# Evaluation of The Impact Of Urban Expansion On Surface Temperature Variations Using Remote Sensing-Gis Approach

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***Abstract*-Jimeta has experienced a rapid urban expansion over the past three decades due to population explosion and accelerated economic growth. This paper reports an investigation into the application of the integration of remote sensing and geographic information systems (GIS) for detection urban growth and assessing its impact on surface temperature. Remote sensing techniques were utilized to carry out land use/cover change detection by using multi-temporal Landsat Thematic Mapper data. Urban growth patterns were analyzed by using a GIS-based modeling approach. The integration of remote sensing and GIS was further applied to examine the impact of urban growth on surface temperatures. The results revealed a notable and uneven urban growth in the study area. This urban development had raised surface radiant temperature by 90C from 1986 to 2008 in the urbanized area. The integration of remote sensing and GIS was found to be effective in monitoring and analyzing urban growth patterns, and in evaluating urbanization impact on surface temperature.**

*Keywords*- Surface temperature, remote sensing, GIS, urban expansion, Jimeta.

## I. Introduction

Land covers constitute the biophysical state of the earth's surface and immediate subsurface and they serve as sources and sinks for most of the materials and energy movements and interactions between the earth spheres. Changes in land-cover include changes in biotic diversity, actual and potential primary productivity, soil quality, runoff, and sedimentation rates (Steffen et al, 1992 in Weng, 2001), and cannot be well understood without the knowledge of land-use change, which plays a greater role in deriving them. Therefore, land-use and land-cover changes have environmental implications at local and regional levels, and of course, are linked to the global environmental processes. Because of the interrelated nature of the elements of the natural environment, the direct effects on one element may cause indirect effects on others.

Urbanization, the conversion of other types of land to uses associated with growth of populations and economy, is a main type of land-use and land-cover change in human history. The rate of urbanization (growth in population and physical structures) of most cities has been in the increase Since the beginning of industrial revolution. For instance, at The beginning of the 20th Century, only 16 cities in the world had populations over one million; by the early 2000s there were over 400 (Stefanov et al, 2001a) and may be much higher today. This has a great impact on climate. In Nigeria, land-use and land-cover patterns have undergone a fundamental change due to accelerated population explosion and economic development under different economic policies of past governments. Urban growth has been speeded up, and extreme stress to the environment has occurred. This is particularly true in regions such as Jimeta-Yola area where massive agricultural land is disappearing each year, converting to urban or related uses. This is evident in areas like Saminaka and Jambutu where over 50% of the developed lands there used to be bushes and farmlands in about 2 decades ago. This involves the removal of natural land cover and the introduction of urban materials in form of clearance of natural vegetation; reclamation of swampy areas; construction of buildings, roads, and other concrete surfaces like parks and pools (Xu and Cheng, 2004). Hence, there is a continual replacement of the highly beneficial and pleasing rural green spaces and trees with bricks, concrete, and ejection of poisonous pollutants unto the atmosphere as city grows. This coupled with the social and technological sophistication of the contemporary world, lead to radical changes in the nature of the surface and atmospheric properties of cities. There are therefore, changes from precious, homogeneous countryside climate characterized by clear air and water to highly polluted, unpleasant, noisy, heterogeneous and unpredictable atmospheric conditions of urban areas as they grow. It is such deliberate and/or inadvertent modifications of the natural environment that result to the transformations of the radioactive, thermal, and aerodynamic characteristics of the city environment thereby altering the natural solar and hydrologic cascades of urban areas.

As stated earlier, Jimeta has reportedly been growing rapidly owing to favorable socio-economic, political, and physical factors. This growth became so pronounced when the city was accorded the status of a state and Local Government headquarters. Evaluating the magnitude and pattern of Jimeta's urban growth is an urgent need. This is to generate information that could help in tackling some of the problems that accompanied rapid urban growth. The goal of this study is therefore, to employ the integrated use of remote sensing and GIS in addressing environmental issues in Nigeria at a local level with a view to evaluating urban growth patterns

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in Jimeta city and to analyze the impact of such growth on surface temperature. Specifically, the study investigate changes in land use and land cover, as a result of urban expansion over time (1986-2008) and how this relates to urban micro-climate.

## II. Study Area

The study area, Jimeta, is located between latitudes $9^0$ 10' to $9^0$ 15'N and longitudes $12^0$ 11' to $12^0$ 17'E. Jimeta, a twin city to Yola town, is the seat of Yola North Local Government Headquarters and Adamawa State capital of Nigeria. The area has a Sudan type of vegetation and a tropical climate marked by wet and dry seasons. The minimum temperature recorded is about $15^0$C and a maximum of about 40 $^0$C. The city has been experiencing an increasing population explosion since it assumed a status of Adamawa State capital in 1976. Like any other Nigerian cities, Jimeta comprises of so many land use types ranging from institutional, commercial, and residential. The city is clearly stratified in terms of population densities (Ilesanmi, 1999). These are low, medium and high density areas. The low density areas are well planned units where government officials reside while medium and high density areas are made up of common people with little or unplanned buildings.

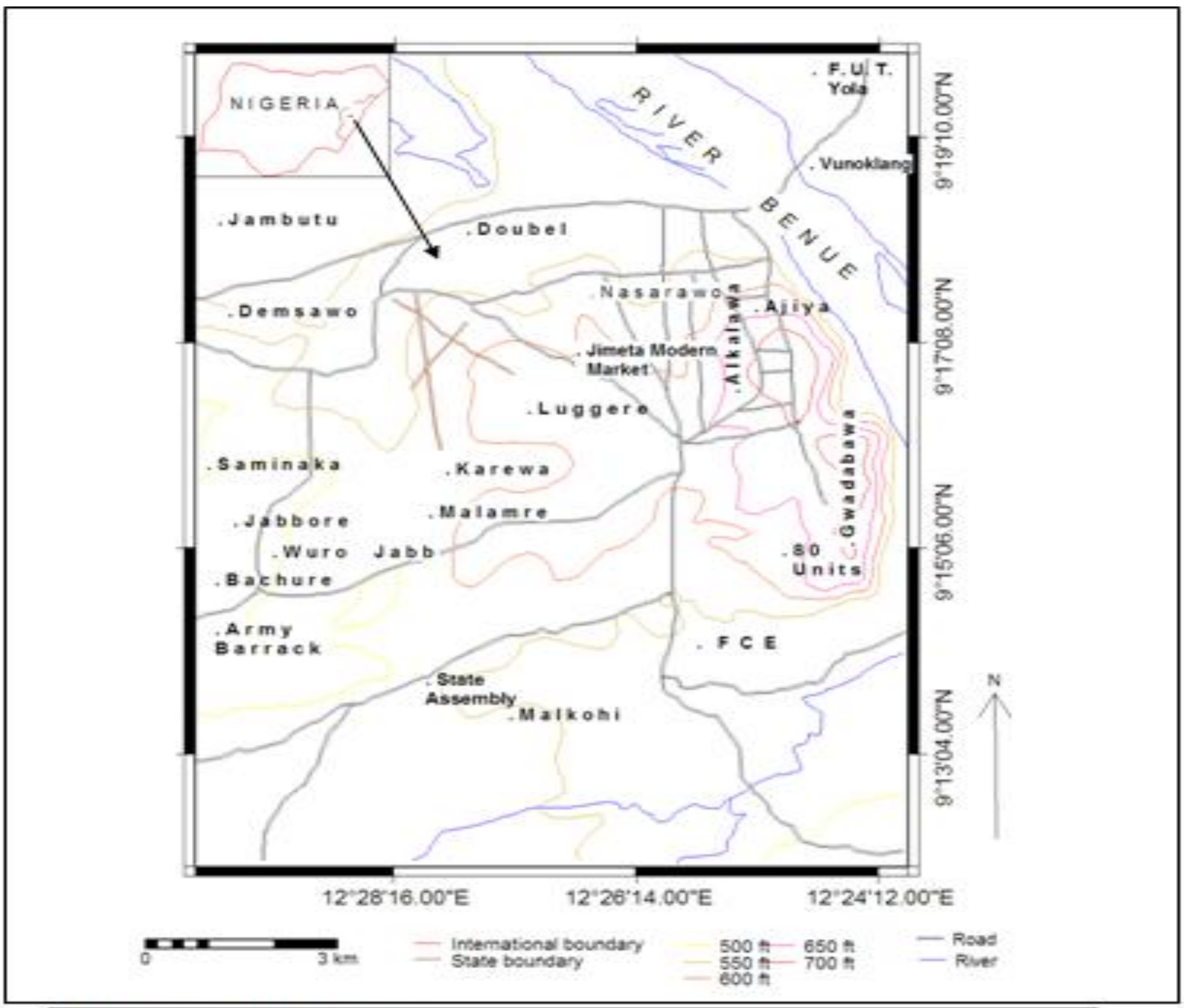


Fig 1: Map of the Study Area

In recent times, Jimeta has risen as the premier commercial, industrial and transportation urban area of the northeastern Nigeria. The rapid growth of Jimeta, particularly within the past 30 years, has made it one of the fastest growing metropolitan areas in Nigeria. The population of Jimeta increased significantly by 69% between 1973 and 1991 and 58% between 1991 and 2006 (NPC 2006). Concomitant with this high rate of population growth has been an explosive growth in retail, educational, commercial and administrative services within the area. This has resulted in tremendous land cover change dynamics within the metropolitan region, wherein urbanization has consumed vast acreages of land adjacent to the city proper and has pushed the urban fringe farther away from the original Jimeta urban core. An enormous transition of land from forest and agriculture to urban land uses has occurred in the area, the extent of which needs to be investigated for the sake of planning for the ever growing population.

## III. Materials and Methods

### *A. Land Use Land Cover Change (LULCC) Detection*

Landsat TM and ETM+ of 1986 and 2008 respectively constitute the data used in this research. With the aid of Erdas Imagine's histogram computation tools, each Landsat image was enhanced using histogram equalization (in order to gain a higher contrast in the peaks of the original histograms) to increase the volume of visible information. This procedure is important for helping identify ground control points in rectification. All the images are rectified to a common UTM coordinate system based on the 1:50,000 topographic maps of the study area. Each image was then radiometrically corrected using relative radiometric correction method. A supervised classification with maximum likelihood algorithm was conducted to classify the landsat images using bands 4, 3, and 2. The accuracy of the classification was verified by field-check. The change detection algorithm employed for detecting land use and cover change was image differencing. This is because image differencing is probably the most widely applied change detection algorithm (Singh, 1989 in Bottomley, 1999). Percentage Change In The Pixel Values Of Land Cover/Use Was Then Computed Using RASTER ATTRIBUTES/EDIT/COMPUTE STATISTICS Subroutine And Values Were Compared For The Periods Involved. A change matrix was produced with the help of Erdas Imagine software. Quantitative areal data of the overall land use/cover changes as well as gains and losses in each category between 1986 and 2008 were then compiled.

### *B. Urban Expansion Detection and Analysis*

The urban expansion images, which were obtained from image classification, was further overlaid with several geographic reference images to help analyze the patterns of urban expansion, including an image of city boundary, major roads, and urban centers. These layers were constructed in a vector GIS environment and converted into a raster format (grid size = 30m). The city boundary image was utilized to find urban land change information within the city. Because proximity to a certain object, such as roads, has important implication in urban land development, urban expansion processes often show an intimate relationship with distance from these geographic objects. Using the buffer functions in ArcGIS, a buffer image was generated, showing the proximity to the major roads of the study area. Ten buffer zones were created around a major road with a width of 500m. Local conditions have been taken into account in selecting these buffer widths. The buffer image was overlaid with the urban expansion image to calculate the amount of urban expansion in each zone. The density of urban expansion was then calculated by dividing the amount of urban expansion by the total amount of land in each buffer zone. Those values of density can be used to construct a distance decay function of urban expansion. In order to analyze the nature, rate and location of urban land change, an image of urban built-up land was extracted from each original land cover image. The extracted images were then overlaid and recoded to obtain an urban change (expansion) image.

### *C. Derivation and Detection of Changes in Land Surface Temperature.*

Urban development usually gives rise to a dramatic change of the Earth's surface, as natural vegetation is removed and replaced by non-evaporating and non-transpiring surfaces such as metal, asphalt and concrete. This alteration inevitably results in the redistribution of incoming solar radiation, and induces the urban-rural contrast in surface radiance and air temperature. To measure the surface temperature change from 1986 to 2008, surface radiant temperature were derived from radiometrically corrected TM, and ETM+ thermal infrared data (band 6). As known, the Landsat TM, and ETM+ sensors acquire the surface temperature data and store them as 8-bits Digital Numbers (DNs). In order to convert these DNs to temperature data, expressed in degrees Celsius, they were firstly converted to radiance values using the "gain" and "offset" values specific to the individual scenes and then radiance data were converted to the degrees Celsius using Landsat Project Science Office (2002) procedure.

*(i)Conversion of Digital Numbers (DNs) to Radiance values*

For the calculation of the radiance values of the TM data the following formula has been used:

$$Radiance = DN * Gain + Offset, \quad \text{Where:} \tag{1}$$

$$Gain = 0.05518$$

$$Offset = 1.2377996$$

Whereas for the calculation of the radiance of the ETM+ data the following formula was used:

$$Radiance = ((L_{MAX} - L_{MIN}) / (DN_{MAX} - DN_{MIN})) * (DN - DN_{MIN}) + L_{MIN}, \text{ where:} \tag{2}$$

*For band 6L* and *For band 6H*

$L_{MAX} = 17.04$

$L_{MAX} = 12.65$

$L_{MIN} = 0.0$

$L_{MIN} = 3.2$

$DN_{MAX} = 255$

$DN_{MAX} = 255$

$DN_{MIN} = 1$

$DN_{MIN} = 1$

The values for all these parameters were obtained from the data header files.

*(ii)Conversion of Radiance to Temperature (0C)*

After the calculation of the radiance values, the temperature values were derived using the inverse of Planck function, thus:

$$T_{(^0C)} = \left[ \frac{K_2}{L_n\{K_1 / CV_R + 1\}} \right] - 273 \qquad (3)$$

Where:

$T_{(^0C)}$ = *Temperature in Degrees Celsius*
$CV_R$ = *Cell (pixel) value as radiance*
$K_1$ = *607.76 (for TM) or 666.09 (for ETM and ETM+) in* $mW\, cm^{-2}\, sr^{-1}\, \mu m^{-1}$
$K_2$ = *1260.56 (for TM) or 1282.71 (for ETM and ETM+) in Kelvin*

In examining the spatial relationship between land use/cover types and the surface energy response as measured by surface temperature, a classified image of 1986 and 2008 were overlaid to the surface temperature images of corresponding years.

## IV. Results

### *A. Urban expansion of Jimeta*

Results of image analysis showed that Jimeta city has experienced a series of drastic changes in its administrative boundaries. These changes affect the computation of urban built-up areas at different periods of time. The current city jurisdiction came into effect in 1996 as a result of the creation of Yola North Local Government Area with eleven political wards. These wards are Yelwa, Limawa, Ajiya, Alkalawa, Gwadabawa, Luggere, Demsawo, Jambutu, Nasarawo, Doubeli, and Karewa. It was discovered that Jimeta started growing faster as an urban centre from the middle of 1970s when Yola was made the headquarters of the defunct Gongola state in 1976. Even though Yola has been the nominal headquarters of Gongola and later Adamawa state, but virtually all the government offices and other official buildings are found in Jimeta. That is to say the actual seat of Adamawa state is in Jimeta. The city expanded from 33,133 hectares in 1986 to 51, 578 hectares in 2008. Most of the new developments took place in the suburbs as organized clusters for accommodating especially residential expansions, academic institutions, emerging settlements, warehouses, or external transportation facilities, in addition to rapid developments on the outskirts of the old city core. Karewa and parts of Gwadabawa were designated as Government Residential Areas (GRA) in the 1980s. This led to massive construction of offices and government quarters in these areas. New residential buildings quickly swelled up to reach these areas. By this time, new developments were mostly directed to the suburbs in order to contain the growth of the inner city.

The 1980s also witnessed a dramatic urban development in another area, in addition to the above. The reconstruction, expansion and upgrading of Yola airport to international status; buildings of Africola soft drinks factory in Kofare industrial area; establishment of Army Barracks to the west of Karewa; establishment of Federal College of Education, Yola in Karewa played greater role in shaping a modern Jimeta city. Office buildings, hotels, and recreational facilities, soon emerged and added to the attributes of modern Jimeta. New bridge (over River Benue) was constructed to provide a carriage-way across River Benue to the north, laying the foundation for future northern expansion. The urban and built-up areas grew even faster in the late 1980s, owing primarily to the development of commercial activities, especially the movement of the market from the present day shopping complex to its present site, after Maitasine raids in 1984. The Jimeta main market, which was relocated to the same area with the motor park, together had witnessed massive construction of shops, stalks and pavements. The relocation of this market led to the springing up of nearby settlements of Demsawo, Upper Luggere, and Nasarawo. Meanwhile, recent development had been tending towards western and southern axis of Jimeta.

By the late 1990s and early 2000s, Jimeta witnessed yet another significant expansion in terms of both land area and population. This is evident in areas like Jambutu, Saminaka, Jabbore, Wuro-Jabbe and Mayanka areas where various stages of land development have been taking place. Moreover, the land-use and land-cover maps derived from the Landsat images show that the urban and built-up area increased by 18, 445 hectares, or by 55.7% in the 22-year period (1986-2008). This indicates that other land cover types were massively converted to urban land use at an annual rate of 838.4 hectares. Overlying the urban land-use maps with a city boundary and major roads reveals that there has been a significant expansion in the size of Jimeta. If this trend continues, Jimeta will soon join Yola town to become a megacity.

### *B. Land use and land cover change of Jimeta from 1986 to 2008*

The result of urban expansion as presented in section 4.1 above is the changes in land use and land cover. In an effort to investigate the nature of these changes, Landsat satellite data were subjected to pixel-by-pixel classification. The overall accuracy of the classification of 1986 and 2008 images were found to be 84% and 88% respectively (Table 1 and 2). The accuracy values are corroborated by Kappa statistics of 82%, and 85% respectively for 1986 and 2008 data. The only source of error was that some built-up lands were classified as bare surface while some croplands were classified as forest areas or forest areas as croplands; and some marshy lands were represented as water bodies and vice-versa. This is owing to similarities in their spectral characteristics. Clearly, these data have reasonably high accuracy, and thus are sufficient for urban growth detection. From Table 3, it is clear that there was a considerable change in the land use and land cover of the study area during the 22-year period (1986-2008). Four of the land cover types i.e. built-up land, cultivated land, bare surfaces, and marshy lands increased in area by 55.7%, 28%, 6.7%, and 0.7% respectively, while forest areas and water bodies decreased in area by 88.6% and 5.8% respectively. The subtraction of the 1986 from 2008 land use/cover map further reveals that of 55.7% increase in urban built-up land, over 80% resulted from cultivated land and bare surfaces.

**Table 1: Error Matrix of Land Use and Land Cover Map, 1986**

| Class data | Reference data UC | BS | CL | FT | UB | ML | WB | RT | CT | PA(%) | UA(%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| UC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | --- |
| BS | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 2 | 50.0 | 100.0 |
| CL | 0 | 0 | 17 | 1 | 1 | 0 | 0 | 18 | 19 | 89.5 | 94.4 |
| FT | 0 | 0 | 1 | 10 | 0 | 0 | 0 | 12 | 11 | 90.9 | 83.3 |
| UB | 0 | 0 | 0 | 1 | 9 | 0 | 0 | 11 | 10 | 90.0 | 81.8 |
| ML | 0 | 0 | 0 | 0 | 1 | 3 | 1 | 5 | 5 | 60.0 | 60.0 |
| WB | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 3 | 66.7 | 66.7 |
| Column Total | 0 | 1 | 18 | 12 | 11 | 5 | 3 | 50 | 50 | | |
| Overall Accuracy = | | 84.0% | | | | | | | | | |
| Kappa Statistics = | | 82.0% | | | | | | | | | |

Table 2: Error Matrix of Land Use and Land Cover Map, 2008

| Class data | Reference data UC | BS | CL | FT | UB | ML | WB | RT | CT | PA(%) | UA(%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| UC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | --- | --- |
| BS | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 3 | 33.3 | 100.0 |
| CL | 0 | 0 | 10 | 1 | 0 | 0 | 0 | 12 | 11 | 90.9 | 83.3 |
| FT | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 4 | 3 | 100.0 | 75.0 |
| UB | 1 | 0 | 1 | 0 | 21 | 0 | 0 | 22 | 23 | 91.3 | 95.5 |
| ML | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 5 | 4 | 100.0 | 80.0 |
| WB | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 5 | 6 | 83.3 | 100.0 |
| Column Total | 1 | 1 | 12 | 4 | 22 | 5 | 5 | 50 | 50 | | |
| Overall Accuracy | | = | 88.0% | | | | | | | | |
| Kappa Statistics | | = | 85.0% | | | | | | | | |

UC = Unclassified; BS = Bare surface; CL = Croplands; FT = Forest trees; UB = Urban built-up; ML = Marshy lands; WB = Water bodies; RT = Reference total; CT = Classified total; PA = Producer's Accuracy; UA = User's Accuracy

**Table 3: Statistics of changes in LULC between 1986 and 2008**

| LULC type | Area in 1986 | Area in 2008 | Difference | % difference |
|---|---|---|---|---|
| Bare surface | 1,088 | 1,161 | 73 | 6.7 |
| Cropland | 66,124 | 84,616 | 18,492 | 28.0 |
| Forest | 41,226 | 4,703 | -36,523 | -88.6 |
| Marshy land | 7,978 | 8,030 | 52 | 0.7 |
| Urban land | 33,133 | 51,578 | 18,445 | 55.7 |
| Water bodies | 9,204 | 8,666 | -538 | -5.8 |

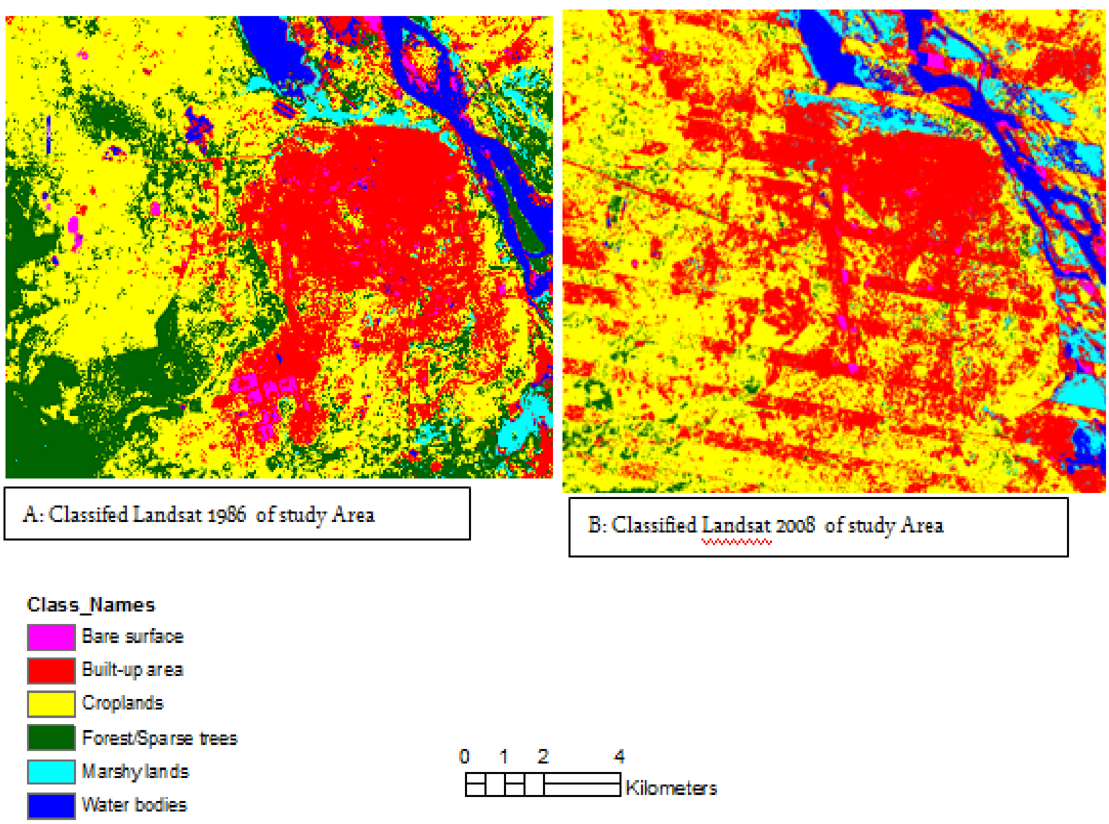


Fig 2: Land use and Land cover of the study Area, 1986 and 2008

In percentage terms, the largest increase in urban built-up land in 1986 occurred in Karewa area. Increase in built-up land in Karewa area corresponds with the period when most of the former government's built quarters were constructed. Massive urban sprawl in these areas can be ascribable to location of government projects and institutions like FCE, Army barracks, Airport, which tend to draw population to themselves. This is not surprising because increasing human population in an area tend to increase urbanization. For instance, the population of both Jimeta and Yola town was 17, 000 in 1963 and that of Jimeta alone sharply rose to about 100, 000 in 1980. Also, other human activities like farming, grazing, land excavation especially roads constructions etc seems to have led to increase in the extent of bare surface and cultivated lands. All these have contributed to increasing the rate of expansion of urban Jimeta. Hence, urban built-up areas increased from 33, 133 hectares in 1986 to 51, 578.1 hectares (55.7%) in 2008

.A post-classification algorithm was adopted to obtain precise quantitative information of land use conversion in Jimeta for the 22 years period (1986-2008). The results are shown in Table 4. The trends of conversions of different land cover types as shown in this table indicate that from 1986 to 2008:

- 13,952 hectares of forest/sparse trees, 22, 346 hectares of cropland, 368 hectares of bare surface, 1, 326 hectares of water area, and 2, 697 of marshy lands changed to built-up land. Therefore, built-up land use increased by about 18, 445 hectares or (55.75%).
- 22, 016 hectares of natural vegetation or forest, 4, 779 hectares of water surface, 577 hectares of bare surface, and 4, 260 hectares of marshy lands changed to cropland. During the same period, 22, 346 hectares of cropland changed to urban built-up, 485 hectares of cropland changed to bare surface, 2, 668 hectares and 3, 351 hectares of cropland changed to water and marshy lands respectively. Therefore, cropland area increased by 18, 492 (28%) hectares during this period.
- 13, 952 hectares of natural vegetation changed to urban land, 302 hectares changed to bare surface, 22, 016 hectares changed to cropland, 1, 664 to water surface and 2, 089 hectares changed to marshy lands. Therefore, natural vegetation decreased by 36, 523 (88.6%) during the period.
- 577 hectares of cropland, 32 hectares of natural vegetation, 48 hectares of water surfaces, and 55 hectares of marshy lands changed to bare surface. During the same period, 368 hectares, and 557 hectares of bare surfaces changed to built-up lands and croplands. Therefore, bare surface increased by about 73 (6.7%) hectares.
- Water surface decreased while marshy lands increased with insignificant values. Water surfaces decreased by 539 (5.9%) hectares for the period between 1986 and 2008 and marshy lands increased by 52 (0.72%) hectares during the period.

**Table 4: Land use change matrix in Jimeta city from 1972 to 2008 (Hectares)**

| | 2008 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1972 | Unclassified | Urban land | Bare Surface | Crop land | Forest trees | water body | Marshy lands | 1972 Total |
| Unclassified | 32854 | 0 | 0 | 0 | 0 | 0 | 0 | 32854 |
| Urban | 0 | 11,197.2 | 242.7 | 17,693.7 | 983.5 | 1,337.1 | 1,678.8 | 33,133 |
| Bare surface | 0 | 368.3 | 8.1 | 576.5 | 32.4 | 47.6 | 55.2 | 1088 |
| Cropland | 0 | 22,346.2 | 484.6 | 35,311.7 | 1,962.4 | 2,668.2 | 3,350.9 | 66,124 |
| Forest trees | 0 | 13,932.1 | 302.0 | 22,015.7 | 1,223.5 | 1,663.7 | 2,089.1 | 41,226 |
| Water bodies | 0 | 1,326.3 | 65.7 | 4,779.4 | 265.6 | 2,313.4 | 453.5 | 9,205 |
| Marshy lands | 0 | 2,696.5 | 58.3 | 4,260.2 | 236.9 | 321.9 | 404.3 | 7,978 |
| 2008 Total | 32854 | 51,578 | 1,161 | 84,616 | 4,703 | 8,666 | 8,030 | 191,608 |
| Change (hec.) | 0 | 18,445 | 73 | 18,492 | -36,523 | -539 | 52 | 74,124 |
| Change (%) | 0 | 55.7 | 6.7 | 28.0 | -88.6 | -5.9 | 0.7 | 38.7 |

Analyses of the conversion matrix of land uses in Table 4 has revealed that:

i. Urban expansion encroached a lot of cropland, forest and marshy lands.
ii. The areas of natural vegetation that was transformed to other land were very excessive
iii. Table 4 also proved that the transformed area between cropland and natural vegetation were tremendous. The cumulative change extent between cropland and natural vegetation was also very extensive.
iv. Because urban built-up had a non-reversible natural attribute, it was impossible to be converted into other lands.

### *C. Characteristics of Land Surface Temperature (LST) in Jimeta*

Fig 3 (A and B) were produced to show the spatial distribution of emissivity-corrected land surface temperature in 1986 and 2008 in Jimeta. The statistics of land surface temperature in 1986 indicates that the lowest temperature was a NoData ($0^0$C), the highest temperature $28^0$C and the mean 18.6$^0$C, with a standard deviation of 4.4$^0$C. The minimum temperature was 0$^0$C (NoData) because of the heavy cloud cover at the rural location of the northwestern axis of the image. This insulated the area and could not allow the contact between sensor and the outgoing radiation thereby leading to zero temperature value. From the figure, it becomes apparent that all the urban or built-up areas have a relatively high temperature. Some 'hot spots' (the high temperature class) can be clearly identified. The most extensive hot spot was found in the center of the town (around Luggere and Nasarawo areas). Another noticeable hot spot were detected in Alkalawa, Ajiya, Limawa and NEPA areas, which are related to the densely populated points. However, there did not exist an extensive hot spot in some old locations such as Gwadabawa and Doubeli wards, in spite of their high construction and population density. This is probably due to their border location and proximity to river Benue. The lowest temperature in the urban areas (19$^0$C to 22$^0$C) appeared in: (i) extreme western axis around Damilu and Kofare. (ii) Eastern part of the Gwadabawa ward and Government quarters area (iii) Southeastern parts around 80 unit area, which were substantially rural at that time. Both the northwest (Jambutu area) and most locations in the extreme south have moderate temperature ranging from 16$^0$C to 19$^0$C, where cropland and ponds are common. The differences reflect not only the differences in solar illumination, the state of vegetation and atmospheric influences of remotely sensed TM/ETM+ dataset, but also changes in land use and land cover.

The average temperature for 2008 was 29.1$^0$C, with standard deviations of 2.5$^0$C. The standard deviations were also smaller than that in 1986 (Table 5), indicating that the surfaces experienced a relatively little variation in land surface temperature during these periods. The central parts of the city can easily be distinguished from the outskirt. The central parts showed a high temperature of over 36$^0$C, while in the outskirts, a lower temperature of 17$^0$C exist. A major hot spot expanded northwards, eastwards and southwards from the urban core areas (Nasarawo and Luggere area). In other words, a major hot spot seemed to stretch out from Luggere area to Nepa, Ajiya, Limawa and Nasarawo, forming a high temperature corridor.

In addition, three large hot spots emerged in 2008 image, one centered at Fallujah (new market area) and Jambutu and Kofare (industrial area). Both areas had undergone rapid urban sprawl since 1990s. Numerous strip-shaped hot spots were also detectable in

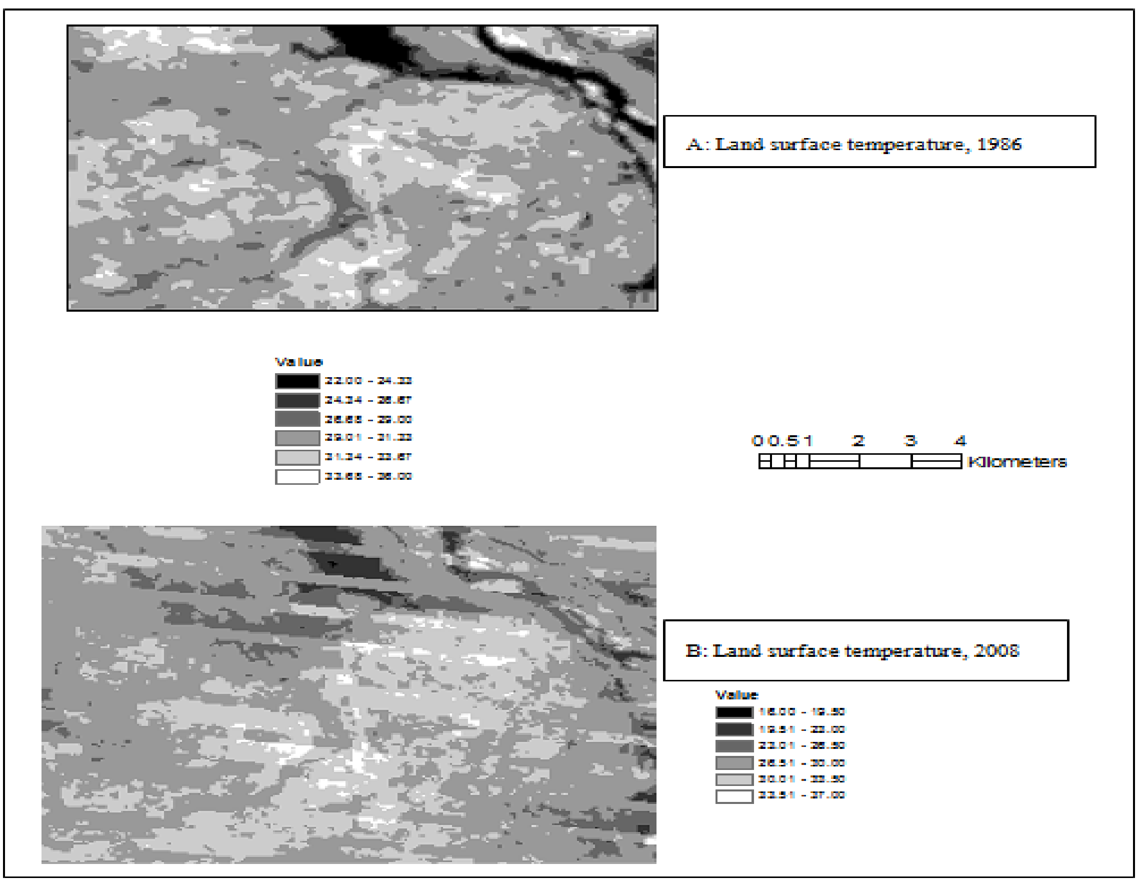


Fig 3: Land Surface Temperature Variation in Jimeta, 1986 and 2008

Table 5: Descriptive Statistics of Land Surface Temperatures, 1986 – 2008

| Statistics | 1986 ($^0$C) | 2008 ($^0$C) |
|---|---|---|
| Maximum | 28 | 37 |
| Minimum | 0* | 16 |
| Mean | 18.6 | 29.1 |
| Standard deviation | 4.4 | 2.5 |

*Source: Result of experiment conducted on the images*

* No data record because of the inability of sensor to detect temperature due to heavy cloud cover

the south, around State House of Assembly complex area and Army barrack, where there has been a rapid growth in settlements. There were also many small urban heat islands along the busy highways of Mohammed Mustapha and Atiku Abubakar (former Mubi) road. The non-existence of extensive urban heat islands in the extreme east and northern parts of the city could be attributed to the cooling effect of River Benue.

The distinctive land surface temperature patterns are associated with the thermal characteristics of land cover classes. To better understand the impact of urban development on land surface temperatures, the thermal signature of each land cover type was obtained by overlaying a land surface temperature image with a land use and land cover map of the same year. The average value of land surface temperature by land cover types is summarized in Table 6. It is clear that urban or built-up land exhibited the highest surface temperature (28$^0$C in 1986, and 37$^0$C in 2008), followed by bare surface (25$^0$C in 1986 and 32$^0$C in 2008). These results corroborate the results of station-comparison experiment conducted by the researcher (Zemba, 2002) in 2002.

This result also implies that urban development did bring up surface temperature by replacing natural vegetation with non-evaporating, non-transpiring surfaces such as metal, concrete, and stone. The standard deviation of the surface temperature values was relatively small for urban cover (1.31$^0$C and 1.65$^0$C for 1986 and 2008 respectively), indicating that urban surfaces did not experience a wide temperature variation because of the nature of non-evapotranspirative materials. The lowest surface temperature in 1986 was observed in areas with thick vegetation covers (forests, bushes and thick grass covers) by the side of River Benue in Bwaranji, Jambutu and former forest reserve area around Agric Quarters in Damilu (17$^0$C), followed by water bodies (19$^0$C). This pattern is in contrast with that of 2008, where the lowest radiant temperatures are found at water surface (23$^0$C) followed by natural vegetation (26$^0$C), and then marshy lands (27$^0$C). This is because most areas of thick vegetation cover had disappeared by 2008. This different pattern is also primarily attributed to the differences in solar illumination, the state of vegetation, and atmospheric influences on the remotely sensed TM/ETM+ dataset. The difference in data acquisition date, though the same season, is clearly reflected in the surface radiant temperatures of water bodies. The radiant temperature of water bodies is higher than the natural vegetation by about 2$^0$C in 1986, while in 2008 it is lower than that of vegetated surface by about 3$^0$C.

Because of the distinctive characteristics of River Benue and Lakes Geriyo and Njuwa, their radiant temperature values also vary. Lakes with average value of 22.45$^0$C registered a much higher temperature than River Benue (with mean value of 18.25$^0$C) in 2008. Lakes often have higher concentration of dissolved materials hence, higher temperature than rivers.

Thick vegetation zones show a considerably low radiant temperature in both 2008, because dense vegetation can reduce the amount of heat stored in the soil and surface structures through transpiration. However, bush areas show a relatively larger standard deviation in radiant temperature values (2.52$^0$C in 1986, and 2.51$^0$C in 2008) compared with other land cover types, indicating the heterogeneous nature of tree covers. Croplands tend to have sparse vegetation and exposed bared soil. The influence of surface soil water content and vegetation probably contribute to a broad variation in their surface radiant temperature value.

Given the relationship between surface radiant temperature and the texture of land cover that is influenced by land use, changes in land use and land cover was found to have a profound effect on the surface radiant temperature. GIS coupled with image processing helped the researcher to visualize the impact of land use and land cover change on surface radiant temperature.

**Table 6: Average surface temperature by land cover types**

| Land Use & land cover | Mean LST 1986 ($^0$C) | Mean LST 1998 ($^0$C) | Mean LST 2008 ($^0$C) |
|---|---|---|---|
| Built-up land | 28 (1.31) | 36 (1.54) | 37 (1.65) |
| Bare surface | 25 (1.47) | 32 (1.56) | 32 (1.86) |
| Croplands | 22 (2.12) | 29 (2.39) | 28 (2.61) |
| Marshy lands | 21 (1.34) | 28 (1.43) | 27 (1.83) |
| Forest/sparse trees | 17 (2.52) | 25 (2.53) | 26 (2.51) |
| Water | 19 (2.08) | 24 (2. 40) | 23 (2.47) |

*Source: Derived from Landsat Images. Values in brackets refer to standard deviations*

## V. Conclusion

An integration of remote sensing and GIS was employed for evaluation of rapid urban expansion and its impact on surface temperature in Jimeta-Yola, Nigeria. Two Landsat TM and ETM+ images of 1986 and 2008 respectively were utilized. Results revealed a notable increase in urban land use/cover between 1986 and 2008. Urban land development was uneven in different parts of the city and the density of urban expansion showed a tendency of decline as the distance increased away from the city centre.

The combined use of remote sensing and GIS allowed for an examination of the impact of urban expansion on surface temperature. The results showed that urban land development raised surface radiant temperature by about 9$^0$C between 1986 and 2008. This study has also demonstrated that the direct effect of urban land use/cover change on one environmental element can cause indirect effects on the other. The increase of surface radiant temperature was related to the decrease of biomass. The spatial pattern of radiant temperature increase was correlated with the pattern of urban expansion. This is particularly true when all these patterns were referenced to major roads.

The integration of remote sensing and GIS has provided an efficient way to detect urban expansion and to evaluate its impact on surface temperature. The digital image classification coupled with GIS has also demonstrated its ability to provide comprehensive information on nature, rate and location of urban land expansion. Biophysical measurements including surface radiant temperature and biomass were conveniently extracted from Landsat images. Using a technique of image differencing, the environmental changes over time were evaluated. Hence, to examine the environmental impact of urban expansion, the mapped patterns of environmental changes can be linked to urban expansion pattern by correlation analysis.

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