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Impact of Built-up Areas Surrounding the International Baghdad Airport on Aviation Meteorology

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Urbanization expansion, International Baghdad Airport, Built-up Index, Air temperature, Wind shear

Abstract
This study focuses on the development of urbanization around International Baghdad Airport and its impact on aviation meteorology in terms of the vertical changes of air temperature and wind. Based on the results published in [Zeina, Al-Jiboori 2023], built-up areas were calculated using the satellite images of Landsat in ArcGIS 10.7 software in the month of July in five-year intervals between 1985 and 2020: 1985, 1990, 1995, 2000, 2005, 2010, 2015 and 2020. The result shows that surface air temperature has the lowest value, at 34.85 °C, in 1985, and the highest one, at 39.55 °C, in 2020. Variations in wind shear were also observed in 1990, 2005 and 2015 with a value of 0.06 s-1, while 2000 and 2020 both had a value of 0.054 s-1. In representing the relationship between the extracted areas and their meteorological parameters, we found a weak positive relationship between Built-up Index (BUI) area and air temperature, and a significant positive correlation between BUI areas and wind shear.

1. INTRODUCTION

The surrounding land – and boundaries of airspace – around airports must remain free of obstacles for aircraft to perform their operations safely at the airport; the airport cannot be used if there is a proliferation of obstacles in those areas. The impact of escalating extreme weather conditions or high-impact weather occurrences in these areas will also be significant; for example, extreme air temperatures and heat waves, and the negative health effects associated with them, are more frequent [Wahab et al. 2022]. Neglecting variations in urban density and potential urban intensification may result in an underestimation of an urban heat island's scale, particularly in a city's densest areas. Intensified urbanization has the potential to elevate temperatures in some of the city's hottest areas, and future research should strive to include more realistic urban expansion scenarios, for example, by using government plans in the design of scenarios [e.g. Nichol et al. 2013; Chapman et al. 2017].

Urban expansion is defined as the physical extension of the geographical footprint of towns, cities, and metropolitan areas into the surrounding countryside, which impacts aircraft during takeoff or landing. It also causes turbulence, which can cause aviation accidents that lead to material and human losses [Kreuz et al. 2017].

Air temperature also has an important influence on the formation of meteorological dangers. In the areas of fuel capacity and interpretation, it also has a direct impact on airplane safety. In nonstop intercontinental travel, because fuels expand as air temperature rises, the outside temperature at the airport during fueling may have an impact on an aircraft's fuel storage capacity [Chevron 2006]. Fuels may also gel or freeze in extremely low temperatures [Keel et al. 2000]. Because there is a positive relationship between expanding urbanization and air temperature, as well as an inverse relationship between said urbanization and solar radiation and wind speed, the growth of green areas without adequate coordination will have an impact on the local ecosystem [Abdulrahman et al. 2020; Al-Jiboori et al. 2020]. Replacing vegetation with impermeable surfaces results in warming, which will alter the local urban climate and change ecological conditions [Dong et al. 2014].

Weather is a primary contributing factor in 23% of all aviation accidents. The total global economic impact of weather, in terms of accidents, damage and injuries, delays, and unexpected operating costs, is estimated to be $3 billion [Kulsea 2002]. Many meteorological parameters, such as heavy precipitation, lightning, turbulence, dust or sand storms, heat waves, and wind, influence aviation, impacting operational performance, the infrastructure of airports and aircraft, and working conditions at outdoor aviation activities [International Civil Aviation Organization 2005].

In the present study, the latter two parameters, which are particularly sensitive to changes in surface properties,

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are examined as to how they are affected by urban expansion in Baghdad, in terms of air temperature and low-altitude wind shear. Wind shear is a change in wind speed and/or direction that can occur either horizontally or vertically and is most often associated with frontal activity, thunderstorms, temperature inversions or surface obstructions [Federal Aviation Administration 2008]. Wind shear can also occur at high or low altitudes; here we only discuss low-altitude vertical wind shear, which tends to have the most serious effect on an aircraft.

There are many studies about aviation meteorology. For example, Hahn [1989] studied the effect of wind shear on flight safety. The study found that wind shear affects the flight performance as well as the aircraft motion, especially low-level wind shear during landing and take-off. Schultz et al. [2018] showed that airport performance scores could be used in comprehensive air traffic network simulations to evaluate the impact across the network of weather-induced local performance deterioration. Wind shear was significantly observed at higher wind speed conditions (^{3} 6 ms^{-1}) [Hon, Chan 2022] and complex terrain [Xu, Niu 2019]. Recently, Chan et al. [2023] have applied large-eddy simulation around the Hong Kong International Airport, which proved to be a reasonable method of capturing low-level wind shear in the springtime.

There has also been some research on changes in land cover change in Baghdad specifically. For example, Al-Saadi et al. [2020] studied the varieties of urban vegetation cover and their impact on minimum and maximum heat islands. The study demonstrated that maintaining and expanding plant cover in semiarid urban contexts is the most effective technique for lowering the possibility of thermal impacts and heat stress, which are worsened by regional and global warming. Ali and Al-Ramahi [2020] also studied the influence of urbanization on annual evaporation rates in Baghdad City using remote sensing and showed that vegetation plays a key role in lowering temperatures and minimizing urban heat islands.

The main contribution of this paper is to document the effect of urbanization expansion surrounding airports on aviation meteorology and air traffic at lower elevations.

Urban expansion in Iraq, especially in the areas surrounding the International Baghdad Airport (IBA), has brought with it urban land changes, such as an increase in built-up surfaces, roads, bridges and other impermeable surfaces. This has been considered a random expansion resulting from population growth, as well as political conditions and military operations in the country. However, there is very little understanding about the relationship between the growth of urban areas and meteorological parameters. The parameters most related to this subject are vertical changes in the air temperature and winds over a long-term period. The objectives of this study are to 1) determine the annual variations in built-up areas surrounding Baghdad International Airport (IBA); 2) analyze monthly means for both temperature and wind shear for only July over eight years; and 3) establish empirical relationships correlating urban expansion around IBA with these parameters. The structure of the paper is organized as follows: section 2 provides the details of study area and data collection sources. Section 3 presents the analysis procedure with a flow diagram. In the following section, descriptions of the built-up index, climate factors, and their combined effects are discussed. Finally, a summary of main conclusions is reported in section 5.

2. SITE AND DATA

2.1. Study area

The area of study for this paper (see Figure 1) was around IBA, located in the west of the capital of Iraq, Baghdad, on

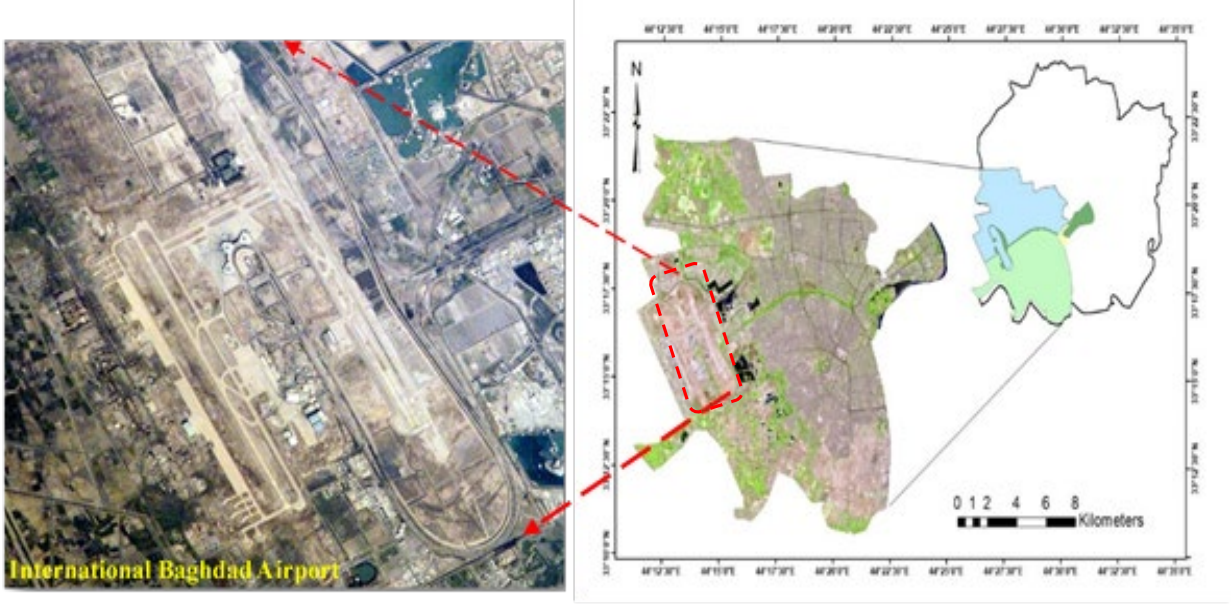


Figure 1. A picture of the study area (left) with its location in the southwest of Baghdad (right)

Table 1. Some properties for Landsat images and their acquisition dates

Satellite	Sensor	No. of bands	Acquisition date
Landsat-5	TM	7	1985/07/29
Landsat-5	TM	7	1990/07/11
Landsat-5	TM	7	1995/07/09
Landsat-7	EMT+	8	2000/07/14
Landsat-5	TM	7	2005/07/27
Landsat-5	TM	7	2010/07/18
Landsat-8	OLI	11	2015/07/23
Landsat-8	OLI	11	2020/07/20

the Karkh side. It includes three municipalities: Green Zone, through which the Airport Highway runs for 12 km, Al-Mansour, and Al-Rashid. The total area of the study covers about 266 km^2. Geographically, the region has 33.2625° N latitude, 44.2344° E longitude, and a height of 35 m above mean sea level. Between 1985 and 2020, it has witnessed several changes in vegetation cover and the emergence of low-rise blocks, as well as more compact buildings.

After 2003, especially in this part of Baghdad, the state has turned to a vertical construction method, building more residential complexes with the goal of achieving comprehensive urban development. There are 78% more vertical investment residential complexes on the western side of the capital (Al-Karkh) than on the eastern side (Al-Rusafa), due to the presence of larger building lots on the Al-Karkh side and the higher incomes of its residents [Al-Ani 2021].

2.2 Data sources

2.2.1. Satellite images

In this quantitative study, changes in the built-up surface were investigated using eight Satellite Landsat images at intervals of five years, spanning from 1985 to 2020. One image of from July of each year was acquired to provide a reliable representation of urban and vegetation coverage. July was chosen because the weather in Baghdad is usually clear and cloudless at this time, resulting in clearer and higher-resolution images. Satellite images from Landsat-5 Thematic Mapper (TM), 7 Enhanced and Thematic Mapper plus (EMT$^+$) and 8 Operation Land Imager (OLI) data were obtained from United States Geological Survey [https://earthexplorer.usgs.gov]. Satellite characteristics, with the sensor, number of bands, and date of image acquisition for each one, are reported in Table 1. All images were captured at path/row 37/168, except the one from Landsat-8, which was at 37/169. They all use the WGS84 system and are in the UTM system (Zone 38 N). For surface details measured in meters, the research region was download by sub-setting the image in a square area. The data is in TIFF format with a spatial resolution of 30 m x 30 m at 16-bit radiometric resolution.

2.2.2. Meteorological data

The monthly air temperature and wind speed data used in this study were acquired from the NASA Prediction of Worldwide Energy Resources (https://power.larc.nasa.gov) with grid points of 0.1° × 0.1°. The dataset was downloaded for the point within Baghdad City defined by latitude (33.25° N) and longitude (44.25° E); air temperature (in °C) was measured at an altitude of 2 m and wind speed was measured at 10 and 50 (in m/s), at 5-year intervals during the period between 01/01/1985 and 01/09/2020. Owing to the lack of the radiosonde data at the Iraqi Meteorological Organization and Seismology, such data was not approved. The standard height for measuring winds is about 10 m; higher altitudes were needed to calculate wind shear.

3. METHODOLGY

First, in order to assess the random and continuous development and expansion of Baghdad City, we adopted the Builtup Index (BUI) proposed by Zha et al. [2003] to quantify the changes between urban built-up areas and other land-cover types. BUI is the spectral index for analyzing urban patterns based on the difference between normalized difference building and vegetation indexes. It can calculate using the following equation (1):

$$\mathrm{BUI} = \left(\frac{\mathrm{MIR} + \mathrm{NIR}}{\mathrm{MIR} - \mathrm{NIR}}\right) - \left(\frac{\mathrm{NIR} - \mathrm{RED}}{\mathrm{NIR} + \mathrm{RED}}\right)$$

where MIR is the Middle Infrared = Band 5 for Landsat-5 and 7 and = Band 6 for Landsat-8; NIR is the Near Infrared = Band 4 in Landsat-5 and 7 and = Band 5 for Landsat-8; and RED is Red = Band 3 in Landsat-5 and 7 and = Band-4 in Landsat-8.

This advantage of this method is its unique spectral response to buildup area and its ability to automatically quantify a spatial pattern. The output binary image shows positive pixels for builtup and barren areas, and the rest of pixel for all other covers [Zha et al. 2003; Tawfeek et al. 2020]. The binary image, with only higher positive value indicating built-up and barren areas, used in ArcGIS program, version 10.7, allows the BUI to map the built-up area automatically. For more details, pre- and post-processing of satellite images, such as clipping, compositing, mosaic bands and extraction of the study area, are explained by Zeina and Al-Jiboori [2023].

The second part of our methodology was the analysis of daily climate data of the two factors of air temperature and wind shear. Wind shear is a change in wind speed and/or direction over a short distance. It can occur either horizontally or vertically, and is most often associated with strong temperature inversions or density gradients [Al-Ghrybawi, Al-Jiboori 2019]. In this study, this was only calculated for July of each year. This month was selected to coincide with the satellite images analyzed in this study. The air temperature (°C) at 2 m, during the period

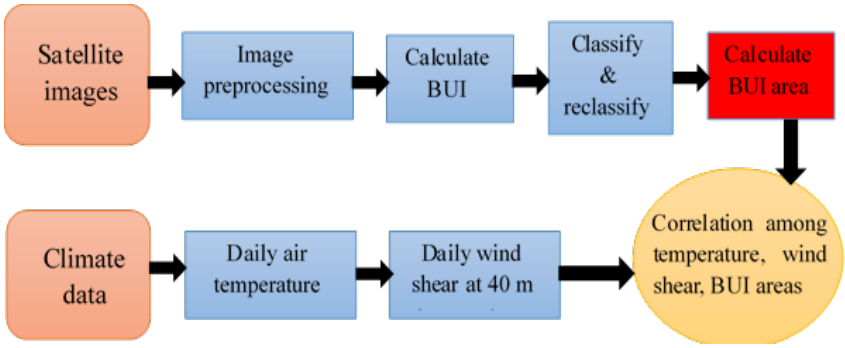


Figure 2. Flowchart of methodology

between 01/7/1985 and 31/07/2020, and wind speed, measured at two heights 10 (U_{10}) and 50 m (U_{50}), during the period between 01/01/1985 and 01/09/2020, were used. "Monthly" means these data were calculated only for the July of each year for this study. From the mean wind speed, the mean wind shear was calculated in (s^{-1}) using the equation (2):

$$\text{Wind shear} = \frac{\overline{U}_{50} - \overline{U}_{10}}{Z_{50} - Z_{10}} = \frac{\overline{U}_{50} - \overline{U}_{10}}{40}$$

where $\overline{U}_{50}$ is the mean wind speed at the height of 50 m (Z_{50}) and is the $\overline{U}_{50}$ mean wind speed at 10 m (Z_{10}).
In third part of the study, the built-up indexes, average air temperatures, and wind shear values were projected on two charts using the Origin 9.2 program, showing the extent to which the air temperatures are proportional to the BUI of the area, as well as to wind shear. These were analyzed using the linear regression equation (3):

$$Y = \delta + \varepsilon * X$$

where Y is the air temperature, wind shear, or any dependent variable, and X is the built-up area, time, or any independent variable. The constant a is the intercept and b represents the slope. The values of a and b were derived from the experimental data above.
Finally, the statistical parameter R^2 was used to measure of the goodness of fit of a real point data, which when close to 1 indicates that the regression predictions perfectly fit the data. According to the discussion above, the methodology of this study can be summarized in the flowchart shown in Figure 2.

4. RESULTS AND DISCUSSION

4.1. BUI areas

Based on Eq. (1), UBI pixels with positive values representing the built-up surface were assigned to classes or groups. The digital areas of the BUI were calculated after postprocessing to classify and reclassify images according to their BUI. The BUI results presented in Figure 3 show that the highest value of the urban expansion area was in 2015, when it reached 181.1 km^2, forming 68% of the total area. This indicates that many commercial centers were established within the study area, as well as several vertical residential complexes, where the number of completed and under-construction units exceeded 348 units, across a number of 4-to-33 story buildings [Al-Ani 2021]. The lowest value was in 2000, at approximately 118.5 km^2, forming 4% of the total area. Around this time, political instability meant that Iraq was going through the worst economic conditions within the time range of the study. More discussion of the relationship between built-up area size and vegetation cover can be found in Zeina and Al-Jiboori [2023]. The increase in urbanization expansion in our study area is also substantiated by Al-Jiboori et al. [2020], which studied land use changes at two-year intervals between 2000 and 2015 across the whole of Baghdad.

4.2. Analysis of climate factors

Daily meteorological metrics (mean air temperature at 2 m, and wind speed measured at two heights, 10 and 50 m) were obtained from climate data sourced from NASA. The temporal and spatial variability of the monthly mean for July in the area around IBA were studied for the years 1985, 1990, 1995, 2000, 2005, 2010, 2015 and 2020. The results can be described below:

Monthly mean air temperature
The results of the monthly means of both air temperature and wind shear are presented in Figure 4. After analyzing these variables, we noticed that the relationship between monthly mean temperature and the studied years in this paper can be described as a general linear increase; its value in 1985 was 34.85 °C, reaching 39.55 °C in 2020, which causes greater flight turbulence, indicating a future impact on aviation. As a result of land stripping and the increase in urban space, weather conditions will be affected in the future. Using Eq. (3), the line of best fit (dashed line) was passed through the data points, deriving empirical constants – for example, intercept = -175.1 and slope (or trend) = 0.11 °C – every five years, with a moderate

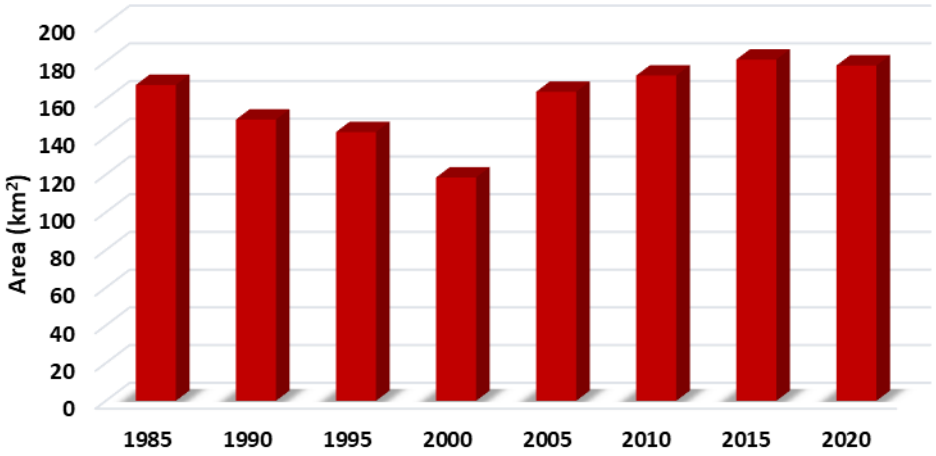


Figure 3. Histogram of the built-up areas according to the years studied

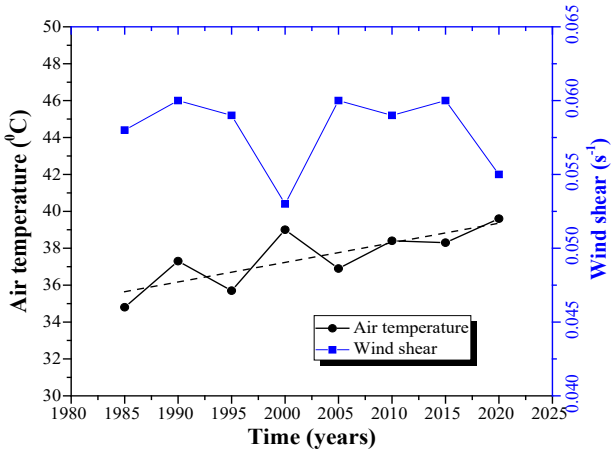


Figure 4. Time series of air temperature and wind shear for July for the studied five-year intervals

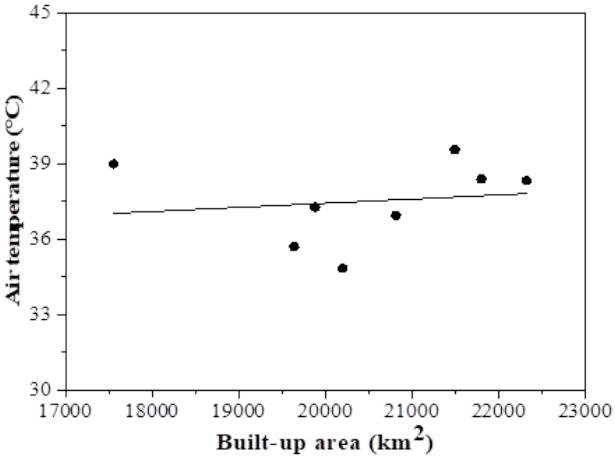


Figure 5. Monthly air temperature vs. BUI area

goodness of fit ($R^2 = 0.62$). For the sake of comparison, this trend equals 0.022 °C per year when divided by 5, which is less than the 0.06 °C per year reported in Wahab et al. [2022]. This difference is expected because of different sources of data used in these two papers.

Monthly mean vertical wind shear

Using the wind speed data recorded at 10 and 50 m, low-altitude wind shear values were calculated for July using the vertical difference in wind speed divided by a depth of 40 m. The results are shown also in Figure 4. All values of vertical wind shear are positive, meaning that the values at wind speed 50 m were larger than those at 10 m. The highest values of wind shear were observed in 1990, 2005 and 2015 (0.06 s^{-1}), while the lowest values were 0.053 s^{-1} in 2000 and 0.055 s^{-1} in 2020. There is a difference in vertical wind shear across the years of study, but their values have no regular behavior in the manner that air temperature does.

4.3. Effect of BUI on some aviation meteorological parameters

To determine the effect of built-up surface on aviation parameters (air temperature and wind shear), the monthly means was plotted on a Y-axis against the area of BUI on the X-axis (see Figures 5 and 6, respectively). The data points in these figures were fitted to the general expression (Eq. 3) with the resulting values of the empirical constants a and b reported in Table 2. They are presented to estimate the relationship of BUI with air temperature and wind shear for the years 1985, 1990, 1995, 2000, 2005, 2010, 2015 and 2020. There is a direct relationship between the increase in air temperature and the increase in the urban expansion, as well as an increase in the value of wind shear. Figure 5 shows the linear relationship between the BUI area and the monthly July air-temperature mean, with no scattering of data.

Table 2. Statistical items for the relation between BUI area and temperature wind shear

Relation between	Intercept (a)	slope (b)	R^2
BUI and air temperature	34.13	1.64	0.152
BUI and wind shear	0.03	5.67	0.57

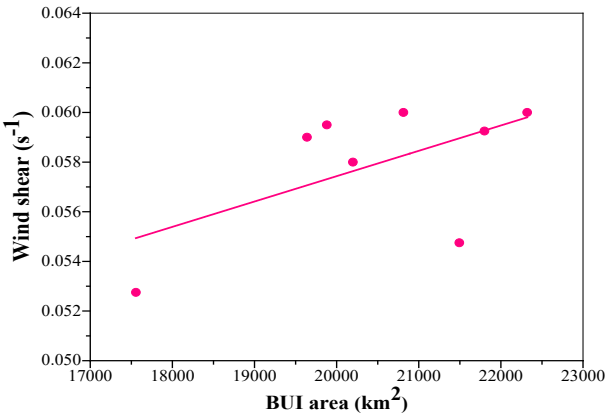


Figure 6. The relationship between wind shear (s^{-1}) and BUI area (km^2)

The relationship has clearly increased with the increase in BUI area. The value of intercept, a, equals 34.13, while the slope has the small value 1.65 °C/km^2 with an R^2 value of 0.152. Therefore, the urban expansion, shifting toward the IBA, resulted in increased air temperature with a slope of 0.27 °C/km^2.

During analysis of wind speed at heights of 10 and 50 m to calculate vertical wind shear, it was observed that all the values of wind shear are positive, i.e. there is a wind-speed between heights of 10 and 50 m. The main factors impacted by sensitivity to wind shear were shown to be air speed, flight path regulation, and air speed regulation. The shear dependency, as modeled in the simulation of Lehman [1978], was also important. Figure 6 shows the relationship between BUI area and monthly means of wind shear per second, in which the data points have more scattering.

Despite the high scattering, the results showed that there was a direct linear relationship between BUI areas and wind shear, with the wind shear value increasing with the BUI area value. The line of best fit for all the data shows a sharp-increase behavior, with an intercept value of a=0.03, slope of 5.67 $(s.km)^{-1}$ and R^2 of 0.572. This slope has a high gradient with BUI area.

5. CONCLUSION

In this study a statistical method was presented to determine the impact of the urban expansion on aviation micrometeorology around International Baghdad Airport between 1985 and 2020. The changes in land cover showed that there is an impact on the local climate, and the following conclusions can be drawn:

- The mean air temperature was continuously increasing, with the highest temperatures recorded in 2020. It is possible that this is related to decreases in the amount of vegetation cover as a result of the conversion of agricultural and open land to populated and commercial areas and commercial usage. Aside from that, there are also some random settlements.
- Clear differences in vertical wind shear were observed during the study years 1990, 2005 and 2015, where the highest value observed was 0.06 s^{-1}. There could be several factors contributing to this, surface roughness being just one of them.
- There was a direct linear relationship between BUI area with air temperature and wind shear, where a weak upward relation was found between BUI area and air temperature, and a significant upward relation was found between BUI area and wind shear.

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REFERENCES AND LEGAL ACTS

AL-ANI M.A.I. 2021. The efficiency of vertical housing complexes in the city of Baghdad and ways to develop them for the period 2003-2020. Baghdad: College of Art, Iraqi University.

ALI A.K. Al RAMAHI F.K. 2020. A study of the effect of urbanization on annual evaporation rates in Baghdad city using remote sensing. Iraqi Journal of Science, 2142–2149.

ALI Z.R., MUHAMEED A.S. 2016. The study of temporal change on land cover/land use prevailing in Baghdad governorate using RS & GIS. The Iraqi Journal of Agricultural Sciences, 47, 3: 846–855.

AL-GHRYBAWI S.R., AL-JIBOORI M.H. 2019. Study of surface heat inversions characteristics around Baghdad station, Scientific Review–Engineering and Environmental Sciences, 28, 4: 610–618. doi: HYPERLINK "https://

doi.org/10.22630/PNIKS.2019.28.4.55" https://doi.org/10.22630/PNIKS.2019.28.4.55 .

AL-JIBOORI M.H., ABU AL-SHEAR M.J., AHMED M.M. 2020. Impact of land surface changes on air temperatures in Baghdad. Kuwait Journal of Science, 47, 4: 118–126.

AL-SAADI L M., JABER S.H., AL-JIBOORI. M.H. 2020. Variation of urban vegetation cover and its impact on minimum and maximum heat island. Urban Climate 34.

ASGARIAN A., AMIRI, B.J., SAKIEH Y. 2015. Assessing the effect of green cover spatial patterns on urban land surface temperature using landscape metrics approach. Cab Direct 209–222.

CAPA Center for Aviation. 2019. Climate change: its impact on aviation. The time to plan is now. Informa PLC. Retrieved Feb. 4, 2022, from https://centreforaviation.com/analysis/reports/climate-change-its-impact-on-aviation-the-time-to-plan-is-now-454475.

CHAN P.W., LAI K.K., LI Q.S. 2023. Performance of large-eddy simulations for capturing low-level wind shear at the Hong Kong International Airport for a whole wind-shear (spring) season. Atmospheric Dynamics 32, 5: 383–394. doi: 10.1127/metz/2023/1122.

CHAPMAN S. 2017. The impact of urbanization and climate change on urban temperatures: a systematic review. Landscape Ecology 32, 6. doi: HYPERLINK "https://link.springer.com/article/10.1007/s10980-017-0561-4" \t "_blank" 10.1007/s10980-017-0561-4

CHAPMAN S., WATSON J.E., SALAZAR A., THATCHER M., MCALPINE C.A. 2017. The impact of urbanization and climate change on urban temperatures: a systematic review. Landscape Ecology, 32, 10: 1921–1935. doi: 10.1007/s10980-017-0561-4

CHEVRON. 2006. Aviation Fuels Technical Review. Chevron Corporation.

DOAN P., ODURO C.Y. 2012. OduroPatterns of population growth in peri-urban Accra, Ghana. International Journal of Urban and Regional Research 36, 6: 1306–1325. doi: 10.1111/J.1468-2427.2011.01075.X

DONG W.H., LIU Z., ZHANG L.J., et al. 2014. Assessing heat health risk for sustainability in Beijing's urban heat island. Sustainability 6, 7334–7357.

FEDERAL AVIATION ADMINISTRATION. 2008. Wind Shear. Retrieved from http://FAASafety.gov.

GISGeography 2021. Retrieved from https://gisgeography.com/ndvi-normalized-difference-vegetation-index/

HAHN K.U. 1989. Effect of wind shear on flight safety. Progress in Aerospace Sciences 26, 23: 225–259. doi:10.1016/0376-0421(89)90004-3

HON K.K., CHAN P.W. 2022. Historical analysis (2001-2019) of low-level wind shear in Xining Airport. Meteorological Applications 29, 2: e2063. doi: 10.1002/met.2063.

INTERNATIONAL CIVIL AVIATION ORGANIZATION. 2005. Manual on Low-Level Wind Shear (1st Ed.).

KEEL. 2000. Aviation Weather Information requirents study. Virginia: National Aeronautics and Space Administration.

KREUZ M., LUCHKOVA T., SCHULTZ. 2017. Effect of restricted airspace on the ATM system. World Conference on Transport Research. Shanghai.

KULSEA G. 2003. Weather and aviation: How does weather affect the safety and operations of airports and aviation and how does FAA work to manage weather-related effects? Environmental Science. Retrieved from https://www.transportation.gov/sites/dot.gov/files/docs/kulesa_Weather_Aviation.pdf

LEHMAN. 1978. Aviation; Safety and Human Factors. National Technical Information Service.

MOBARAKI O., MOHAMMADI J. and ZARRABI A. 2012. Strategy for sustainable urban development: A case study of Urmia city. Greener Journal of Social Sciences 2, 1: 41–49. doi: 10.15580/GJSS.2012.1.GJSS1203

NICOL J., HANG T.P., EDWARD N.G. 2014. Temperature projection in a tropical city using remote sensing and dynamic modeling. Climate Dynamics 42, 11–12: 2921–2929.

RAHNAMA R. ABBASZADEH G.R. 2006. Comparative study and analyzing compactness/Sprawl ratio In the Metropolitan cities of Mashah And Sydney. Journal of Geography and Development, 101-128.

SCHULTZ M., LORENZ S., SCHMITZ R., DELGADO L. 2018. Weather impact on airport performance. Aerospace 5, 4: 1–19. Doi: 10.3390/aerospace5040109

SHIFLETT S.A., LIANG L.L., CRUM S.M., FEYISA G.L., WAND J., JENERETTE G.D. 2016. Variation in the urban vegetation, surface temperature, air temperature nexus. Science of the Total Environment 579: 495-505.

TAWFEEK Y.Q., JASIM F.H., AL-JIBOORI M.H. 2020. A study of canopy urban heat island of Baghdad, Iraq. Asian Journal of Atmospheric Environment 14, 3: 280–288. doi:10.5572/ajae.2020.14.3 280

TIN S.N., MUTTITANON, W. 2021. Analysis of enhanced built-up and bare land index (EBBI) in the urban area of Yangon. International Journal of Geoinformatics 17, 4: 85–96. doi:10.52939/ijg.v17i4.1957

WAHAB B.I., NAIF S.S., AL-JIBOORI M.H. 2022. Development of anuual urban heat island in Baghdad under climate change. Journal of Environmental Engineering and Landscape Management 30, 1: 179–187. doi: 10.3846/jeelm.2022.16374

WILSON E.H., HURD J.D., CIVCO D.L., PRISLOE M.P., AMOLD C. 2003. Development of a geospatial model to quantify, describe and map urban growth. Remote Sensing of Environment 86, 3: 275–285. doi: 10.1016/S0034-4257(03)00074-9.

ZEINA T.M., AL-JIBOORI M.H. 2023. Assessing urbanization in the surroundings of International Baghdad Airport using Landsat data. IOP Conference Series: Earth and Environmental Science 1223: 012021. doi: 10.1088/1755-1315/1223/1/012021.

ZHA Y., GAO I., NI S. 2003. Use of normalized difference built-up index in automatically mapping urban areas from TM imagery. International Journal of

Remote Sensing 24, 3: 583–594. doi: HYPERLINK "https://doi.org/10.1080/01431160304987" 10.1080/01431160304987

XU T., NIU W. 2019. A case study of low-level wind shear in Xining Airport. E3S Web of Conference, 131. doi: 10.1051/e3sconf/201913101037.

SUMANOVAC D. 2008. Critical Situations and the Flight Safety System, Promet-Traffic & Transportation 20, 4: 223-229. doi: 10.7307/ptt.v21i4.1005