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| RESEARCH ARTICLE

Paper Title:

APPLICATION OF REMOTE SENSING IN MONITORING AND MODELING URBAN SPRAWL IN JOS NORTH AND JOS SOUTH LGAS OF PLATEAU STATE

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| ABSTRACT
The search-light of this article was beamed at Jos North and Jos South Local Government Areas because of the unprecedented and un-planned growth with massive expansion experienced over the years; with visible evolution that is substantial in all its ramifications.

| KEYWORDS
Urban, Sprawl, Growth, Shannon Entropy, TM, GIS, RS and CBD

| ARTICLE INFORMATION

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Abstract
The search-light of this article was beamed at Jos North and Jos South Local Government Areas because of the unprecedented and un-planned growth with massive expansion experienced over the years; with visible evolution that is substantial in all its ramifications. The temperate climate, natural and beautiful topological attractions which caused the influx of admirers that brought about abrupt swollen population in the city centers. The two cities (Jos and Bukuru) have experienced improved infrastructures, despite the perennial in-security suffered in the past ten (10) years. The aftermath of these crises gave rise to clusters of settlements around the city centers and along the fringes thereby expanding their boundaries. Urbanization is considered as the most influential driver of land use and land cover changes The integration of remote sensing (RS) and Geographic Information System (GIS) techniques made it possible and effective tool for detecting urban sprawl and modeling of changes over a period of time. In order to maintain a systematic urban growth pattern at regional or global level, effective planning policy must be put in place at the local level of authority before gravitating to the centre. This aimed at quantifying the

magnified urban growth in Jos North and Jos South LGAs of Plateau State using Shannon's Entropy Approach to measure growth with the aim of determining the compactness or dispersion of built-up land growth in Jos and Bukuru urban centers. The entropy values obtained for this study was 0.15in2000 and 0.54 in the year 2015, while in the year 2024 the entropy value was 0.234; all are very close to the upper limit value of log(n) i.e.,-1.og. 4 indicating a dispersed growth. The study also

emphasized the potential of LandSatTM data, Global landcover facility (GLCF) and(United State Geological Survey (USGS) data, which covered both Jos North and Jos South LGAs and environs for a period of 24 years and it has a path and row of P188 and R53. The findings facilitated the understanding of the present and projecting the future growth scenarios. Furthermore, preparation of effective planning and management strategies for controlled and systematic urban growth both at states and local government areas that have the tendency of growth be encouraged at all levels.

1.Introduction :-

The aftermath of the Nigeria independence in 1960 heraled urban growth as a result of massive movement of people from the hinter-land to the urban centres for livelihood. Urban growth was differentiated from urbanization and urban development, rather urban growth refers to the increase in human population and development within a city or metropolitan area [15]; while, urban sprawl refers to the low density urban that used to be rural [10]. It js a common phenomenon in Nigeria and it is often encouraged by following the master plan and environmental laws. Urban sprawl can mean one or two concepts which include: development on the fringe of a city or metropolitan area, as opposed to already-developed areas and or development that is oriented towards cars and unfriendly to people on foot and the environment.
It is generally characterized by a single family home, often detached, with little in the way of common services (like a grocery store) and the complete lack of multi-unit residential units (i.e. apartment buildings) surrounding areas (rural) to the urban center. Urban Sprawl is regarded as an important problem in many cities throughout the World particularly in metropolitan cities [15].

The land of urban sprawl which are seen as land that has lost their rural characteristics, yet cannot be defined as urban include specific uncertainties that resulted into various problems such as un-planned urban growth and use of non-agricultural purpose. It is an hinter-s urban areas.
It was described as urban sprawl or as a leapfrog development [11]; whereas It was also looked at as growth with cancer or virus [3].

The pattern of settlement in Jos CBD and Bukuru township were fashioned after religious affiliations. For instance, Ungwan Rogo, Ungwan Rimi and Gangare are all of the same faith; and are within Jos CBD with huge human population. While Tudun-Wada, Kabong, Apata and Utan are contiguous and in close proximity with same faith also with high human population; and they felt more secured living in close proximity. In fact, majority of these places were not planned and are prone to environmental hazards. Whereas, Bukuru township had evolved to an extent butt better planned than Jos CBD. Development has gradually shifted to Shen, Du, Latyia, Gura-Topp and Kwang. Presently, it is quite difficult to define in terms of growth the boundary between Bukuru town and Jos.
It is against this background that this article deployed remote sensing tool and GIS in order to monitor and model the pattern of sprawl or leapfrog development that has taken place over the yeaes in Jos and Bukuru centers and suggest how to open up new area for even development and socio-economic growth.

2. Related Work

Urban Sprawl was better described which is more suitable rather than defining it [18, 6]. But, in the past 15years, the study areas, Jos and Bukuru have witnessed a unique type of growth. The impact of persistent sectarian crisis which eventually ravaged the areas led to segregation in the pattern of neighbourhoods based largely on religious affinity. Consequently, pockets of new clusters emerged around the city centers whose inhabitants share common religion and tradition.

Despite the incessant crisis, Jos and Bukuru remain a strategic commercial and agricultural hub in Nigeria, especially in the Northern states. The prevailing dynamics accounted for the type of leapfrog settlement experienced in the recent times. The growth extended to the nearby localities like Zinariya, along Bauchi road, where massive development is on-going. Others include Latya, Kwang, Gura-Topp, Shen and Du: all these localities were initially meant for agricultural and mining purposes, but the past 15years rapid growth evolved, both residential and economic activities to the extent that, there is no thin line between Jos and Bukuru and the city center; development has engulfed the entire place.

The Burgess concenrtric zone model for an ideal city [2] was adopted for this article and it is hinged on three main ideologies namely; that settlement sprawling is based on ecological approach in explaining land use pattern; residential aggregation plus social segregation and spatial patterns of various land use zones. But of the three ideologies, Burgess adopted the concepts used by plant ecologists (i.e., idea of competition, dominance, invasion and succession) within the city, people compete for limited space (Competition); those who are best able to pay (Dominance) achieve the most desirable locations (Invasion and Successin). Those individuals and functions with the lowest level of economic competence have the least choice, occupying the poorest locations. The Central Business District (CBD), is the most accessible location that is attracted by all sorts of commercial activities. The shortage of land induced keen competition and struggle for survival amongst the populace. The location was dominated by those activities with high rentals.

The idea of land use in the city center by Burgess was thought to continue with each successive neighborhood moving further from the CBD. The new immigrants would move into the cheapest residential areas of the city. When they became economically established, they would migrate outwards. Thus lower residential class moved to adjacent neighborhoods and more affluent residents moved further outwards. Land value decreases with increasing distance; the highest land value is at the city centre because of keenest competition and scarcity of land within different areas of the city, different single functions formed the dominant element [17, 2,1].

3. Materials and Method:-

3.1. Materials

Materials and data used for this article were drawn from different sources representing Jos North and Jos South LGAs of Plateau State covering a period of 15 years. The imageries are cloud-free and have excellent quality. Sub-scenes covering the study areas were further extracted from other imageries. The major data input for this article are remotely sensed satellite images of varied resolutions obtained from GLCF (Global landcover facility) and USGS (United State Geological Survey), which covered the study area and its environs for a period of 15 years. The path and row of the study area is (P188 and R53). The two images used for the study are the Landsat Thematic Mapper (TM) of 2000 with 30 meters resolution and Landsat 7 ETM+ also with 30meter resolution. Figure 1 below revealed the USGS satellite imagery website used for the study area.

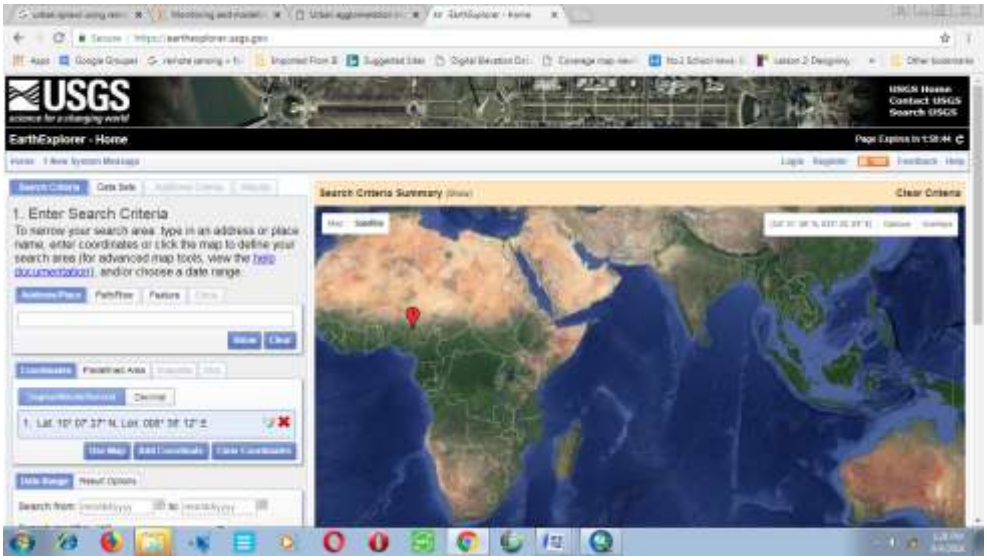


Figure 1: United State Geological Survey web site (USGS).
Source: Author's Lab work (2025)

3.2.Method:-

The approach here was to acquire satellite imageries from LandSat multi-temporal dates (TM 1990, ETM 2000 and ETM+ 2015 and 2024). Pixel-based classification was applied in order to classify the imageries. Six categories of classes were generated as Land Use/ Land Cover which include:

1) Thick Forest
2) Light Forest
3) Built up area
4) Farm land
5) Water bodies
6) Bare land

The accuracy assessment was generated to validate the Land use Land cover image classification of the two dates. The extraction by attribute function using extraction tool in ArcGIS 10.1 was deployed in extracting the built-up areas only and other features were discarded. Eleven (11) zones were created using 2500m buffer from the city center. The total Area of the built up area in each zone was computed using zonal Analysis in Arc Gis 9.3. The value generated were imported in Microsoft Excel for analysis to ascertain the magnitude of Urban Sprawl. The Shannon's entropy and comparative analysis were the key factors in analyzing sprawl. Figure 2 below is the complete scene of the satellite imageries for Jos and Bukuru, the study areas.

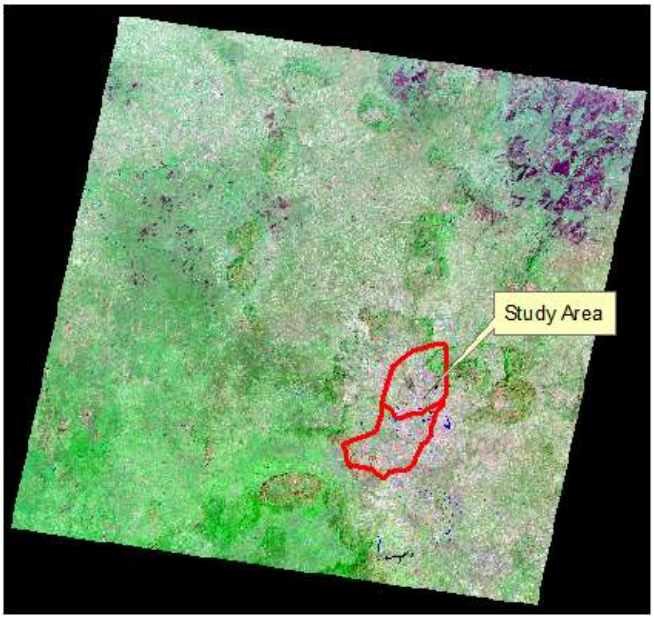


Figure 2: LandSat scene covering t:e study area.
Source: Author's Field Work (2025)

The pre-processing activities were carried out in order to enhance the quality of the image and the readability of features on the imagery. This was done whereby, all the existing data in the form of maps, images and tables were converted into a suitable form for permanent storage within the GIS database says, Prince and Florence (2013). This also include image restoration, which was the correction of distortions, degradations and noise introduced during the imaging process. These errors can degrade the quality of the remotely sensed data collected, which may have impact on the accuracy of human or machine assisted image. The radiometric enhancement was performed to sharpen the area of interest; that is Jos North and Jos South LGAs of Plateau State. Table 1 below is the resultant effect of image enhancement.

Table 1. Radiometric Enhancement.

RADIOMETRIC ENHANCEMENT	These functions enhance the image using the values of individual pixels within each band.
LUT (Lookup Table) Stretch	Creates an output image that contains the data values as modified by a lookup table.
Histogram Equalization	Redistributes pixel values with a nonlinear contrast stretch so that there are approximately the same number of pixels with each value within a range.
Histogram Match	Mathematically determines a lookup table that converts the histogram of one image to resemble the histogram of another.
Brightness Inversion	Allows both linear and nonlinear reversal of the image intensity range.
Haze Reduction	Dehazes Landsat 4 and 5 TM data and panchromatic data.
Noise Reduction	Removes noise using an adaptive filter.
Destripe TM Data	Removes striping from a raw TM4 or TM5 data file.

Source: ERDAS Imaging 9.1(Tutoria1)
The screen-shot in figure 3 below was the window of operation when image enhancement took placed at prompt of ArcGIS10.1 of the file geo-database.

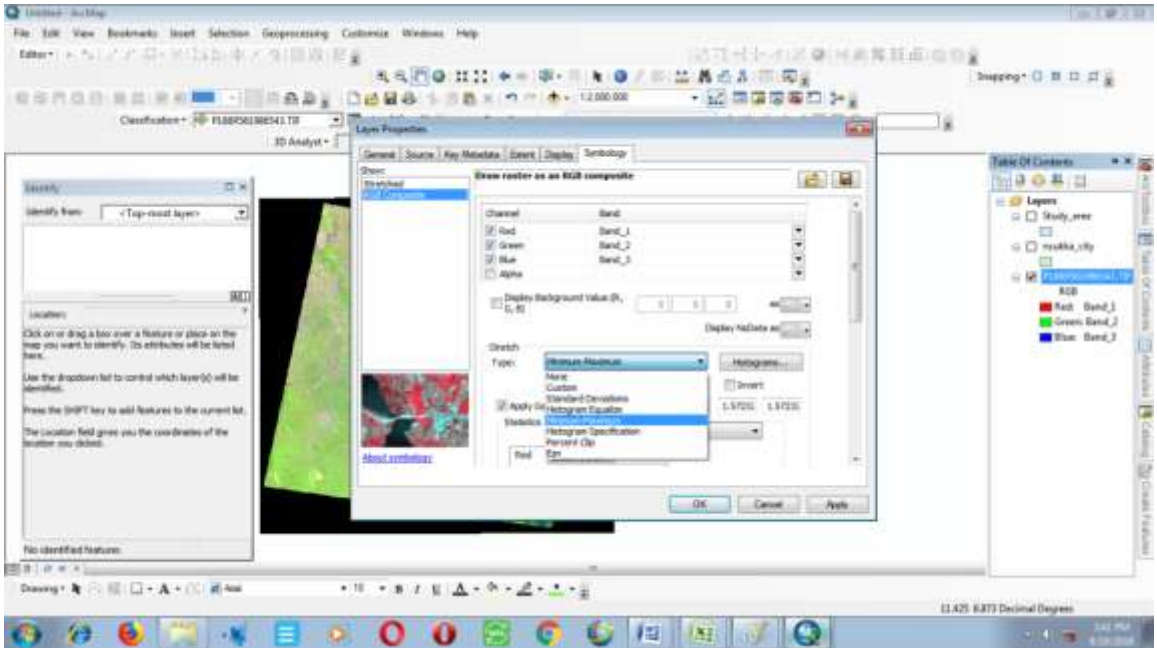


Figure 3: Image Enhancement in ArcGIS.
Source: Author's Field work(2025)

Below figure 4is the sequence of operations followed to achieve the said image processing for this article:

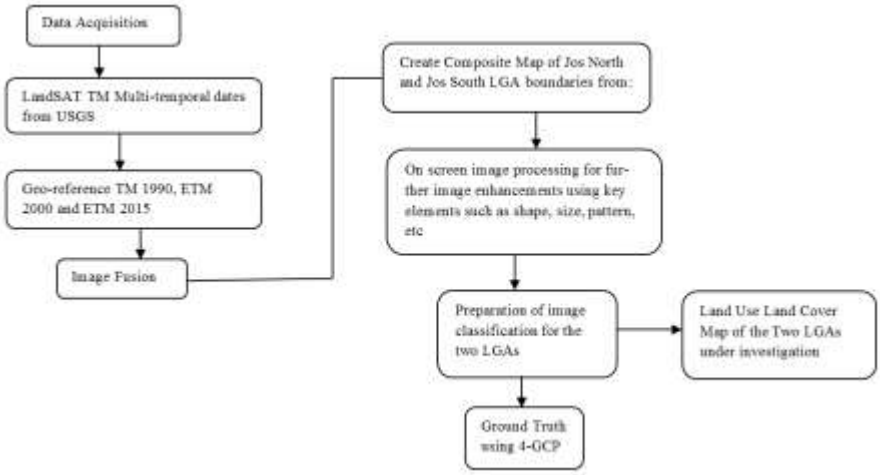


Figure 4: Sequence of Operation.
Source: Author's Field Work (2025)

4.Results and Discussions:-

Output 1: Resampling by Sub-setting

Sub-setting of the Study Area and Resampling

Sub-setting refers to breaking out a portion of a large file into one or more smaller files. Often, image files contain areas much larger than a particular study area. In these cases, it is helpful to reduce the size of the image file to include only the area of interest (Jos North and South LGAs). This will not only eliminate the extraneous data in the file, but it will also speed-up processing time due to the smaller amount of data to process. This is is imperative, particularly when dealing with multi-band data.

The color composite image was resampled for this article using the maximum and minimum coordinate of the study area and the pixel size was defined as 30meter for LandSat TM and UTM and the same reference system was used in re-sampling process. The output image is the subset image of the study area. The image re-samples operation enable registration of multi-date image of the same area as shown in figure 4 below:

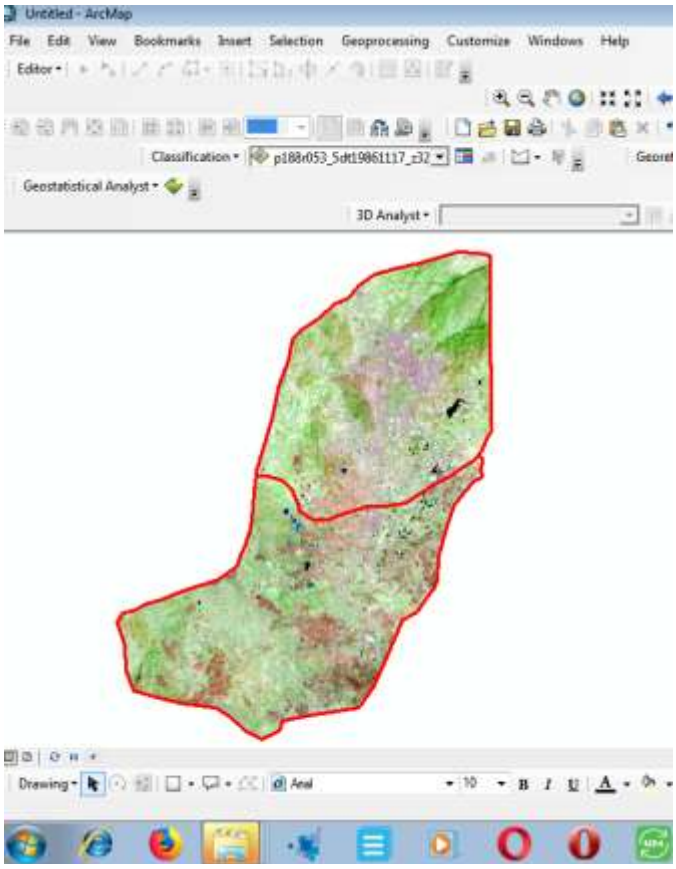


Figure 5: Re-sampled Land cover of the area under investigation.
Source: Author's Field Work (2025)

Output 2

Land Use Land Cover Classification

A supervised (that is, full Gaussian approach) classification using the maximum likelihood algorithm in ArcGIS 10.1 was employed to generate six (6) main Land use Land cover classes for all images (Table 4below) Built up area (1), farm land (2) dominated by human exploitation such as agriculture area, plantation area, bush burned, and bush cleared for road construction etc, light forest dominated by grasses and bush land (3), Thick Forest area : area dominated by thick vegetation covered . (4)River: area covered by water body and it ramification (5), and Bare land: including field and open area. These Land use Land cover classes were derived from images of years 2000 and 2015, then part of the year 2024 for the study areas. This was made possible because the researcher is familiar with the study area through dedicated field observation, whereby the spectral characteristics of the classes in the sampled area were not too difficult to identify. In the training sample 75 samples set were used to identify the spectral signature of the feature classes, the figure 5 below revealed the classification process of Land use and Land Cover of both Jos North and Jos South LGAs, the study areas.

How Image Classification was carried out in ArcGIS

The goal of classification is to assign each cell in the study area to a known class (supervised classification) or to a cluster (unsupervised classification). In both cases, the input to classification is a signature file containing the multivariate statistics of each class or cluster. The result of each classification is a map that partitions the study area into known classes, which correspond to training samples, or naturally occurring classes, which correspond to clusters defined by clustering. Classifying locations into naturally occurring classes corresponding to clusters is also referred to as stratification. The Image Classification toolbar provides an integrated environment to help with the multi step workflow that is necessary for performing a classification.

When performing classification, group similar features into classes by assigning the same symbol to each member of the class. Aggregating features into classes allows you to spot patterns in the data more easily. The definition of a class range determines which features fall into that class and affects the appearance of the map. By altering the class breaks (the boundary between classes), it can create very different-looking maps. Classes can be created manually, or use a standard classification scheme. What determines to which class or cluster each location will be assigned is dependent on the multivariate statistics that are

calculated on the input bands. Each cluster is statistically separate from the other clusters based on the values for each band of each cell within the clusters. The statistics establishing the cluster definition are stored in a signature file.

There are four steps in performing a classification:

1) Create and analyze the input data.
2) Produce signatures for class and cluster analysis.
3) Evaluate and, if necessary, edit classes and clusters.
4) Perform the classification.

The multivariate file containing the spectral signature of the satellite imagery for the study area classified the cells in the imagery into six classes as show Table 1.

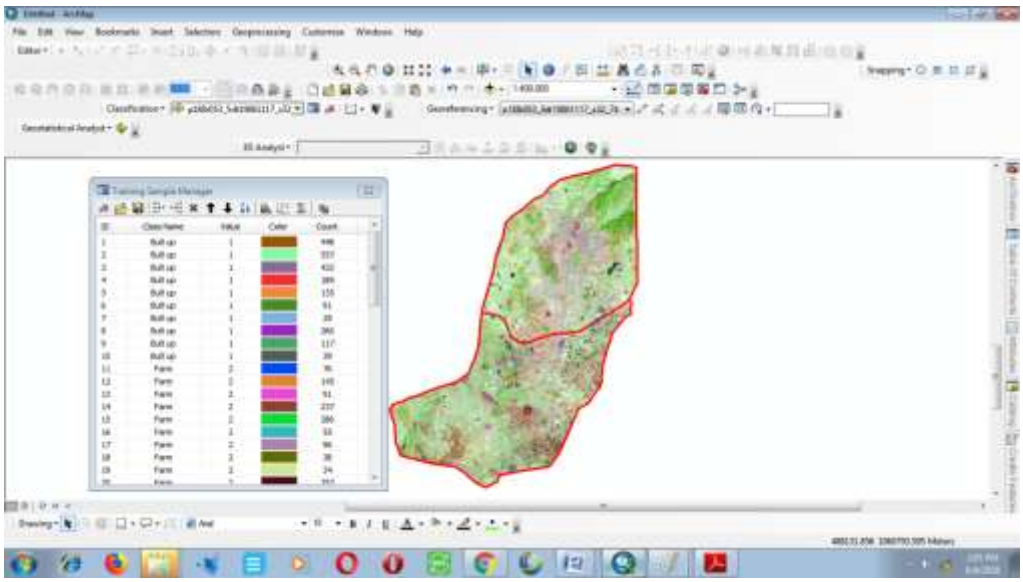


Figure 6: Six Classes of LULC process in ArcGis 10.1:
Source: Author's Field work (2025)

Output 3:

The multi-variate file containing the spectral signature of the satellite imagery for the area under investigation classified the cells in the imagery into six classes as shown in Table 2 below; while figure 5 below revealed the six classes of LULC of the study area.

Table 2. The Selection of Land use / Land cover classes.

Code	TrainingSample	Description
1	Built up area	Area occupied by people for Habitation
2	Farm Land	Farm land area including agriculture area, and plantation area ,
3	Savannah area	Area Occupied by grass and bush
4	Forest	Area occupied by Thick vegetation.
5	River	area cover by water bodies and its ramification
6	Bare land	Open area and field.

Source: Author's Field Work (2025)
Output 3

Shannon Entropy Estimation

The present study aims at quantifying the urban growth in Jos North and Jos South LGAs of Plateau State using Shannon's Entropy Approach is worth exploring scientifically. The study area was divided into eleven (11) zones using multiple ring buffers created around the city centers at 2500 meters interval as revealed in Figure 6 below. At the end, clip out the built-up area of each buffer zone, then compute the density of the built-up area in each zone. Entropy values were also calculated for all these zones. The results of the entropy calculation are shown in Tables 2 (for year 2000) and 3 (for year 2015 and part of 2024) below.

The Shannon's Entropy was computed to detect the urban growth phenomenon following Yehand Li (2001), using the formula below:

$H_n = -P_i \log_e(P_i)$

Where; Pi is the proportion of the variable in the zone and n is the total number of zones.

Entropy value ranges from 0 to Log (n) Where Log (n) =Maximum limit of Entropy. B note the followings below:

1) If the value is closer to zero, then the distribution is very compact
2) If the value is closer to Log (n), then the distribution is dispersed (Sudhira et al., 2004).

The classified land use maps of the two periods (year 2000 and 2015 and part of 2024) were further rec-lassified into two categories ofbuilt-upland and non-built-up land areas (see figure 6 below). The red spots represent clustered built up areas, while the black background represents non built up areas or land areas for other uses`

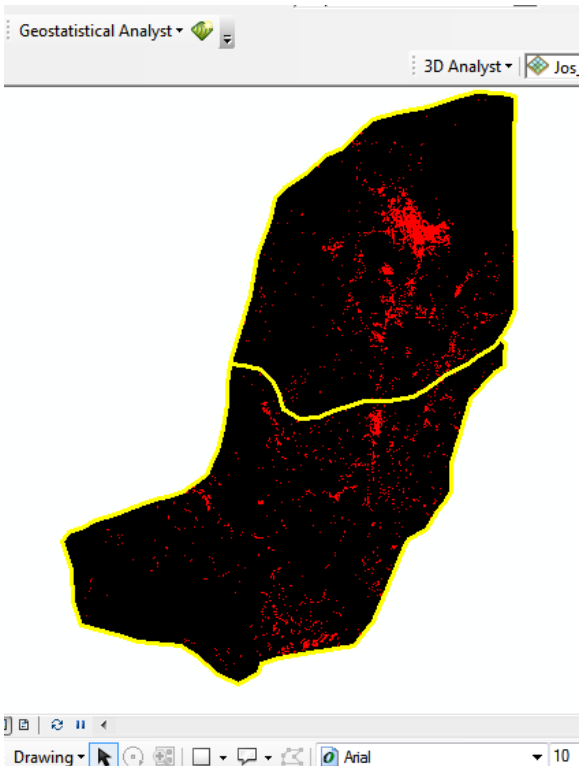


Figure 7. Classified Built-upLand and non-built-up Land areas of the stydy areas.
Source: Author's field work (2025)

The two classified maps (Figure 6 above) were then converted to 30 meter vector GRID data using the Zonal statistics tool in ArcGIS. Only the median value corresponding to the built-up area was kept and the rest are discarded. In order to calculate Shannon's Entropy, the study area was divided into11zonesusing multiple ring buffers created around the city centers at 2500 meters interval (see figure 7.below). At the end, the clipping out of the built-up areas of each buffered zone were carried out in order to ascertain the actual density of built up areas per zone, which gave rise to the computation of the total area per zone in the study area.

Entropy:
Entropy refers to a measure of the amount of energy that cannot be used to do work. The thermodynamic free energy is the amount of work that a thermodynamic cannot perform: it is the internal energy of a system minus the amount of energy that cannot be used to perform work. That unusable energy is given by the entropy of a system multiplied by the temperature of the system. Entropy values were calculated for all the eleven zones using the above formula and the results of the entropy values are shown in a Tabula format, (see Tables 4 and 5).

Run the 1_Multi-Buffer Cencentrict Zones Tools
7. In Arc Tool Box, double click on 1_multiBuffer concentric Zone Tools to open it.
8.Click SHOW HELP in order to view information about the tool
9. Click on the help parameters, the help sidebar provides information about the parameters
10. Click the TOOL HELP button to open the help file
11. Specify the following parameters:
    a) Input features Jos (point.Shp)
    b) Unique ID Field: Point_ID
    c) Maximum Buffer: 2500 meters
    d) Increment: 2500 meters
    e) e, Create a folder for the output
    f) Keep overlap output? No is the default answer
12. Click OK, wait for a long while, then dismiss the status dialog when completed

13. Click the ADD DATA button and add Point_MultiRing.shp file to the map document.
14. Right click on the layer name in order to open the Attribute Table: Note the field headings
    a) Area: Total area of each buffer ring
    b) First_Point: this corresponds to the original unique ID field specified
    c) LAST_BUFF: this corresponds to the buffer distance and it is a multiple of the distance specified

15. Close Table when finished.

Table 1: Multi-Ring Buffer Polygon.

FID	Id	B_Area	FIRST_Poin	LAST_Point
0	1	1.7028	2500	2500
1	2	5.7681	2500	5000
2	3	8.7686	2500	7500
3	4	11.3796	2500	10000
4	5	14.7609	2500	12500
5	6	19.4148	2500	15000
6	7	17.4317	2500	17500
7	8	15.2973	2500	20000
8	9	10.4697	2500	22500
9	10	8.9130	2500	25000
10	11	1.5885	2500	27500

Source: Autho's Field Work (2025)

16. In Arc Tool Box; double click 2_MultiIntersectAreas to open it
17. The Help sidebar provides information about each parameter
18. This step is optional: Click the HELP TOOL button to open the help file
19. Specify the following parameters:
    a) Input Buffer features: Jos (Point_Shp)
    b) Unique ID Field: First_Point
    c) Buffer Distance Field: LAST_BUFF
    d) Buffer Area Field: B_Area
    e) Input Land cover Features: landcover.Shp
    f) Land Cover Class Field: Number
    g) Open a folder for the Out-Put

20. Click OK; wait for a short while, then dismiss the status dialog when completed

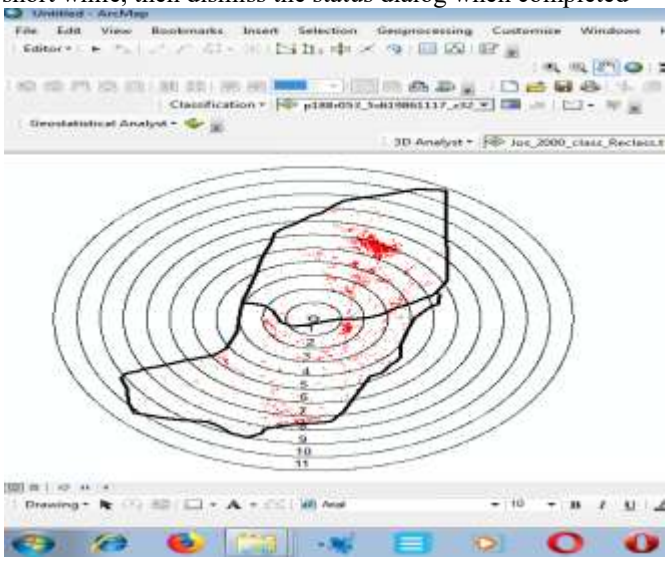
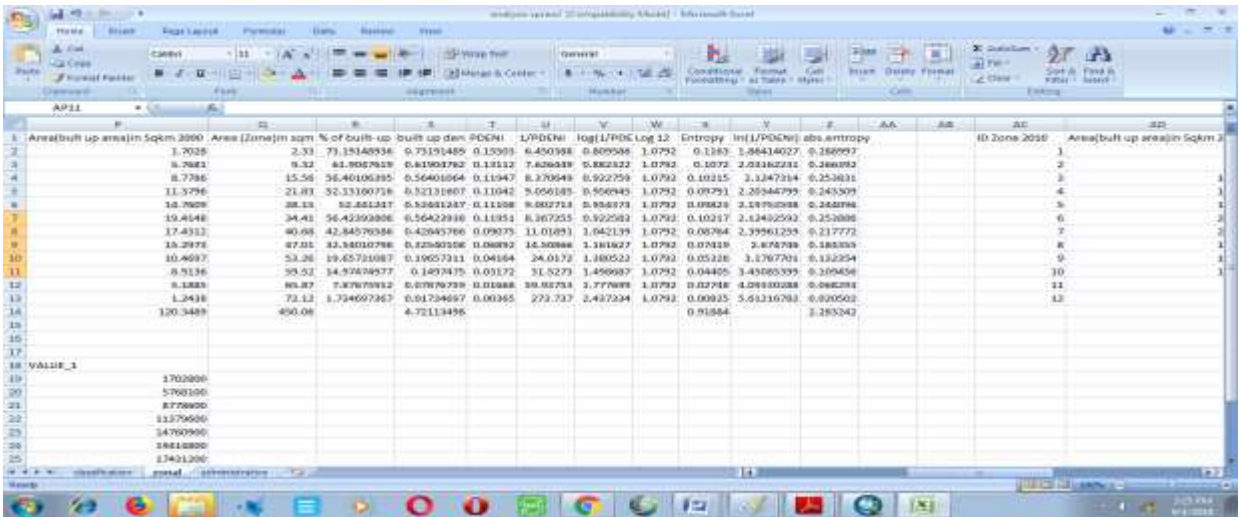


Figure 8: Ideal construction of a city center.
Source: Author\s Foeld Work (2025)

The table below as generated at prompt revealed the result of the calculation of enthropyofArcGIS 10.1:
Table 2:Shannon Entropy Computation for the Eleven Zones



Source: Author's Field Work (2025)

Table 5 above was generated from the computation of the entropy values for the two periods under investigation using excel spread sheet. The table revealed the number of zones in the study area; the area per zone; the number of built up area per zone; proportionate density of built up areas; entropy values; and the Log^n i.e. the limit of entropy value per zone. The table also shows percentage of growth per zone and from its value, a zone can be said to be either dispersed, compact or a leapfrog settlement from the city center.

Output 5

Composite map of LandSat image

Figure 4.5 below is the LandSat 7 TM composite map of the study area as at the year 2000. It shows that, those dark patches represented built up areas around the two city centers of Jos and Bukuru. As at the year 2000, there were leapfrog settlements, particularly in Jos North LGA, but not much was experienced in Jos South LGA. However, there were indications and the propensity of movements of settlements away from the city center in the year 2000, due to shift in intense agricultural activities at the edges of the city centers. Besides, the center was already becoming too congested for any form of activities, therefore, the propelling forces of pulling away from the city center has started to reveal from the year 2000.

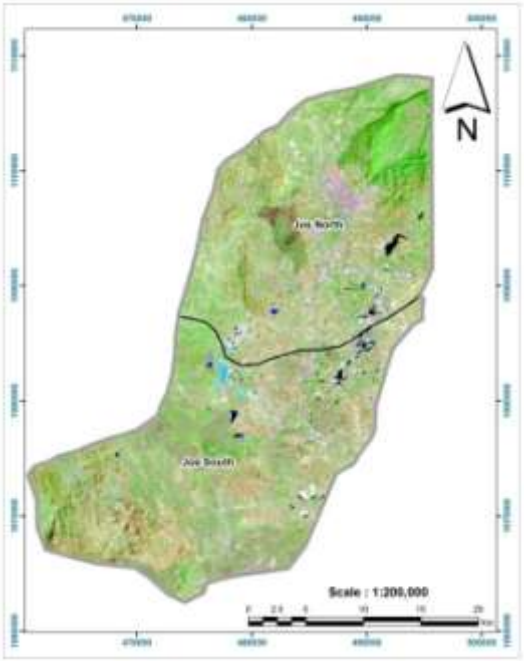


Figure 9.: LandSat 7 TM of 2000 Composite Map of the Study Areas.
Source: Author's Field Work (2025)

Output 6

Composite Map of the Study Areas in 2015 and Part of 2024

But when compared with the LandSat 7 TM composite map of the year 2015 and some months in 2024, there were denser built up areas closer to the edges of the two LGAs than in the year 2000. The 2015 composite map of the study area experienced more leapfrog settlements sprawling along Zinariya, Azurfa, Yelwan Nabor, Maza and Naraguta: all in Jos North LGA. While in Jos South, settlement sprawling extends Bukuru to Shen, Du, Gura-Topp, Latya, Sha'aka, Guut and Diye-Zaramaganda (See figure 9 below).

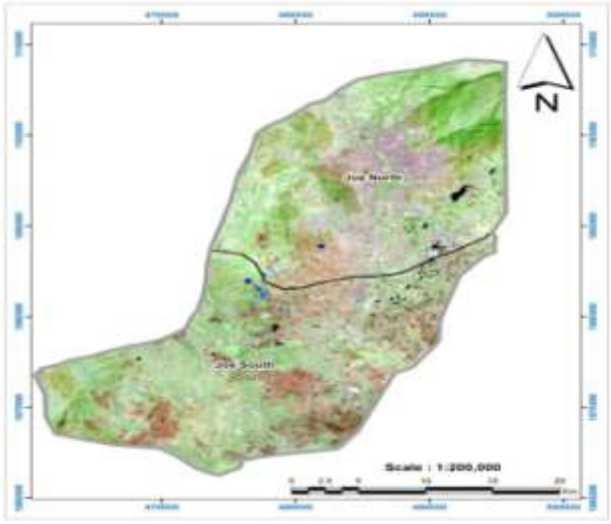


Figure 10: 2015 and Part of 2024 Composite Map of the Study Areas
Source: Author's Field Work (2025)

Output 6

Land use /Land cover of the study area for the Year 2000.

The six classes of Land use and Land cover of the study area for the year 2000 was revealed in figure 9 below and when compared with the density of built-up areas after 15-years, there is a remarkable difference in the two lGAs, particularly when the image is zoomed. More leapfrog settlements were experienced as shown in figure 9 below. The density at the city centers are abysmally high, thereby causing pressure on the available social infrastructures, pollution of different types and distorting the aesthetics of the city centers.

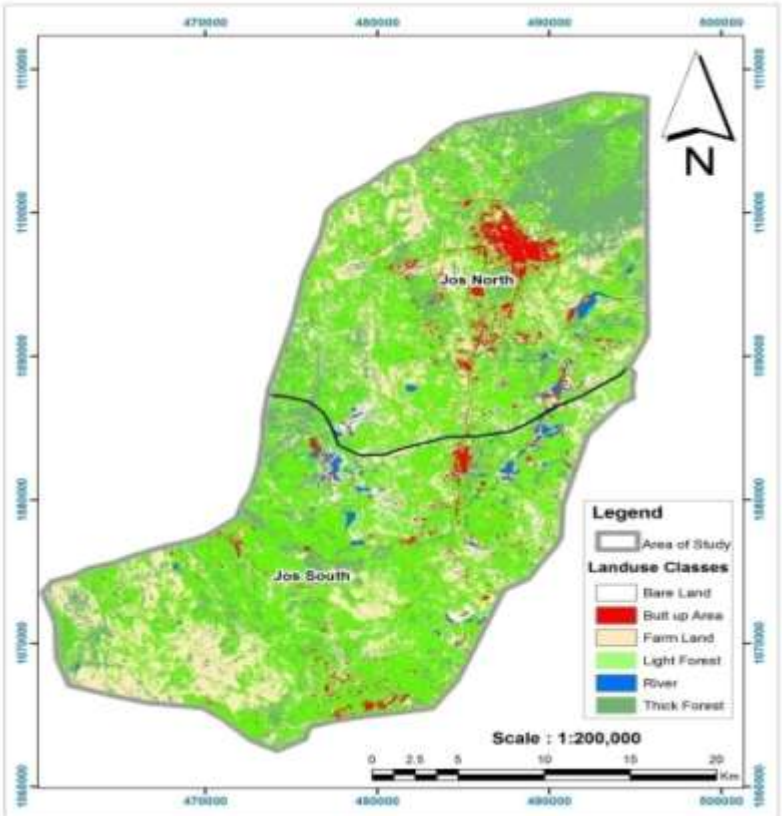


Figure 11: Land use/Land cover of the Study area in 2000
Source: Author's Field Work (2025)

Output 7

Statistical Analysis of LULC of the Study Areas

The table below is the summary of Land use and Land cover for the year 2000 classified into six different classes with areas covered in m^2 by each land cover and their overall percentage compared with the total land area of the study in meter square (m^2). The feature class with the largest land cover is the High forest (421210.3700 m^2) and equivalent to 49.37% land cover, followed by Thick forest with an area of 16688.5700 m^2 which represents 19.57 percent land cover, areas used for Farming covers' 13977.6800 m^2 which is equal to 16.38%, Bare land is 7808.1300 m^2 representing 9.15 percent, Built up areas occupies 3755.3400 m^2 which represents 4.40% and only 1.12 percent was occupied by Rivers (958.2300 m^2). This means, the study area in the year 2000 has less than 5% of the total land area as built up, which also implies that, human activities and population is not significant enough to trigger settlement sprawling outside the city centers

Table 3: Statistical Table of LULC of 2000 of the study area.

Pixel Value	Classes	Count	Area m^2	PCT(%)
1	Built Up	41726	3755.3400	4.40
2	Farm	155252	139726800	16.38
3	Light Forest	467893	421210.3700	49.37
4	Thick Forest	185423	16688.5700	19.57
5	River	10647	958.2300	1.12
6	Bare Land	86757	7808.1300	9.15
Total		947698	852928200	100.00

Source: Author's Labwork (2024).

Figure 10 below is the histogram describing the Land use and Land cover of the two contiguous LGAs under investigation for the year 2010

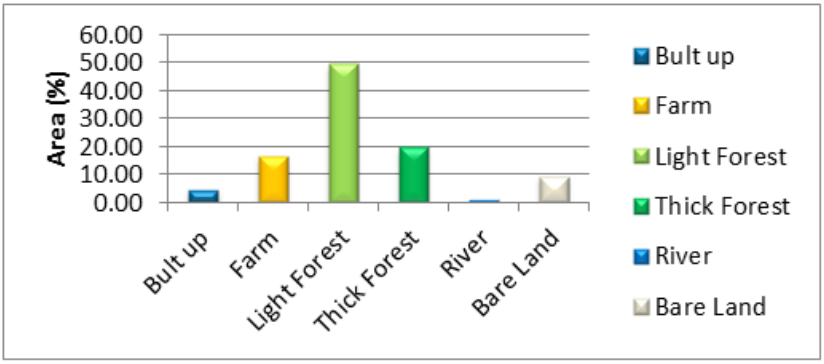


Figure 12: Histogram of LULC of study area in 2010.
Source: Author's Field Work (2025)

Output 7

Land use/Land cover of 2015

After fifteen (15) years interval with some months in the year 2024, the study area has experienced a significant change in Land use and Land cover as revealed in figure 11 and table 5 below.There were leapfrog settlements at the edges of the city centers boundaries in the two Local Government Areas under review. The proportion of built-up areas and farming activities in 2015 when compared with year 2000/2010 is quite significant. Meaning, built-up areas have increased tremendously.

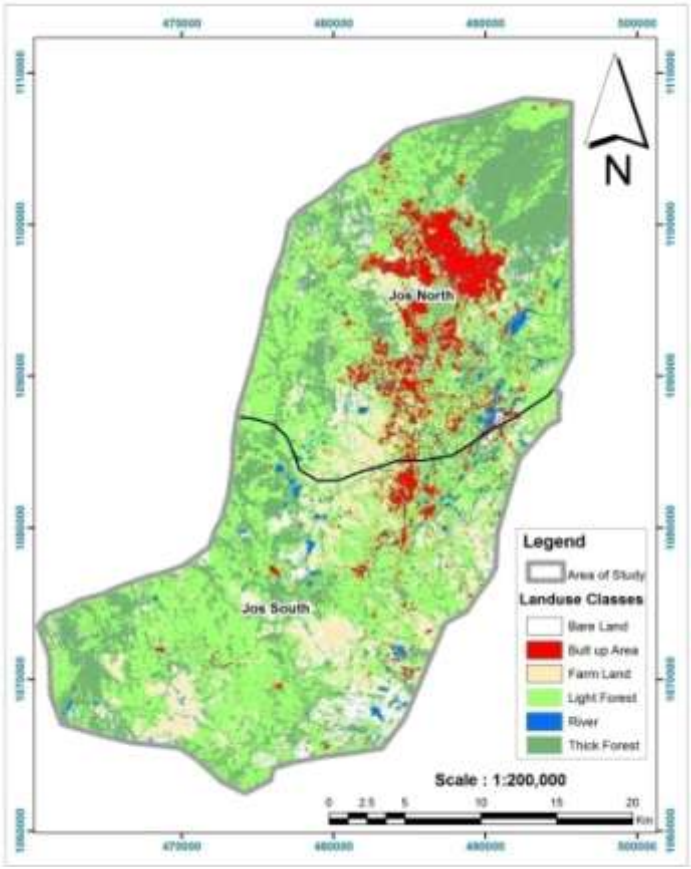


Figure 13. LULC of the Study area in 2015.
Source: Author's Field Work (2025)

The Land use/Land cover of the study area in 2015revealed that built-up area accounted for 7.37 % covering 62859600m^2, Farm land occupied 7.16% (61052400 m^2), Light forest and thick forest occupied 47.13% and 27.75%, almost 401961600 m^2 and 236705400 m^2 respectively, River occupied 2.05% which is equal to 17459100 m^2, while Bare land occupied 8.55% with 72890100 m land cover^2 of the study area. What it imply is that, human activities and population has increased significantly to the extent that, the bare land and forest areas have started shrinking when compared with the year 2000: whereby farming activities has increased trimendously by half of what it was 15-years ago, while the volume of water in the river has increased and covers more land space because of the topography and human activities or due to climate change in the recent times. The increase in farming activities suggests that there is economic diversification compelled with the poor socio-economic status of the residents in the study area, so many resolve to subsistence farming.

Table 4: Statistical table of LULC of 2015 for the study area.

Pixel Value	Classes	Count	Area	PCT(%)
1	Built up	69844	62859600	7.37
2	Farm	67836	61052400	7.16
3	Light Forest	446624	401961600	47.13
4	Thick Forest	263006	236705400	27.75
5	River	19399	17459100	2.05
6	Bare Land	80989	72890100	8.55
Total		947698	852928200	100.00

Source: Author's Field Work (2025)
Figure12 below revealed the graphical representation of what transpired in the year 215 and part of 2024 in terms of land use and land cover.

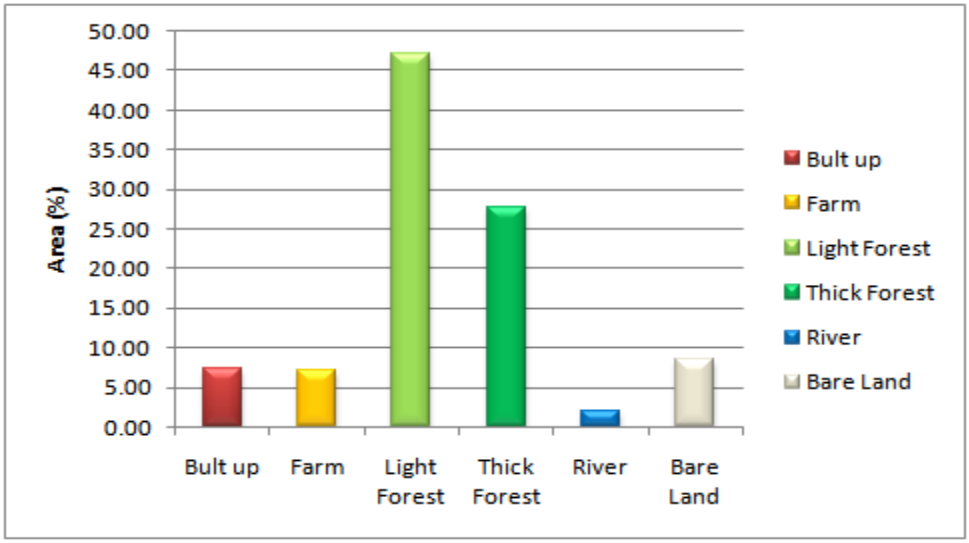


Figure 14: Histogram of LULC of study area in 2015
Source: Author's Field Work (2025)

Output 7

Identification of Urban Sprawl in 2000

The main feature class for this study are Jos and Bukuru city centers which are represented as point features with equal status but not weighted distance of multiple rings like buffer in each of the zone. The resulting polygon table will have identifiers for each of the polygons created in the buffering process, and an additional attribute indicating if the particular polygon lies inside or outside the buffer zone (see Tables 6 and 7 below) However, for this article, all the polygons were lying inside the buffer zone since buffer zone is a specified zone and it is equi-distance (2500meter) , but not weighted. The purpose of buffering is to carryout analysis that would vividly reveal how settlements are supposed to be fashioned such that, the required socio-economic facilities are available and climate change did not constitute issues to the settlements. The GIS process of buffering a point data (Jos and Bukuru city centers depicted as point feature) simply involves the creation of a 'circular' polygon about each point of radius equal to the buffer width. For the two multiple points (Jos and Bukuru), the layers are being buffered and the system must check for overlaps in each point's buffer. Any overlapping sections must be removed, in order that the result of the operation depicts polygons representing the area covered by all overlapping buffers. This process involves two additional operations: intersection and dissolve. The buffering process results in a new layer in the system consisting of polygon data which represents the buffered eleven zones of fixed not weighted distance as revealed for year 2000 in figure 4.11 and for year 2015 in figure 13 below..

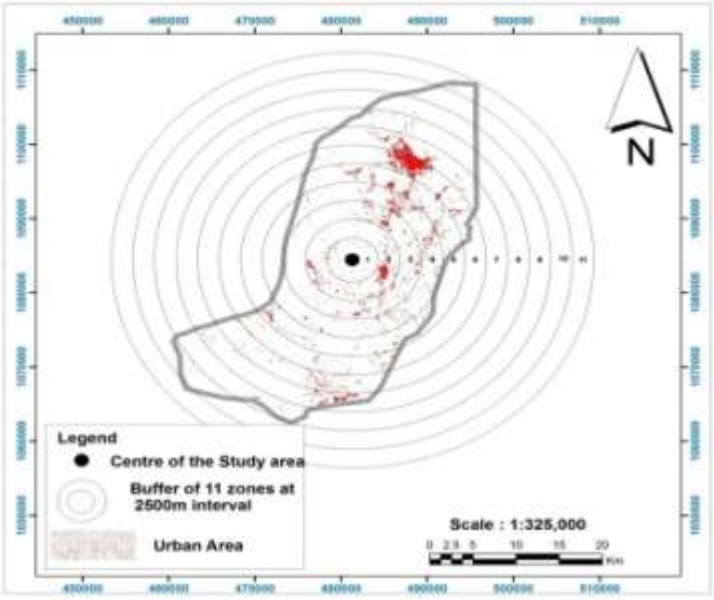


Figure 15. Urban Sprawl in Year 2000using Shannon Entropy.
Source: Author's Lab work (2025)

Table 6 below revealed zones 1-5 which are compacted type of settlement sprawling with an Entropy of between 0.01 and 0.20: meaning that, these zones have more human population and building density than zone six (dispersed), while zones seven to eleven are also compact with entropy between 0.06 and 0.13. This means the two city centers are highly concentrated in the year 2000 and the $\log^n$ for these zones have not exceeded its limit. When comparing the total land cover in square meter of zone one and the proportion of land occupied (density) by built up areas, it is almost insignificant (0'019%) and it is the same for other classes, except for zone two.(6.19%). This further confirms what transpired in Table 4 above.

Table 5: Estimate of Urban Sprawl in 2000 (Shannon Entropy).

Zones	Built up 2000 (m2)	Area Zone (m2)	Density	PDENi	log(1/PDENi)	Log (n)	Entropy	Sprawl
1	523800	27482341.05	0.01	0.43	0.36	1.04	-0.15	Compact
2	4133700	66752345.42	6.19	1.41	-0.15	1.04	0.20	Compact
3	4504500	106021165.6	4.25	0.96	0.02	1.04	-0.01	Compact
4	5683500	120571096	4.71	1.07	-0.03	1.04	0.03	Compact
5	5123700	112795010	4.54	1.03	-0.01	1.04	0.01	Compact
6	9148500	106740053.1	8.57	1.94	-0.29	1.04	0.54	Dispersed
7	5307300	105516389.9	5.03	1.14	-0.06	1.04	0.06	Compact
8	2580300	91610652.69	2.82	0.64	0.19	1.04	-0.12	Compact
9	421200	73545004.15	0.57	0.13	0.89	1.04	-0.11	Compact
10	75600	34667978.01	0.22	0.05	1.31	1.04	-0.06	Compact
11	51300	6425734.643	0.80	0.18	0.74	1.04	-0.13	Compact
n	37553400	852127770.6	4.41	1.00	0.00	1.04	0.00	Compact

Source: Author's Lab work (2025)

Output 8

Identification of Urban Sprawl in 2015

The buffer for the year 2015 and part of the year 2024 was the same process with that of year 2000 round the two city centers using the same 2500meter interval. Intersection and dissolve operations were carried out at prompt of ArcGIS in order to trim out the land area that is outside the zone of the study area, i.e. Jos and Bukuru boundaries already delineated in the composite map (see figure 4.6 above). Please note that, the interval between the eleven zones were also not discriminated and not weighted as well. This was done in order to make easy comparisons between the 15-years under review and also to measure impact.

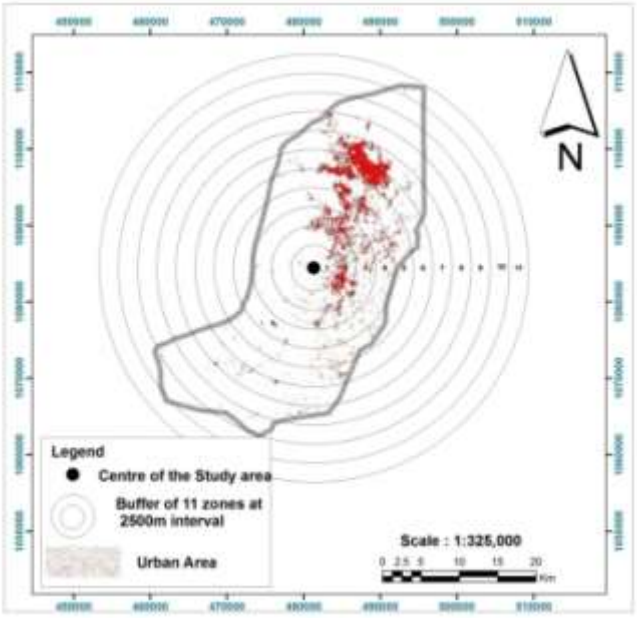


Figure 16:Urban Sprawl of 2015 and Part of 2024 (Shannon Entropy).
Source: Author's Lab work (2025)

Output 8

There are remarkable differences between the entropy values of year 2015 and some parts of 2024 when compared with year 2000 under review in terms of land cover per zone and their densities. Zone one in the year 2015 had an approximate density of 3.91% with 0.14 entropy while in the year 2000 it was 0.01%.. Zones one to five are compact type of settlement sprawl, especially towards the edges of the city centers with an entropy between 0.04 to 0.36 and all having the same $\log^n$. This means the population clusters are higher with increased built-up areas springing up everywhere, particularly in the year 2024. It also means that, more land areas are being occupied, because of increased human activities. Zone six is dispersed having a density of 0.15, while the same zone six in years 2000 had a density of 8.57. This means many people have relocated outside the city

centers to another part of the study area. Table 7 below explains further the estimation derived from the Shannon Entropy computation.

Table 6: Estimate of Urban Sprawl in 2015 (Shannon Entropy).

Zones	Built up 2015 (m2)	Area Zone (m2)	Density	PDENi	log(1/PDENi)	Log (n)	Entropy	Sprawl
1		27482341.05	3.91	0.53	0.28	1.04	0.14	Compact
2	8244000	66752345.42	12.35	1.67	-0.22	1.04	0.36	Compact
3	10463400	106021165.6	9.87	1.34	-0.13	1.04	0.16	Compact
4	8442000	120571096	7.00	0.95	0.02	1.04	0.02	Compact
5	7560000	112795010	6.70	0.91	0.04	1.04	0.04	Compact
6	15672600	106740053.1	0.15	1.99	-0.30	1.04	0.57	Dispersed
7	9470700	105516389.9	8.98	1.22	-0.09	1.04	0.10	Compact
8	1502100	91610652.69	1.64	0.22	0.65	1.04	0.14	Compact
9	161100	73545004.15	0.22	0.03	1.53	1.04	0.04	Compact
10	23400	34667978.01	0.07	0.01	2.04	1.04	-0.02	Compact
11	230400	6425734.643	3.59	0.49	0.31	1.04	0.15	Compact
n	62843400	852127770.6	7.37	1.00	0.00	1.04	0.00	Compact

Source: Author's Lab Work (2025)

5. Conclusions:-

The deployment of remote sensing tool to determine the magnitude of settlement sprawl in the two city centers for the past 15-years and above was accomplished with six (6) different types of land use and land cover. Although, the task was stressful but the art and science of remote sensing with geographic information system (GIS) tools became a veritable tool to achieve the said objective of this article. The buffer operations carried out in all the 11-zones of the study areas revealed the leapfrog built-up areas at the edges of the city centers. The buffer at 2500meter would enable planners and government to make policies for effective planning in order to avoid slums and effective infrastructural distribution to the teeming populace

Urban growth in Jos and Bukuru city centers as analyzed and revealed above using remote sensing technique serves as a model foe which effective planning and control of indiscriminate sprawling of buildings around the fringes of the city centers.
The buffer created around point features serves as a guide to provide drainage and wastes disposal system within the city centers, thereby reducing the risks of flooding, health hazards and restoring or maintaining the aesthetics of the city centers.
The model would assist the land authority to have a comprehensive land information system (LIS), in order to harness the available land resources and generate revenues for the authority.

Buffering is often done by increasing the distance at constant rate in specified direction. The buffering process does not change evenly if the shape of the spatial extent changes and the final spatial delineation may be reached non-simultaneously. It was constructed shape-based buffers from generator points and their constrained convex polygons to address the conceptual question of simultaneity in distance-based buffer. The process is conformal to the initial constraint shapes, which are predetermined by other factors or processes. This method can be applied to situations where the final scenario is preset and the delineation of a space must be reached simultaneously. This method has potential application in emergency preparedness and response to better address fairness issues when a geographic region must be zoned arbitrarily. The limitation of the method is that when the preset shape is concave and the generator

point is very off-centered, the buffered shape may not be bounded by the initial spatial extent. The method is developed and implemented using VBA scripts, and could serve the GIScience community at large.

Abbreviation
GLCF: Global land cover facility USGS: United State Geological Survey

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Conflicts of Interest
Tjere is no conflict of interest with any Author.

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