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Effect of elevation on land surface temperature (LST) variation in Jos and Environs, Nigeria

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ABSTRACT

Elevation is one of the factors causing temperature variation in different parts of the world. The increase in elevation usually resulted in the decrease in temperature, a phenomenon called Environmental Lapse rate (ELR). This research examines the effect of elevation on Land Surface Temperature (LST) in Jos and environs, Nigeria. Satellite data obtained from Shuttle Radar Topography Mission (SRTM) and Landsat 8 OLI/TIRS were used. The elevation of the study area was obtained from the SRTM data. The Landsat 8 data were used to derive the LST using single-channel algorithm. The relationship between elevation and LST was analysed using correlation analysis. The results showed that the study area is generally on a high elevation ranged from 550 metres to 1,800 meters above sea level. There was variation in the spatial distribution of the LST as a result of differences in elevation. The LST ranged from 19°C to 35°C was recorded in the highest and lowest elevation respectively. The LST decreased by 16°C for 1,250 meters increase in elevation indicating the effect of Environmental Lapse Rate (ELR). A moderate negative correlation was found between LST and elevation (r =0.46). Elevation was found to be a comfortable place of living as a result of the lower surface and air temperature.

1. INTRODUCTION

Currently, the rising of temperature as a result of climate change is affecting the world (Tofan et al. 2020; Me-Ead and McNeil 2016). Land Surface Temperature (LST) is one of the essential parameters considered in the study of climate change (Sumit et al. 2018). It is the skin temperature of the surface that involved the soil and vegetation surfaces (Sumit et al. 2018). The spatial and temporal variation of the LST is important in understanding the interaction between human activities and the environment (Thanh 2018; Stathopoulou and Cartalis 2009). The surface temperature has an impact on the air temperature (Koç et al. 2019; Song et al. 2017; Chrysoulakis et al. 2013). Air is heated when it contacts warm surfaces which make it rise up (Mitchell 2011; Lowry 1967). According to the United States Environmental Protection Agency (EPA), excess heat has effect on human heath causing discomfort and illness like heat exhaustion, heat stroke, heat cramps and heat related mortality. For instance, in the United States, from 1979-2003, over 8000 people died as a result of excess heat (EPA, 2017). In Europe, 20,000 lives were claimed by heat wave in 2003 mostly poor and elderly (Satterthwaite, 2008). Increase in temperature forces people to areas of comfort (Koç et al 2019).

Land cover type and elevation are some of the important factors responsible for the variability of the LST (Malb´eteau et al. 2017). Temperature tends to decrease with the increase in elevation (Xiaoxue et al. 2020; Bailey 1996). This decrease in temperature is referred to as the Environmental Lapse Rate (ELR) and for every 1,000 metres, there is a decrease of 5°C to 10°C (Sumit et al. 2018). Measurement of LST from the ground stations cannot represent the surface temperature of an area most especially developing countries that have few stations (Thanh et al. 2018). Satellite measurement provides a better result than the interpolated ground stations (Sumit et al. 2018; Cheval and Dumitrescu 2009). LST can be measured by the ground-based, air-born and satellite-based sensors (Denis et al. 2015). Some of the prominent satellite imageries used in retrieving the LST include Moderate Resolution Imaging Spectroradiometer (MODIS), Advanced Very High

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Resolution Radiometer (AVHRR), Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and Landsat (Thanh et al. 2018). Many types of research on the LST were conducted on the flat surfaces focusing on the effect of land use/land cover on the LST variation. Relief is one of the factors that cause variation in the LST (Tofan et al. 2020; Gao et al. 2008). Twenty percent of the world continental surface is covered by the mountains (Malb´eteau et al. 2017; Meybeck et al. 2001). In Nigeria, the Jos plateau formed a major part of the north-central highlands. Elevation affects the climatic system of the area. Therefore, this research examines the effect of elevation on LST variation in Jos and environs.

2. METHOD

2.1 Study Area

The study area is located between Latitudes 9°17' and 10°23'N and Longitude 8°33' and 9°19'E covering an area of 5,324.62 km². It covers Jos North, Jos South, Bassa, Riyom, Barikin Ladi and Jos East Local Government Areas of Plateau State, North-central Nigeria. (Fig. 1). The climate is a tropical climate with a mean annual rainfall of 1,324mm with the highest rainfall recorded in July and August (Lekwot et al 2015). There is also a temperate climate as a result of the high altitude which is responsible for the low temperature with a monthly average temperature between 21°C and 25°C throughout the year (Isioye et al 2020). The coldest temperature is recorded during Harmattan from December to February while the warmest temperature is recorded between March and April (Lekwot et al 2015).

The vegetation is characterised by stunted trees with tall grasses and shrubs (Atipo et al 2020). The topography is characterised by highlands with different height ranges from 1,200 meters to 1,825 meters above sea level (Lakwot et al 2015). Jos plateau located in the city is the source of many rivers in Northern Nigeria like Kaduna, Gongola, Hadejia and Yobe rivers (Goyal and Pathirage 2018).

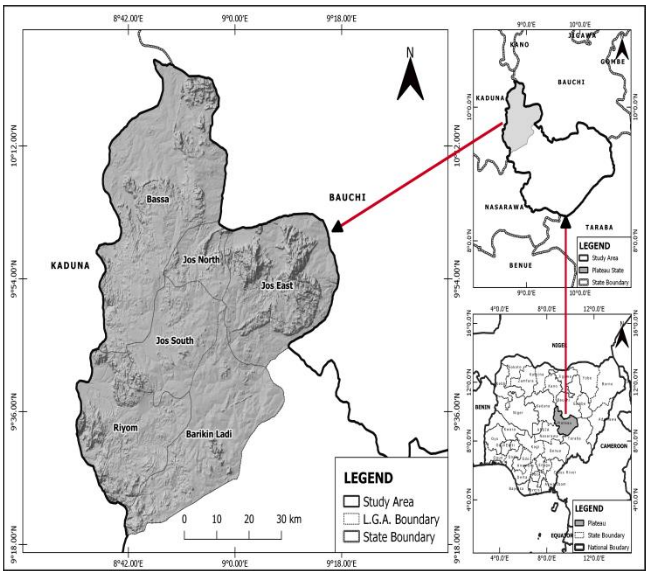

Figure 1. Map of the study area

2.2. Generation of Elevation

The elevation data were obtained from NASA's Shuttle Radar Topography Mission (SRTM). The 30 meters spatial resolution imagery was used to generate the Digital Elevation Model (DEM) using QGIS 3.14 'Pi'.

2.3. Calculation of LST

Landsat 8 (OLI/TIRS) acquired on the 13th November, 2020 was used retrieve the Land Surface Temperature (LST). The thermal band 10 was resampled to 30 meters resolution like other bands. Single-channel algorithm was used to derived the LST from the imagery (Palafox-Juárez et al. 2021).

Firstly, the spectral radiance of the top of the atmosphere was calculated followed by the brightness temperature from the absolute radiance values. The obtained results were converted to degree Celsius from degree Kelvin. Normalize Difference Vegetation Index (NDVI) was used to extract the surface emissivity to estimate the LST. Finally, the LST was calculated using the brightness temperature and surface emissivity. QGIS 3.14 'Pi' was used for the processing of the data.

3.4. Relationship Between LST and Elevation

The LST map was overlaid on the elevation map and the LST values and their corresponding elevation values were extracted. The values were used to assessed the relationship between the LST and elevation. Statistical Package for Social Science (SPSS) was used for the correlation analysis.

3. RESULTS

Figure 2 shows the elevation of the study area. The relief of the study area is unevenly distributed and ranged from 550 to 1,800 meters. The lowest elevation was found in Riyom in the south-west of the study area. A lower elevation of 800 meters was found in the north and eastern part of Jos East. Elevation ranged between 1,050 and 1,550meters was found mostly at the centre of the area in Jos North and South and extended to the southern part. The highest elevation was found in the east with a height of 1,800 meters.

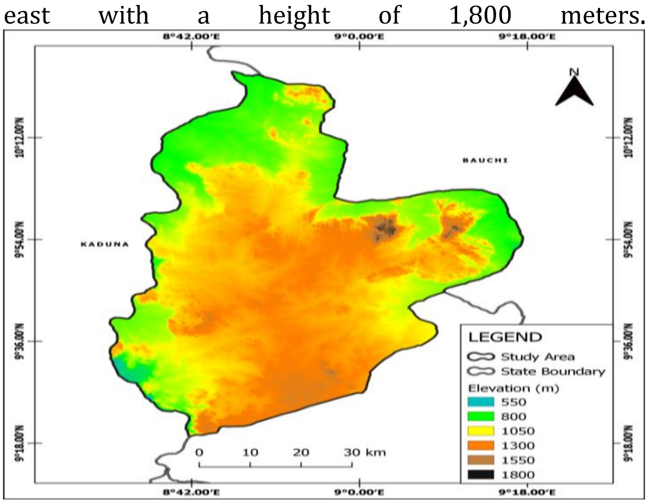

Figure 2. Elevation of the study area

2.3. Calculation of LST

Figure 3 shows the distribution of the surface temperature. The LST distribution varies and ranged from 19°C to 35°C. The highest surface temperature of 35°C was recorded in western Riyom, northern Bassa and Eastern Jos East with an elevation of 800 meters. A temperature ranged from 25.4°C to 28.6°C was found in most of the centre southern parts with a higher elevation ranged from 1,050 to 1,300 meters. Low surface temperature (22.2°C) was found in Barikin Ladi in the south with an elevation of 1,550 metres. The lowest surface temperature of 19°C was recorded in the highest points of the area with an elevation of 1,800 meters located in Jos East in the eastern part of the study area.

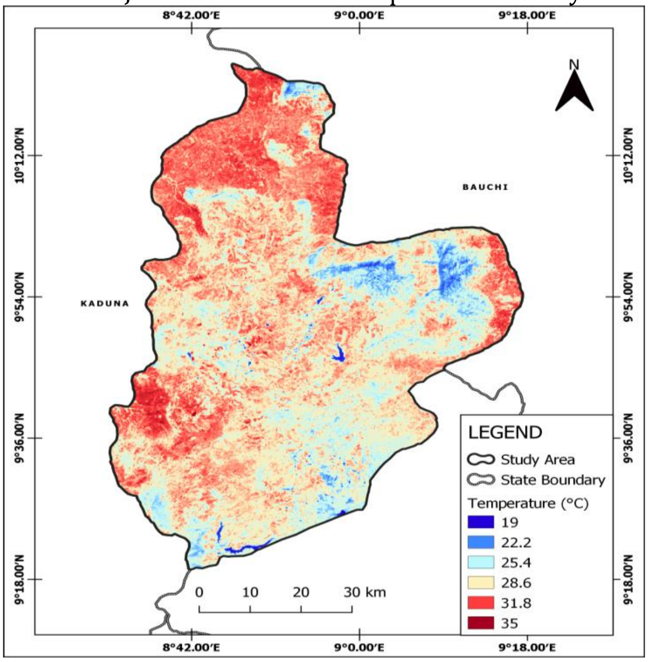

Figure 3. Land Surface Temperature of the Study Area

2.4. Relationship Between LST and Elevation

Figure 4 shows the relationship between LST and elevation. A weak linear relationship between the LST and elevation was observed. The correlation coefficient was r=0.46. The relationship shows that increase in elevation resulted to decrease in LST. The increase of 1,250 meters resulted to the decrease of 16°C.

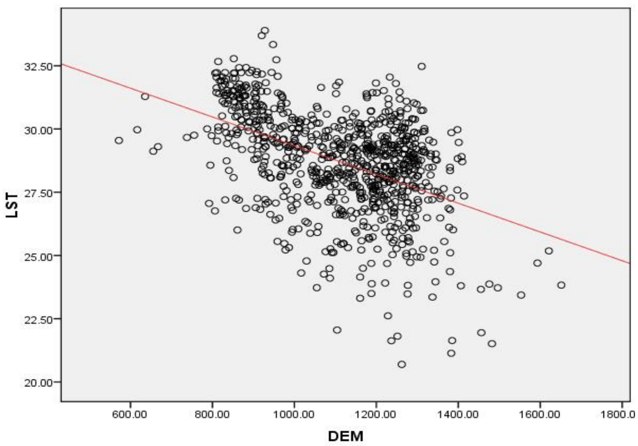

Figure 4. Scatter plot of LST and elevation

4. DISCUSSION

The elevation of the study area is generally high ranged from 550 meters to 1,800 meters. This is because of the highlands nature of the topography formed by the basement complex rocks. The study area also formed part of the north-central highland that is the sources of many rivers in Northern Nigeria (Goyal and Pathirage 2018). The elevation was reported to be ranged from 1,200 to 1,829 meters above sea level (Lakwot et al 2015).

The spatial distribution LST varies with elevation with 19°C and 35°C as the lowest and highest values respectively. The increase in elevation led to a decrease in LST. This is as a result of the Environmental Lapse Rate (ELR) effect where temperature decreases with an increase in altitude. For every 1000 meters of elevation, there is a decrease in temperature ranges from 5°C to 10°C (Sumit et al. 2018). The low air temperature on the high elevation lowered the surface temperature. The relationship between LST and elevation showed a moderate negative relationship with correlation coefficient r=0.46. This is because of the influence of elevation in decreasing the surface temperature. The high elevation is responsible for the temperate type of climate that makes the temperature of the study area lower throughout the year (Isioye et al 2020). The lower air temperature affects the surface temperature by lowering it. This result agreed with that of Sumit et al. (2018) that found a decrease of 3.5°C-4.6°C per 1,000 metres in Jaipur, India with a strong linear correlation (r=0.73-0.87) between LST and elevation. The moderate negative correlation found in the study area could be attributed to the interference of the terrain factors (aspect, slope and shaded relief), land use/land cover and weather condition.

5. CONCLUSION

This study examined the effect of elevation on LST variation in Jos and environs located in the North-central highland in Northern Nigeria. The study area is located on a high elevation raged from 550meters to 1,800 metres above the sea level. The LST ranged from 19°C to 35°C and varies spatially with elevation. The LST decreased with the increase in elevation indicating Environmental Lapse Rate (ELR). For the increase of 1,250 meters, there is a decrease of 16°C. Decrease in air temperature as a result of the increase elevation is responsible for the lower surface temperature. The relationship between LST and elevation showed a moderate negative linear relationship (r=0.46). Atmospheric condition, land use/ land cover and nature of topography influence the decrease of LST with the increase in elevation. High areas provide comfortable places for living because of the lower surface and air temperature.

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