Urban Island Modeling for Semi-Arid Cities: The Case of the City of Oujda

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Abstract. There is often a difference between the surface temperature and the various types of land use within cities, where it rises in built-up areas and barren lands and decreases in areas with vegetation cover and dense afforestation. In this study, the urban heat island phenomenon was analyzed by linking the relationship between the different types of land use in the city of Oujda and the surface temperature based on Landsat imagery and some indicators. These indicators include the Normalized Difference Vegetation Index (NDVI), which measures the health and density of vegetation, and the Land Surface Temperature (LST), which provides a direct measurement of the temperature of the land surface. The results showed variations in the surface temperature of the city of Oujda, which rises in areas with a low level of afforestation and vegetation cover, as well as in built-up areas, the industrial district, and barren lands. In contrast, the surface temperature of the land decreases in areas with an increase in vegetation cover. This study found that the impact of the surface temperature varies according to the nature of land use, vegetation cover, and other factors. It highlighted the importance of geographic information systems and remote sensing in studying climate changes and revealing the importance of vegetation cover in reducing this phenomenon.

Keywords: Urban Heat Island, Landsat, NDVI, Oujda, Morocco.

1 Introduction

An urban heat island effect is one of the major problems of modern climatology, ecology, and urban planning [1]. With the rapid development of cities, the heat island effect [2] is becoming increasingly significant and endangering people's health [3]. Health-related challenges associated with heat periods include increased mortality and morbidity [4], emerging urban expansion and densification causing warming in cities. So-called urban heat islands (UHIs) overprint natural conditions in the atmosphere, at the surface, and in the subsurface [5]. Cities are further impacted by the urban heat island (UHI) effect. The UHI is expressed by elevation temperatures within cities compared to their rural surroundings [6]. Oujda City is considered one city that has witnessed significant urban expansion over the recent decades. This expansion has led to a change in land use and the encroachment of urbanization on agricultural lands and vegetation cover. This study aims to estimate the

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surface temperature of Oujda City (LST), relying on Landsat satellite imagery Using ArcGIS. The determination of the LST was based on calculating the NDVI index, the luminosity temperature and the LSE using ArcGIS [7].

2 Data and methods

2.1 Study Area

The city of Oujda is in Morocco's far northeastern part. It is situated at longitude 4°15' W and latitude 34°40' N. Oujda is a border and inland city located within the territorial jurisdiction of the Prefecture of Oujda-Angad, established in 1994. The Province of Berkane borders it to the north, the Province of Taourirt to the west, the Province of Jerada to the south, and the Moroccan-Algerian border to the east. Oujda also belongs to the Oriental Region (Fig. 1).

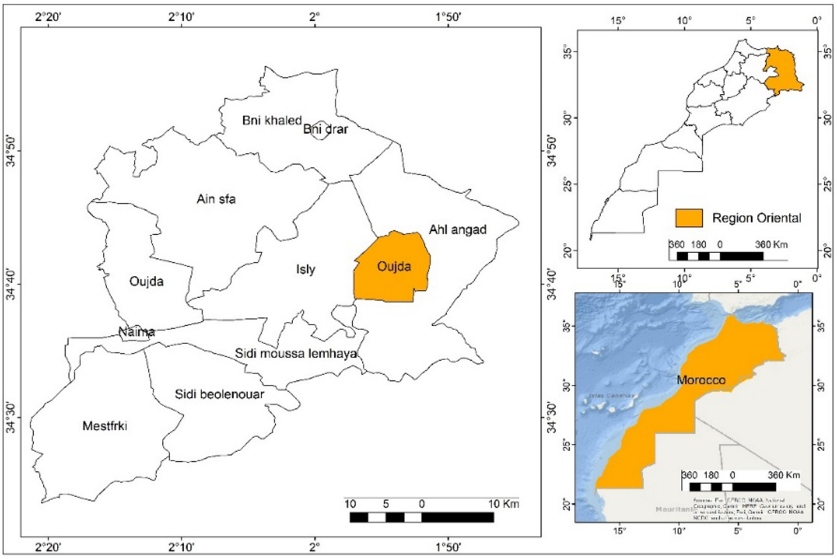

Fig. 1. Study Area.

2.2 Methods

The Landsat 8 data, acquired through the Earth Explorer website, offers a comprehensive view of the Earth's surface. This is made possible by the Landsat 8 satellite payload, which incorporates two sensors: the Operational Land Imager (OLI) and the TIR Sensor (TIRS). The OLI captures data in the visible, near-infrared, and shortwave infrared portions (VNIR, NIR, and SWIR) of the spectrum, ensuring a complete coverage [8]. In the raster.

Equations should be centred and should be numbered with the number on the right-hand side.

In the raster calculator of ArcGIS, it can be written as:

$$LST= (BT / (1+ (10.8 * BT / 14388) * ln (E))) \quad (1)$$

Finally, LST is plotted in pseudo colour for whole tile.

When downloading the data, the period selected was from January to November. Landsat 8 data were primarily utilized in the study for the year 2022. The vegetation indices, such as NDVI, were calculated for the mentioned duration for each study area. These images were then reclassified in ArcGIS to compare the changes [9]. The findings of this study are significant as they provide a deeper understanding of the vegetation characteristics, as estimated by the Normalized Difference Vegetation Index (NDVI) [10]:

$$NDVI=((NIR-R))/((NIR+R)) \quad (2)$$

Where NIR is Near-infrared and R is the red Channels, NDVI Value ranges from – 1 to +1

3 Results

3.1 Land surface temperature

Fig. 2, 3, 4, and 5 provide a clear visual representation of the variation in land surface temperature across the months. In January, the surface temperature ranged between 5°C and 15°C. In May, the land surface temperature ranged between 20°C and 38°C. In July, the land surface temperature ranged between 33°C and 46°C. Lastly, the land surface temperature in November ranged between 13°C and 29°C. This variation in surface temperature across the different months, as depicted in the figures, is likely due to the Earth's tilt, its orbit around the sun, and other factors that influence the amount of solar radiation received by different regions throughout the year.

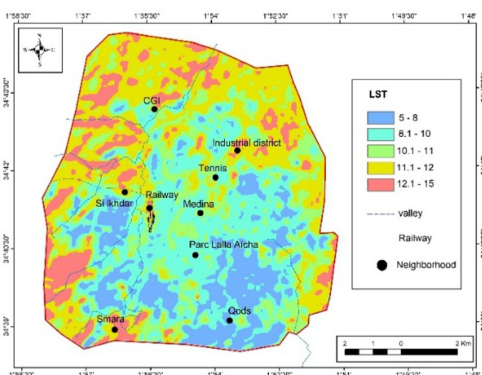

Fig. 2. LST of January 2022.

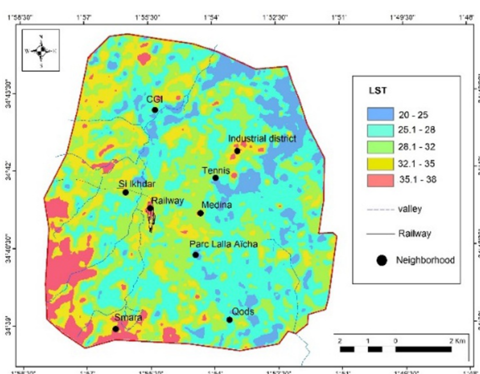

Fig. 3. LST of May 2022.

The observed variations in land surface temperature within the city, particularly during January and May, have significant implications. In January, the LST rises in the northern parts of the city, where the soil lacks vegetation cover, while it decreases in the city centre. Notably, LST reached 8.7°C in the CGI neighbourhood, 8.4°C in Lalla Aicha Park, 12.3°C in the Samara neighbourhood, 14.1°C at the train station, 12.7°C in the industrial zone, and 7.5°C in the Al-Quds neighbourhood.

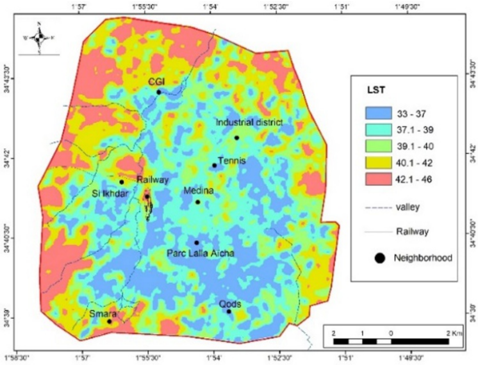

Fig. 4. LST of July 2022.

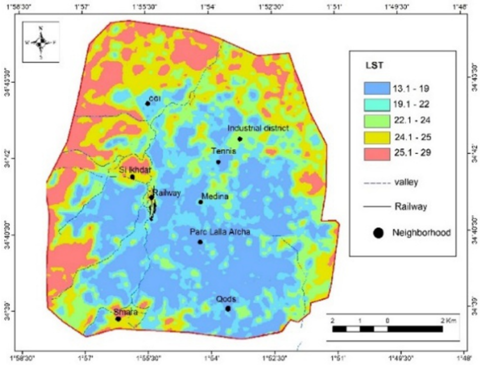

Fig. 5. LST of November 2022.

In May, LST is generally moderate throughout most of the city, except for the areas located southwest of the city and near the train station, while the temperature of the land surface decreases in the north, northeast, and southeast. LST reached 26.1°C in the CGI neighbourhood, 24.1°C in Lalla Aicha Park, 25.4°C in the Al-Quds neighbourhood, 37.6°C in the Samara neighbourhood, 37.4°C at the train station, and 34.8°C in the industrial area (Table 1).

Table. 1: The surface temperature of some neighborhoods in the city of Oujda according to the months 2022

Neighborhood	January	May	July	November
CGI	8.7 °C	26.1 °C	33.5 °C	14.5 °C
Tennis	9.8 °C	27.3 °C	35.1 °C	18.4 °C
Medina	10.6 °C	32.4 °C	39.7 °C	23.4 °C
Parc Lalla aicha	8.4 °C	24.1 °C	33.2 °C	14.7 °C
Qods	7.5 °C	25.4 °C	34.9 °C	15.4 °C
Smara	12.3 °C	37.6 °C	43.2 °C	26.5 °C
Railway	14.1 °C	37.4 °C	40.3 °C	24.9 °C
Si lkhdar	11.5 °C	29.7 °C	39.4 °C	24.7 °C
Industrial district	12.7 °C	34.8 °C	39.8 °C	23.7 °C

During November, LST generally rises on the city's outskirts from the northern and western sides, while it decreases in the city Centre. LST reached 14.5°C in the CGI neighbourhood, 14.7°C in Lalla Aicha Park, 15.4°C in the Al-Quds neighbourhood, 26.5°C in the Samara neighbourhood, 24.9°C at the train station, and 23.7°C in the industrial area. In July, LST rises on the city's outskirts, while it decreases in the south. LST reached 33.5°C in the CGI neighbourhood, 33.2°C in Lalla Aicha Park, 34.9°C in the Al-Quds neighbourhood, 43.2°C in the Samara neighbourhood, 40.3°C at the train station, and 39.8°C in the industrial area (table 1). he reasons for the variation in the temperature of the Earth's surface is due to the nature of land use, where the temperature decreases in upscale neighbourhoods such as CGI and Qods neighbourhoods due to the high density of afforestation, as well as in Lalla Aicha Park due to the abundance of vegetation cover. In contrast, the temperature rises in the Al-Samara neighbourhood as it is an informal settlement devoid of vegetation and afforestation, in addition to the dark colour of the houses, where the darker the colour, the greater the absorption of the sun's rays. As for the train station, the railway contributes to more excellent ray's absorption. The rise in temperature in the areas located in the west of the city is also explained by the fact that they are barren lands devoid

3.2 Relationship of land surface temperature with NDVI

From the analysis of Figures 6, 7, 8, and 9, it is evident that there is a relationship between the NDVI index and the land surface temperature. The land surface temperature higher in the regions where the NDVI index is lower, while the land surface temperature is lower in the regions where the NDVI index is high.

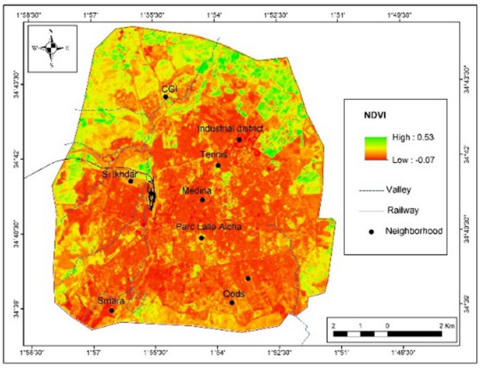

Fig. 6. NDVI of January 2022.

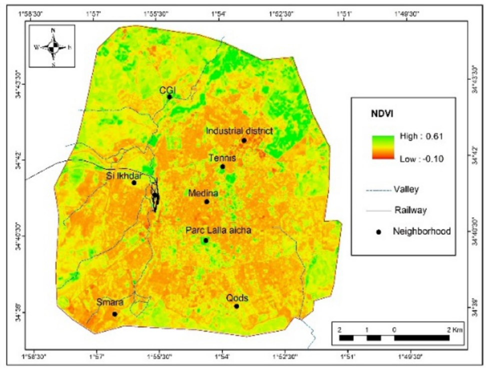

Fig. 7. NDVI of May 2022.

As mentioned earlier, the land surface temperature is higher in the Samara neighbourhood, the industrial zone, and the train station, which is attributed to the lower NDVI index, which indicates a weaker vegetation cover. Meanwhile, the land surface temperature is lower in Lalla Aicha Park, the CGI neighbourhood, and the Al Quds neighbourhood, which is attributed to the higher NDVI index, which indicates a more abundant vegetation cover. Therefore, the vegetation cover works to reduce the land surface temperature.

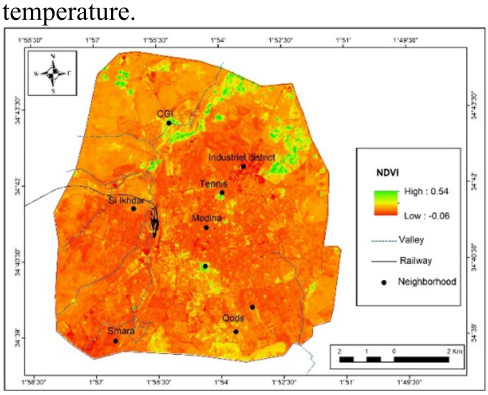

Fig. 8. NDVI of July 2022.

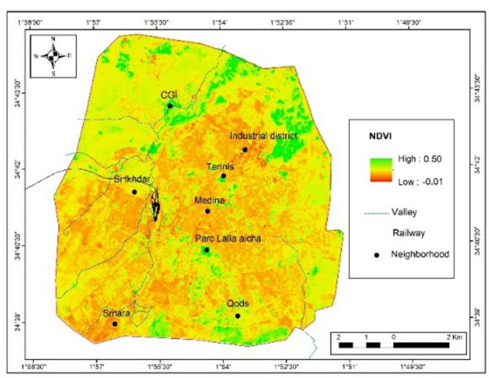

Fig. 9. NDVI of November 2022.

4 Discussion

The surface temperature of the Earth varies in the city of Oujda. It has also been observed [11] that there is a temperature difference between Oujda and Fez in Morocco, which is also due to air pollutants that contribute to the phenomenon of global warming. The results from five cities in Bangladesh [12] show a variation in urban heat islands among these cities, particularly in the center, as well as an increase in the average urban temperature.

The phenomenon of heat islands exhibits distinct characteristics in arid and semi-arid areas. We found that the surface temperature of the Earth is higher in bare land during most seasons in the city of Oujda compared to other types of land use. This has also been observed by the researcher [13] in the city of Ben Guerir in Morocco, where results show that the average temperature varies depending on the nature of urbanization. It is higher in bare soils compared to other urban areas, with differences between seasons. This characteristic is typical of dry and semi-dry regions, where the surface temperature of the Earth is elevated in bare land due to a higher concentration of heat, low vegetation cover, and low relative humidity. The presence of sandy soils, which contain little water, especially in summer, contrasts with clay soils. Thus, the higher the amount of water in the soil, the lower the surface temperature of the Earth.

In Tehran, Iran [14], it has been observed that the surface temperature of the Earth is high in urban areas, particularly in bare soils of arid or semi-arid zones. The dry soils surrounding the city contribute to the formation of urban heat islands.

There is also a strong relationship between the phenomenon of heat islands and vegetation cover; the latter reduces this phenomenon when vegetation is abundant. This was found by [15] in the city of Marrakech, Morocco, where the surface temperature of the Earth is significantly lower than in areas devoid of vegetation cover.

5 Conclusion

In this research, the urban heat island effect was detected in Oujda. The results revealed that the land surface temperature varies according to the months of the year, and it appears particularly clear in the summer. The common denominator between these months is the variation in land surface temperature according to land use in the city of Oujda. The land surface temperature rises in the bare lands due to the sandy nature of the soil and the weak vegetation cover; it also rises in the informal settlements due to the lack of green spaces, in addition to rising in the industrial district due to the nature of the materials used in industrial buildings which absorb more radiation, as well as rising at the train station where the railway lines that absorb the sun's rays are concentrated. It is observed to decrease in green spaces, agricultural and forested lands, and upscale neighbourhoods due to the dense presence of trees. From this, we conclude that there is a relationship between vegetation cover and the heat island phenomenon. It has been found that the areas with a higher NDVI index have a lower land surface temperature, while the areas with a lower NDVI index have a higher land surface temperature. This study has shown the importance of geographic information systems in studying climate change, and they may also be helpful for stakeholders in the urban environment and climate change field. We urge stakeholders to take an active role in increasing afforestation in areas where land surface temperature is rising to mitigate this phenomenon.

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Author Contribution
The authors reviewed and approved the final manuscript, with contributions from Djebbour Mounir in the study, methodology, analysis, and interpretation, and Sbai Abdelkader in supervision, reviewing the Data, and making corrections.

Consent for publication
All the authors have agreed to publish this article.

Competing interests
The authors declare that they have no competing interests.

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