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DEVELOPMENT OF ANNUAL URBAN HEAT ISLAND IN BAGHDAD UNDER CLIMATE CHANGE

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Highlights

- This study presents long-term temperature at two stations located rural and urban sites and then calculated annual urban heat island.
- There was a warming increasing trend of 0.052 °C/year for period of 42 years.
- Annual UHI were found to be always positive intensity with a mean value of 1.78 °C.
- The potential synergy between urban heat island and extreme heat events is examined to enrich the existing knowledge.

Abstract. This study investigated the confirmation of climate change by analyzing the long-term records of annual means of temperature taken from synoptic station located at International Baghdad Airport (rural site) available for the period from 1978 to 2019. Furthermore, based on annual temperature data recorded by automatic weather station installed at Mustansiriyah University (urban station), available for the period 2008–2019, the difference between urban and rural temperatures called as urban heat island (UHI) intensity was annually calculated. Statistic descriptive methods including temperature trend, percentile function and R-square were employed to recognize the contribution of UHI in enhancing the local warming climate. The results show that there was a warming trend of 0.052 °C/year for period of 42 years and 0.02 °C/year for recent 12 years at rural station which is lower than 0.13 °C/year observed at urban station. Also the results for annual UHI were found to be always positive intensity which ranges from 0.8 to 2.4 °C with a mean value of 1.78 °C. As a result of high annual UHI intensity, hot day events during 2008–2019 were extracted from daily temperatures exceeding of threshold value of 37.5 °C that dominate in summer months with totally 204 events and with an annual average of 17 days. Finally, under the continuing local warming climate, potential effects caused by UHI and its mitigation strategies are further presented.

Keywords: urban heat island, urban warming, hot days, temperature trend, potential effects and mitigations, Baghdad.

Introduction

The majority of the world's population has been urbanized and continuously projected to rise in future. As the urban population goes on to grow, the life quality in dense cities is facing to be harder in available standard living requirements. The current global average air temperature has been reaching about 1–1.1 °C warming (Intergovernmental Panel on Climate Change [IPCC], 2019; World Meteorological Organization, 2009). In the report of IPCC (2007), there was one chapter having the UHI existence caused by urban growth and its influence on climate change. Although urbanization has a great role in economic and social development, it has been created some environmental problems in urban areas, e.g. increased air or surface temperature, energy demand, air and water pollution, etc. (Cui & Shi, 2012). This gradually leads to an increase of greenhouse gas emissions which contribute to the global climate change (Alcoforado & Andrade, 2008; Shahmohamadi et al., 2011).

Air temperature increases within the city relative to surrounding it known as the urban heat island (UHI), which emerges from replacing open areas and vegetation to buildings, roads and other infrastructure (Oke, 1976; Landsberg, 1981; Montavez et al., 2000; Stewart, 2011; Tawfeek et al., 2020). The UHI effect may be intensified under regional climate change with implications for heat stress, severe heat waves, morbidity and mortality with very high summer temperature (Santamouris, 2020).

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The focus is on Baghdad city, the capital of Iraq, as it has gone through rapid population growth in the last two decades after 2003. This leads to increase the inner immigration from other provinces to the city. Figure 1 illustrates the population census in the city for the period 2008–2019 (Encyclopædia Britannica, 2020), which shows increasing tendency of population with growth rate of 2.38%. Beside to the absence of the law and random expansion, the city faces the challenges of an unplanned development. Daily, seasonal and annual UHIs have recently investigated by Tawfeek et al. (2020) for only three years 2008, 2013 and 2019 using air temperature data and then examined their variations with the changes in built-up areas based on satellite Landsat data. They found that yearly mean UHIs were suspected of warming climate with value of 1.4, 1.5 and 2.4 °C at these years, respectively. In recent years, the observation evidence to study correlation between annual means for both UHIs and extreme heat waves is still not unveiled under intensified climate.

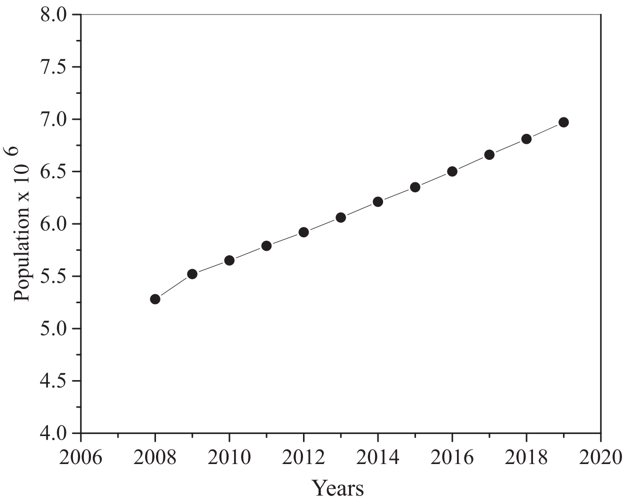

Figure 1. Population during 2008–2019 in Baghdad

The main goal of this work is to (1) present long-term temperature trend at rural site to confirm local climate change in Baghdad and comparing them with that at urban site, (2) calculate annual UHI intensity for a period from 2008 to 2019 and provide its trend, (3) study the impact of UHI on extreme weather events in terms of hot days and finally (4) examine the correlations between UHIs and annual mean temperatures. Considering to the first three objectives, the potential interaction or synergy between the UHI and hot events could be more understood in the arid or semiarid climate context. The mechanism behind such synergy that contributes to local and regional UHI may attribute to persistent high pressure anticyclones associated with weak wind speed, less surface moisture, high solar radiation anthropogenic activities, land use/land cover, construction materials, etc. (Li & Bou-Zeid, 2013; Founda & Santamouris, 2017; He et al., 2020a, 2021). They interact synergistically and nonlinearly to generate adverse heat stress conditions. Both UHI and hot events can exacerbate the adverse effects in vulnerable cities, especially if they foster each other and warming climate change. Previous studies (for example, Founda & Santamouris, 2017) were examined this synergy according to the instantaneous weather situations for coastal cities.

1. Material and methods

1.1. Study area

Baghdad is located in the middle of Iraq and covers an area of 894.3 km^2 which form 0.2% of Iraq's total area. It has the highest population density among other Iraqi provinces and is the second among the Arabian World after Cairo. Tigris river passes through city dividing it into two halves: Rasafa side (Eastern part) and Karkh side (Western part), as shown in Figure 2. The average elevation above sea level for Baghdad is 34 m and it extended by 33° 12' – 33° 29' N in latitudes and 44° 10' – 44° 30' E in longitudes. The köppen climatic classification for Baghdad is BWH, semiarid, dry summer and damp winter (Roth, 2007). The annual average air temperature is 25 °C and average rainfall per year is 140 mm with no rain at summertime.

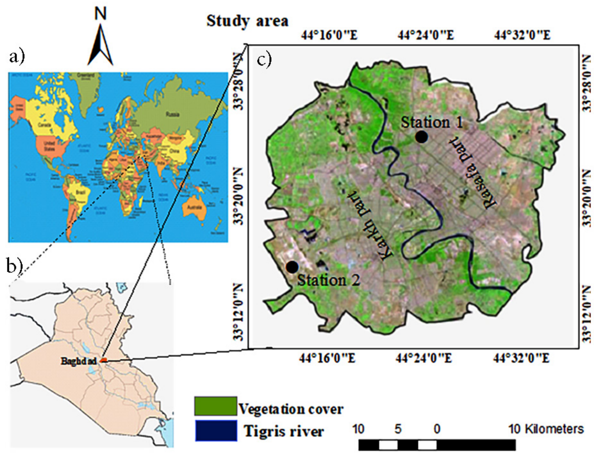

Figure 2. Administrate maps of (a) the world, (b) Iraq and (c) Baghdad, the study area

1.2. Topography description

The area of the present study is located within the province of Baghdad called by Ammant Baghdad, which is situated in what was ancient Mesopotamian plain. It is a major managerial, political, economic, and communications hup of Iraq (see its view in Figure 3a). The terrain of Ammant Baghdad is characterized by very gentle slope extending from the north with elevation of 48 m towards the south with 23 m (Bukheet et al., 2016). Therefore, there are no actually natural boundaries within the study area. The texture of the landscape is comprised of residential areas, vegetation cover, water bodies, and bare land, with the percentages of 51, 34.7, 2, and 12.3, respectively (Al-Jiboori et al., 2020). The main water bodies such as Tigris river, streams, canals, and reservoirs form the main source of the irrigation for agricultural activities, especially

a) Aerial photograph for Baghdad b) Mustansiriyah University c) International Baghdad Airport

Figure 3. Photographs of (a) Baghdad city, (b) Campus of Mustansiriyah University (urban site), (c) International Bagdad Airport (rural site)

at seasons: spring, summer and autumn. Also in Rasafa part, there is a 24-km Military canal that abandons the Tigris and finish at Diyala river, south of the city. Vegetation cover mostly comprised of shade trees (e.g. date palms, etc.), grain yield production (e.g. wheat, barley, etc.) and short plant species (e.g. shrubs, grasses, etc.). They are mainly distributed in the north and south, while they are scattered in the different places of the city, especially in the west and east. The residential areas are arranged by adapting the same concept of rectangular grid system.

1.3. Data sources

We analyze the climatic data records of annual mean air temperature collected from the national meteorological station (number 2 at Figure 2) with a 2-m height at International Baghdad Airport under the Iraqi Meteorological Organization and Seismology. This station lies in the surroundings of the city in an open area of bare lands about 20 km south-west from its center and considered as rural site (see Figure 3c). This station has long-term availability of data which benefit in quality research of understanding the climate variability and local climate change in nearby. The time series of these data were used to confirm the local climate warming and to calculate UHI by comparing with another station (number 1 at Figure 2) installed on the roof of building with four floors (14 m high above the ground) following to the Mustansiriyah university located in Rasafa side of the city center (see Figure 3b). Both urban and rural stations are automatic weather station and their photographs can be found in the reference (Tawfeek et al., 2020). Urban station has been started at the service since last three months of 2007 that measures many elements at every hour, fixing on 1 m metal bar over the highest roof floor covered by concrete plates. Its site can be classified as urban core associated to medium density of mixed land uses such as official departments, commercial companies, residences (or housing), and other uses.

The length of time period of annual mean temperature data taken from station 2 was from 1978 to 2019, while the period from 2008 to 2019 was for station 1. Although the height difference between two stations is 12 m, their temperature records did not show any significant differences. The reason is that the two stations are located within the surface boundary layer, which describes with a constant heat flux (Stull, 1988; Garratt, 1994). Other data such as daily mean temperature data for station 2 were used to extract extreme hot days occurred in Baghdad, which could be used an indicator to confirm the UHI effect on local climate change.

To assess the possible impacts of urban structure such as evolution of the surrounding environment of station 2 on air temperature, homogeneity test was applied in order to obtain more reliable databases. The RHtests version 4 software used to detect significant changes points in annual time series (Wang & Feng, 2013). The data were homogenous and not need for further adjustment, which improve the results of trends.

2. Methodology

2.1. Trend analysis

To confirm the changes in urban climate and its significant contribution to the local and regional average warming, first an annual temperature trend procedure was applied by drawing the best straight line through the archived temperature records at both urban and rural stations using simple linear regression equation (least squares minimization) given as:

$$T_{r\,or\,u} = \alpha_{r\,or\,u} + \beta_{r\,or\,u} \times t, \tag{1}$$

where the subscripts r and u refer to rural and urban stations, respectively; α is the intercept; β is the slopes (trends) of these lines that are called the rural and urban temperature trends, respectively; t is the independent variable (year). The constants α and β are based on the independent variables of temperature records and time (years). They were computed by use of Origin software (version 9.3) in this paper.

Of course, the magnitude of trend and even sometimes sign depends on the length of time used to estimate it.

For the comparison, second trend of rural temperature record for the same period (12 years) as for urban station is also calculated. This will be useful in understanding the inherent difficulty in detecting the UHI contribution in the rise of local warming in surroundings represented by rural trend. This can be expressed as urban contribution (C_u), which defined as the ratio of the difference between annual urban and rural temperature to annual urban temperature multiplying 100 (Zhou & Ren, 2011; Zhang et al., 2014) given as:

$$C_u = \left| \frac{\beta_u - \beta_r}{\beta_u} \right| \times 100, \quad (2)$$

where $C_u = 0$ indicates no contribution and $C_u = 100\%$ refers to high contribution, i.e. $0 \geq C_u \geq 100$. The absolute value is taken to neglect, in certain aspects, negative values due to the effects of unknown local factors such as dust, aerosols, haze, etc. Through the linear fitting analysis, a goodness of fit (R^2) and a significant level represented with p-value less than 0.05 were reported.

2.2. Urban heat island intensity

Cities generally are characterized with a warmer climate compared to the surrounding rural areas. Elevated temperature in cities termed the UHI which is the one of the most significant human activities to modification of natural landscapes. Thus UHI intensity is defined as:

$$\text{UHI} = \Delta T = T_u - T_r, \quad (3)$$

where T_u and T_r are annual mean temperatures at the urban and rural stations, respectively. Heat islands rise in most urban areas of the world, in particular Baghdad that characterized with a high percent of absorbed surfaces replacing by bare lands and vegetated areas to residential housing (Dong et al., 2014). Naturally, these surfaces consist of stone, concrete, pebbles and gravel that have ability to absorb heat at the surface (Oke, 1981; Landsberg, 1981). Furthermore, anthropogenic emission and addition of heat generated by electrical generators (like 500 KV) spreading in Baghdad city contribute to the intensity of the UHI especially in hot summers and cold winters.

2.3. Hot days analysis

In the climate change context, we also try to detect the influence of annual UHI intensity on enhancing the frequency and intensity of extreme warm and hot days occurred in rural site as a referenced station for the period 2008–2019. The 95th percentile function was separately applied for all daily mean temperature data of each year. The threshold value of daily mean temperature was obtained to define the occurrences of hot days (Founda & Santamouris, 2017). With using Excel program, threshold value was 37.55 °C for all daily mean temperature data and hence the number of hot days were extracted through all days of each year. Before deriving the threshold value there was no missing data and homogeneity of all data is reasonable.

3. Results and discussion

3.1. Time-series analysis of annual temperature

Figure 4 shows the historical records for annual mean air temperatures and their trends at both sites: rural and urban stations. The clear increasing in annual temperature values at urban site comparing to those at rural site can reflect the emerging of positive UHI resulting from the substantial modifications occurred in the surface of the landscape of Baghdad city. The increased thermal difference between the center of the city and its surrounding has potential implications, especially in arid regions such as discomfort to the people, energy demand and environment pollution. This phenomenon will be more worst under global warming condition whereas Iraq's climate was getting warmer as shown in Figure 4. The general upward trends were also found in Iraq by Muslih and Blazejczyk (2017), in which using mean annual and monthly averages of mean air temperature recorded at seven stations spreading through it, the strongest warming trends were significant in the summer months.

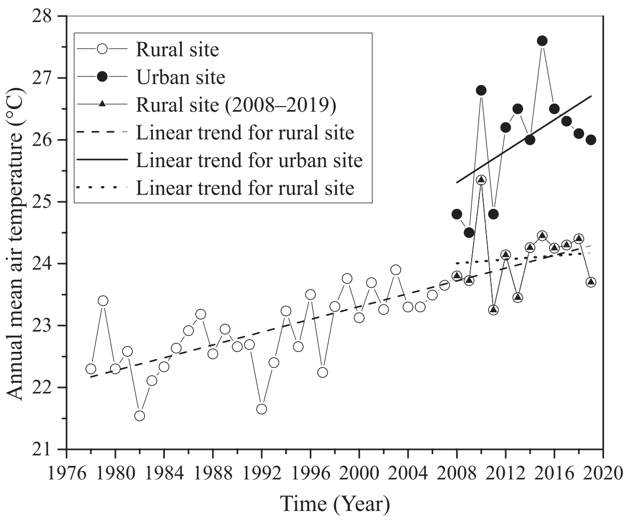

Figure 4. Annual mean air temperatures with their trends at rural and urban stations

In rural site, through long-term record (42 years), the trend represented by solid line was calculated using Eq. (1) which has a clear warming uptrend with a value of 0.052 °C/year and high correlation coefficient ($R^2 = 0.63$). This trend value is the same to that observed in Taiz city, Yemen for the period 1979–2009 (Al Buhairi, 2010) and consistent with that reported in Riyadh city, Saudi Arabia (0.06 °C/year) over the period 1978–2009 (Alghamdi & Moore, 2014). Another interesting result was found in the year of 2010 where there was a high fluctuate value of annual temperature with positive anomaly of 2 °C. For comparing to urban site, the trend in rural site was also recalculated but for the period from 2008 to 2019. Rural annual temperatures exhibited a weak uptrend (= 0.02 °C/year) and correlation ($R^2 = 0.01$).

Meanwhile, Figure 4 displays also the measurements of annual temperatures (T_u) and its trend in urban site. It is noted that annual mean temperature has increased in both years 2010 and 2015. They are, in general, larger than those at rural site with an exceeding trend (0.13 °C/year) and moderate correlation (R^2 = 0.51). The values of constants (α and β) derived from annual temperature values with their years are reported in Table 1. Among all trends stated from Table 1, the results R^2 = 0.63 and p-value = 0.001 for the rural site at period 1978–2019 confirmed that the positive trend (β = 0.052 °C/year) observed is statistically significant. Using Eq. (2), the level of the urban contribution caused by UHI to the rural trend has totally significant percentage (85%) for the period 2008–2010. This high ratio can be attributed to the urban effect to the overall temperature trend for rural station.

Table 1. Empirical values for the intercept (α) and slope (β) at rural and urban sites

Site	Period	Constants		R^2	p-value
		−α	β (trend)		
Rural	1978–2019	80.1	0.052	0.63	0.001
Rural	2008–2019	229.6	0.02	0.01	0.05
Urban	2008–2019	6.6	0.13	0.26	0.09

We now examine the relationship between urban temperature and rural temperature on yearly time scale. Figure 5 presents this relationship for the period 2008–2019, which found to be increased with non-linear behavior. The data points were fitted by the relation below with its goodness of fit (R^2 = 0.71).

$$T_r = -186.3 + 16.1 \times T_u - 0.3 \times T_u^2 . \quad (4)$$

It means that urban temperature does not increase with the same rate as those of rural temperature. This is expected because that materials used in built environments exhibit different responses in storing and releasing long-wave radiations.

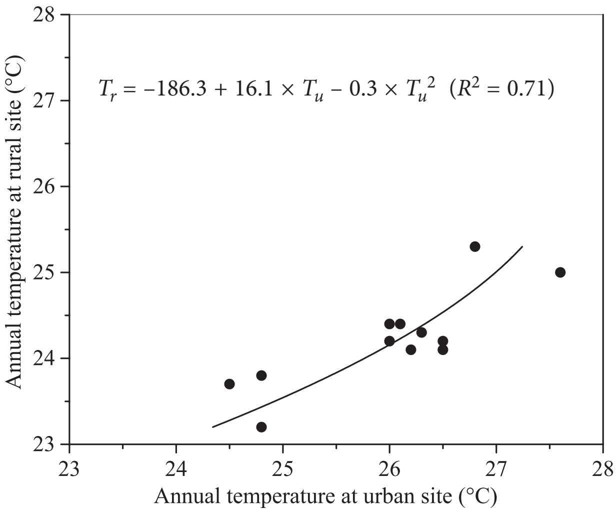

Figure 5. The relationship between annual temperatures at rural and urban stations

3.2. Time-series analysis of annual UHI intensity

Using the values of annual mean temperatures recorded at rural and urban sites for Baghdad city, the computation of annual UHI intensity was preformed using Eq. (3). The results of UHI across all studied years were experienced the positive values demonstrating a warming climate over the period 2008–2019. Figure 6 displays annual mean differences in urban-minus-rural temperature, i.e. UHI intensity, over this period, in which there was a linear increase in UHI values. The annual intensity of UHI was highest at two years: 2.4 °C in 2013 and 2.6 °C in 2015 and lowest with a value of 0.8 °C at 2009. In the future few decades, the effect of UHI owing to urbanization, land use changes and growth in population will be expected to more serious effects enhancing warming rate. This can be enhanced by the increased areas of built-up index calculated by (Tawfeek et al., 2020) whereas the areas of this index were 621.7 km^2 in 2008, 706.3 km^2 in 2013 and 727.3 km^2 in 2019. UHI values are fitted in the similar way to Eq. (1) and found to be a clear rising trend line (solid line in Figure 6). The constants, α and β, were empirically derived from UHI data. The increase rate of UHI intensity (β) was 0.08 °C/year with a moderate correlation R^2 = 0.28. The intercept of this line was −157.3 °C.

In order to show the high trend of Baghdad city, we compare our annual trend result to those observed in megacities for some Asian capitals such as Beijing (China), Seoul (Korea) and Tokyo (Japan) (Lee et al., 2020), in which, seasonal trends were determined for the period from 1992 to 2012. For comparison, their annual trends of UHI intensity were computed. All annual trend values are reported in Table 2. As stated from the table, the annual trend of UHI intensity for Baghdad is higher than those observed in other Asian cities with about a decimal order. Further, the moderate coefficient (R^2 = 0.28) between UHI values and their fitting line (trend) at Baghdad is better than corresponding values at these cities.

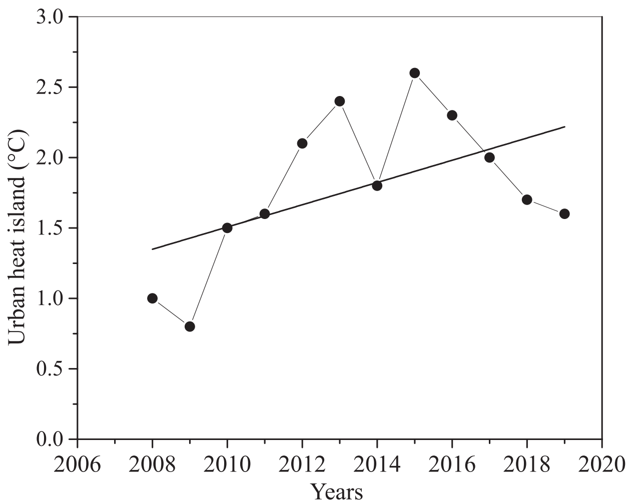

Figure 6. Annual mean urban heat island intensity with its trend at Baghdad city

Table 2. Values of UHI trend for some Asian capitals

City	Baghdad	Beijing	Seoul	Tokyo
UHI trend (°C/year)	0.08	0.008	0.00077	0.0051
R^2	0.28	0.14	0.12	0.13
Period	2008–2019	1992–2012		

From this comparison, we conclude that Baghdad city has random and worse planning under the absence of law. After changing the political system in Iraq of 2003 year, so many agricultural and barren lands have been transformed to impervious surfaces (paved roads and buildings). After destroying the electrical plants during the war of 2003, all Iraqi cities have been undergone from big shortage in energy, thus many high capacity electrical generators are still installed and worked inside of Baghdad districts, which release the thermals and pollutants to urban canyons and canopy of surface layer. All reasons above have a great role in rising urban air temperature in Baghdad. To confirm the effect of these generators and noting which season showing more UHI intensity, seasonal and annual means of UHI with their standard deviations over the period 2008–2019 were calculated and presented in Figure 7. The largest UHI intensity is at summer season with value of 2.2±0.7 °C which is expected because of high consuming energy. This value reduces to lowest one of 1.32±0.37 °C at winter for cooling the atmosphere and consequently reducing energy use.

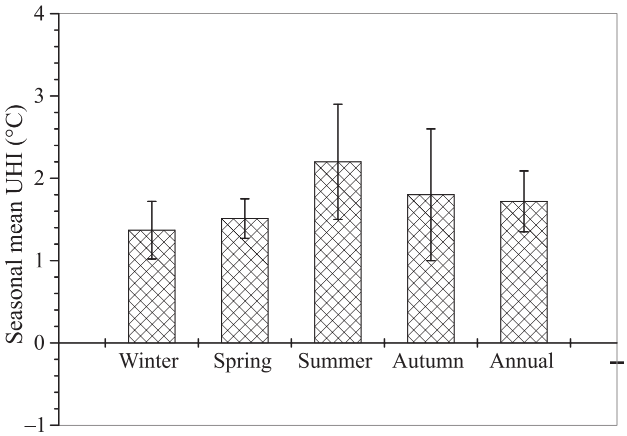

Figure 7. Histogram bars of seasonal and annual means of UHI over the period 2008–2019 with standard deviations represented by vertical lines

3.3. Potential effects and mitigations of annual UHI

3.3.1. Hot days

Here we try to display the practical evidence for influence of annual UHI on intensifying the extreme cases of hot days. The magnitude and strength of UHI can be contributed in evolving the extreme heat events. Mostly the high extreme temperature that based on 95th percentile have been widely computed in published articles in the worldwide (Fang et al., 2016). Of course, frequent higher temperatures have great potential impacts on people's health, and lifestyle and economy. The threshold value of 37.55 °C calculated by percentile function was used to extract the number of hot days for all daily data of air temperature recorded at rural station for the studied period. All hot days events were found at summer months (June, July and August) and sometimes in September. The results of annual UHI are compared with the number of hot days with their temperature range of larger than 37.55 °C and their dates are reported in Table 3. The total number of

Table 3. No. of extreme days with their maximum temperature range during summers and annual mean UHIs for the period 2008–2019

Annual UHI (°C)	Day	Month	Year	No. of days	Extreme temperature range (°C)
1	27–29 22, 26 1–2, 22–23, 25–31 2	June July August September	2008	16	37.8–39.5
0.8	12, 17, 27 11–12	June July	2009	5	37.7–38.65
1.5	12–15 7, 10–14, 16, 21, 27–31 1–2, 6–14, 16–18, 23–24	June July August	2010	33	37.6–41
1.6	1, 6 9–10, 12–15, 20, 26–31 1–4, 22	June July August	2011	20	48.7–50.9
2.1	16–18 14–15, 17–31 3–4	June July August	2012	22	37.6–40.8
2.4	2	September	2013	1	37.75
1.8	29 5, 25 15–16, 18–20, 26, 28–29	June July August	2014	11	37.56–41.15
2.6	15–16 19–22, 25–27, 29–31 1–7, 18–20	June July August	2015	22	37.6–42.15
2.3	24, 29–30 14, 17–22 3, 5, 14, 28–31	June July August	2016	17	37.56–41.6
2	27–28 3–10, 12, 16–24, 27–29 2–14, 17–18, 22 1–2	June July August September	2017	41	37.6–41.8
1.7	3–7, 11, 26 4	July August	2018	6	37.6–39.25
1.6	20–21 7–9 1, 21–24	June July A	2019	10	37.7–38.7

hot days is 204 with an average of 17 days annually in 2008–2019. Majority of hot days was observed in 2010 (33 events) and 2017 (41 events) which associates with UHI intensity larger than 1.5 °C. Also large extreme temperature range was occurred in successive four years from 2014 to 2017 associated with high UHI intensity exceeded 1.8 °C. The more frequent extreme events are more likely to cause societal or environmental problems.

3.3.2. Potential effects

The continued increase of uptrends of annual mean air temperature and UHI, as shown in Figure 4 resulting from the transformations of agricultural coverage and barren land to impervious surfaces, paved or covered with building made by asphalt and concrete caused by increasing population potentially has effects in the future. The decreased change in green coverage with cutting tall shade trees (e.g., dates palms) reduces evapotranspiration process and consequently causing frequent hot days and heat waves (Zahraa et al., 2020), discomfort to people living in the center of the city (Mukhelif et al., 2016), which lead to illness and sometime death. The increased built-up surfaces as well as the lack of vegetation observed in the reference of Tawfeek et al. (2020) are the main reasons in formation of canopy urban heat island over Baghdad city. The reason is because of the low albedo and high heat capacity of these surfaces, which absorb the short-wave radiation during the day and then emit it to the air during the night as long-wave energy.

During the recent decades and military courses after 2013, Iraq's administrative cities like Baghdad have been undergone from the great shortage in electricity demand especially in summers where maximum air temperatures are over 45 °C (Zahraa et al., 2020). Thus many big electricity generators with 500 KV capacity have been installed in all districts of Baghdad to meet the suitable standards for living. These generators have been greatly contributed to enhancement the UHI and then influencing problems of pollution environment such as air and noise pollution and high air temperature (Ridha, 2017).

3.3.3. Potential mitigation strategies

The fact of urban warming shown in Figure 4 will likely exceed to more frequent, severe and longer high air temperature, especially in summers of arid zones like Baghdad. Thus, several mitigation strategies should be adapted to reduce potential effects described in subsection above in case of increasing the intensity of canopy urban heat island. Nuruzzaman (2015) reviewed and collected strategies suggested by the researchers and also explained how they could be work to minimize the UHI effect. We suggest using strategies that are convenient and can be applied in future to our study area such as increasing vetegetation cover, i.e. trees, green roofs, green spaces, green walls, etc. (Abo Elata, 2017; Abulibdeh, 2021), pervious paving materials to dominate the evaporative cooling effect, which are affected by the water absorption capability (Wang et al., 2019), proper modification in city's design to allow cooler with wind penetration (He et al., 2020a, 2020b) and adapting innovative marterials to refelect high solar energy and low heat release, e.g. grey infrastructure (Qi et al., 2019).

Urban vegetation as a powerful strategy palys an important role in hot and semiarid climates to cool the canopy of the city. Towards to increasing the shade trees by replanting the native species (e.g. date palms) within and outside the city which can be considered as huge canopy of forests, and even they can also protect the houses and pedestrians from direct sunlight. These trees can efficiently grow in dry and hot climates. Planting other trees, other vegetation cover (e.g. shrubs, grass, etc.), green roofs on the building, urban parks and household gardens may help to mitigate urban warming and then increase the albedo and latent heat flux through evapotranspiration process. All of them tend to reduce the air and surface temperatures and pollution levels which improve local climate environment. Thus, management is required in order to select suitable vegetation, trees or plants as tool for reducing heat stress. Green vegetation cover seems to be more proper measure for our situation comparing to other strategies such as water bodies, pervious pavement, urban planning and high albedo materials.

Conclusions

Based on annual means of air temperature taken from two meteorological stations located on various rough surfaces: rural and urban sites, the several trends of both urban heat island and temperature, including the extraction of the number hot days and their extreme temperature ranges, are investigated to aviod the environmental problems relating heat stress and human health of urban sociaties. Our analysis suggests that there is nonlinear relationship between rural and urban temperatures in the lower part of surface air layer. This reveals that the different build materials in urban environments have different capacities in storing and releasing thermal energy. During the studied period in this work between 2008 and 2019, an upward trends of annual temperatures were clearly observed in both rural and urban sites with high changing rate of urban temperature (0.13 °C/year). The effect of urbanization development in Baghdad on observed warming rate in rural station were exmined by calculating annual contrasties in temperature between urban-rural areas and urban contribution ratio. The UHI and C_u values were found to positive intensities for all years above ranging from 0.8 to 2.6 °C and 85%, respectively. The findings of this study suggest that there is positive sighnificant incraesing trend in time series of annual UHI with a value of 0.08 °C/year. In the climate change context, the contribution of the UHI to the local warming climate was examined by extracting extreme hot days and their temeprature were increased in summers with intensifying UHI, where there were more than 30 hot days in two years of 2010 and 2017 with highest temperature of 42 °C that exceeded threshold value of

37.55 °C. As an overall result, such work would gradually be applicable in suggesttion relevant strageties for mitigation the adverse effects of UHI on stakeholders.

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