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Investigation of climate change impacts on tourism climate comfort in Iran

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Abstract

In this study, Mieczkowski's Tourism Climate Index (TCI) was used for Iran to investigate the climate change impacts on outdoor human comfort. The long-term data covering a network of 153 stations were used to compute TCI under baseline conditions (1981–2015) and a climate change scenario (HadCM3-A1B) for 2016-2045. In this study LARS-WG was used for downscaling of large spatial resolution GCM outputs to a finer spatial resolution. User-friendly and multi-platform software which is called ITCIC (Iran Tourism Climate Index Calculator) was designed to calculate TCI. The spatial distribution of TCI for baseline and climate change conditions was investigated and the covered area by each TCI class was calculated by using ArcGIS 10. The annual distributions of TCI were investigated based on Scott and McBoyle (2001) Models. Also, a suite of multiple linear and non-linear regression models was used to determine the relationship between TCI, latitudes, longitudes and elevations of regions. Root mean square error (RMSE), mean error (ME), mean absolute relative error (MARE) and coefficient of determination (R^2) were used to evaluate the modeling accuracy. The best time and regions for outdoor activities in the base and future periods were determined. Comparison of the covered area by each TCI class in the base and future periods showed that the climate change occurrence was led to improving climate comfort. The results of error evaluation criteria showed that non-linear regression was appropriate for all month except January and October.

Keywords: Climate Change, Climate Comfort, Iran, Multiple Regressions, Tourism Climate Index (TCI)

1. Introduction

Most research on human climate comforts motivated by the potential usefulness of climatological data within planning processes for tourism and recreation. The specifications of weather and climate are not necessarily good determinates for tourism but they do establish an important factor in both financial terms, for tourism operators and tourists' experiences. Several attempts have been made to identify optimal climate conditions for tourism in general and for specific tourism activities (Mieczkowski, 1985; de Freitas, 1990; Lise and Tol, 2002; Bigano *et al.*, 2006). Tourism climate comfort and its effect on tourists' health and activities are highly dependent on climate conditions. In this regard the growing sectors of population traveling for vacation and tourism often select their destinations according to weather and climate conditions. Statistical analyses by Maddison (2001), Lise and Tol (2002) and a simulation study by Hamilton *et al.,* (2003) show a strong influence of climate as a factor that determines a demand for tourism. Therefore, Climate is therefore an important contraption for tourism and tourism planners need some form of information to factor it into their trip evaluation process, an index approach which can capture the multifaceted nature of weather and the complex ways in which weather variables (i.e., air temperature, relative humidity, sunshine duration, wind speed and precipitation) can be incorporated into tourism planning has been argued for (de Freitas *et al.*, 2008). Significant effort has been devoted to preparing climate indices and several indices have been developed over the last 40 years to assess climate suitability for tourism activities (Crowe *et al.*, 1973; Mieczkowski, 1985; Becker, 2000; Morgan *et al.*, 2000; Maddison, 2001; Lise and Tol, 2002; Gomez Martin, 2004; Hamilton and Lau, 2005; Bigano *et al.*, 2006; Matzarakis, 2007; de Freitas *et al.*, 2008). Tourists and tour operators can use these climate indices to select the best time and place for a particular vacation, or plan activities appropriate to weather expectations. One of the commonly applied indices is that of Physiologically Equivalent Temperature (PET). This index evaluates thermal conditions relating to human energy balance. PET results can be presented graphically or as a bioclimatic map. Graphs mostly display the temporal behavior of PET, whereas spatial distribution is specified in bioclimatic maps (Matzarakis *et al.*, 1999). Other possibilities are CIT (Climate Index for Tourism) (de Freitas *et al.*, 2008) and CTIS (Climate Tourism Information Scheme) (Matzarakis, 2007; Lin and Matzarakis, 2008), both of which are based on the integration of thermal, aesthetic and physical facets of weather and climate. One of the most comprehensive schemes proposed so far is that of Mieczkowski (1985), who developed the 'Tourism Climate Index' (TCI). Mieczkowski's (1985) index was designed to use climate data that was already widely available for tourist destinations worldwide. The TCI merges seven features of climate into a single climate index. The TCI was originally conceptualized as a composite measure that would systematically assess the climatic elements that were most relevant to the quality of the tourist experience for the 'average' tourist (i.e., the most common tourism activities of sightseeing and shopping). TCI has subsequently been used in a slightly modified form by Morgan *et al.,* (2000) for beach environments, and in a number of recent studies that assess the potential impact of global climate change on the climate resources of destinations around the world (Scott and McBoyle, 2001; Scott *et al.*, 2003; Amelung and Viner, 2006). In Iran, several researchers analyzed and calculated TCI. Farajzadeh and Matzarakis, (2009) computed PET and TCI in the northwest of Iran in the period 1985- 2005 from a network of 15 meteorological stations. There are a number of research about investigation of climate change impacts on tourism by using different bioclimatic indices such as (Yazdanpanah *et al.*, 2016; Amelung *et al.*, 2014; Amelung *et al.*, 2007; Hamilton *et al.*, 2005; Scott *et al.*, 2004; Hamilton *et al.*, 2004). Nasirihendkhaleh *et al.,* (2014) evaluated and separated Fars province (south-central Iran) touristic climate using TCI and GIS framework. Esmaili and Fallah Ghalhari, (2014) evaluated the bio-climatic conditions of the tourists in Mashhad (northeast of Iran), through the use of PET index on an hourly scale. Morris *et al.* (2017) considered the impact of urbanization level on the interactions of the urban area, the urban climate, and human thermal comfort. Anđelković *et al.,* (2016) proposed a new mathematical formulation of climate parameters for calculating the tourism climate comfort index (TCCI) and determined the appropriate destinations and favorable resorts for tourists in each month in Serbia. Cohen, (2013) studied the perception of human thermal sensation for Coastal Mediterranean outdoor urban environments by using a bioclimatic index. The aim of this paper is an investigation of climate change impacts on bioclimatic conditions for tourism in Iran for the baseline and future periods. In addition, this paper aimed to apply the TCI developed by Mieczkowski, (1985) and provide a comprehensive information source for the most suitable time periods, per region, for outdoor activities. It was the first attempt to use this index for the entire country. For this purpose, a user-friendly and multi-platform software was designed in JAVA programming language. This software is consonant with the format of Islamic Republic of Iran's Meteorological Organization (IRIMO) database. Finally, multiple regression models were used to determine the relationship between the geographic component such as latitude, longitude, elevation, and TCI and spatial analysis of TCI values.

2. Materials and methods

2.1 Study area and Data

Iran with 1648000 square kilometer area and 70 million people are one of the largest countries in the Middle East. This country is bordered to the north by the countries of Armenia, Azerbaijan and Turkmenistan and the Caspian Sea; to the east by Afghanistan and Pakistan; to the south by the Gulf of Oman and the Persian Gulf; and to the west by Iraq and Turkey. In general, Iran as a big country has a plenty of cultural (religious and pilgrimage attractions), historical and environmental (rural tourism, ecotourism and agritourism) attractions making it an area with high potential capacity for domestic and foreign tourists. Iran is one of the 10 important tourism and ecotourism destinations in the world. The topography of Iran is very complex and highly variable, resulting in diverse climatic conditions and significant variations regionally.

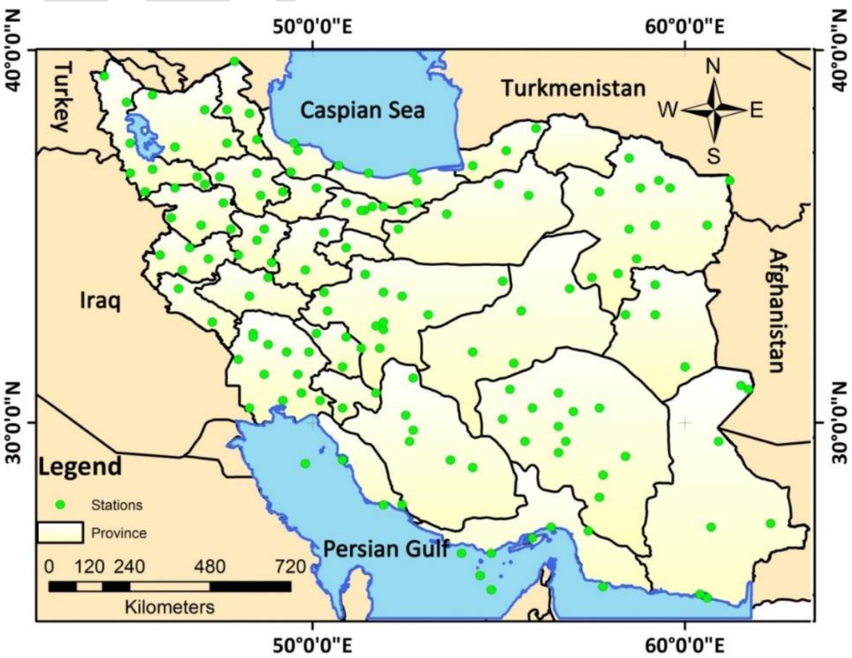

Figure 1. Study area and location of stations

The analysis required the use of two major datasets, which contains mean monthly climate data such as dry bulb temperature (DBT), maximum daily air temperature, mean daily air temperature, minimum daily relative humidity, total precipitation, total hours of sunshine, and average wind speed for historical time period of 1981-2015 that was obtained from 153 synoptic meteorological stations of IRIMO and the general circulation model outputs under the A1B-HadCM3 scenario for the future time period of 2016-2045. The A1B emissions scenario is one of the A1 family scenarios that describes "a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and rapid introduction of new and more efficient technologies" (Setegn *et al.*, 2011). The spatial resolution of gridded data in the HadCM3 model is 2.5° latitude × 3.75° longitude. Since general circulation models' (GCM) are coarse in resolution and are unable to resolve significant sub-grid scale features, in this study LARS-WG was used for downscaling of large spatial resolution GCM outputs to a finer spatial resolution. The procedure of calculation of TCI under A1B scenario is the same as the historical data sets. Figure 1 shows the spatial distribution of 153 synoptic meteorological stations considered in the analysis. These stations were located in different subclasses of arid, semi-arid, Mediterranean, semi-humid, humid, very humid (A) and very humid (B) climates of Iran based on Extended-De Martonne classification (Rahimi *et al.* 2013).

3. Mieczkowski's Tourism climate index

TCI developed by Mieczkowski (1985) was based on previous research related to climate classification for tourism and recreation (Crowe, 1976). TCI consists of five sub-indices, each represented by one or two monthly climate variables. The five sub-indices and their constituent variables were as follows: (1) day time comfort index (maximum daily temperature (°C) and minimum daily relative humidity (%)), (2) daily comfort index (mean daily temperature (°C) and mean daily relative humidity (%)), (3) precipitation (total precipitation, (mm)), (4) sunshine (total hours of sunshine), and (5) wind (average wind speed (m s^{-1} or km h^{-1}). Equation 1 represents the index.

$$TCI=2\times(4\times CID+CIA+2\times R+2\times S+W) \qquad (1)$$

Where CId is daytime comfort index consisting of the mean maximum air temperature (°C) and the mean minimum relative humidity (%), CIa the daily comfort index consisting of the mean air temperature (°C) and the mean relative humidity (%), R is precipitation (mm), *S* is daily sunshine duration (hr) and W is the mean wind Speed (m s^{-1}).

In the equation proposed by Mieczkowski, the highest weight is given to the daytime comfort index to reflect the fact that tourists are generally most active during the day. The amount of sunshine and the amount of precipitation are given the second highest weights, followed by daily thermal comfort and wind speed. With an optimal rating for each variable of 5.0, the maximum value of the index was 100. Based on each location's index value, its suitability for tourism activity was then rated on a scale from –30 to 100. Mieczkowski, (1985) divided this scale into 10 categories, ranging from ideal (90-100), excellent (80-89), and very good (70-79) to extremely unfavorable (10-19) and impossible (9 to –30) (Table 1).

Table 1. Rating categories in tourism climate index Mieczkowski (1985)

TCI score	Code	Descriptive Category	Mapping Category
90<TCI<100	9	Ideal	Excellent
80<TCI<89.9	8	Excellent	
70<TCI<79.9	7	Very good	Very good and Good
60<TCI<69.9	6	Good	
50<TCI<59.9	5	Acceptable	Acceptable
40<TCI<49.9	4	Marginal	
30<TCI<39.9	3	Unfavorable	Unfavorable
20<TCI<29.9	2	Very unfavorable	
10<TCI<19.9	1	Extremely unfavorable	
-20<TCI<9.9	0	Impossible	

4. Scott and McBoyle (2001) Models

Scott and McBoyle (2001) proposed that the climate could be classified for each tourist destination into one of six annual distributions. If TCI ≥80 for each month of the year, Tourism climate typology in the model is an 'optimal'. If TCI <40 throughout the year it suggests a 'poor' year-round tourism climate. The peak curves for 'summer' and 'winter peak' were similar and outstanding by season in which more suitable climatic conditions occurred. A 'summer peak' corresponds to amid- to high latitude locations where summer was considered as the most pleasant period of the year for tourism activity. A 'winter peak' would occur in the lower-latitude locations where cooler and/or lower humidity conditions in winter make conditions more comfortable for tourists compared to hot and/or humid summer weather. Where spring and fall months were more suitable for tourist activity a 'bimodal' or 'shoulder peak' distribution was shown. The tourism climate resources in regions with separate wet and dry seasons were mostly dependent on precipitation. The TCI in these regions displayed a dry season peak when the climate was most conducive to tourism activity (Scott *et al.,* 2004).

5. Software development for Iran's TCI calculations

Effective Temperature Index calculation

Psychrometric charts are very important in many respects such as the design of air conditioning systems and human comfort. These calculations account for the relationships inter depending dry and wet bulb temperatures, relative humidity, enthalpy and specific volume. In Mieczkowski's index, CIa (daily comfort index) and Cid (daytime comfort index) are considered as comfort indicators that their levels are obtained from the psychrometric diagram which ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers) thermal comfort standard has been drawn. According to a definition of ASHRAE, thermal comfort is the intellectual condition that can be expressed satisfaction with the environment. According to ASHRAE (1972), thermal zone forms the optimal zone for the TCI, with a rating of 5.0 points. The rating scale then decreases gradually on both sides of the optimal zone, according to an ideal assigned set of sequential values. The boundaries between the rating zones are the effective temperature lines derived from the ASHRAE comfort chart. In this study, because of a high volume of data and required calculations, authors decided to extract the equations of lines and curves of ASHRAE comfort chart by the set of points. Then a short program was written in Excel software and the rating of CIa and CId were determined for each month in studying stations. Figure 2 shows the output of the program for determination of CId and CIa rates of Shiraz station.

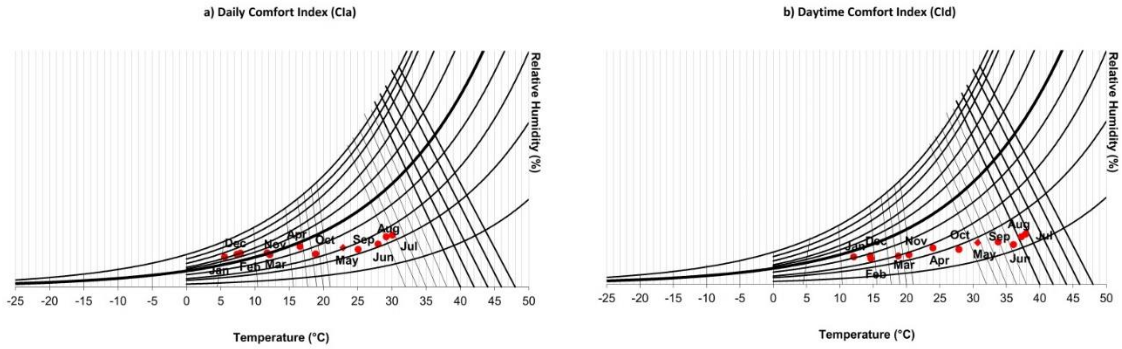

Figure 2. (a) CIa (daily comfort index) and (b) CId (daytime comfort index) for months of a year in Shiraz station

6. Software presentation for Iran's TCI evaluation

In order to assess climate comfort range for tourism planning in Iran, weather and climatic data in synoptic stations obtained from IRIMO are used in TCI computation. The proposed software (ITCIC) provides various situations in tourism management and hospitality. This is user-friendly and multi-platform software that supported Windows, Linux and Macintosh OS X operating systems and developed using JAVA language. The JAVA files are in Notepad format (HTML. format). The program accesses the required data files and converts them to Excel files and saves them automatically on the same drive. The program is set up to omit the years with incomplete weather data and then calculate the TCI monthly normal climatic variables. The calculated climatic normal information for each station include, maximum and mean daily temperature, minimum and mean daily relative humidity. This information is then transferred to ASHRAE effective temperature Chart and the rating of CIa and Cid are determined for each month separately (Figure 2). The TCI values are calculated and categorized by the program is imported to the display window (Figure 3). The point of interest here is to determine the rank of the wind speed. This variable is an intangible factor to evaluate the TCI. Four distinct wind rating schemes were proposed by Mieczkowski, (1985).

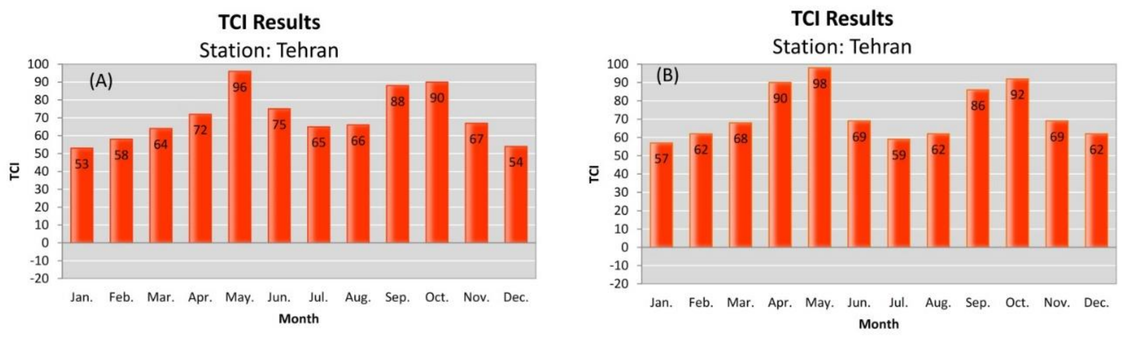

Figure 3. (A) TCI results in the base period (1951-2015), (B) TCI results in the future period (2016-2046)

They include the normal system, trade wind system; hot climate system and wind chill cooling rates. The rating of normal, trade wind and hot climate systems could be proposed based on Mieczkowski's table and converted into the computer code. However, if the months in which the mean daily maximum temperature is less than 15 °C and the mean wind speed is greater than 8 km h^{-1}, a wind chill nomogram prepared by Canada is used (Mieczkowski, 1985). If these conditions occur in a month, a window automatically opens and requests the wind rate. Otherwise, by running the program and call the desired stations file, a window will open and requests the CIa and CId values for each month. As it is shown in Figure 3, the final outputs of this program are given in graphic and table forms for each station.

7. Regression model

In this study, multiple regression models were used for spatial analysis of TCI values and determining the relationship between the geographic component such as latitude, longitude, elevation, and TCI. Therefore, for determining the best regression model, the calculated TCI values by mentioned software for each month in a year were used as dependent variable and geographic parameters such as latitude, longitude, elevation above the sea level in 153 stations were used as independent variables. Multiple regression analysis was performed using stepwise and enter modes. Any correlations of 0.7 or above between independent variables suggest that Multicollinearity is a potential problem. A common statistic is the tolerance index. Multicollinearity is likely to be problematic when it is low (Baggio and Klobas, 2011). To quantify the effects of the geographical coordinates on TCI, analysis of variance of the linear regressions were performed using the F test at 95% confidence level. The Kolmogorov-Smirnov and Durbin-Watson tests were used to verify whether they presented, a normal distribution, and errors independence, respectively (Bosco *et al.*, 2015). The modeling accuracy was assessed by the root mean square error (RMSE), mean error (ME), mean absolute relative error (MARE) and coefficient of determination (R^2) and can be calculated by equations 2 to 5 (Liu, 2014; Moffat *et al.*, 2007).

$$RMSE=\sqrt{\frac{\sum_{i=1}^{n}(TCI_o-TCI_p)^2}{n}} \quad (2)$$

$$ME=\frac{\sum_{i=1}^{n}(TCI_p-TCI_o)}{n} \quad (3)$$

$$MARE=\frac{1}{n}\sum_{i=1}^{n}\frac{\left|TCI_o-TCI_p\right|}{TCI_o} \quad (4)$$

$$R^2=1-\frac{\sum_{i=1}^{n}[TCI_o-TCI_p]^2}{\sum_{i=1}^{n}[TCI_o-\overline{TCI_o}]^2} \quad (5)$$

Where, TCI_P ، TCI_o and $\overline{TCI_o}$ are the calculated TCI values by regression models, the obtained values by main model and average of the obtained values by main model, respectively and n is the number of samples.

8. Results and Discussion

Since Iran is an attractive tourist destination, human climate comfort indicators will be useful for travel planning. Using ITCTC program, Iran's climatic data were used to calculate monthly climate indices. Some of the results are provided as an example. Table 2 shows the monthly TCI values for the base (1981-2015) and future (2016-2045) periods in Tehran station. This information can be classified into one of six annual TCI distributions. Based on the results of this study, the model for 153 synoptic weather stations had been determined.

Table 2. Monthly TCI values, descriptive and mapping category as output ITCTC software for Tehran station

Station	Tehran				Station	Tehran			
Code	40754				Code	40754			
Latitude	35 41 N				Latitude	35 41 N			
Longitude	51 19 E				Longitude	51 19 E			
Elevation	1190.8 M				Elevation	1190.8 M			
Period	baseline (1981-2015)				period	future (2016-2045)			
Month	**TCI**	**Code**	**Descriptive category**	**Mapping category**	**Month**	**TCI**	**Code**	**Descriptive category**	**Mapping category**
Jan.	53	5	Acceptable	Acceptable	Jan.	57	5	acceptable	acceptable
Feb.	58	5	Acceptable	Acceptable	Feb.	62	6	good	very good & good
Mar.	64	6	Good	Very Good & Good	Mar.	68	6	good	very good & good
Apr.	72	7	Very Good	Very Good & Good	Apr.	90	9	Ideal	excellent
May.	96	9	Ideal	Excellent	May.	98	9	Ideal	excellent
Jun.	75	7	Very Good	Very Good & Good	Jun.	69	6	good	very good & good
Jul.	65	6	Good	Very Good & Good	Jul.	59	5	acceptable	acceptable
Aug.	66	6	Good	Very Good & Good	Aug.	62	6	good	acceptable
Sep.	88	8	Excellent	Excellent	Sep.	86	8	Excellent	very good & good
Oct.	90	9	Ideal	Excellent	Oct.	92	9	ideal	excellent
Nov.	67	6	Good	Acceptable	Nov.	69	6	good	very good & good
Dec.	54	4	Acceptable	Acceptable	Dec.	62	6	good	very good & good

Table 3 shows the Scott and McBoyle, (2001) models based on monthly TCI changes in Iran's province centers. In baseline and future periods 24 provinces were found to be bimodal-shoulder peaks. In these areas spring and autumn seasons were determined as having a comfortable climate for tourism activity, especially for ecotourism and agritourism. In these cities, the heat made the summer climate uncomfortable for tourists while winters were considered cool. Four provinces had summer peak and one of them had winter peak distribution. None of the stations were followed by an optimal, dry season peak or a weak distribution. Spatial distributions of TCI for all months in baseline and future periods were investigated by using ArcGIS ver.10 software and Kriging method of Interpolation. The most suitable areas and months for tourism activities were determined and are shown with 24 maps for two periods in Figures 4 and 5, respectively.

Table 3. TCI score and its annual distribution in Iran's province centers for baseline (1981-2015) and future (2016-2045) periods

Station	Period	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual TCI distribution
Ahvaz	Baseline	65	79	84	78	58	44	43	44	52	64	83	73	Bimodal Peaks
	Future	77	88	96	69	41	42	43	43	44	62	90	84	Bimodal Peaks
Arak	Baseline	37	44	58	73	89	88	72	76	91	91	61	52	Bimodal Peaks
	Future	50	53	63	68	80	90	86	88	87	72	60	51	Bimodal Peaks
Ardabil	Baseline	42	44	49	62	77	88	96	92	88	67	51	47	Summer peak
	Future	50	54	59	67	87	96	96	96	86	76	60	52	Summer peak
BandarAbbas	Baseline	85	85	84	73	49	42	36	36	39	53	80	85	Winter Peak
	Future	90	94	88	58	43	39	46	46	37	49	76	90	Winter Peak
Birjand	Baseline	61	60	76	87	92	74	70	74	92	91	76	63	Bimodal Peaks
	Future	65	64	78	92	92	91	84	84	92	90	79	66	Bimodal Peaks
Bojnurd	Baseline	54	55	56	76	89	94	84	86	94	87	61	54	Summer peak
	Future	60	63	77	88	84	95	84	89	89	91	76	61	Summer peak
Bushehr	Baseline	66	76	87	72	62	49	44	43	48	68	88	75	Bimodal Peaks
	Future	74	85	90	76	56	49	42	47	47	69	89	83	Bimodal Peaks
Esfahan	Baseline	58	66	68	87	96	80	71	72	87	89	71	63	Bimodal Peaks
	Future	78	88	92	88	61	62	60	52	60	75	89	87	Bimodal Peaks
Ghazvin	Baseline	54	53	58	77	86	84	70	70	92	84	57	48	Bimodal Peaks
	Future	57	59	68	87	92	76	66	66	88	88	65	58	Bimodal Peaks
Ghom	Baseline	62	62	73	88	88	66	56	60	71	89	73	60	Bimodal Peaks
	Future	60	66	87	94	73	61	49	54	74	89	78	63	Bimodal Peaks
Gorgan	Baseline	55	55	58	79	83	71	60	60	67	78	78	56	Bimodal Peaks
	Future	64	61	68	85	81	61	51	55	69	86	77	62	Bimodal Peaks
Hamedan	Baseline	47	48	55	70	90	91	77	77	94	88	59	50	Summer peak
	Future	50	56	64	77	96	92	66	74	90	87	60	48	Summer peak
Ilam	Baseline	42	49	48	79	96	90	70	70	92	82	61	51	Bimodal Peaks
	Future	58	64	71	88	94	73	61	64	88	90	70	63	Bimodal Peaks
Karaj	Baseline	55	53	56	83	94	86	70	71	84	91	63	43	Bimodal Peaks
	Future	56	58	68	87	98	75	65	66	88	88	64	57	Bimodal Peaks
Kerman	Baseline	59	60	73	90	94	74	70	74	94	91	77	62	Bimodal Peaks
	Future	62	69	87	94	74	64	62	74	75	90	89	70	Bimodal Peaks
Kermanshah	Baseline	47	49	50	74	86	79	67	67	76	87	63	47	Bimodal Peaks
	Future	57	60	67	84	88	67	57	58	76	88	69	62	Bimodal Peaks
Khorramabad	Baseline	48	57	56	80	92	72	63	63	76	87	72	53	Bimodal Peaks
	Future	62	64	79	88	86	68	56	56	76	89	78	63	Bimodal Peaks
Mashhad	Baseline	52	53	52	79	91	86	71	76	95	87	67	54	Bimodal Peaks
	Future	56	62	67	90	94	73	63	74	88	90	69	61	Bimodal Peaks
Oroomieh	Baseline	47	51	51	63	84	96	88	88	94	82	59	54	Bimodal Peaks
	Future	51	57	65	71	92	88	79	79	93	88	63	55	Bimodal Peaks
Rasht	Baseline	39	43	43	70	82	77	64	54	55	63	48	37	Bimodal Peaks
	Future	57	59	60	83	87	73	65	61	75	85	64	57	Bimodal Peaks
Sanandaj	Baseline	45	46	45	62	84	87	72	72	90	84	63	50	Bimodal Peaks
	Future	57	59	70	86	92	76	64	66	88	88	69	60	Bimodal Peaks
Semnan	Baseline	57	63	68	87	90	71	61	66	84	90	74	62	Bimodal Peaks
	Future	61	67	80	90	88	62	52	55	72	91	70	64	Bimodal Peaks
Shahrekord	Baseline	46	58	58	71	90	91	77	81	94	90	63	52	Bimodal Peaks
	Future	56	62	68	81	92	87	77	74	93	90	67	60	Bimodal Peaks
Shiraz	Baseline	54	60	72	88	94	71	66	67	80	92	83	58	Bimodal Peaks
	Future	64	68	87	96	92	64	52	62	74	96	77	68	Bimodal Peaks
Tehran	Baseline	54	58	63	84	96	75	65	71	88	90	67	58	Bimodal Peaks
	Future	57	62	68	90	98	69	59	62	86	92	69	62	Bimodal Peaks
Yasuj	Baseline	38	40	44	81	91	87	76	77	91	89	65	45	Bimodal Peaks
	Future	60	67	71	89	95	77	66	77	87	89	72	65	Bimodal Peaks
Yazd	Baseline	64	66	80	93	88	66	59	59	76	93	83	64	Bimodal Peaks
	Future	64	66	89	98	73	61	49	61	74	94	79	66	Bimodal Peaks
Zahedan	Baseline	60	66	85	95	88	66	63	67	88	91	89	69	Bimodal Peaks
	Future	66	81	88	94	89	75	63	65	75	96	89	70	Bimodal Peaks
Zanjan	Baseline	48	45	53	68	86	96	86	86	94	81	58	48	Summer peak
	Future	51	57	65	72	93	87	79	79	93	88	63	55	Summer peak

9. Baseline Period (1981- 2015)

The spatial distribution of TCI over the study area in baseline period is showed in Figure 4. The covered area by each TCI classes was calculated by using ArcGIS software. During the base period, Iran's climatic conditions were divided into 5 classes in January including "Marginal", "Acceptable", "Good", "Very Good", and "Excellent". The western and northwestern parts of the country with 16.6%

of the total area have TCI values 40-50 in “Marginal class”. 35.91 % of total area in central has “Acceptable” condition. The corresponding area for “Good”, “Very Good”, and “Excellent” are “38.92%”, “7.63%”, and “0.93%”, respectively. In February, the northwestern parts of Iran (include East and West Azerbaijan provinces, Gilan, Hamedan, Kurdistan, and Kermanshah) with 10.8% of total area, experienced “marginal” climate conditions. The climatic conditions have ascending trend from west to east. The provinces such as Mazandaran, Zanjan, Qazvin, Alborz, Tehran, Qom, Markazi, Lorestan, Chaharmahan and Bakhtiari, Kohgiloyeh and Boyer Ahmad, west of Isfahan, west and north of Fars were located in “Acceptable” class with 26.9% of total area. 39.8% of Iran’s area include North Khorasan, Razavi Khorasan, western parts of South Khorasan, Yazd, north of Kerman, south of Fars, and Khuzestan have “Good” climate condition. The southeastern parts of Iran have “Very Good” climate conditions. In March the TCI values have ascending trend from northwest to southeast. So that the most appropriate destinations were located in southeastern parts of the country, and the northwestern area has acceptable conditions. Based on Figure 4, Sistan and Baluchestan have “Excellent” and “Ideal” conditions for outdoor activities.

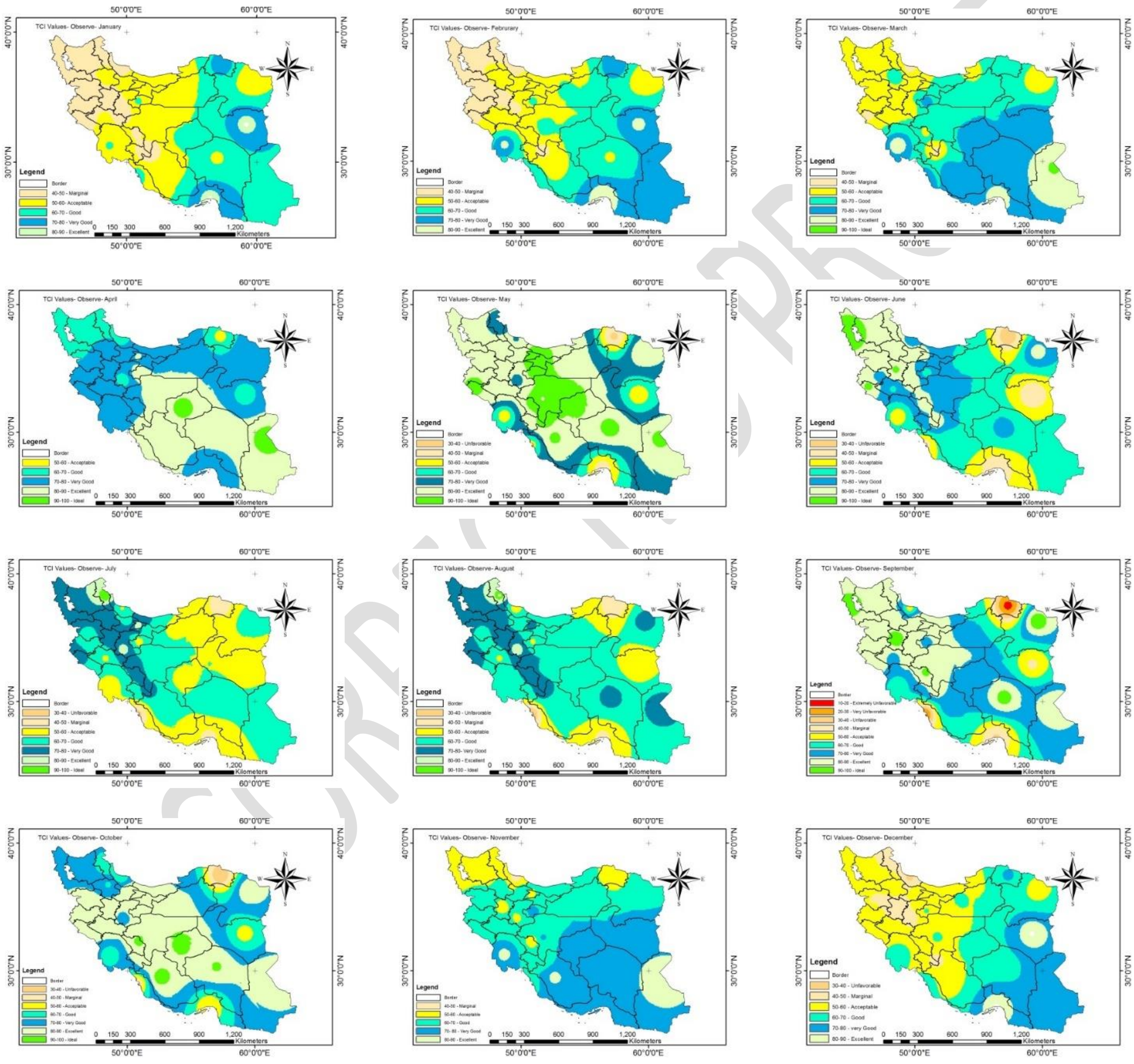

Figure 4. Spatial distribution of Tourism Climate Index over the study area in the base period (1981-2015)

The results of TCI showed that in April, the largest area is related to “Very Good” class located in the northeast, north, south, and western parts with 55.3 % of total area. The provinces of Isfahan, Yazd, Kerman, Sistan and Baluchestan, Fars and Bushehr with about 31.65% area have the “Excellent” condition for outdoor activities. Northwestern parts of the country and North Khorasan (about 11%) is located in “Good” class. The variation of TCI index in May indicated that in this time tourist can be selected various destinations based on own preferences. In this time the most appropriate destinations are Mazandaran, Tehran, Alborz, Isfahan, and Yazd provinces, while North Khorasan and Homozgan province have “Marginal” and “Unfavorable” conditions. In the month of June during baseline period, 46.64 % of the country has the “Good” condition that this area was covered central parts of Iran. The provinces of North Khorasan, South Khorasan, Hormozgan, and Bushehr have inappropriate conditions for outdoor activities. In the month of July, TCI scores were divided into 7 classes include “Ideal”, “Excellent”, “Very good”, “Good”, “Acceptable”, “Marginal”, and “Unfavorable”. Due to the distribution of TCI scores on Figure 4, it can be noted that the “Good” class has the largest area (43.32%). The “Acceptable” category was covered 39.66% of total Iran’s area. 0.11% of Iran’s area was covered by “Unfavorable” condition that this category was eliminated in the future period, for improving climate conditions under climate change conditions. In the middle of summer (August), Iran’s climatic conditions were divided into 7 classes such as “Ideal”, “Excellent”, “Very Good”, “Good”, “Acceptable”, “Marginal”, and “Unfavorable”. The climatic condition 60.73 % of total Iran’s area was situated in “Good” class. Ardabil province, that is located in the west of Caspian Sea, has the highest amount of TCI and Ideal conditions for tourism activities.

In September, 41.16% of the country including “parts of Sistan and Baluchestan, Kerman, Yazd, Fars, Khuzestan, Semnan, Mazandaran, and Gilan provinces” has “Very Good” climatic condition. Due to TCI values, 4.74% of the country does not have appropriate conditions for tourism activities. In the beginning autumn (October), the highest area of the country (51.09%) have “Good” climatic condition, while 0.88 and 0.41 % of the country have “Marginal” and “Unfavorable” climatic condition. In total, 98.7% of the country has appropriate conditions for tourism activities. TCI value in November was in the range of 31 and 96. The TCI values increased from northwest to southeast. The 44.9 and 39.24 % of the country was situated in “Good” and “Very Good” classes. In the first priority the northern parts of Sistan and Baluchestan (4.77% of the country) have “Excellent” condition; in the second priority the southern parts of Razavi Khorasan, South Khorasan, Yazd, Kerman, Hormozgan, Fars, and Khuzestan provinces (39.24%) have “Very Good” condition. The central, northeastern, western, and southwestern parts of country (44.9%) have “Good” condition and were situated in third priority. The northwestern parts of country and North Khorasan (10.92 %) have “Acceptable” climatic condition. Therefore, the 99.8% of the country have an appropriate condition for outdoor activities. In the latest month of the year, December, the northern, western, and central parts of the country (37.12%) was located in “Acceptable”, while the northeastern ,southern, and eastern parts of country were located in “Excellent”, “Very Good”, and “Good” with 2.51, 22.85, and 31.61 % of Country. The 5.83 and 0.08 % of the country has “Marginal” and “Unfavorable” climatic conditions. The amount of TCI increased from northwest to southeast. In this study, the results of TCI and annual TCI distribution in northwest of Iran (such as Ahar, Parsabad, Ardabil, Sagez, Jolfa, Sanandaj, Khoy, Sarab, Mahabad, Tabriz, Maku, Takab, Marageh, Zanjan and Ourmieh) are consistent with the general results of Farajzadeh and Matzarakis (2009). In both studies Makoo, Ahar, Ardabil, Khoy, Sarab, Takab, and Ourmieh had summer peak distribution and ParsabadMoghan and Jolfa had bimodal-shoulder peak. Based on the results of Gangomkar and Mohseni (2011) over the Mazandaran Province in the northern parts of Iran, the best time for tourism and outdoor activities is June. In the second preference May, July, August and September were suitable. While the results of this study showed that May and October with TCI values (80-100) had Excellent and ideal condition. Also, April, June, July and September with TCI values (60-80) had Very good and good conditions. It seems the difference might be related to the difference in length of input data, impact of climate change and recent year's data on average of climatic data.

10. Future Period (2016- 2045)

The Spatial distribution of TCI over the study area in the future period under A1B scenario is shown in Figure 5. The results of A1B Scenario in January showed that based on TCI values Iran’s climatic conditions were divided into 4 parts such as “Acceptable”, “Good”, “Very Good”, and “Excellent”. The northwestern and northeastern parts of Iran (29% Iran’s area) will have experienced “Acceptable” climatic condition. Owing to the conformity of January with autumn and winter seasons, it was expected that the hot and dry areas have better conditions for tourism activities in Iran. Therefore 1.89 % of Iran’s area has “Excellent” climatic condition, 7.9 % has “Very Good” climatic condition, and 61.21 % has “Good” climatic condition. Comparison of the results of this month in baseline and future periods showed that the climatic condition was improved for tourism activities. Based on the A1B scenario, in the second month of the year, February, the northwestern parts of Iran with Areas of 13.15% will have experienced "Acceptable" climatic condition. The northern and central parts of the country (about 45.82% of total area) have TCI values 60-70 with "Good" climatic conditions.

The major parts of some provinces such as Kerman, Sistan and Baluchestan, Fars, Bushehr, and Khuzestan have "Very Good" climatic condition that included in 34.64% of the total country area. Among all destinations, the southern coastal area such as Khuzestan, Bushehr, Sistan and Baluchestan, and Hormozgan province have "Excellent" and "Ideal" conditions for tourism activities in February. Being located near the sea to cause this area has best climatic conditions in winter. Comparison of the results of baseline and future periods indicated that occurrence of climate change led to improving the climatic conditions for outdoor activities. So that with eliminating "Marginal" class in the baseline period, future condition shifted right and creates "ideal" class.

In the future period, under climate change impacts, the month of March have conformity with late winter and early spring season. With starting the spring season, it was expected that the climatic conditions get better for outdoor activities in Iran.

The climatic conditions divided into 5 classes such as “Ideal”, “Excellent”, “Very Good”, “Good”, and “Acceptable”. The northwestern part of Iran (about 17.3% of Iran’s area), such as “West Azerbaijan”, “East Azerbaijan”, “Ardabil”, “Zanjan”, “Hamedan”, “Qazvin”, “Kermanshah”, “Markazi”, “Alborz” and parts of Mazandaran, Tehran, and Razavi Khorasan province that have cold climate, will have experienced “Good” climatic condition. Some provinces such as Ilam, Lorestan, north of Isfahan, Kohgiloyeh and Boyerahmad, Chaharmahal and Bakhtiari, Semnan, North Khorasan, Razavi Khorasan, northern parts of South Khorasan, and north of Fars will have located in “Very Good” classes (about 38.6% of Iran’s area). The southern part of Iran (about 38.6% of Iran’s area) such as southern part of Isfahan and South Khorasan, Yazd, Kerman, Sistan and Baluchestan, Hormozgan, Fars, Bushehr, and parts of Khuzestan will have experienced “Excellent” climatic condition. Also, climatic conditions in April divided into 5 classes such as “Ideal”, “Excellent”, “Very Good”, “Good”, and “Acceptable”.

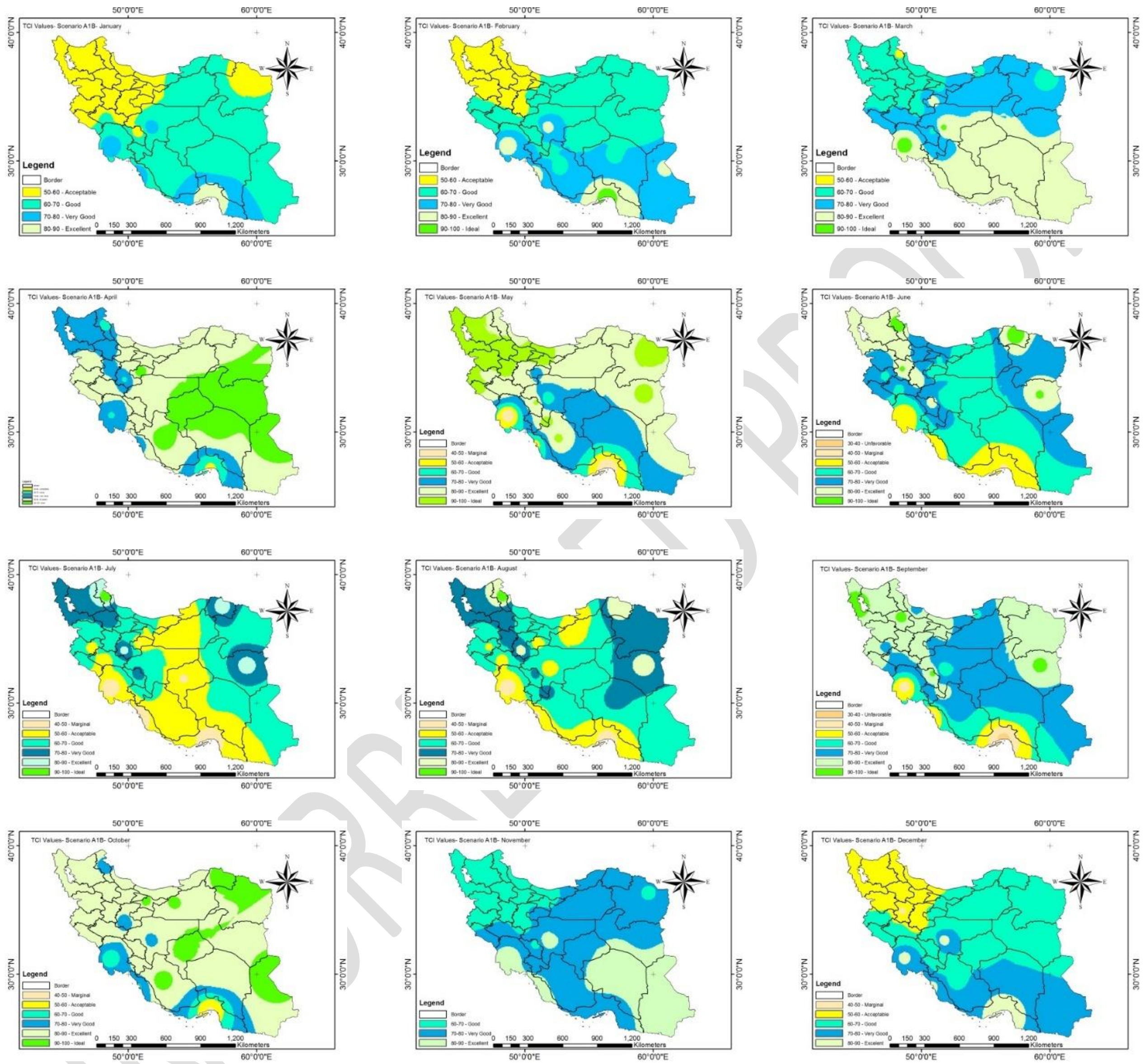

Figure 5. Spatial distribution of Tourism Climate Index over the study area under scenario of A1B in the future period (2016-2045)

Spatial distribution of TCI Index in April shows that 25.5 % of Iran’s area such as Qom, south of Razavi Khorasan, South Khorasan, Yazd, northwest of Fars, north of Kerman and north of Sistan and Baluchestan will have Ideal climatic conditions for tourism activities. Based on Figure 5, the climatic condition gets better from south to north and west to east. Owing to climate change impacts on climatic variables, the climatic condition gets better for tourism activities. In May, when the weather starts getting warm, the spatial distribution of TCI shows that the best destinations are northwestern parts of the country and Razavi and South Khorasan (11.89% total area of Iran). Next the coast of the Caspian Sea (including the Gilan, Ardabil, Golestan, and parts of Mazandaran province), Semnan, North Khorasan, Razavi and South Khorasan, northern parts of Sistan and Baluchestan, Markazi, Chaharmahal and Bakhtiari, and Lorestan will have experienced “Excellent” climate condition. From center to the south of Iran, TCI scores get smaller so that the Hormozgan and Khuzestan provinces will have experienced “Marginal” climate condition. In the month of June, 12.1 % of Iran’s area will have experienced “Acceptable” conditions, especially in

Khuzestan, Bushehr, Fars, Hormozgan and Kerman provinces under the A1B scenario. The coastal area of Hormozgan (about 0.0908%) will have experienced “Marginal”, “Unfavorable” conditions. Other parts of the country have “Good” (33.18%), “Very Good” (41.07%), “Excellent” (12.54%), and “Ideal” (1.02%) conditions. So that the impact of climate change on TCI index is positive and causes to increase the appropriate area for tourism activities. In July under the A1B scenario, climatic conditions include 6 classes such as “Ideal”, “Excellent”, “Very Good”, “Acceptable”, and “Marginal”. The corresponding area of each class is 0.2, 2.01, 11.99, 47.33, 35.5, and 2.96 % of Total Iran’s area, respectively. In this month, the eastern parts of the country (east of Golestan and Semnan, North Khorasan, Razavi Khorasan, South Khorasan, east of Kerman and parts of Sistan and Baluchestan) have appropriate conditions for outdoor activities. In this time western provinces (West and East Azarbayjan, Ardabil, Rasht, Kermanshah, Ilam, Zanjan, Markazi, Qazvin, west of Isfahan, Chahrmahal and Bakhtiari have the same condition. Based on the results of A1B scenario, August has conformity with the middle of the summer season in Iran. In this time southern area such as Hormozgan, south of Fars, Bushehr, Khuzestan, and parts of the Northern Province (Semnan, Mazandaran, and Golestan) have “acceptable” climatic condition. Moreover, 1.31 % of total Iran’s area (located in Hormozgan, and Khuzestan province) has “Marginal” condition. Other parts of Iran (about 77.81%) have “Ideal”, “Excellent”, “Very Good”, and “Good” condition for traveling and leisure time. With occurrence of Climate change, the class of “Unfavorable” was eliminated and the areas of “Ideal”, “Excellent”, and “Very Good” classes were increased. In September, owing to the elimination of “Very unfavorable” and “Extremely unfavorable” classes, the number of classes reduced from 9 to 7. Under the A1B scenario, all provinces with 93.61 % of Iran’s area have the appropriate condition for traveling and outdoor activities. Among all provinces, Khuzestan, Busher, southeast of Fars, Hormozgan, and south of Kerman have “Acceptable”, “Marginal”, and “Unfavorable” conditions (about 6.4% total Iran’s area). In October, “Unfavorable” class was eliminated and the class of “Excellent” has the largest covered area (about 66.9% total Iran’s area). In this time, south coastal areas have “Very Good”, “Good”, and “Acceptable” conditions with corresponding area 15.5, 2.81, and 1%, respectively. In November, Iran’s climatic conditions were divided into 3 classes such as “Excellent”, “Very Good”, and “Good”. The northwestern parts of the country (West and East Azerbaijan, Ardabil, Zanjan, Kurdistan, Qazvin, Qom, Markazi, and Hamedan) with 27 % of Iran’s area will have experienced “Excellent” climate condition. The central parts of the country with 55 % of Iran’s area will have experienced “Very Good”.

Table 4. The linear and non-linear equations of TCI for each month (TCI_{month})

Month	Equation	Equation name
January	$TCI= (31.611(Y) +6.815(X)-0.321(Z))/ (1.166(Y) +0.023(X)-0.003(Z) - 16.643)$ $TCI= (31.611(Y)+6.815(X)-0.321(Z))/ (1.166(Y) +0.023(X)-0.003(Z) - 16.643)$ $TCI=(522989.695-2808.371(X)-0.218(Z)-25966.820(Y)-0.005(Z)^2+62.312(X)^2+379.553(Y)^2) / (0.577(Y)^2+0.436(X)^2)$	Linear regression (Baggio and Klobas 2011) Nonlinear regression (a) Nonlinear regression- Ratio of Quadratics (b) (Moffat *et al.*, 2007)
February	$TCI = - 1.902(Y) + 0.308(X) – 0.011(Z) +119.615$ $TCI=-13.782(Y)-0.730(X)-0.003(Z)+0.172(Y)^2 +0.01(X)^2-2.776E-6(Z)^2+344.240$	Linear regression Nonlinear regression-Quadratic
March	$TCI= - 1.907(Y)+ 0.392(X) – 0.01(Z) +118.812$ $TCI=(10.029(Y)+20.631(X)-0.421(Z))/ (0.633(Y)+0.235(X)-0.005(Z)-13.907$	Linear regression Nonlinear regression
April	$TCI = 0.831(X) – 0.003(Z)+ 36.907$ $TCI=(683167.043-13087.440(X)+98.629(Z)-25697.725(Y)-0.055(Z)^2+449.566(X)^2+48.806(Y)^2) / (-3.442(Y)^2+3.462(X)^2)$	Linear regression Nonlinear regression- Ratio of Quadratics
May	$TCI = 1.509(Y) + 0.378(X) + 0.011(Z) -1.272$ $TCI=(-745314.203-4816.605(X)+234.750(Z)+28838.05(Y)-0.059(Z)^2+85.230(X)^2+479.639(Y)^2) / (9.226(Y)^2+0.183(X)^2)$ $TCI=(122.317(Y)-35.016(X)+1.728(Z))/(0.83(Y)-0.625(X)+0.015(Z)+38.001)$	Linear regression Nonlinear regression- Ratio of Quadratics (a) Nonlinear regression (b)
June	$TCI = 2.285(Y) + 0.017(Z) -21.071$ $TCI=(20468.915(Y)-2652.472(X)+169.236(Z))/ (Y+X+9804.451)$	Linear regression Nonlinear regression- Michaelis Menten (Moffat *et al.*, 2007)
July	$TCI = 1.876(Y) + 0.017(Z) -15.267$ $TCI=(5004.279(Y)-603.208(X)+49.822(Z))/(Y+X+ 2783.549)$	Linear regression Nonlinear regression- Michaelis Menten
August	$TCI = 1.572(Y) + 0.018(Z) -4.904$ $TCI=(3.594E8 (Y) - 8587381.781 (X)+ 4490069.929 (Z)) / (Y+ X+ 2.427E8)$	Linear regression Nonlinear regression- Michaelis Menten
September	$TCI=1.670(Y) + 0.018(Z) +2.321$ $TCI=(169.686(Y)+12.452(X)+4.707(Z))/(-0.357(Y)+ 0.02(X) +0.028 (Z) + 123.983)$	Linear regression Nonlinear regression
October	$TCI = 0.395(X) + 0.009(Z) +51.082$ $TCI=(-10153.462(X)+32752.823(Y)+84.550(Z)-10153.462(Z)^2 +137.989(X)^2 -305.236 (Y)^2 -373682.715) / (2.306(Y)^2 + 0.25(X)^2)$	Linear regression Nonlinear regression- Ratio of Quadratics
November	$TCI = - 1.892(Y) + 0.433(X) – 0.0061(Z)+ 118.244$ $TCI=(42.286(Y)+42.287(X)-1.049(Z))/(1.597(Y)+0.404(X)-0.012(Z)-26.710)$	Linear regression Nonlinear regression
December	$TCI = - 1.808(Y) + 0.356(X) – 0.0084(Z)+ 110.223$ $TCI = -14.742(Y) -1.708(X)+0.188(Y)^2+0.021(X)^2 -2.411E-6(Z)^2 +375.851$	Linear regression Nonlinear regression- Quadratic

November is the best month for traveling to Iran. All destinations have an appropriate climatic condition at this time. In December, comparison of baseline and future periods showed that the class of “Unfavorable” was eliminated and 15.6 % of Iran’s area located in northwestern parts will have experienced “Acceptable” climatic conditions. While the 53.46 % of Iran’s area located in northern, western, central, and eastern parts of the country were situated in “Good” class. Southern parts of Iran include Khuzestan, Sistan and Baluchestan, Bushehr, south of Fars and Kerman has “Very Good” conditions. Also, the southern coasts of Iran located in Hormozgan province have the most appropriate conditions at this time.

11. Regression models

The regression models were investigated by using three geographic variables (latitude (Y), longitude (X), elevation above the sea level (Z)) as the independent variable and calculated monthly TCI values as the dependent variable. The linear and non-linear regression models are presented in Table 4. Also, the scatter plot of monthly TCI values was shown in Figure 6. The root mean square error (RMSE), mean error (ME), mean absolute relative error (MARE) and coefficient of determination (R^2) were used to compare the accuracy of models that their results are shown in Table 4. The standard errors rates of the parameter estimate in non-linear models are high except for February and December. However, the differences in the statistical performance measures of the linear and non-linear models for each month in Table 4 shows that non-linear models worked more accurate. For instance, the non-linear model for April month explained 56% of the variation in TCI values while the linear model explained for only 18%. All regression coefficients of the linear model for April month have been significant at the 95% confidence level except for latitude. This suggests that latitude is not important to TCI modeling for this month. However, all coefficients of the model for January, February, March, May, November and December months have been significant at the 95% confidence level. According to Table 5, the corresponding p-values for F-test indicate the linear regression models are significant at the 95% confidence level. Figure 6 compares the simulated TCI using the regression models with the baseline TCI values result from the main model (Mieczkowski, 1985) for each month. The good performance of the multiple regression models indicates that they can be used in the practical applications.

Table 5. Model errors and statistical significance

Dependent variable	Independent variables	p-value for t-test	p-value for F-test	model	R^2	RMSE	ME	MARE
TCI_{Jan}	Lat.	0	0	Linear	0.501	9.701	1.9×10^{-7}	0.132
	Long.	0.007		Nonlinear (a)	0.571	8.363	0.015	0.125
	Elev.	0		Nonlinear (b)	0.658	8.123	0.002	0.116
TCI_{Feb}	Lat.	0	0	Linear	0.683	8.079	6.5×10^{-8}	0.114
	Long.	0.013		Nonlinear	0.786	6.638		0.107
	Elev.	0						0.150
TCI_{Mar}	Lat.	0	0	Linear	0.554	10.263	2.6×10^{-7}	0.150
	Long.	0.013		Nonlinear	0.606	9.644	0.144	0.006
	Elev.	0						
TCI_{Apr}	Long.	0	0.027	Linear	0.181	11.037	1.3×10^{-7}	0.183
	Elev.	0.027		Nonlinear	0.56	8.090	0.0001	0.122
TCI_{May}	Lat.	0	0	Linear	0.498	10.288	3.9×10^{-7}	0.161
	Long.	0.17		Nonlinear (a)	0.626	8.884	0.0003	0.139
	Elev.	0		Nonlinear (b)	0.592	9.270	0.009	0.144
TCI_{Jun}	Lat.	0	0	Linear	0.777	8.491	2.6×10^{-7}	0.119
	Elev.	0		Nonlinear	0.78	8.345	0.0005	0.112
TCI_{Jul}	Lat.	0	0	Linear	0.802	7.486	2.5×10^{-7}	0.111
	Elev.	0		Nonlinear	0.806	6.312	0.0023	0.106
TCI_{Aug}	Lat.	0	0	Linear	0.822	7.070	0	0.100
	Elev.	0		Nonlinear	0.821	6.987	0.0002	0.087
TCI_{Sep}	Lat.	0	0	Linear	0.778	8.141	1.9×10^{-7}	0.106
	Elev.	0		Nonlinear	0.798	7.766	0.021	0.100
TCI_{Oct}	Long.	0.004	0	Linear	0.338	9.553	2.6×10^{-7}	0.150
	Elev.	0		Nonlinear	0.712	8.147	0.0003	0.116
TCI_{Nov}	Lat.	0	0.004	Linear	0.526	9.349	6.5×10^{-8}	0.138
	Long.	0.003		Nonlinear	0.586	8.739	0.005	0.127
	Elev.	0						
TCI_{Dec}	Lat.	0	0	Linear	0.588	8.710	6.5×10^{-8}	0.118
	Long.	0.008		Nonlinear	0.745	6.861	6.5×10^{-5}	0.109
	Elev.	0						

12. Conclusion

Climatic and geographical analyses are required for tourism and tourism investors. The impact of weather information can also be assessed from the aspect of human biometeorology. Tourism Climate Index (TCI) is a useful index, for it uses climatic variables in relation to biometeorological studies on a single index that is promptly explainable by the traveler. According to studies included in this article, the results can be classified into three parts. At first, a user-friendly and multi-platform software was developed in JAVA language to calculate and present Iran’s Tourism Climate Indices. The proposed program called ITCIC, allows determination of TCI of Iran’s synoptic weather stations according to the months of the year. Using ITCIC allows easy calculation of TCI with a large number of climatic data and captures the changing patterns of TCI during the year at each of the stations. Different climate comfort zones from the viewpoint of tourism have been identified by using ArcGIS software. The TCI provides a useful measure of climate for the average tourist and may be used to evaluate the appropriateness of sub-index rating systems and weightings in the TCI against stated visitor preferences. Furthermore, additional validations are needed in order to further assess the value of weather and climate in tourism research, especially for agritourism and ecotourism sectors. This study focused on the impacts of climate change on human comfort by using Mieczkowski's tourism climate index (TCI) and the LARS-WG statistical downscaling method under the A1B scenario. For this purpose, long-term data of 153 synoptic meteorological stations were used in the period of (1985-2015) and TCI values were predicted for the period of 2016-2045. The spatial variation of tourism climate index was investigated for baseline and future period. Finally, the monthly TCI values were simulated using the linear and non-linear regression models with the baseline geographical coordinate variables as inputs. The multiple linear regression models all showed that latitude was the most important and significant factor correlated with the monthly TCI except for April and October months, while elevation factor had the lowest correlation with TCI, inversely. Comparison of simulated TCI values by using regression models and baseline TCI values showed that a good accuracy of TCI prediction. Thus, it is assumed that there are other unknown factors influencing TCI values that were not taken into account in the analyses and they have the potential for explaining more variations in TCI values.

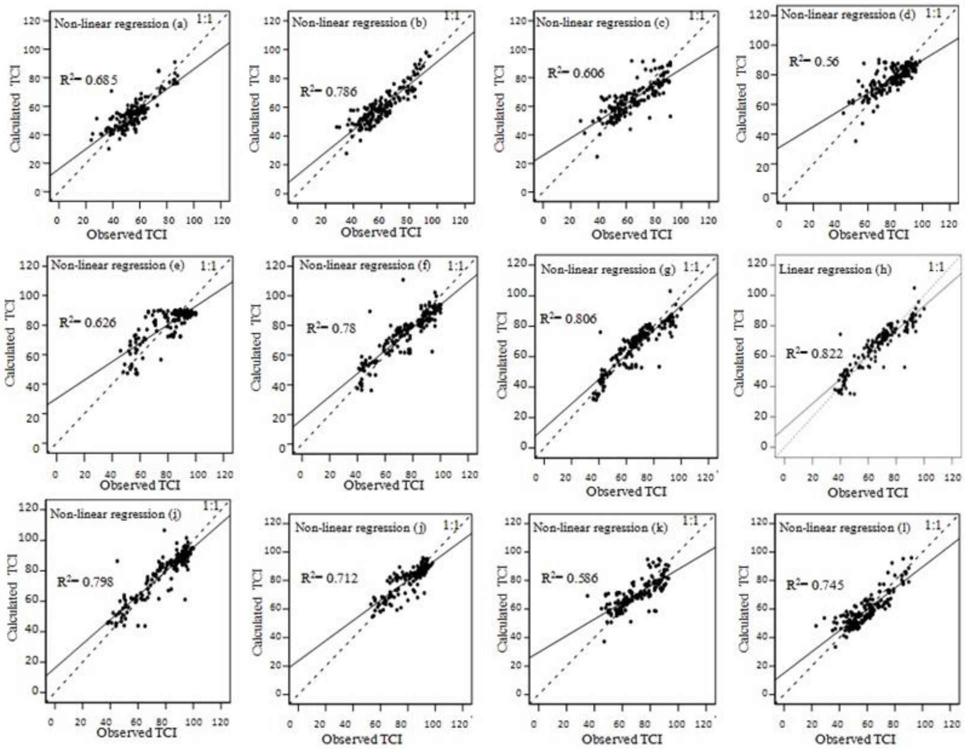

Figure 6. Scatter plot of the baseline TCI values result from the main model (Mieczkowski's, 1985) vs. calculated TCI values result from the linear and non-linear models in January (a), February (b), March (c), April (d), May (e), June (f), July (g), August (h), September (i), October (j), November (k) and December (l) across Iran

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