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Will Cities Survive?

Study of land use/cover change impacts on thermal microclimate using QGIS in urban agglomeration

Case study: city of Biskra, Algeria

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ABSTRACT: Thermal comfort and air quality are major concerns for people living in urban areas. In the last decades, cities are growing quickly and the increased urbanization is leading to the expansion of cities, which changes the properties and composition of the landscape. However, the surface temperatures are increasing, globally, because of anthropogenic climate change. Land use and land cover change have been shown to have a significant effect on climate through various pathways that modulate land surface temperature and rainfall. The objective of this study is to understand how the land use and land cover change affects the thermal microclimate in the city of Biskra (Algeria) using QGIS for the period between 2010 and 2020. The analysis results reveal that the mean temperature of the city has increased by ~4 °C during the past decade with the most accelerated warming (~7 °C) occurring during the recent decade (2010 to 2020). Our study shows also that 32% to 56% of this observed overall warming is associated with land use/cover and the largest changes are related to changing vegetation cover as evidenced by changes to both land use and land covers classes and normalized difference vegetation index (NDVI).
KEYWORDS: Thermal microclimate, Land use/land cover, QGIS analysis, LST, NDVI, Statistical correlation

1. INTRODUCTION

Nowadays urban design requires comprehensive and vast knowledge in different fields. Many problems related to urban climate, air pollution, ecosystems, energy consumption, traffic and health are caused by the highly densified development despite of the benefits brought by the urbanization process [1]. From the literature review for background studies, the local climate of an urban area can be affected by several features that should be properly cared for a sustainable urban environment such as: the urban thermo-physical and geometrical characteristics, anthropogenic activities and heat sources present in the area.

There is a strong relation between the urban morphology and the urban microclimate [2]. In other words, urban morphology parameters have an obvious impact on microclimate. Designers are obliged to consider many issues for the effective urban design such as the local climate, which has become a crucial task to consider for high-density cities [3].

Stromann Andersen and Sattrup in their research [4], stated that the geometry of urban canyons may affect the total energy consumption of low-energy buildings. In the other hand, Wong in his research [5] proved that increasing the height and density of the surroundings (greenery and buildings) lowers the temperature of the external microclimate and reduces the cooling load of the building by around 5%. A simplified spatial model developed by Adolphe [6], based on a set of morphological indicators in terms of various parameters, such as density, rugosity, sinuosity, contiguity and solar admittance in order to simplify the analysis of outdoor microclimate tendencies and the energy balance of urban patterns.

Based on previous studies and research show that human outdoor comfort is influenced by multiple factors depending on air temperature, wind speed, relative humidity and solar radiation [7]. It was found, that peoples feel comfortable in the temperature range of 21 ℃ to 27.5℃, and relative humidity included between 30% to 65% with wind speed values greater than 5 m/s [7]. In hot and arid region, which is the case in our study, factors such as strong solar radiation, high temperature, low humidity, dazzling light and dust storms can reduce thermal comfort, which has higher health risks for city dwellers [8]. Therefore, researchers are paying more attention to outdoor thermal comfort in urban settings as part of urban design. Land surface temperature (LST) and normalized difference vegetation index (NDVI) are very important factors mainly used in surface urban heat island (SUHI) analysis [9].

The objective of this research is to analyse the effect of land use and land cover change on the urban microclimate of the city of Biskra (South-East of the capital Algiers) by analysing Land surface temperature (LST) and Normalized Difference Vegetation Index (NDVI) data for a period of 10 years using QGIS.

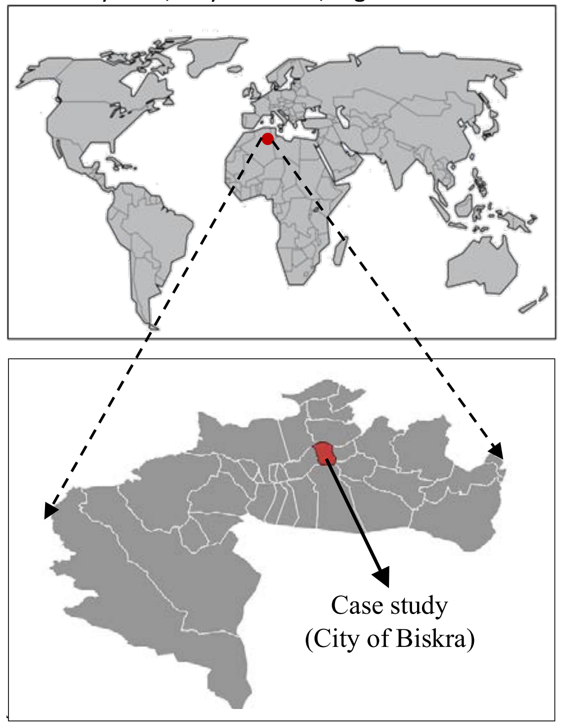
2. MATERIALS AND METHOD

Through a combination of ground, satellite remote sensing and reanalysis products using QGIS, we investigate the recent changes of land surface temperature in the urban agglomeration of the city of Biskra (Algeria) between 2010 and 2020 and assess its relation to land use/cover. However, we analyse whether the surface temperature and the vegetation would increase and, if so, whether these are in response to changes in land cover and/or changes in climate.

2.1 Case of study

Biskra is a main town in Algeria, situated in the south east (Latitude: 34° 52′ North, Longitude: 5° 45′ East) on the border of the Sahara Desert with a surface of 127,55 km2 (Fig. 1). The city has a large amount of solar potential (5-6 kWh/m²/day) and (2190 kWh/m²/year). In addition, the microclimate of Biskra city is characterized by sunny sky, little rainfall and high air temperatures exceeding 30°C during nearly half of the year (from April to November), an average annual humidity of 46%. Research given by Daich et al (2017) has shown that Biskra has an intermediate sky with an average annual cloud cover of around 40% [10].

Figure 1:
The study area, City of Biskra, Algeria



2.2 Data collection

In this study, MOD11_A2, Terra MODIS LST eight-day data, the Landsat 7 and the Landsat-8 Operational Land Imager (OLI), the Landsat-8 (ETM+) and TIRS (Thermal Infrared Sensor) have been used to collect data about Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI). The data can be obtained and retrieved based on spatial and temporal criteria.
LST was retrieved by applying the split-window algorithm from Landsat 8 TIRS data. The image code, date, cloud cover and scene searched are presented in Table 1. TIRS data were then converted to TOA spectral radiance using the radiance rescaling factors provided in the metadata file. The conversion of thermal bands of Landsat 8 satellite data into luminance values is necessary; the luminance values obtained are then used to transform the luminosity into temperatures.

Table 1:
Landsat 7 and Landsat 8 (OLI, TIRS and ETM+) images selected in the study.

Image Code	Acquisition Date	Cloud cover	Zone /Path
LE07_L1TP_194036_20100427_20161214_01_T1	24-04-2010 10 :05 :53	4	194
LC08_L1TP_194036_20200430_20200509_01_T1	30-04-2020 10 :13 :07	4	194

In addition, it is known that Land Surface Temperature was based on fractional vegetation cover (FVC) and was calculated using NDVI images. The NDVI was calculated using Landsat 8's bands 4 and 5 images as inputs with NDVI-min from the dry soil and NDVI-max from dense vegetation. This index was calculated using Equation (1):

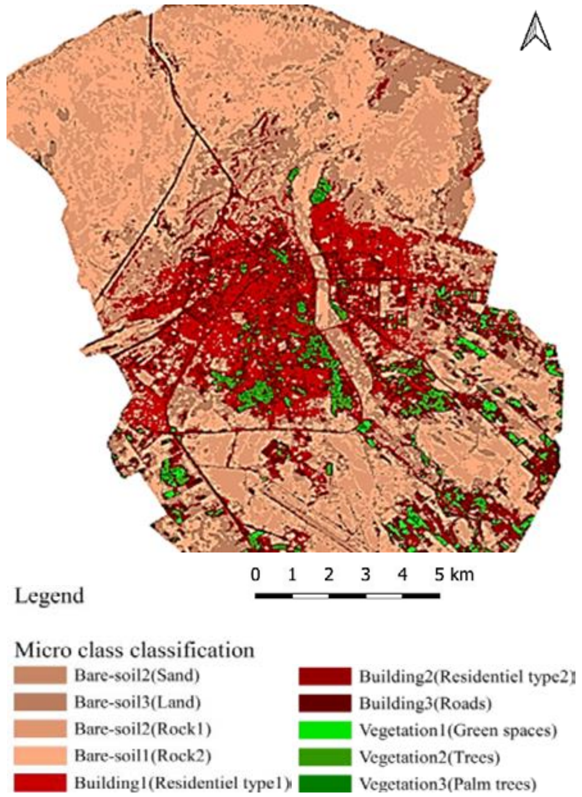
$$NDVI=(\rho NIR-\rho RED)/(\rho NIR+\rho RED) \qquad (1)$$

Where NDVI - Normalized Difference Vegetation Index;
ρNIR - near-infrared light;
ρRED - visible red light;

At the end, the LST derived from Landsat data sets are analyzed and compared with NDVI calculated values.

Figure 2 shows Land cover types, which were categorized using the maximum likelihood classifier, into building (type 1, type 2 and roads), vegetation (green spaces, trees and palm trees) and soil (sand, land, rock 1 and rock 2).

Figure 2:
Surface biophysical properties: Micro class classification of the case study



3. VALIDATION OF THE RESULTS

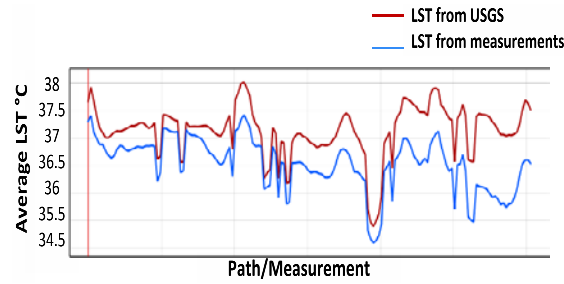
Mobile measurement was frequently used in micro-scale urban investigations [11]. ,In order to validate the Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI) results obtained by QGIS 3.22.4 and analyse the relationship between these two indices, we have used a mobile meteorological station equipped with multifunction thermometer, infrared thermal camera and GPS (Fig. 3). The observation campaign was executed in April, 20, 21, 22, 23, 24, 25, 26 and 27, 2020. For this, seventy-four stations were defined to cover the micro-scale urban features for representative areas of the Biskra city center in a path of 3700m (Fig. 4). The distance between two stations is fifty meters. The measurement height was about 1.1 m above the ground surface level. The observed data represents the exposed micro-climate conditions of each station (measurement point). Thus, normalization on the measured air temperature in eight days of investigation is demanded before doing the comparative analysis.

The Results presented in Figure 5 showed that the measured mean temperature in the path is with a range of ±7% which indicates a significant positive correlation between LST obtained from USGS and LST measured with the mobile meteorological station. In the next section, the presented data have been obtained only from QGIS.

Figure 3:
Mobile meteorological station

Figure 4:
Selected Path for the validation

Figure 5:
Validation results



4. RESULTS AND DISCUSSION

4.1. Land Surface Temperature (LST) Analysis

Figure 6 and Figure 7 show the LSTs and the spatial dynamics of changes over time in LST in the study area for the analysed years (2010-2020). The results show that the mean LST (°C) increased from 29°C in 2010 to 33°C in 2020. The greatest transformation in Land Surface Temperature was in the West, South and top South-Western parts of the city, while the lowest LST was observed at the top of the Northern. The high LST zones represent bare earth surface (sand, land, rock 1 and rock 2) surrounding the city, whereas the low LST zones are developed mainly by the concentration of dense vegetal cover especially trees and built-up especially residence type 1 and 2. The data shows also that in 2020, the city center of Biskra faced a range of 35.98°C and 41.18 °C, some 3°C–7 °C higher than that of the suburban/rural area (range of 33.68°C and 35.98°C) which causes the urban heat island phenomenon. The study shows also that

32% to 56% of this observed overall warming is associated with climate change and land use/cover.

Figure 6:
LST results (2010)

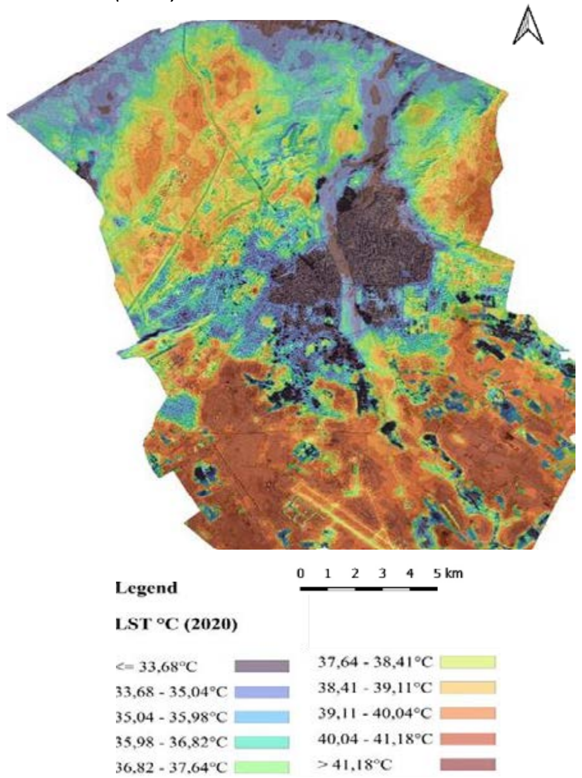
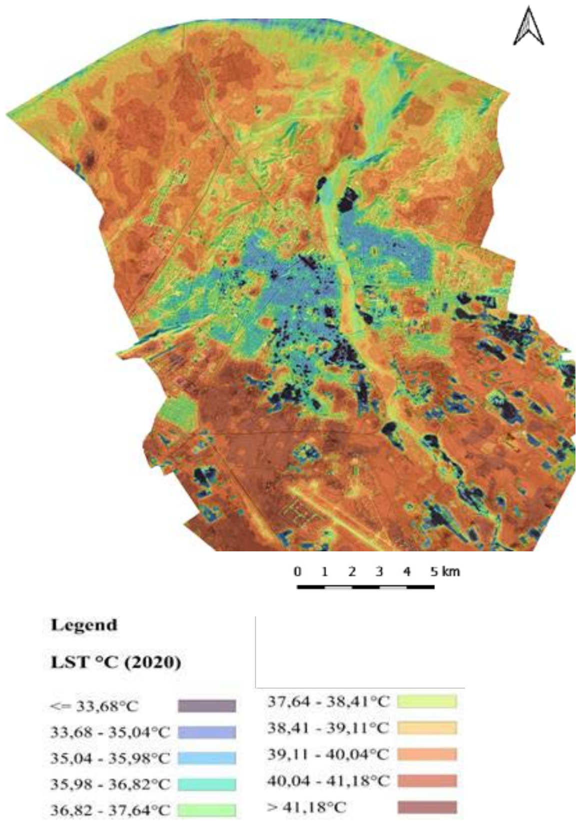


Figure 7:
LST results (2010)



4.2 Normalized Difference Vegetation Index (NDVI) analysis

Figure 8:
NDVI results (2010)

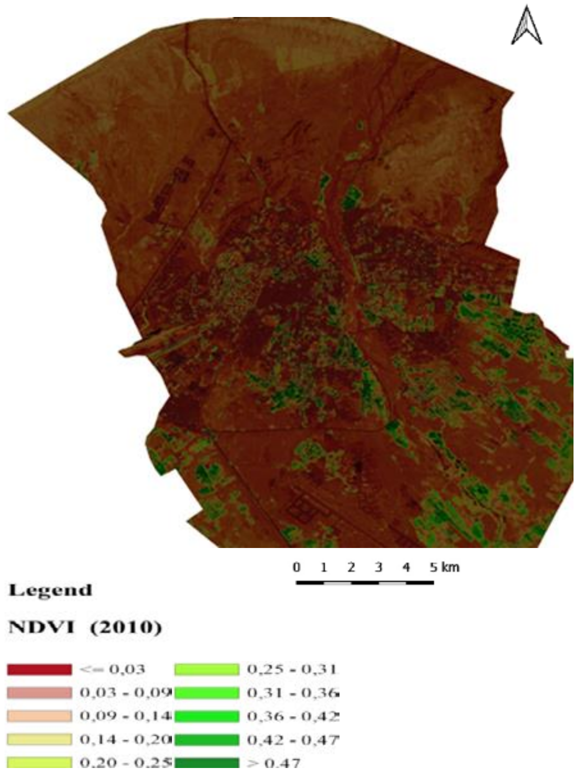
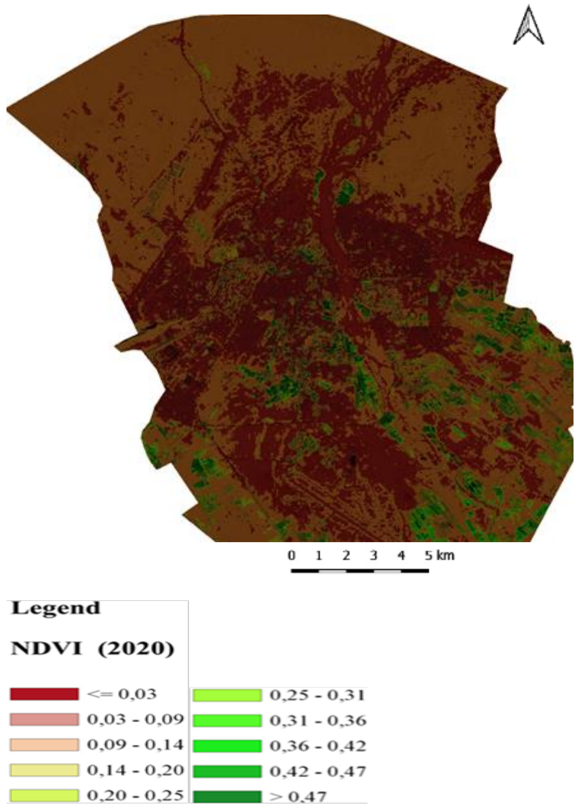


Figure 9:
NDVI results (2020)



5. CONCLUSION

This investigation aims to study the effect of land use and land cover change on the urban microclimate by assessing the trend of spatiotemporal relationship between Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI) for Biskra city (Algeria) using QGIS from 2010 to 2020. The results show that mean LST of the study area has been increased with a very significant rate (~4 °C). Generally, the average land surface temperature (LST) increased by nearly 5 °C in the city and nearly 3 °C at the city boundary situated at 10km from the city center. LST level increased due to increased greater population pressure resulting in rapid expansion of built-up areas with detriment of green space area, which cause the urban heat island phenomenon.

Moreover, the data indicates that there was a negative relationship between Land Surface Temperature and Normal Difference Vegetation Index for the whole of the study area. The relationship is quite insignificant for low LST zones (north and north-eastern areas). These areas have relatively high NDVI values.

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