenial temperature. On the one hand, the northern regions of the country were observed to be most affected by the high atmospheric system, while the central regions of Iran and Zagros Mountains were mainly affected by the middle and lower atmospheric systems. The temperature of Zagros Mountains was mostly influenced by altitude and ripples, while the temperature in the northern regions and Caspian coastal strip was influenced by the immigrant cold flow and proximity to the sea. In this regard, the high coefficient of the changes in this climatic area based on cluster analysis and DFA was estimated at 7.46 and 6.79, respectively, which indicated the fluctuations and changes in this area.

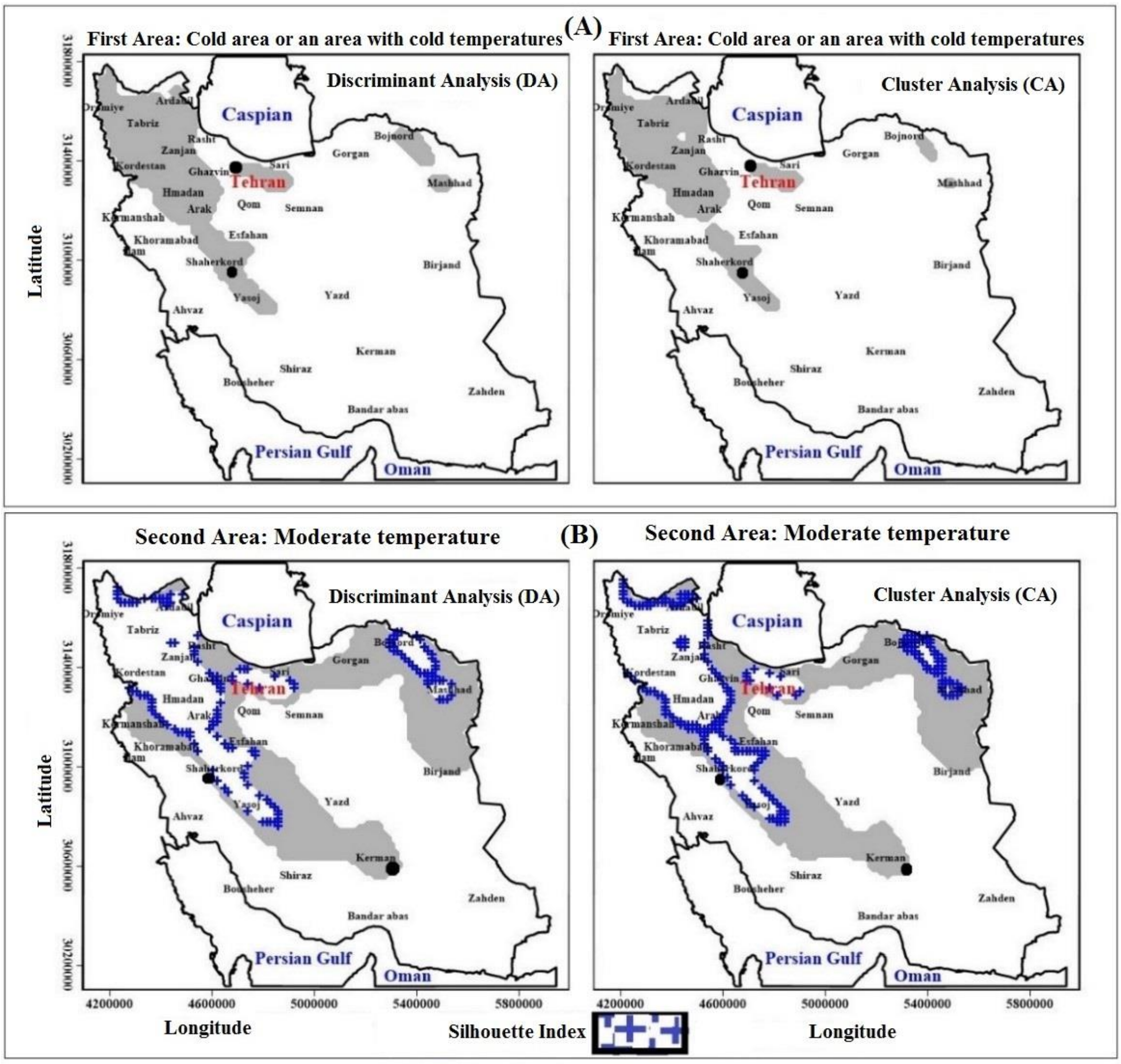

Figure 2: The area with cold (A) and moderate (B) temperature based on cluster and discriminant analysis

The skewness value obtained by the cluster analysis and DFA was negative and estimated to be - 0.22 and - 0.13, respectively, while this value was observed to be positive (0.12) based on the silhouette index. Therefore, it could be concluded that the mentioned analytical methods showed the higher temperature of these areas compared to the areas with lower temperature. According to the silhouette index, the areas with the temperature of below average were more frequent compared to the areas with high temperatures [20].

3.3. Areas with Extremely High Temperatures

According to the cluster analysis, DFA, and silhouette index, the areas with extremely high temperatures were located in the southwest, south, and southeast of Iran, covering the coastal strip of south from Ahvaz to Bandar Abbas (Figure 3). The space covered by the extremely warm areas based on the cluster analysis, DFA, and silhouette index was estimated at 21.17, 20.96, and, respectively (Table 1). The identified regions with extremely high temperatures coincided and covered the same geographical areas. Furthermore, the validation of the silhouette index in the identification of the areas with extremely high temperatures was in line with the cluster analysis and DFA, and only the suspicious spots were scattered in the borders of these areas (Figure 3). The descriptive characteristics of the extremely warm areas indicated that the mean temperature in these areas based on the cluster analysis, DFA, and silhouette index was 11.42 °C, 11.68 °C, and 11.42 °C, respectively, with the highest mean temperature of 24.44 °C.

According to the central profile (mean, median, and mode) in the cluster analysis and DFA of the areas with extremely high temperatures, the temperature had non-normal distribution in these regions. In addition, the temperature in these areas had significant fluctuations on a daily basis, while the low coefficient of variation represented the stability of the climatic elements. The high coefficient of variation in these climatic areas based on the cluster analysis and DFA was 5.83 and 5.91, respectively (Table 2), which indicated high fluctuations. Moreover, the high amount of variance based on the cluster analysis and DFA of these areas was estimated at 2.03 and 2.08, respectively (Table 2), which denoted significant variations and fluctuations in temperature in the extremely warm regions. On the other hand, the positive coefficient of elongation and negative skewness value based on the cluster analysis and DFA of the extremely warm areas demonstrated that the frequency of the values above average was higher compared to the frequency of the values below average.

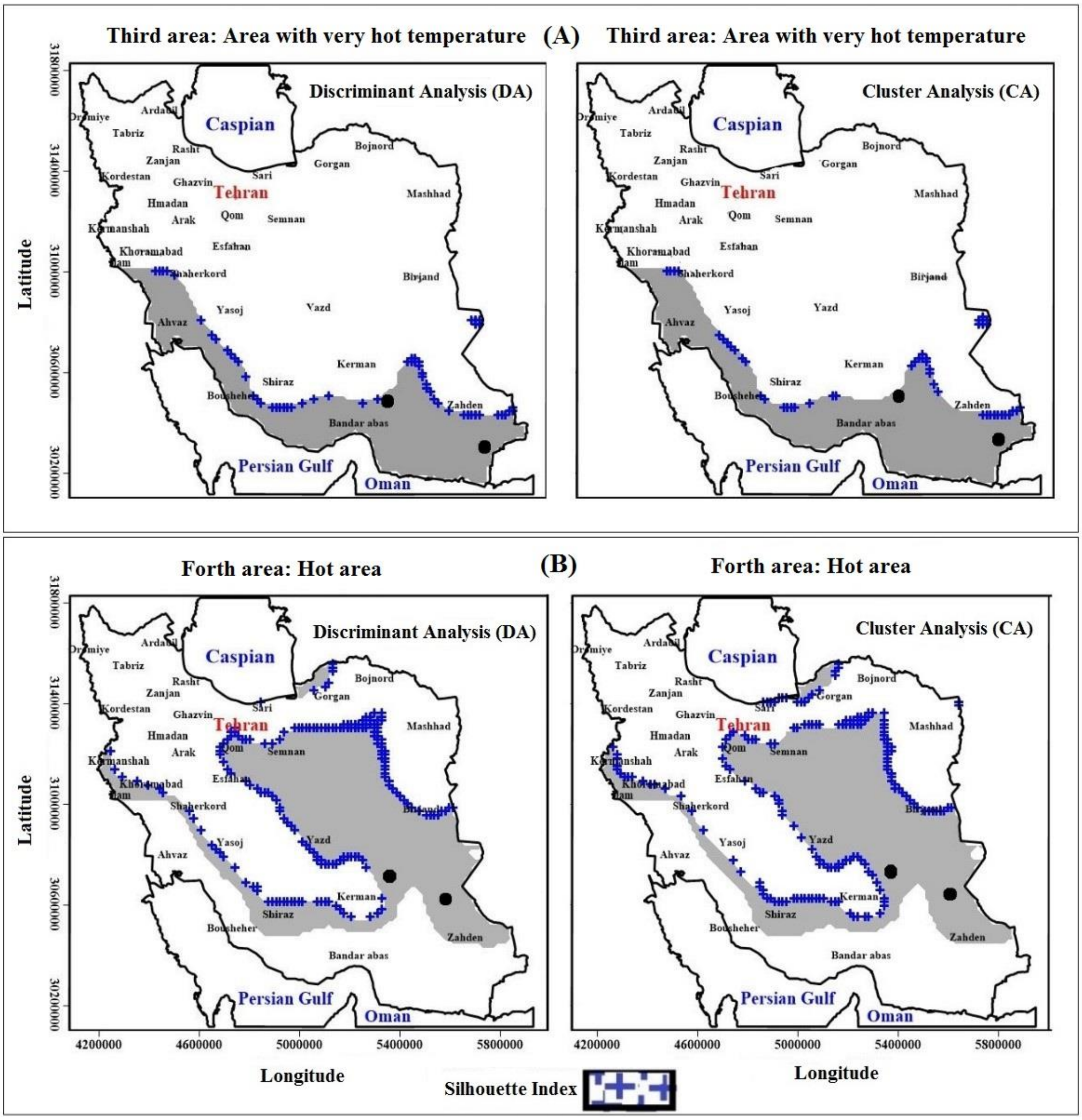

Figure 3: The very hot (A) and hot (B) areas based on the cluster and discriminant analysis

3.4. Warm Areas

Warm areas covered most of the studied regions, and the results of the cluster analysis, DFA, and silhouette index showed the coverage of these areas to be 36.45%, 34.97%, and 21.37% of the entire thermal regions. Some of the covered areas in these climatic regions were in the central and eastern parts of Iran since these regions are located within the belt of arid and semi-arid climates. In cold and warm seasons, these areas are less affected by the systems of cold nature and subtropical high pressure, respectively. According to the results of the present study, the warm thermal regions in Iran included Qom, Tehran, Isfahan, Yazd, and parts of Zahedan, Kerman, and Shiraz, as well as diverse spots in Golestan, Kermanshah, and Kurdistan. Based on the cluster analysis and DFA, the warm areas in Iran are homogenous with the error rate of 0.2% (Figure 3).

The validation of the silhouette index in the identification of the warm areas indicated that these regions were almost homogenous with the regions detected by the cluster analysis and DFA. Therefore, it could be inferred that the identification of these areas has been highly accurate, with only a few suspicious spots in the borders of the warm thermal. The mean temperature of the warm areas based on the cluster analysis, DFA, and silhouette index was estimated at 19.6 °C, 19.18 °C, and 19.22 °C, respectively.

High volatility and differences in the central profiles (mean, median, and mode) of the warm areas in the cluster analysis and DFA indicated that the temperature in these areas had non-normal distribution, which is similar to the other studied regions (Table 3). In addition, the temperature of these areas had significant fluctuations due to the high variance and variation coefficient, which were estimated at 6.88 and 6.56 based on the cluster analysis and DFA, respectively. On the other hand, the amount of variance denoted the distributed data around the average, and the highest variance based on the cluster analysis and DFA was determined to be 1.72 and 1.58, respectively (far above the average) (Table 3). In addition, the positive elongation coefficient in the moderately thermal areas indicated that the extreme values above the average in data were more frequent compared to the extreme values that were below average.

Table 3: Descriptive characteristics of the area of moderate temperature and the warm area

Parameter	CA	DFA	CA	DFA
	Moderate thermal region	Moderate thermal region	Warm area	Warm area
Mean	14.86946	15.16497	19.06601	19.1888
Median	14.94703	15.19748	19.08159	19.15594
Mod	12.69376	13.14992	16.72516	16.9692
Std	1.110319	1.031162	1.312914	1.259058
CV	7.467108	6.799627	6.886151	6.56142
Variance	1.232808	1.063294	1.723744	1.585226
Maximum	16.72161	16.96589	21.68277	21.73261
Minimum	12.69376	13.14992	16.72516	16.9692
Skewness	-0.22907	-0.13425	0.123634	0.173648
Kurtosis	1.988476	2.000455	2.133321	2.150687
Variation of range	4.02785	3.815976	4.957618	4.76341
First quarter	14.00143	14.39004	18.01813	18.20005
Second quarter	14.94703	15.19748	19.08159	19.15594
Third quarter	15.81742	16.0087	19.97728	20.08605

3.5. Analysis of the Thermal Region Cycles in Iran

In order to evaluate and analyze the temperature cycle in various areas in Iran, PCA was initially performed, and the representative of each area was identified. Following that, spectral analysis was used to determine the cycles of each area with the representative temperatures. According to the findings regarding the first areas (cold with high temperatures), there were mostly mid-term cycles of 25-16 years, with the predominant possibility of 0.4 - 0.6. In the second areas (moderately thermal regions), in addition to 10-year mid-term cycles, a short-term cycle of two years was observed to be predominant in terms of temperature. Due to the high variance of a 10-year cycle, it could be stated that 10-year cycles are more important in the second areas . In the third areas (extremely warm areas), unlike the other areas, short-term cycles of 2-4 years were observed to be dominant in terms of temperature. In the fourth areas (warm areas), 4-5-year cycles with the possibility of 0.2-0.22 were observed to be predominant. In general, it could be inferred that short-term cycles of two, four, and five years dominate the temperature in the climate of Iran].

Many researchers have attributed these cycles (2-4 years) to El Niño-Southern Oscillation (ENSO) and biennial changes (QBO) of the large patterns of the general circulation scale of the atmosphere and orbital circuits. For instance, Kane et al. (1991) [21] attributed the 2-3-year precipitation cycles in Massachusetts, Hartmann et al. (2008) [22] attributed the 2-3-year precipitation cycles in China, and Asakereh et al. (2012) [23] attributed the 2-3 year precipitation cycles in the northwest of Iran to the QBO. In addition to the aforementioned cycles, the 4-5 year cycles have been observed in the temperature of some thermal regions. For instance, Azad et al. (2010) reported the 4-5-year cycles in the Indian monsoon precipitation to be caused by the ENSO phenomenon [24].

In another research, Kalayci et al. (2004) [25] reported the 2-6-year precipitation cycles in Turkey, which was attributed to the ENSO phenomenon. Furthermore, Asakereh et al. (2012) claimed that 3-5-year cycles played a pivotal role in precipitation in the northwest of Iran. In the mentioned study [23], these cycles were also attributed to the ENSO. In the present study, cycles of 11 years or more were also observed in some areas (first and second areas), especially in Urmia and Zanjan. According to the findings of JahanBakhsh et al. (2008) [26], these cycles were due to the cycle of sunspot activity and North Atlantic oscillations, especially in the Azerbaijan region. In addition, the non-sinusoidal cycles that have the return period of equal to the length of the statistical period have been reported in some stations, such as Qazvin, Sanandaj, and Tehran, which could be attributed to the trend in the data.

4. Conclusion

For the climate zoning of Iran in the present study, multivariate statistical techniques (cluster analysis and DFA) were used. For the verification of the areas that were identified by cluster analysis and DFA, the silhouette index was also applied. To this end, the data on the daily temperature trend within the past 50 years (1961-2011) were extracted from 383 synoptic stations in Iran. According to the obtained results, the validation silhouette index could identify the areas with high temperatures, which were also the optimal areas detected by the cluster analysis and DFA. However, there were also suspicious spots in the other areas with moderate temperatures, as well as the warm and extremely warm thermal regions in the borders of the studied thermal regions.

In this regard, four thermal regions were identified, including cold areas located in the northwest and west of Iran, moderately thermal areas in the northeast and north of Iran, as well as parts of Zagros Mountains and central Iran. The warm areas are mostly located in the central and eastern regions of the country, and the extremely warm areas are mainly located in the southern regions of the country (from Ahvaz to Bandar Abbas) along the southern coast. Our findings indicated that the warm areas were ranked first in terms of temperature, while the cold areas had the lowest rank in the country. On the other hand, the maximum changes and temperature fluctuations were observed in the warm areas, while the minimum changes and temperature fluctuations were denoted in the cold areas.

According to the results of the present study, the extremely warm areas have high temperatures in the warm periods of the year due to the subtropical high pressures. In winter, these areas have low temperatures due to the withdrawal of these high pressures, as well as the influence of the cold air mass at high latitudes, which in turn increase the rate of temperature changes and fluctuations. On the other hand, the identified cold areas (western and northwestern regions of the country) are commonly affected by the cold flows from higher latitudes during the year, leading to their low temperatures in most periods, as well as lower rates of temperature changes and fluctuations.

The comparison of the central indices, coefficients of variation, and variance indicated significant locative temperature changes and fluctuations in all the identified regions across the country. However, none of these regions had normal distribution in terms of the temperature values since the identified thermal regions are influenced by various atmospheric systems at different times and places, thereby leading to temperature changes and fluctuations in the country.

The analysis of the cycles demonstrated that the temperature in the first and second areas had mostly mid-term and occasionally long-term fluctuations. On the other hand, the third and fourth areas had mostly short-term fluctuations of 2-5 years. In general, it could be concluded that the temperatures in various regions of Iran are affected by several factors and exhibit a variety of patterns, so that diverse short-term, medium-term, and long-term cycles may be dominant in the thermal regions of Iran. In conclusion, our findings demonstrated that in addition to the large-scale atmospheric systems that were previously described, local factors and neighboring conditions could also be involved in the emergence of various temperature patterns in these regions. Moreover, factors such as proximity to the Persian Gulf and Oman Sea, being located in the shade of Zagros Mountains, and irregularities could also cause significant variations in temperature patterns.

Authors' Contributions

This article was carried out by all the authors. Y.Kh., and H.A., designed and wrote the manuscript. M.S., and M.D., contributed to carry out data collection and data analysis

Conflict of Interest

The authors affirm that there is no conflicts of interest that may have influenced the preparation of this manuscript.

Acknowledgments

This work was supported by the research laboratory of department of environmental science in university of Zanjan (ZNU: 20821). The authors are grateful to Znu for supporting this study.

References

1. Khalili K, Nazeri M, Ahmadi F. The Use of PCI Index in Studying the Pattern of Precipitation and Analysis of Its changes Trend in Annual Scale and Season Scale during Recent Half Century, the Irrigation and Drainage Journal of Iran. *Irrig drainage J Iran*. 2015; 39: 195 -208.

2. Walther GR, Post E, Convey P, Menzel A, Parmesan C, Beebee TJ, et al. Ecological Responses to Recent Climate change. *Nature*. 2002; 416(6879): 389-95.

3. Parmesan C. Ecological and Evolutionary Responses to Recent Climate Change. *Annu Rev Ecol Evol Syst*. 2006; 37: 637-69.

4. Parmesan C, Burrows MT, Duarte CM, Poloczanska ES, Richardson AJ, Schoeman DS, et al. Beyond Climate Change Attribution in Conservation and Ecological Research. *Ecology Letters*. 2013; 16(s1): 58-71.

5. Lee SY, Ryan ME, Hamlet AF, Palen WJ, Lawler JJ, Halabisky M. Projecting the Hydrologic Impacts of Climate Change on Montane Wetlands. *Plos One*. 2015; 10(9): e0136385.

6. Salinas CX, Mendieta J. Mitigation and Adaptation Investments for Desertification and Climate Change: an Assessment of the Socioeconomic Return. *Mitig Adapt Strateg Glob Chang*. 2013; 18(5): 659-72.

7. Kaviani M, Bohlul A. Principles of Water and Weather. *16th edition, Tehran: the Samt Publisher;* 1999.

8. Ryerson T, Andrews A, Angevine W, Bates T, Brock C, Cairns B, et al. The 2010 California Research at the Nexus of Air Quality and Climate Change (CalNex) Field Study. *J Geophys Res Atmos*. 2013; 118(11): 5830-66.

9. Tarasova O, Brenninkmeijer C, Jöckel P, Zvyagintsev A, Kuznetsov G. A Climatology of Surface Ozone in the Extra Tropics: Cluster Analysis of Observations and Model Results. *Atmos Chem Phys*. 2007; 7(24): 6099-117.

10. Bravo Cabrera J, Azpra Romero E, Zarraluqui Such V, Gay García C, Estrada Porrúa F. Significance Tests for the Relationship between" El Niño" Phenomenon and Precipitation in Mexico. *Geofísica internacional*. 2010; 49(4): 245-61.

11. Zhou D, Khan S, Abbas A, Rana T, Zhang H, Chen Y. Climatic Regionalization Mapping of the Murrumbidgee Irrigation Area, Australia. *Prog Nat Sci*. 2009; 19(12): 1773-9.

12. Lau CC, Lam JC, Yang L. Climate Classification and Passive Solar Design Implications in China. *Energy Convers Manag*. 2007; 48(7): 2006-15.

13. Zolfaqari H. Study on the Natural Seasons in Kermanshah Province. *Geogr Res*. 2005; 76: 107-90.

14. Armesh M, Khosravi M. Climatic Regionalization of Markazi Province: An Application of Factor and Cluster Analysis. *Geogr Environ Plann*. 2012; 23(2): 87-100.

15. Mazidi A, Khodagholi M. Climatic Zoning of Yazd Province by Using Multivariate Statistical Methods. *J Geogr Reg Dev*. 2009; 13: 158-39.

16. Nazari pour H, Saeed Abadi R. Determination of Zahedan Climatic Seasons. *J Geogr Dev*. 2012; 26: 87-97.

17. Frey BJ, Dueck D. Clustering by Passing Messages between data Points. *Sci*. 2007; 315(5814): 972-6.

18. FarshadFar E. Advanced Multivariate Statistical Methods. *Razi Univ Kermanshah Press*. 2010.

19. Chatfield C. The Analysis of Time Series: an Introduction. CRC Press; 2016.

20. Alijani B, DoostKamian M, Ashrafi S, Shakeri F. Study on the Changes in the Patterns of Within-Decade Spatial Autocorrelation of Precipitation in Iran during the Last Half Century. *J Geogr Urban Plan*. 2015; 5(14): 71-87.

21. Kane RP, Teixeira NR. Power Spectrum Analysis of the Annual Rainfall Series for Massachusetts (NE, USA). *Clim Change*. 1991; 18(1): 89-94.

22. Hartmann H, Becker S, King L. Quasi-Periodicities in Chinese Precipitation Time Series. *Theor Appl Climatol*. 2008; 92(3): 155-63.

23. Asakereh H, Razmi R. Analysis of the Changes in Annual Precipitation of Northwest of Iran. *Geogr Environ Plan*. 2012; 3: 147-62.

24. Azad S, Vignesh T, Narasimha R. Periodicities in Indian Monsoon Rainfall over Spectrally Homogeneous Regions. *Int J Climatol*. 2010; 30(15): 2289-98.

25. Kalayci S, Karabörk M, Kahya E. Analysis of El Nino Signals on Turkish Streamflow and Precipitation Patterns Using Spectral Analysis. *Fresenius Environ Bull*. 2004; 13(8): 719-25.

26. JahanBakhsh S, EdalatDoost M. Climate Change in Iran (Case Study: North Atlantic Oscillation Index as an Indicator of the Effects of Solar Activity on Changes in Precipitation of Azerbaijan. *3rd Conference of Iran Water Resources Management*; 2008.