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A Study on Vulnerability of Alahsa Governorate to Generate Urban Heat Islands

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Abstract**—**The purpose of this study is to investigate Alahsa Governorate status and its vulnerability to generate urban heat islands. Alahsa Governorate is a famous oasis in the Arabic Peninsula including several oil centers. Extensive literature review was done to collect previous relative data on the urban heat island of Alahsa Governorate. Data used for the purpose of this research were collected from authorized bodies who control weather station networks over Alahsa Governorate, Eastern Province, Saudi Arabia. Although, the number of weather station networks within the region is very limited and the analysis using GIS software and its techniques is difficult and limited, the data analyzed confirm an increase in temperature for more than 2 °C from 2004 to 2014. Such increase is considerable whenever human health and comfort are the concern. The increase of temperature within one decade confirms the availability of urban heat islands. The study concludes that, Alahsa Governorate is vulnerable to create urban heat islands and more attention should be drawn to strategic planning of the governorate that is developing with a high pace and considerable increasing levels of urbanization.

Keywords**—**Urban heat island, Alahsa Governorate, weather station, population density.

I. Introduction

ALAHSA Governorate is located in the South-eastern corner of Saudi Arabia occupying the southern part of the eastern region between 17-26 latitudes and 48-55 longitudes. Alahsa climate has hot dry summers and cool rainy winter [5].

Alahsa Governorate covers a vast area of around 530 000 km^2, representing 68% of the area of the eastern region and 24% of the area of Saudi Arabia. It is considered as the largest oases in the Arabic Peninsula. It is famous for palm cultivation [6].

According to Census 2010, the population of Alahsa province is 1, 063, 112 people. The Governorate consists of many cities and villages in addition to the most famous empty desert that is called Empty Quarter. Hofuf and Mubarraz are the oldest and most developed urban cities in the region [1]. Hofuf city is considered as the capital city because of its economic role in the region. Its economic role increased after the discovery of oil in Eastern Province of the Kingdom in 1939. Several oil centers are in Alahsa Governorate. The most famous field is named Al-Ghawar. It is considered as the largest oil filed providing more than half of the cumulative oil production of Saudi Arabia. It measures 280 by 30 km x"[1].

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II. Historical Background

Because of population growth and continuing migration to both Hofuf and Mubarraz cities, urban development passed over four stages during the period 1957-2012 [1]

A. First Stage: Before 1963

This stage is considered as the city origination phase. Water is one of the most important foundations for the emergence of the region and the stability of human. Wherever springs and water wells are located, communities are formed. Hofuf and Mubarraz cities are famous of their permanent springs and water wells that help in formalizing the cities and affect the level of urbanization by increasing the rate of migration. They are characterized by tribal groupings communities having their own lands and natural resources [1].

The first phase was characterized as the phase of looking for the best position to stabilize population making use of the presence of wells and springs as a source of permanent water for drinking and agriculture. The stability of the region was supported by the discovery of oil in 1939 in Eastern region that led to the evolution of national income and creation of municipal system that affects action plans for development and supervision. Fig. 1 shows an aerial view to Hofuf and Mubarraz during first stage of growth before 1963 [1].

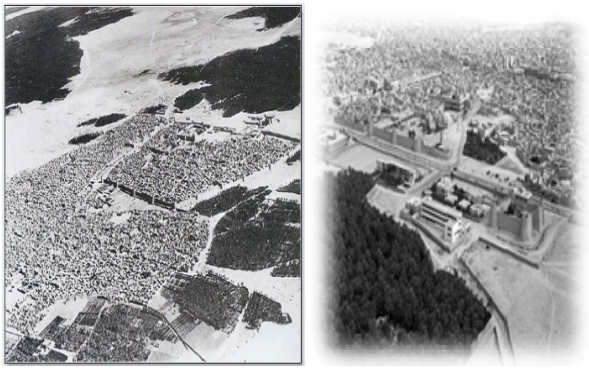

Fig. 1 First growth stages for Hofuf and Mubarraz before 1963 [1]

B. Second Stage: 1963-1973

This stage is considered as growth and configuration phase. The region passed through many urban growth stages during these ten years. Documented economic and social changes were recorded during this decade with noticed urban growth rates and development especially in the development of transport networks. Five-year development programs started with the concurrent trebling increase in oil prices. That directly affected the whole country income and lead to

doubling of national incomes. New neighborhoods were built at both Hofuf and Mubarraz towns. Population grown as well as commercial activities increased on main streets in the heart of the metropolis. The expansion of development at that time was in southern and Western directions of the region and its commercial centers. At that stage, major services and Government departments were centered at Hofuf town and a transportation system connected the town with Mubarraz town. Therefore, at this stage Hofuf was considered as administrative capital of the surrounding territory [1].

C. Third Stage: 1973-1994

This is stage is considered as the evolution and jump development phase. Because of the accumulation of wealth and escalating economic development, substantial urban growth rates were recorded in Alahsa specifically in Hofuf and Mubarraz. In this period, employment of non-Saudi labor, expatriates, started to satisfy development and reconstruction operations' needs. This phase was characterized by urban extension towards the West and South, resulting in the emergence of residential buildings on both sides of the new roads that stretch beyond the capital of Hofuf. Due to the increased migration of nomads, districts were formed as Alrogaigah District. At this stage Hofuf started to take its current form as a capital city [1].

D. Fourth Stage: 1994- 2012

This stage is the recent recorded phase. A considerable increase in urban growth in Alahsa Governorate took place; from 7649 to 22869 Acre of built area. The growth in city of Hofuf was from 3730 to 14877 Acre, which influenced the current urban development. Moreover, the approved expected urban growth is 38000 Acres in 2028 by adding approximately 19000 Acres to Hofuf and Mubarraz City. Fig. 2 shows urban growth stages and trends in Hofuf and Mubarraz [1].

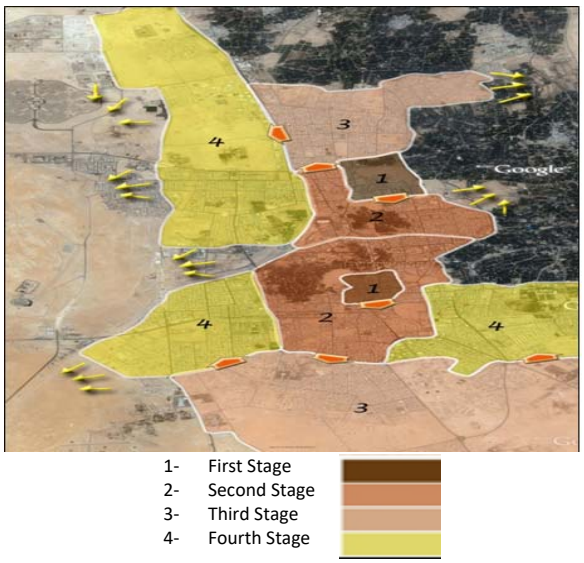

Fig. 2 Stages and trends of urban growth in Hofuf and Mubarraz City [1]

III. Material and Method

Data were collected from authorized bodies who control weather station network over the study area, Alahsa Governorate, Eastern Province, Saudi Arabia. After a comprehensive and long investigation, there are only three weather stations covering Alahsa Governorate. Below is detailed information about them:

A. Alahsa Meteorological Station

Alahsa Meteorological Station is counted as the main and oldest authorized governmental meteorological station in the region. It works under ministry of Defense and Aviation, presidency of Meteorology and Environmental Protection, National Meteorology and Environmental Center. It is located inside Alahsa Airport premises at 25 17 53 N Latitude and 49 29 11E Longitude, 178.17 m Elevation. The data collected from this station are for 2004 and 2014 for three months that are counted as the hottest months of the year [5]. Accordingly, the data used are for June, July and August.

B. Training, Agricultural & Veterinary Research Center (TAVRC) Meteorological Station

The TAVRC Meteorological Station is located inside King Faisal University (25.3401 latitude and 49.5968 longitude) within the premises of the Training, Agricultural & Veterinary Research Center. The data collected from this station are for less than two years. It is for 2013 and 2014, which is the maximum data that could be provided by the authorized bodies. According to the purpose of the study, the data used from this station are confined to 2014 to match the data collected from Alahsa Meteorological Station while data for 2013 is excluded from analysis.

C. College of Engineering Meteorological Station

The third station is located inside King Faisal University too. It is controlled by King Abdulaziz City for Science and Technology and College of Engineering, King Faisal University. It is the latest station established before three years. Although its data are very recent, it will help in comparing the data collected from other stations for 2014. Nevertheless, data retrieval process for the station is on hold waiting for renewing of contract between King Faisal University and King Abdulaziz City. Therefore, data is not included for this study.

The data collected from the above-mentioned stations are used mainly to investigate the temperature pattern over the Governorate. Fig. 3 shows the location of Alahsa Airport and King Faisal University using Google maps on Saturday, April 30, 2016. TAVRC Meteorological Station is located within the most populated well developed urban area in Hofuf city. While Alahsa Meteorological Station is located at the far end of the city in a less populated and less developed area. Reference [8] defined the urban heat island as the difference in temperature between the urban and rural areas. Accordingly, the research investigated and analyzed the temperature measured at TAVRC and Alahsa stations during June, July and August of 2014. Moreover, it investigated temperature

measured at Alahsa station in 2004 and 2014 for months of June, July and August.

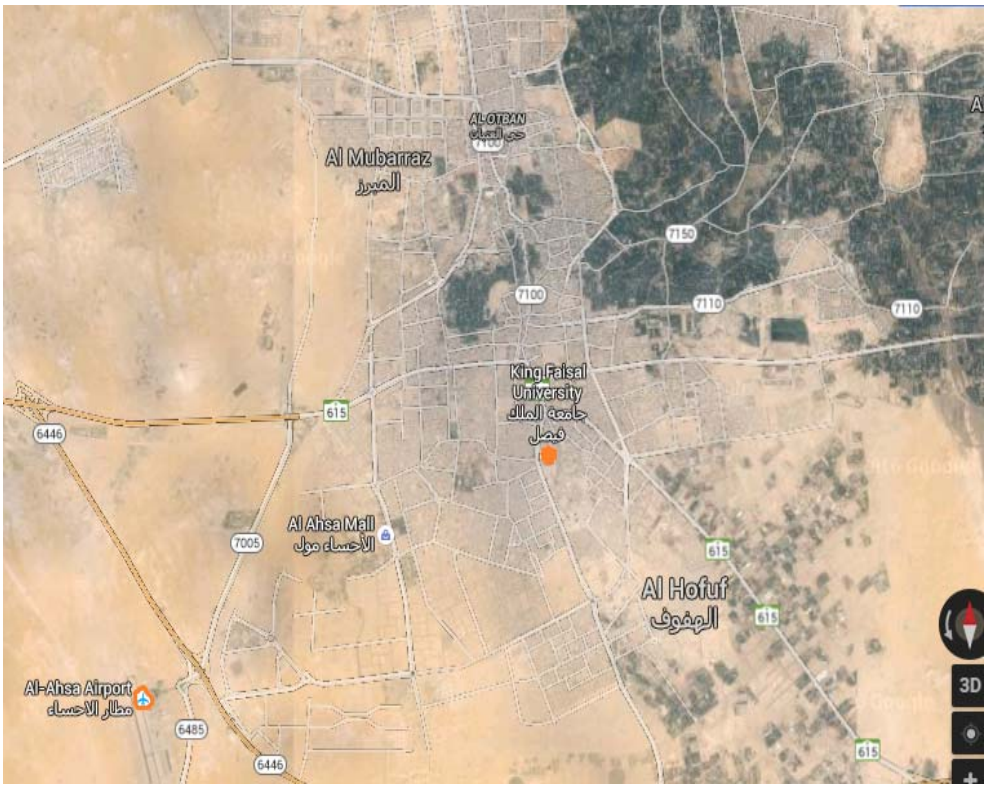

Fig. 3 The location of Alahsa Airport and King Faisal University [4]

III. Results and Discussion

A. TAVRC and Alahsa Stations during June, July and August of 2014

Fig. 4 shows the average maximum temperature measured in degree Celsius at TAVRC and Alahsa station during June, July and August 2014. The difference in maximum temperature between the two stations in the three previously mentioned months is more than 1.5 °C. It reached 2.0 °C during June, 2014 which confirmed that the city centers are always hotter than suburban areas [2].

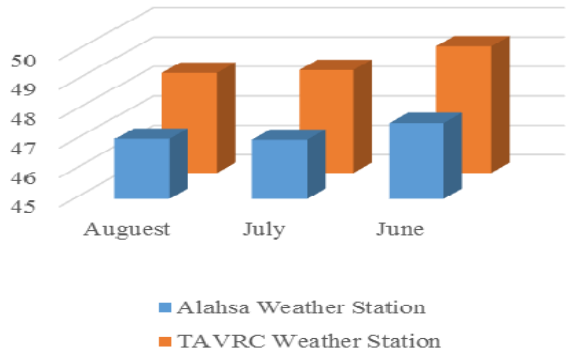

Fig. 4 Maximum temperatures at TAVRC and Alahsa station during June, July and August 2014

B. Alahsa Station in 2004 and 2014

As mentioned previously, the study focuses on the hottest months of the year; June, July and August. Fig. 5 shows the average maximum temperatures measured during June, July and August for 2004 and 2014. The difference in temperature between June 2004 and June 2014 is 2.3 °C while it is 1.5 °C for August. On the other hand, the highest temperature recorded is during July 2004 which is contradicting research expectation for increase in temperature in 10 years' period from 2004 to 2014. The study shows that this highest temperature was accompanied by the heights relative humidity and lowest wind velocity as shown in Fig. 6. Therefore, it is excluded. On the other hand, Fig. 6 shows the average maximum temperature with respect to average mean wind speed, average wind velocity and population for June 2004 and 2014. The chart confirms that there is an increase of temperature with respect to increase of wind speed, velocity and population.

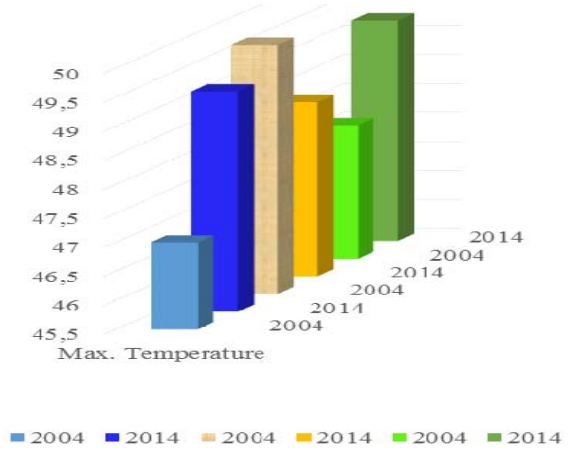

Fig. 5 Maximum temperatures during June, July and August, 2004 and 2014

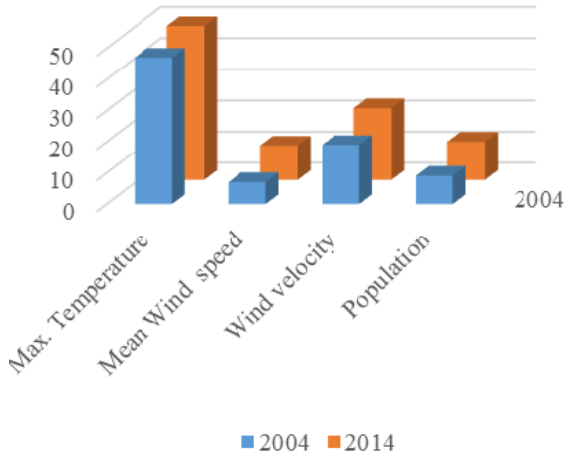

Fig. 6 Max. temperature (^{O}C), mean wind speed, velocity and population, June 2004 and 2014

V. Conclusion

The results of the study confirm previous studies [2], [3], [7], [8] that show that, as the population increases the temperature increases. The study proves that, there is an increase of temperature counted for 2.3 °C for one-decade period from 2004 to 2014. Moreover, it shows that there is variation in the intensity of temperature between TAVRC and Alahsa station counted for 2.0 °C difference. The variation in temperature between Alahsa and TAVRC station confirms the availability of UHI within the area under study. Such variation on temperature confirms the need of extensive research to measure the intensity of this UHI, nucleus of UHI and exact number of HUIs available within the Governorate.

As the study confirms that, Alahsa Governorate is susceptible to occurrence of urban heat islands, further studies are recommended to locate the nucleus of the those UHIs which will contribute much to support decision makers in strategic planning and future development of the governorate that experiencing high pace on urban development with considerable increasing levels of urbanization.

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