Spatio-Temporal Analysis of Urban Heat Hazard in Jos Metropolis

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ABSTRACT

The rapid urbanization has produced a remarkable effect on the surface thermal response. The effects significantly influence internal urban microclimate on a regional scale. This has led to the transformation of natural landscape into anthropogenic surfaces in urban settlements. Thus, this assesses spatio-temporal analysis of urban heat hazards in Jos Metropolis. In this study, the surface temperature and land cover types retrieved from Landsat ETM+ and OLI images of Jos Metropolis for 2005 and 2019 were analysed. The Erdas imagine 9.2 and ArcGIS 10.1 were used for data preparation and map composition. Thermal band data were used to compute surface temperature maps for the two years, and the relationship between land use land cover and surface temperature was analyzed. Results from land use land cover maps between 2005 and 2019 revealed a notable increase with an annual average rate of 5.1 %. Also, urban land development raised the surface temperature by 1.36⁰C between 2005 and 2019. Bare land exhibited a high value of surface temperature while vegetation showed low values of surface temperature. The result also shows that there is an occurrence of physiological discomfort in the environment with a very strong heat stress leading to an increase in the probability of heatstroke and cardiovascular embarrassment. Focus should be given on the effect of urban growth, growing impervious surfaces, and careful greening methods was recommended.

Keywords: Hazard, Metropolis, Urban, Heat, Jos, Vegetation,

BACKGROUND

Over the years, the rapid growth in population and industrialization has resulted in the concentration of economic and social functions in the urban areas such scenario altered urban morphology and energy composition [1-3]. Unplanned and hasty urbanization in modern cities, especially during the last 45 years, has resulted in environmental problems such as altering the local climate and a higher amount of air pollution in urban areas [3]. The simultaneous rapid growth in both population and economic output per capita and the consequent changes in land use pattern comes at a cost to the natural environment [4-6]. Indeed, this change is one of the most widely documented climatic effects of man modification of environmental factors [7].

Urban heating and the formation of the urban heat island (UHI) attributes of growing urban density that is of interest across many disciplines because the UHI signal reflects a broad suite of important land surface changes impacting human health [8]. The intensity of the UHI tends to vary depending on the size of cities, and it increases as the size of a city increases, due to the larger size of the built-

up areas [9]. Local meteorological conditions, geography (topography, presence of water bodies such as lakes or rivers, soil types) also affect a UHI magnitude [7]. However, this effect can raise city air temperatures by 2°C to 10°C above the surrounding area [10]. The primary consequences of these are the consistent rise in temperature in the urban area, known as urban heat island [7].

An Urban Heat Island (UHI) is an urban area or metropolitan area that is significantly warmer than its surrounding rural areas due to human activities [11]. The temperature difference usually is larger at night than during the day and is most apparent when local winds are weak [12-13]. Urban Heat Island is affected by human activities, such as changes in land use and land use cover in urban areas [14]. Studies have revealed that land use and land cover change are major determinants to global climate change [15].

Luke Howard, in the 1810s first investigated the phenomenon although he was not the one to name the phenomenon. Urban Heat islands were created by a combination of heat-absorptive surfaces such as dark pavements and roofing, heat-generating activities such as engines and generators and the absence of vegetation which provides evaporative

cooling [16]. The situation is aggravated mainly due to the loss of green areas of the urban environment as consequences of industrialization that has led to the conversion of natural areas to public housing [17-18].

The hazards nature of UHI are injurious to human health. Efe [19] revealed that hazards like urban warming, depleting ozone gases and excessive sweat lead to a reduction in working efficiency. Higher temperature affects human health and has been reported to have cause hazards such as; respiratory difficulties, heat syncope, heat cramps and exhaustion, non-fatal heat stroke, circulatory collapse, and increased danger of heat stroke and cardiovascular embarrassment and heat-related mortality [20-21]. A study by Centers for Disease Control and Prevention (CDCP) (2006) revealed that from 1979—2003, excessive heat exposure contributed to more than 8,000 premature deaths in the United States. This figure exceeds the number of mortalities resulting from floods, lightning, hurricanes, tornadoes and earthquakes combined. According to the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC) [22] and Berry [23] noted that UHI have some environmental and health implications on its

residents as it provokes the physical trauma caused by natural disasters like storms and flood and causes heat wave which influences human physiology; increasing illness, mortality via heat exhaustion with children and elderly being the vulnerable.

Similarly, Nigeria and Jos city has also witnessed an unprecedented growth in urbanization relative to the increasing population [24-25]. Studies have also shown that the population of the urban areas of Nigeria constitutes about 48.2 percent of the country's total population and projection has indicated that more than 60 percent will reside in urban centres by the year 2025 [26-27]. In Jos, rapid industrialization has occurred since 1976 to date. The urban growth has been accelerated and has caused extreme stress to the environment hence the following objectives were formulated to; determine the land cover types distribution in Jos metropolis, examine the spatial variation in land surface temperature and examine the impacts of urban heat hazards on human body physiological comfort. It is against this context, that this study seeks to assess spatio-temporal analysis of urban heat hazards in Jos Metropolis.

MATERIALS AND METHODS

Study Area

Jos metropolis is the administrative capital of Plateau state and it covers an area of 249.7km² with an altitude of 1,217m (3,993ft) above sea level [28-30]. The town of Jos was originally established in 1915 as a tin mining camp and its early history was closely linked to the prosperity of the tin mining industry. In 1976, it became the capital of the then Benue-Plateau State and, later, the Plateau State. The State has become an important administrative and commercial centre [31].

Jos metropolis is located almost in the Middle Belt geographical center of Nigeria (Figure 1). It lies precisely within latitudes 9°45'46.82" to 9°57'58.38" North of the Equator and longitudes 8°48'57.78" to 8°58'0.88" East of the Greenwich Meridian. Relatively, Jos Metropolis is situated within Jos North and Jos south LGA, it is bounded to the West by Bassa LGA, the East by Jos East and to the South-East by Barkin-Ladi LGA. The metropolis is located in the extreme Northern part of the state [28,31].

The climate of Jos city is much more pleasant than that of surrounding plains. According to Balogun [31], the climate of Jos Plateau is dominantly influenced by its relatively high altitude and position along the Inter Tropical Convergence Zone (ITCZ). Jos Metropolis is

controlled by two winds systems that affect the Nigerian climate, the moist South-westerly winds during the rainy season and the dry North Easterlies during the dry season. The South-westerly winds are responsible for much of the rains occurring between April and October, while the North Easterlies are responsible for the dry season lasting from November to March. The Jos Metropolis climate can be described as having a tropical rainy climate, with heavy rains between June and August. It also has a semi temperate climate with temperatures ranging from 18⁰C to 25⁰C. Generally, weather conditions of Jos Metropolis are warmer during the rainy season [31].

The topography of Jos metropolis is composed of eroded gneiss formations with granites intrusions and an average altitude of 1250m above sea level. This region with impressive ridges separated by extensive plain that has striking geomorphologic features [31]. It has a ground broken by rocky out crops and open plains found at the southern part. The Area generally present an undulating plain versified by few broken ridges and granite inselbergs. The hills are characterized by huge protruding out crop with slope of varying steepness. This terrain has resulted from natural erosion [28].

The highest surface of the Jos metropolis occurs around Ngel and Bukuru, which forms the hydrological center of Nigeria from which fast flowing water move through the irregular gentle slopes into the Lake Chad, river Niger, Benue and Gongola. Jos lies within the Basin of Delimi River which flow into Lake Chad. The Delimi and its tributaries of which the creek have been straddled by the built-up area of Jos, due to the seasonality of flow caused by the rainfall regime, these streams contain water during the wet season but dry up in the middle of the dry season. However, today most of the channels have been widened by mining and

other activities such as quarrying for building purposes leaving extensive pools of water in the dry season though some are being reclaimed [28,31].

Jos metropolis being the administrative capital, and the commercial nerve centre of Plateau State, is the most densely populated area in the state. It covers parts of Jos North and Jos South Local Government Areas (LGAs). According to the 2006 Nigerian census result, the city has a population of 836,910 people, and a projected population of about 1.1 million people with a growth rate of over 3% per annum as of 2014 [29].

Figure 1: Nigeria showing the study area

Data and Analysis

Secondary method of data collection was used to obtain the relevant data required. This study covers a period from 2005 to 2019. Landsat ETM and Landsat OLI were used to capture the urban heat behavior and to analyze the urban heat signature of Jos Metropolis (Figure 2,3,4 and 5). All the

images (Table 1) were obtained from the U.S. Geological Survey (USGS) and Land Viewer Earth Observatory Systems websites, which provide 30 meters resolution imagery. In addition, Google Earth image, topographical maps, land cover maps and the shape file of the study area were used. Detail characteristics of the imageries used are given in Table 1.

Table 1: List of Landsat Imageries

Y e a r	Thermal Bands	Acquisition Date	Remote Sensing Imageries
2 0 0 5	2, 3, 4 & 6	2 0 0 5 / 0 2 / 2 8	Landsat ETM +
2 0 1 9	2, 4, 5, & 10	2 0 1 9 / 0 3 / 1 7	Landsat OLI

Figure 2:2005 False Colour Composite (2,3,4).
Landsat image

Figure 3:2019 False Colour Composite (2,4,5)
Landsat image.

Figure 4: 2005 Thermal Band 6 of the study area.

Figure 5: 2019 Thermal Band 10 of the study area.

The subset study area technique and the supervised classification technique of remote sensing was used for the sampling. A representative subset of the study area in which a method of finding sample units (100 x 100m) in the detected stand-replacing disturbances is demonstrated. Disturbance areas (stands) detected with Landsat time series; stands are generalized; The borders of the stands are refined using CHM; 100 x 100m sample units are placed inside the stands. For the supervised classification, selected training samples and classified image was done based on chosen samples. Training samples are key because they determine which class each pixel inherits in the overall image. Three main parameters were considered in carrying out this study which includes, Land Use Land Cover (LULC), Normalized Difference Vegetation

Index (NDVI) and Land Surface temperature (LST). The procedures in analyzing and achieving these parameters are discussed below: ERDAS Imagine 9.2, was used for image processing and analysis, ArcGIS, was used for data preparation and map composition while Microsoft office 2007 was used for reporting and analysis.

All images (Landsat ETM+ for 2005 and OLI image for 2019) were preprocessed by the U.S. Geological Survey (USGS) National Center for Earth Resources Observation and Science (EROS) to correct radiometric and geometrical distortions of the images to level 1G product. All the bands were utilized at a spatial resolution of 30m. These spectral bands were layer stacked to produce a composite image of the study area for each year (2005 and 2019) for the purpose of land use/land cover classification and image

analysis. Thermal band 6 for Landsat ETM+ and band 10 for Landsat OLI (Figure 4 and 5) were used to extract the surface temperature from all the periods under consideration. The composite images and thermal bands were clipped with a rectangular area of interest in Erdas Imagine 9.255. The thermal bands had their original pixel sizes of 120m for ETM+ and 100m for OLI. Images were resampled to 30m using the nearest neighbor algorithm to match the pixel size of another spectral band. In order to examine the effects of human activities in the study area, a land cover classification is necessary for detection of LULC changes as a result of rapid urbanization from 2005 to 2019. The classes considered were Farmland, Vegetation, Bare land, water body and Built-up area. After selecting training areas, a supervised classification with the maximum likelihood algorithm was conducted to classify the Landsat images using bands 2 (green), 3 (red) and 4 (near infrared). Visual image interpretation was done with field knowledge and making reference to Google earth images of the study area. The error matrixes of the three-land use and land cover maps were generated to assess the accuracy of the classification result. Accuracy Assessment Land cover maps derived from classification

of images usually contain some sort of errors due to several factors that range from classification techniques to methods of satellite data capture. Therefore, evaluation of classification results is an important process in the classification procedure. The accuracy assessment was done by generating 200 equal random points for the classified images, using the accuracy assessment tool in Erdas Image. The error matrix was generated using the same accuracy assessment tool in Erdas Imagine by comparing the randomly selected pixels with the corresponding referenced data. 3.3.4.4 change detection analysis.

The change detection algorithm employed for detecting land use and cover change was image differencing. Image differencing is one of the widely used change detection approaches and is based on the subtraction of images required in two different times. In the Digital Number (DN) value of one date for a given band is subtracted from the DN value of the same band of another date. Change detection analysis was carried out to evaluate the changes in land use/land cover and surface temperature maps of the study area.

The following equation was used to convert the digital number (DN) of TIR bands of Landsat data into spectral radiance [32] $L\lambda =$

$$\frac{(L_{MAX\lambda} - L_{MIN\lambda})}{(Q_{CALMAX} - Q_{CALMIN})} * (Q_{CAL} - Q_{CALMIN}) + L_{MIN\lambda}$$
 (1) where: $L\lambda$ = Spectral Radiance at the sensor's aperture in watts/(meter squared * ster * μm) Q_{CAL} = the quantized calibrated pixel value in DN $L_{MIN\lambda}$ = the spectral radiance that is scaled to Q_{CALMIN} in watts/(meter squared * ster * μm) $L_{MAX\lambda}$ = the spectral radiance that is scaled to Q_{CALMAX} in watts/(meter squared * ster * μm) $Q_{CALMIN\lambda}$ = the minimum quantized calibrated pixel value (corresponding to $L_{MIN\lambda}$) $Q_{CALMAX\lambda}$ = the maximum quantized calibrated pixel value (corresponding to $L_{MAX\lambda}$).

To convert the spectral radiance values to brightness temperature, the equation below were used (Landsat 7 Science Data User's Handbook, 2002):

$$T_k = K_2 \div \ln(K_1 \div L\lambda + 1) \quad (2) \quad 57$$

Where T_k is effective at-satellite temperature in Kelvin, $L\lambda$ is spectral radiance in $\text{W}/(\text{m}^2 \text{ ster } \mu\text{m})$ and K_2 and K_1 are pre-launch calibrated constants.

Then finally convert the temperature in Kelvin to Celsius using the formula:

$T_c = T_k - 273.15$, where T_c is Temperature in Celsius and T_k is Temperature in Kelvin.

The normalized difference vegetation index (NDVI) is a simple graphical indicator that

can be used to analyze remote sensing measurements, typically but not necessarily from a space platform, and assess whether the target being observed contains live green vegetation or not. Live green plants absorb solar radiation in the photo-synthetically active radiation (PAR) spectral region, which they use as a source of energy in the process of photosynthesis. Leaf cells have also evolved to re-emit solar radiation in the near-infrared spectral region (which carries approximately half of the total incoming solar energy), because the photon energy at wavelengths longer than about 700 nanometers is not large enough to synthesize organic molecules. A strong absorption at these wavelengths would only result in overheating the plant and possibly damaging the tissues. Hence, live green plants appear relatively dark in the PAR and relatively bright in the near-infrared [33]. By contrast, clouds and snow tend to be rather bright in the red (as well as other visible wavelengths) and quite dark in the near-infrared. The pigment in plant leaves, chlorophyll, strongly absorbs visible light (from 0.4 to 0.7 μm) for use in photosynthesis. The cell structure of the leaves, on the other hand, strongly reflects near-infrared light (from 0.7 to 1.1 μm). The more leaves a plant has, the

more these wavelengths of light are affected. Since early instruments of Earth Observation, such as NASA's ERTS and NOAA's AVHRR, acquired data in visible and near-infrared, it was natural to exploit the strong differences in plant reflectance to determine their spatial distribution in these satellite images.

The NDVI was calculated from these individual measurements as follows:

Where:

RED = Spectral reflectance measurements acquired in the red (visible) region

NIR = Near-infrared region

This spectral reflectance are themselves ratios of the reflected over the incoming radiation in each spectral band individually; hence they take on values between 0.0 and 1.0. By design, the NDVI itself thus varies between -1.0 and +1.0. It should be noted that NDVI is functionally, but not linearly, equivalent to the simple infrared/red ratio (NIR/VIS). The advantage of NDVI over a simple infrared/red ratio is therefore generally limited to any possible linearity of its functional relationship with vegetation properties (e.g., biomass). The simple ratio (unlike NDVI) is always positive, which may

have practical advantages, but it also has a mathematically infinite range (0 to infinity), which can be a practical disadvantage as compared to NDVI. Also, in this regard, note that the VIS term in the numerator of NDVI only scales the result, thereby creating negative values. NDVI is functionally and linearly equivalent to the ratio $NIR / (NIR + VIS)$, which ranges from 0 to 1 and is thus never negative nor limitless in range [34]. But the most important concept in the understanding of the NDVI algebraic formula is that, despite its name, it is a transformation of a spectral ratio (NIR/VIS), and it has no functional relationship to a spectral difference (NIR-VIS). In general, if there is much more reflected radiation in near-infrared wavelengths than in visible wavelengths, then the vegetation in that pixel is likely to be dense and may contain some type of forest. Subsequent work has shown that the NDVI is directly related to the photosynthetic capacity and hence energy absorption of plant canopies. Meanwhile before running or calculating the NDVI, the DN values was converted to TOA reflectance. The OLI and ETM+ band data were converted to TOA planetary reflectance using reflectance rescaling coefficients provided in the product metadata file (MTL file). The

following equation was used to convert DN values to TOA reflectance:

Where:

$\rho\lambda$ = TOA planetary reflectance, without correction for solar angle. Note that $\rho\lambda$ does not contain a correction for the sun angle.

M_p = Band-specific multiplicative rescaling factor from the metadata (REFLECTANCE_MULT_BAND_x, where x is the band number)

A_p = Band-specific additive rescaling factor from the metadata (REFLECTANCE_ADD_BAND_x, where x is the band number)

Q_{cal} = Quantized and calibrated standard product pixel values (DN)

Note that $\rho\lambda$ is not true TOA Reflectance, because it does not contain a correction for the solar elevation angle. This correction factor is left out of the L1 scaling at the users' request; some users are content with the scene-center solar elevation angle in the metadata, while others prefer to calculate their own per-pixel solar elevation angle across the entire scene. Once a solar elevation angle is chosen, the conversion to true TOA Reflectance is as follows:

Where:

$P\lambda$ = TOA planetary reflectance

θ_{SE} = Local sun elevation angle. The scene center sun elevation angle in degrees is provided in the metadata (SUN_ELEVATION).

θ_{SZ} = Local solar zenith angle; $\theta_{SZ} = 90^\circ - \theta_{SE}$

Remote sensing of temperature uses the amount of radiation reflected or emitted in the thermal infrared portion of the electromagnetic spectrum (EMS). The thermal infrared range of the EMS is generally considered to be between 3 and 14 μ m. Due to absorption by atmospheric water in some portion of the EMS, wavelengths for measuring thermal infrared radiation are generally considered to be from 3 to 5 μ m and 8 to 14 μ m. A number of factors affects the thermal infrared radiation reflected or emitted from the land surface, these include: Variation in sun angle, Composition, density and texture of the components of the land, Topography, Moisture at the surface, etc.

Thermal infrared remote sensing provides an opportunity to estimate land surface temperature from thermal band images. Satellites are equipped with sensors which can detect a range of infrared heat. To estimate the thermal conditions of land

surface by satellite, it is necessary to find the relationship between the surface temperature and land cover types.

Surface Temperature is one of the significant variables that have been measured by remote sensing satellites. This information has a variety of usages in environmental and ecological studies as well as for spatial decision making in GIS.

The main approaches to estimate LST are: to first separate the effect of intervening atmosphere and then decouple LST and LSE and to simultaneously remove atmospheric and emissivity effects. Hence, the prevalent methods of LST estimation require PRIORI surface emissivity information.

Different LST retrieval methods have been developed according to different data sources, such as the:

1. Split-window method
2. Temperature/emissivity separation method
3. Single-Channel method;
4. Mono Window Algorithm; and
5. Radiative Transfer method.

The split-window method and temperature/emissivity separation method are used for retrieving or estimating temperature in satellites and sensors like ASTER and MODDIS due to their multiple thermal bands

while the other three LST retrieval methods: radiative transfer equation, mono-window algorithm and single-channel algorithm can be applied to Landsat ETM+ and OLI. Although all of these methods can provide good results, they have their disadvantages and challenges. The radiative transfer equation is not available without *in situ* parameters of atmospheric profiles simultaneously when the satellite passes, that is, it needs in-situ atmospheric profile data simultaneously with the satellite passes which is usually unavailable in daily life. The disadvantage of single-channel algorithm is that additional information is required supplied by the satellite, namely: emissivity, transmissivity, and ascendant and descendant atmospheric radiance. These radio probes information is sometimes difficult to obtain.

In this study, the mono-window algorithm was used, this algorithm for obtaining LST helped avoid the dependence on radio sounding in the radiative transfer equation RTE method and doing atmospheric correction. This algorithm merely needs three parameters: emissivity, transmittance and effective mean atmospheric temperature. Apart from the ease and accuracy that comes with using the mono-window algorithm, one other thing that necessitates its application in

this study is that the study used Landsat Satellite which includes OLI and ETM+ data. With this, the following method was adopted sequentially.

OLI and ETM+ band data of Landsat was converted to TOA spectral radiance using the radiance rescaling factors provided in the metadata file using the formula:

Where:

L_{λ} = TOA spectral radiance (Watts/ (m² * srad * μ m))

M_L = Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_x, where x is the band number)

A_L = Band-specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_x, where x is the band number)

Q_{cal} = Quantized and calibrated standard product pixel values (DN)

While TM band data of Landsat 5 was converted to TOA spectral radiance using the radiance rescaling factors provided in the metadata file using the formula:

Where:

L_{λ} = spectral radiance

G =Gain value for a specific band

DN =Quantized and calibrated standard

product pixel values

B =Bias value for a specific band

Conversion to spectral radiance is necessary to correct atmospheric effect on the reflectance value; absorption and scattering create an overall effect of “ haziness” which reduces the contrast in the image. Scattering also creates the “ adjacency effect” in which the radiance recorded for a given pixel partly incorporates the scattered radiance from neighboring pixels. In order to make a meaningful measure of radiance at the Earth’ s surface, the atmospheric interferences must be removed from the data. This process is called “ atmospheric correction” . Brightness temperature is a measurement of the radiance of the microwave radiation traveling upward from the top of the atmosphere to the satellite, expressed in units of the temperature of an equivalent black body. The brightness temperature (or T_B) is the fundamental parameter measured by passive microwave radiometers. The brightness temperatures, measured at different microwave frequencies, are used at Remote Sensing Systems to derive wind, vapor, cloud, rain, and SST products.

OLI and ETM+ band data were converted from spectral radiance to brightness

temperature using the thermal constants provided in the metadata file using the Formula: $T_s = K_2 \div \ln (K_1 \div L_\lambda + 1)$ (2) 57

Where:

T_s = At-satellite brightness temperature (K)

L_λ = TOA spectral radiance (Watts/ (m² * srad * μm))

K_1 = Band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_x, where x is the band number, 10 or 11)

K_2 = Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_x, where x is the band number, 10 or 11)

CF = Conversion Factor to Degree Celsius (272.15)

Land surface emissivity (LSE) is the average emissivity of an element of the Earth's surface calculated from the measured radiance and land surface temperature (LST). This emissivity calculated using the formula:

Where:

ϵ = Land Surface Emissivity

$\ln$ = Log

NDVI = Normalized Difference Vegetation Index

Land surface temperature is how hot the “surface” of the Earth would feel to the touch in a particular location. From a satellites point of view, the “surface” is whatever it sees when it looks through the atmosphere to the ground. It could be snow and ice, the grass on a lawn, the roof of a building, or the leaves in a forest canopy. Land Surface temperature was calculated using the formula:

Where:

T = Land Surface Temperature

T_s = At-Satellite Brightness Temperature

λ = wavelength of the emitted radiance = 11.5μm [35]

$\rho = hc/\sigma = 1.438 \times 10^2 \text{ mK}$; σ = Stefan Boltzmann constant ($5.67 \times 10^{-8} \text{ Wm}^{-2}\text{K}^4$), h = Plancks constant ($6.626 \times 10^{-34} \text{ Js}$) and $c = 2.998 \times 10^8 \text{ m/s}$.

ϵ = Land Surface Emissivity

This can also be referred to as stacking data; it involves combining spatial and attributes data from two or more spatial data layers that are in the same coordinate system. Overlay analysis allow one to compare both attribute and location information about multiple map layers, it is one of the most powerful components of GIS. This operation allows the analysis of two or more data of different

historical sources, for example a map created by government agency with an aerial photo taken about the same time. Or, it also allows one to analyze change over time by comparing similar sources created at different points in time.

In this study, the overlay was carried out using the land use land cover (LULC) classified image and the map of the Land Surface Temperature (LST) generated from the thermal bands of the study area over the years in view. First of all, map of the land use land cover (LULC) classified image of the different years was overlaid over each other starting with the earliest year to compare and determine the magnitude of change in the land use land cover (LULC) of the study area. Same process was carried out of the Land Surface Temperature (LST) to know the magnitude of UHI and how it has change over the years. Lastly, the Land Surface Temperature (LST) map was overlaid on land use land cover (LULC) classified image map to examine the magnitude and level of the UHI base on different land use and land cover types. In overlay operations, new information that was not present in individual maps is produced. This operation can be carried out on both vector and raster data; vector overlays combine point, line and

polygon features while raster overlay is cell-by-cell comparison, combination or operation.

People are affected by increase temperatures for longer period, as recorded in previous studies [42-46]. Higher temperature does not only make life uncomfortable in urban areas but also adversely affects people' s health [36,37]. The comforts thermal for tropical area ranges between 22 °C to 27 °C [38]. An index called Universal Thermal Climate Index (UTCI) was developed to monitor the impact climatic condition on human [39,40]. There are five categories of heat stress based on the level of temperature, such as Extreme Heat Stress ($> +46$ °C), Very Strong Heat Stress (+38 to +46 °C), Strong Heat Stress (+32 to +38 °C), Moderate Heat Stress (+26 to +38 °C) and No Thermal Stress (+9 to +26 °C) and in this study, the UTCI is being combined with effective temperature (ET) index to explain the relation between temperature condition and the level of sensation (very hot, hot, warm, slightly warm and neutral), comfort (very uncomfortable, uncomfortable and comfortable), psychology (body heating, increasing stress due to sweating and blood flow, and normal regulation by sweating and vascular change), and health (circulatory collapse, increasing

danger of heat stroke, cardiovascular embarrassment and normal health) [40-41]. Those indices will determine the urban heat hazard in our study area.

RESULTS

The vegetation indices considered in this study is the red edge Normalized Difference Vegetation Index. The high and low Normalized Difference Vegetation Index value was 0.43 high and -0.48 low, respectively in 2005 and 2019. Spatial variation of NDVI is affected by the amount vegetation cover and topography, slope, solar radiation availability, and other factors. NDVI is commonly used to measure land surface greenness based on the assumption that NDVI value is positively proportional to the amount of green vegetation in an image pixel area [47]. This NDVI verified in this study as Figure 6 and 7 shows the variation of NDVI across Jos Metropolis in 2005 and 2019 respectively, the NDVI values for the

vegetated areas are positive while the other classified features are negative; built-up area, cultivated land, rock outcrops and water body.

Surface temperature Figure 8 and 9 present the classifications of land cover for the years in view. It has established as a major indicator of surface urban heat island presence in cities and urban areas. The relationship between land cover and surface temperature was analyzed for each year by producing images that provided a visual resource for analyzing the intensity and spatiality of LST change. The Red, Green and Blue (RGB) composition created through composite banding was useful for identifying land cover types and selecting training areas for the supervised maximum likelihood classification. Each composed image ordered into five area classes: built-up area, cultivated land, vegetation cover, rock outcrops and water body.

Figure 6: 2005 NDVI of the study area.

Figure 7: 2019 NDVI

Figure 8: Land Use Cover Classification in 2005

Figure 9: Land Cover Classification in 2019

From the result shown in Figure 10 and Table 2, the land cover type that dominated Jos Metropolis in 2005 was Cultivated Land, (72.06Km²) which is about 39.26% of the total land area follow by Rock Outcrop (69.78Km²) 38.02%, Built-up Area

(21.24Km²) 11.57%, Vegetation Cover (18.67Km²) 10% and Water Body covering the least at (1.80Km²) which is 0.98% of the land area.

Figure 10: Percentage distribution of land cover types of Jos Metropolis, 2005

Table 2: Land Cover Distribution for the years (2005 and 2019)

Classes	2005		2019	
	Area(sq.km)	Area (%)	Area(sq.km)	Area (%)
Built-up area	21.24	11.57	39.49	21.51
Cultivated land	72.06	39.26	63.00	34.32
Vegetation cover	18.67	10.17	34.96	19.05
Rock outcrop	69.78	38.02	44.35	24.16
Water body	1.80	0.98	1.76	0.95
Total	183.55	100.00	183.55	100.00

Figure 11: Histogram distribution of land cover types of Jos Metropolis, 2019.

From Table 2 and Figure 11 on land cover type in 2019, the result from the analysis shows that the dominant land cover type is still the Cultivated Land (63.00 Km²), 34.32% though with slight change in the figure with that of 2005, a decrease in about 8.02Km² and 4.94% of the land area. This is

followed by Rock Outcrop (44.35Km²), 24.16%, with a decrease in 25.43Km² and 13.86%, Built-up Area (39.49Km²), 21.51% with an increase in 18.25Km² and 9.94%, Vegetation Cover (34.96Km²), 19.05% with an increase in 16.26Km² and 8.88% and Water Body (1.75Km²), 0.95% with a decrease in 0.05Km² and 0.03% of the area.

Figure 12: Land surface temperature (2005).

Figure 13: Land surface temperature (2019).

This study categorizes UHS with high and low classes based on the Land Surface Temperature Figure 12 and 13. The high temperature (red color), the coverage was higher in 2019 compare to 2005. The area with high temperature in 2019 is mainly distributed in the South eastern part, it spread to the western and Northern part of Jos Metropolis.

DISCUSSION

The natural vegetation has been degraded for agricultural activities leaving little or no green vegetation, Figure 6. During this period (dry season precisely on the 28th of February, 2005) it is believed that there is little or no vegetation as a result of the absence of rainfall, the dry vegetation exposes the soil and the rock outcrops at this period are seen clearly as most trees have shaded their leaves. Also, cultivated farm lands at this period of the year have no green leaves in them having a positive value of 0.43 and a negative value of -0.48.

For 2019, the image Figure 7 was acquired on the 17th of March, 2019, which plants spring from the ground and trees come into blossom after the dry season which is supposed to account for high vegetation cover but reverse was the case in this year as

it did not come up with a thick and healthy green vegetation in the year and has the same positive and negative value of 0.43 and -0.48 respectively. The positive values were observed in the vegetated areas while the negative value can be said to occur in built up area, rock outcrop and cultivated land.

In Table 2 Figure 10, the natural vegetation has been degraded for agricultural activities leaving little or no green vegetation. During this period, it is believed that there is little or no vegetation, because of the absence of rainfall in the area. The dry vegetation exposes the soil and the rock outcrops clearly as most trees have shaded their leaves. Cultivated farm lands at this period of the year have no green leaves in them hence these account for the high percentage of cultivated land (39.26%), at this time development was yet to take place putting the built-up class at 11.57%. The area has little water body due to the absence of rainfall at this period, it accounts for a very small percentage of water cover (0.98%) and are only confined to the water body like pounds with little quantities. The percentage of vegetation in the metropolis is less despite less development because of little or no water to sustain it, this result in weak and pile vegetation in the area which is revealed in

NDVI (Figure 6 and 7).

Distribution of land cover types of Jos Metropolis, 2019, shows that there is a significant change in almost all the various classes of land cover type Table 2 and Figure 11. This can be attributed to the fact that development has begun in the area after about fifteen years which is evident in the rise of figure for Built-up area from 21.24Km² and 11.57% in 2005 to 39.49Km² and 21.51% in 2019. It could be said that population might have triggered the need for the expansion in built-up area for housing in other to support the ever-increasing population. Also, vegetation cover value also increased from 18.67Km² and 10.17% to 34.96Km² and 19.05% as the Landsat OLI was acquired on the 17th of March, 2019, during this period, plants spring from the ground and trees come into blossom after dry season leading to high vegetation cover. The rise in value for these two land cover types are evident in the rapid decrease in the remaining three land cover types which are the cultivated land, rock outcrop and water body. This is because expansion in housing and green leaves has encroach into parts of these areas thereby leading to the decrease in the value of such areas.

From the result in Figure 13, the largest area of Urban Heat Island occurred in 2019, it was mostly agglomerated in the South Eastern part, then it spread to the Western and Northern part of Jos Metropolis (Gwong, Kwang, Dura, Rayfield, Hwolshe, Tudun Wada and Federal Lowcost). It can be concluded that changes in land-use from vegetated area to built-up area is the main reason for these circumstances and this is in conformity with the result from [[48-51], which reveals that the area of Urban Heat Island were significantly reduced as a result of the changes in land use cover. Significantly, hot spot of high Land Surface Temperature was recorded in built up, rock out crops and cultivated lands with significantly cold spot in vegetated cover and water body, this is in agreement with [25] that hot spot of high Land Surface Temperature were recorded in built up, rock out crops and cultivated lands with significantly cold spot in vegetated cover and water body. This finding validates [52] that the lowest temperature was observed in River Yamuna (Mumbai). Vegetation and water body play a very important role in the modification of land surface temperature [3] Based on the Land Surface Temperature, the trends show an increase in surface

temperature during 2005 and 2019 (Figures 12 and 13). The lowest temperature was from the range of 30.72-34.86⁰C and it was obtained in 2005 while the highest temperature was recorded within the range 31.96-36.22⁰C in 2019. It can be deduced that 2019 is the warmest period in Jos Metropolis. The Effective Temperature (ET) index was employed to infer the impact of urban maximum air temperature and the

human health condition, the Effective Temperature (ET) index was employed (Table 3). Based on the ET index, the urban maximum air temperature (heat) was warm 31.96-36.22⁰C in 2019. This temperature range mostly cause very uncomfortable conditions due to the increasing stress caused by sweating and blood flow to increase in the probability of heatstroke and cardiovascular embarrassment in human health condition.

Table 3: Effective Temperature (ET) index in Jos Metropolis

Year	Temperature (°C)	Sensation		Psychology	Health
		Temperature	Comfort	Body heating, failure of regulation	Circulatory collapse
	>40	Very hot	Very uncomfortable	Increasing stress caused by sweating and blood flow	The increasing danger of stroke
	35-40	Hot	Very uncomfortable	Increasing stress caused by sweating and blood flow	Cardiovascular embarrassment
2005 and 2019	32-35	Warm	Uncomfortable	Increasing stress caused by sweating and blood flow	Cardiovascular embarrassment
2005	30-32	Slightly warm	Uncomfortable	Normal regulation by sweating and vascular change	Cardiovascular embarrassment
	25-30	Neutral	Comfortable	Normal regulation by sweating and vascular change	Normal health

Source: authors field survey

The urban heat hazards were determined by relating the temperature value from Land Surface Temperature with Universal Temperature Climate Index (Table 4). Based on the index, the hazards occurred in 2005

and 2019, with stress category from moderate heat stress of 26⁰C-32⁰C to strong heat stress of 33⁰C-38⁰C (Table 4). Fortunately, there is no extreme heat stress of over 46⁰C in this study.

Table 4: Universal Temperature Climate Index (UTCI) in Jos Metropolis

Range of maximum temperature	Stress category	Year
Above 46 ⁰ C	Extreme heat stress	
39-46 ⁰ C	Very-strong heat stress	
33-38 ⁰ C	Strong heat stress	2019
26-32 ⁰ C	Moderate heat stress	2005
9-26 ⁰ C	No thermal stress	

Source: authors field survey

CONCLUSION AND RECOMMENDATIONS

Integration of remote sensing and GIS was employed to evaluate increased surface temperature on human health in Jos Metropolis. This study has demonstrated that the direct effect of urban land use/cover change on one environmental element can cause direct or indirect effects on the other, thereby affecting human health. Findings from this study revealed a general decline in natural surfaces and increased developed surfaces from 2005 to 2019. The resulting GIS analysis showed that built up areas are increasing at an annual average rate of 5.1 %

while the Surface Temperature (ST) has gone up with 1.36⁰C during the study period. Bare land exhibited the high values of surface temperature while vegetation showed low values of surface temperature. The year 2019 recorded the highest urban heat, causing very uncomfortable condition due to the increasing stress caused by sweating and blood flow leading to increase the probability of heatstroke and cardiovascular embarrassment, hazardous to human health. The variations in surface temperatures of the identified land use/cover types of Jos Metropolis suggest that urban growth is a major factor responsible for land

transformation. The increase in the rate of surface temperature has its attendant effects on both the environment and residents' health. Therefore, planting of trees and vegetation in and around the study area should be encouraged to minimize the increase in surface temperatures of the land use/cover types.

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Conflict of Interest

There is no conflict of interest in the cause of writing this research.

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