

Determination of Thermal Bioclimatic Conditions for Tourists in west and North West of Iran using PET

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Abstract— *Tourism has become an important sector that has an impact on development of country economy. The main benefits of tourism are income creation and generation of jobs. For many regions and countries it is the most important source of welfare. The purpose of this study is to determine the most suitable months for human thermal comfort and tourism activities in west and North West of Iran by using Physiologically Equivalent Temperature (PET). The data, which covering the period 1985–2010, from a dense network of 32 meteorological stations in west and north west of Iran was used to compute the PET. Mean air temperature, relative humidity, vapor pressure, wind speed, and cloud cover data were obtained from the Iran Meteorological Organization (IRIMO). Ray Man model was used to calculate the PET. Based on the calculations of PET in the region, it is shown that the months March and December in the west parts of Kermanshah, the months April, May and October in Kermanshah and Kurdistan and the June and September in the northern parts of the region such as Azerbaijan, and Hamadan are laying in the comfortable class that representing the most suitable months for tourism and tourist activities.*

Keywords— *Tourism, physiologically equivalent temperature (PET), climatic comfort, Ray Man, west and North West of Iran.*

I. INTRODUCTION

Nowadays tourism industry is developing into one of the most important and most lucrative industries worldwide. In 2012, international tourist arrivals exceeded one billion for the first time in history, contributing 9 % to global GDP, 1.3 US\$trillion in exports (United Nations World Tourism Organization 2013, Ruddy and Scott 2014). Tourism is heavily depended on weather and climate in such a way that fair weather and climate knowledge of destination play a key role in tourism industry and they can be attracting or off putting factors for tourists (Fallahi et al, 2012). Usually,

geographical location, topography, landscape, vegetation and fauna are factors that influence decisions regarding areas to be visited. Weather and climate are two additional factors (Matzarakis, 2006; Farajzadeh and Matzarakis, 2009). Climate and tourism are closely related and the relationship between these two is indicated whereby "Climate Comfort Index" (Ataei et al, 2013). The climatic indices, which are primary used for tourism climate assessments and thermal comfort studies, present a certain number of important points. From the point of view of human-biometeorology they do not include the effects of short and long wave radiation fluxes which are generally not available in climate records. The required, for the human energy balance, short and long wave radiation fluxes are calculated using synoptic and climatological and astronomical data (VDI 1998; Matzarakis et al 2000; Matzarakis 2007).

Commonly used indices that measure the effect of the thermal environment on humans are PMV (Predicted Mean Vote) (Fanger 1972), PET (*Physiological Equivalent Temperature*) (Höppe, 1999, Matzarakis et al, 1999), and SET* (standard effective temperature) (Gagge et al. 1986). The advantage of these thermal indices is that they require the same meteorological input parameters i.e. air temperature, air humidity, wind speed, short and long wave radiation fluxes (Matzarakis 2007). The *physiologically equivalent temperature* (PET) is a thermal index derived from the human energy balance. It is well suited to the evaluation of the thermal component of different climates. PET is preferable to other thermal indexes such as the predicted mean vote because of its units (°C), which make results more comprehensible to urban or regional planners. PET results can be presented graphically or as bioclimatic maps (Matzarakis et al., 1999). In this regard Rayman which is an improved model calculates the average radiant temperature and thermal indexes in simple and complex environments based on the data from weather stations and climatic elements such as temperature, humidity and wind

speed (Matzarakis 2009). This model can be used to evaluate urban bioclimate and thermal indexes including (PET), (SET) and (PMV).

Iran, among the world's eighth leading countries considering its cultural and historical sites, and based on the diversity of landscape and continental ecotourism attractions, ranked in the top five countries of the world (Esmaili and Fallah Ghalhari, 2014). However, little research has been done to establish environmental and continental information for tourists that can not the following research:

Matzarakis and Farajzadeh (2009), in a paper entitled "Quantification of climate for tourism in the northwest of Iran" concluded that all the stations in northwest Iran have a month with (TCI) over 80 which can be considered an ideal index comfort. Esmaili and Fallah Ghalhari (2014) have studied Bioclimatic Conditions of Mashhad for Tourists activities and concluded the months of April, May and October have the best bioclimate condition in Mashhad. Ataei and Hashemi Nasab (2012), in a research Evaluated Human Bioclimate of Semnan Province by using (PET) and (PMV)

and showed that in the months of October and November comfort climate prevailing in the city.

Ranjbar et al (2009), in a paper studied the relation between climatic conditions and annual tourism trend in the city of Marvdasht. Ataei et al (2013) determined a suitable calendar for tourism in Ahwaz using PET and Concluded that Ahwaz has comfortable and suitable conditions during the cold seasons of the year and is the best destination for tourists in the winter.

Because of the availability of large tourist attractions in West and Northwest of Iran, the purpose of this study was to examine and analyze the thermal bioclimate (physiologically equivalent temperature) and determine the most suitable months for tourist activities in the west and north west of Iran.

II. STUDY AREA

The study area is located between 29° 58' to 39° 49' latitude and 44° 03' to 50° 39' longitude and includes the west and north west of Iran. This region has a diverse climate. In the northwest, winters are cold with heavy snowfall and subzero temperatures during December and January.

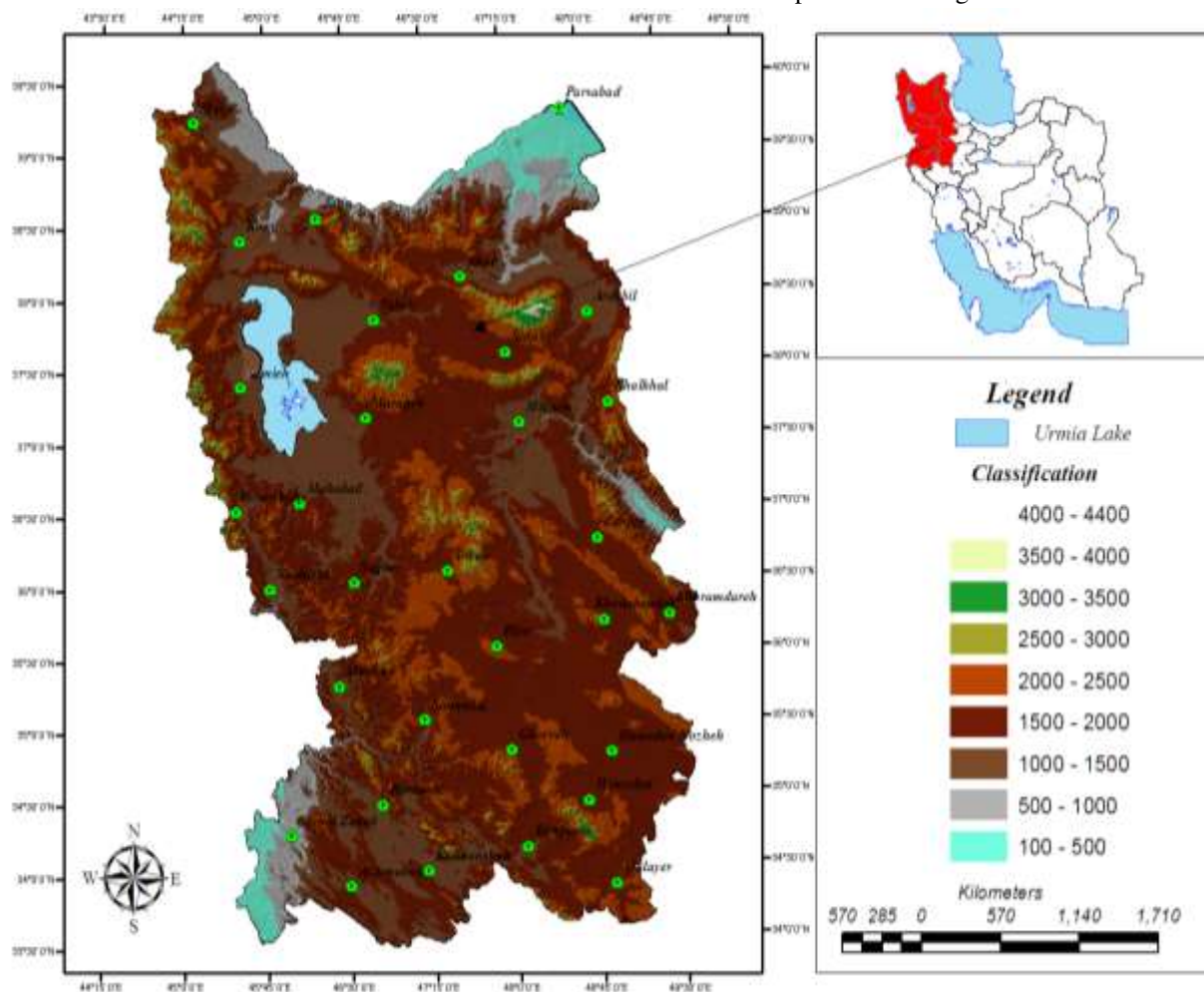


Fig.1: Topographic map, weather stations and geographical location of the study area

Spring and fall are rather mild, while summers are dry and hot. In the south, winters are mild and the summers are hot. In general, the west of Iran has plentiful cultural, historical and environmental attractions (ecotourism) considering as one of the most potential spots for tourist capacity. More than 100 tourism landmarks, plentiful cultural, historical and natural attractions (ecotourism and geotourism) and variety of climates can be found in the region and are mostly visited by the domestic and foreign tourists. In this region, the following provinces are located: West Azerbaijan, East Azerbaijan, Zanjan, Kurdistan, Ardabil, Kermanshah and Hamadan (Figure 1). Uremia lake and Sahulan cave palace in West Azerbaijan, Arasbaran forests and Kandovan village in East Azerbaijan, Qezel Ozan River and Soltanieh Dome in Zanjan, Sabalan Mountains and Sar Ein Mineral Springs in Ardabil, Alisadr cave in Hamadan, zarivar lake in Kurdistan, Bistun vault in Kermanshah are also interesting locations for visitors.

III. DATA AND METHODS

In the present study to assess Physiological Equivalent Temperature, the climatic data of 32 synoptic stations over a 25- year time period (1985-2010) were obtained in a quality controlled format from the I. R. of Iran Meteorological Organization (IRIMO). The meteorological elements dry temperature in Celsius, relative air humidity in percent, wind speed in meter per second, vapor pressure in hPa, the cloud amount in Octa are necessary for calculating PET. The mean radiant temperature can be calculated by combining the theoretical maximum global radiation and the mean cloud cover within the radiation and bioclimate model Ray Man (Matzarakis et al, 2000). The obtained data were fed into Excel program. Next, considering compatibility with (PET) method they were fed into Ray Man and finally the outputs were analyzed. The Human meteorological conditions are analyzed by means of 25-day mean values of thermal sensation measured at 7am, 2pm and 9pm during the year.

The thermal sensation is defined by means of physiologically equivalent temperature PET as the physiologically significant assessment of the thermal environment derived from the human energy balance (Höppe, 1999, Matzarakis et al., 1999, Matzarakis 2007). Since the 1960s, heat balance models of the human body have become more and more accepted in assessing thermal comfort. More universally applicable models take into account all basic thermoregulatory processes, like the constriction or dilation of peripheral blood vessels and the physiological sweat rate (Höppe 1993, 1999). The Munich energy balance model for individuals (MEMI) (Höppe 1993) is such a thermo physiological heat balance model. It is the basis for calculating the physiologically equivalent temperature (PET). PET is defined to be equivalent to the air temperature that is required to reproduce in a standardized indoor setting and for a standardized person the core and skin temperatures that are observed under the conditions being assessed (VDI 1998; Höppe 1999, Matzarakis 2007). The standardized person is characterized by a work metabolism of 80 W of light activity, in addition to basic metabolism; and by 0.9 clo of heat resistance as a result of clothing.

The calculation of PET includes the following steps:

- Calculation of the thermal conditions of the body with MEMI for a given combination of meteorological parameters.
- Insertion of the calculated values for mean skin temperature and core temperature into the model MEMI and solving the energy balance equation system for the air temperature T_a (with $v = 0.1$ m/s, $VP = 12$ hPa and $T_{mr} = T_a$).

Finally the resulting air temperature is equivalent to PET (Matzarakis 2007). PET allows the evaluation of thermal conditions in a physiologically significant manner, too. With respect to this, Matzarakis and Mayer (1996) transferred ranges of PMV for thermal perception and grade of physiological stress on human beings (Fanger 1972) into corresponding PET ranges (Table 1).

Table.1: Ranges of the physiologically equivalent temperature (PET) for different grades of thermal perception by human beings and physiological stress on human beings (Matzarakis and Mayer 1996, Matzarakis 2007)

PET	Thermal Perception	Grade of Physiological Stress
4 °C	very cold	extreme cold stress
8 °C	Cold	strong cold stress
13 °C	Cool	moderate cold stress
18 °C	slightly cool	slight cold stress
23 °C	Comfortable	no thermal stress
29 °C	slightly warm	slight heat stress
35 °C	Warm	moderate heat stress

41 °C

Hot
very hotstrong heat stress
extreme heat stress

They are valid only for the assumed values of internal heat production and thermal resistance of the clothing. This model can be used to evaluate urban bioclimatic and thermal indexes including (PET), Standard Effective Temperature (SET), Predicted mean Vote (PMV). The model has been developed in Germany according to international guidelines between atmosphere and short-and-long-wave fluxes. Ray man model is a run model for evaluation of bio meteorological weather quality, urban and regional planning at micro and macro level (Matzarakis, 2009).

IV. RESULTS AND DISCUSSION

Choosing a travel time and destination in terms of climate comfort can positively affect the quality of tourism. Enjoying a fair weather while travelling will increase the tendency to stay longer and coming back to the same spot. In contrast an unfavorable climatic condition enhances a negative experience. According to the PET index (table 1), the numerical value of 18-23 range shows a comfort condition without the warm or cold tensions. In this classification, the numerical values of 23- 29 and 13-18 indicate a slightly warm and cool stresses that can wear light or heavy clothes to bring the comfort condition.

In order to obtain an overview of PET changes in the region, four stations of Kermanshah, Sanandaj, Tabriz and Ardebil were selected from different geographic regions and the biometeorological conditions are analyzed by means of ten-day mean values of thermal sensation during the year. By means of the probability of occurrence of different thermal sensations that enable more detail information about bioclimate. The relative frequencies for PET values divided into 10 classes in order to evaluate the thermal stress for the Period from 1985 until 2010.

The relative frequencies for PET in Kermanshah station is shown in Figure 2. In Kermanshah station, thermal comfort occurs from March to June and September to November, with highest Probability (>30 %) in the months May and October and minimum frequency in July to August (about 0

%). Cold stress (<4 °C) can be observed from November to March with highest Probability (>50 %) in the months January and February. Days with strong heat stress, can be observed from June to October with maximum frequencies (More than 45%) in the months July and August.

Figure 3 shows the relative frequencies for PET in Sanandaj station. In this station, thermal comfort occurs throughout the year except July and August, with maximum frequencies (>30 %) from 10st of May to 10th of June and 10th of September to 20st of October and minimum frequency in December to March (about 0%). Cold stress (<4 °C) can be observed from November to April with highest Probability (>80 %) in the months January and February. Days with strong heat stress, can be observed from 1st of June to 20th of September with maximum frequencies (More than 30%) in the months July and August.

As can be seen in Figure 4, in Tabriz station, thermal comfort occurs from April to October, with maximum frequencies (>30 %) from 20st of May to 20th of June and 1st of September to 10st of October and minimum frequency from November to March (about 0 %). Cold stress (<4 °C) can be observed from October to May with maximum frequencies (>90 %) in the months December, January and February. Days with strong heat stress, can be observed from 20st of June to 10th of September with maximum frequencies (More than 8%) from 20st of July to 10th of August.

The relative frequencies for PET in Ardabil station is shown in Figure 5. Ardabil is considered as one of the coldest cities in Iran, in this station, thermal comfort occurs from April to October, with maximum frequencies (>30 %) from 10st of June to 10th of September and minimum frequency in November to April (about 0 %). Cold stress (<4 °C) can be observed from September to June with maximum frequencies (>95 %) in the months December, January and February. Days with strong heat stress in Ardabil rarely happens and can be observed from July to September with frequencies less than 2%.

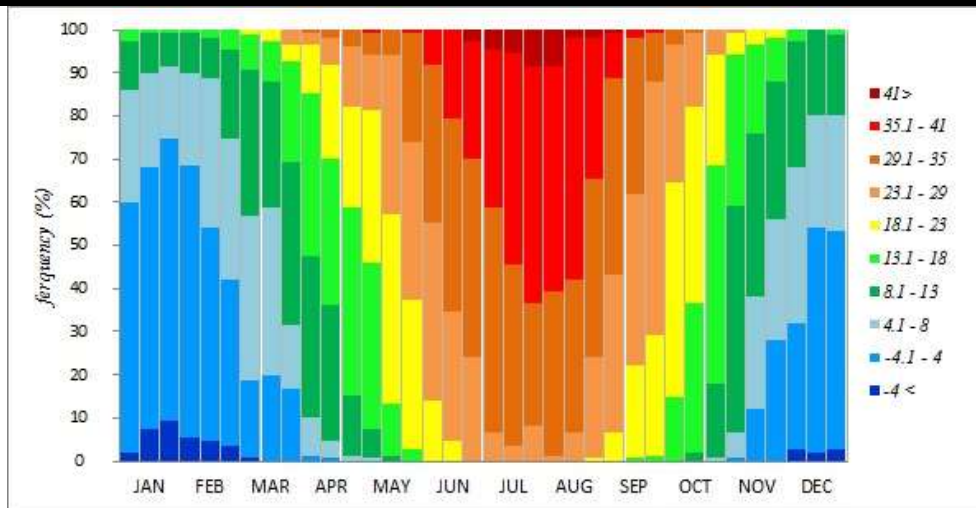


Fig.2: Probability of occurrence of different PET classes for the meteorological station Kermanshah for the period 1985–2010.

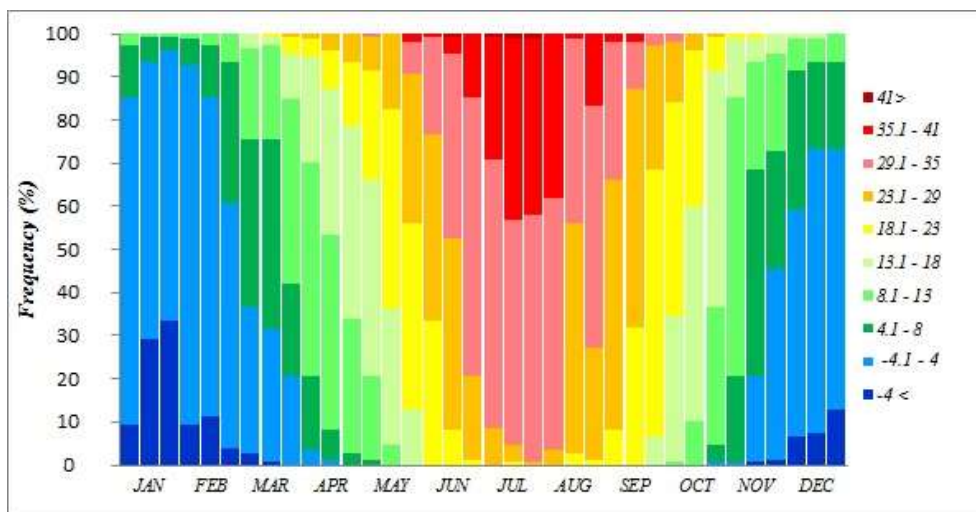


Fig.3: Probability of occurrence of different PET classes for the meteorological station Sanandaj for the period 1985–2010.

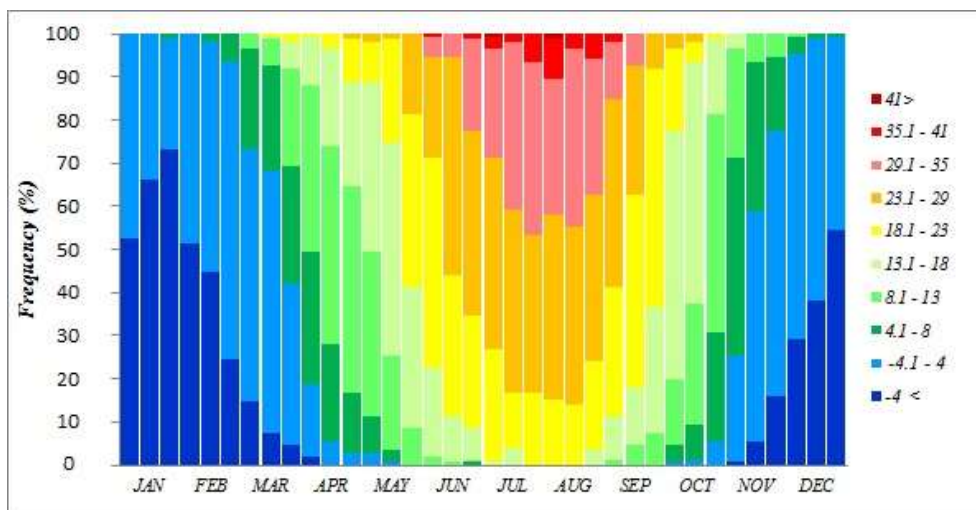


Fig.4: Probability of occurrence of different PET classes for the meteorological station Tabriz for the period 1985–2010.

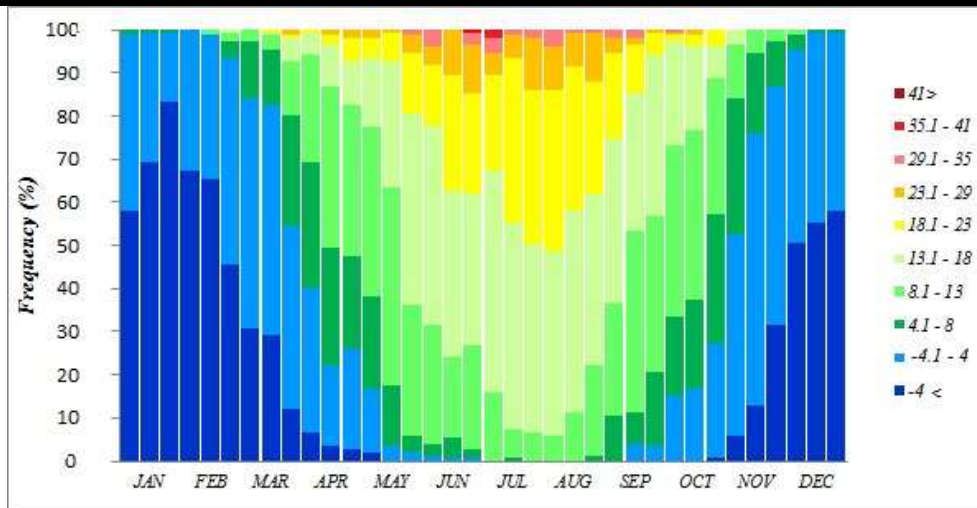


Fig.5: Probability of occurrence of different PET classes for the meteorological station Ardebil for the period 1985–2010.

Figure 6 shows the mean daily changes in the PET for Ardebil, Tabriz, Kermanshah and Sanandaj stations in the period 1985–2010. The thermal comfort zone (the numerical value of 13 to 29 degrees) is marked on the chart. In Kermanshah and Sanandaj stations, there is a cold physiological stress with different intensities from 1st of January to 30th of April and 20th of October to 31st of December. From 1st of May to 15th of June and 10th of September to 20th of October the physiological stress is zero and there is a climate comfort condition. There is a warm

physiological stress with different intensities from 15th of June to 10th of September.

Based on PET of Tabriz station, there is a cold physiological stress with different intensities from 1st of January to 10th of May and 15th of October to 31st of December. From 10th of May to 15th of July and 15th of August to 15th of October the physiological stress is zero and there is a climate comfort condition. There is a warm physiological stress with slight intense from 15th of July to 15th of August.

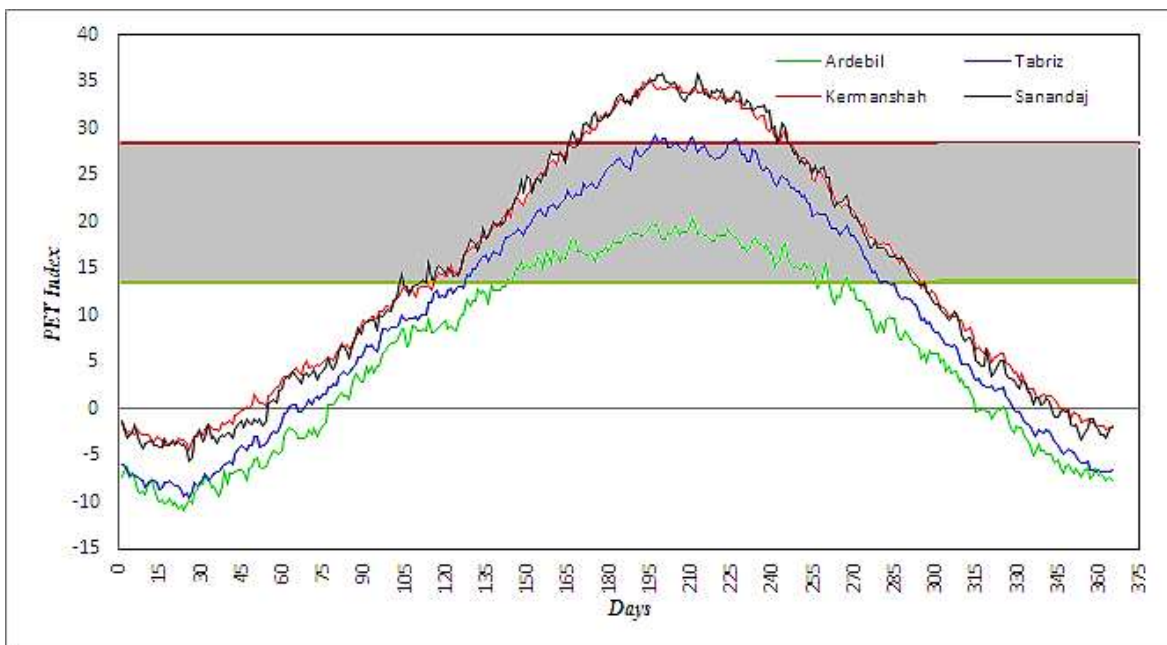


Fig.6: PET variations and comfort range at selected stations for 1985–2010

In Ardebil station, there is a cold physiological stress with different intensities from 1st of January to 15th of May and 20th of September to 31st of December. From 15th of May to

20th of September, the physiological stress is zero and there is a climate comfort condition. There isn't warm physiological stress in Ardebil station throughout the year.

In order to study the temporal and spatial changes in climate comfort, the monthly maps predicted and evaluated. Figure 7 shows the PET conditions for January. In this month, there is an extreme cold stress dominates in the provinces of Azerbaijan¹, Kurdistan and Hamadan, while there is a strong cold stress in the provinces of Kermanshah. The PET condition for February is the same as January. There is an extreme cold stress in the northern parts of the study area such as Azerbaijan, Kurdistan and Hamadan, while a moderate cold stress is dominant in west parts of Kermanshah such as Sarpole Zahab station (Fig. 8). In March, the amount of cold stress compared to the months of January and February have been reduced. There is an extreme and strong cold stress in the northern parts of the region such as Azerbaijan, Kurdistan and Hamadan and moderate cold stress in west parts of Kermanshah (Fig. 9). In April, the western parts of Kermanshah provinces such as Sarpole Zahab are associated with comfortable perception, while there is a slight cold stress in Jolfa, Khoy, Parsabad, Miyaneh and Aslamabad stations and moderate to strong cold stress in other areas (Fig. 10).

In the month of May by increasing the air temperature, the cold stress is reduced in the study area, so there is slight heat stress in the west parts of Kermanshah provinces and slight cold stress to comfort conditions in most parts of Azerbaijan, Kurdistan, Hamadan and Kermanshah (Fig. 11). The PET condition for June is indicated a strong to moderate heat stress in the western parts of Kermanshah provinces and Parsabad station, a slight heat stress in most parts of study area and climatic comfort conditions in the Stations of Ahar, Sarab, Ardebil, Khalkhal, Khodabandeh, Khorramdareh and Bijar (Fig. 12).

July is the hottest month in the study area. The PET condition for July is indicated a strong to moderate heat stress in the western parts of Kermanshah province, a slight to moderate heat stress in most parts of Azerbaijan, Kurdistan, Hamadan and Kermanshah provinces and climatic comfort conditions in the Stations of Ahar, Sarab, Ardebil and Khalkhal (Fig. 13). Physiological equivalent temperature index in August is also similar to July, so that the PET condition shows a strong heat stress in the western parts of Kermanshah province such as Sarpole Zahab station, a slight to moderate heat stress in most parts of Azerbaijan, Kurdistan, Hamadan and Kermanshah provinces and climatic comfort conditions in the Stations of Sarab, Ardebil and Khalkhal (Fig. 14). In September, the intensity of the heat stress compared with the months of July and August have been reduced. There is a moderate

heat stress in the western parts of Kermanshah province, slight heat stress in the Stations of Kermanshah, Aslamabad, Sanandaj, Khoy, Jolfa, Miyaneh and Parsabad, climatic comfort conditions in most parts of region and slight cold stress in the Stations of Sarab, Ardebil, Khalkhal and Khodabandeh (Fig. 15). In October, the heat stress reduced and cold stress has started in the northern parts of study area. The PET condition for October is indicated climatic comfort conditions in the western parts of Kermanshah province, a slight to moderate cold stress in most parts of region and strong cold stress in the Stations of Sarab, Ardebil and Khalkhal (Fig. 16). The physiological equivalent temperature condition in November shows a moderate cold stress in the western parts of Kermanshah province and strong to extreme cold stress in Other areas (Fig. 17). In December, the severity of cold stress has increased. The PET condition in December shows a strong cold stress in the western parts of Kermanshah province and extreme cold stress in other areas (Fig. 18).

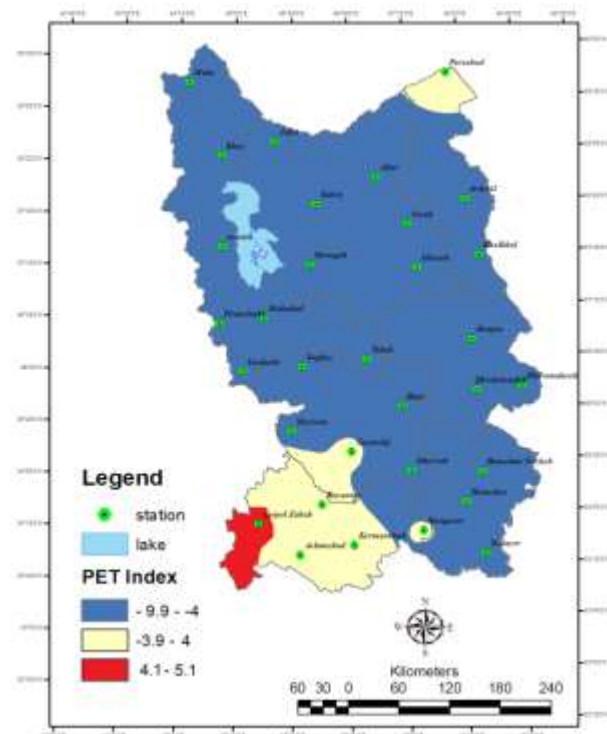


Fig.7: Geographical distribution of PET in January

¹. In this paper, Azerbaijan includes the provinces of East Azerbaijan, West Azerbaijan, Ardabil and Zanjan

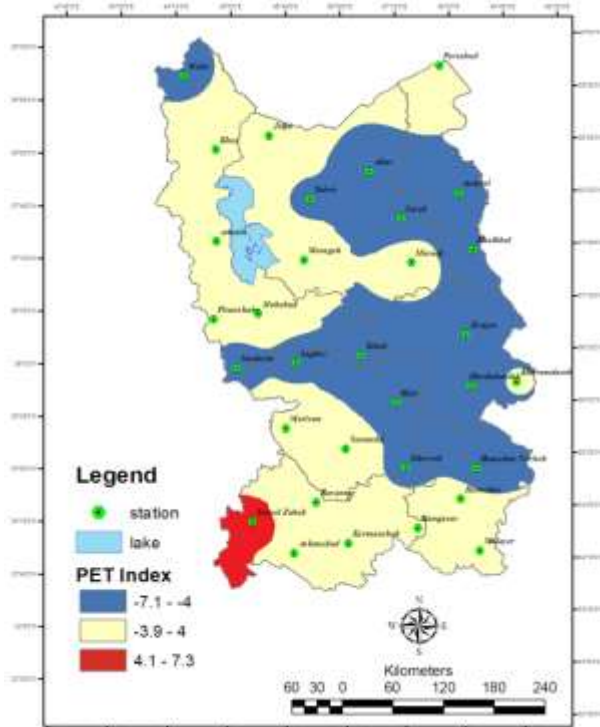


Fig.8: Geographical distribution of PET in February

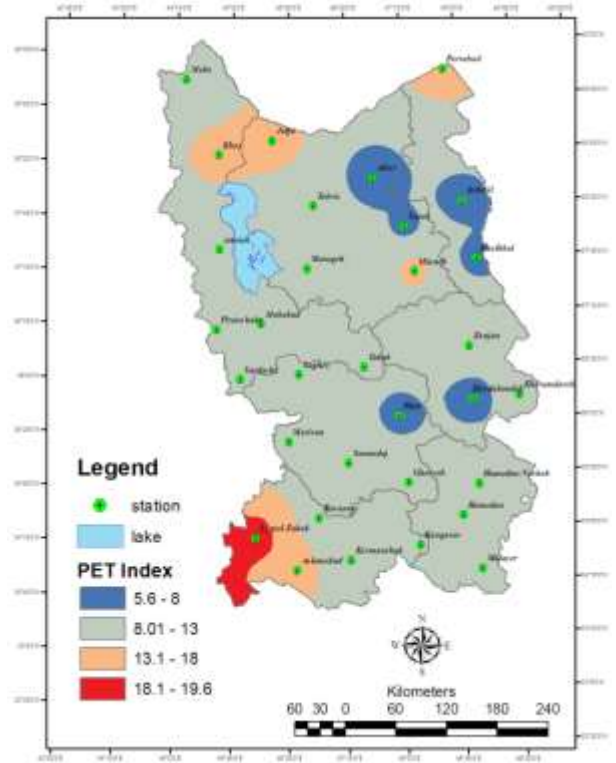


Fig.10: Geographical distribution of PET in April

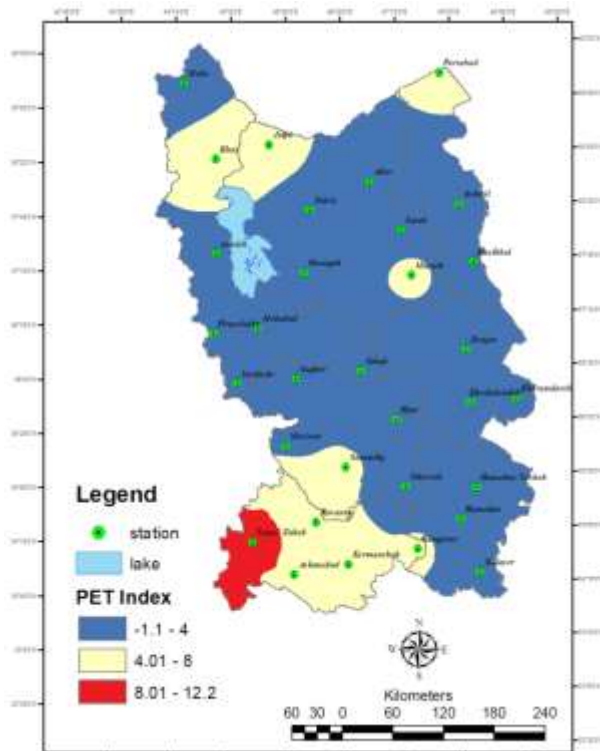


Fig.9: Geographical distribution of PET in March

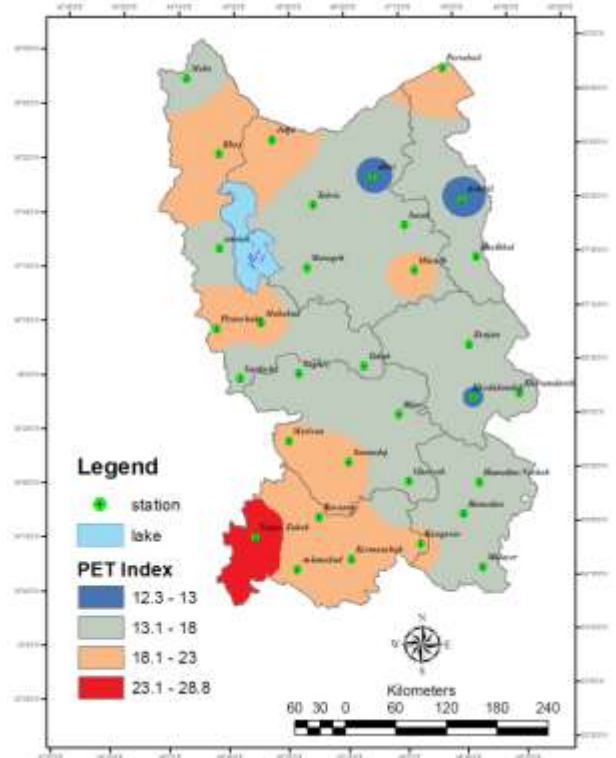


Fig.11: Geographical distribution of PET in May

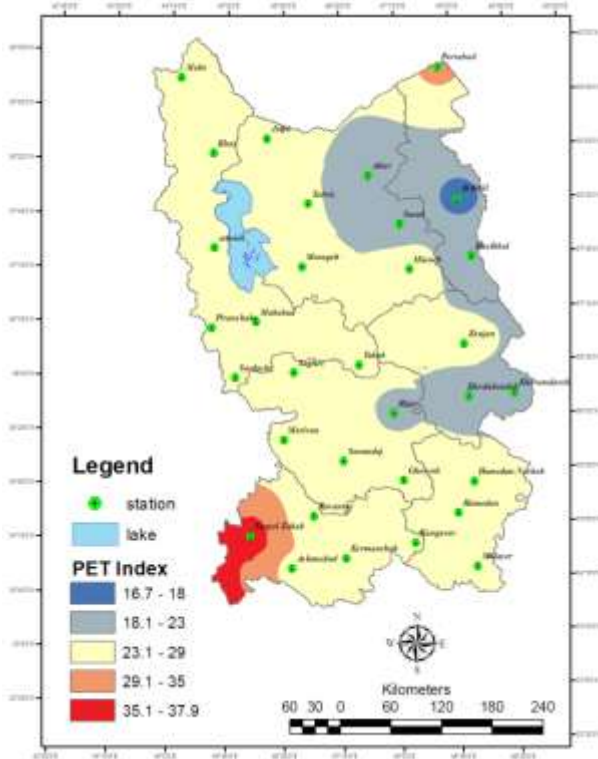


Fig.12: Geographical distribution of PET in June

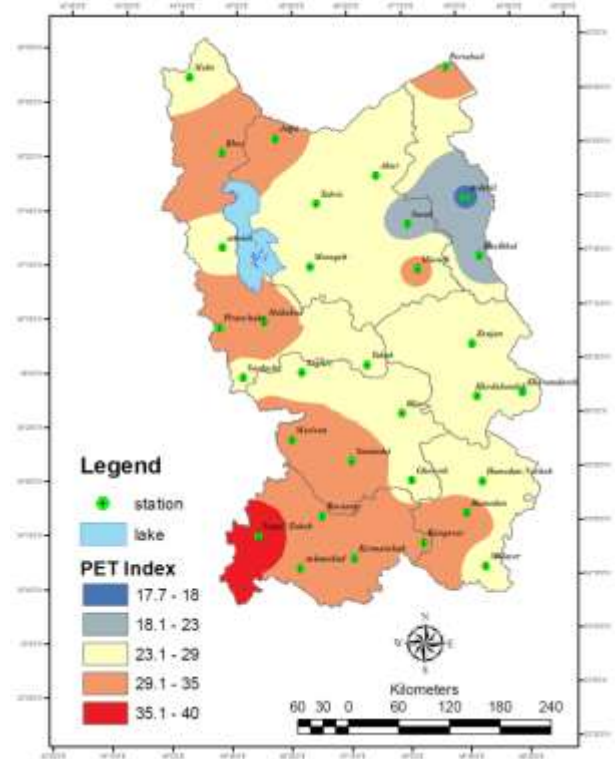


Fig.14: Geographical distribution of PET in August

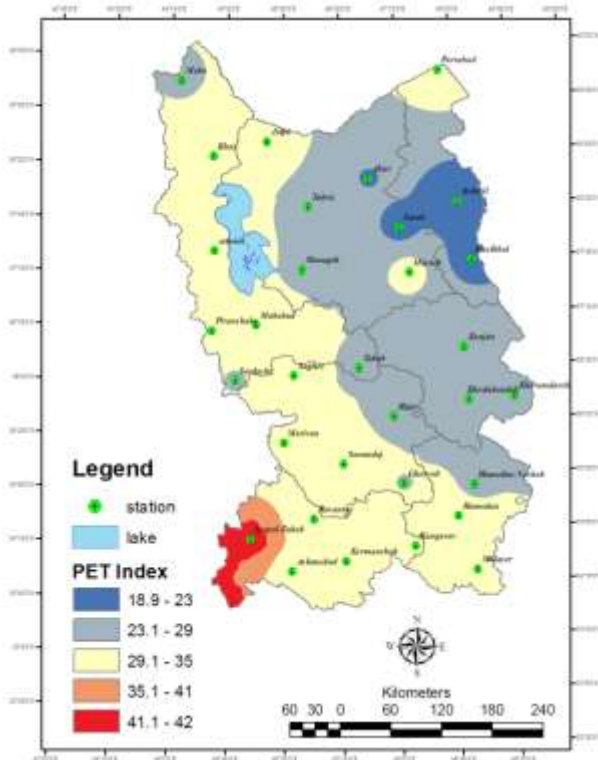


Fig.13: Geographical distribution of PET in July

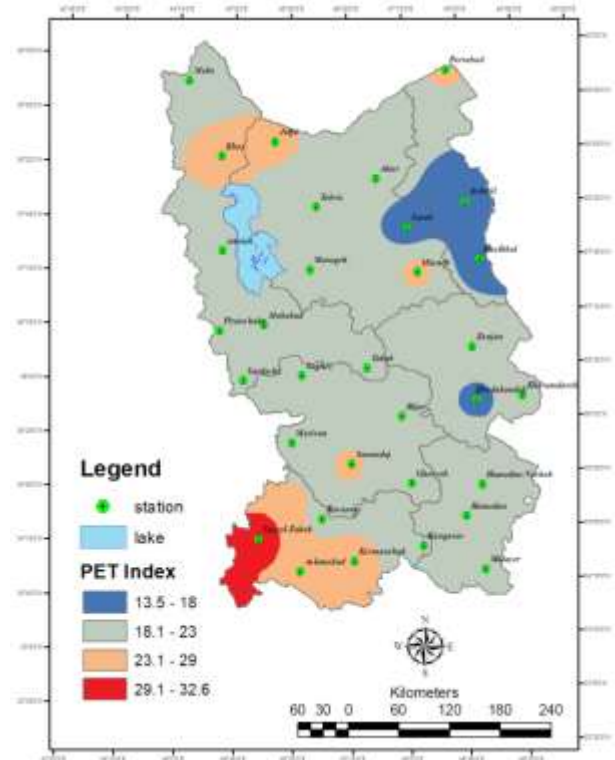


Fig.15: Geographical distribution of PET in September

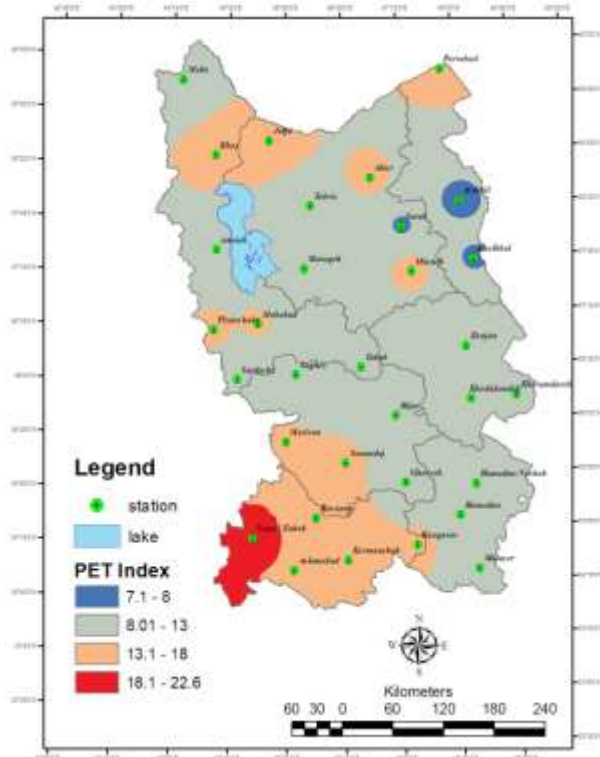


Fig.16: Geographical distribution of PET in October

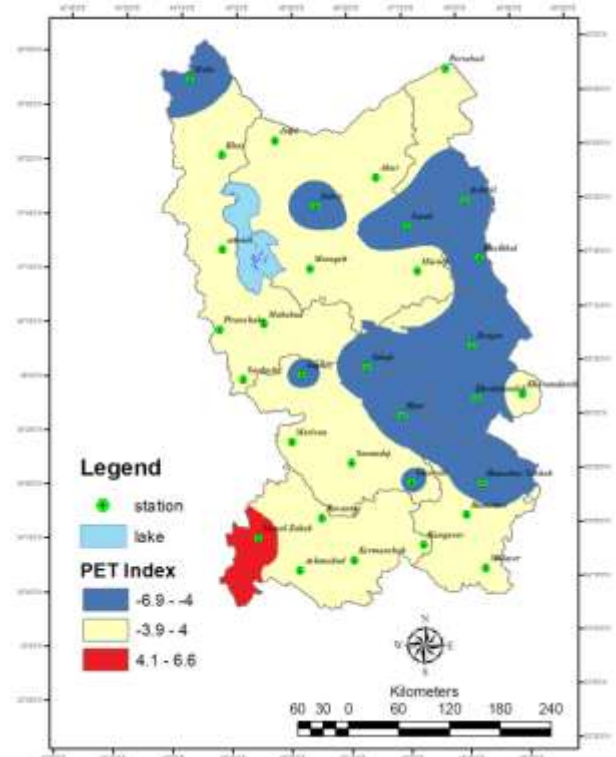


Fig.18: Geographical distribution of PET in December

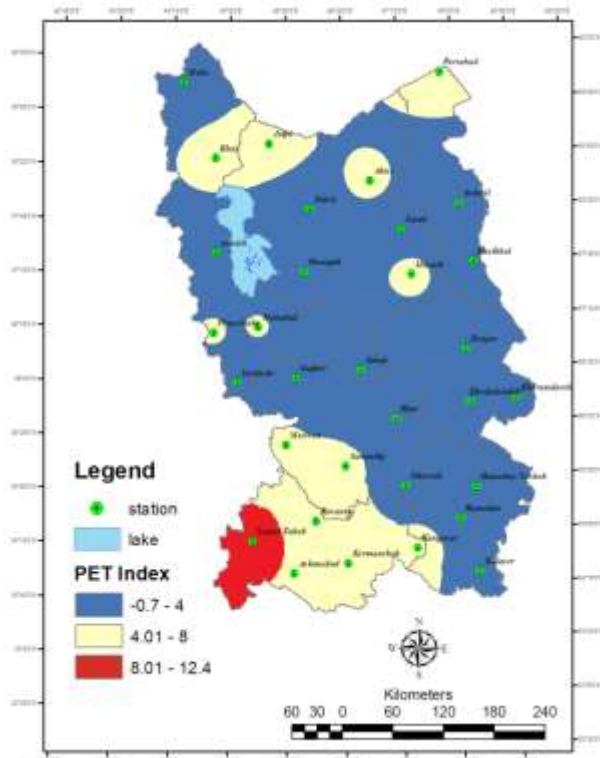


Fig.17: Geographical distribution of PET in November

V. CONCLUSIONS

The extent of Iran in different latitudes and climatic diversity, providing good conditions for tourist activities (in terms of bioclimate and climate comfort) in all seasons. In this paper, the climatic tourism potential and thermal comfort conditions during the period (1985–2010) were analyzed for west and north west of Iran. In the study area, the most suitable areas for tourist activities in the summer are Azerbaijan and especially Ardebil province. In spring and autumn, the best thermal comfort conditions in the province of Kermanshah and Kurdistan and in winter the best thermal comfort conditions in the western parts of Kermanshah is provided. The findings of this study can be valuable for tourism in the region. The analysis of climate and bioclimate, especially if presented in a clear and simple way to be understandable for everyone, provides a basis for the promotion of tourism destinations (Zaninović and Matzarakis 2007). The information can be used by tourist managers in advertising, by tourists who want to decide when to take their holidays and by physicians to warn their patients for the periods that are unsuitable for health therapy. For example, the people who have difficulty tolerating the summer heat, such as the elderly, should choose the best period of biometeorological conditions to take their vacations, which prevail in the southern parts of region such as Kermanshah in March and December, in the middle sectors such as

Kurdistan in April, May and October and in the northern parts such as Azerbaijan and Hamadan in June and September. For sportsmen who prefer an active and dynamic vacation, pleasant or even cool conditions would be more convenient than summer heat, when the body has to use the energy for defense from heat.

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