

Assessment of Bioclimatic Conditions of a Cold climate in Iran- Kurdistan using Wind Chill Index (WCI)

M. Asghari¹, H. R. Heidari², G.H. Teimori³, G. F. Ghalhari ⁴ and S. F. Dehghan^{*5}

¹Department of Occupational Health and Safety Engineering, School of Public Health, Arak University of Medical Sciences, Arak, Iran.
E-mail: m.asghari2011@gmail.com.

² Health Faculty, Golestan University of Medical Sciences, Gorgan, Iran. E-mail: hr.heidari.tums@gmail.com.

³Department of Occupational Health Engineering, School of Health, Torbat Heydariyeh University of Medical Sciences, Torbat Heydariyeh, Iran.
E-mail: teimorigh1@gmail.com.

⁴Faculty of Geography and Environmental Sciences, Hakim Sabzevari University, Khorasan-Razavi, Iran.
E-mail: af1632312105@gmail.com.

^{*5}Environmental and Occupational Hazards Control Research Center, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

^{*}Correspondence Author's Email: Somayeh.farhang@gmail.com
(somayeh.farhang@sbmu.ac.ir ORCID: <https://orcid.org/0000-0002-6607-6396>).

ABSTRACT

This study aimed to use the wind chill index (WCI) in one of the cold climates of Iran –Kurdistan to assess thermal comfort situation between 1995 and 2014 in different seasons of the province. Six synoptic stations of the Kurdistan province based on climatic categorization were studied. WCI was calculated using long-term metrological data from 1995 to 2014. The trend of the index changes was investigated and compared in two decades (1995-2004 vs 2005-2014). The bioclimatic condition of each station was determined for different seasons and months. In general, the lowest WCIs observed in July and August months, and highest WCIs were in February and January months. In addition, the prevailing bioclimatic situation was different from pleasant to very cold in this province. The results of the Mann-Whitney test show that the mean WCI has decreased in the second decade compared to the first decade. Significant relations were seen between two studied decades, except for Saez and Zarrineh. The different cities of Kurdistan province are experiencing almost identical climate conditions. Moreover, the mean WC index decreased in the second decade compared to the first decade, reflecting the warming of Kurdistan's climate.

Keywords: Wind Chill Index, Bioclimatic, Thermal Comfort, Heat Stress, Iran

Mathematics Subject Classification Number: 62P20

1. INTRODUCTION

The country of Iran has a variety of heat and cooling patterns due to its diverse climate, which has a big impact on people's physical and mental well-being (Ahrens, 2015; Asghari *et al.*, 2020; Ghalhari *et al.*, 2020). Therefore, the analysis of climate from a medical perspective as a cause of disease (Nastos and Matzarakis, 2012), from an economic perspective as energy consumption patterns and impacts on productivity and performance (Asghari *et al.*, 2020), and also from urban issues as a key factor for

tourism planning and development is noticeable (Zare *et al.*, 2018). Climatic factors and weather condition can sometimes lead to changes in human body with adverse effects. According to medical research, seasonal variations and temperature variations can result in a number of illnesses, including influenza, heart disease, stroke, asthma, hyperthermia, and even death (Cann *et al.*, 2013; Fallah Ghalhari *et al.*, 2015). Many studies have also reported the adverse effects of heat and cold stress on mortality (Kjellstrom *et al.*, 2018).

All of the environmental heat-related factors and climatic parameters must be considered in order to evaluate how the climate affects the human body (Matzarakis, 2007; Matzarakis and Amelung, 2008; Abdulla *et al.*, 2012). Therefore, thermal condition of the human should be presented as indicators that reflects the response of people to climatic conditions and encompasses a range of degrees from excellent to unacceptable (Matzarakis and Amelung, 2008; Organization, 2014). These indicators make it easier to interpret the complex impacts of different atmospheric elements and allow comparisons of different locations from this perspective (De Freitas, 2001; Shakeri *et al.*, 2019) (Kangrang *et al.*, 2017). A person's perception of heat is influenced by how their body exchanges heat with its surroundings. Mainly, air temperature, mean radiant temperature, air speed, clothing insulation, metabolic rate, and relative humidity are the factors that affect thermal comfort because they control heat gain and loss (Vanos, 2011; Asghari *et al.*, 2019) (Zaoui *et al.*, 2017).

The skin's surface and its surroundings are constantly exchanging heat (15). The air surrounding the skin is covered in a thin layer of warm molecules on a cold day, which shields the body from the elements. The body feels extremely cold and uncomfortable as a result of the wind moving the thin layer of air next to the body. This is illustrated by a quantitative index called as the Wind Chill Index (WCI). This indicator converts wind cooling power to a temperature equivalent on a calm day with wind speed of less than or equal to 6.4 km/h (Shitzer, 2006b, a; Roshan *et al.*, 2010) .

WCI is caused by wind at low temperatures, and the higher the wind speed and the lower the temperature, the greater the intensity of the wind and its effects on the thermal sensation perceived by the human (Osczevski and Bluestein, 2005). The importance of the WCI is that it can be used as a suitable criterion for choosing the type of clothing or optimum energy consumption in cold weather (Shitzer, 2006b; Roshan *et al.*, 2010). In addition, as a natural hazard, the chill winds affect parts of the country every year and causes many problems (Roshan *et al.*, 2010). According to the many researchers, the use of this index is beneficial to maintain human health in cold weather. So that, the meteorological organizations of many countries, regularly inform people about WCI to help them for selection and wearing appropriate clothing using public media and/or internet sites (Curtis *et al.*, 2017; Kim *et al.*, 2018). In addition, understanding the thermal state of an area from a thermal comfort perspective can be a key factor in attracting tourists in a country (Perch-Nielsen *et al.*, 2010; Lin *et al.*, 2011; Potchter *et al.*, 2018).

Therefore, this study aimed to use the WCI in one of the cold and mountainous climates of Iran (Kurdistan province) to analyze thermal comfort situation between 1995 and 2014 in different seasons and parts of the region.

2. METHODS

2.1. Characteristics of studied climate

The province of Kurdistan with an area of 29137 km² lies in western of Iran. The climate of the province mostly influenced by the altitude and direction of the Zagros Mountains, the climatic currents of the Atlantic Ocean and the Mediterranean Sea, which is a major cause of snow and rainfall in this area. In general, Kurdistan territory is located in the cold mountainous climate of Iran. The map found in Fig1, the location of Kurdistan in Iran is depicted (Hanafi and Hatami, 2013; Fallah Ghalhari *et al.*, 2015).

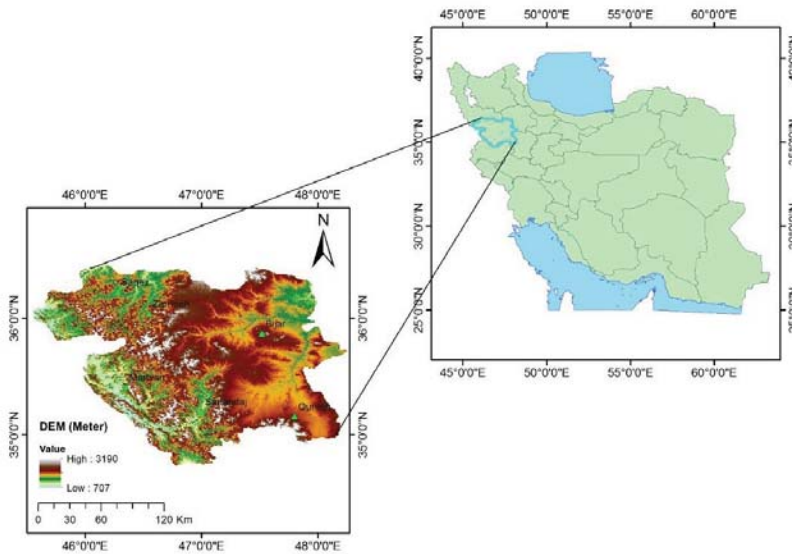


Figure 1. Geographical characteristics of the Kurdistan province

This province's highest and lowest points differ in elevation by roughly 2400 meters. The province's highest point is 3300 meters high Shahoo Mountain, while its lowest point is the Alutt region in Baneh, a Kurdistan city, at roughly 900 meters. The average annual temperature is 13°C and up to 8°C for the elevations. The average annual rainfall in the province is about 500 mm, which reaches more than 800 mm in the western and northwest elevations of the region (Hanafi and Hatami, 2013).

Due to the specific geographical conditions, high altitude of cities in the province and existence of high mountains, the winter atmospheric rainfalls are often snowy, hence, the minimum temperature and the number of frost days in this area is very important. According to the surveys, the number of frost days in the cities of Bijar, Sanandaj, Saqez, Marivan and Baneh reaches 160, 110, 113, 85 and 85 days, respectively. In this regard, it provides a good base for longer snow durability and snow protection for winter sports, especially skiing (Mirmousavi *et al.*, 2014).

2.2. Data selection and climatic categorization

Iranian Meteorological Organization meteorological data, including temperature and relative humidity, were taken from six synoptic stations in Kurdistan province between 1995 and 2014 (as shown in Table 1).

Table 1: Climatic and meteorological characteristics of the studied stations by De Martonne and Embereger methods

Station	Climatic categorization		I*	Q**	Annual precipitation (mm)	Temperature		
	De Martonne	Embereger				Maximum (°C)	Minimum (°C)	Average (°C)
Sanandaj	Semi- arid	cold semi-arid	19.6	37.6	458.4	36.8	-5.4	13.4
Saqez	Mediterranean	highlands climate	23.6	41.1	499.4	34.3	-8.1	11.1
Bijar	Semi- arid	cold semi-arid	16.5	31.2	344	31.7	-6.9	10.9
Marivan	Very humid	cold humid	43.5	85.9	991.2	35.4	-4.6	12.8
Zarrinreh	Mediterranean	highlands climate	22	35.6	395.8	29.4	-9.7	7.9
Qorveh	Semi- arid	cold semi-arid	15.8	30.2	338.9	32.4	-6.8	11.4

*Region aridity coefficient; **Embereger coefficient

Due to weather characteristics of the studied regions, two climatic categorization methods including revised De Martonne and Embereger used in the present study. De Martonne suggested equation 1 for the climate classification (Ghalhari *et al.*, 2020).

$$I = (P / (T + 10)) \quad (\text{Eq.1})$$

Where is:

P: mean of the annual precipitation (mm)

T: mean of the annual temperature (°C)

The term I is a region aridity coefficient, which affected by temperature and precipitation. Based on the De Martonne's climatic classification, the climate of Kurdistan divided into 4 types of climate including semi-arid, Mediterranean, humid and very humid climates.

However, in the Embereger method, a coefficient known as the Embereger coefficient (Q) obtained as equation 2 using the mean of the annual precipitation, average minimum daily temperature in the coldest month of the year, and average maximum daily temperature in the warmest month of the year. Using the Q, the climate type extracted from the Embereger chart. In this classification, Kurdistan province is divided into 4 types of climate including cold semi-arid, highlands climate, cold semi-humid, and cold humid. Table 1 shows the type of climatic class in each of the studied stations and their meteorological characteristics (Hanafi and Hatami, 2013).

$$Q=2000P/(M^2-m^2) \quad (\text{Eq.2})$$

Where is:

Q: Embereger coefficient

P: mean of the annual precipitation (mm)

M: average of maximum daily temperature in the warmest month of the year (°C)

M: average of minimum daily temperature in the coldest month of the year (°C)

After climatic categorization, using two methods mentioned above, a synoptic station in each defined category was selected for the study. The stations which were cities of the Kurdistan included Bijar, Sanandaj, Qorveh, Marivan, Saqez and Zarrineh.

2.3. Wind Chill Index (WCI)

In order to determine the human bioclimatic status in this study, WCI was used. The index was first introduced by Paul Siple in 1939 and has since been considered as one of the most important indices for assessing climate conditions. This indicator represents the energy dissipated in kilocalories per square meter of body surface within one hour under normal conditions of inactivity and normal skin temperature of 33 °C (91.4 °F). The index can be calculated as following formula(Osczevski and Bluestein, 2005; Tseliou *et al.*, 2010) :

$$H = (10.45+10\sqrt{V-V}) (33-T) \quad (\text{Eq. 3})$$

Where is:

H: Energy dissipated of body surface (Kcal/hr/M²)

V: Average monthly wind speed (m/s)

T: Average monthly temperature (°C)

The required parameters for calculation of WCI obtained from Iranian Metrological Agency. After calculating the WCI for each month, it would interpreted based on the defined range in Table 2 to estimate the comfort status in different months of the year(Osczevski and Bluestein, 2005) .

Table 2: Interpretation of thermal sensation based on energy dissipated or wind chill

Bioclimatic conditions	Energy dissipated (Kcal/hr/M ²)
Body freezing temperature	1400 >WC
Extremely cold	1400 <WC ≥1200
Very very cold	1200 <WC ≥1000
Very cold	1000 <WC ≥800
cold	800 <WC ≥600
Very cool	600 <WC ≥300
cool	300 <WC ≥200
Pleasant (comfort sensation)	200 <WC ≥50
Warm	50 <WC ≥20
Hot	20 <WC ≥10
Extremely hot	10 <WC

2.4. Statistical analysis

SPSS software, Version 22, was used to analyze the data. The standard deviation and mean were used to report quantitative data. Kolmogorov-Smirnov test was used to analyze data normalcy. The average of meteorological parameters over the first ten years was compared using the Mann-Whitney test (1995-2004) and the second decade (2005-2014).

3. RESULTS

Table 3 compares the mean and standard deviation of environmental factors influencing thermal comfort in several Kurdistan province cities over the course of two decades, using meteorological data spanning 20 years. The highest average temperature was for Sanandaj with the mean of air temperature of 14.24 ± 9.34 and 14.72 ± 9.67 °C for the first decade and the second decade, respectively.

Table 3: Comparison of the mean of air temperature in different stations of Kurdistan from 1995 to 2014

Period	Station	Air temperature (°C)					
		M±SD of minimum temperature	P*	M±SD of maximum temperature	P*	M±SD of average temperature	P*
Sanandaj	1995-2004	6.11±8.12	0.016	22.3±11.1	0.01	14.24±9.34	0.011
	2005-2014	6.5±8.37		22.95±11.54		14.72±9.67	
Bijar	1995-2004	5.79±8.45	0.005	17.18±11.45	0.296	11.49±9.8	0.066
	2005-2014	6.22±8.8		17.36±11.71		11.79±10.1	
Qorveh	1995-2004	5.68±8.7	<0.001	17.92±11	0.121	11.8±9.72	0.003
	2005-2014	6.53±8.94		18.21±11.36		12.37±10	
Saqqez	1995-2004	2.69±8	<0.001	19.2±11.25	0.024	10.96±9.23	0.011
	2005-2014	3.28±8.4		19.5±11.45		11.4±9.54	
Marivan	1995-2004	5.17±7.76	0.619	21±11	0.018	13.13±8.89	0.115
	2005-2014	5.25±7.4		21.6±11		13.38±9	
Zarrineh	1995-2004	1.98±8.39	0.116	14.45±11.28	0.01	8.22±9.68	0.029
	2005-2014	2.25±8.56		15.1±11.26		8.66±9.73	

P: Considered significant less than 0.05

In addition, the lowest values were for Zarrineh with the mean of air temperature of 8.22 ± 9.68 and 8.66 ± 9.73 for the first decade and the second decade, respectively.

According to the Mann-Whitney test results, there was an increase in the mean and standard deviation of the environmental parameters in the second decade as compared to the first, including the minimum, maximum, and mean daily temperatures. On the other hand, the highest relative humidity was reported in the first decade in the city of Saqqez with mean and standard deviation of $53.61 \pm 20.1\%$ and the lowest one was in Qorveh city with mean and standard deviation of $43.1 \pm 20.2\%$. In addition, the highest and lowest relative humidity in the second decade belonged to Marivan with mean

and standard deviation of $53.80 \pm 19.95\%$ and Bijar city with mean and standard deviation of $46.21 \pm 20.2\%$, respectively.

As shown in Table 3, air temperature values including (minimum, maximum and average) increased in the second decade compared to the first decade, and this increase was significant in most stations ($p < 0.05$). Air temperature fluctuations in different months between years of 1995 to 2014 demonstrated in charts of Fig. 2, distinctively. In contrast, the fluctuations of air velocity have accompanied with a decrease in second decade compared to first decade (Fig. 3).

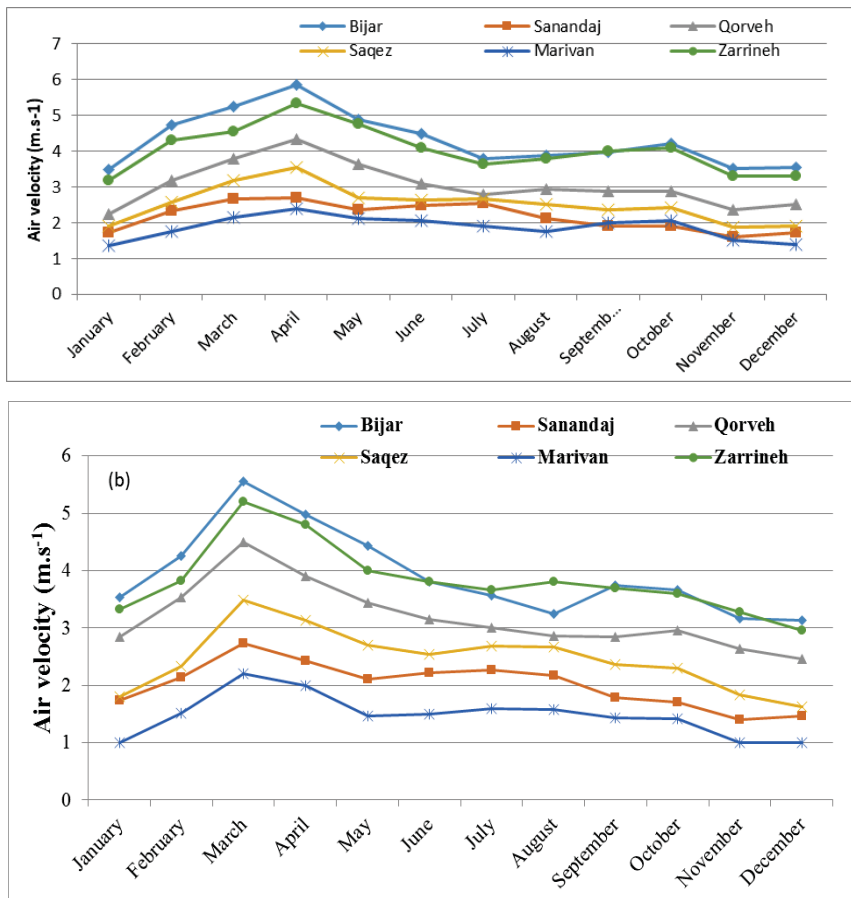
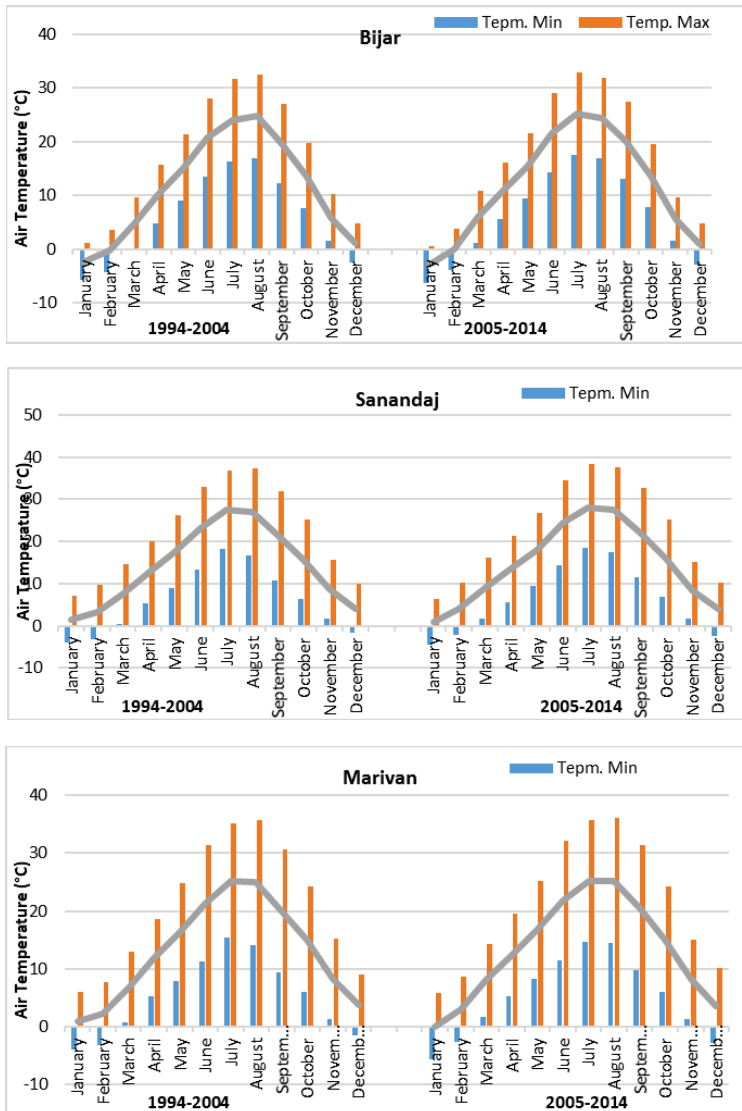


Figure 2. Air velocity fluctuations in different months between a) 1994-2004 and b) 2005-2014



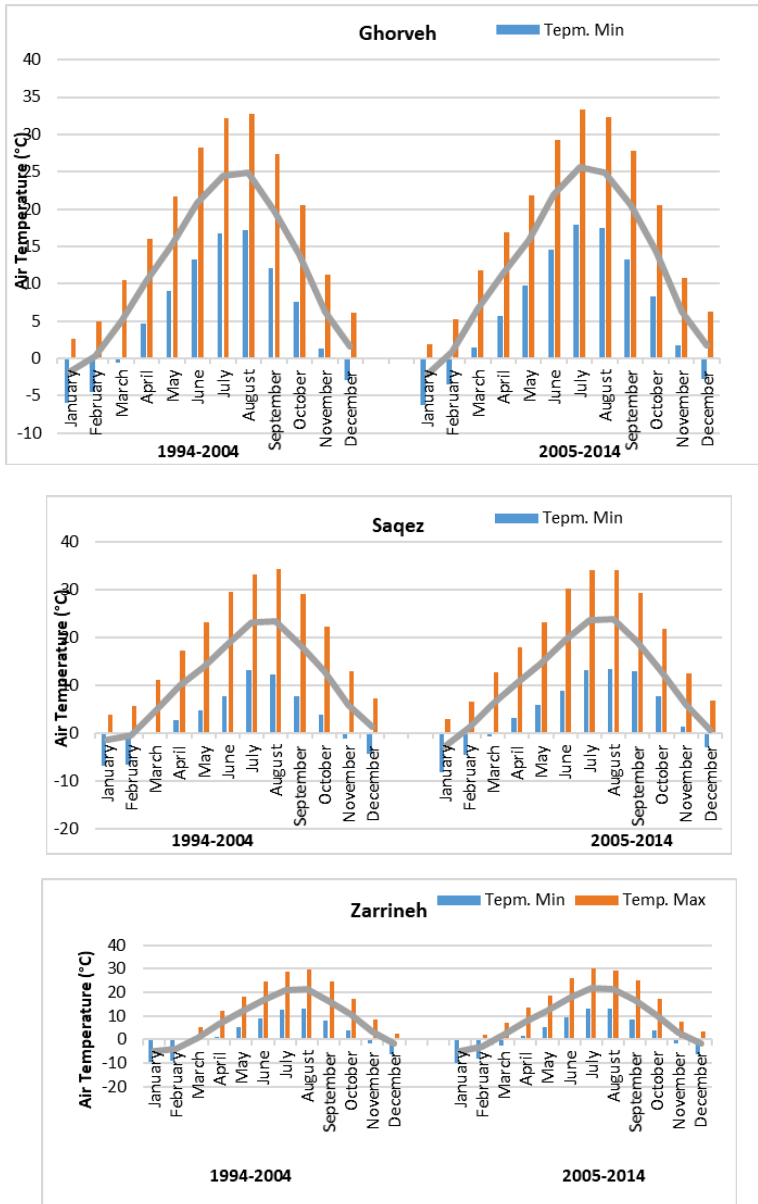


Figure 3. Air temperature fluctuations between 1994 to 2014 in different months and synoptic stations

1

The results of Table 4 showed that in two studied decades, the lowest and highest values of the WC index have occurred in which months of the year, frequently? In addition, what was the prevailing bioclimatic situation in that area? The results shown that generally, the lowest WCIs observed in July

and August months and highest WCIs in February and January months. In addition, the prevailing bioclimatic situation was different from pleasant to very cold in this province.

Table 4: The changes of the WC index in different months, decades and stations

Station*	Months of the year				Bioclimatic condition
	First decade, (1995-2004)		Second decade, (2005-2014)		
	Lowest WCI	Highest WCI	Lowest WCI	Highest WCI	
Bijar	August	February	July	January	Cool to very cold
Sanandaj	July	February	July	January	Pleasant to cold
Qorveh	August	February	July	August	Pleasant to cold
Saqez	August	February	August	January	Cool to cold
Marivan	July	February	August	January	Pleasant to cold
Zarrineh	August	February	July	January	Cool to very cold

*The studied cities of Kurdistan province

Table 5 shows the comparison of the mean WCI at the stations under study for two decades. The results of the Mann-Whitney test show that the mean WCI has decreased in the second decade compared to the first decade. Significant relations were seen between two studied decades, except for Saqez and Zarrineh ($p < 0.05$).

Table 5: Comparison of the mean WCI in two decades in the deferent cities

Station	Period	WCI ($M \pm SD$)	P*
Sanandaj	1995-2004	403.19 $\pm$ 208.2	0.05
	2005-2014	393.3 $\pm$ 209.3	
Bijar	1995-2004	547 $\pm$ 254.7	0.05
	2005-2014	530.2 $\pm$ 252.6	
Qorveh	1995-2004	496.53 $\pm$ 234.96	<0.001
	2005-2014	469.56 $\pm$ 232.56	
Saqez	1995-2004	488.2 $\pm$ 212.31	0.114
	2005-2014	478.3 $\pm$ 200.77	
Marivan	1995-2004	411.68 $\pm$ 187	<0.001
	2005-2014	381.36 $\pm$ 179.55	
Zarrineh	1995-2004	612.8 $\pm$ 265.47	0.997
	2005-2014	609.32 $\pm$ 250.3	

*P: Considered significant less than 0.05.

The maps of the Fig. 4 and 5 shown the values of WCI in different seasons of the studied decades. The maps of Fig. 4 showed that the highest average values are for the northern half of the province (Zarrineh and Bijar cities) and the lowest ones for the southwestern regions (Sanandaj and Marivan cities). In addition, the index values decrease from the north side of the province to the south.

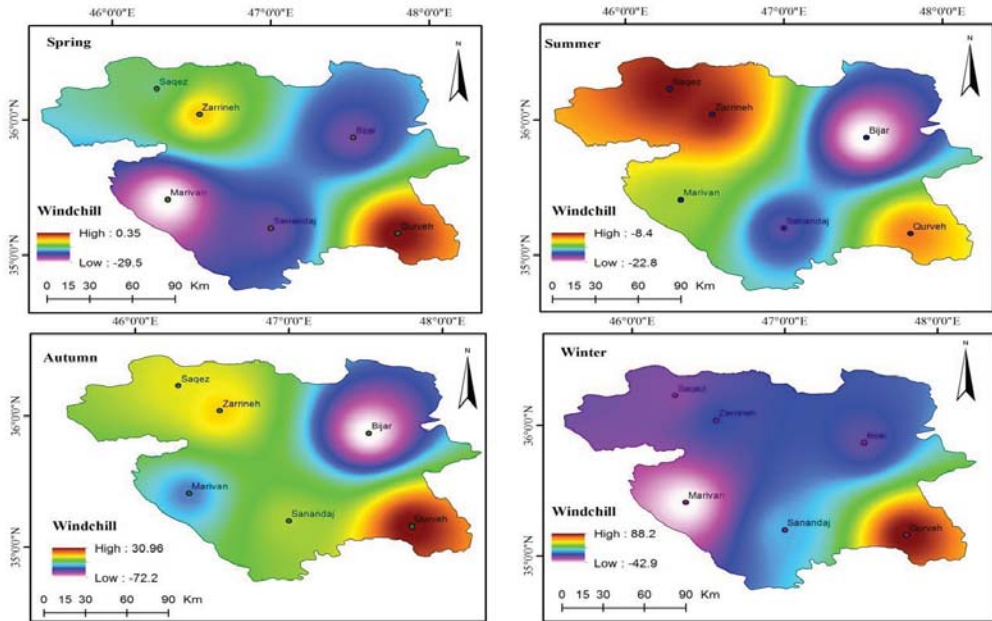


Figure 4. The maps of the mean of WC index in different seasons between 1995 and 2004

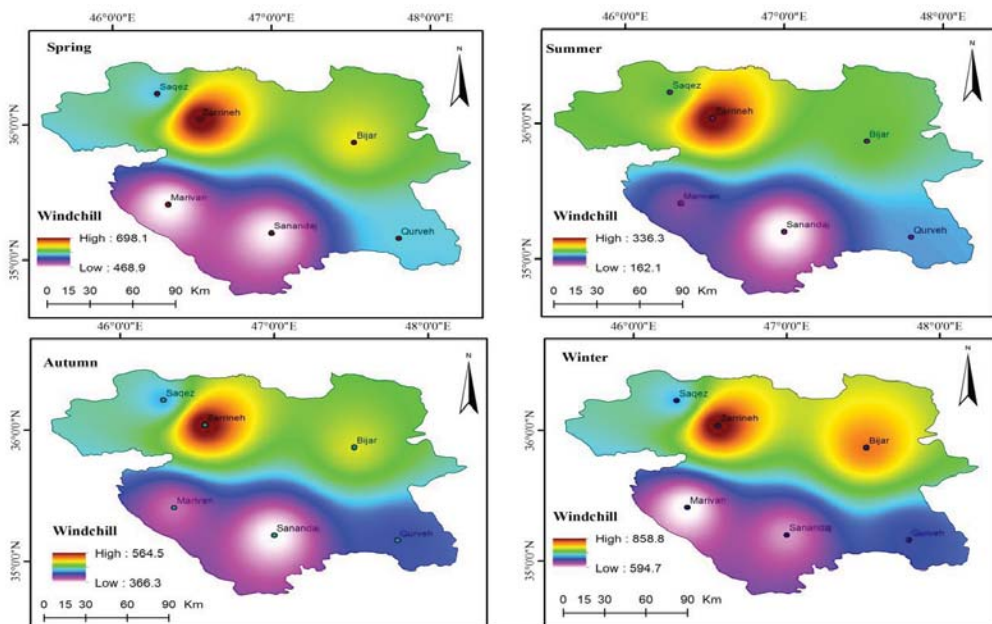


Figure 5. Anomaly maps of the mean WC index in different seasons between 2005 and 2014

The zoning of the WCI in the first decade indicates that none of the province's regions is in the climate comfort zone (50-200 Kcal/hr/M²) in the spring and most of the province's regions are in very cold to cold conditions.

In summer, the southwest areas of the province (cities of Sanandaj and Marivan) are in a comfort condition (pleasant) and the rest of the province is cool to very cold. In the autumn like in the spring, most of the regions are in very cold to cold conditions, and the climate is pleasant in the province. In the winter, all parts of the province are cold to very cold due to the cold weather. Therefore, most areas of the province are outside of the climate comfort zone.

4. DISCUSSION

In this study, bioclimatic conditions have analyzed and compared over two decades using the WCI in different stations of Kurdistan province. The WC index survey's findings demonstrated that, in the first and second decades of the study, respectively, the index's highest values were frequently observed in February and January. Additionally, in the first and second decades of the study, August and July had the lowest index values, respectively. On the other hand, the bioclimatic status of the studied areas has varied from pleasant to very cold (Table 4). According to the seasonal anomaly maps in Fig. 5 (difference of the index values in two decades), the areas located in the southeast of the province (Qorveh) and northwest (Zarrineh) have the highest positive anomalies in spring and the areas in the southwest to northeast (Sanandaj to Bijar) have negative anomalies.

Due to global warming, the air temperature in areas with negative anomalies increased and this increase in temperature has reduced the index values toward climate comfort. In the summer, the index anomaly values were negative in all provinces. The most negative anomalies were in Bijar and the least ones in the northwest and in the cities of Zarrineh and Saez. It should be noted that during the first decade in the northwest of the province and in summer, very cool conditions prevailed (Fig. 3). The decline in the indicator values in this region in the second decade has shown that the index is moving towards climate comfort but there is still a gap until it reaches climate comfort (values below 200 Kcal/hr/M²).

In the autumn, the most negative anomalies are in Bijar and Marivan, indicating that these cities are moving towards climatic conditions. On the other hand, Qorveh city in the southeast of the province has a positive anomaly, indicating that the city has moved away from climate comfort. In the winter, most areas of the province have negative anomalies (Fig. 5). In other words, the index values are lower in this season and the weather is warmer than in the first decade. Therefore, in second decade the climate is more favorable than in the first decade, but cold stress is present in most areas. Qorveh city in the southeast of the province has had positive anomalies, indicating that the index values in this city have increased in the second decade and cold stress has increased in the city.

In general, there are still cold to extremely cold conditions in most parts of the province, even though the amount of WCI is decreasing during this season and moving towards warmer climates, similar to what happened in the first decade. In a study by Falah Qalhari *et al.*, they evaluated the thermal comfort of Kurdistan province using the Universal Thermal Climate Index (UTCI). Results showed that Kurdistan province has moderate to severe cold stresses due to human climatic conditions (Falah Ghalhari *et al.*, 2015). Mohammadi *et al.*, studied climate comfort status of Kurdistan province using daily data of metrological variables, standard effective temperature (SET) and physiological equivalent temperature (PET). According to the SET index, the highest climatic comfort was observed at Marivan, Sanandaj, Baneh, Bijar, Qorveh, Saqez and Zarrineh stations, respectively. Similarly, according to the PET index, the highest level of climatic comfort was observed in Marivan, Qorveh, Baneh, Sanandaj, Bijar, Zarrineh and Saqez stations, respectively. Most of the stations studied had the highest climatic comfort in November, October and May, but in the Zarrineh station the climatic comfort was seen in the summer (Mohammadi *et al.*, 2017).

Rahimi *et al.* also analyzed the climate comfort condition in the Tabriz city. Their results showed that summer and spring have the highest climatic comfort conditions (Gaveidelrahimeh and Ahmadi, 2013). Nastos *et al.* investigated the role of climate in Athens mortality using climate comfort indices. The findings demonstrated a significant linear relationship between climate comfort and mortality (Nastos and Matzarakis, 2012). Kunst *et al.* in the Netherlands studied the correlation of the temperature and two indices of WCIs (developed by (a) Steadman & (b) Siple and Passel) with daily mortality variations. Their results showed that mortality induced by heart disease was positively and strongly correlated with Steadman's WCI relative to Siple and Passel's WCI and temperature (Kunst *et al.*, 1994).

Bouden and Ghrab investigated thermal comfort in five Tunisian cities. In their research, they asked about 200 people about their natural living conditions at work and at home each month for a year and compared them with thermal comfort indices. The results of the study showed a significant relationship between the declared thermal comfort conditions (subjective responses) and thermal comfort indices (Bouden and Ghrab, 2005). Toy *et al.* studied the bioclimatic comfort in Erzurum in three urban, rural and urban- forest areas of Turkey and concluded that the urban- forest areas were more compatible with the thermal comfort indices used (Toy *et al.*, 2007).

According to the results, the heat stress has occurred in summer and the most severe cold stresses occurred in winter, especially in February, due to the specific geographical location, high altitudes of the region, the cold air storm, the length of the glacial period, and the arrival of western winds during the cold season. In summer, all the countries of Iran have put in the subtropical high pressure of Azores, which combined with hot and dry air, can cause severe heat stress (Falah Ghalhari *et al.*, 2015).

The results showed that the mean ambient temperature parameter increased in the second decade compared to the first decade. On the other hand, the comparison of the mean WCI in the two decades showed that the mean thermal comfort index decreased in the second decade compared to the first

decade, which was statistically significant in the cities of Sanandaj, Bijar, Qorveh and Marivan. The decline in the index indicates the warming of the Kurdistan's climate. In a study, Daneshvar et al. also showed a significant decrease in precipitation and a significant increase in upward longwave radiation (ULR) throughout Iran, which is indicating the effects of global warming and climate change in these areas (Mansouri Daneshvar *et al.*, 2019) .

Khorani et al. studied the climate comfort of Kurdistan province for planning the tourism and determined that according to the index of human fatigue, most of the cities in the province for 4 months of the year including May, June, September and October have a moderate and favorable climate for excursion (Bakhtiari *et al.*, 2018)

Hamilton et al., studied the effects of climate change on tourism in Germany, the United Kingdom and Ireland. They concluded that in the coming years, due to climate change, the tourist attraction would gradually shift to the northern regions (Hamilton and Tol, 2007) .

5. CONCLUSION

Human comfort depends on various climate and ecological factors. According to the results of the study, different cities of Kurdistan province are experiencing almost identical climate conditions. On the other hand, the mean thermal comfort index decreased in the second decade compared to the first decade, reflecting the warming of Kurdistan's climate and a significant decrease in WC index was observed in the cities of Sanandaj, Bijar, Qorveh and Marivan. Therefore, in terms of climate condition, the best time for tourism in Kurdistan province is summer.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the corresponding author, without under reservation.

ETHICS STATEMENT

Ethical approval for this study was obtained from Golestan University of Medical Sciences (IR.GOUMS.REC.1400.132).

ACKNOWLEDGEMENTS

The authors would like to highly appreciate the Iran Meteorological Organization for the provision of required data. The authors declare that there is no conflict of interests.

CONFLICT OF INTEREST STATEMENT

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

FUNDING

No funding was received to assist with the preparation of this manuscript and for conducting this study.

AUTHOR CONTRIBUTIONS

MA: conceptualization, methodology, writing—reviewing, and editing. HH: conceptualization, analysis, interpretation. GT: conceptualization, data collection, first draft of the manuscript. GFG: data analysis, software. SFD: supervision, reviewing and editing. All authors contributed to the article and approved the submitted version.

REFERENCES

- Abdulla, P., Sanma, J., James, E., 2012. Analysis of nearshore wave height, direction and breaker angle of southwest coast of India using visually observed data. *International journal of ecology development* 22, 74-87.
- Ahrens, C.D., 2015. *Meteorology today: an introduction to weather, climate, and the environment*. Cengage Learning Canada Inc.
- Asghari, M., Ghalhari, G.F., Abbasinia, M., Shakeri, F., Tajik, R., Ghannadzadeh, M.J., 2020. Feasibility of relative strain index (RSI) for the assessment of heat stress in outdoor environments: Case study in three different climates of Iran. *The Open Ecology Journal* 13.
- Asghari, M., Teimori, G., Abbasinia, M., Shakeri, F., Tajik, R., Ghannadzadeh, M.J., Ghalhari, G.F., 2019. Thermal discomfort analysis using UTCI and MEMI (PET and PMV) in outdoor environments: case study of two climates in Iran (Arak & Bandar Abbas). *Weather* 74, S57-S64.
- Bakhtiari, B., Bakhtiari, A., Afzali Gorouh, Z., 2018. Investigation of climate change impacts on tourism climate comfort in Iran. *Global NEST Journal* 20, 291-303.
- Bouden, C., Ghrab, N., 2005. An adaptive thermal comfort model for the Tunisian context: a field study results. *Energy and Buildings* 37, 952-963.
- Cann, K., Thomas, D.R., Salmon, R., Wyn-Jones, A., Kay, D., 2013. Extreme water-related weather events and waterborne disease. *Epidemiology & Infection* 141, 671-686.
- Curtis, S., Fair, A., Wistow, J., Val, D.V., Oven, K., 2017. Impact of extreme weather events and climate change for health and social care systems. *Environmental Health* 16, 23-32.

- De Freitas, C., 2001. Theory, concepts and methods in tourism climate research. Proceedings of the First International Workshop on Climate, Tourism and Recreation. A. Matzarakis and CR de Freitas, pp. 3-20.
- Fallah Ghalhari, G., Mayvaneh, F., Shakeri, F., 2015. Evaluation of thermal comfort and human health using Universal Thermal Climate Index (UTCI) Case Study: Kurdistan province. Iranian Journal of Health and Environment 8, 367-378.
- Gaveidelrahimej, Y., Ahmadei, M., 2013. Estimation and time analysis of climatic comfort in Tabriz Megalopolis. Geography and Development Iranian Journal 11, 173-182.
- Ghalhari, G.F., Dehghan, S.F., Shakeri, F., Ghanadzadeh, M.J., Asghari, M., 2020. Assessing the monthly changes of heat stress indices in outdoor environment during a 15-year period: Case of study in a dry and warm climate. Urban Climate 31, 100538.
- Hamilton, J.M., Tol, R.S., 2007. The impact of climate change on tourism in Germany, the UK and Ireland: a simulation study. Regional Environmental Change 7, 161-172.
- Hanafi, A., Hatami, I., 2013. Producing climate map for Kurdistan Province using information technology system. Scientific-Research Quarterly of Geographical Data (SEPEHR) 22, 24-28.
- Kangrang, A., Prasanchum, H., Hormwichian, R., 2017. Future runoff under land use and climate changes in the Ubolratana Basin, Thailand. International journal of ecology development 32, 53-66.
- Kim, H., Lee, K., Kim, T., 2018. Investigation of pedestrian comfort with wind chill during winter. Sustainability 10, 274.
- Kjellstrom, T., Freyberg, C., Lemke, B., Otto, M., Briggs, D., 2018. Estimating population heat exposure and impacts on working people in conjunction with climate change. International journal of biometeorology 62, 291-306.
- Kunst, A.E., Groenhouf, F., Mackenbach, J.P., 1994. The association between two windchill indices and daily mortality variation in The Netherlands. American Journal of public health 84, 1738-1742.
- Lin, T.P., De Dear, R., Hwang, R.L., 2011. Effect of thermal adaptation on seasonal outdoor thermal comfort. International Journal of Climatology 31, 302-312.
- Mansouri Daneshvar, M.R., Ebrahimi, M., Nejadsoleymani, H., 2019. An overview of climate change in Iran: facts and statistics. Environmental Systems Research 8, 1-10.
- Matzarakis, A., 2007. Climate, thermal comfort and tourism. Climate change and tourism-assessment and coping strategies, 139-154.
- Matzarakis, A., Amelung, B., 2008. Physiological equivalent temperature as indicator for impacts of climate change on thermal comfort of humans. Seasonal forecasts, climatic change and human health. Springer, pp. 161-172.
- Mirmousavi, S.H., Abakhti, G.H., Khaefi, N., 2014. Study Of Climate Characteristics In The Provinces

Of Kermanshah And Kordestan Based On Factor And Cluster Analyses. *Geography and Planning* 18, 215-233.

Mohammadi, B., Mohammadkhani, P., Gholizadeh, M.H., 2017. Preparing Iran's bioclimatic map by using the predicted mean vote index. *Geographical Researches* 32, 21-39.

Nastos, P.T., Matzarakis, A., 2012. The effect of air temperature and human thermal indices on mortality in Athens, Greece. *Theoretical and Applied Climatology* 108, 591-599.

Organization, W.H., 2014. Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s. World Health Organization.

Osczevski, R., Bluestein, M., 2005. The new wind chill equivalent temperature chart. *Bulletin of the American Meteorological Society* 86, 1453-1458.

Perch-Nielsen, S.L., Amelung, B., Knutti, R., 2010. Future climate resources for tourism in Europe based on the daily Tourism Climatic Index. *Climatic change* 103, 363-381.

Potchter, O., Cohen, P., Lin, T.-P., Matzarakis, A., 2018. Outdoor human thermal perception in various climates: A comprehensive review of approaches, methods and quantification. *Science of the Total Environment* 631, 390-406.

Roshan, G., Mirkatouli, G., Shakoor, A., Mohammad-Nejad, V., 2010. Studying wind chill index as a climatic index effective on the health of athletes and tourists interested in winter sports. *Asian Journal of Sports Medicine* 1, 108.

Shakeri, F., Abbasinia, M., Ghanadzadeh, M.J., Asghari, M., Tajik, R., 2019. Use of Becker and neurotic pressure bioclimatic indices in the assessment of thermal comfort in outdoor environments based on meteorological data: case study in three different climates of Iran. *Iran Occupational Health* 16, 33-46.

Shitzer, A., 2006a. A parametric study of wind chill equivalent temperatures by a dimensionless steady-state analysis. *International journal of biometeorology* 50, 215-223.

Shitzer, A., 2006b. Wind-chill-equivalent temperatures: regarding the impact due to the variability of the environmental convective heat transfer coefficient. *International journal of biometeorology* 50, 224-232.

Toy, S., Yilmaz, S., Yilmaz, H., 2007. Determination of bioclimatic comfort in three different land uses in the city of Erzurum, Turkey. *Building and environment* 42, 1315-1318.

Tseliou, A., Tsiros, I.X., Lykoudis, S., Nikolopoulou, M., 2010. An evaluation of three biometeorological indices for human thermal comfort in urban outdoor areas under real climatic conditions. *Building and Environment* 45, 1346-1352.

Vanos, J., 2011. Modelling outdoor thermal comfort of humans performing physical activity: applications to health and emergency heat stress preparedness. University of Guelph.

Zaoui, L., Hassini, A., Belbachir, A., 2017. Assessing spatio-temporal sand dune changes within the

Sahara of Algeria using landsat satellite data. International journal of ecology development 32, 76-87.

Zare, S., Hasheminezhad, N., Sarebanzadeh, K., Zolala, F., Hemmatjo, R., Hassanvand, D., 2018. Assessing thermal comfort in tourist attractions through objective and subjective procedures based on ISO 7730 standard: A field study. Urban climate 26, 1-9.