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LOCAL CLIMATE ZONE CLASSIFICATION OF THE CITES OF KADUNA AND FCT IN NIGERIA

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ABSTRACT

This paper was based on level 0 method of World Urban Database and Access Portal Tool (WUDAPT) in classifying the Local Climate Zones (LCZ) of the cities of FCT and Kaduna. The requirement of the methodology was the reason why the study focused mainly on the core urban areas in which AMAC was fully captured in FCT where by Kaduna south and Kaduna north and larger part of Chikun captured for Kaduna study area. Only five built LCZ types were classified for Kaduna city covering 15.52% while the entire land cover types were covered mainly scattered trees (48.92%), followed by low plants 12.69% while the remaining 22.87% represents dense trees (85%), bush/scrub (7.40%), bare rock/paved (6.15%), bare soil/sand (6.20%) and water (0.26%). on the other hand Abuja LCZ map indicates that 26.37% of the entire coverage was classified as built LCZ type while 73.63% was classified as land cover LCZ. The core city of Abuja majorly AMAC was classified as compact low-rise (7.37%) though with lots of mixture of other LCZ noted for mix urban built up. Low plants take up most of the rural land cover types (39.67%) followed by scattered trees 27.96% and others. The overall accuracy is 84.69% and Kappa Coefficient is 0.96 for Kaduna. The overall accuracy is 87.99% and Kappa Coefficient is 0.98 for Abuja; both demonstrated a satisfying result for the LCZ classification. It can be concluded that the WUDAPT level 0 method is credible and effective for conducting LCZ classification for Nigerian cities

Keyword: World Urban Database and Access Portal Tool (WUDAPT), Local Climate Zones (LCZ), cities, urban climate, classification, map.

INTRODUCTION

One of the elements of the physical environment is urban climate, but this element is often ignored in urban planning. Ren and Kaztschner, (2009) noted that it is necessary to factor the climatic information holistically and strategically into the process of planning in an attempt to design a sustainable city. Nigeria as a developing nation is sensitive to the effects of climate change. Both people and the economy of the nation are particularly vulnerable to the effects of climate change. In the events where resources are affected, whole communities are in turn implicated. For climate change adaptation to be effective in cities, government and planners need to consider climate environment such that physical development will be guided by policies for city sustainable development. Degradation of environmental quality has been an associated problem faced by the developing countries with dramatic growth of their urban population coupled with maximum destruction of natural resources (Balogun *et al*., 2010).

Bloch, Monroy, and Fox, (2015) acknowledged that Nigeria's urban population has expanded rapidly over the past 50 years and will continue to grow relatively fast in the coming decades. There was a

10 fold increase in the size of Nigeria's urban population between 1950 and 1990 considering data sources from the available censuses of 1952, 1963 and 1991 from about 3 million to roughly 30 million. The more urban areas develop the more they replace the open land and vegetation. The expansion of urban areas has brought with it many environmental problems which include air pollution and urban heat island (UHI) among others.

Universal approach of describing and characterizing the physical nature of cities has been a thing of great concern to urban climatologist not only recently. Initially, much of the existing terminology was not transferable across cultural and various geographical regions of the world. In an attempt to address this problem, Stewart & Oke, (2012) developed the Local Climate Zone (LCZ) classification scheme in general and particularly to help standardize observation and documentation method in urban heat island studies. Properties of surface structure (such as building, tree height and density) were used to group the scheme into seventeen zones; each zone is local in scale, this indicates that it represents horizontal distance of 100s of meters to several kilometers. The scheme represents a logical starting point for World Urban Database and Access Portal Tools (WUDAPT) which aim to compile consistent information of urban climate across global cities. WUDAPT was developed in Dublin in 2012 by a team of researchers in remote sensing, GIS, urban climate, architecture and environmental science led by Gerald Mills and Jason Ching. The template of WUDAPT is based on the National Urban Database and Portal Tool (NUDAPT) developed in 2009 (Cai *et al.*, 2016) to be a universal, simple and objective method to be used as part of a global protocol to derive information about the form and function of cities. The growing need to improve the urban system and ensure the healthy development of the urban agglomeration call for methodologies which can be of global value and also give room for further improvement from time to time.

Majority of the world cities operate like management systems that respond by way of mitigating the actions that cause some undesirable changes after then adapt the system to cope with some environmental hazards; better management system can help in prevention rather than cure. Since different cities have different capacities to respond based on their differences in political cultures, economic base, socio-cultural make-up among other things, there is a need to have a common language between the cities to describe urban landscapes in global perspective. Experts of the scientific community (such as climatologists, environmental engineers, geographers, ecologists, urban planners and technologists) are looking for more standardized information/data on the urban form and function of cities so as to devise solutions to aid architects, designers and municipal governments (such as City Planning Departments, Public Works Departments, Zoning Boards, Transportation Offices among others) in developing good evidence-based design guidelines for best practices which are related to mitigation and adaptation to climate change (Cleugh *et al.*, 2009). However, there arise the need for a consistent database on global cites at scales which are suitable for scientific inquiry and policy formulation, but such does not exist.

This study therefore explored the possibility of the level 0 WUDAPT method in classifying LCZs of the core cities of Abuja and Kaduna in Nigeria so as to generate results that can be used as input data for urban climate model simulation and climatic-spatial planning both at city and regional scale. An extensive accuracy assessment of the classification also serves as a validation tool for viability of the method in the study areas.

MATERIALS AND METHODS

Study Area

The location of the study area (Kaduna and Abuja) in Nigeria is indicated by Figure 1. The study cities in each state include majorly Abuja Municipal Area Council (AMAC) in FCT on Latitudes 8˚30'N to 9˚ 15'N and Longitudes 7˚00'E to 7˚45'E buffered by parts of other area councils; Kaduna North and Kaduna South local government areas on Latitudes 10˚20'N to 10˚ 35'N and Longitudes 7˚25'E to 7˚32'E including parts of Chikun, Igabi and some other local governments. The total area coverage of the study area is 1,761.92Km² (core urban area) the breakdown in each state is as follows: FCT (1,642.41Km²) and Kaduna (119.51Km²). Kaduna is one of the two most populous northern states according to the 2006 population census figure and located at the North Central region of Nigeria. Kaduna is located at the southern part of Kano state while FCT is located at the southern part of Kaduna, apart from its unique location at the heart of the country, Nigeria. The study areas are located in the Guinea Savanna belt of Nigeria, the Zone experience similar climatic conditions but with local variations due to relief and topographic effects which modify the thermometer and rain gauge readings within the study area. Generally, the belt is categorized under Köppen's Aw **(**Tropical wet and dry or savanna) climate. On a general note, the study area experiences two main seasons on a yearly basis; namely the wet season and the dry season. The rainy season lasts from about April to October. The area experiences a period of Harmattan between the months of December to February. The study area (FCT and Kaduna) lies largely on the Guinea Savanna vegetation belt of Nigeria, characterized by woodlands and tall grasses interspersed with tall dense species. Some parts of this area fall within the Northern Guinea Savanna which has comparatively fewer and shorter trees than in the Southern Guinea Savanna. The Northern Guinea Savanna also composed of Savanna wood lands (trees), shrubs patch land or extensive grass land. Kaduna metropolis is situated on the high plains of Hausaland which consist mainly of the Precambrian rocks of the basement complex, mainly of older granites, schist and quartzite in different composition.

Hills in the FCT occur either as clusters or they form long ranges. The most prominent of these ranges are the Gawu, Gurfata, Bwari-Aso, Idon Kasssa, Wuna and the Was-Sukuku ranges. The last one is fact a complex of ridges that run across the centre of the FCT from Kwali in the west, to Wasa in the east.

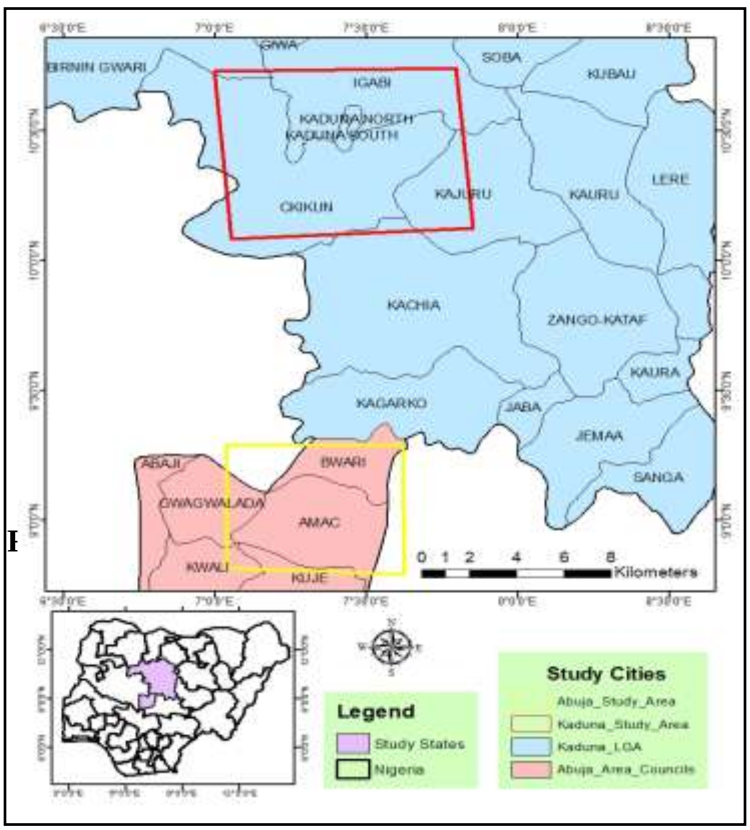

Figure 1: Map of Study Area

Data and Software

The following are the datasets and the software used for the study:

1. Landsat 8 (Operational Land Imager) images
2. City Template Folder
3. Google Earth Pro Software version 7.3.2

4. System for Automated Geo-scientific Analysis (SAGA)-GIS software version 2.0.5
5. ArcGIS software version 10.2
6. Global Mapper software version 18.2.0

Data Collection and Procedure Guidelines

The very first procedure was to create the Region of Interest (ROI) which correspond to the study cities in each state. There are conditions for selecting the ROI as created in Google Earth Pro software, the conditions are as follows:

a. The guideline about the ROI covering the entire urbanized area was considered and also the buffer area and the required dimension of the ROI was also followed. Boarders and label layer in GE pro were also switched on in the process to serve as a guide in the choice.

Ruler tool was also used to guide in the ROI dimension, Figure 2 and the style of the polygon changed to transparent and the colour changed to outlined; the polygon must be rectangular shape but do not need to be exact. Yellow line on Figure 2 indicating the length as measured in GE Pro, red line indicating the actual rectangle with the name under My Places.

b. The ROI was saved as a KMZ file by right clicking on it, Save Place As option in the dialogue box.

Importing the ROI into SAGA GIS and Projecting the ROI to (UTM) the Projection of Landsat Data

The main objective involves identification and mapping the various LCZ in the study areas which requires satellite image of the study area, the training data to be used for classification and the software. After successful creation of the ROI and downloading the required Landsat scenes for the study, the next step was to import the ROI into SAGA GIS and project the ROI to Universal Transverse Mercator (UTM), the projection of Landsat data because the downloaded Landsat data scenes were all level 1 GeoTIFF Landsat data; meaning that they have been geo-referenced. This operations were performed using SAGA GIS. Another important data used in this study also downloaded from WUDAPT website and the city template folder includes the file containing the format for the city name called the city template file for consistency in city name format and another file for the colour scheme also called cmap were downloaded. The cmap contain such important function of making the colours in each LCZ classes in different classification to be consistent; the prepared regions of interest are indicated in Figure 3.

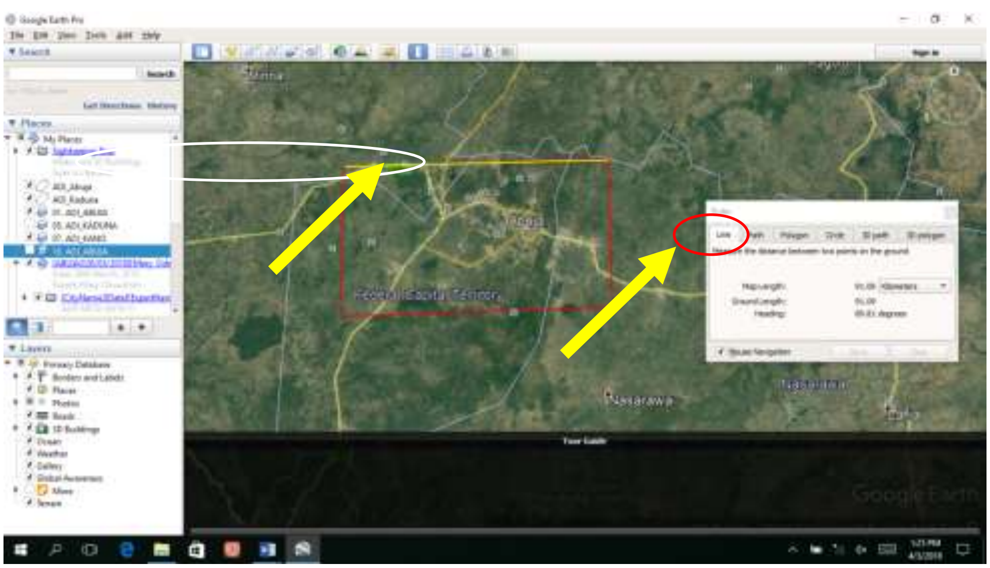

Figure 2: Abuja Region of interest
Source: Google Earth Pro, 2018

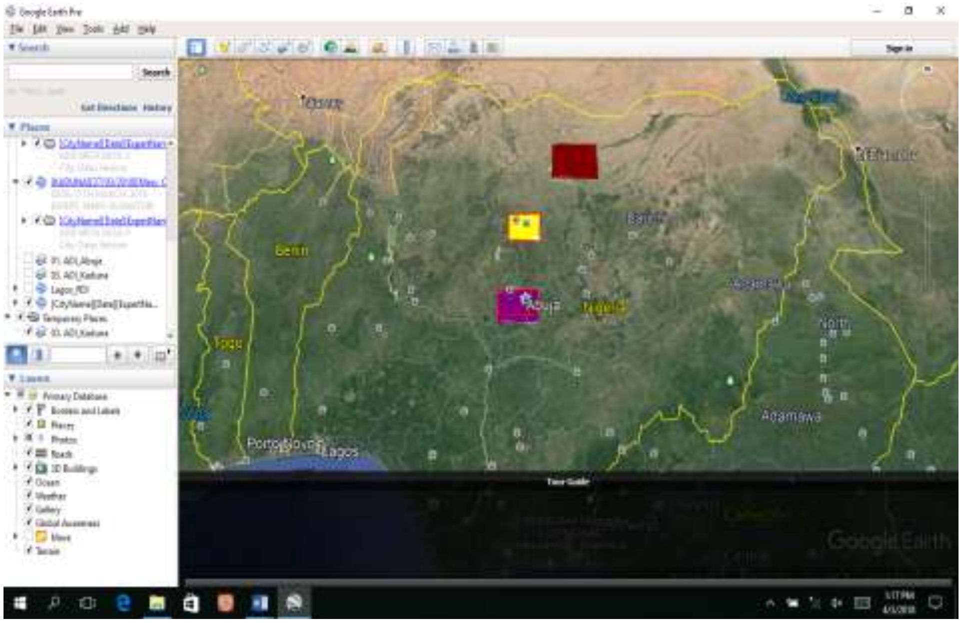

Figure 3: The Prepared Regions of interest (ROI) in Google Earth Pro
Source: Google Earth Pro, 2018

The region of interest was imported into SAGA GIS and projected into the same projection with the Landsat dataset; then, the projected ROI imported into GE pro for digitization of the training areas. The prepared training dataset, the ROI and the Landsat dataset were further imported into SAGA GIS to generate the Local Climate Zone Classification (LCZC). The methodology flow is indicated on Figure 4.

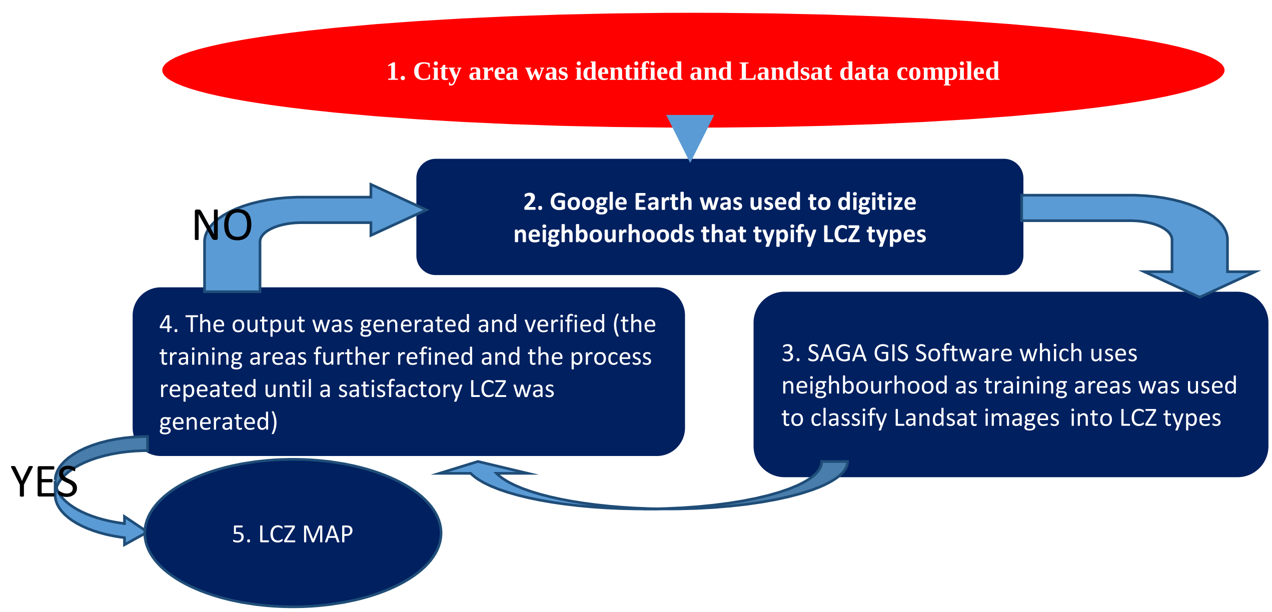

Figure 4: Refined Flow Chart for WUDAPT Level 0 Method used for generating LCZ Classification
Source: (Gerald Mills) Adapted from www.wudapt.org/wudapt, 2018

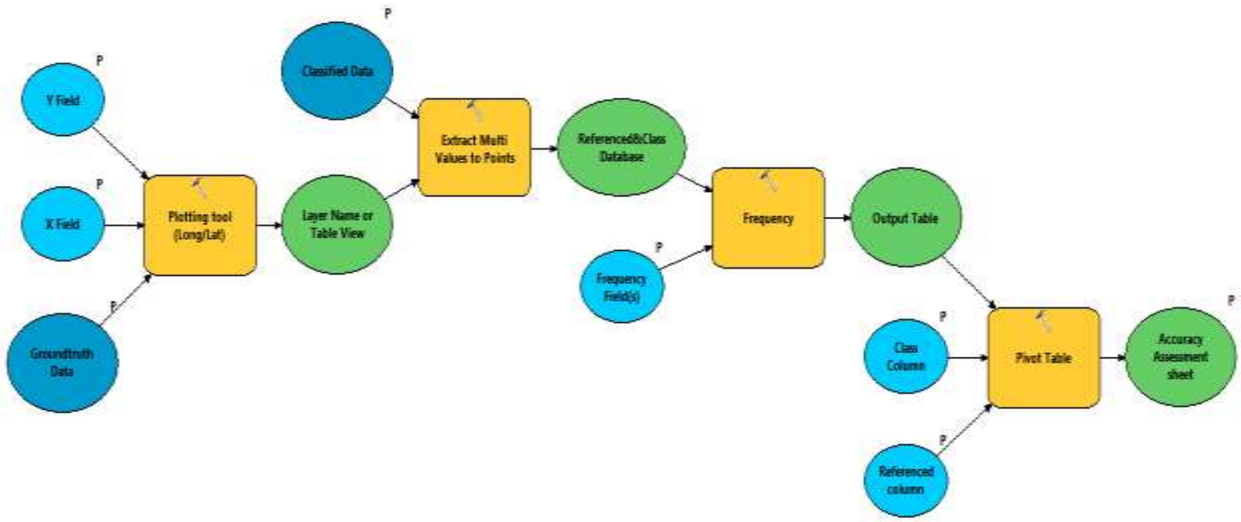

Figure 5: Accuracy Assessment Methodology Flow

After generating the LCZ classification in SAGA GIS, the methodology flow of the validation known as the accuracy assessment is indicated on Figure 5.

Kappa coefficient defined in terms of the elements of the confusion matrix; represented by xij, total number of test pixels (Observations) represented in the confusion matrix is P. All the details are represented on Table 2 and Table 3.

RESULTS

Identifying and Mapping the Local Climate Zones (LCZ) in the Study Areas

Local Climate Zone Mapping of Kaduna and FCT

The LCZ map of Kaduna study area is seen on Figure 6 while that of FCT is on Figure 7. The maps show the morphology characteristics of rural and urban area and also detect the potential Urban Heat Island (UHI) distribution pattern of the Metropolitan area.

Only five built LCZ types were classified for Kaduna city covering just 15.52% of the study area while the entire land cover types of the LCZ were covered but the classified land cover type mostly belong to scattered trees (LCZ B otherwise denoted with LCZ 102 for the purpose of analysis) this covered 48.92% of the entire study area; followed by low plants (LCZ D or LCZ 104) 12.69% and others in their different area coverage as indicated on Table 1. The major variation in coverage of the different LCZ type is also presented on Figure 8 that shows the coverage in hectares across the study area.

The entire municipal area are mainly classified as compact low-rise (LCZ 3), Open Low-rise (LCZ 6) and Lightweight Low-rise (LCZ 7) representing 0.11%, 3.86% and 1.71% respectively. Rural areas are classified as Sparsely Built (LCZ 9) 0.86% while other areas classified as Heavy Industries (LCZ 10) covered 8.98% of the entire built up areas.

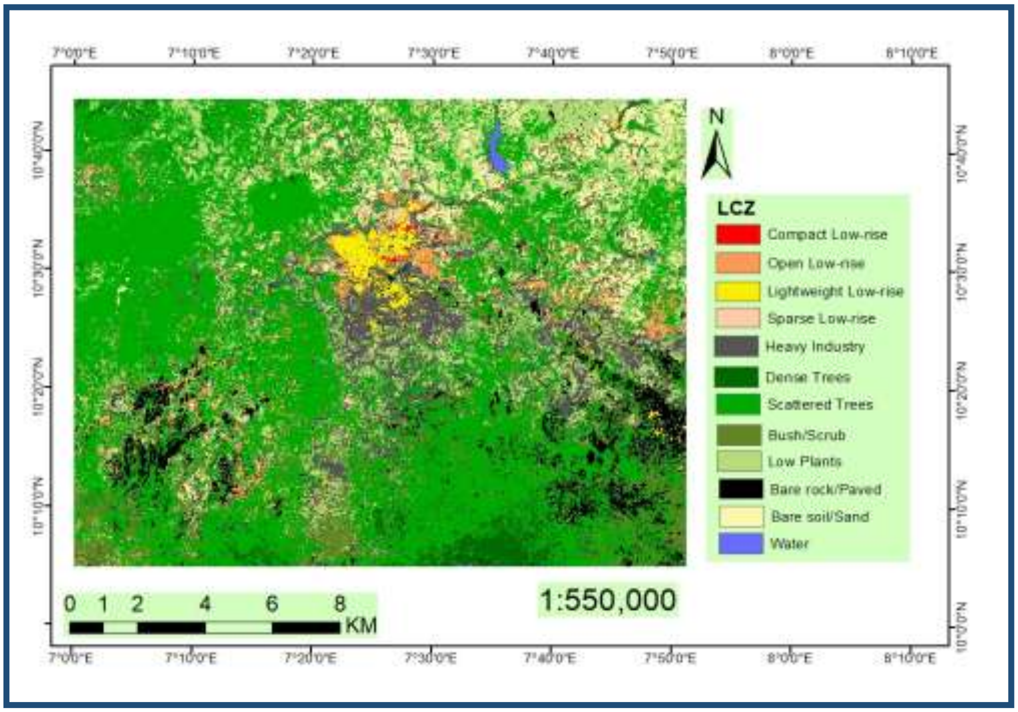

Figure 6: **Kaduna Local Climate Zone Classification**

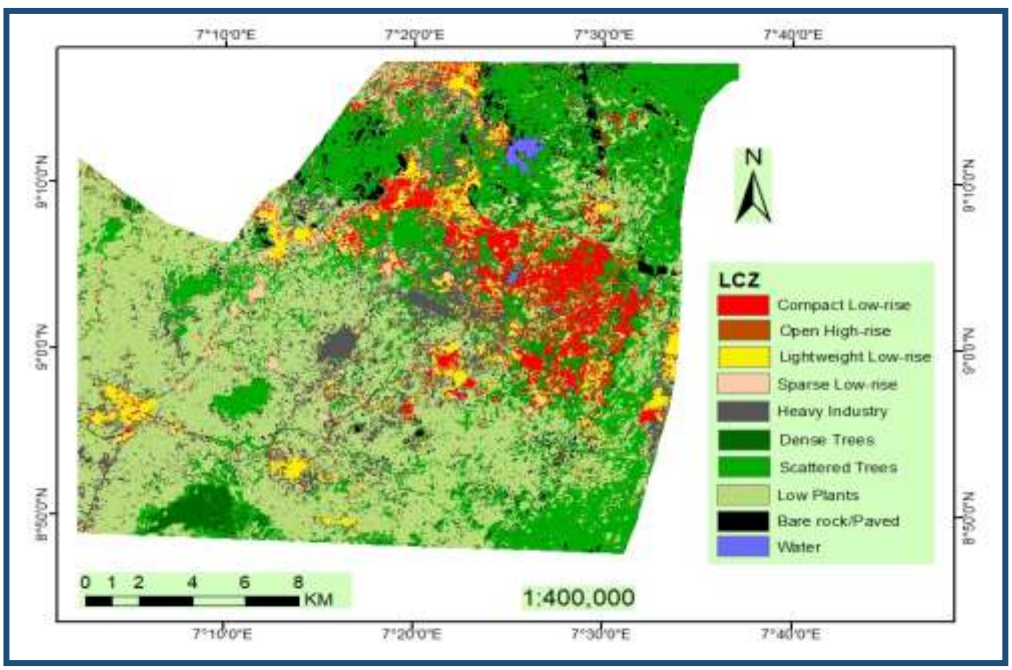

Figure 7: **Abuja Local Climate Zone Classification**

The FCT LCZ map on the other hand indicates that 26.37% of the entire coverage was classified as built LCZ type while 73.63% was classified as land cover LCZ type as indicated on Figure 7. The classified built LCZ types include compact low-rise, open high-rise, lightweight low-rise, sparse low-rise and heavy industry. The core city of Abuja majorly in Abuja Municipal Area Council were classified as compact low-rise (7.37%) though with lots of mixture of other LCZ types but cannot be captured because of the scale of WUDAPT level 0 method but were noted for mix urban built up to be elaborated further in subsequent research. The central Business District area was classified as open high-rise covering 0.23%. Vast areas of Abuja built up were classified as lightweight low-rise (6.19%) and the rural areas as sparse low-rise (2.03%) while the Airport, Stadium and other industrial areas were classified as heavy industry (10.55%). Details of the classification are presented on Table 1 and Figure 7.

Land cover types classified for Abuja LCZ map include dense trees, scattered trees, low plants, bare rock/paved and water. The map indicates that low plants take up most of the rural land cover types covering 39.67% followed by scattered trees 27.96% and others in their ratios as presented on Figure 7.

Table 1: Local Climate Zone Area Coverage

LCZ	LCZ Description	Kaduna Coverage(Ha)	% Coverage	Abuja Coverage(Ha)	% Coverage
1	Compact high-rise	0	0.00	0	0.00
2	Compact mid-rise	0	0.00	0	0.00
3	Compact low-rise	778	0.11	19983	7.37
4	Open high-rise	0	0.00	637	0.23
5	Open mid-rise	0	0.00	0	0.00
6	Open low-rise	26231	3.86	0	0.00
7	Lightweight low-rise	11606	1.71	16772	6.19
8	Large low-rise	0	0.00	0	0.00
9	Sparse low-rise	5872	0.86	5509	2.03
10	Heavy industry	61070	8.98	28596	10.55
101	Dense trees	19397	2.85	5855	2.16
102	Scattered trees	332642	48.92	75822	27.96
103	Bush/scrub	50333	7.40	0	0.00
104	Low plants	86287	12.69	107566	39.67
105	Bare rock/paved	41832	6.15	9458	3.49
106	Bare soil/sand	42157	6.20	0	0.00
107	Water	1747	0.26	940	0.35
Total		679952	100	271138	100

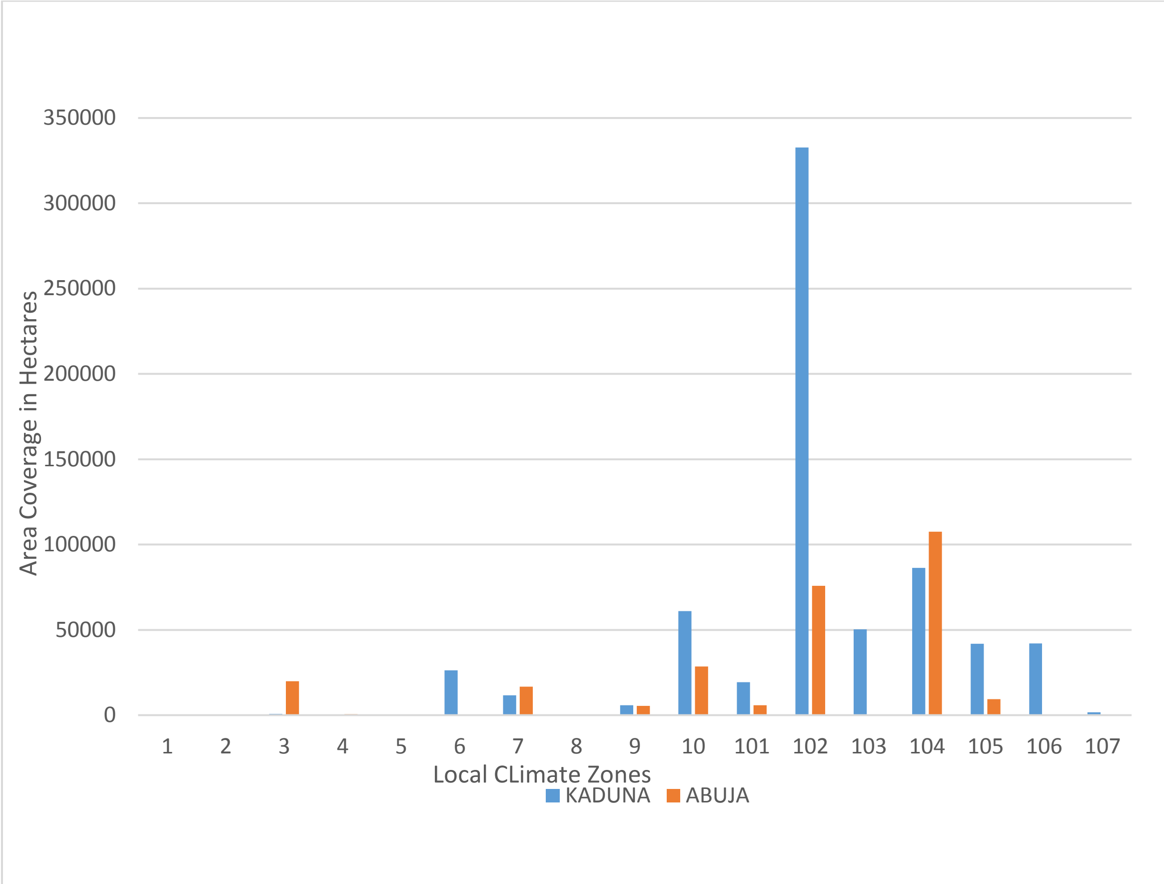

Figure 8: Area Coverage by Local Climate Zone in Hectares

Accuracy Assessment of LCZ Classification

Confusion Matrix is analysis that usually summarizes the results of an accuracy assessment in rows and columns. An assessment that always compares the classified LCZ classes with the reference data to reveal the level of similarity and differences.

The overall accuracy is 84.69% and Kappa Coefficient is 0.96 for Kaduna. The overall accuracy is 87.99% and Kappa Coefficient is 0.98 for FCT. The result of the accuracy assessment for the cities of Kaduna and FCT demonstrated a satisfying result for the LCZ classification. It can be concluded that the WUDAPT level 0 method is credible and effective for conducting LCZ classification for Nigerian cities especially those that share similar urban morphological characteristics to that of Kaduna and the FCT.

The result of the producer and user's accuracy for both cities also have relatively good accuracy for both Kaduna and FCT cities as shown in Table 2 and Table 3. The confusion matrix also indicate that lightweight low-rise and sparse low-rise have the same accuracies for producer and user while open low-rise, scattered trees, bush/scrub, bare rock/paved and bare soil/sand have higher users accuracy which is taken to be most adopted accuracy. On the other hand the error matrix for FCT indicate that heavy industry, dense trees, low plants and water have higher users accuracy while the accuracies of compact low-rise, open high-rise, lightweight low-rise, scattered trees and low plants are also remarkably satisfactory. Dense trees and bare soil/sand show zero accuracy for Kaduna, the possible reason may be that limited information was provided by the training data which makes it difficult for the classification to be established in the Landsat image; image with better resolution can be the proactive way out to such cases.

Table 2: Confusion Matrix of Kaduna

LCZ	3	6	7	9	10	101	102	103	104	105	106	107	Total Reference Points	Users Accuracy
3	6	1	0	0	0	0	0	0	0	0	0	0	7	85.71
6	0	8	0	0	0	0	0	0	0	0	0	0	8	100.00
7	0	0	20	0	0	0	0	0	0	1	0	0	21	95.24
9	0	0	0	23	0	0	0	0	0	0	0	0	23	100.00
10	0	0	0	0	20	0	1	0	1	0	7	0	29	68.97
101	0	0	0	0	0	0	11	0	0	0	0	0	11	0.00
102	0	0	0	0	0	0	34	1	1	0	1	1	38	89.47
103	0	0	0	0	0	0	0	22	1	0	0	0	23	95.65
104	0	0	1	0	0	0	1	1	19	1	0	0	23	82.61
105	0	0	0	0	0	0	0	1	0	16	0	0	17	94.12
106	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
107	0	0	0	0	0	0	0	0	0	0	0	9	9	100.00
Total Classified Points	6	9	21	23	20	0	47	25	22	18	8	10	209	
Producers Accuracy	100.00	88.89	95.24	100.00	100.00	0.00	72.34	88.00	86.36	88.89	0.00	90.00		
Po	177													
Pc	4927													
Kappa	0.9643													
Overall Accuracy	84.689													

Table 3: Confusion Matrix of FCT

LCZ	3	4	7	9	10	101	102	104	105	107	Total Reference Points	Users Accuracy
3	61	1	0	0	2	0	2	0	0	1	67	91.04
4	0	15	0	0	2	0	0	0	0	0	17	88.24
7	4	0	40	1	0	0	0	0	0	1	46	86.96
9	0	0	1	20	0	0	0	0	0	4	25	80.00
10	0	0	0	1	28	0	0	3	0	0	32	87.50
101	0	0	0	0	0	17	0	0	0	1	18	94.44
102	0	0	1	0	0	9	36	0	0	0	46	78.26
104	0	0	0	0	1	0	1	46	1	0	49	93.88
105	0	0	0	0	0	1	0	2	23	0	26	88.46
107	0	0	0	0	0	0	0	0	0	7	7	100.00
Total Classified Points	65	16	42	22	33	27	39	51	24	14	333	
Producers Accuracy	93.85	93.75	95.24	90.91	84.85	62.96	92.31	90.20	95.83	50.00		
Po	293											
Pc	13666											
Kappa	0.97863											
Overall Accuracy	87.988											

DISCUSSION

It is worth to note that Ferreira *et al.*, (2018) in their work on urban form representation of heterogeneous city of Belo Horizonte in Brazil for application in urban climate studies applied three methods and eventually came up with the calculation of the complete aspect ratio method as their best method (a quantitative approach) which can be used to represent the city in surface energy balance simulations and also as an input parameter in weather simulation.

On the contrary, this present study prefers to adopt a modified LCZ classification scheme in which there may be a need to redefine, re illustrate and adjust the properties of the LCZ classes in such a way that the objective of WUDAPT will still be valid and the outcome can also be compared with homogeneous cities to greater extent. This was possible coupled with sub classes as raised in the work of Stewart and Oke (2012) where users are at liberty to create new subclasses for sites that deviate from the standard set of LCZ classes. These sub classes represent combination of built types, land cover types and properties as the case may be. The notation for new subclasses as suggested is LCZ Xai where "X" represents the higher parent class, "a" represents the lower parent class and "i" represents variable or ephemeral land cover property. It was also noted for the classified compact low-rise (LCZ 3) and open low-rise (LCZ 6) in the FCT and Kaduna that some of the land cover are not paved in all cases but the provisions of the subclasses are enough to modify the cases here while the characteristics of the new classes can be redefined. Beside LCZ1 to LCZ6, other built type LCZ for heterogeneous cities also call for some modification in definition and surface properties, but the colour scheme for the visual presentation can vary but not to be altered or removed and this also serve as an opportunity and a bases for comparison to a greater extent with homogeneous cities of the world.

Some major parameters of great importance and good research focus areas in urban climate studies are the values of geometric and surface cover properties for the Local Climate Zones presented in Appendix A such as the sky view factor (SVF), aspect ratio, building surface fraction (BSF), Impervious Surface Fraction, Pervious Surface Fraction, Height of Roughness Element, and Terrain Roughness Class. The relevance of these parameters as can be extracted from this study cannot be limited to this study but serve as an open doors to many other studies substantiated through various studies especially with lots of case studies from Colombo, Sri Lanka and other cities in the world carried out by group of authors such as Perera and Emmanuel (2016), Bechtel *et al.*, (2015), Perera *et al.*, (2012), Perera and Langapodi (nd) and Perera and Weerasekara (2014).

The LCZ classification for both cities indicates an existence of a significant mix in the urban fabric of the cities but mostly observed from FCT where most built-up LCZ have sub-categories. The result of the ground truth indicates few or no compact high-rise (LCZ 1) but vast open high-rise (LCZ 4) around the Central Business District (CBD) combined with sub-categories of compact and open low-rise (LCZ 3 and 6) denoted by LCZ 4_{36}. The vast areas classified as compact low-rise (LCZ 3) also have sub-category of Lightweight low-rise (LCZ 7) in most cases also denoted by LCZ 3_7 with the exception of Gwarinpa Estate which perfectly fit into compact low-rise (LCZ 3) but with different building structures ranging from Masfa to single phases, corner shops and bonny BB which were all well-structured.

Other areas worth to mention involves Utako classified as compact low-rise (LCZ 3) also mix with compact mid-rise (LCZ 2) denoted by LCZ 3_2. Wuse and Garki also follow the same manner as LCZ 3_2 though classified as LCZ 3 and Yanyan and Lugbe village classified as Lightweight low-rise (LCZ 7) but made up of unorganized built up settings having vast of the characteristics of sparse low-rise (LCZ 9) denoted by LCZ 7_9.

Kaduna city fabric is majorly compact low-rise (LCZ 3) and Lightweight low-rise (LCZ 7), the only area in Kaduna city where high-rise buildings are found is along constitution road and it is very difficult to classify because there are mixture of high, medium and low-rise buildings in an unorganized manner. The sub-classes here can be said to be mixture of compact low-rise building as the major class with compact and open mid-rise buildings as the sub classes LCZ 3_{25}.

Areas around Race Course road, Coronation Crescent, Unguwan Sarki and the environs form another cluster of mix buildings but with abundant trees and pervious land cover, sharing the characteristics of both compact low-rise and sparse low-rise buildings (LCZ 3 and LCZ 9); classified as Lightweight low-rise (LCZ 7) as the major class with LCZ 3 and LCZ 9 as the sub classes denoted by LCZ 7_{39}.

Summary of the sub-categories of the LCZ classes both in Kaduna and Abuja include:

1. Compact Low-rise with Compact High-rise as the sub class - LCZ 3_2
2. Compact Low-rise with Lightweight low-rise as the sub class - CLCZ 3_7
3. Open High-rise with two sub classes: Compact Low-rise and Open Low-rise - LCZ 4_{36}
4. Lightweight Low-rise with Sparse Low-rise as the sub class LCZ 7_9
5. Compact Low-rise with two sub classes: Compact High-rise and Open High-rise - LCZ3_{25}
6. Lightweight Low-rise with two sub classes: Compact Low-rise with and Sparse Low-rise - LCZ 7_{39}

CONCLUSION

The methodology put forward in this study on one hand was to bring out the details of urban fabrics in form of Local Climate Zones to map regions of uniform surface air temperature distribution at horizontal scale of 10^2 to 10^4 meters the method developed by Stewart and Oke in the year 2012.

Despite the fact that Nigerian cities are heterogeneous, this method with the extensive provision of combining LCZ classes has made it possible to have a remarkable result and proactive accuracy, with the result of this study, similar study can be carried out in other cities of the nation and there is a basis of comparison both at the country level and also at the regional scale.

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