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LAND COVER CHANGE IMPACTS ON THE TREE DENSITY AND CARBON STOCK IN SOKOTO METROPOLIS, NORTH-WESTERN NIGERIA

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By

MURTALA DANGULLA

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for Doctor of Philosophy

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DEDICATION

To my mother, for her love and prayers

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Chairman : Associate Professor Latifah Abd Manaf, PhD
Faculty : Environmental Studies

Urban trees and forests provide an array of ecosystem services to urban dwellers; the most important of which is the storage and sequestration of atmospheric carbon. However, these resources are being increasingly affected by land cover changes caused by accelerated and unregulated growth in most urban areas of the world. The objective of this study was to assess land cover change impacts on the density of trees and carbon stock in Sokoto metropolis, North-western Nigeria. Landsat images for 1990, 1999 and 2015 were processed for land cover classification and change detection using the Maximum Likelihood Classification and Post Classification Comparison techniques. Data on tree species and their origin was collected from field survey of 189 sample plots while the density and distribution of carbon stock in the metropolis was quantified and predicted with the InVEST model. The classification revealed five broad land cover classes which include the Built-up Area, Farmland, Green Area, Open Space and Wetland/Water. The Built-up and Green areas continuously increased from 25.4% and 13.7% of the total area respectively in 1990 to 59.03% and 16.91% respectively in 2040. Conversely, the Farmland and Open Space continuously decreased from 38.2% and 20.9% of the total area respectively in 1990 to 12.96% and 9.94% of the total area respectively in 2040. The Wetland/Water on the other hand fluctuated in size throughout the study period, with a net reduction of approximately 60 hectares. The pattern of expansion was generally radial but more evident in the north and eastern parts of the metropolis. Overall classification accuracy was 91.7%, 92.1% and 90.3% for 1990, 1999 and 2015 respectively. The study recorded 722 tree stems belonging to 30 species in 17 genera and 14 families. Majority of the species (21) are native to the area while 9 are exotic. However, the exotic species contributed more tree stems (73.3%) than the native species (26.7%). About 62% of these stems were recorded in the Built-up Area but the highest stem density of 78.4 ha-1 was recorded in the Green Area. The most dominant species were *Azadirachta indica*, *Mangifera indica*, *Adansonia digitata*, *Ficus polita* and *Terminalia catappa* while the dominant families were Meliaceae, Fabaceae, Moraceae, Combretaceae and Anacardiacea. There was significant difference in mean trees stem diameter ($f = 5.79$, $p < 0.001$) and basal area ($f = 5.21$, $p < 0.001$) across the land cover classes but no significant difference in mean trees stem height ($f = 1.82$, $p > 0.123$). Based on NDVI and NDBI differencing, a simple linear correlation revealed significant positive relationship between urban expansion and tree density in the metropolis for 1990 ($r = 0.980$, $p = 0.001$), 1999 ($r = 0.986$, $p = 0.001$) and 2015 ($r = 0.972$, $p = 0.001$). Carbon density, distribution and sequestration in the metropolis were also strongly influenced by the type and extent of land cover, with majority of the carbon contributed by the soil. The total carbon was estimated at 697,563.49 Mg, 717,972.27 Mg and 731,465.96 Mg, corresponding to mean carbon of 73.9 Mg/ha-1, 76.0 Mg/ha-1 and 77.5 Mg/ha-1 in 2015, 2030 and 2040 respectively and valued at USD 34,874,625.00 (NGN 12,624,614.00), USD 35,894,975.00 (NGN 12,993,980,950.00) and USD 43,883,814.00 (NGN 15,885,940,668.00) in the respective years. The total sequestered carbon on the other hand, was estimated at 2,0407Mg between the year 2015 and 2030 and 1,3497Mg between the year 2030 and 2040 and valued at USD 734,399.00 (NGN 265,852,438.00) and USD 548,091.00 (NGN 191,831,850.00) between the respective years. The Built-up and Green Areas contributed more carbon than the other land cover classes while trees species with the highest carbon storage were *Tamarindus indica, Azadirachta indica, Parkia biglobosa, Delonix regia, Mangifera indica* and *Sclerocarya birrea*. These species are thus recommended to be widely planted in the metropolis. Urban afforestation and climate change mitigation programmes in Sokoto metropolis should thus place emphasis on higher carbon storing species and especially the native species which are declining in population.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

IMPAK PERUBAHAN LITUPAN TANAH KE ATAS KEPADATAN POKOK DAN STOK KARBON DI METROPOLIS SOKOTO, BARAT LAUT NIGERIA

Oleh

MURTALA DANGULLA

Mei 2019

Pengerusi : **Profesor Madya Latifah Abd Manaf, PhD**
Fakulti : **Pengajian Alam Sekitar**

Pokok dan hutan bandaran menyediakan pelbagai perkhidmatan ekosistem kepada penduduk bandar; yang paling penting adalah penyimpanan dan sekuester karbon di atmosfera. Walau bagaimanapun, sumber ini semakin terkesan oleh perubahan litupan tanah yang disebabkan oleh perkembangan pesat dan tidak terkawal di kebanyakan kawasan bandar dunia. Objektif kajian ini adalah untuk menilai kesan perubahan litupan tanah terhadap kepadatan pokok dan stok karbon di metropolis Sokoto, Barat Laut Nigeria. Imej Landsat bagi tahun 1990, 1999, dan 2015 telah diproses untuk pengkelasan litupan tanah dan pengesanan perubahan menggunakan teknik Pengkelasan Kebarangkalian Maksimum dan Pengkelasan Selepas Perbandingan. Data berhubung spesies pokok dan asal-ususlnya dikumpulkan melalui tinjauan lapangan ke atas 189 sampel plot manakala kepadatan dan taburan stok karbon di metropolis telah dikuantifikasikan dan diramalkan menggunakan model InVEST. Pengkelasan tersebut menunjukkan lima kelas litupan bumi luas yang merangkumi Kawasan Binaan, Tanah Ladang, Kawasan Hijau, Kawasan Terbuka, dan Tanah Bencah/Air. Kawasan Binaan dan Kawasan Hijau meningkat pada tahun 1990, masing-masing daripada 25.4% dan 13.7% secara berterusan kepada 59.03% dan 16.91% pada tahun 2040. Sebaliknya, Tanah Ladang dan Kawasan Terbuka masing-masing pada tahun 1990 menurun secara berterusan daripada 38.2% dan 20.9% kepada 12.96% dan 9.94% pada tahun 2040. Selain itu, saiz Tanah Bencah/Air naik-turun sepanjang tempoh kajian, dengan pengurangan bersih hampir 60 hektar. Corak pengembangan secara amnya berbentuk radial tetapi lebih menyerlah di bahagian utara dan timur metropolis. Secara keseluruhannya ketepatan pengkelasan adalah 91.7% bagi tahun 1990, 92.1% pada tahun 1999 dan 90.3% pada tahun 2015. Kajian ini telah merekodkan sejumlah 722 batang pokok daripada 30 spesies dalam 17 genus dan 14 famili. Majoriti pokok adalah spesies tempatan manakala 9 adalah spesies eksotik. Walau bagaimanapun, spesies eksotik menyumbangkan lebih bilangan batang pokok (73.3%) berbanding spesies tempatan (26.7%). Kira-kira 62% batang pokok

direkodkan di Kawasan Binaan tetapi kepadatan pokok tertinggi adalah sebanyak 78.4 ha^{-1} yang direkodkan di Kawasan Hijau. Spesies paling dominan adalah *Azadirachta indica, Mangifera indica, Adansonia digitata, Ficus polita,* dan *Terminalia catappa* manakala family paling dominan adalah dari Meliaceae, Fabaceae, Moraceae, Combretaceae, dan Anacardiacea. Terdapat perbezaan signifikan antara purata diameter batang pokok ($f = 5.79$, $p < 0.001$) dan kawasan basal ($f = 5.21$, $p < 0.001$) di antara kelas litupan bumi tetapi tiada perbezaan signifikan antara purata tinggi batang pokok ($f = 1.82$, $p > 0.123$). Berdasarkan perbezaan NDVI dan NDBI, korelasi linear ringkas menunjukkan hubungan positif dan signifikan di antara peluasan kawasan bandaran dan kepadatan pokok di metropolis untuk tahun 1990 ($r = 0.980$, $p = 0.001$), 1999 ($r = 0.986$, $p = 0.001$), dan 2015 ($r = 0.972$, $p = 0.001$). Kepadatan, taburan, dan sekuester karbon di kawasan metropolis sangat dipengaruhi oleh jenis dan takat litupan bumi, dengan majoriti karbon disumbangkan oleh tanah. Jumlah karbon diramalkan sebanyak 697,563.49 Mg, 717,972.27 Mg, dan 731,465.96 Mg, bersamaan dengan purata karbon sebanyak 73.9 Mg/ha^{-1}, 76.0 Mg/ha^{-1}, dan 77.5 Mg/ha^{-1} untuk tahun 2015, 2030, dan 2040. Jumlah ini bernilai sebanyak USD 34,874,625.00 (NGN 12,624,614.00), USD 35,894,975.00 (NGN 12,993,980,950.00) dan USD 43,883,814.00 (NGN 15,885,940,668.00) bagi tahun 2015, 2030 dan 2040. Jumlah sekuester karbon diramalkan sebanyak 2,0407 Mg antara tahun 2015 dan 2030, bernilai USD 734,399.00 (NGN 265,852,438.00); 1,3497 Mg antara tahun 2030 dan 2040 yang bernilai USD 548,091.00 (NGN 191,831,850.00). Kawasan Binaan dan Kawasan Hijau menyumbangkan jumlah karbon yang lebih banyak berbanding kelas litupan bumi yang lain manakala spesies pokok dengan penyimpanan karbon tertinggi adalah *Tamarindus indica, Azadirachta indica, Parkia biglobosa, Delonix regia, Mangifera indica* dan *Sclerocarya birrea* yang mana spesies ini dicadangkan untuk ditanam. Program penghutanan bandar dan mitigasi perubahan iklim di metropolis Sokoto haruslah mengutamakan spesies yang menyimpan karbon yang tinggi terutamanya spesies tempatan yang semakin menurun populasinya.

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Thank you all and may Allah reward you abundantly.

Declaration by graduate student

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LIST OF ABBREVIATIONS

AGB	Aboveground Biomass
AGC	Aboveground Carbon
AHVRR	Advanced Very High-Resolution Radiometer
ANN	Artificial Neural Network
ANOVA	Analysis of Variance
AOI	Area of Interest
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
BA	Basal Area
BGB	Biomass
BGC	Belowground Carbon
C	Carbon
CA Markov	Cellular Automata/Markov Chain
CD	Change Detection
COST	Cosine of the Sun Zenith Angle
DBH	Diameter at Breast Height
DLC	Dead Litter Carbon
DN	Digital Number
DOS	Dark Object Subtraction
ETM	Enhanced Thematic Mapper
ETM+	Enhanced Thematic Mapper Plus
EMR	Electro-magnetic Radiation
ESDAC	European Soil Data Centre
EVI	Enhanced Vegetation Index
FCC	False Colour Composite

GCP	Ground Control Point
GIMMS	Global Inventory Modelling and Mapping Studies
GIS	Geographic Information Systems
GPS	Global Positioning System
GRA	Government Reserved Area
HWSD	Harmonized World Soil Database
IGBP	International Geosphere-Biosphere Programme
ITD	Inter-tropical Discontinuity
ISODATA	Iterative Self-Organizing Data Analysis Technique
InVEST	Integrated Valuation of Environmental Services and Tradeoffs
IVI	Importance Value Index
KIA	Kappa Index of Agreement
Km	Kilometre
L1 T	Level 1, Terrain Corrected
LCM	Land Change Modeler
LiDAR	Light Detection and Ranging
MLC	Maximum Likelihood Classification
MLP	Multi-layer Perceptron
MODIS	Moderate Resolution Imaging Spectrometer
MSAVI	Modified Soil Adjusted Vegetation Index
MSS	Multispectral Scanner
MSS	Multispectral Scanner
NASA	National Aeronautics and Space Administration
NDBI	Normalized Difference Built-up Index
NDVI	Normalized Difference Vegetation Index
NIR	Near Infrared

OLI TIRS	Operational Land Imager – Thermal Infrared Sensor
ORNL DAAC	Oak Ridge National Laboratory Distributed Active Archive Center
PA	Producer Accuracy
PCC	Post Classification Comparison
RGB	Red, Green and Blue
RMSE	Root Mean Square Error
ROC	Receiver Operating Characteristics
RS	Remote Sensing
SAVI	Soil Adjusted Vegetation Index
SOC	Soil Organic Carbon
SVI's	Spectral Vegetation Indices
SVM	Support Vector Machine
SWIR	Shortwave Infrared
TCMA	Twin City Metropolitan Area
TIR	Thermal Infrared
TM	Thematic Mapper
TOA	Top of Atmosphere
TSAVI	Transformed Soil Adjusted Vegetation Index
UA	User Accuracy
USGS	United States Geological Survey
UDUS	Usmanu Danfodiyo University
UTM	Universal Transverse Mercator
WGS	World Geodetic System
WRS	World reference System

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Urban areas are unique ecosystems that combine natural, man-made as well as socio-economic features and accommodate a large percentage of the global human population. Due to increasing human populations and the proportion of impervious surfaces in urban areas also, they have profound influence on terrestrial ecosystems. These include air and water pollution, rise in local temperatures popularly known as the urban heat island phenomenon, introduction of alien species and general modification of the landscape through land use or land cover changes among others.

Land cover changes are the most prominent features of urbanization, resulting to habitat fragmentation, degradation of ecosystem integrity, biodiversity loss and species extinction (Brown et al., 2018). Although land cover change is a natural phenomenon that has occurred throughout human history, the present trend is however unprecedented since the industrial revolution and today, only a few landscapes remain in their natural state (Sreenivasulu et al., 2014).

The impacts of urbanization and its resultant land cover changes on urban ecosystems have been widely discussed in the literature. Among other things, the phenomenon has led to the alteration of habitat structure and modification of the diversity and composition of urban vegetation. Urban expansion has also caused the displacement of some trees and forests and increased population density and associated human activities and infrastructure, which directly or indirectly affect urban trees and forests as well as their management.

Although they constitute less than 3% of the total land surface, urban areas also account for a large percentage of global energy consumption and CO_2 emission principally from the burning of fossil fuels through transportation, industrialization and domestic energy demands. On the other hand, urban areas are important global carbon sinks where considerable amounts of carbon are stored in the different pools (i.e. aboveground, belowground, soil and dead litter). It is however believed that the density and distribution of these carbon stocks are adversely affected by changes in urban land cover (Zhang et al., 2014). As urban lands are converted from one form to another, carbon is also transferred. This significantly distorts the regional and to some extent, global carbon balance and indirectly accelerate the process of global warming and climate change.

As the world population increasingly becomes urban and cities continuously expand, there is the growing awareness of the relevance of urban trees and forests, and the ecosystems services they provide which significantly affect the lives of the teeming urban populations. These include tangible services such as the provision of food materials, income, shade, habitat for insects and birds, wood fuel and medicines as well as intangible services such as soil erosion control, prevention of floods and diseases and water quality improvement as well as for recreation, aesthetics and spirituality purposes. The provision of these services however, depends on the type, composition and diversity of trees species, which vary between climatic regions and from one city to another.

One of the most important ecosystem services provided by trees in general is the storage and sequestration of atmospheric carbon. Trees accumulate woody biomass in their tissues as they grow over time and sequester CO_2 in both above-ground and below-ground biomass over one growing season (Martin et al., 2012; McPherson, 1998). Through the provision of shade and cooling effects also, trees moderate urban temperatures, thereby reducing the cost of energy use and generally mitigating the impacts of climate change in urban areas.

Nigeria is the most populous country in Africa, ranked 7th in the world and possibly the 3rd by 2050 (United Nations, 2017). Nigeria is also projected to experience the highest urbanization rates and probably, add about 189 million people to its present urban population by the year 2050. The proportion of urban land in the country will therefore continuously increase from approximately 464,192 hectares in 2000 to 2.3million hectares by the year 2030 (Bloch et al., 2015). This will also imply increasing demand for natural resources and their ecosystem services in urban and peri-urban areas.

Although information on urban trees and the ecosystems services they provide in urban areas especially in relation to climate change mitigation is increasing in recent literature, most research in this area was conducted in developed countries in Europe and Asia while not many studies have been documented in developing countries, especially in Africa. According to Nero (2017a), the contribution of many African cities to the regional and global carbon fluxes is considered insignificant and thus, rarely estimated.

1.2 Problem statement

Urbanization is a natural phenomenon that involves changes in the physical and functional components of the built environment and symbolizes increased urban populations, expansion of urban built-up areas and land cover changes. These changes have occurred over the past 500 years and are envisaged to continue to occur in the next century, with significant impacts on people, ecosystems and the amounts and distribution of atmospheric carbon.

Urban expansion is primarily associated with increased demand for shelter, food, fibre, water and fuel which seriously affect urban and peri-urban vegetation and limit the ecosystem services they provide. With urban expansion, many forested areas within and around urban centres are cleared for infrastructure development such as construction of housing estates by both the government and private agencies, and the construction of roads, hospitals, schools and shopping complexes to cater to the growing demands of the urban population. Old trees are often cleared as they may pose threats to adjacent buildings or properties. In some cases, trees and forests around urban areas are subsumed into urban landscapes thereby exposing them to a number of threats such as invasion by exotic species, human activity induced fires, pest and pathogen outbreaks, and unmanaged outdoor recreation activities (Chavez, 2005).

Sokoto metropolis is one of the most densely populated and fast-growing cities in Northern Nigeria, that is also experiencing serious land cover changes. The city is also located in the drier part of the country where total rainfall is low (350 mm to 670 mm), temperatures are high throughout the year (mean ranges between 27˚C and 36˚C) and vegetation is generally scanty. In this city therefore, urban trees face concerted pressure both from anthropogenic and natural sources, constraining their potentials to effectively provide important ecosystems services to the growing urban population. As a result, the impacts of further increases in temperature which may be brought about by climate change invariably exposes people and other biological organisms to more environmental stresses.

To the best of the author's knowledge, there is no established record of the type, density or distribution of tree species or their carbon storage potentials in Sokoto city and no carbon assessment has ever been undertaken. There is therefore no explicit data on the total carbon, its distribution, transformations and sequestration in the different carbon pools; there are no reliable estimates of future carbon storage or sequestration in this city and there are no reliable estimates of the monetary values of these crucial ecosystem services. Hence, the dynamics of urban trees and carbon stock in relation to land cover changes in this city are poorly understood. This impinges on effective climate change mitigation policies and creates major research gap.

1.3 Research objectives

The general objective of this research is to assess land cover change impacts on the density of trees and carbon stock in Sokoto metropolis, North-Western Nigeria. The specific objectives are:

1. to examine the rate and pattern of land cover changes in Sokoto metropolis from 1990 to 2015 and predict changes for 2030 and 2040;
2. to assess tree species composition, density and diversity in the metropolis;
3. to estimate the biomass and carbon stock of the tree species in the metropolis;
4. to examine the relationship between urban expansion and tree density in the metropolis; and
5. to predict the distribution and density of carbon in relation to land cover changes in the metropolis

1.4 Research questions

The research attempts to answer the following questions:

1. What is the rate and pattern of land cover change in the area from 1990 to 2040?
2. What is the composition, density and diversity of tree species in the area?
3. How is the biomass and carbon stocking potential of tree species in the area?
4. What is the relationship between urban expansion and tree density?
5. What is the future distribution and density of carbon in relation to land cover changes in the area?

1.5 Research hypotheses

H_o 1: There is no significant difference in tree density between the different land cover classes in the metropolis

H_o 2: There is no significant difference in the density and distribution of carbon stock between the different land cover classes in the metropolis

H_o 3: There is no significant effect of urban land cover change on tree density and carbon stock in the metropolis

1.6 Significance of the Study

Urban expansion is a natural, global phenomenon but one that varies over space and time. This phenomenon is accompanied by an increased demand for housing and other infrastructure such as roads, electricity, water supply, as well as educational, recreational and commercial facilities that need efficient planning. Knowledge of the pattern, rate and direction of urban expansion in Sokoto metropolis as provided by this study is essential for urban and socio-economic planning that involve the provision and distribution of the above infrastructure, thus helping achieve the much-desired urban sustainability.

Urban trees are an important component of the urban ecosystem which provide a number of benefits to urban inhabitants. Knowledge of the composition, diversity and structural characteristics of trees as well as the proportion of land covered by trees in urban areas is therefore crucial for understanding the type and extent of these services and how to maximize their provision to the wider urban public, thus improving environmental quality and human health in the city. This study provides a synthesis of the composition, abundance, vulnerability and carbon storage and sequestration potentials of trees in Sokoto metropolis. This knowledge is useful for urban tree selection, planting and management in the metropolis as well as for measuring and monitoring change over time, hence justifying the need for their documentation.

To mitigate impacts of climate change globally, especially in Sub-Saharan Africa where cities are more vulnerable, there is a need to reduce or at least, stabilise the quantity of carbon in the atmosphere through "substantial and sustained reductions of greenhouse gas emissions" (IPCC, 2013). This action implies documenting accurate inventories of national estimates of carbon storage and sequestration, which also include accounting for carbon losses and sequestration due to land cover changes. This study has not only provided adequate estimates and future prediction of the total carbon in the different pools but also the sequestration rate and monetary values of these important ecosystem services. It therefore provides the government and related agencies with sufficient data and a reference point on which future carbon estimates could be based for effective climate change mitigation strategies in the metropolis.

1.7 Scope of the study

This study focussed on assessing the dynamics of land cover changes and how they affect the density and distribution of trees (including shrubs) and total carbon in Sokoto metropolis between 1990 to 2015. The study also attempts a prediction of the total carbon in the metropolis for 2030 and 2040 using the Integrated Valuation of Environmental Services and Tradeoffs (InVEST) model. Total carbon is the summation of carbon in the aboveground, belowground, soils and dead litter. Only trees and shrubs that were ≥5cm diameter and ≥5m height were targeted for the aboveground and below ground carbon calculations. Smaller trees and other forms of urban vegetation such as vines and herbs were not included. The study was also restricted to the metropolitan area and its periphery and thus, other surrounding agricultural or forested areas were not covered.

The study was conducted within the framework of the urban filter. This is the traditional urban growth setting where urbanization and its associated land cover changes affect urban vegetation through habitat transformation, habitat fragmentation, environmental conditions and human preferences. Hence the interest of this study lies in the effects of these land cover changes on the urban trees and carbon storage and sequestration in the metropolis only. However, the drivers of such changes were not explored and other aspects of urban tree planning, management and challenges such as pests, diseases and environmental stresses were considered beyond the scope of this study. Finally, only the ecosystem services of carbon storage and sequestration were covered in this study. Other ecosystem services which may be provided in the metropolis were not addressed

1.8 Organization of the thesis

This thesis is organized in five chapters.

Chapter 2 is a review of related literature on the concepts, definitions and the broader view of urbanization, land cover changes, urban trees and carbon stock. The chapter discussed the different approaches to the assessment of land cover changes, urban trees and carbon stock in urban areas, including the use and application of Remote Sensing (RS). In this chapter also, the composition and diversity of urban trees and the ecosystems services they provide in urban areas were discussed. The chapter concluded by highlighting the scholarly efforts in carbon stocks modelling and prediction as well as the conceptual framework of urban filter adopted by the study.

Chapter 3 presents the general methodology adopted and materials used in the study. It described the study design and framework, the study area, the types and sources of data used and the procedure for data collection and analysis. This chapter also described the process of carbon modelling and prediction employed in the study using the Integrated Valuation of Environmental Services and Tradeoffs (InVEST) model.

In Chapter 4, results of the various analyses conducted in the study, land cover and carbon modelling and prediction were presented and discussed. These were also compared with other studies in Nigeria, Africa and other countries around the world in order to validate the findings.

Chapter 5 presented a summary of the major findings and conclusion of the study. It also highlighted the various policy implications of the study and made some recommendations for policy formulation and implementation and for further research.

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Murtala Dangulla joined the service of Usmanu Danfodiyo University Sokoto first as an administrative officer in 2005 and later as a graduate assistant in 2008. He obtained an M. Sc in Environmental management from Ahmadu Bello University, Zaria in 2013 and later enrolled into PhD in Environmental Quality and Conservation at the Universiti Putra, Malaysia in 2014.

LIST OF PUBLICATIONS

Dangulla Murtala, Latifah Abd Manaf, Mohammad Firuz Ramli, Mohd Rusli Yacob and Ahmad A. Makmom. Quantifying the Aboveground Biomass and Carbon Storage of Urban Trees Species in Sokoto Metropolis, North-western Nigeria (Accepted for publication), *Planning Malaysia Journal*, 2019

Dangulla Murtala, Latifah Abd Manaf, Mohammad Ramli and Mohd Rusli Yacob. Spatio-temporal analysis of urban expansion and land use/land cover dynamics (Accepted for Publication) *Journal of Engineering and Applied Sciences,* 2019

Dangulla Murtala, Latifah Abd Manaf, Mohammad Firuz Ramli and Mohd Rusli Yacob. Urban Tree Composition, Diversity and Structural Characteristics in North-western Nigeria. (under review), *Urban Forestry and Urban Greening*.

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