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Seasonal bioclimatic mapping of Iran for tourism

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ABSTRACT

In this study, spatial properties and potentials of Iran bioclimatic in seasonal scale have been studied. To do this, physiological equivalent temperature (PET) was calculated for 101 synoptic stations using GIS software. In the first stage, bioclimatic analysis of each season was carried out, and the obtained data were correlated to the tourism field. According to the obtained results, bioclimatic variation of Iran is significant; spring season has the best conditions in terms of climatic comfort and autumn is in the second rank. In bioclimatic map of summer, thermal stress is dominant. Cold stress of winter is more intense and widespread than thermal one.

Keywords: physiological equivalent temperature, Cold stress, Warm stress, climatic comfort.

INTRODUCTION

Climate and weather play important roles to find destinations for tourists as they are sensitive to the climate [1, 2, and 3]. Although climate is not the main reason to select the destination, it is important for tourists where to go and when to go [4]. Climate is a key factor considered by tourists, consciously or implicitly during travel planning, and represents both a push and pull factor for tourists [5, 6, 7]. Tourism activities usually occur outdoors and inappropriate climatic conditions are considered as a barrier for them [8].

One of the direct important effects of climate on tourism is its seasonal effect [9, 10, and 11]. For example, coastlines in summer are important in terms of beach activities, while mountaineer zones are important for recreation and sightseeing in summer, and skiing in winter [12]. Regarding the performance limits of tourism activities in winter and summer, tourism industry and business should be planned so that its profit would be obtained during this period. Hence, optimal understanding and predicting bioclimatic seasonal changes is very important and significant economically for beneficiary parts like airports, hotels, travel agencies, etc. [8]. Recently, the increasing growth of tourism industry has caused motivations in the field of bioclimatic researches related to tourism [13, 14, and 15].

Iran has much potential to develop tourism because of its cultural and historical places and also ecotourism attractions. However, research on tourism climatology is limited in Iran. The few research attempts that exist on this direction are case studies that have only considered one or more famous tourist cities [16, 17]. Other cases of research have been conducted regionally for north-east of Iran [18] and Orumieh lake in north-west of Iran [19]. However, the whole country has not been evaluated spatially in any case of research. The objective of this study is to explore the potentials and spatial properties of climatic conditions of Iran to be used in the tourism field. To do this, climatic data have been integrated to the environmental ones to show the spatial distribution of PET (Physiological Equivalent Temperature) data in a seasonal scale.

MATERIALS AND METHODS

2.1. Bioclimatology Index

Several concepts and methods are used to study the climatic conditions. Most concepts consider simple climatic properties such as minimum and maximum temperatures, cloudiness, solar radiation, and ultraviolet radiation and rainfall [20, 21]. However, the effect of climate on human beings cannot be explained by a simple climatic parameter. Therefore, several models and indicators have been created to describe this mechanism and quantify thermo-physiological phenomena of human body [22]. New models calculate radiation (flux) between human body and environment, using many empirical factors. Output data of these models, are different climatic indicators which convert physiological stress to the quantitative data [22, 23, 24, 25, 26, 27].

The first thermal balance model was invented and described by Fanger [23]. In the next two decades, Jendritzky [24] could regulate the complicated Fanger method by assigning proper variables for outdoor conditions, which is now known as MEMI model (Munich Energy Balance Model for Individuals). MEMI is one of the thermal balance models of thermo-physiology which is a base to obtain indicators such as PMV (Predict Mean Vote) and PET (Physiological Equivalent Temperature) indices. The model is based on the energy balance of human body and its equation is as follow:

(1) $M + W + R + C + ED + ERe + Esw + S = 0$

Where, M is the metabolic rate (internal energy production), W is the physical work output, R is the net radiation of the body, C is the convective heat flow, ED is the latent heat flow to evaporate water diffusing through the skin, ERe is the sum of heat flows for heating and humidifying the inspired air, ESw is the heat flow due to evaporation of sweat, and S the storage heat flow for heating or cooling the body mass. The individual terms in this equation have positive signs if they result in an energy gain for the body and negative signs in the case of an energy loss (M is always positive; W, ED and Esw are always negative). The unit of all heat flows is in Watt [28].

The individual heat flows in Eq.1, are controlled by the following meteorological parameters [22, 28, 29]:
–Air temperature: C, ERe
–Air humidity: ED, ERe, ESw
–Wind velocity: C, ESw
–Mean radiant temperature: R

Thermo-physiological parameters are required in addition:
– Heat resistance of clothing (Clo units)
– Activity of humans (in Watt)

Table 1. PET threshold values of the different degrees of sensitivity [26]

PET(°C)	Thermal sensivity	Grade of physiologic stress
	Very cold	Extreme cold stress
4		
	Cold	Strong cold stress
8		
	cool	Moderate cold stress
13		
	Slightly cool	Slightly cold stress
18		
	Comfort	No thermal stress
23		
	Slightly warm	Slightly heat stress
29		
	warm	Moderate heat stress
35		
	Hot	Strong heat stress
41		
	Very hot	Extreme heat stress

PET (°C) is the most comprehensive and applicable indicator among outputs of MEMI model to evaluate climatic conditions and recognize tourism climatic resources. When computing energy exchange of human body, thermal status of body can be estimated for a given composition of climatic variables, climatic activities and a kind of coverage (determined by radiation flux, temperature of body and rate of transpiration). 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 [22, 28]. 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. This index has a widespread and known unit called degree of Centigrade and its results is feasible and easy for users such as planners, programmers and even people who are not familiar to climatology terms. PET indicators' thresholds (Table 1) depend upon different degrees of thermal sensitivity and physiological stress of human body.

2.2. Region & Data

Iran is located in the Middle East from 44 to 63E and 25 to 40N and is 17th in the world in terms of area. About 90% of Iran is composed of continental plateau and more than half of the country is composed of mountains. Hence, it is a mountaineer country. Two main mountain ranges are Zagros and Alborz have been extended from north-west to south-east and from north-west to north-east, respectively. With the average height of 1200 meters, the highest and lowest points of Iran are 5671 meters and 30 meters from sea level, respectively.

According to Koppen's classification, there are 10 different climatic conditions in Iran [31]. 81% of Iran's area has dry weather (class B), 17% moderate weather (class C), and 2% cold weather (class D). One of the main problems to analyze spatially climatic variables in Iran is inaccessibility to the network obtained data. In addition, local synoptic station networks do not have appropriate homogeneity or compression. In the present study, maximum numbers of the synoptic stations which had long-term statistical period were used. The positions of 101 synoptic stations which used in this research are shown in Figure 1. Daily data including temperature (°C) , relative humidity (%), wind speed (m/s), cloudiness (octa) and water vapor pressure (hPa) were received from Iranian meteorological organization from 1988 to 2007 (20 years).

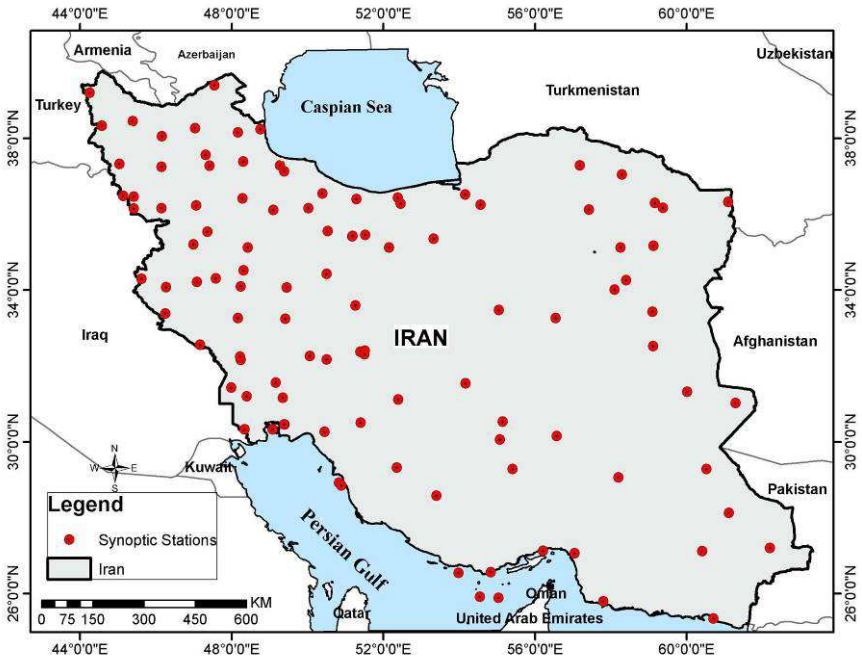

Figure 1. Iran's position with selected synoptic stations (period 1988-2007)

Spring (PET) = 51.6 - 0.00578 altitude - 0.864 latitude + 0.167 longitude (2)
Summer (PET) = 76.8 - 0.00522 altitude - 0.823 latitude - 0.211 longitude (3)
Autumn (PET) = 59.3 - 0.00618 altitude - 1.11 latitude - 0.0509 longitude (4)
Winter (PET) = 2.5 - 0.00604 altitude - 1.05 latitude + 0.112 longitude (5)

Using RayMann model [30], PET was calculated for 101 synoptic stations and obtained according to the mean daily data in each season. To prepare the climatic map, multivariate regression method was used. In this method, PET index is considered as function of elevation, longitude and latitude. To do this, a map of elevation, latitude and longitude was prepared with 20×20 km boxes.

In order to use regression equations and to estimate indicators, the following linear equations were used for each cell with 20×20 km:

It is noted that Blazejcyk & Matzarakis [32] and Gulyas & Matzarakis [13] used this method in preparing climatic maps of the Netherlands and Hungary, respectively. Finally, seasonal maps were presented based on threshold values of PET (Table 1). All of the maps were plotted in ArcGIS software Ver. 9.3.

RESULTS AND DISCUSSIONS

There is a 15 degree difference between south and north latitudes of Iran and this causes many variations in climatic conditions and the sun radiation amount received. In addition, existence of roughness and its variations is one of the main factors of climatic variations in Iran, so that climatic regions of Iran follow the roughness pattern [31]. Latitude large extending makes significant changes in temperature in seasonal scale which its effects can be perceived by seasonal bioclimatic maps. Several famous touristic cities of Iran have been shown on the bioclimatic maps.

3.1. Spring season

According to the obtained results (Figure 2), bioclimatic conditions in spring are very variable so that there are seven different categories of PET index in it (Figure 3). The average amount of PET index has obtained 22 Centigrade degrees for this season (Table 2). There is 35 Centigrade degrees difference between maximum values of PET index in south-east of Iran and its minimum values in Alborz altitudes. On piedmont regions, there are climatic comfort conditions (18<PET<23) and in low height internal regions, there is heat thermal stress. In the spring season, one third of the area of the county has low thermal stress (23< PET< 29). Maximum value of PET is in south and south-east of the country which results in high thermal stress. Since low thermal and cold stress conditions can be converted to the comfort conditions by little changes (for example, amount of activity or type of clothing), PET values between 13 to 29oC is considered as the climatic comfort region [14].

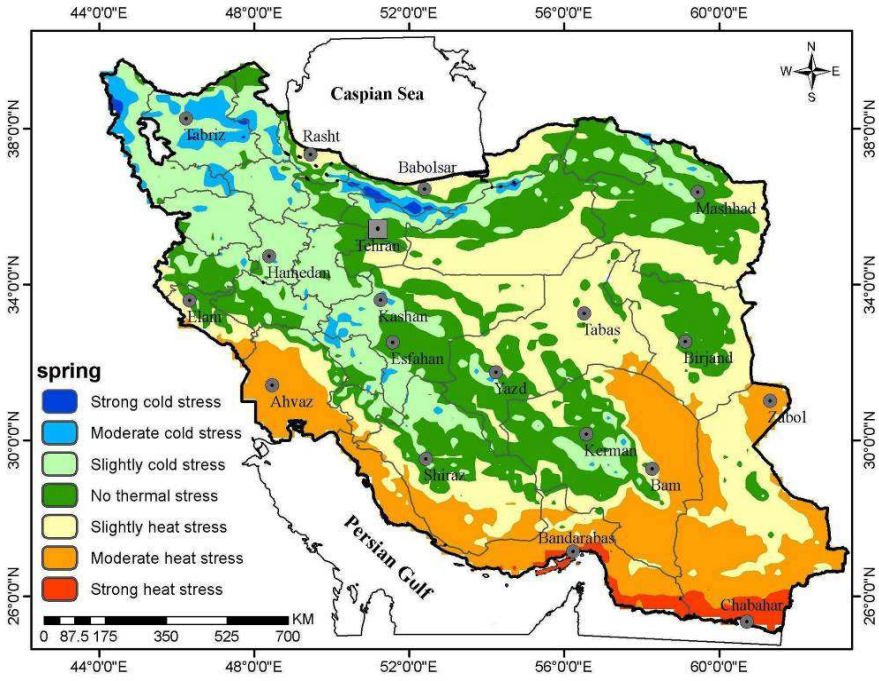

Figure 2. Bioclimatic conditions for spring season

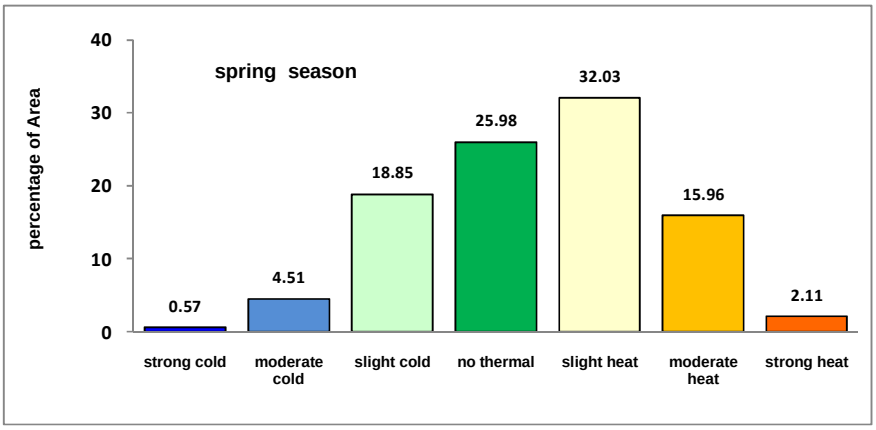

Figure 3. Area Percentage of PET categories for spring season

Table 2. Statistical properties of seasonal bioclimatic maps according to PET categories

Season	Maximum	Minimum	Mean	Standard deviation
Spring	37	-2	22	6.1
Summer	44	3	32	5.4
Autumn	30	-8	14	6.2
Winter	21	-16	5.8	6.3

Thus, in the spring season, about 76.8 % of the country is in climatic comfort region (Figure 2). This region involves north-west and mountaineer regions of Zagros (slight cold stress), north coastlines (slight heat stress), piedmont regions of the north and south Zagros and Alborz mountain range.

3.2. Summer season

Azor subtropical high pressure is dominant during warm season in Iran. Azor subtropical high pressure comprised on north Atlantic ocean and affects all our country in south of Alborz ranges which causes to make continental tropical air mass (CT) on Iran. Hence, in summer bioclimatic map, cold stress is only observed on top peak of Damavand (5671 m) in Alborz range. Heat stress almost involves all regions from 36 degrees latitude and bellow.

In summer, there is Heat stress (PET> 23) in 95.5 % of Iran (Figure 4). Moderate heat stress (29< PET< 35) is dominant with 39.3 % of physiologic stress (Figure 5). Composition of moisture & high temperature causes making humid conditions in south coastline of Iran. The occurrence of very high heat stress and record of maximum values of PET (44oC) in south coastline, especially in Khuzestan plain in south-west of the country, is because of this issue. Average PET for this season was obtained 32 degrees centigrade. Standard deviation of this index in this season was obtained 5.4 degrees centigrade (Table 2).

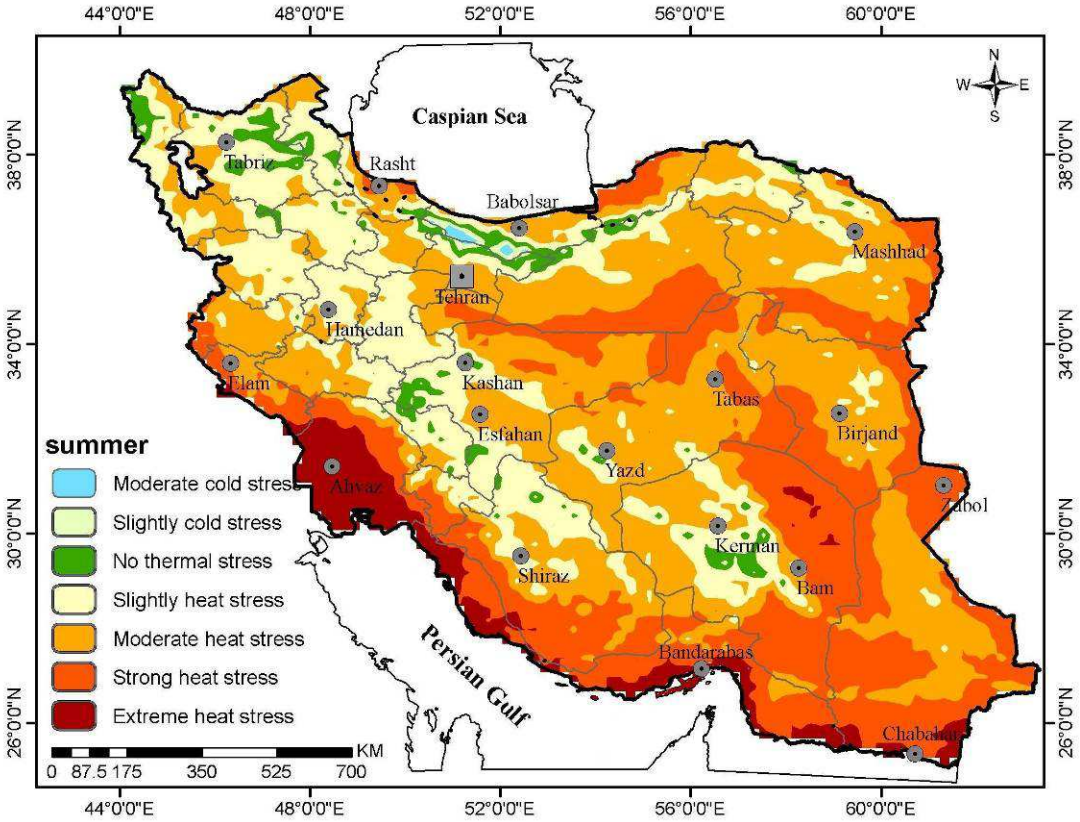

Figure 4. Bioclimatic mapping for summer season

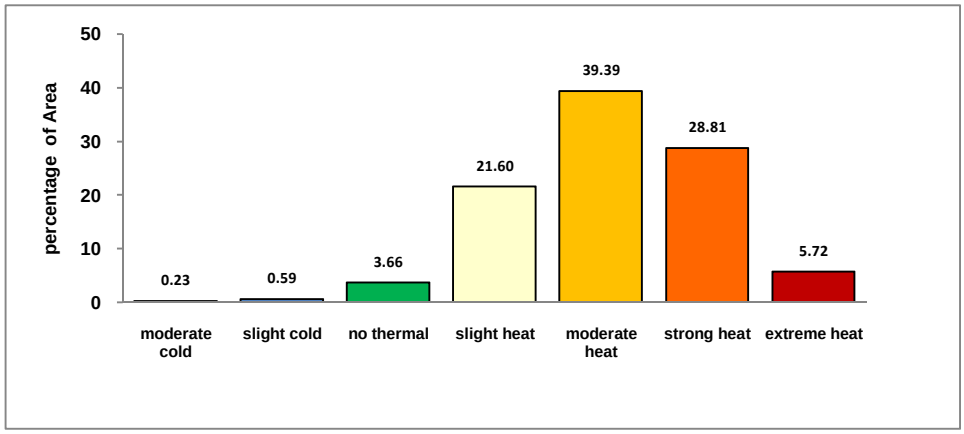

Figure 5. Area Percentage of PET categories for spring season

3.3. Autumn season

Starting the cold seasons, subtropical high pressure moves back to the south latitudes and provides entrance of cold air mass to the north half of Iran. In addition, Siberia high pressure is created from the middle of October and affects Iran by falling dry and cold air. In bioclimatic map of autumn (Figure 6), cold stress distribution is completely compatible to the mountaineer regions. The strongest cold stress is seen in North-west Mountains and Alborz range. With the decrease of height and movement to the south latitudes, cold stress is converted to warm stress. Average value of PET index for this season is obtained 14oC and its minimum and maximum values are obtained 8 and 13oC, respectively. Slight and moderate cold stress involves more than half of the country with 31 and 28.5%, respectively. No stress region (comfort) with 14.7 % of the area is located in the third rank (Figure 7). Slight heat stress is extended as a strip parallel to the coastline strip from west to the east of south coastlines. However, in northern coastline, in spite of high latitude, there is slight cold stress, caused by the balancing effect of the sea and also low height of the region. The tourist city Rasht is located in this area.

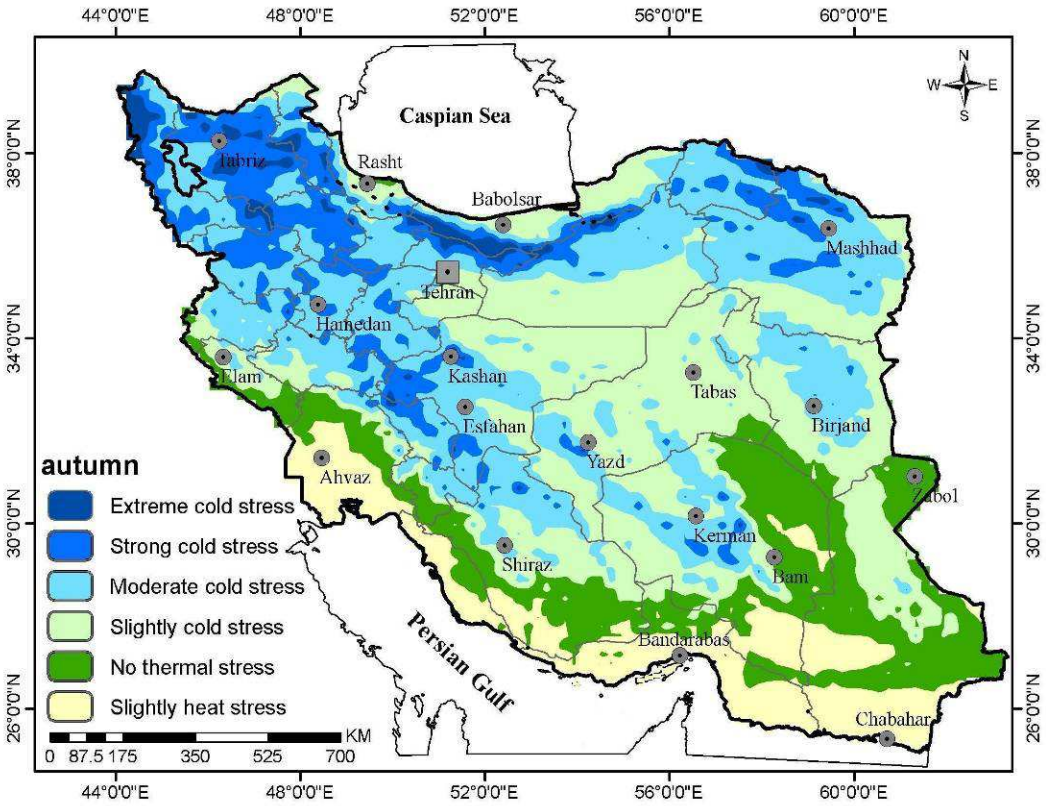

Figure 6. Bioclimatic mapping for autumn

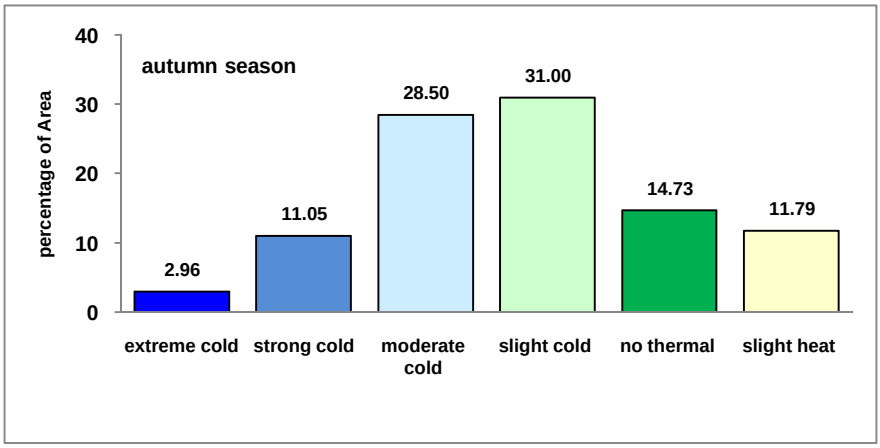

Figure 7. Area percentage of PET categories for autumn and winter seasons

3.4. Winter season

Siberia high pressure is dominant in Asia from the middle of October to the middle of March .This system plays an important role because of its wide spread region in Asia, in the cold half time of the year. Maximum activity of the system is in winter and this is the main cause of the coldness and dryness of weather as well as the intense cold stress in this season. In winter, north half of the country (except a narrow strip of north coastline) is affected by high and very high cold stress conditions.

According to the bioclimatic map of this season (Figure 8), moderate and slight cold stress is only seen in latitudes lower than 33oN. No stress regions (climatic comfort) have been extended as a strip in Oman Sea coastlines from Chabahar to Kish Island. Climatic differences between north and south of Iran are significant in this season. While most parts of the country like west and north-west have bioclimatic limitations (intense cold stress), south coastlines of the country is in desired conditions (Figure 5.b). This note can be considered as a bioclimatic potential. In the north coastlines, the effect of the sea has decreased cold stress which confounds cold stress homogeneity of the north half of the country.

Extreme cold stress (PET< 4) almost involves 40 % of the country and is the dominant aspect in the climate of Iran (Figure 9). Average value of PET index for this season is obtained 5.8oC and its minimum and maximum values are obtained -16 and 21oC, respectively (Table 2).

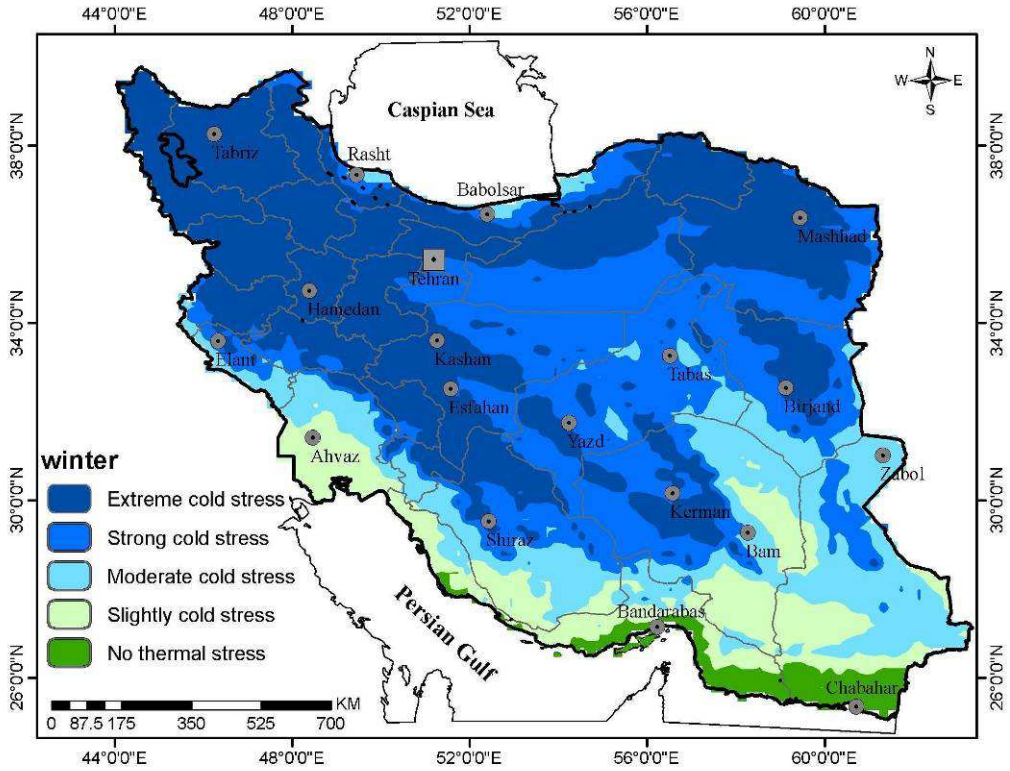

Figure 8. Bioclimatic mapping for winter

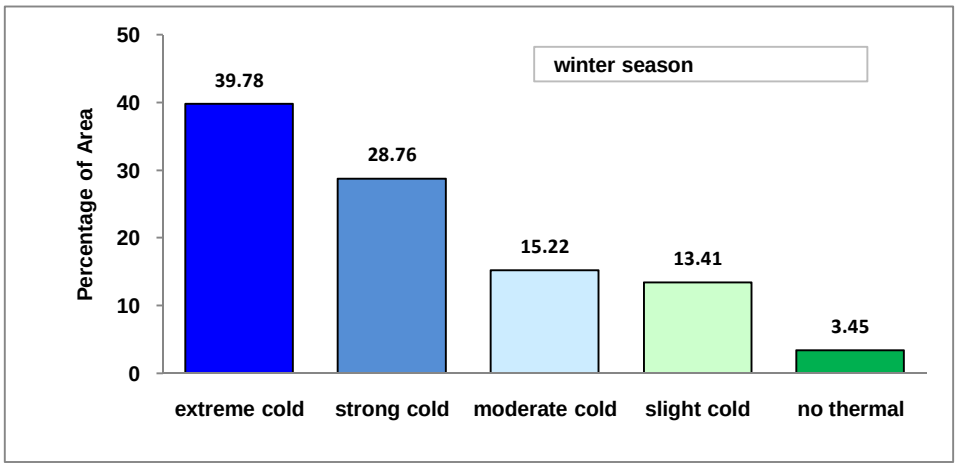

Figure 9. Area percentage of PET categories for autumn and winter seasons

CONCLUSION

Variant topographic condition and position of Iran has caused variable weather conditions. This climatic variation causes bioclimatic variation especially in a season scale. Study of seasonal bioclimatic maps shows that Iran has very variable conditions in this respect. PET index values increase from north to south and from east to west which indicates the role of longitude and latitude but the obtained results of this research show that the effect of height is more important. Physiologic stress distribution follows certainly from height levels and PET index value decreases by increasing height. Cold stress in mountaineer levels of south half and, in contrast, thermal stress in low land region of north coastlines and low height plains in north of the country point to this fact. Results of seasonal bioclimatic maps analysis showed that spring has the best conditions in terms of climatic comfort. Autumn is in the second rank. In bioclimatic map of summer, thermal stress is dominant but the intensity of the winter cold stress is

more strong and extensive in comparison to thermal stress in summer. By comparing the number of categories of PET index among different seasons, it is concluded that spring and summer have the most variable bioclimatic conditions in that there are seven bioclimatic categories in the country. Autumn is in the second rank with 6 bioclimatic categories; and finally, winter has 5 bio-climatic categories and has more homogenous conditions in comparison to the other seasons.

According to the bioclimatic map of spring, cities like Isfahan, Shiraz, Mashhad and Yazd are recommended for tourism because they are located in climatic comfort zone. North coastline, which is the destination of the most internal tourists in summer, has slight thermal stress during spring. During summer, most parts of Iran, especially south coastline suffer from thermal stress and are not recommended for tourism. Also, north coastlines are not suitable for tourists because of high humidity or temperature (sultry condition). Bioclimatic map of this season shows moderate and strong heat stress (Rasht city) in north coastal areas. In autumn, by decreasing the radiation angle of the sunlight and eventually decrease in temperature, cold stress appears in mountaineer regions in north-west and north-east of the country. Regarding the climatic comfort conditions and low heat stress, south half of the country (below 32°N) has good weather conditions. Thus, cities like Shiraz, Bam, Ahvaz, Chabahar, and coast cities like Bandarabbas, Kish & Qeshm islands, are recommended for tourism.

According to the bioclimatic map of winter, there are three bioclimatic regions in Iran. Caspian Sea coastlines have moderate cold stress; central regions and north-west have strong and extreme high cold stress. While these two regions limit the tourism because of high cold stress, south coastlines, especially Oman sea coastlines are located in desirable and climatic comfort conditions (no stress) and are suitable for tourism.

Information and bioclimatic maps can be used to improve the destination selection and development of new facilities. Results of this study help tourists to recognize good time and place to travel and if they schedule for the travel, this information can help them to select appropriate clothing and activities. In addition, travel agencies can design different timetables in different seasons to secure tourists comfort.

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