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# Evolution the Relationship Between Physiologically Equivalent Temperature and Some Meteorological Parameters for Basra City, Iraq

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**ABSTRACT:** ***Background:*** *Physiologically equivalent temperatures (PET) is highly efficient in evaluating the thermal component of any given microclimate as a single thermal index. The assist stakeholders in understanding and interpreting existing bioclimatic, allowing them to make any required modifications and become more robust to predicted climate change.* ***Objective:*** *This study assesses the relationship between Physiologically equivalent temperatures (PET) and some Meteorological Parameters.* ***Methods:*** *The data for this study includes observed mean monthly air temperature values, relative humidity, and wind speed for the period (2001-2020). The data was acquired from "Iraqi Meteorological Organization and Seismology (IMOS)" stations for Basra city. The radiation and Human Bioclimatic (RayMan) model were used to simulate bioclimatic indices (SET, UTCI, PET, PMV).* ***Results:*** *The findings revealed that the greatest mean values for PMV (4.3), SET (36.3), PET (45.5), and UTCI (42.1) were seen in July and August. The measurements have a nice thermal sensation of PMV (-0.5 - 1.9), SET (19.2- 29), PET (18.1- 31.8), and UTCI (15.9 - 28.7) is most noticeable in the months of (March, April, and October). The results showed the PET values (cool) and (Slightly cool) between (9- 18.3) for January, February, March, and December. The value of UTCI was between (5.9- 8.5) within classes (Slight cold stress), the values of PMV (-2.6- (-2.1)) within classes (strong cold stress) and (Slight cold stress) and the value of SET was (10.2- 12.4) within classes (Slight cold stress).* ***Conclusions:*** *Correlations between PET and air temperature (0.99), indicating good agreement between PET and air temperature, and relative humidity (0.96). PET and wind speed ($R^2$=0.56). The scattering pattern of PET and other thermal indices shows that all indexes have a significant correlation coefficient, between PET and UTCI ($R^2$=0.99), between PET and SET ($R^2$=0.98), and ($R^2$=0.99) between PET and PMV.*

**KEYWORDS:** *Physiologically equivalent temperature; Bioclimatic condition; Thermal discomfort; Rayman model; Basra*

## INTRODUCTION

One of the most significant variables influencing human life in the past and today is the climate. The weather greatly affects how people live their daily lives. people's choices for food and clothing, the distribution of the earth's surface, housing demands, and urban climate—which play a significant part in forming human character—all have strong relationships with bioclimatic comfort [1]. Heat waves and other periods of exceptionally high temperatures pose a major meteorological risk to people's health and well-being. Heat-related illnesses including dehydration and sunstroke are among the negative effects on health [2]. Under "steady State" conditions, the thermal sensation of heat discomfort felt when the average skin temperature rises over the level corresponding to the State of comfort, to roughly 32-33°C under sedentary conditions [3].

Over the years, the utilization of outdoor spaces and the impact of outdoor climatic conditions and thermal adaption variables on people's thermal perceptions have both been the subject of numerous field research [4]. Since the human thermal sense depends on two personal factors (clothing

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and activity level) the dynamic climatic circumstances outside make it challenging to evaluate [5]. "Physiologically equivalent temperature (PET) is based on the Munich Energy-balance Model for Individuals (MEMI)", which a precise description of the body's thermal conditions [6]. Physiologically equivalent temperature (PET) "is a measurement of changes in thermal comfort in humans. The RayMan model makes it simple to compute PET values, which is why it is so often used. PET research spans the global, local, and micro-scales. RayMan uses normal meteorological data from synoptic or climatic stations and is simple to use [7]–[10].

RayMan is an excellent tool for calculating Radiation fluxes. The RayMan model, developed in accordance with "German Engineering Society Guideline 3787", calculates the radiation flux in simple and complex environments using a variety of parameters. In addition to the meteorological characteristics [4] "(Jendritzky et al., 2000)" have been frequently utilized in human-biometeorological evaluations in recent years "(Burkart et al., 2011)" established on the "Munich Energy-Balance Model for Individuals (MEMI)" "(Jendritzky et al., 2000) [9]". (Aws M. Salman et al., 2021) evaluated the effect of UHI mitigation strategies on outdoor human thermal comfort in three different common types of urban patterns in the biggest and most populated city in Baghdad Iraq, [10]. (Alaa M. Al-Lami1 et al.,2023) Utilized the RayMan model, analyze the behavior of the SET, UTCI, PET, and PMV bioclimatic indices in Baghdad city throughout the period (1981-2021) [11].

In this study, The Rayman model would use to assess the relationship between physiologically similar temperatures and multiple meteorological characteristics (relative humidity, wind speed, and air temperature).

## MATERIALS AND METHODS

### Study Area and Data

Basra City situated in the extreme southeast of Iraq, on the Mesopotamian Plain. Geographically, it is located between the Latitude circles of (29° 3' 0" N) and (31° 12' 0" N), and the Longitude circles of (40° 27' 36" E) and (48° 18' 0" N).

The region experiences an arid environment and very little to no precipitation in summer and modest total mean rainfall in the winter. The NW-SE wind is the primary wind direction. In the summer, the location is hot and muggy, while in the winter, it is chilly. Figure 1 depicts the location of Basra province [12].

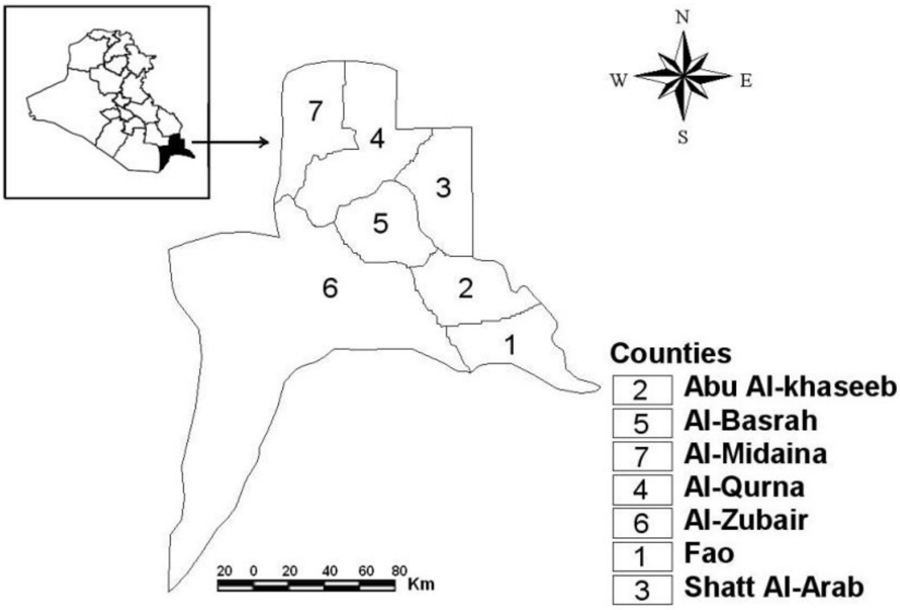


**Figure 1**. Iraq map with study sites

Basra's surface elevation ranges from 5 to 26 meters above sea level. Summers are hot and dry, while winters are chilly and damp. Averaging 31.2 °C, the maximum temperature varies from 34 °C in January to 54 °C in July. The lowest average temperature is 17.6 °C, with lows of -6 °C in January and 21 °C in August. Around 152 mm of rainfalls on average each year [13].

The data of monthly means of relative humidity (%), wind speed (m/s), and air temperature (°C) that used in this study were obtained from The Iraqi Meteorological Organization and Seismology (IMOS) for twenty years (January 2001 - December 2020) for Basra city.

Modern human biometeorological methods employ the human body's energy balance to extract thermal indices, which based on the energy balance of people and explain how clothes and activity affect humans' responses to short- and long-wave radiation, air temperature, air humidity, and wind speed [10].

## Physiologically Equivalent Temperature

employed as a metric to analyze the thermal bioclimatic. It commonly used as a thermal bioclimatic index [14]. It has frequently employed as an indicator for assessing the thermal bioclimatic, enabling straightforward comparisons with earlier studies. PET is determined using a model of human energy balance [15]. PET is the air temperature at which the body's heat budget balanced in a typical indoor environment with the same core and skin temperatures. The model based on the human body indices' energy balance:

$$M + PW + R + C + ED + ERe + ESw + S = 0 \tag{1}$$

Where" M" the metabolic average, "PW" the result of physical work, "R" the body's overall radiation output, "C" represents the convective heat flow, "ED". The amount of latent heat flux needed to cause water to evaporate when it passes through the skin, "ERe" is the sum of the inspired air's heat fluxes and humidity, "ESw" is the heat flow from sweat, and "S" is the heat storage heat in the body mass [16].

## Universal Thermal Climate Index

A thermal comfort indicator called the UTCI based on models of how people body heat balance. The indicator intended to be used at all geographical and temporal scales, under all climatic conditions. The UTCI-Fiala multinode human thermoregulation model, which combined with an adaptive clothing model, used to mimic the human response. The UTCI was described as the air temperature of the reference environment, causing an equivalent dynamic physiological reaction which according to the model [17]. Categories for assessment of thermal stress shown in Table 1. This index was calculated using athletic relationships [9].

$$UTCI = 3.21 + 0.872.T + 0.2459.Tmrt + (-2.5078.V) - 0.0176.RH \tag{2}$$

## Predicted Mean Vote

To account for energy exchange, the PMV employs a two-node body model, which consists of a skin node and a core node. It allows for breathing as well as latent and visible heat transport from and to the skin [18].

## Standard Effective Temperature

The equivalent air temperature in an isothermal environment in which a person wearing proper exercise clothing has the same amount of heat stress (skin temperature) and thermoregulatory strain (skin wetness) [19]. Table 1 shows different categories of index values for different degrees of temperature sensitivity.

**Table 1**. Categories of bioclimatic variables [16], [17], [19]

| Index thermal sensation | PET | UTCI | PMV | SET |
|---|---|---|---|---|
| ”very cold stress” | <4 | <-40 | <-3.5 | — |
| ”very strong cold stress” | — | -40-(-27) | -3.4-(-2.5) | — |
| ”cold” | 4-8 | -27-13 | -2.4-(-1.5) | — |
| ”Cool” | 8-13 | -13-0 | 1.4-(-0.5) | <17 |
| ”Slight cold stress” | 13-18 | 0-9 | -0.4-0.5 | — |
| ”Comfortable” | 18-23 | 9-26 | 0 | 17-30 |
| ”Slight warm stress” | 23-29 | — | 0.6-1.5 | — |
| ”Warm” | 29-35 | 26-32 | 1.6-2.5 | 30-34 |
| ”Hot” | 35-41 | 32-38 | 2.6-3.5 | 34-37 |
| ”Very Strong heat stress” | — | 38-46 | — | — |
| ”Very hot” | >41 | >46 | >3.5 | >37 |

## RayMan Model

The Rayman model was developed in accordance with “German Engineering Society Guideline 3787 (VDI, 1998)”[20]. RayMan software utilized in this investigation to calculate four trustworthy bioclimatic indices: “SET, PMV, PET, and UTCI” values. Meteorological variables such as dry air temperature, relative humidity, and wind speed, demanded for RayMan to generate bioclimatic indicators. One of the main features of the model is the ability to simulate both simple and complex short- and long-wave radiation flux densities from the three-dimensional environment [19].

## RESULTS AND DISCUSSION

In Figure 2, According to the findings, the greatest monthly mean values for the thermal indices “(PMV, SET, PET, and UTCI)” were observed in July and August, respectively, for PMV (4.3), (4.3), SET (36.3), (36.6), PET (45.5), (45.6), and UTCI (42.1), (41.6). All of these values indicate a high thermal perception of hot. Additionally, the readings of PMV (-0.5 to 1.9), SET (19.2 to 29), PET (18.1 to 31.8), and UTCI (15.9 to 28.7) were within acceptable values in the months of March, April, and October. With the exception of PMV (-2.6), which was determined in January, the extremely cold score did not show in any score. The findings indicated that the PET values collected in January, February, March, and December fell into two categories: chilly and somewhat cool, from 9 to 18.3. The value of UTCI was between (5.9 to 8.5) within classes (Slight cold stress), the values of PMV (-2.6 to -2.1) within classes (strong cold stress) and (Slight cold stress) and the value of SET was (10.2 to 12.4) within classes (Slight cold stress).

Figure 3, demonstrates relationships between the PET and weather conditions (such as air temperature, relative humidity, and wind speed). The results show the correlation between PET and air temperature is a positive and robust, with the highest correlation value ($R^2$=0.99), indicating that there is good agreement between PET and air temperature. According to Blazejczyk et al. (2012), The relationship between PET and air temperature is stronger, and UTCI is more sensitive to changes in these variables. [20], [21]. Nevertheless, a declining correlation between PET and RH ($R^2$=0.96), and the lowest correlation coefficient ($R^2$=0.56) was discovered between PET and wind speed. the results appeared that all indices show an increased trend from January to June. On the other hand, these indices declined in different months of the year.

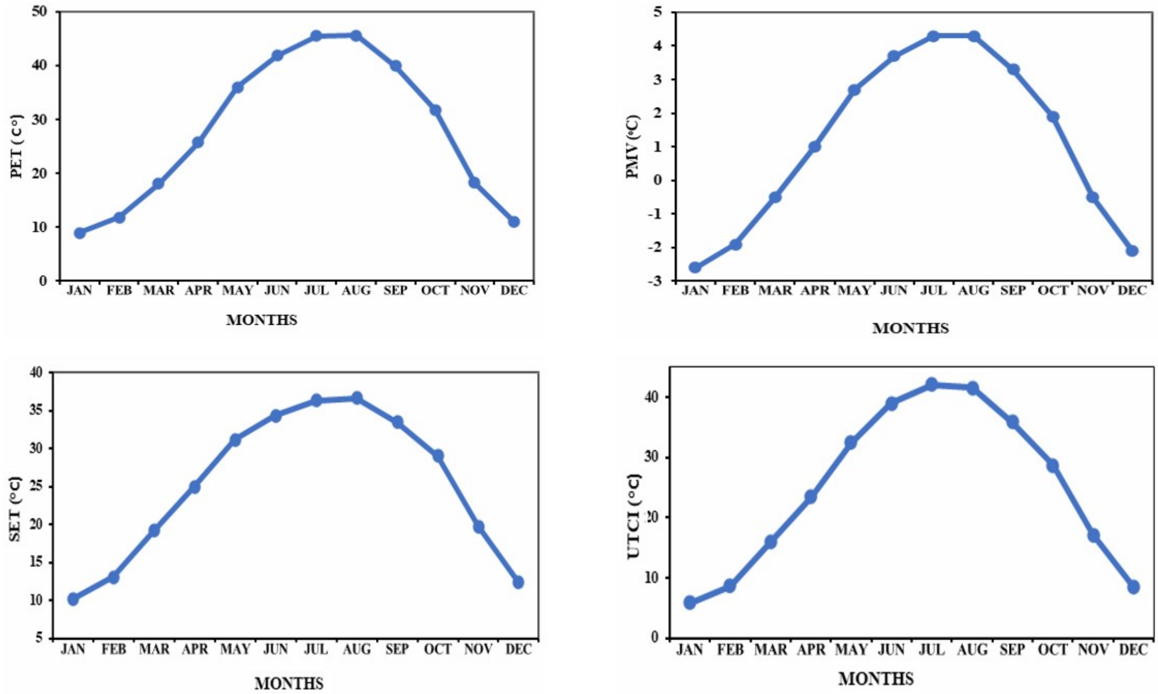


**Figure 2**. Monthly averages for Basra for (PMV, SET, PET, and UTCI)

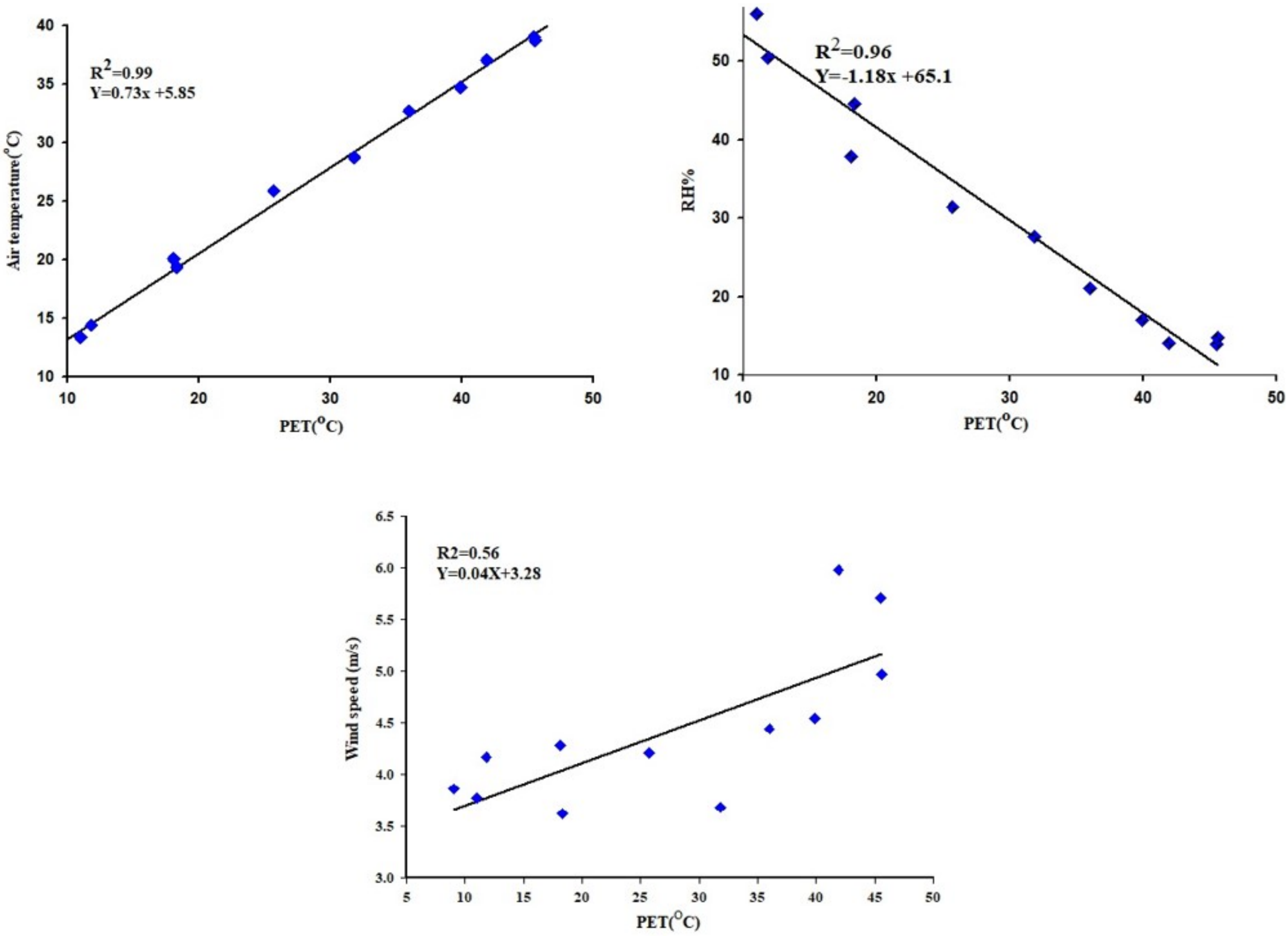


**Figure 3**. The relationship between PET and meteorological parameters

The scattering pattern of PET show that all indices have a significant correlation coefficient in Figure 4, The statistical correlation between PET and UTCI ($R^2$=0.99), indicating that there is good agreement between PET and UTCI. Between PET and SET, the correlation coefficient ($R^2$=0.98) was discovered, and ($R^2$=0.99) between PET and PMV. The values for indices derived from human thermal balance models PMV, and SET were similar to UTCI.

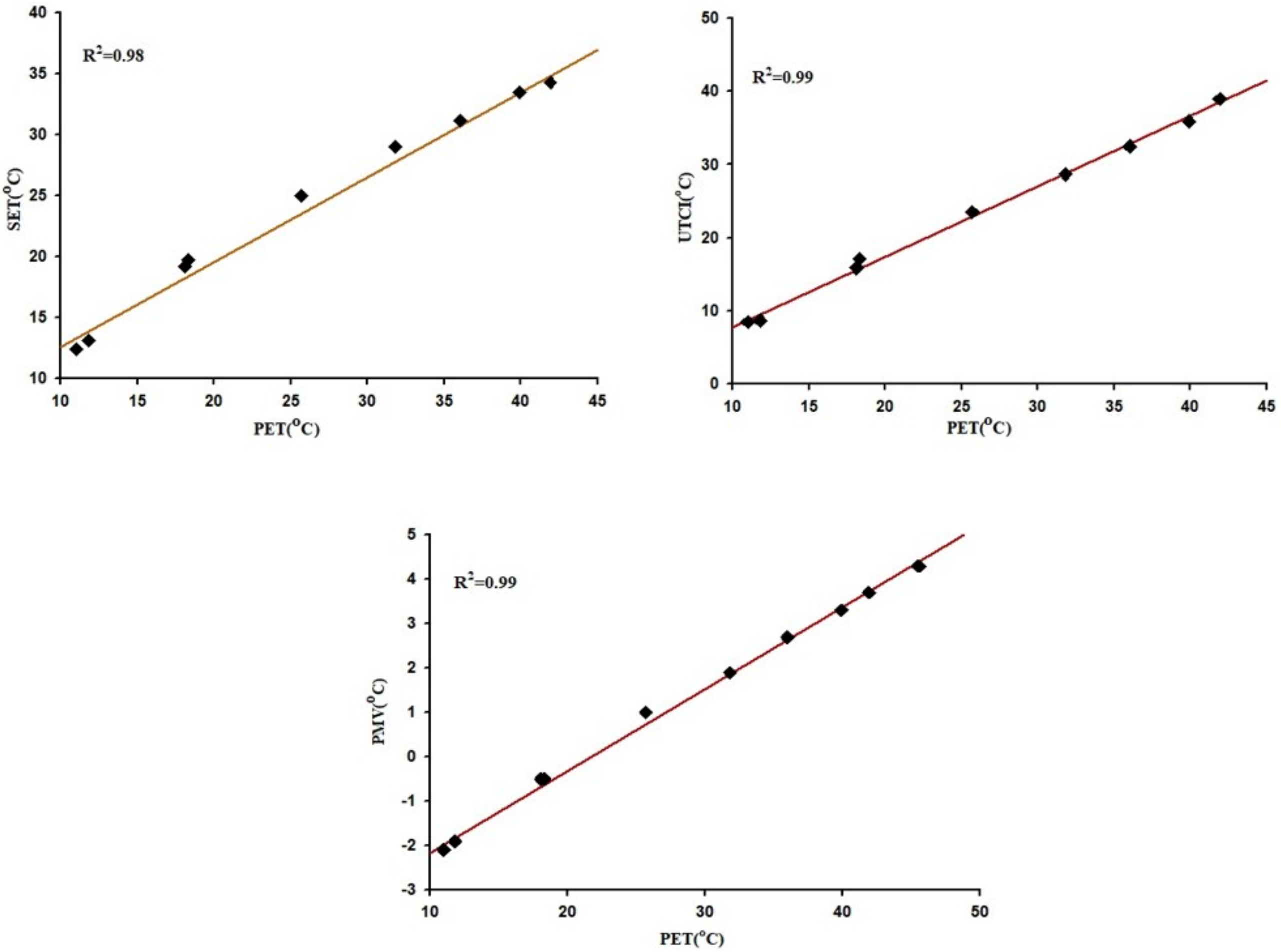


**Figure 4**. The connection between various thermal indices and PET

## CONCLUSION

According to the results, the maximum monthly mean values of the thermal indices PMV, SET, PET, and UTCI observed in July were 4.3, 36.3, 45.5, and 42.1, respectively, and in August were 4.3, 36.3, 45.6, and 41.6, respectively. The result indicated that the PET values collected in January, February, March, and December fell into two categories: chilly and somewhat cool between 9 and 18.3. The values of UTCI were between 5.9 and 8.5 within the classes: slight cold stress, the values of PMV (-2.6 to -2.1) are strong cold stress and slight cold stress. The values of SET were between 10.2 and 12.4 with slight cold stress. the results showed that all indicated an increased trend from January to June. On the other hand, these indices declined in different months of the year. The statistical determination coefficient between PET and UTCI ($R^2$=0.99), indicated that there is good agreement between PET and UTCI. The values for indices derived from human thermal balance models PMV, and SET were similar to UTCI.

## SUPPLEMENTARY MATERIAL

*None.*

## AUTHOR CONTRIBUTIONS

*Zahraa A. Al-Ramahy conceived and designed the study, conducted the experiments, analyzed the data, and wrote the manuscript.*

## FUNDING

*None.*

## DATA AVAILABILITY STATEMENT

*The data was acquired from Iraqi Meteorological Organization and Seismology (IMOS) stations for Basra city for the period 2001–2020.*

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## CONFLICTS OF INTEREST

*The authors declare no conflicts of interest.*

## REFERENCES

[1] C. B. Karakuş and D. Demiroglu, "A study of the relationship between bioclimatic comfort zones and land use: The case of sivas province (turkey)," 2021. doi: 10.21203/rs.3.rs-1035870/v1.

[2] C. Di Napoli, F. Pappenberger, and H. L. Cloke, "Assessing heat-related health risk in europe via the universal thermal climate index (utci)," *International Journal of Biometeorology*, vol. 62, no. 7, pp. 1155–1165, 2018. doi: 10.1007/s00484-018-1518-2.

[3] A. Akinbobola, C. A. Njoku, I. Balogun, and C. P. Bean, "Basic evaluation of bioclimatic conditions over southwest nigeria," *Journal of Environment and Earth Science*, vol. 7, no. 12, pp. 53–62, 2017.

[4] W. Yang, N. H. Wong, and G. Zhang, "A comparative analysis of human thermal conditions in outdoor urban spaces in the summer season in singapore and changsha, china," *International Journal of Biometeorology*, vol. 57, no. 6, pp. 895–907, 2012. doi: 10.1007/s00484-012-0616-9.

[5] L. Amirtham, E. Horrison, and S. Rajkumar, "Impact of urban morphology on microclimatic conditions and outdoor thermal comfort– a study in mixed residential neighbourhood of chennai, india," in *ICUC9 - 9th International Conference on Urban Climate jointly with 12th Symposium on the Urban Environment*, 2015.

[6] A. Bleta, P. T. Nastos, and A. Matzarakis, "Assessment of bioclimatic conditions on crete island, greece," *Regional Environmental Change*, vol. 14, no. 5, pp. 1967–1981, 2013. doi: 10.1007/s10113-013-0530-7.

[7] G. Adiguzel, "Analysing the impacts of different urban green areas on human thermal comfort in bornova, ī̇zmir," *Journal of International Environmental Application and Science*, vol. 13, no. 1, pp. 50–56, 2018.

[8] M. Pecelj, A. Matzarakis, M. Vujadinović, M. Radovanović, N. Vagić, D. Đurić, and M. Cvetkovic, "Temporal analysis of urban-suburban pet, mpet and utci indices in belgrade (serbia)," *Atmosphere*, vol. 12, no. 7, 2021. doi: 10.3390/atmos12070916.

[9] M. Baaghideh, F. Mayvaneh, A. Shekari Badi, and T. Shojaee, "Evaluation of human thermal comfort using utci index: Case study khorasan razavi, iran," *Natural Environment Change*, vol. 2, no. 2, pp. 165–175, 2016.

[10] A. M. Salman and Y. M. Saleem, "The effect of urban heat island mitigation strategies on outdoor human thermal comfort in the city of baghdad," *Frontiers of Architectural Research*, vol. 10, no. 4, pp. 838–856, 2021.

[11] A. M. Al-Lami, O. L. Khaleed, and M. M. Ahmed, "Assessment of some bioclimatic indices using rayman model for baghdad-iraq," in *IOP Conference Series: Earth and Environmental Science*, vol. 1223, 2023. doi: 10.1088/175-51315/1223/1/012019.

[12] H. H. Karim, A. R. Ziboon, and L. M. Al-Hemidawi, "Assessment of water quality indices for shatt al-basrah river in basrah city, iraq," *Engineering and Technology Journal*, vol. 34, no. 9, pp. 1804–1822, 2016. doi: 10.30684/etj.34.9A.8.

[13] M. Elmwafi, F. Zarzoura, and Z. Jumaah, “A comparative study of the different remote sensing techniques for evaluating land use/cover in basra city, iraq,” *MANSOURA ENGINEERING JOURNAL*, vol. 45, pp. 21–31, 2020.

[14] F. A. Zwain, T. T. Al-Samarrai, and Y. I. Al-Saady, “A study of desertification using remote sensing techniques in basra governorate, south iraq,” *Iraqi Journal of Science*, pp. 912–926, 2021. doi: `10.24996/ijs.2021.62.3.22`.

[15] T. M. Giannaros, D. Melas, and A. Matzarakis, “Evaluation of thermal bioclimate based on observational data and numerical simulations: An application to greece,” *International Journal of Biometeorology*, vol. 59, no. 2, pp. 151–164, 2014. doi: `10.1007/s00484-014-0832-6`.

[16] R. E. Molenaar, B. G. Heusinkveld, and G. J. Steeneveld, “Projection of rural and urban human thermal comfort in the netherlands for 2050,” *International Journal of Climatology*, vol. 36, no. 4, pp. 1708–1723, 2015. doi: `10.1002/joc.4453`.

[17] M. M. Pecelj, M. Z. Lukić, D. J. Filipović, and B. M. Protić, “Summer variation of the utci index and heat waves in serbia,” 2019. doi: `10.5194/nhess-2019-270`.

[18] S. Toy and S. YILMAZ, “Evaluation of urban-rural bioclimatic comfort differences over a ten-year period in the sample of erzincan city reconstructed after a heavy earthquake,” *Atmósfera*, vol. 23, no. 4, pp. 387–402, 2010.

[19] G. Roshan, H. S. Almomenin, S. Q. da Silveira Hirashima, and S. Attia, “Estimate of outdoor thermal comfort zones for different climatic regions of iran,” *Urban Climate*, vol. 27, pp. 8–23, 2019. doi: `10.1016/j.uclim.2018.10.005`.

[20] A. Gulyas and A. Matzarakis, “Selected examples of bioclimatic analysis applying the physiologically equivalent temperature in hungary,” *Acta climatologica et chorologica*, vol. 40, no. 41, pp. 37–46, 2007.

[21] A. Urban and J. Kyselẏ, “Comparison of utci with other thermal indices in the assessment of heat and cold effects on cardiovascular mortality in the czech republic,” *International Journal of Environmental Research and Public Health*, vol. 11, no. 1, pp. 952–967, 2014. doi: `10.3390/ijerph110100952`.