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Spatiotemporal Analysis of Climate Comfort for Tourism Development in Jordan

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Abstract

Tourism is one of the major sectors that influences the gross domestic product of countries. In this study, Thom's Discomfort Index (DI) is used to evaluate the long-term climate comfort of humans in a spatiotemporal context in Jordan. Geospatial models were created to generate the distribution maps of climate variables and the DI for each month of the year. The maps were classified into eight comfort levels. The monthly long-term average of one-day visitors (2005-2018) was used for evaluation of the climate comfort. Results showed clear spatiotemporal variations in climate comfort levels in the country.

The cold sensation was found from December to March in the highlands and the desert plateau, the moderate climate comfort level concentrated in April, May, and September in most of the country, and the hot comfort levels were found in Jordan Valley and the desert plateau in July and August.

Keywords: Thom's Discomfort Index (DI); ecotourism; applied climatology; GIS; human health, Jordan.

التحليل المكاني والزمني للراحة المناخية لتنمية السياحة في الأردن

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ملخّص

تعد السياحة واحدة من القطاعات الرئيسية التي تؤثر على الناتج المحلي الإجمالي للبلدان. في هذه الدراسة، تم استخدام مؤشر Thom's Discomfort Index (DI) لقياس الراحة لتقييم الراحة المناخية طويلة الأجل على الإنسان في السياق الزمني والمكاني في الأردن. تم إنشاء نماذج جغرافية مكانية لإنشاء خرائط توزيع المتغيرات المناخية وخرائط الراحة المناخية لكل شهر من السنة. تم تصنيف الخرائط إلى ثمانية مستويات من الراحة كما تم استخدام المتوسط الشهري طويل الأجل للزوار ليوم واحد خلال الفترة (2005-2018) لتقييم نتائج الراحة المناخية. وأظهرت النتائج اختلافات مكانية وزمنية واضحة في مستويات الراحة المناخية في منطقة الدراسة. حيث تم تسجيل مستوى الإحساس بالبرد من كانون أول إلى آذار في المرتفعات والهضبة الصحراوية فيما تركز مستوى الراحة المناخية المعتدل في نيسان وأيار وأيلول في معظم أنحاء منطق الدولة، وتم تسجيل مستويات الراحة الحارّة في وادي الأردن وهضبة البادية الصحراوية في تموز وآب من العام

الكلمات الدالة: مؤشر ثوم للراحة، المناخ التطبيقي، نظم المعلومات الجغرافية، الصحة البشرية، الأردن

1. Introduction

Climate is one of the most aspects that affect , environment, population, socioeconomic and human activities including tourism (Michailido et al., 2016). In this context, thermal components of climate such as temperature, humidity, wind, and thermal radiation are critical as they could affect the human energy balance and cause thermal discomfort which in-turn might negatively affect the human physical and mental performance (Choi and Yeom 2019; Li et al. 2018; Mijani et al. 2019). Several studies stated that the out-door thermal comfort sensation of people is influenced by climate. The heterogeneity and distribution of climate conditions and characteristics cause a spatiotemporal variation of thermal comfort sensation (Song and Wu 2018; Mushore et al. 2017). Yet, thermal comfort varies between individuals due to their age, weight, health conditions and sensitivity to high temperature. As a result, a location and period might show different thermal comfort status from a group to other.

Hence, it is very important to monitor the spatiotemporal patterns of thermal comfort and study their effects on tourism. This could be measured by the sole use of individual climate parameter. However, this might not provide an adequate indication of thermal comfort due to the human bodies' variations. Therefore, climatological-based thermal comfort indices were developed as mathematical operations to evaluate the thermal conditions in more physiological significant manner. These indices represent the combined effect of thermal sensation including all climate relevant variables that affect human comfort (Hirashima et al. 2018). Currently, many combinations for climate parameters are used. The wide range of these indices provide numerical evaluation in the form of categorical levels of human thermal comfort conditions according to assessment scales (Potchter et al. 2018; Mohd and Ujang 2016). Generally, there are three major factors affecting outdoor thermal sensation of people: temperature (°C), relative humidity (%), and wind speed (m/min). Studies indicated that the ranges of these three factors should be between 18°C and 22 °C, 20% to 60 %, and 3.1 m/min to 13.7 m/min, respectively, to satisfy the majority of people at given clothing status and activity (Smith and Parmenter 2013; Roy et al. 2011).

In the context of tourism, climate conditions have significant role as they could determine the timing, duration, destination, and type of tourism activities (de Freitas 2017). Despite the considerable development in entertainment technologies, people mostly prefer to move to places where the elements of climatic comfort are suitable or favorable especially for out-door activities. Therefore, more attention to climate conditions is necessary for tourism planning and development (Mowforth and Munt 2008). Generally, tourism destinations and activities are affected by climatic fluctuations in several ways. For example, tourist areas might be exposed to extreme heat waves, extreme cold, drought, storms or heavy rain that may affect the comfort, safety, and services in these areas (Roshan, Yousefi, and Fitchett 2016). Therefore, it is very important to understand the spatial and temporal distribution of climatic conditions of tourism activities in order to plan or invest in this sector (Timothy 2018). Several studies were conducted to explore the climate comfort for tourism in Jordan, for example, et al. (2018) applied the tourism climatic index (TCI) to specify the preferable months for tourism in Jordan regions using a neural network to analyze several parameters of meteorologist (raining, temperature, speed of wind, moisture, sun radiation) by analyzing and specify and equiponderate it with THI index. Their results showed that the finest time of the year to entice tourists is " April" whereas July to August were not convenient for tourism because of high temperature. Al-Shorman and Magablih (2006) proposed a tourism index (TI) for the country of Jordan based on five factors that determine how international tourists plan their tours (climate, the development, accessibility, popularity, and proximity of the site). Each of these factors was interpolated using data collected from 22 tourist sites using GIS. The results show that Jordan is suitable for tourism any time of the year despite the location (TI = 50–85%), which stands for "marginal" to "very good" tourism activity according to their classification. Bani Domi and Al-shorman utilized GIS to create tourism climate indices for Jordan on a monthly scale. The study depends on a 10-year meteorological data (1993-2002) from 16 meteorological stations distributed all over the country. The tourism climate index formula was used. The results showed that there are significant monthly variations of the TIC's, however, they still assert that Jordan is suitable for tourism at any time of the year. This study aims to present the first stage of the proceeding long-term spatiotemporal outdoor thermal comfort maps for the whole geographic extent of Jordan with more concentration on the main visitors'attractive areas in the country. These maps would be significantly used as tools for developing tourism strategies and plans in Jordan. Note that, the overall point of view in this article was to identify other potential regions in Jordan for ecotourism including the known ecological regions.

2. Materials and Methods

2.1 Study Area

Jordan (Figure 1) is located between (29 and 32 North, and 34 and 39 East). It consists of three geographical landscapes: Jordan Valley, the highlands, and the desert plateau. Which are extended from the north to the south. Jordan climate is characterized with a combination of the Mediterranean climate in the highlands, above 700 meters above sea level, where temperate summers and cold winters dominate, the subtropical climate in Jordan Valley in the areas below 300 meters above sea level, in which hot summers and warm winters exist and the desert climate in the desert plateau where elevation is between 300 to 700 meters above sea level with hot summers and cold winters (Hazaymeh and Hassan 2017).

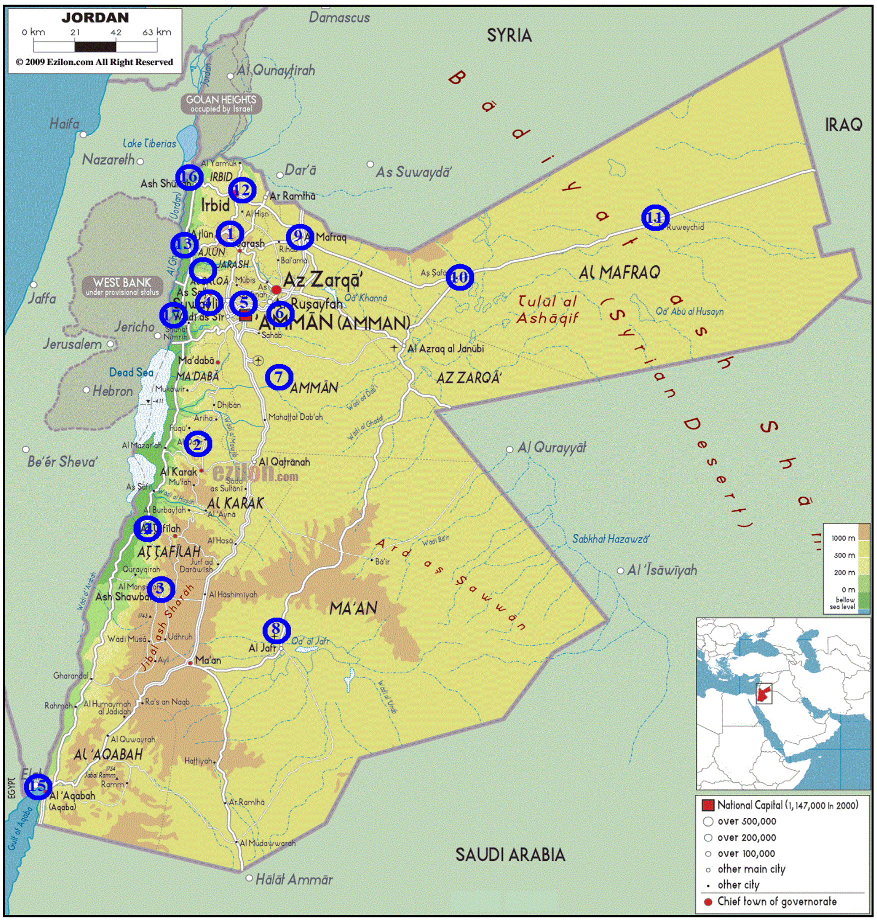


Figure 1: Topographic map of Jordan and the spatial distribution of 17 climate stations used in the study. Source: After www.gif-map.com under the Creative Commons Attribution-ShareAlike 3.0 Licence.

2.2 Climate Data and its Pre-processing

Here, three climate variables including air temperature (in Celsius) and relative humidity (%) obtained from the Jordanian Meteorological Department were used in the form of long-term average (1985 – 2018) collected from 17 climate stations covering the country. The data included information about the geographic location, elevation, landscape, and the daily records of the three climate variables in a paper sheet. The 17 climatic stations (Table 1) were selected to (i) ensure geospatial representation of the three geographical landscapes in Jordan, (ii) consider the effects of geographical variation on climate variables, and (iii) measure the availability of the long-term historical records over 30 years. After that, all data were converted into digital format as MS-Excel sheets, then stored with their official names. These data were then revised, checked, verified in terms of their quality and reliability; then compared with other sources. Following, the monthly long-term averages of the variables of each station were calculated. The coordinating system of the stations was converted to the UTM Zone 36N. Finally, a map showing the spatial distribution of these stations was generated as Figure (1) shows.

Table 1. Spatial characteristics of 17 climatic stations used in the study.

Station	Longitude	Latitude	Elevation (m)	Landscape
Ras Munif	35.75	32.36	1150	
Alrabba	35.74	31.26	920	
Shobak	35.57	30.52	1320	
Salt	35.44	32.2	796	Highlands
Univ. of Jordan	35.53	32.1	980	
Irbid	35.81	32.56	686	
Marka Airport	35.59	31.59	781	
Queen Alia Airport	35.59	31.43	722	
Jafr	36.09	30 .17	865	
Almafraq	36.15	32.22	686	Desert Plateau
Safawi	38.08	32.12	674.2	
Rowaished	38.12	32.30	683	
Deir Alla	35.37	32.13	-224	
Gore Alsafi	35.28	31.2	-350	
Aqaba	35.0	29.33	15	The Jordan Valley
Bakoora	35.37	32.38	-170	
Wadi Al Rayan	35.35	32.24	-200	

2.3. Methodology

A schematic estimating diagram of the spatiotemporal distribution of climate comfort condition in Jordan is shown in Figure (2). It consisted of three main steps: (i) generating the spatial distribution maps of climate variables; (ii) calculating Thom's Discomfort Index (DI) and its geospatial model; and (iii) evaluating the climate comfort maps.

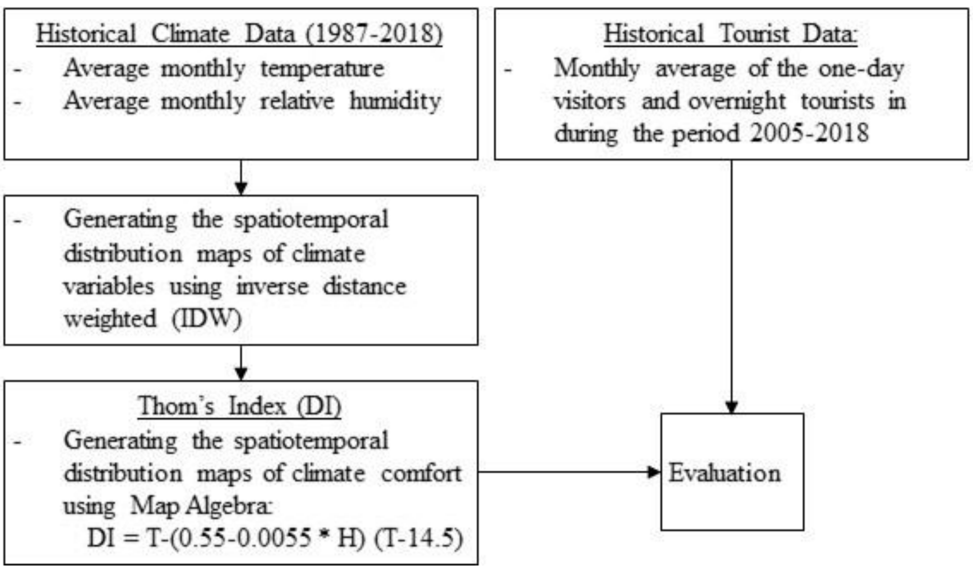


Figure 2: A schematic diagram for estimating the spatiotemporal distribution of climate comfort condition in Jordan by using Thom's Index.

2.3.1 Generating the spatial distribution maps of climate variables

To estimate the spatiotemporal distribution of climate comfort conditions in Jordan, the three climate variables influencing the thermal sensation were first converted to maps showing their spatial distribution in a continuous form (i.e., raster format) using geostatistical interpolation technique. In this study, due to the limited number of climate stations, it is opted to interpolate the values of climate variables for unsampled locations using Inverse Distance Weighted (IDW) interpolation technique. In this context, the protocol of the following four steps was followed: (i) each climate station was given a local descending weight that increases relatively to the proximity of the station location. (ii) the closer unsampled locations to the station location were given greater weighting value comparing to the outermost locations, (iii) the values of each variable of the climate stations within a specific radius were used to estimate the total weighted average value for unsampled locations, and (iv), the estimated value of unsampled locations were obtained from a linear combination of the surrounding locations using equation (1) (Bartier and Keller, 1996)

$$\hat{v}_i = \frac{\sum_{i=1}^{n} \frac{1}{d^{p}{}_{i}} v_i}{\sum_{i=1}^{n} \frac{1}{d^{p}{}_{i}}}, \qquad (1)$$

Where Vi is the value to be estimated, vi is the known values and dp i…, dp n are distances from n data points to the power of p of the point to be estimated. Note that IDW was selected due to: (i) its suitability when the variables of interest are having spatial variation in the study area such as the case of climate data, (ii) it did not extrapolate the values of variables of interest, such that, all interpolated values are within the range of the data points, (iii) it is suitable when the sample locations are limited, and (iv) the ability to control the number of sampling locations and radius of the search window is available (Wong 2017; Borges et al. 2016; Hsu, Mavrogianni, and Hamilton 2017; Pellicone et al. 2018).

2.3.2 Calculating Thom's Discomfort Index (DI) and its geospatial model

In this study, Thom's Discomfort Index (DI) was selected to measure the climate comfort conditions in relation to tourism activates in Jordan. DI is suitable for evaluating the climatic comfort conditions in regions that have various spatial and temporal climate conditions such as Jordan. It is one of the most common bioclimatic indices used for outdoor thermal comfort applications (Polydoros and Cartalis, 2014) It provides an easily evaluated measure describing the degree of discomfort at various combinations of temperature and humidity. This bioclimatic index is based on a simple empirical formula that provides proper and general evaluation of the discomfort conditions at a given location where the temperature and relative humidity is spatially variable (Adegoke and Dombo 2019).

It classifies the human comfort by determining the levels of comfort under certain climatic conditions depending on temperature and relative humidity conditions as shown in Table (2) (Musa, 1979). The index is mathematically calculated using Equation (2) (Thom 1959):

$$DI = T-(0.55-0.0055 * H) (T-14.5) \qquad (2)$$

Where T is long term average temperature (C□), and H is relative humidity. DI is divided into eight comfort/discomfort levels as shown in Table (2). The classes show that the human discomfort increases as the DI values increases. The index values lower than 10 indicate that serious cold discomfort feeling is experienced by people and values above 27 are considered as serious hot discomfort level.

A geospatial model was built within GIS environment to generate the spatial distribution maps of DI climate comfort index. The model was applied to all months of the year using IDW technique within GIS. Then, the generated maps were classified into eight classes according to Thom's classification. Noting that the processing environment was set to covering the whole geographical extent of Jordan including the known ecological regions. As we aimed to evaluate the climate comfort conditions in the whole country and to define the other potential regions for ecotourism industry development.

Table 2. Climate comfort levels as per Thom's classification of regions with varying climate conditions throughout the year.

DI value	Symbol	Comfort Level
< 10	C-	Very cold discomfort.
10 – 15	C	Moderate cold discomfort
15 – 18	P-	moderate comfort
18 – 21	P	comfort
21 – 24	P+	heat-inclined comfort
24 – 27	H	heat-inclined discomfort
27 – 29	H +	extreme heat discomfort
> 29	H + +	significant and serious health stress

2.3.3 Evaluation of climate comfort maps

To evaluate the levels of DI climate comfort maps, the average of monthly long-term one-day visitors and overnight tourists in Jordan during the period of 2005-2018 could be used as an indicator of a location for being attracted for ecotourism. In this study, due to the limitation of data availability, it was opted to use the available information and records from the ministry of tourism in Jordan as a proxy to determine the levels of thermal comfort for each month and its suitability for tourism according to climatic comfort levels (Table 1 and Figure 3). These records were obtained from Jordanian ministry of tourism and the department of statistics for the period of 2005-2018 which then calculated into monthly long-term averages over this period.

Table 3. Monthly long-term average of one-day visitors and overnight tourists in Jordan during the period of 2005-2018

Month	Long-term average	Long-term average minus expatriate
Jan.	405778	405778
Feb.	362686	362686
Mar.	438594	438594
Apr.	505383	505383
May.	452554	452554
Jun.	516835	516835
Jul.	679366	468201
Aug.	720458	509293
Sep.	553574	553574
Oct.	485219	485219
Nov.	435147	435147
Dec.	423624	423624

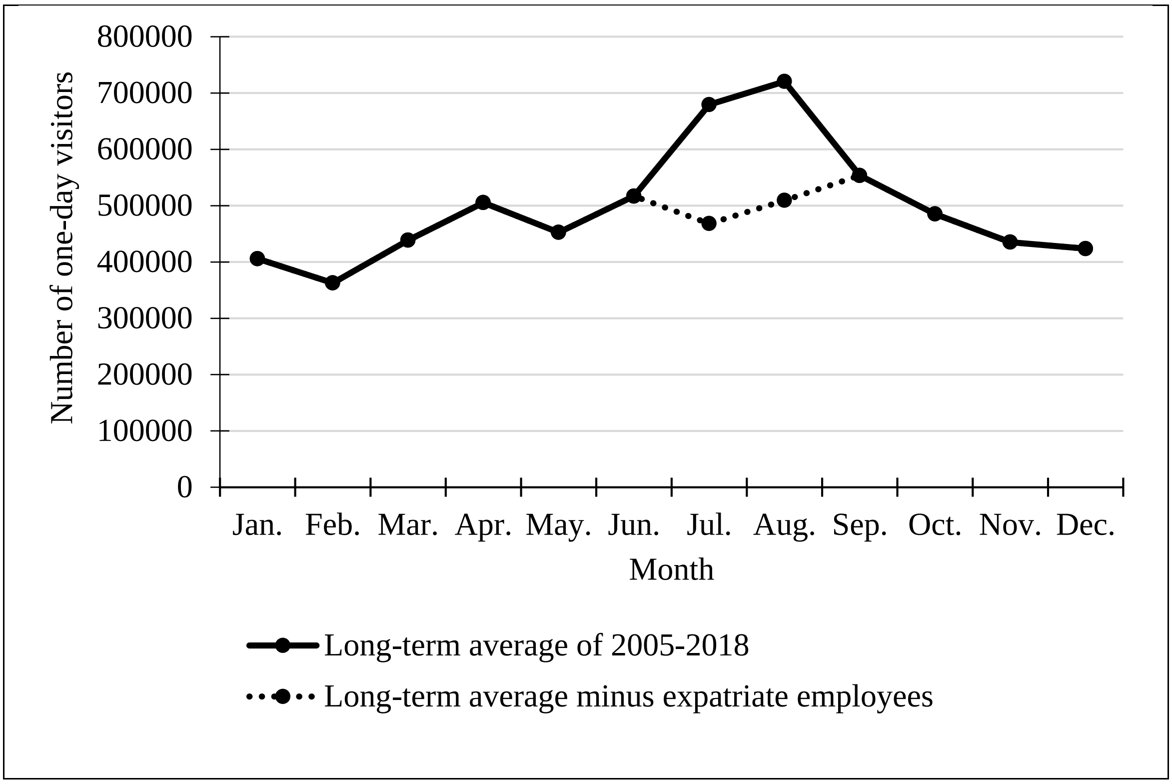


Figure 3: Monthly long-term average of one-day visitors and overnight tourists in Jordan during the period of 2005-2018.

4. Results and Discussion

4.1 Analysis of monthly spatial distribution maps of DI climatic comfort

Figure (4) shows the monthly spatial distribution maps of the Thom's Discomfort Index. The results of the long-term analysis of January (Figure 4a) showed that the values of DI were approximately in the range of 5.9 -16.3. These values represent the three levels of DI such as (i) level C- in the highlands of Ajloun, Ras Munif, Shobak, and Sharah mountains; (ii) level C in the areas of northeastern, central, and southern Badia; and (iii) level P- in the lowland areas of the northern and central Jordan Valley, the Dead Sea, and Aqaba in the southwest of the country. As such, the sense of coldness is common and dominate in most areas of Jordan during this month which has negative impacts on ecotourism and reduces the internal and external tourist movement. This could be explained by the average number of one-day visitors and overnight tourists during the period of 2005-2018 which was 405778 tourists only comparing to the other months as shown in Table 1. In February (Figure 4b) a slight rise of approximately one degree in DI scale to reach level P- (i.e., 6.9 -17.5) that covered more geographic areas. The average number of one-day visitors and overnight tourists was somehow like that of January with approximately 362686 tourists in all tourist areas in Jordan.

The results showed a continues rise in DI comfort levels to reach level P in March (Figure 4c). The geographic areas covered by the relative comfort levels (i.e., P- and P) were larger compared to February. The values of DI were between 9.3 and 18.7 during this month. This could show that these areas are moving towards moderation season. Therefore, the tourist can feel higher levels of comfort in these areas. Noting that most of these areas are located in lowlands in Jordan Valley, Aqaba, and the Dead Sea. However, major concern should be taken in consideration for the possibility of the formation of thunderstorms and flash floods resulting from the atmospheric disturbances that often occur in March in these areas. The records of one-day visitors and overnight tourists showed noticeable increase of visitors to reach 438594 in March which might be attributed to the increase of geographic extent of comfort levels (P) and (P-). In April (Figure 4d), all geographical regions experienced significant improvement in the DI comfort levels, with values range from 13.8 to 21.3. This range covers levels (P) in Jordan Valley and the Badia, and (P+) in the highlands which make these areas attractive destinations for tourists and visitors. The average number of one-day visitors and overnight tourists was 505383 in all tourist areas in Jordan with an approximate increase of 13.2% comparing with March. A reason for this increase might be the improvement in the sensation level of climate comfort. In May (Figure 4e), the (P) level (i.e., 15.6 - 25.1) dominated the majority of Jordan, while levels (P-) and (P+) had minimally covered some areas in the highlands such as the Sharah and Ajloun mountains; and in Jordan Valley which might be an indicator that May would be the best for ecotourism in Jordan. However, the number of one-day visitors and overnight tourists in this month had decreased comparing to April by approximately -10.5% in all tourist areas in Jordan. Such decline in the number might be attributed to the coincidence of the final exams in schools and universities in Jordan, as students represent approximately 23% of the Jordanian population (Department of Statistics, 2018).

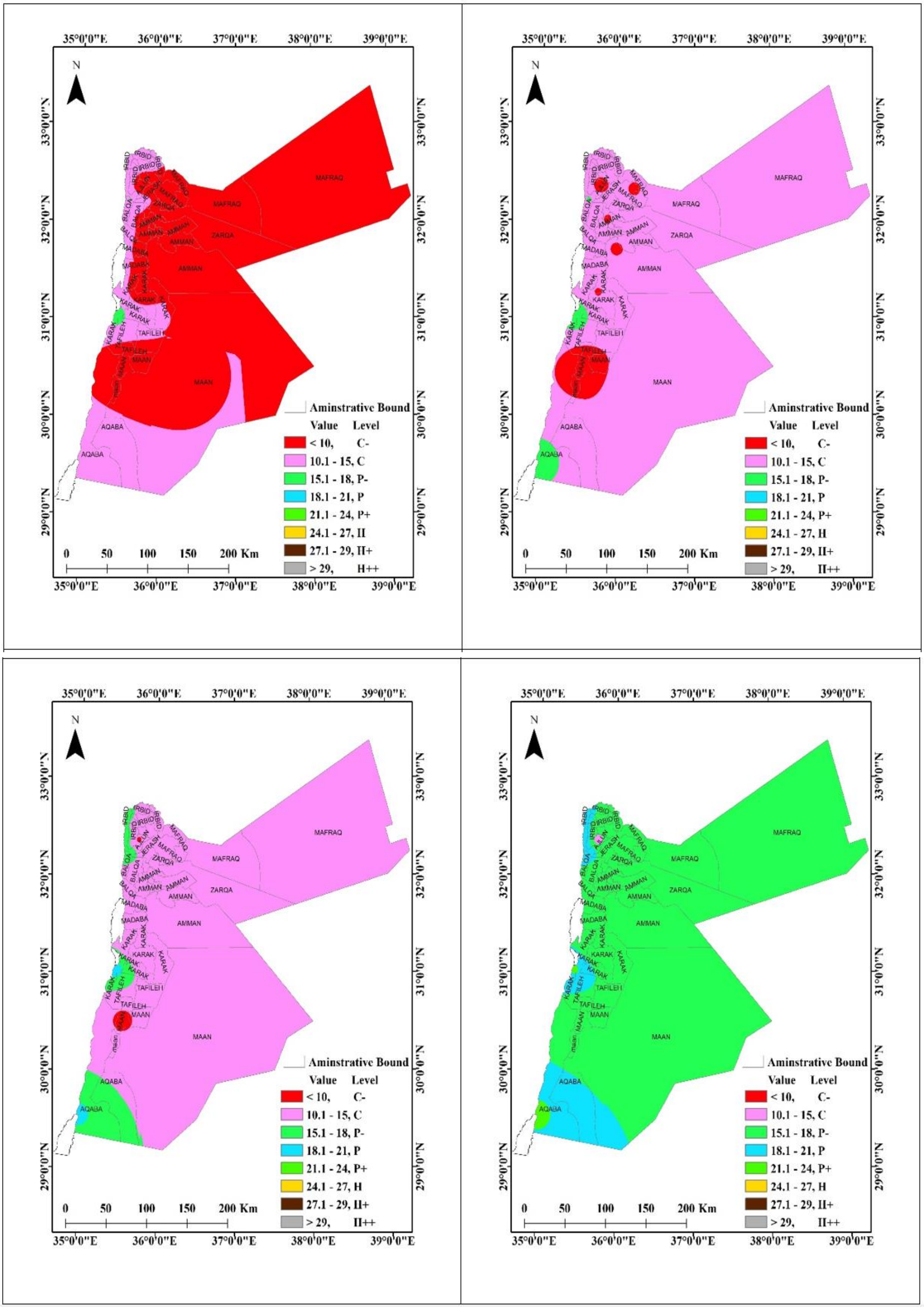
In June (Figure 4f), the values of comfort levels have risen by approximately two degrees (17.8 - 26.1) comparing with May which points out that the values tend towards the levels of heat discomfort (H) in some areas such as the areas in the northern and central lowlands in Jordan Valley and Aqaba. Meanwhile, the values of level (P-) shrank to cover small areas in Ajloun highlands and the Sharah mountains while the other comfort levels (P) and (P+) covered the remaining areas of Jordan. According to the Ministry of Tourism, the long-term average of one-day visitors and overnight tourists in this month was (516835) in all tourist areas in Jordan. The DI values in July (Figure 4g) range between (19.2 & 28) which is represented by levels (P) in Ajloun Balqa highlands, and the Sharah mountains, and (P+) in Madaba, Amman and Zarqa. Therefore, these regions would be suitable to have more tourists comparing with other months. which might be explained by the noticeable increase in the long-tern average of one-day visitors and overnight tourists (i.e.,679366 tourist) during this month comparing with the previous months in all tourist areas in Jordan. This increase might be due to the sense of climatic comfort. In addition to, it is also associated with the period of public holidays of schools and universities; and the return of Jordanian expatriates and the arrival of international tourists who like to spend their summer vacations and holidays in such environment. On the other hand, the areas of Badia in the north and south of Jordan had higher levels of heat discomfort such as (H) and (H+) in some locations which may push them to be unattractive for ecotourism. In August (Figure 4h), the highlands and the central and southeastern Badia region had experienced the comfort levels (P) and (P +), respectively which increased the potentiality of these regions to be suitable destinations for ecotourism, especially for activities such as hiking and desert adventures. August was found to be the highest month of recorded one-day visitors and overnight tourists with (720458 tourists). This might be due to the climatic comfort factors in Jordan. The other areas in the lowlands and Aqaba, besides the eastern and northeastern Badia, had witnessed high levels of discomfort (H, H+, and H++) which showed possible serious negative impact on human health. As a result, ecotourism during this month in such regions might not be suitable

September (Figure 4i) witnessed moderate levels of climate comfort such as levels (P-, P, P+, and H). The values of DI levels in this month range from 17.6 to 27. These comfort levels are mostly favorable for ecotourism activities and have covered most parts of Jordan. This is common in September as one of autumn's moderate months in Jordan that makes it suitable for tourism activities in most parts of the country. Although September is climatologically comfort for ecotourism, the long-term average of one-day visitors and overnight tourists declined by approximately -23.1% comparing with July and August. This might be explained by the end of holidays period of schools and universities, and the return of the Jordanian expatriates to their works outside Jordan. The moderate DI comfort levels (P-, P, and P+) in the range of 15 to 24.2 were the dominating ones in October in major parts of Jordan (Fig. 4j) whereas small areas in the highlands and lowlands have witnessed the DI levels (C) and (H), respectively. The average number of one-day visitors and overnight tourists for this month was approximately (485219) in all tourist areas of Jordan. This decline in the number of visitors and tourists might be due to the lack of enough climate comfort information and bulletins about this month to guide visitors and tourists to these locations. In November (Figure 4k) the levels of DI comfort were noticeably declined to reach the values of 10.6 – 21, which represent the levels of (C) in Ajloun highlands and the Sharah Mountains, and the (P) in the southern and northern parts of Jordan Valley and Aqaba whereas the level of (P-) appeared in the northern, north-eastern , south-eastern and central Badia. Accordingly, the regions of Jordan Valley and Badia could be suitable for ecotourism during this month as they have moderate climatic comfort levels. However, they need sincere work to provide adequate infrastructure to setup economic projects and tourist investments to increase the number of visitors and tourists and to promote the economy in these regions.

According to the Jordanian ministry of tourism, the long-term average of one-day visitors and overnight tourists was (435147) during the period of 2005-2018 in all tourist areas in Jordan. Finally, the DI values returned back to the levels of cold discomfort in December (Fig. 4l). The DI levels of (C-) and (C) were dominating the majority of Jordan except for the northern and southern Jordan Valley and Aqaba where (P-) level was registered which would be suitable for ecotourism during winter in Jordan. According to the Jordanian Ministry of Tourism the average long-term number of one-day visitors and overnight tourists was (423624) for the period of 2005-2018 in all tourist areas in Jordan. Table (4) shows a summary of the monthly comfort levels according to Thom classification for each climatic station used in this study.

Table 4. Summary of the monthly climate comfort levels according to Thom classification for each climatic station used in this study

St.	Elevation	Jan.		Feb.		March		April		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
		DI	Level	DI	Level	DI	Level	DI	Level	DI	Level	DI	Level	DI	Level	DI	Level	DI	Level	DI	Level	DI	Level	DI	Level
Baqura	170-	13.6	C	14.2	C	16.2	P-	19.8	P	23.2	P+	25.7	H	27.3	H+	27.3	H+	25.8	H	23.6	P+	19.3	P	15.0	P-
Rwaished	683.0	9.6	C-	11.3	C	14.4	C	17.8	P-	20.7	P	23.2	P+	24.7	H	24.7	H	22.8	P+	19.8	P	14.6	C	10.8	C
Irbid	616.0	10.0	C	11.1	C	13.3	C	16.4	P-	19.8	P	21.8	P+	22.9	P+	23.0	P+	22.1	P+	19.9	P	15.4	P-	11.5	C
Wadi Rayan	200-	13.5	C	14.4	C	17.1	P-	19.9	P	22.8	P+	25.5	H	27.6	H+	28.2	H+	26.4	H	23.7	P+	18.6	P	14.7	C
Ras Muneef	1150.0	6.7	C-	7.6	C-	9.5	C-	13.8	C	17.1	P-	19.0	P	20.4	P	20.5	P	19.6	P	16.8	P-	13.0	C	8.6	C-
Mafraq	686.0	8.6	C-	9.8	C-	12.4	C	16.0	P-	19.0	P	21.0	P+	26.7	H	22.2	P+	21.1	P+	18.7	P	13.9	C	9.8	C-
Safawi	674.0	9.5	C-	11.0	C	13.9	C	17.5	P-	20.8	P+	23.1	P+	24.4	H	29.9	H++	23.0	H	20.1	P	14.8	C	10.8	C
Der Alla	244-	15.1	P-	15.4	P-	17.5	P-	21.0	P	23.5	P+	25.6	H	27.2	H+	27.3	H+	26.2	H	24.4	H	20.4	P	16.5	P-
Salt	915.0	9.9	C-	10.4	C	13.1	C	15.8	P-	18.9	P	20.7	P	21.9	P+	21.8	P+	20.8	P	19.4	P	15.2	P-	11.1	C
Jordan Uni.	980.0	8.8	C-	9.6	C-	12.6	C	15.3	P-	18.2	P	20.2	P	22.0	P+	21.7	P+	20.5	P	18.4	P	14.3	C	10.7	C
Amman Airport	780.0	9.9	C-	11.0	C	13.4	C	16.4	P-	19.7	P	21.7	P+	22.9	P+	22.9	P+	21.8	P+	19.9	P	15.1	C	11.1	C
Queen Alaia Airport	722.0	8.6	C-	9.8	C-	12.0	C	15.5	P-	18.6	P	20.4	P	21.4	P+	21.3	P+	20.5	P	18.4	P	14.0	C	9.8	C-
Rabbah	920.0	9.0	C-	9.9	C-	11.7	C	15.2	P-	17.9	P	20.0	P	21.4	P+	21.2	P+	20.4	P	18.3	P	14.2	C	10.3	C
Ghor Safi	350-	16.3	P-	17.5	P-	18.7	P	21.2	P+	25.1	H	26.1	H	28.0	H+	28.1	H+	27.0	H	24.2	H	21.0	P+	17.5	P-
Shobak	1365.0	5.9	C-	6.9	C-	9.3	C-	15.0	P-	15.6	P-	17.8	P-	19.2	P	19.3	P	17.6	P-	15.0	P-	10.6	C	7.1	C-
Jafer	865.0	9.7	C-	11.5	C	14.1	C	17.6	P-	20.7	P	22.7	P+	23.8	P+	23.9	P+	22.2	P+	19.9	P	14.9	C	11.0	C
Aqaba	51.0	14.8	C	15.8	P-	18.2	P	21.3	P+	23.9	P+	25.7	H	26.8	H	26.8	H	25.3	H	23.1	P+	19.5	P	16.0	P-


Aminstrative Bound
Value Level
< 10, C-
10.1 - 15, C
15.1 - 18, P-
18.1 - 21, P
21.1 - 24, P+
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27.1 - 29, H+
> 29, H++
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MADABA
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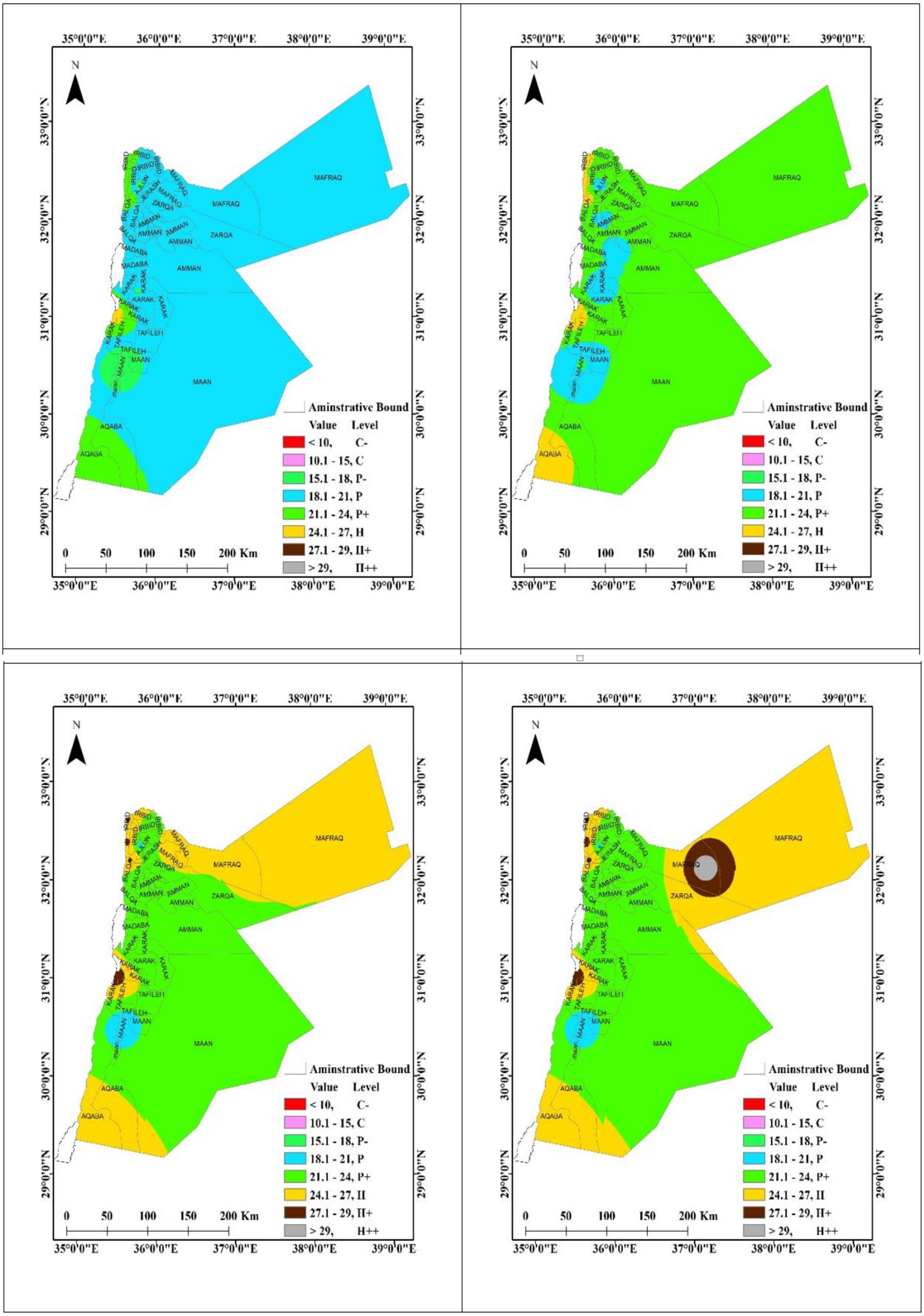
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MAFRAQ
BALQA
ZARQA
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Aminstrative Bound
Value Level
< 10, C-
10.1 - 15, C
15.1 - 18, P-
18.1 - 21, P
21.1 - 24, P+
24.1 - 27, H
27.1 - 29, H+
> 29, H++

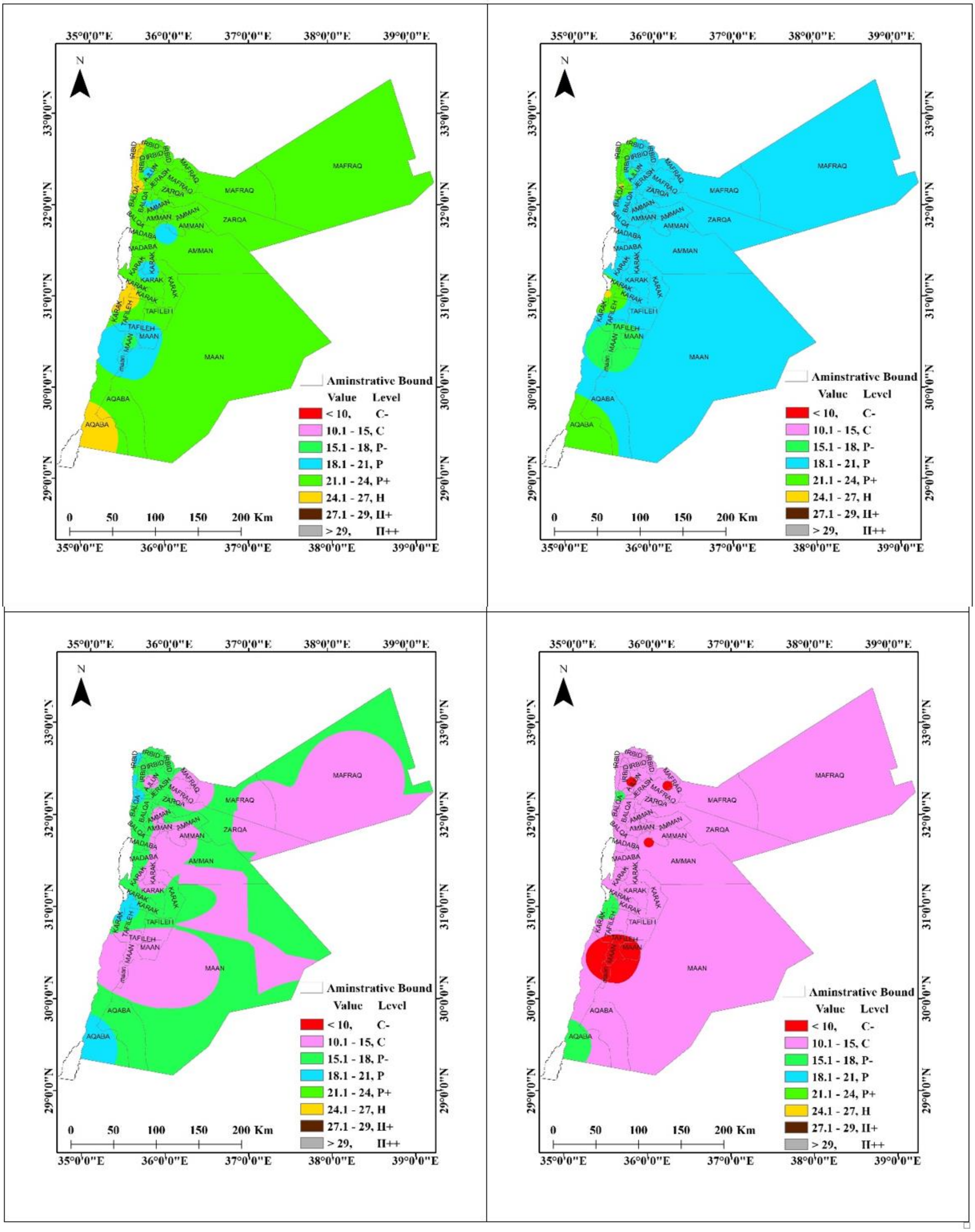

Figure 4: The monthly spatial distribution maps of the Thom's Discomfort Index (DI). (a) January, (b) February, (c)March, (d) April, (e) May, (f) June, (g) July, (h) August, (i) September, (j) October, (k) November, and (l) December.

4.2 Analysis of the temporal magnitude of DI levels

Figure (5) shows the temporal distribution of the magnitude of the monthly average long-term DI levels. It shows that the magnitude of each DI level varies in each month. For instance, in January, three DI levels were identified (i.e., C-, C, and P-). However, the C- and C levels were the dominant ones to indicate a cool sensation for the human body. Similar outcomes were found in February, but with major magnitude for the C level. For March, the two dominant levels were C and P- The C- and P levels were also found but with minimal magnitude which indicates an overall moderate sensation in March. In April, the P- and P levels were fully covered in the DI scale, which shows moderate and comfort inclined DI levels. In May, the DI values heads for the comfort levels (i.e., P-, P, and P+). The heat-inclined discomfort level (H) was minimally identified in this month, which might be attributed to the fact that May is an intermediate month between winter (cold) and summer (hot) in Jordan.

The values of DI nearly reached the upper threshold of heat-inclined discomfort level (H) in June. However, the comfort and the heat-inclined levels were the dominated ones. In July and August, the heat discomfort sensation was strongly identified by the H, H+, and H++ levels. For example, a significant and serious health stress could be identified in August in some areas in Jordan. A nice drop in the DI levels towards the comfort levels stated again in September; levels P, P+ and H were strongly appeared with full loading. It is noted that September is the first month of Autumn in Jordan to be dominated by moderate temperature. October had witnessed similar situation to September but with lower DI values, where a moderate and cold discomfort level was found in some areas. The months of November and December were closely similar to February and January, respectively, whereas the cold discomfort sensation was the dominant one.

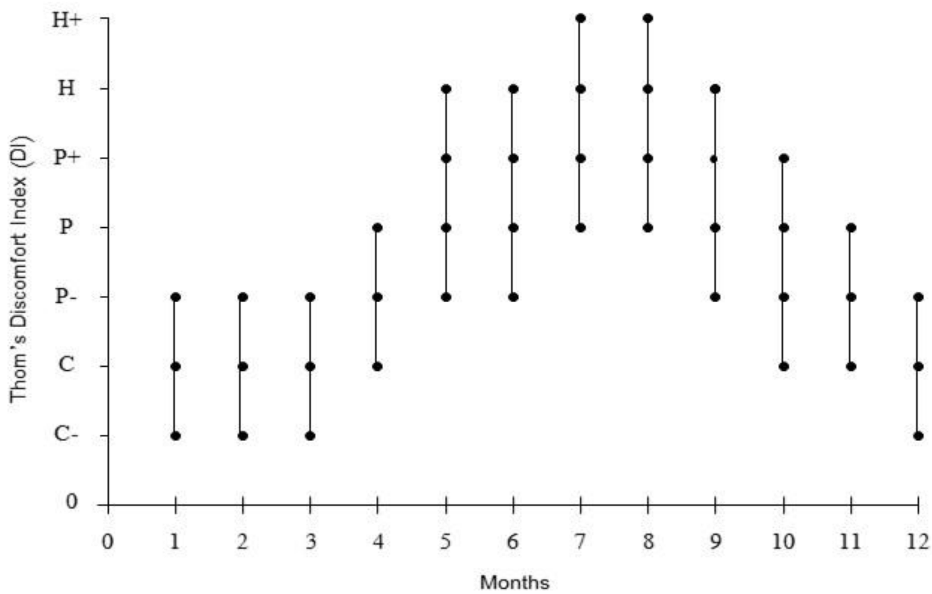

Figure 5: The long-term monthly distribution of the magnitude of Thom's Discomfort Index (DI). The numbers on the y-axis show the cut-thresholds for each DI level.

5. Conclusion

Climate is one of the most important factors in tourism industry. It may determine the tourist destination and time due to its impacts on human comfort. In this study, a spatial and temporal analysis was carried out to generate detailed maps showing the most comfortable tourism regions for tourism and recreation in Jordan from a climatological perspective. A monthly long-term analysis of climatic elements (i.e., temperature and relative humidity) in the period of 1985-2016 was used and compared with the average long-term number of one-day visitors and overnight tourists for the period of 2005-2018 in all tourist areas in Jordan. The findings showed that the most comfortable months for tourism activities were from May to September. The detailed maps of climatic comfort levels show the most suitable areas for tourism and recreation sites. This would help decision makers and investors to provide and enhance the infrastructure and other tourist facilities in these tourism sites to contribute to the development to their local societies. Also, it is expected that the outcomes of this study would support decision makers in building different scenarios that contribute to the development of tourism industry in Jordan.

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