Boletín de la Asociación de Geógrafos Españoles, 77, 521–548
ISSN: 0212-9426
DOI link: http://dx.doi.org/10.21138/bage.2550

How to cite this work: Mihăilă, D., Piticar, A., Briciu, A. E., Bistricean, P. I., Lazurca, L. G., & Puţuntică, A. (2018). Changs in bioclimatic indices in the Republic of Moldova (1960–2012): consequences for tourism. *Boletín de la Asociación de Geógrafos Españoles, 77,* 521–548. doi: 10.21138/bage.2550

Changes in bioclimatic indices in the Republic of Moldova (1960–2012): consequences for tourism

Cambios de los índicos bioclimáticos en la República de Moldavia (1960–2012): consecuencias para el turismo

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Received: 28.01.2017 Accepted: 16.04.2018 Published: 15.06.2018

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Abstract

This study includes a diagnostic and evolutive analysis of the bioclimate of Republic of Moldova, made by using the Wind Chill (WCI) and Cooling Power (CP) indices. The bioclimate of the cold season (October—March) had, in the time period 1960—2012), a warming trend, highlighted by the decrease of WCI values. During the warm season, the bioclimate of Republic of Moldova recorded a gradual warming, highlighted by the decrease in CP index values. The CP index values were analyzed in relation to those of the Tourism Climate Index (TCI), useful for planning the tourist activities of any kind. The actual values of TCI and the ones anticipated for the future indicate, for the Republic of Moldova, an increasing bioclimate favorability for all forms and types of tourism.

Key words: bioclimate trends; Republic of Moldova; tourist activities.

Resumen

El presente estudio incluye el análisis diagnóstico y evolutivo del bioclima de la República de Moldavia según Wind Chill Index (WCI) y Cooling Power (CP). Entre 1960 y 2012, el bioclima de la temporada fría (octubre-marzo) presentó una tendencia de calentamiento gradual, evidenciada por la baja de los valores de WCI. Durante la temporada cálida, el bioclima de la República de Moldovia registró un calentamiento gradual, evidenciado por la baja de los valores de CP. Los valores del índice CP han sido analizados según los valores del Índice Climático turístico (TCI), útil para planificar actividades turísticas de cualquier tipo. Los valores actuales de TCI y los anticipados para el futuro indican un clima favorecedor para todo tipo o toda clase de turismo en la República Moldavia.

Palabras clave: tendencias bioclimáticas; República Moldavia; actividades turísticas.

1 Introduction

Usage of bioclimate and tourism-climate indices in the analysis of man-climate and tourism-climate relationships is a necessity and also an opportunity, fully applied in the specific scientific researches. During the 20th century, over 100 indices were used for assessing the bioclimate conditions only. (Blazejczyk et al., 2012). The importance of a mixed approach of the meteorological parameters in assessing climate impact on humans was suggested almost a century ago (Buttner, 1938). Bioclimatic indices refer to comfort/discomfort situations, stress conditions and pathology of the human body exposure to caloric excess or deficit. Because most people of the world live in urban environment, most bioclimatic studies analyze the built areas (Jaúregui et al., 2002; Nastos & Matzarakis, 2013; Huang et al., 2015). The scientific studies that analyzed the climate trends by using the bioclimatic indices are not numerous and do not cover all the climatic zones or large territories. In Europe, the climate change implies an increased thermal discomfort (Robine et al., 2008; Schär et al., 2004). The Cooling Power indices were sometimes used in bioclimatic studies (Siple & Passel, 1945; Tzenkova et al., 2008).

There are few bioclimatic studies that describe the bioclimatic environment in areas close to our study area. For example, Merciu (2010) analyzed the variability of WCI in order to determine the degree of discomfort felt by tourists in the high region of Parâng Mountains, Romania. Teodoreanu and Mihăilă (2012a, 2012b) studied the bioclimatic comfort and discomfort from Suceava Plateau, relying on the monthly, daily and hourly data by using the WCI and Wind-Chill Equivalent Temperature indices. They made statements on the bioclimatic characteristics and harsh weather, but they have not determined trends of these indices. For the other neighbor country of Moldova (Ukraine), Katerusha and Matzarakis (2015) have analyzed PET and the relationship between the bioclimatic indices and tourism.

The CP index was used in numerous studies, such as those of Ramezani and Palic (2012) and of Farajzadeh and Matzarakis (2012) (the latter also indicated the most favorable period for tourism in the area of Orumieh Lake, Iran).

The WCI and CP bioclimate indices have some disadvantages originated in the inclusion of only two climate parameters in the bioclimate analysis - air temperature and wind speed -, but have the advantage of being computed very easily; they are easily understood not only by specialists, but also by the wide public and have a good temporal applicability and availability for the studied territory.

TCI is a complex, validated bioclimate index with a great spatial and temporal applicability, fulfilling our objectives. TCI was proposed by Mieczkowski (1985) and it combines seven items/climatic parameters. This index was used by many researchers (Ramezani & Palic, 2012; Scott et al., 2004) to carry out studies on the implications of climate in tourism. Some studies analyze TCI for areas in the Central and Southern Europe (Amelung & Viner, 2006; Kovacs & Unger, 2014).

The climate change affects the touristic potential of all places in the world. Scott et al. (2004) conducted a study for climate-tourism forecast by using the TCI for the Canadian provinces, until 2050 and 2080, when TCI values indicate better values than the current ones. Also, Scott and McBoyle (2001) explored the impact of designed climate changes on climatic-touristic resources in North America by using TCI.

Amelung and Viner (2006) studied the impact of climate change on the TCI values of the Mediterranean and other European regions. Hamilton and Tol (2007) discovered that, according to the evolution of TCI values, in the UK and Ireland the attractive touristic areas will gradually move to north in the near future; also, weather conditions will be more favorable for summer tourism in northern coastal areas of Germany. Overall, TCI is analyzed for the European continent by Amelung and Moreno (2009) by using data from 1960—1990 and for all seasons; the authors also make projections of the climate-tourism resources for 2020 and 2080, taking 1970 as a reference year.

The few bioclimatic studies about the Republic of Moldova bioclimate represents non-peer review literature which is not published in English. For the Republic of Moldova, there is no study about the selected bioclimatic indices and their trend. To our knowledge, an assessment of the climate favorability for tourism in the Republic of Moldova based on TCI has not been conducted so far.

The main purpose of this study is to realize the second bioclimatic study of the Republic of Moldova`s territory, by including the bioclimatic features from an average year in their inter-monthly evolution based on the bioclimatic indices WCI —analyzed from October to March— and CP —analyzed from April to September—, by showing trends of the selected bioclimatic indices for the 1960—2012 period and by estimating bioclimatic forecasts for the 2020 and 2030 time horizons; the WCI-CP relationships are analyzed and CP, a bioclimatic index available for the entire year, is correlated with TCI in order to indicate the favorability/restrictiveness degree of the climate for tourism in Republic of Moldova.

The future use of PET and radiant mean temperature (Tmrt) indices (Matzarakis et al., 2010) or of weather types (Besancenot—Mounier—Lavenne method, Besancenot et al. (2004), applied in Spain by Gómez (2006) and in Romania by Apostol and Gaceu (2011)) in the diagnosis and forecast analyses of the territory of Republic of Moldova will reveal, through their complexity, new bioclimate and climate-tourism specificities of this country. The use of climate-tourism schemes (CTIS) (Freitas et al., 2008; Lin & Matzarakis, 2008) could bring a decadal assessment of various climate parameters favorability/unfavorability for tourism in Republic of Moldova. Useful for climate-tourism studies on Republic of Moldova could also be the methods applied by Gómez (2004), Martínez (2011) or Martinez and Gómez (2012). The analysis of the evolution of bioclimate changes in Republic of Moldova can be improved by the thermicity algorithm written by Miró et al. (2016).

The objectives of this study are (1) to analyze the spatial and temporal distribution of WCI and CP indices during the months of an average year based on the monthly data from the 1960—2012 period, (2) to identify trends of the input parameters of WCI and CP (air temperature, air humidity, wind speed) for the 1960—2012 period and (3) to analyze the current state of tourist activities that depends in various proportions on weather particularities in Republic of Moldova by using the inter-monthly evolution CP and TCI indices for identifying the most favorable or restrictive periods of the year for tourism.

2 Material and methods

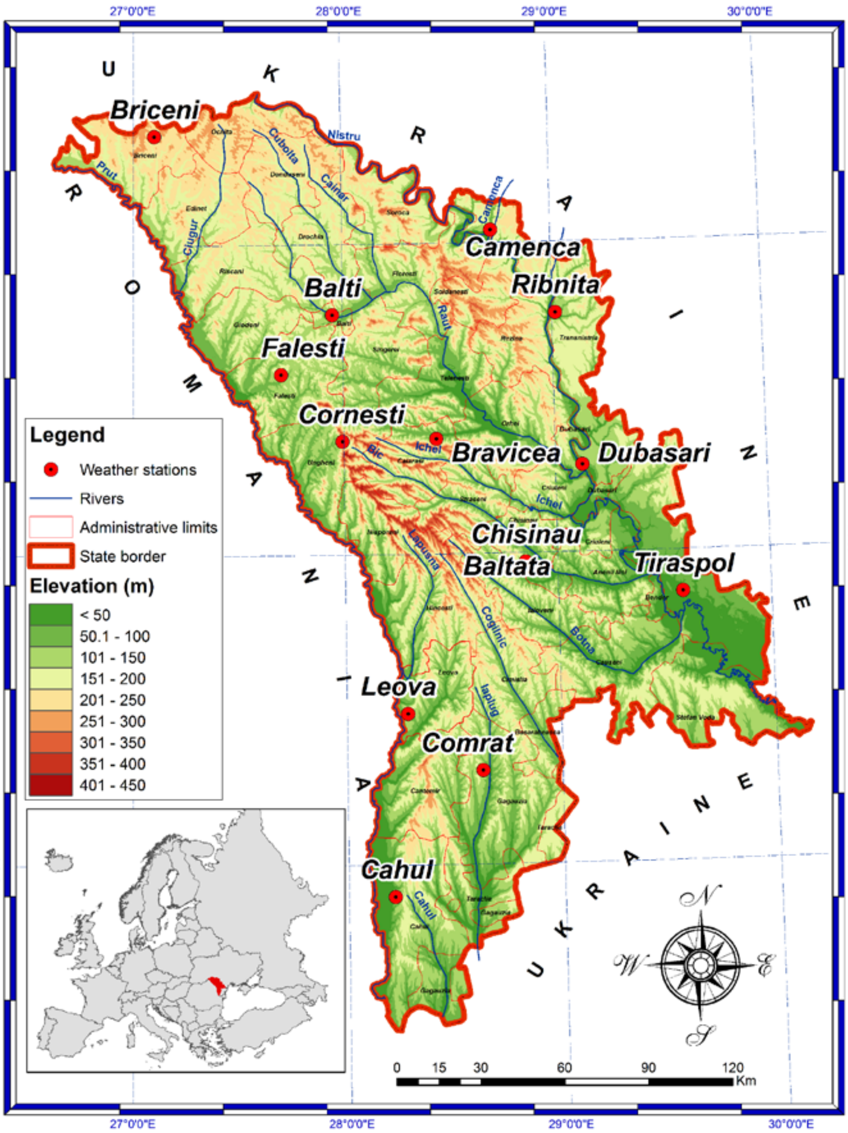
2.1 Study area

The Republic of Moldova is part of SE Europe, in the NE Balkan Peninsula, having a surface of 33,843.5 km^2 (Figure 1). Moldova is a plateau and a hilly plain having an average elevation of 147 m above sea level. In the central part of Moldova lies Codru Plateau —the highest region (Bălăneşti Hill, 429.5 m, the main wooded area of Moldova). The southern part of the country and Nistru River lower plain have the lowest elevation (Nistru valley, 2 m, in the south-eastern part of Moldova). The climate of Moldova is continental temperate and is characterized by annual mean air temperature ranging from 8—9 °C in N to 10—11 °C in S. Annual precipitation values vary between 600 and 650 mm in the northern and central part and between 500 and 550 mm in the southern and south-eastern part. The zonal character of the precipitation distribution is substantially modified by the terrain elevation, exposition and slope. The higher amounts are determined both by higher elevations and woody lands. Great variations of the air temperature exist, with frosty winters (when air temperatures fall below -30°C; the absolute minimum was -35.5 °C at Brătuşeni on January 20, 1963) and canicular summers (when the absolute maxima reach over 40 °C in air; the absolute maximum was 42.4 °C at Făleşti on August 7, 2012) and over 70 °C on soil surface (74 °C in Leova on July 19, 2007).

The rainfall is also highly variable. During some years, the precipitation oscillated between from under 300 mm/year to over 900 mm/year. The highest amount (952 mm) was reached in 2010 at Briceni, while the lowest amount (208 mm) was recorded in 1928 in Comrat. All climate data were provided by the State Hydrometeorological Service (SHS) of the Republic of Moldova.

According to the National Bureau of Statistics of the Republic of Moldova (2015), this country had a population of 3.55 million people in 2014. Of the total population, 723,500 (20.4 %) were employees. In tourism, between 2002 and 2012, there was an average annual number of only 1,684 employees. In Republic of Moldova, the percentage of tourism in GDP is not included in the official statistics, but it is estimated in various journalistic sources as accounting for only 0.9 % of GDP in 2015. The capacity of tourist reception reached 28,548 seats in 2014, of which 2,084 seats belonged to health-care structures. The number of tourists staying in all tourist structures climbed in 2014 to 283,001, and 93,897 of them were foreign tourists. In health-care structures 32,920 tourists were accommodated in 2014, of which only 665 were foreigners. The number of overnight stays in the same year reached 1,514,273 (217,930 overnight stays of foreign tourists). In health-care structures, the number of overnight stays was 477,477, of which 8,329 were the overnights of foreign tourists. The main countries providing tourists to Republic of Moldova in 2014 were Romania (22,624 tourists), Ukraine (10,951), Russian Federation (8,368), USA (6,064), Italy (5,143) and Germany (4,642). The accommodation capacity of the receiving structures in 2007–2014 period was used on an average of 36.6 % (between 17.7 % in hotels and motels and 68.6 % in health-care structures). Tourist balance of Republic of Moldova is asymmetrical; for example, only through travel agencies and tour operators, in 2014, from Republic of Moldova left 180,646 tourists and arrived 14,362 tourists. This country is primarily one emitting tourists and not one of their landing.

Figure 1. Republic of Moldova: location of weather stations



Source: own elaboration

The legislative framework of Moldova (Law no. 352/24.11.2006) identifies tourism as one of the priority areas of the economy. In Republic of Moldova, there are over 15,000 anthropogenic tourist attractions and over 300 important natural areas. The efforts undertaken by the Moldavian authorities, according to the tourism development strategy "Tourism 2020", may covert the tourism in the future into a domain that contributes to the economic growth in this country (the strategy anticipates a 3 % annual increment of the number of domestic tourists, a 4 % yearly increase in the number of foreign tourists and a 0.3 % increase of the contribution of tourism to GDP of Moldova within 2014–2020) (GRM, 2014).

Health tourism and other forms of tourism (wine tourism, rural tourism, sport tourism, week-end tourism etc.) may be vectors of tourism development in the future, after the expansion and endowment at new standards of the existing tourist resorts and recreation/treatment facilities (the seaside resort "Nufărul Alb" in Cahul, Codru spa resort in the Hârjauca city, the sanatorium "Bucuria-Sind" in Vadul lui Vodă city, Constructorul sanatorium from Chișinău, the republican center "Speranța" in Vadul lui Vodă city, Struguraș in Cocieri settlement (Transnistria)) are fulfilled.

2.2 Data

In the present study, we used air temperature, relative humidity and wind speed monthly data from the 1960–2012 time interval and 13 meteorological stations in the Republic of Moldova (Figure 1, Table 1). Data were provided by SHS. By using the previously mentioned parameters, WCI and CP were calculated. WCI and CP indices allow for the bioclimatic analysis of certain intervals of the year. WCI is relevant for revealing the discomfort, stress conditions and pathology of human body exposure to harsh weather (low air temperatures and strong winds) during the cold semester (October 1–March 31) and especially during the winter months (DJF).

Table 1. Geographical coordinates of the weather stations used in this study

No.	Station name[a]	Latitude (N)	Longitude (E)	Elevation (m)
1	Briceni	48°21′00″	27°06′00″	258
2	Camenca	48°02′24″	28°42′36″	39
3	Bălţi	47°46′12″	27°56′59″	103
4	Rîbniţa	47°46′12″	29°00′36″	97
5	Făleşti	47°34′48″	27°42′00″	160
6	Corneşti	47°22′12″	27°59′24″	234
7	Bravicea	47°22′12″	28°26′24″	81
8	Bălţata	47°03′36″	29°02′23″	79
9	Chişinău	46°58′12″	28°51′00″	172
10	Tiraspol	46°52′12″	29°34′48″	38
11	Leova	46°29′24″	28°16′48″	158
12	Comrat	46°18′00″	28°37′12″	136
13	Cahul	45°54′00″	28°12′36″	14

Key: [a] The stations are sorted from N to S

Source: own elaboration

The cooling power of the environment (CP) is an index that can be used without restriction in any area of the globe and for the entire year. This index is measured as Mcal/cm^2/sec, represents the energy losses at the skin surface of the human body and allows us to easily compare it (in this case for the October–March period) with the quantifiable energy losses of the WCI. The values of both indices are maximum in the winter months indicating the biggest caloric losses of the body under a cold and windy atmosphere.

2.3 Methods

WCI was calculated in the present study according to the Beçancenot formula (1), created in 1974 by Beçancenot (1974) who updated and simplified the Siple and Passel's WCI formula from 1945:

$$WCI = (10*w+10.45-w)*(33-t) \qquad (1)$$

where WCI is measured in W/m^2/h, w is wind speed in m/s and t is air temperature in °C. WCI conveys in a quantitative way the combined air temperature and wind speed effect on the human body caloric balance and represents the intensity of caloric loss (through radiation, conduction, convection, evaporation) in W per body surface unit area (m^2) and per time unit (h). Ionac and Ciulache (2008) found the effect of the various WCI values on the human body (it depends on the caloric loss intensity. Becker (1972) proposed CP as a mathematical model to identify the human bioclimatic comfort:

$$CP = (0.26+0.34*w^{0.662})*(36.5-t) \qquad (2)$$

where w = wind velocity (m/s), t = daily average temperature (°C), CP = cooling power of the environment (Mcal/cm^2/sec).

In equation (2), one can observe that the cooling power of the environment depends on the difference between human body temperature and air temperature and also on the wind speed. The relationship between the cooling power values and the bioclimatic stimulation thresholds for humans was described by Becker and used with modifications by other authors (Jahanbakhsh, 1998).

Between WCI and CP there are very strong correlations for the cold semester of the year that confirms the validity of the used indices (Figure 2). In our approach, after CP is validated by the direct relationship with WCI for the October–March period, we use this index to analyze the bioclimatic conditions for the warm semester of the year (between April-September). Ultimately, the CP values are compared for every month of the year with TCI. Because, in Moldova, two periods with distinct bioclimatic characteristics occur each year - the warm one (April–September), with discomfort, stress and pathology caused by the caloric excess from the hot time intervals, and the cold one (October–March), when the medical and bioclimatic phenomena are a result of the caloric deficit, we have chosen to use the selected indices.

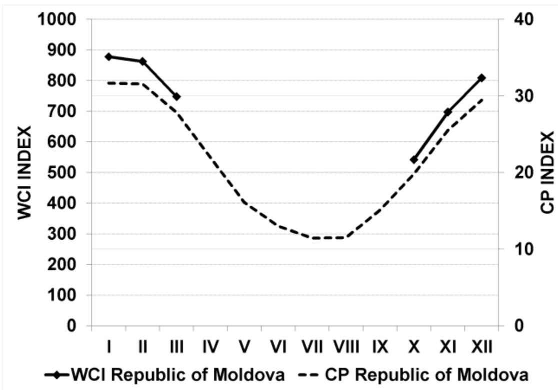
In order to connect the bioclimatic indices during a year (under a multiannual trend outlined clearly enough) to the touristic activities of Republic of Moldova, we used TCI, proposed by Mieczkowski (1985). TCI is calculated by using two complex climate indicators (daytime comfort index (CID), daily comfort index (CIA)) and three simpler climate indicators (precipitation (P), sunshine (S), wind (W)) (Mieczkowski, 1985).

The TCI formula is:

$$TCI = 2*[(4*CID)+CIA+(2*P)+(2*S)+W] \quad (3)$$

Each indicator receives points from 5 to 0 (5 means that the indicator offers ideal conditions for the practice of tourism and 0 means that it imposes very restrictive conditions). In order to calculate CID and CIA, correlation graphs are drawn on a system of two axes; the horizontal axis corresponds to the maximum daytime temperature and, respectively, to the mean daily air temperature; the vertical axis represents the daily minimum air humidity and, respectively, the daily mean air humidity. The intersection of the axes is represented by the highest temperature values and the lowest humidity values; the index value here is 5 —as the temperature values decrease on the horizontal axis and the humidity values increase on the vertical axis, the index values are reduced towards 0.

Figure 2. Correlations between WCI—CP for the territory of Republic of Moldova (1960—2012)



Source: own elaboration

For the months with precipitation between 0 and 14.9 mm, the score given to P was 5, while for those with precipitation over 150 mm, the given score was 0. For the months in which the mean daily sunshine duration was ≥10 hours, S received 5 points, while for those when the mean daily sunshine duration was under one hour, the given score was 0. Concerning W, at mean daily wind speed ≤ 0.63 m/s it received 5 points, while at mean daily wind speed ≥ 10.7 m/s it received 0 points. The impact of various TCI scores on tourism is described by Mieczkowski (1985). Finally, we correlated for all months of the year the mean values of CP with those of TCI for seven weather stations that uniformly cover the entire Republic of Moldova from north to south.

In order to determine the bioclimatic indices trend in monthly, seasonal and annual time series we used two methods: a nonparametric method (Mann-Kendall test combined with the Sen's slope test (Sen, 1968)) and a parametric method (linear regression, by using the T-test). These methods have some advantages: missing values are allowed, data does not have to be in conformity to any particular distribution and the Sen's slope is not affected by singular errors in the data row. MAKESENS software (Salmi et al., 2002) was used for two types of statistical analysis: firstly, for testing the presence of a positive or negative monotonous trend by using the Mann-Kendall nonparametric test and, secondly, for calculating the estimated linear trend slope by using Sen's nonparametric method. The Mann-Kendall test was frequently used for studying the bioclimatic indices (Zaninovic et al., 2006; Dobrinescu et al., 2013; Ramezani & Fallahzadeh, 2014).

The aim and objectives of this study are fulfilled by using in the calculation of bioclimatic indices the monthly averages of the following climatic elements: temperature, humidity, wind. By using them we outline the major bioclimatic characteristics of Republic of Moldova and their trend, detailed on different temporal samples. The study itself does not aim to identify critical or ideal temporal sequences of weather-body relationship, which would have required daily or even hourly data, but this kind of analysis can succeed the current approach. Where the context required (calculation of TCI), we used daily values of climate elements (temperature —the average daily maxima and daily average; humidity —the average daily minimum and daily average; rainfall, sunshine, wind speed).

For this study we used the climatic database of the State Hydrometeorological Service of Moldova. The available database allowed us to choose a set of climatic indices that was not used in the bioclimatic studies for Republic of Moldova until now. Because THI (that would have responded well to the aim of this study) was previously analyzed in a recent scientific study (Mihăilă, 2015) and a series of other indices (Humidex, TEE, ISE, ISH, SSI, ITU etc.) have only a very limited spatial and temporal applicability (for some months of the year or for other types of climate), we concluded that the research targets can be achieved by using the WCI and CP indices, which together cover all months of the year, throughout Republic of Moldova and give convincing results.

The spatial distribution of the bioclimatic indices was calculated and mapped in ArcGIS for different time intervals. The average multiannual values of the three bioclimatic indices were interpolated by using the ordinary kriging method. This spatial interpolation method starts from the premise that the values of a variable are autocorrelated on short distances (Patriche, 2009). Other global interpolators, including regression, are not able to remove the anomalies in the spatial distribution of the analyzed climatic element and require a relatively large number of points (stations) to identify a statistically significant relationship. Another disadvantage of the regression consists of "smoothing" the real spatial variation, with modification of the real values from the known points depending on the identified relationship. In contrast to the regression, that integrates altitude, the interpolation by ordinary kriging has the advantage of keeping their own values in the known observations points (weather stations) and of reproducing the deviations/"islands" with their real higher or lower values of the analyzed bioclimatic indices.

Consequently, we chose ordinary kriging because it is a suitable interpolation method for the climate elements and phenomena with a higher spatial variability and lower spatial predictability (e.g. the wind speed in the calculation equations depends on atmospheric dynamic). Moreover, the distribution and evolution of the measured meteorological elements (temperature, humidity, wind) in the 13 weather station from Republic of Moldova do intrinsically include the latitude, the dynamic and geographical conditions (altitude etc.) of the monitoring sites

Another problem which requires the use of ordinary kriging instead of other methods is given by the classification in few comfort/discomfort classes of some indices (e.g. CP, for which we can identify only three classes, while during May, June and September the entire Republic of Moldova falls into one class) for which we do not have a more representative spatial variation.

3 Results

3.1 Trends in the primary climatic parameters

The air temperature, relative humidity and wind speed time series are not affected by the switch from the classical instruments to the automated ones (2004–2008) or by the changes in the geographical coordinates of the weather stations. Transition from manual to automated observations system was done keeping the old monitoring locations and conducting parallel joint observations (classic and automated measurements), the differences between their results during dual observations being insignificant. It was also found that the automatic monitoring system, which gradually took over the duties of observations, has not brought jumps nor substantially modified values in the datasets.

Marin et al. (2014) have analyzed the annual trends in air temperature, wind speed and relative humidity for the territory of Romania (1961–2013) and observed significant temperature increasing trends, significant wind speed and relative humidity decreasing trends for the majority of measuring points.

Before analyzing the trends in the selected bioclimatic indices, we analyzed the trends of the meteorological elements that are included in the selected formulas. We used monthly data of mean, maximum and minimum air temperature, mean relative humidity and mean wind speed. Concerning the air temperature, we noticed that 97.1 % of the analyzed time series showed increasing trends (determined through Mann-Kendall and T tests); 62.9 % have statistically significant increasing trends (Table 2). In the case of thermal maxima and minima, we noticed that the data showed a very high percentage of the increasing trends (97.1 % for maximum air temperature (MaxT) and 95.7 % for minimum air temperature (MinT)). 65.7 % of MaxT and 51.4 % of MinT have statistically significant increasing trends. As far as maximum and minimum air temperatures are concerned, we can confirm that the aerial environment in Moldova was obviously marked by a considerable warming (Nedealcov, 2014).

The relative humidity time series indicate that the atmosphere above Moldova has become drier (82.9 % decreasing trends, 27.1 % statistically significant decreasing trends). A warm and dry atmosphere is not at all benefic for the human body, especially during the warm season when there is a real danger of releasing great concentrations of aerosols caused by the frequent dust storms (Potop & Soukup, 2009; Parmacli & Staicova, 2013; Croitoru & Overcenco, 2013). The studied area is often affected by dust storms because of the Suhovei wind. A strong decreasing trend is also recorded by the wind speed time series. 95.7 % of them show a decay of the wind speed close to the active surface; 82.9 % of all time series show statistically significant decreasing trends.

Table 2. Percentage of trends in the climatic parameters at weather stations in the Republic of Moldova during 1960–2012 (% /total number of stations; Mann-Kendall test)

	Total increasing	Significant increasing trend	Total decreasing trend	Significant decreasing trend	Stationary trend
Primary climatic parameters used for bioclimatic indices calculation					
Average air temperature	97.1	62.9	0.0	0.0	2.9
Relative humidity	10.0	0.0	82.9	27.1	7.1
Wind speed	2.9	0.0	95.7	82.9	1.4
Complementary climatic parameters					
MaxT	97.1	65.7	2.9	0.0	0.0
MinT	95.7	51.4	2.9	0.0	1.4

Source: own elaboration

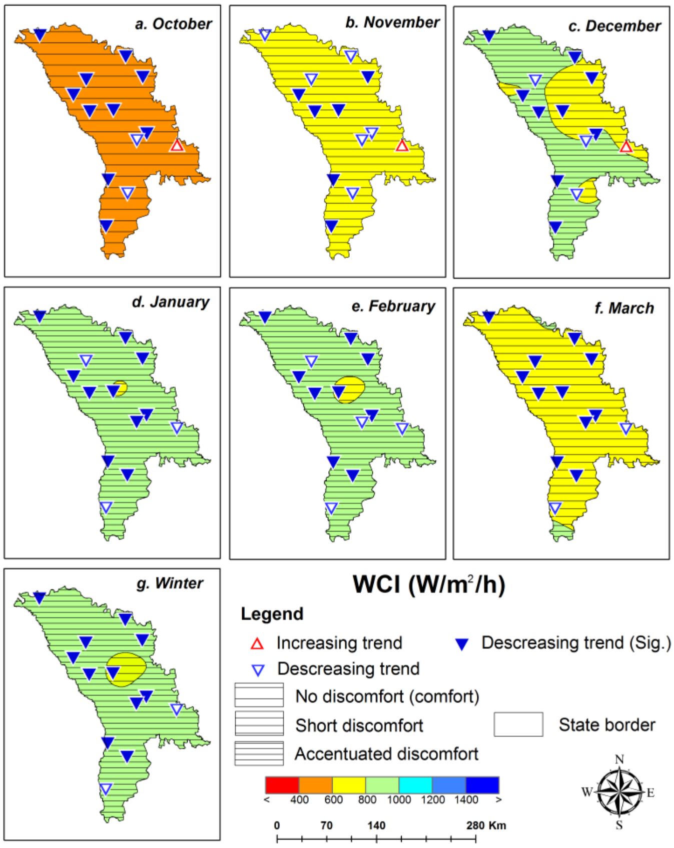
3.2 Spatial distribution and temporal evolution of WCI in the cold semester (October–March)

This period of the year was chosen for analysis because WCI has a real bioclimatic importance only for this interval of the year (especially for winter, DJF) (Figure 2). During October–January, from one month to another, while the WCI values keep increasing, the thermal discomfort increases; during January-March, the opposite pattern is available and the thermal discomfort decreases.

January has the clearest thermal discomfort and risk, as indicated by WCI values between <800 and >960 W/m2/h. For all cold semester months, we observed the same WCI areal distribution. The areas with the highest WCI values are the NNE, WSW and central-western ones (Figure 3). There is a continuous zone with high values of this index linking the northern Moldavian Plateau with the Tigheci Rolling Hills (S) and passing through Bălţi Plain and Prut valley. During the cold season, these areas have some factors (long and frequent thermal inversions in the bottom part of the valleys) that favor low air temperature and high wind speed values. The lowest WCI values are specific for the high and woody areas of the Moldavian Plateau, Nistru valley and central Moldova that are characterized by moderate values of air temperature and wind speed. The same case is for the southern Moldavian Plain and lower Nistru valley where, during the cold season, the moderating Black Sea influences can be felt. A small thermal moderation created by the Stânca-Costeşti Lake also exists, but the low WCI values in the lake area are due to the high Moldavian Plateau barrier function too.

The WCI trends indicate a clear decrease at the yearly and seasonal levels. This index shows an air warming phenomenon in Moldova. Only for autumn we have noticed that the trends are not clearly decreasing or increasing. The Mann-Kendall test results for winter confirm that all WCI time series are decreasing (93 % have a statistically significant decreasing trend). The winter spatial distribution of the WCI trends in Moldova shows the spatial dominance of the decreasing trends, even of the statistically significant decreasing trends. Only in the south-eastern part (Tiraspol) and south-western (Cahul) parts of the territory, the winter WCI permanently has an inconstant behavior (Figure 3).

Figure 3. Spatial distribution and trends of WCI index according to the Mann-Kendall test at the meteorological stations from the Republic of Moldova (1960–2012)



Source: own elaboration

The evolution of WCI during October–March indicate a continuous and statistically significant decreasing trends in the central and western part of Moldova. The other territories alternatively record the same behavior or less significant trends of various signs.

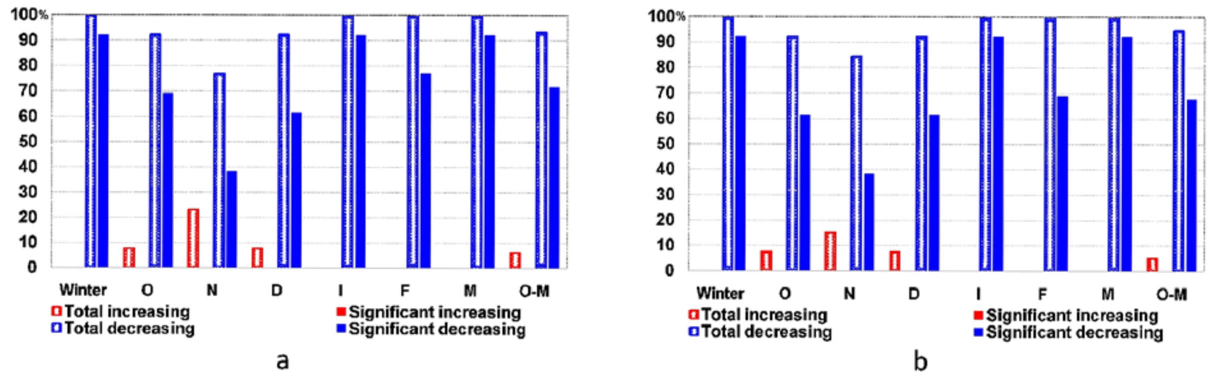
Mann-Kendall and T tests indicate that, during October-March, the positive WCI trend occur, but is not statistically significant (Figure 4a, 4b). November has the highest anomalies of this type, with 15 % increasing trends (of all trends in various points of Moldova).

During the entire October-March interval and especially during the winter months, the percentages of the months when WCI is statistically significant decreasing are high (68-72 % for October-March, 92 % for winter) (Figure 4a, 4b). This fact is a clear sign of warming that occurs in the cold season of the year and is a positive bioclimatic characteristic, taking into consideration that winters are frequently very cold, even frosty, in this part of Europe.

The magnitude of the WCI annual trends during 1960–2012 shows that, in winters, the WCI index dropped every year by 2.36–2.4 W/m^2. The sum for the 53 years indicates that WCI dropped by 125.08–127.2 W/m^2 (Table 3).

During the entire cold semester, the Sen's slope and the slope of the linear regression indicate the decreasing WCI annual values. January is the month when the decreasing WCI values are most relevant (between -3.16 and -3.21 W/m^2). The sum for the 53 years shows that WCI dropped in January by 167.48–170.13 W/m^2.

Figure 4. Percentages of increasing and decreasing trends on different temporal intervals of WCI (Mann-Kendall test - A; t test - b) at the meteorological stations from the Republic of Moldova (1960–2012)



Source: own elaboration

Table 3. WCI (w/m^2/year) mean trend slope in the Republic of Moldova (1960–2012)

	Winter	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Oct.-Mar.
WCI – Sen's slope	-2.36	-1.02	-0.97	-1.40	-3.16	-2.50	-2.20	-1.87
WCI – linear regression	-2.40	-0.86	-0.99	-1.39	-3.21	-2.40	-2.33	-1.86

Source: own elaboration

3.3 Spatial distribution and temporal evolution of the CP index during the warm semester (April–September)

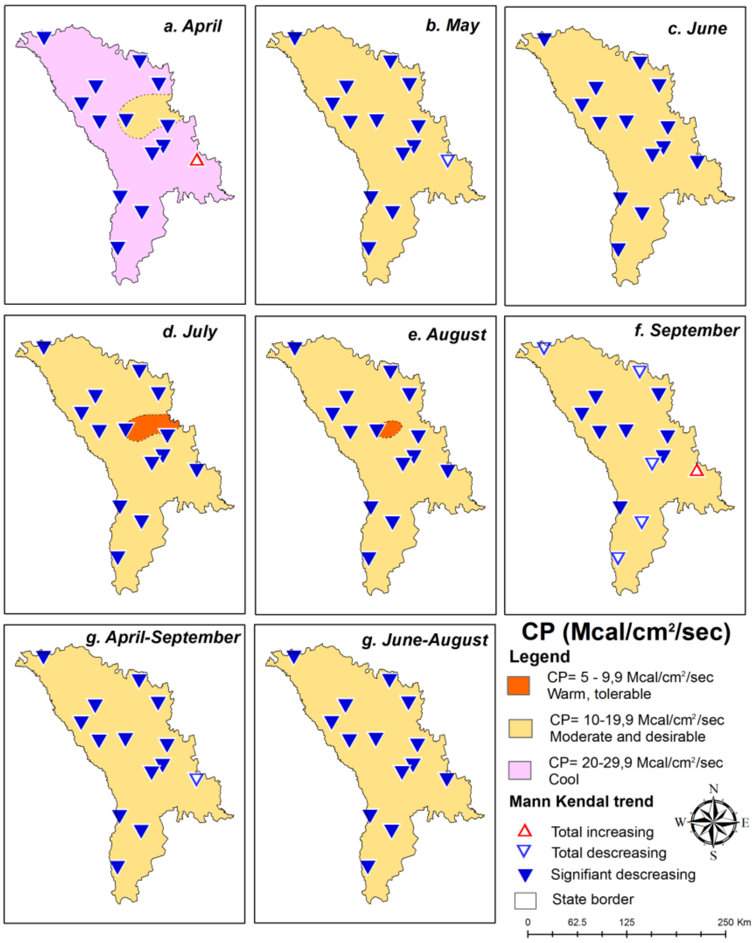
The spatial distribution of CP for any of the analyzed months (April–September) has north-south or west-east territorial differences which cannot be rendered by the selected cartographic method when using the standard thresholds used by other authors. However, it can be observed that, in April, July and August, in the middle valley of Răut, from Telenești and Orhei districts, the CP values are slightly lower (Figure 4) due to the surrounding forested high hills. A more detailed analysis based on mean monthly CP values reveals that, in winter and spring, it shows a general trend of slight growth (about 3 $Mcal/cm^2/sec$ in winter and 1.5–2 $Mcal/cm^2/sec$ in spring). In summer, when the bioclimatic comfort is medium to high, the CP values decrease slightly from north to south (1–1.5 $Mcal/cm^2/sec$).

In July and August, there are areas where CP values fall below the threshold of 9.9 points, indicating that the atmosphere is warm, but the heat is a tolerable one. In autumn, the comfortable states, followed by the moderate states caused by the gradual cooling of the atmosphere are spatially dominant. Between North and South the CP values grow almost imperceptibly (with 1 $Mcal/cm^2/sec$).

From one month to another, the CP differences between distinct weather stations lies within the range of ~10 $Mcal/cm^2/sec$ in the winter months, while the corresponding value of the summer months is 5 Mcal/cm2/sec in the summer months (Figure 5). For the whole territory, these differences are lower (being of maximum 5 Mcal/cm2/sec in the winter and 2 $Mcal/cm^2/sec$ in the summer) (Figure 6). The maximum values of this index in the winter indicates bioclimatic discomfort by cooling and the minimum values of summer indicate a dominant bioclimatic comfort, interrupted by tolerable heat. The high CP values in the southern part of Moldova in winter is caused by the northern wind (called Crivăț), which blows stronger on a plain topographic surface with almost no barrier.

Calculating the CP trends for the cold semester months we observed that in 96.4 % of the months the CP values are decreasing and only in 3.6 % of cases they are increasing. From the months with decreasing trends of CP, 83.3 % have a statistically significant decreasing trend. Therefore, we can state that, in the winter, CP is in a slight decrease.

Figure 4. Spatial distribution and trends of CP index according to the Mann-Kendall test at the meteorological stations from the Republic of Moldova (1960–2012) (the original stations plus Dubăsari weather station)

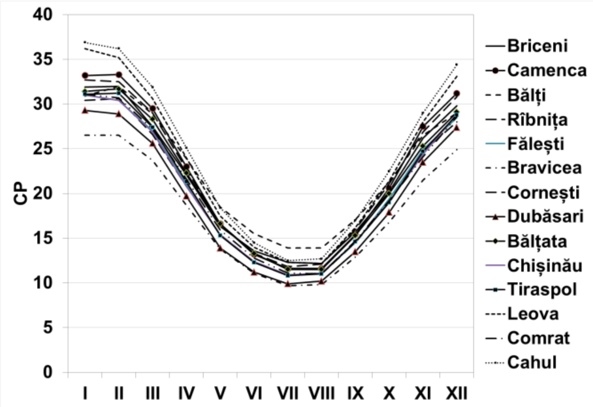


Source: own elaboration

For the months of the warm semester, by using the Mann-Kendall test and the linear regression, we obtained the results shown in Figure 7. July and August are distinct months, with significant decreasing CP trends at all stations. The highest deviation from the mean behavior is recorded in September.

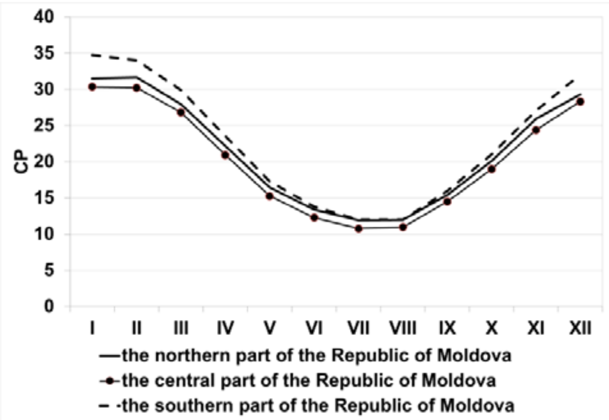
Taking into account the slope of the CP trends (Table 4) we can estimate that, during 1960—2012, the mean monthly values of the analyzed index significantly decreased in July and April (4.3 Mcal/cm^2/sec, according to the linear regression), while the weakest decreasing trend was in September (only 2.2 Mcal/cm^2/sec).

Figure 5. Annual evolution of CP values (Mcal/cm^2/sec)
at the weather stations from Republic of Moldova (1960–2012)



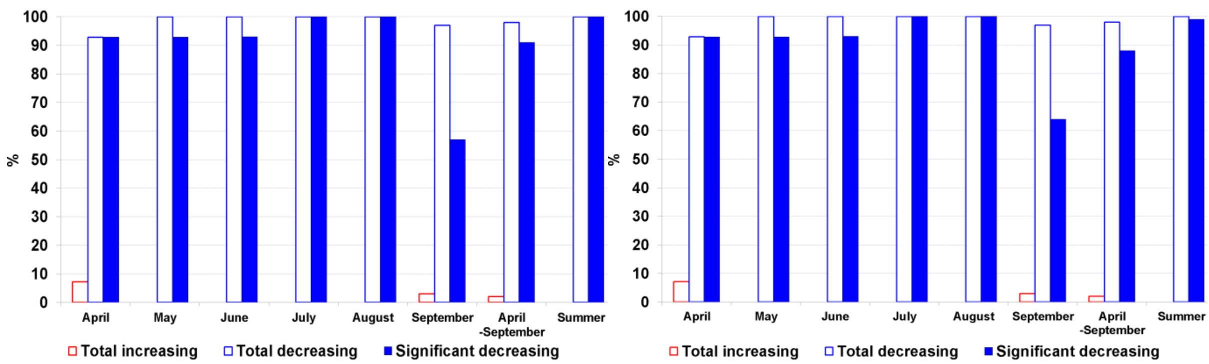
Source: own elaboration

Figure 6. Annual evolution of CP values (Mcal/cm2/sec) in the northern, central and southern third of republic of moldova (1960-2012)



Source: own elaboration

Figure 7. Percentages of increasing and decreasing trends
on different temporal intervals of CP (Mann-Kendall test - a; t test - b)
at the meteorological stations from the Republic of Moldova (1960–2012)



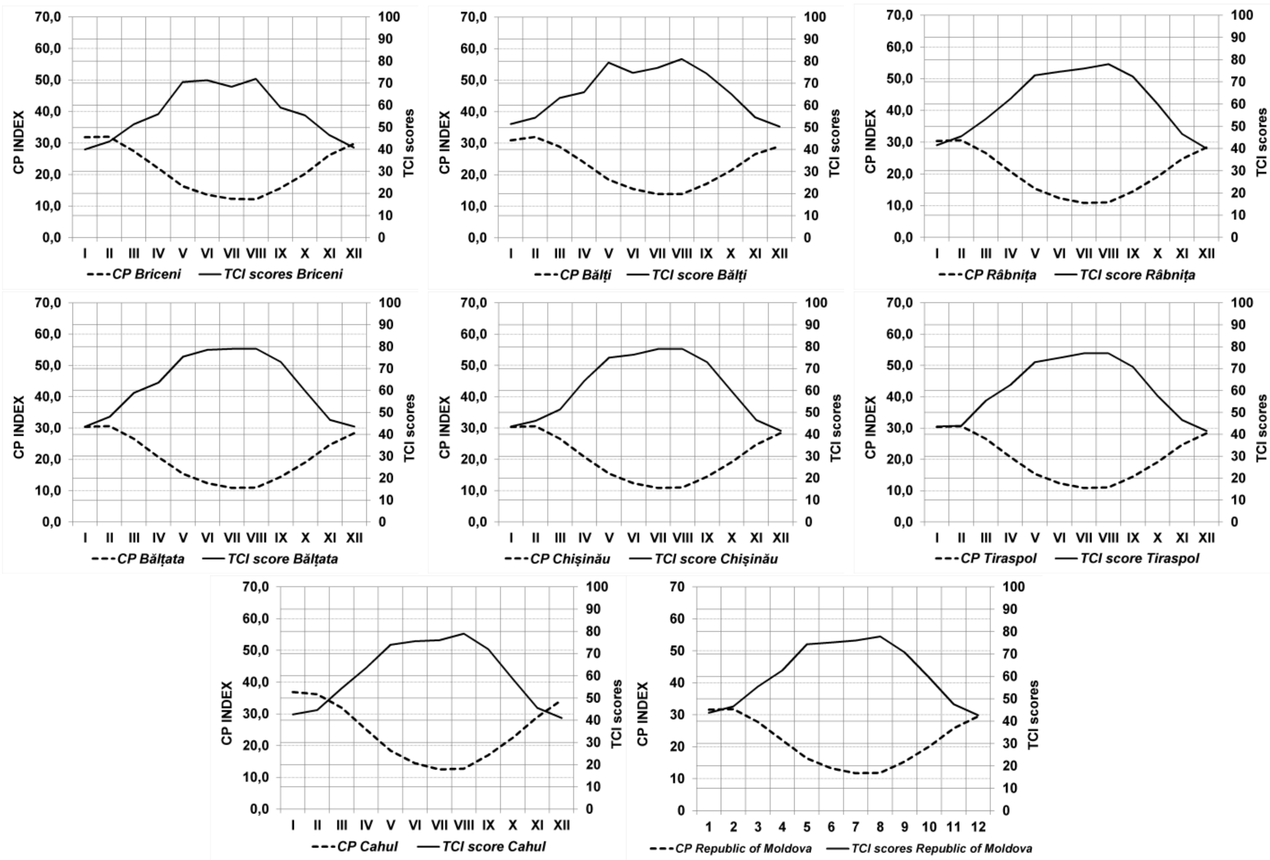
Source: own elaboration

Table 4. CP (Mcal/cm2/sec) mean trend slope
in the Republic of Moldova (1960–2012) and the forecast of the future CP values

	April	May	June	July	August	September
CP – Sen's slope	-0.09	-0.08	-0.07	-0.09	-0.07	-0.05
The magnitude of decreasing	*-3.8*	*-3.4*	*-3.0*	*-3.8*	*-3.0*	*-2.2*
CP forecast values for 2020	21.3	15.8	12.7	11.0	11.3	15.0
CP forecast values for 2030	20.4	15.0	12.0	10.1	10.6	14.5
CP - linear regression	-0.1	-0.09	-0.07	-0.1	-0.09	-0.05
The magnitude of decreasing	*-4.3*	*-3.8*	*-3.0*	*-4.3*	*-3.8*	*-2.2*
CP forecast values for 2020	21.2	15.7	12.7	10.9	11.2	15.0
CP forecast values for 2030	20.0	14.8	12.0	9.9	10.3	14.5

Source: own elaboration

Figure 8. Annual evolution of CP and TCI values
in different locations from Republic of Moldova (1960–2012)



Source: own elaboration

The current trend of CP in the winter and spring months implies that the bioclimatic conditions will improve gradually. On the other side, the current trend of CP in the summer months will lead to a worsening bioclimate. Decreasing current trends of CP values in the autumn anticipate an improvement of the climate peculiarities for tourism.

TCI scores of seven meteorological stations were calculated where all the necessary weather parameters were available. The annual TCI regime, whose development is opposite to that of CP, is shown in Figure 8. The selected stations uniformly cover the studied area.

A summary of the CP and TCI values impact throughout the entire Republic of Moldova is presented in Table 5. We note that from May to September the climate is very good for practicing tourism in this country. In April and October climate provides good conditions for tourism activities in March acceptable, and in the months from November to February less acceptable conditions.

Table 5. Annual evolution of mean monthly values of CP and TCI indices and the bioclimatic and touristic consequences in the Republic of Moldova (1960–2012)

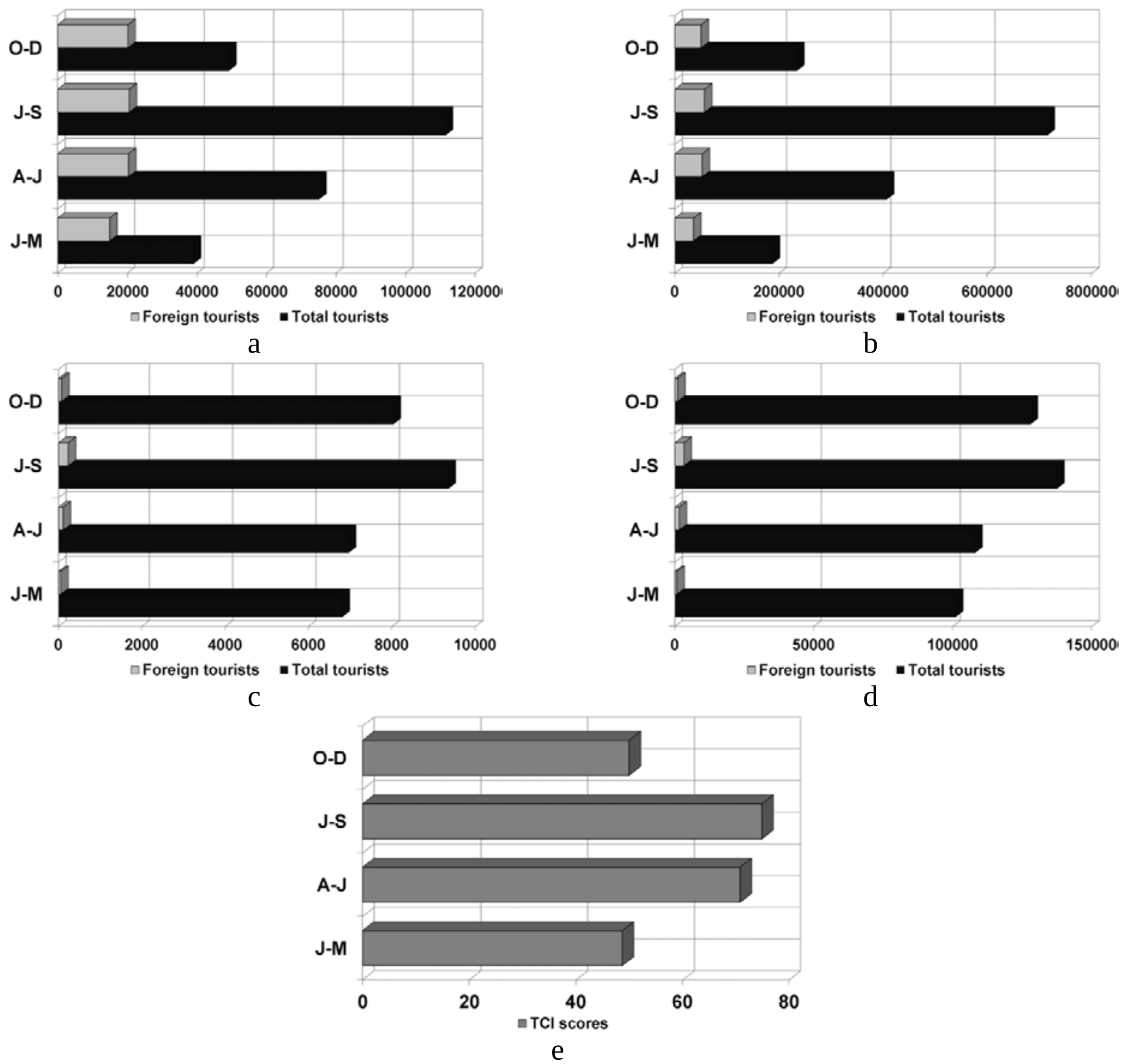
Month	CP (Mcal/ cm^2/s)	Type of bioclimatic stimulation	TCI scores	Description of the TCI values impact on touristic activities	Future evolution of the climate favorability for tourism
I	31.6	Moderate and intense bioclimatic stimulation	43.8	Less acceptable	Positive evolution
II	31.8	Moderate and intense bioclimatic stimulation	46.6	Less acceptable	Positive evolution
III	27.8	Moderate bioclimatic stimulation	55.5	Acceptable	Positive evolution
IV	22.0	Moderate bioclimatic stimulation	62.7	Good	Positive evolution
V	16.4	Bioclimatic comfort from medium to high	74.3	Very good	Positive evolution
VI	13.3	Bioclimatic comfort from medium to high	75.2	Very good	Very positive evolution
VII	11.7	Bioclimatic comfort from medium to high	76.1	Very good	Very positive evolution
VIII	11.9	Bioclimatic comfort from medium to high	77.9	Very good	Very positive evolution
IX	15.4	Bioclimatic comfort from medium to high	70.7	Very good	Positive evolution
X	20.1	Moderate bioclimatic stimulation	59.5	Good	Positive evolution
XI	25.8	Moderate bioclimatic stimulation	47.6	Less acceptable	Positive evolution
XII	29.5	Moderate bioclimatic stimulation	42.7	Less acceptable	Positive evolutions

Source: own elaboration

The bioclimate trends in 1960–2012 (outlined by the WCI and CP indices) indicates an increase in the climate favorability for health tourism, but also for other types of outdoor tourism activities. The future evolution of the qualitative relationship between climate and tourism was forecasted by us through a quantitative analysis of climate elements trend which was included in the TCI calculus by using the 1960-2012 time interval (Table 2). One can observe that, for 8 months per year, the tourism activities will be possible in nature/natural environment without too many climate restrictions.

The annual evolution of weather favorability and climate characteristics influence (together with other factors) the tourist flows in Moldova. The most detailed statistical reporting of tourist flows in Moldova are recorded in the Statistical Yearbook of the Republic of Moldova (NBSRM, 2015) in four quarters of the year: I, II, III and IV.

Figure 9. The annual evolution of: the total number of tourists (2002–2012, a); the total number of overnight stays (2002–2012, b); the total number of tourists in health-care structures (2002–2012, c); the total number of overnight stays in health-care structures (2002–2012, d), TCI (1960–2012, e) (according to the statistical yearbook of the Republic of Moldova (NBSRN, 2015); letters j-d represent months of the year)



Source: own elaboration

Comparing the average quarterly values of the tourists' number and those of the overnight stays with those of TCI, we can see interdependent links between them (Figure 9): the seasonal tourist flows in an average year is imposed by climatic conditions.

4 Discussion

Although in the contemporary society the bioclimatic and climate-tourism analysis is a continuing concern, in the Republic of Moldova this category of analysis did not raised the interest until now. Weather and climate are two pretty important natural factors in choosing a tourist destination (Abegg, 1996). We determined that, in the Republic of Moldova, the average weather condition is favorable for tourism in at least 7 months per year. The tourism industry is particularly sensitive to climate variability (Curtis et al., 2011). Even if the climate variability of Moldova is generally high, between April to October it is attenuated due to the predominance of the anticyclones.

For winter tourism, snow is the main attraction. The Republic of Moldova does not excel in estival or hivernal attractions related to water-sun-beach and, respectively, winter sports, but, with good management, the authorities could develop at a reasonable level these types of tourism. In summer, the climatic resources are favorable for tourism from June until September, while in the winter the favorable period is from December to February. Although the length and quality of the attractive seasons is not ideal, the Republic of Moldova is not the only country facing such problems. Other countries with great touristic vocation have problems in this respect (Scott et al., 2004; Perry, 2001), but take swift action to resolve them.

Maureen et al. (2001) argues that there are powerful climate-tourism conditionings that should be always taken into account by managers and tour operators. For example, in Moldova, the winter touristic traffic is hampered by weather conditions, and in this direction is necessary to make greater efforts. A series of attractions remain blocked in winter or does not fulfill requirements for visitation. In the cities of Republic of Moldova, which have great anthropogenic tourism potential, the winter snow, ice and frost hamper the tourism activity, while, in summer, the heat and pollution often make a suffocating atmosphere.

Republic of Moldova's climatic tourism potential is good and its trend is positive. Forecasts on the climatic-touristic resources made so far have not explicitly targeted the Republic of Moldova, but rather countries or territories with a strongly developed tourism. However, the studies of various authors (Amelung & Viner, 2006; Amelung & Moreno, 2009; Sabine et al., 2010) reveal that the climate change will lead to the improvement of the climatic-touristic resources in Central-Eastern Europe. According to the mentioned studies (and our observations in this study, too) within the 2020—2030 timeframe, the unfavorable conditions during winter will persist. In spring and autumn, the changes will be small but positive. During summer, conditions will improve (TCI scores will rise).

Numerous measures can be implemented in order to increase the touristic activity in the summer (extending the official estival time interval or improving the tourism infrastructure). A challenge in this respect will be linked to the quantity and quality of the local water resources, which are already widely used in agriculture during this season.

The forecasted evolution of the regional and local climate will improve the tourist activities in Republic of Moldova (related to sport, culture, relaxation, business, wine, health etc.), especially during summer, but also during spring and autumn; it will extend the duration of the tourist activities, which will improve their parameters and reduce the existing seasonality. By using the forecasted TCI values, the Republic of Moldova could make some important investments that will improve the tourist infrastructure and offer, having the certainty of obtaining economic benefits on at least the short term. The actual and future planning of tourist activities in Republic of Moldova should take into consideration the forecasted evolution.

5 Conclusions

In the case of the average monthly air temperature, 98.9 % of the analyzed time series have increasing trends and 62.6 % have statistically increasing trends. Concerning MaxT and MinT, increasing trends were also recorded (74.2 % of the time series for MaxT and 59.2 % for MinT had statistically significant increasing trends). This evolution is synchronous with the decrease of the wind speed (84.7 % of the time series with statistically significant negative trend) and the decrease of the relative humidity.

For the cold semester of the year and especially during winter, the climate warming is proved by the WCI decreasing trends. Summed for 53 winters, the WCI index decreased in Moldova by 126.14 W/m^2. In January (for 53 years, too), the WCI average decrease was the most relevant (168.8 W/m^2). These evolutions represent a demonstration of the climate warming in this part of Europe during the cold season.

The spatial distribution and temporal evolution of CP and TCI in the Republic of Moldova indicate that the conditions for the practice of tourism are good and very good from April to October. During the warm semester of the 1960-2012 time interval, the climate recorded a slight warming and it became more dry, less windy and with a sunnier sky, as indicated by the diminishing of CP with values between 4.3 Mcal/cm2/sec (in July and April) and 2.2 $Mcal/cm^2/sec$ (in September). Considering the CP estimates for the years 2020 and 2030, we appreciate that the suitability of climate for tourism will grow in the Republic of Moldova. May has the most favorable trends of the climate-tourism relationship, while July and August tend to evolve into excellent conditions for tourism. Months from April to May (corresponding with the spring holiday and Easter) become increasingly favorable, predictable and constant for the tourism practice. From July to August (summer holiday), the atmosphere may evolve in 2030 at CP values below 10 Mcal/cm^2/sec, in which case the climate will be a warm, but tolerable one, with a low to medium climatic comfort and with excellent conditions for tourism.

Even if in the actual tourism planning of the Republic of Moldova only the economic, social and political reasons are taken into consideration, the climate forcing should be included as an important factor in the official governmental plans for tourism. Taking into account the evolving climate reality, the Moldovan authorities will be able to complete the existing tourism development strategy ("Tourism 2020" strategy) and that will lead to a better management of this area of activity and to the increase of its viability.

Acknowledgments: The authors acknowledge SHS of the Republic of Moldova for providing the meteorological data.

Authorship statement: The authors declare no conflict of interest. Anatolie Puţuntică contributed with regional data. All authors analyzed the data used for this study. Petruţ-Ionel Bistricean made the maps. Dumitru Mihăilă wrote the raw manuscript. Andrei-Emil Briciu has assembled the final manuscript and is the corresponding author.

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