An Integrated Remote Sensing and Urban Growth Model Approach to Curb Slum Formation in Lagos Megacity

Dissertation

zur

Erlangung des Doktorgrades (Dr. rer. nat.)

der

Mathematisch-Naturwissenschaftlichen Fakultät

der

Rheinischen Friedrich-Wilhelms-Universität Bonn

vorgelegt von

Olabisi Sakirat Badmos

aus

Ibadan, Nigeria

Bonn, 2019

Angefertigt mit Genehmigung der Mathematisch-Naturwissenschaftlichen Fakultät der Rheinischen Friedrich-Wilhelms-Universität Bonn

1. Gutachter: Prof. Dr. Carsten Jürgens
2. Gutachter: Prof. Dr. Klaus Greve

Tag der Promotion: 19.03.2019

Erscheinungsjahr: 2019

Acknowledgment

The completion of this thesis was a collaborative effort of many people and institutions, though I may not be able to mention everyone here, I thank them all for their support. First and foremost I am grateful to my Creator, and to whom I owe my very existence

I am very grateful to the Deutscher Akademischer Austauschdienst (DAAD), under the Development-Related Postgraduate Courses, for providing the financial support throughout my doctoral program. I am grateful to the Center for Development Research (ZEF), Center for Remote Sensing of the Land Surface (ZFL), Research Group Remote Sensing (Geography department, University of Bonn) and Department of Geography (Ruhr-University Bochum) for their academic and moral support during my PhD program. I will also like to thank Planet Labs Germany for providing the RapidEye imagery utilized in this study free of charge under the RapidEye Science Archive (RESA). I also thank the staffs of Lagos State urban renewal agency, Lagos state ministry of Physical planning and urban development, Justice Empowerment initiative (JEI) and JAKIN for their assistance during the data collection in Lagos.

I am grateful to many individuals for their advice and guidance. I sincerely appreciate my Supervisors: Prof. Carsten Jürgens and Prof. Klaus Greve for their professional and constant support. I also thank my tutors: Dr Daniel Callo-Concha and Dr Andreas Rienow, they stood by me from research design to the implementation phase. I appreciate your advice and constructive criticisms and I thank you for sparing part of your tight schedule to provide technical and theoretical support. I am also grateful to Prof. Babatunde Agbola for his contribution and constructive criticism during the data collection in Nigeria. I will also like to thank Dr Taibat Lawanson and Dr Muyiwa Agunbiade for helping with the smooth running of my data collection, during my field work in Lagos. I will also like to specially thank my Brother Dr. Biola Badmos, for his moral and technical support throughout my academic pursuit. I am also grateful to Mr Iseoluwa Ademosun for his assistance, especially in the provision of some of the spatial data utilized in this study. I would like to offer special thanks to Late Prof. Gunter Menz, who, although no longer with us, contributed to the development of this thesis during the design phase. Special thanks to my field assistants (Emmanuel, Hammed, Bukola, Anthony, Bunmi, Olaitan, Rotimi and Bode).

I sincerely appreciate Prof. Christian Borgeimester, Ms. Sabine Aengenendt-Baer and the Doctoral program team at ZEF: Dr. Günter Manske, Ms. Maike Retat-Amin and the student assistants for their support. I acknowledge the statistical assistance of Dr. Guido Lüchters. I will also like to thank Dr. Olena Dubovyk, Dr. Irit Eguavoen, Dr. Valerie Graw, Dr. Fabian Santos and Gohar Ghazaryan, for their technical supports. I am sincerely grateful to Mr. Isaac Mbeche and Mr Taiwo Obisesan for their support. And to my colleagues at ZEF, NISIG and Mr George Adejuigbe and family, thanks for making my stay in Germany a memorable one. I am highly grateful to the editors and experts who gave insightful comments and suggestions during the review of the published articles and Ms. Margaret Jend for proof reading this thesis.

Finally, I thank my Parents (Mr. and Mrs. Badmos) for giving me a very good start and for their encouragement. I also thank Mrs. Bola and Mrs. Nike Badmos, Mr and Mrs Alase family, Bolaji Badmos and family, Biodun Badmos and family, Bimpe, Bayo Badmos and family, Bode, Banji, Bamidele, Bisola, Yetunde Badmos, Barister Tijani Ishola and family, Wale, Evelyn, Shakiru, Yasser, Powell, Oyewole, Agatha, David, Samson, Temmy, Peter, Segun, Ebere, Tope, Tunde and Ignatius. My special thanks to others not mentioned for their support.

"Slums could be thought of as the development of a special organ, or they could be thought of as a tumor that's grown, and in some ways is unhealthy and could ultimately lead to the city's destruction. My own feeling is that slums are probably a bit of both"

(Geoffrey West)

Table of Contents

Abstract

Rapid urbanization with limited development has led to slum proliferation in many sub-Saharan African cities. Slums are recognized as a menace to planned cities, as they do not conform to planning standards, thus the need to curb their growth. However, this proves to be a challenge for many of these cities due to unavailability of data on the existing situation. It is against this background that this study aims to contribute ground information and a spatial planning tool to support urban planning to better manage slum formation in Lagos, Nigeria.

Slum growth can be described as spatial or as population growth; hence this study first analyzed and quantified the spatial growth of slums in Lagos using remote sensing techniques and intensity analysis. Then the influence of residential choices of slum dwellers on population growth in Lagos slums was assessed using ethnographic survey approach through questionnaires and focus group discussions. An urban growth model coupling logistic regression with modified cellular automata SLEUTH was used to simulate scenarios of the patterns of slum development in Lagos by 2035.

RapidEye imagery from 2009 and 2015 was used to create maps for each time point for six land-use categories (water, vegetated area, open space, road, slum, and other urban) in the study area. Intensity analysis was applied to quantify the annual intensity of changes at the category and transition level. An overall accuracy (and kappa coefficient) of 94% (0.9) and 89% (0.86) was achieved for the 2009 and 2015 land-use and land-cover maps. The results of this study show that slums in Lagos increased spatially between 2009 and 2015 gaining a land area of 9.14 km^2 influenced by in-migration. However, the intensity analysis reveals slum as an active land-use category, losing some of its land area but also gaining new land area during this period. The annual gain and loss was 10.08% and 6.41%, respectively, compared to the uniform intensity of 3.15%. A systematic process of transition was observed between slums and other urban areas and open space in the interval studied, and this process was mainly influenced by the Lagos state government. The transition from slum to other land-use categories, such as other urban, is attributed to gentrification and demolition processes, while the transition from other land-use categories to slum is due to poor maintenance of existing buildings and encroachment on available spaces in the city.

Questionnaires administration and focus group discussion were conducted in four communities (Ajegunle, Iwaya, Itire and Ikorodu) in Lagos to investigate the factors influencing the residential choices and reasons of the people to remain in the Lagos slums. Descriptive statistics was used to analyze and describe the factors influencing the residential location choice, and logistic regression was applied to determine the extent to which the neighborhood and household attributes influence slum dwellers' decisions to remain in the slums. Over 70% of the respondents were migrants from neighboring geopolitical zones (in Nigeria). The movement patterns of slum dwellers in Lagos support two theories of human mobility in slums: slum as a sink and slum as a final destination. Also, the factors that attracted most of the slum dwellers to the slums (cheap housing, proximity to work, etc.) differ from those that made them stay (duration of stay, housing status, etc.).

A hybrid land-use model, which involves the coupling of logistic regression with cellular automata SLEUTH, implemented in XULU, was utilized for the simulation of scenarios of

slum growth in Lagos. The scenarios were designed based on the modification of the exclusion layer and the transition rules. The scenario 1 was business as usual with slum development similar to the present trend. The scenario 2 was based on the future population projection for the city, while the scenario 3 was based on limited interference by the government in slum development in the city. Distance to markets, shoreline, and local government administrative buildings, and land prices, etc., were predictors of slum development in Lagos. An overall accuracy of 79.17% and a relative operation characteristics (ROC) value of 0.85 were achieved for the prediction of slum development, based on the logistic regression model. The probability map generated from fitting the coefficients of the estimates in the logistic regression shows that slums can develop within the city and at the fringe, and also in places mostly inaccessible to the Lagos state government. Scenarios 1, 2 and 3 predict that the slum area will increase by 1.18 km^2, 4.02 km^2 and 1.28 km^2, respectively, in 2035 through further densification of the existing slums and new development at the south-eastern fringe of the city. The limited growth is due to the high population density in the city, and thus it is assumed that new slums will probably develop in the neighboring cities due to spill over of the Lagos population.

The outcome of this research shows that the landscape is very dynamic in Lagos, and even over an interval of a few years, changes can be observed. It also shows that the integration of remote sensing, social science method and spatially explicit land-use model can address the challenges of data availability in the slum dynamic, especially in sub-Saharan African countries with high slum proliferation. This can support a comprehensive set of techniques important for the management of existing slums and prevention of new slum development

Zusammenfassung

Reduzierung des Slumwachstums in der Megastadt Lagos: Ein integrierter Ansatz aus Fernerkundung und urbanem Wachstumsmodell

Eine schnelle Urbanisierung bei begrenzter Entwicklung hat in vielen afrikanischen Städten südlich der Sahara zu einer Zunahme von Slums geführt. Slums werden dabei als Bedrohung für die Planstädte angesehen, da sie nicht den Planungsstandards entsprechen, ihr Wachstum sollte daher reduziert werden. Dies erweist sich jedoch für viele dieser Länder als Herausforderung, da keine Daten über die aktuelle Situation vorliegen. Vor diesem Hintergrund zielt diese Studie darauf ab, Informationen und ein Raumplanungsinstrument zur Unterstützung der Stadtplanung zur Verfügung zu stellen, dies soll ein besseres Management der Slumbildung in Lagos, Nigeria ermöglichen.

Slumwachstum kann als räumliches Wachstum, oder als Wachstum der Bevölkerung bezeichnet werden; daher hat diese Studie zunächst das räumliche Wachstum von Slums in Lagos mit Hilfe von Fernerkundungstechniken und Intensitätsanalysen analysiert und quantifiziert. Anschließend wurde der Einfluss der Wohnortwahl von Slumbewohnern auf das Bevölkerungswachstum in den Slums von Lagos mit Hilfe eines ethnographischen Erhebung Ansatzes bewertet. Dabei kamen Fragebögen und Fokusgruppendiskussionen zum Einsatz. Ein urbanes Wachstumsmodell, das die logistische Regression mit dem modifizierten zellulären Automaten SLEUTH koppelt, wurde verwendet, um Szenarien und Strukturen der Slumentwicklung in Lagos bis 2035 zu simulieren.

RapidEye-Datenaus den Jahren 2009 und 2015 wurden verwendet, um Karten zu jeden Zeitpunkt für sechs Landnutzungskategorien (Wasser, Vegetationsflächen, Freiflächen, Straßen, Slum und andere städtische Gebiete) zu erstellen. Mit Hilfe der Intensitätsanalyse wurde die jährliche Intensität der Veränderungen hinsichtlich der Kategorien und Veränderungstypen quantifiziert. Für die Landnutzungs- und Bodenbedeckungskarten 2009 und 2015 wurde eine Gesamtgenauigkeit (und ein Kappa-Koeffizient) von 94 % (0,9) und 89 % (0,86) erreicht. Die Ergebnisse dieser Studie zeigen, dass die Slums in Lagos zwischen 2009 und 2015 räumlich gewachsen sind und durch Zuzug eine Landfläche von 9,14 km2 erreicht haben. Die Intensitätsanalyse zeigt auch, dass der Slums in Lagos als aktive Landnutzungskategorie einen Teil ihrer Fläche im Beobachtungszeitraum verloren haben. Der jährliche Gewinn und Verlust betrug 10,08 % bzw. 6,41 % im Vergleich zur einheitlichen Intensität von 3,15 %. Ebenfalls wurde ein systematischer Prozess des Übergangs zwischen Slums und anderen städtischen Gebieten sowie Freiraum in der untersuchten Zeitspanne beobachtet. Dieser Prozess wurde hauptsächlich von der Regierung von Lagos beeinflusst. Der Übergang von Slum zu anderen Landnutzungskategorien, wie zum Beispiel andere städtische Gebiete ist auf Gentrifizierung und Abrissprozesse zurückzuführen, während der Übergang von anderen Landnutzungskategorien hin zu Slums auf eine schlechte Instandhaltung bestehender Gebäude und auf die Beeinträchtigung der verfügbaren Flächen in der Stadt zurückzuführen ist.

In vier Gemeinden (Ajegunle, Iwaya, Itire and Ikorodu) in Lagos wurden Umfragen mit Fragebögen und Fokusgruppendiskussionen durchgeführt, um die Faktoren zu untersuchen, welche die Wahl des Wohnortes beeinflussen, und um zu untersuchen, warum die Menschen in den Slums von Lagos bleiben. Mit Hilfe der deskriptiven Statistik wurden die Faktoren analysiert und beschrieben, die die Wahl des Wohnortes beeinflussen, und mit

Hilfe der logistischen Regression wurde ermittelt, inwieweit die Nachbarschafts- und Haushaltsattribute die Entscheidung der Slumbewohner, in den Slums zu bleiben, beeinflussen. Über 70 % der Befragten waren Migranten aus benachbarten geopolitischen Zonen (Lagos). Die Bewegungsmuster der Slumbewohner in Lagos unterstützen zwei Theorien der menschlichen Mobilität in Slums: Der Slum als Senke oder Endziel. Auch die Faktoren, die die meisten Slumbewohner in die Slums lockten (günstiger Wohnraum, Nähe zum Arbeitsplatz usw.), unterscheiden sich von denen, die sie am Ende zum Bleiben brachten (Aufenthaltsdauer, Wohnstatus usw.).

Ein hybrides Landnutzungsmodell, das eine Kopplung der logistischen Regression mit den zellulären Automaten SLEUTH in XULU verbindet, wurde für die Simulation von Szenarien des Slumwachstums in Lagos bis zum Jahr 2035 verwendet. Die Szenarien wurden mittels der Ausschlussflächen und Wachstumskoeffizienten implementiert. Das Szenario 1 „business as usual“ simulierte eine Slumentwicklung ähnlich dem aktuellen Trend. Das Szenario 2 basierte auf der generellen Bevölkerungsprognose für die Stadt, während das Szenario 3 eine begrenzte Einmischung der Regierung auf die Slumentwicklung in der Stadt einbezieht. Die Entfernung zu Märkten, Verwaltungseinrichtungen, Küsten sowie die Grundstückspreisen usw. waren Antriebskräfte für die Entwicklung der Slums in Lagos. Für die Vorhersage der Slum-Entwicklung auf Basis des logistischen Regressionsmodells wurden eine Gesamtgenauigkeit von 79,17 % und einem Receiver-Operating-Characteristic-Wert (ROC) von 0,85 erreicht. Die Wahrscheinlichkeitskarte, die durch die Anpassung der Koeffizienten und der Schätzungen in der logistischen Regression erzeugt wurde, zeigt, dass sich Slums innerhalb der Stadt und in der Peripherie entwickeln können, aber auch an Orten, die dem Einfluss der Landesregierung von Lagos weitgehend entzogen sind. Szenarien 1, 2 und 3 prognostizieren, dass das Slumgebiet bis 2035 durch weitere Verdichtung der bestehenden Slums und Neuentwicklung am südöstlichen Stadtrand um 1,18 km^2, 4,02 km^2 bzw. 1,28 km^2 zunehmen wird. Das relativ begrenzte Wachstum ist auf die hohe Bevölkerungsdichte in der Stadt zurückzuführen, so dass davon ausgegangen wird, dass sich in den Nachbarstädten durch das Verlagern der Lagos-Bevölkerung neue Slums entwickeln werden

Das Ergebnis dieser Disertation zeigt, dass die Stadtlandschaft in Lagos sehr dynamisch ist, Veränderungen können selbst über einen Zeitraum von nur wenigen Jahren beobachtet werden. Die Ergebnisse zeigen auch, dass eine Integration von Fernerkundung, sozialwissenschaftlicher Methoden und räumlich explizites Landnutzungsmodells das Problem der geringen Datenverfügbarkeit in dynamischen Slums lösen kann. Dies ist besonders hilfreich in afrikanischen Ländern südlich der Sahara mit hoher Slumproliferation. Umfassende Techniken des Slum-Managements, insbesondere zur Verhinderung der Entstehung von neuen Slums, können so wirksam unterstützt werden.

List of Figures

List of Tables

Acronyms and Abbreviations

ABM	Agent based modeling
CA	Cellular automata
EA	Enumeration area
ERA	European reservation areas
GIF	Graphics interchange format
GIS	Geographic information system
GLCM	Grey level co-occurrence matrix
GRA	Government reserved areas
LEDB	Lagos executive development board
LGA	Local government area
LMDGP	Lagos metropolitan development and governance project
LRM	Logistic regression model
LULCC	Land use and Land cover change
NDVI	Normalized difference vegetation index
OBIA	Object based image analysis
SLEUTH	Slope, land-use, exclusion, transportation hill-shade
UGM	Urban growth model
UGMr	Urban growth model reduced
UN	United Nation
UNCHS	United Nations Centre for Human Settlements
XULU	eXtendable unified land use modeling platform

1 GENERAL INTRODUCTION

1.1 Emergence of Slums in Lagos

The genesis of slum development and clearance in Lagos can be traced back to the colonial era in Nigeria. The popularity of Lagos grew as a leading commercial center in the 19th century, which attracted migrants from the Yoruba hinterlands, Europeans (including missionaries) and descendants of West African slaves, mainly of Yoruba origin from Sierra Leone, Brazil and Cuba (Echeruo, 1977 in Olukoju, 2008). Due to the diverse nature of the population in the city, the Planning Ordinance of 1902 was promulgated, which mandated the Governor to establish European Reservation Areas (ERA), as residential neighborhoods for the Europeans. Each ERA had its own local board of health with the responsibility for improving the reservation areas. However, the residential quarters of the indigenous African people were left unregulated, leading to the creation of the earliest slums on Lagos Island (Obalende and Isale-Eko slums) (Nsorfon, 2015).

Afterwards, the Township Ordinance No. 29 of 1917 was promulgated with a mandate to provide infrastructure, public utilities, health, and environmental sanitation, yet there was no appreciable improvement in the indigenous residential areas (Oduwaye, 2009). This indifferent attitude of the colonial government with respect to these areas (also known as native towns) and the high population density led to the two dreadful plagues in Lagos, i.e. the post-World War 1 influenza epidemic and the bubonic plague between 1924 and 1930. These epidemics led to the enactment of the Planning Ordinance of 1928 and the creation of the Lagos Executive Development Board (LEDB). The LEDB mandates include extensive slum clearance, relocation of families from Lagos Island to Lagos mainland, health and sanitation checks, etc. (Ajibade & McBean, 2014). After the clearance of Lagos Island, the LEDB mainly focused on providing residential units for the British government officials and African staff in the colonial administration rather than the evictees of the slum clearance (Nwaka, 2005). This led to movement of evictees to Lagos mainland where development continued without any proper city planning (Bigon, 2008). This trend continued in Lagos until 1960 when Nigeria gained independence, where slums were cleared without adequate resettlement plans.

After Nigeria's independence in 1960, Lagos continued to experience high population growth because of its political and economic status (Immerwahr, 2007). People of different socioeconomic status (upper, middle and lower class) migrated to Lagos for better opportunities. The upper-class citizens and government officials moved to the former ERAs, and to house these prominent groups, new housing schemes were developed in the late 1960s and 1970s in the form of new Government Reserved Areas (GRA) (Olotuah & Bobadoye, 2009). While this was going on, the low-income/poor migrants were also squatting on the available land within the mainland leading to the emergence and growth of communities such as Ajegunle, Badia, Amukoko, etc., popularly called the squatter communities in Lagos (SNC-Lavalin, 1995). While the squatter settlements were growing, villages within and around Lagos were also experiencing growth due to influx of migrants, which caused uncoordinated expansion of these villages. These unplanned villages were absorbed as the city grew (Pugalis, Giddings, & Anyigor, 2014) and were referred to as slum communities. The squatter and slum communities were categorized as [1]blighted communities in the master plan developed for Lagos in 1984 (Lagos-State/UNCHS, 1984) (Figure 1.1).

Actions of the colonialists before independence and the subsequent governments led to the development of Lagos as a bilateral city, where the planned and unplanned sections of the city developed concurrently. Most of the unplanned settlements, which later turned into slum/squatter communities, were located in the oldest settlement area of the mainland, which is close to the lagoon and Lagos Island (central business district of Lagos) (World Bank, 2006). Moreover, government attention to most of these unplanned settlements was minimal, which led to their encroachment on water bodies and other vacant land nearby, thereby increasing the area to accommodate the growing population of Lagos.

The earliest ERAs (Victoria Island, Ikoyi, etc.) created during the colonial era continues to be the elite neighborhood in Lagos, while some of the native towns still exhibit slum characteristics. At present, the Lagos state government tends to put squatter communities under the umbrella of slums, and mostly utilizes the same upgrading approach through provision of infrastructural facilities, as observed in the Lagos Metropolitan Development and Governance Project (LMDGP) carried out in 2006. Hence, this study

[1] Blighted communities includes slums, squatters in Lagos

considers squatters as part of the slum communities, and the terms are used interchangeably throughout the thesis.

1.2 Problem statement

The population growth rate of sub-Saharan African countries from 1995-2015 was 3.95% compared to the 0.68% of developed countries (United Nations, Department of Economic and Social Affairs, 2015). This poses a challenge for many sub-Saharan African countries, as the urban growth experienced is associated with limited or no development, causing emergence of slums in the cities (Davis, 2004; Bobadoye & Fakere, 2013). And these slums, where 61.7% of the urban dwellers lives, have continue to be the dominant residential land-use types in these countries (UN-Habitat, 2013a; Simon, Adegoke, & Adewale, 2013; Peter Hofmann, Taubenbock, & Werthmann, 2015), leading to a major concern for urban planning.

Slums gained more popularity after the launching of “cities without slums” in 1999 (Gilbert, 2007). While it is difficult to reach an agreement on how to define slums, due to their uniqueness in different region, yet they have similar characteristics such as overcrowded, poor housing quality, inadequate infrastructural facilities and degraded environment (UN-Habitat, 2003; Dung-Gwom, 2007; Nsorfon, 2015; Pratomo, Kuffer, Martinez, & Kohli, 2017: cf. ch. 2.2). Although the proportion of the urban population living in slums has reduced, the absolute number of slum dwellers have increased and this number is expected to rise in the near future, especially in the global south (United Nations, 2015; UN-Habitat, 2016), where slum provides low cost housing for the urban poor (Augustijn-Beckers, Flacke, & Retsios, 2011). This implies that slums will continue to exist if no adequate measures are put in place.

Most policies on slum management have been more experimental rather than incremental in many sub-Saharan African countries. An incremental policy utilizes the past trend to develop the best alternative, while an experimental policy is implemented without any prior research(Roy, Lees, Palavalli, Pfeffer, & Sloot, 2014). The development from laissez-faire in the 1950s to forced eviction and slum clearance in the 1970s to slum upgrading and resettlement in the 1980s to the security of tenure and enabling approach in 1990s, and slum-free cities in the 2000s have all been found to be ineffective (Mehta, Dastur, & Janus, 2008; Arimah, 2010; Roy et al., 2014). These policies have not been able to slow down the in-formalization process, because they focus on slum manifestation rather than on the root causes (UN-Habitat, 2003; Sietchiping & Yoon, 2010). Consistently, many studies on slums (especially in sub-Saharan Africa) focus on the impact of existing slums on slum dwellers, physical environment, infrastructural facilities, health, etc., and on how to manage these effects (Pugh, 2000; Robertson, 2009; Omole, 2010; Bobadoye & Fakere, 2013). Most slum management programs/studies have thus been reactive rather than proactive.

Should the status quo be maintained, Lagos, a megacity of slums in Nigeria (IRIN, 2006), might possibly not meet the goals of the United Nations Sustainable Development Summit (2015) calling for cities to be free of slums by 2030. Presently, about 70% of its population resides in slums, and this number might likely increase with the future population growth projected for the city, as slum growth is on a par with urban growth in Nigerian cities (UN-Habitat, 2003; World Bank, 2006; Marx, Stoker, & Suri, 2013; World Population Review, 2015). While the laissez-faire attitude of the Lagos state government, in the past, have led to emergence of new slums (Morka, 2007), the neoliberal approach adopted to governance, since 1999, towards the regeneration of the city to become a befitting megacity, through increasing slum clearances (e.g. Ilubiri, Otodo-Gbame), relocation of slum dwellers (e.g. Adeniji-Adele) and limited slum upgrading (e.g. Lagos Metropolitan Development and Governance Project), have not yielded much positive result either (Badmos, Rienow, Callo-Concha, Greve, & Jürgens, 2018), as what is observed is slum displacement rather than slum reduction (Agbola & Jinadu, 1997). Hence, there is need for new approach to manage slum growth in Lagos.

Although, proactive slum management strategy is significantly less costly and easy to implement than reactive (Mehta et al., 2008), it continues to be a challenge for many sub-Saharan African cities, because of limited or no information on slum development and its drivers (Abbot& Douglas, 2003 in Sietchiping, 2005; Patel & Baptist, 2012; UN-Habitat, 2015). For instance, the last known official gazette enumerating slums in Lagos was in 1984 (Lagos-State/UNCHS, 1984: Figure 1.1), and the observed enormous changes in Lagos, with respect to population and area changes (Filani, 2012), has therefore made this document less relevant for any major slum development initiative. While integrating remote sensing and social science could solve this problem, it is challenging as it requires fusion of different dataset (social and spatial) with scientific traditions, which also requires interdisciplinary approach (Rindfuss & Stern, 1998). In addition, based on the complexity of slums, adopting other studies (e.g. Busgeeth, van den Bergh, Whisken, & Brits, 2008; Dubovyk, Sliuzas, & Flacke, 2011; Stoler et al., 2012; Patel, Crooks, & Koizumi, 2018: cf. Ch 2.4-2.9) without assessing the existing situation will definitely fail, as slums tend to manifest differently between cities and even within cities (Sliuzas, Mboup, & de Sherbinin, 2008).

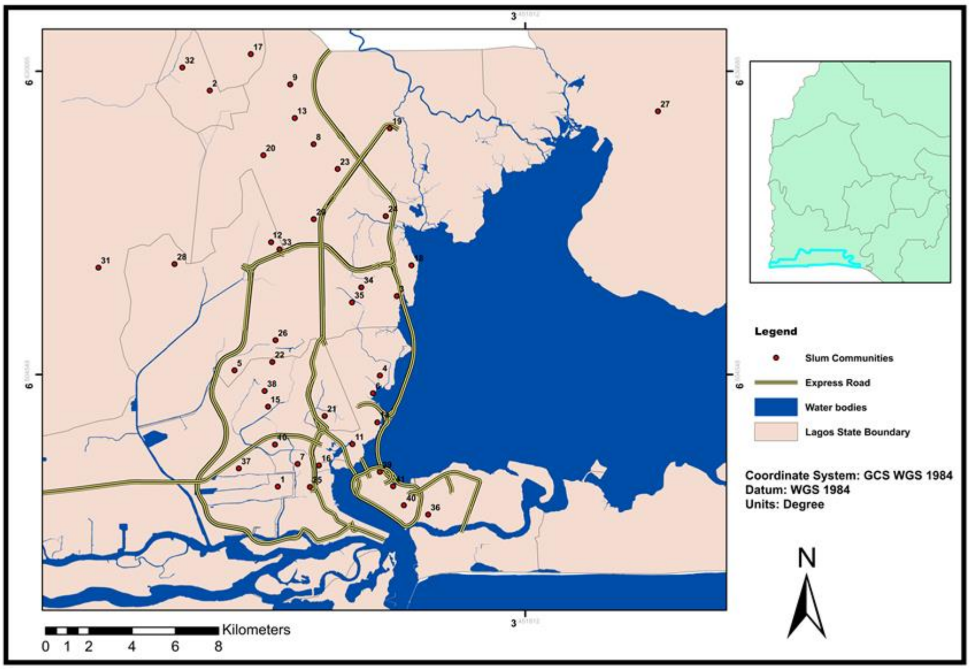


Figure 1.1: Location of slum communities in Lagos in 1984
Adapted from SNC-Lavalin, 1995

1.3 General description of the Study Area

1.3.1 Geographical /Biophysical Characteristics of Lagos

This study was carried out in the city of Lagos[2] (Figure 1.2) located in south-western Nigeria between longitude 2°42'E and 3°42'E and latitude 6°22'N and 6°52'N. The city is low lying with elevations ranging from 37m below sea level to 73m above sea level. It is bordered in the west by the Republic of Benin, in the north and east by Ogun state and stretches over 180km along the Guinea coast of the Bight of Benin on the Atlantic Ocean.

[2] Lagos city, otherwise known as Lagos metropolitan, is located in Lagos state

The city of Lagos was initially within the present-day seven local governments[3], but due to rapid urbanization expanded outwards to the mainland, which has led to the loose classification of the city into mainland and island. The region covers approximately 1.171.28km^2, which is 33% of Lagos state land mass, and harbors more than 80% of the Lagos state population (Oduwaye & Lawanson, 2007).

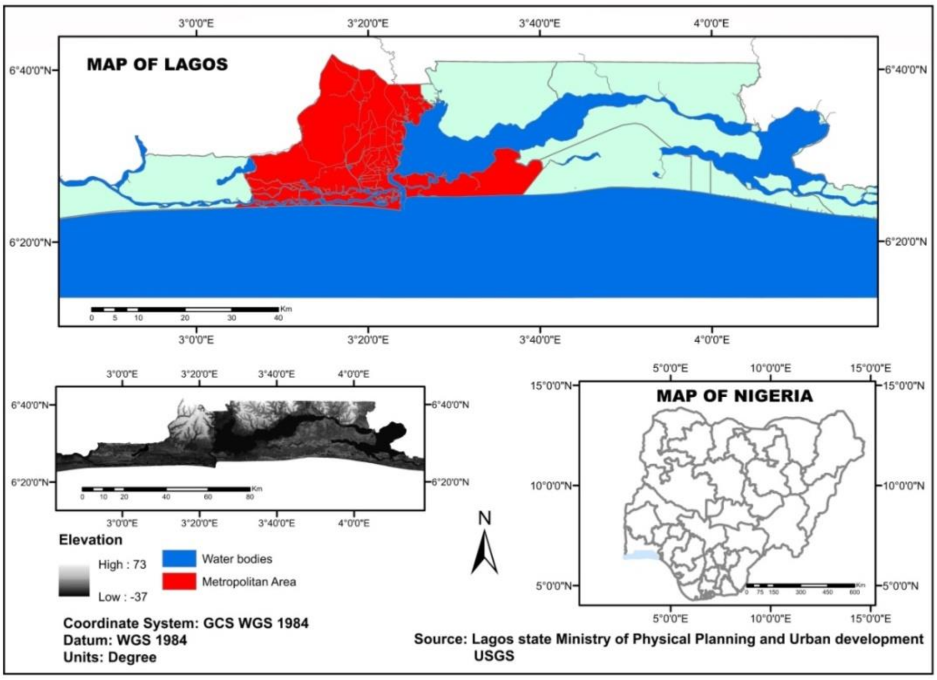


Figure 1.2: Map of Lagos State in Nigeria

1.3.2 Climate

The city experiences a tropical savannah climate with a distinct precipitation difference between the dry and wet season. The dry season is from November to March while the wet season is from April to October. During the rainy season peak period, the city experiences floods, which are aggravated by the poor surface drainage systems of the coastal lowlands (Braimoh & Onishi, 2007).Temperatures range from 28°C to 32°C due to the city's location near the equator with a high humidity level throughout the year (Figure 1.3).

[3] Ajeromi-Ifelodun, Amuwo-Odofin, Apapa, Eti-Osa, Lagos Island, Lagos Mainland and Surulere

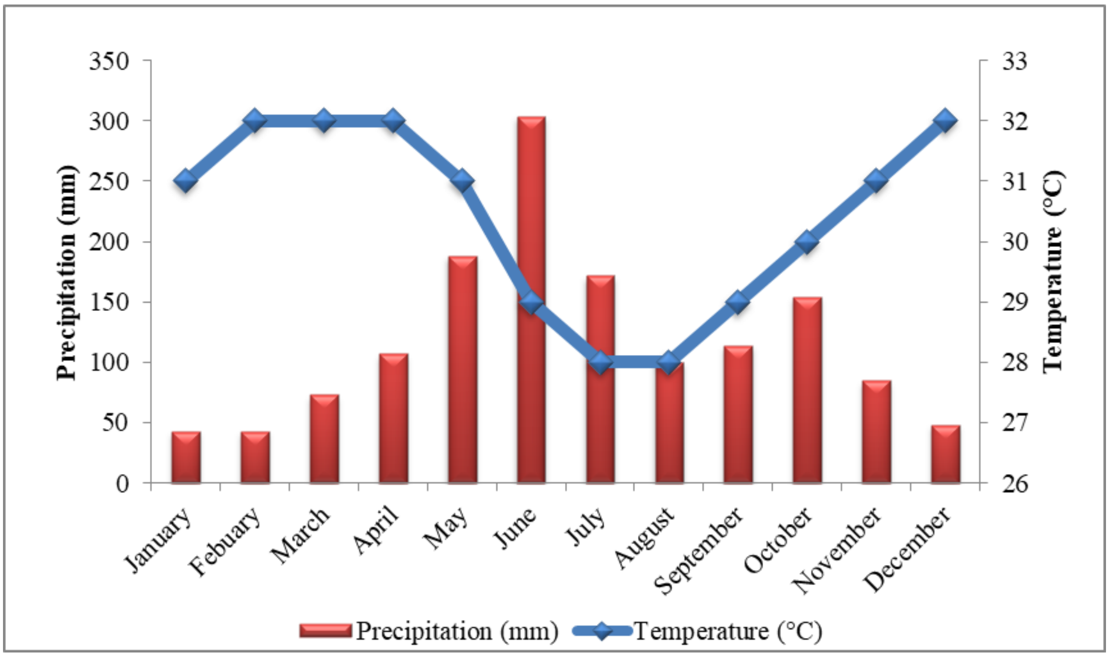


Figure 1.3: Lagos average monthly rainfall and temperatures (1941-2018)
Source: http://hikersbay.com/climate/nigeria/lagos

1.3.3 Lagos Demography, Economy and Administration

Lagos grew from a fishing village to become one of the fastest growing cities in the world (Filani, 2012). The population grew from 25,000 in 1866 to 665,000 in 1963. By 1995, it had reached 10 million, and the city gained the UN definition of a megacity (Abiodun, 1997; Ilesanmi, 2010). Lagos Bureau of Statistics (2013) projected the population of Lagos metropolitan area as 21,324,114 in 2015 (Figure 1.4). The population growth rate is about 600,000 persons per annum, while the average density is over 20,000 persons per square kilometer in the built-up area (Okwuashi & Beulah, 2012). There are two thousand six hundred communities in the city (Obono, 2007). The city is the most urbanized in Nigeria, with the smallest land mass (Ayeni, 1979 in Oduwaye, 2009). Although the city is dominated by the Yorubas, due to in-migration from other parts of Nigeria and neighboring countries, other ethnic groups such as Hausa, Igbo, Fulani, Togolese, and Chinese, etc., and also people of different socioeconomic status live in the city. Victoria Island, Magodo, and Lekki, etc., are examples of high-income residential areas, while Ajegunle, Badia, etc., are examples of low-income residential areas in the city.

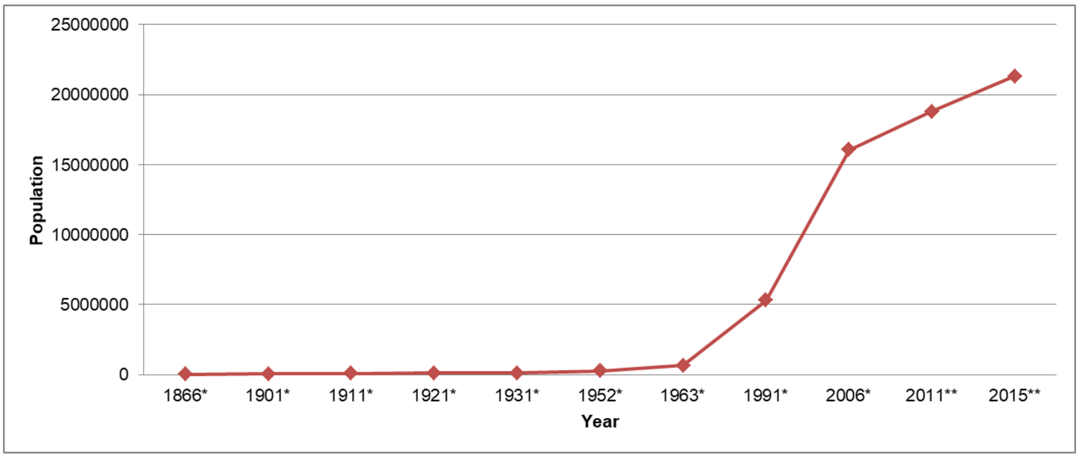


Figure 1.4: Population growth in Lagos Metropolitan, Nigeria
** census data, **population projection*
Source: Abiodun (1997); Lagos Bureau of Statistics (2013)

Lagos became the federal capital of Nigeria after independence in 1960. The Nigeria federation was restructured into 12 states in 1967, which led to the creation of Lagos state. During this period, the state and federal capital was located in Lagos State. Lagos ceased to be Nigeria's political capital when the federal seat of Nigeria's government was moved to Abuja in 1991. Prior to 2002, the Lagos state comprised of twenty local government areas (LGA), however sixteen of these were categorized as part of the Lagos metropolitan area, to create an urban agglomeration (Figure 1.2: Table 1.2). But, each LGA has a separate local administration, hence the Lagos metropolitan area is a statistical division and not an administrative unit (Nsorfon, 2015).

Table 1.2: Local governments in Lagos state

	Local Government	**Land Area (km²)**	
1	Agege	17.00	LAGOS METROPOLITAN AREA
2	Ajeromi Ifelodun	13.90	
3	Alimosho	137.80	
4	Amuwo Odofin	179.10	
5	Apapa	38.50	
6	Eti-Osa	299.10	
7	Ifako/Ijaye	43	
8	Ikeja	49.93	
9	Kosofe	84.40	
10	Lagos-Island	9.26	
11	Lagos Mainland	19.62	
12	Mushin	14.05	
13	Ojo	182.00	
14	Oshodi/Isolo	41.98	
15	Shomolu	14.60	
16	Surulere	27.06	
17	Badagry	443.00	PERI-URBAN
18	Epe	965.00	
19	Ibeju-Lekki	653.00	
20	Ikorodu	345.00	

Source: Lagos Bureau of Statistics (2013)

Economy

Lagos is the major commercial, financial and industrial focal point in Nigeria. The activities are carried out in both the informal and formal sector. The city's budget in 2017 was approximately US$ 2 billion (Lagos state Government, 2016). Its location on the west coast of Africa promoted the development of trade in its hinterland and with neighboring and other countries. Even during the colonial era, it was a major slave trade center (Okwuashi & Beulah, 2012). The city harbors more than 60% of the industrial and commercial activities of Nigeria and also one of the largest sea ports in Africa, accounting for up to 70% of the Nigerian manufacturing value added (Braimoh & Onishi, 2007). Furthermore, trading activities in the city are predominantly in the informal sector. The economic meltdown in the country has led to the decline of the formal sector and the flourishing of the informal sector (Nsorfon, 2015).

1.4 Objectives

The main goal of this thesis is to contribute ground information and a spatial planning tool that can support urban planning to better manage slum formation in Lagos, Nigeria. It is the first study in Nigeria, where remote sensing techniques, social science method and spatially explicit land-use models were integrated to study slum dynamics. Hence, this study substantially contributes to body of knowledge on slums in data starved emerging economy. The specific objectives and corresponding questions are:

1 To link pattern and process of slum growth in Lagos using remote sensed data and intensity analysis
   - How can slum be delineated from other urban land-use types in Lagos?
   - How did slums in Lagos develop?
   - How can we quantify the observed pattern of changes observed?
   - What are the underlying processes leading to the observed changes?

2 To assess the importance of residents' decisions on slum population growth in Lagos using ethnography
   - What is the movement pattern of slum dwellers in Lagos?
   - What are the factors influencing the residential location choices of slum dwellers in Lagos?
   - What are the factors influencing people's intention to stay in the slums?

3 To simulate scenarios of slum growth in Lagos using an urban cellular automata
   - What factors determine slum development in Lagos?
   - How can you spatialize non-spatial processes and include them into urban land use change models?
   - How can the spatial patterns and rates of slum growth be predicted with an urban land use change model?
   - How is the future growth pattern of slums in Lagos based on the simulation of different scenarios?

Slum growth can be described as spatial or as population growth. Objective 1 and 2 of this thesis focused on the spatial and population growth, respectively, in Lagos. The objective 1 linked the pattern and process of slum growth in Lagos by building on slum ontology (Kohli, Sliuzas, Kerle, & Stein, 2012) and object based image analysis, integrating rule sets (Mhangara, Odindi, Kleyn, & Remas, 2011; Shekhar, 2012a; Sori, 2012; Kohli, Warwadekar, Kerle, Sliuzas, & Stein, 2013), with expert knowledge, to delineate slums from other land-use types in Lagos, and then link the pattern and process of its growth using intensity analysis (Aldwaik & Pontius, 2012). The main data is the RapidEye images (2009 and 2015) which covers the oldest section of the Lagos metropolis where most of the slums in Lagos are located (World Bank, 2006).

While remote sensing focus on “where”, social sciences aims to answer “why” (Turner, 1998), which motivated the objective 2 of this thesis where ethnography survey, were used to investigate how residential decisions of slum dwellers affects the population growth in slums. While the few studies on slum dwellers residential location choices focus on the pull and stay factors, independently (Limbumba, 2010; Mudege & Zulu, 2011; Ige & Nekhwevha, 2014), objective 2 considers the two factors together and how they can influenced the population growth in Lagos slums and also proceeded further by investigating the mobility pattern of slum dwellers in Lagos. Questionnaires administration and focus group discussion were conducted in four slum communities in Lagos (Ajegunle, Iwaya, Itire and Ikorodu). The quantitative data, from the questionnaire, were analyzed using descriptive statistics and logistic regression, while the qualitative data, from the focus group discussion, were analyzed using content analysis.

Though the objective 1 and 2 focuses on the past and present situation, the objective 3 simulates future scenarios of slum development in Lagos, through the coupling of logistic regression model with modified cellular automata-based model. The logistic regression was used to compile and integrate the drivers of slum development in Lagos in the cellular automata-based SLEUTH. A modified version of CLARKE’S Urban Growth Model better known as SLEUTH (Clarke, Hoppen, & Gaydos, 1997), functions as the cellular automata component of the model. Although this type of model have been applied in urban growth models studies (e.g., Jokar Arsanjani, Helbich, Kainz, & Darvishi Boloorani, 2013; Rienow & Goetzke, 2015), however this is the first time it will be apply to model slum growth in any city. The modified SLEUTH, also known has Urban Growth Model reduced (Rienow & Goetzke, 2015), applied in this study was reprogrammed by Goetzke (2011) and implemented into XULU, a java-based modeling platform (eXtendable Unified Land Use Modeling Platform), developed at the University of Bonn (Schmitz, Bode, Thamm, & Cremers, 2007). Three scenarios: i) business as usual, based on the present trend, ii) excessive population growth, based on the forecasted population growth, and iii) limited government interference were simulated for slum growth in Lagos by 2035.

1.5 Thesis Structure

This is a cumulative thesis so chapters 1, 2 and 6 introduces this study, relevant literature on this study and conclusion, respectively, while chapters 3, 4 and 5 are standalone chapters with introduction/rationale, methodology, results/discussion and conclusions. These three chapters (3, 4 and 5) focus on each of the specific objectives (compare Figure 1.5). There were some repetitions in these chapters: introduction/rationale and study area description. A brief description of each chapter is given below:

Chapter 1 gives the rationale for this study, general description of the study area, genesis of slum settlements and clearance in Lagos, as well as the aim and specific objectives of the study.

Chapter 2 presents relevant literature on slum dynamics and application of remote sensing to slum growth. The type of urbanization experienced in African and how it causes slum growth is discussed. The concept of slums is also discussed, and slum management is categorized into adaptive and proactive, and it is shown how the two approaches intertwine. Different drivers of slum growth are reviewed with emphasis on locational drivers, and these drivers are categorized into institutional, socioeconomic and biophysical drivers. Different methods of mapping slums and studies on temporal patterns of slums are reviewed. Furthermore, the potential of intensity analysis as a technique to examine land-use and land-cover change is discussed. The chapter concludes by discussing the application of remote sensing and land-use change models to investigate slum dynamics.

Chapter 3 discusses the first objective of this study, i.e. to link the pattern and process of slum growth in Lagos. The study was conducted in six local government areas (Apapa, Ajeromi-Ifelodun, Amuwo-odofin, Surulere, Lagos Island, and Lagos Mainland) of Lagos metropolis, constituting a section of the older part of the city. RapidEye images from 2009 and 2015, obtained under the RapidEye science archive, were used to create maps for each time point for six land-use categories (water, vegetated area, open space, road, slum, and other urban) using an object-based image analysis building on generic slum ontology, while intensity analysis was applied to quantify the annual intensity of changes at the category and transition level. Furthermore, the process leading to the observed pattern of growth was investigated. This chapter was published in the Journal of Remote Sensing (MDPI), a peer reviewed journal about the science and application of remote sensing technology as: **Badmos, O., Rienow, A., Callo-Concha, D., Greve, K., & Jürgens, C. (2018). Urban Development in West Africa—Monitoring and Intensity Analysis of Slum Growth in Lagos: Linking Pattern and Process. *Remote Sensing*, 10(7), 1044.**

Chapter 4 discusses the second objective of this study, which assesses the influence of residential choices of slum dwellers on the population growth of slums in Lagos. Data was collected through the mixed method approach, which combines quantitative (questionnaire administration) with qualitative (focus group discussions) data, in four slum communities (Ajegunle, Iwaye, Itire and Ikorodu) in Lagos. The sample size was calculated using small sample techniques and the buildings sampled in each slum community was randomly selected using spatial random sampling technique (fishnet tool in ArcGis). The data collected during the survey included the socioeconomic characteristics, settlement history, reasons for choice of location of respondents, and the physical characteristics of the building/neighborhood. During the focus group discussion, various issues relating to the slum dwellers' choice of residential location were discussed. Descriptive statistics was used to analyze and describe movement patterns of slum dwellers in Lagos and the factors influencing residential location choices, while logistic regression was utilized to determine the extent to which the neighborhood and household attributes influence slum dwellers decisions to remain in the slums. The slum index was calculated based on the physical characteristic of the slum environment and its impact on slum dwellers' decision to improve their environment. This chapter has been submitted for publication in CITIES, a peer reviewed international journal of urban policy and planning as: **Badmos, O., Callo-Concha, D., Agbola, B., Rienow, A., Badmos, B., Greve, K., & Jürgens, C., Determinants of Residential Location Choices by Slum Dwellers in Lagos Megacity *(Under Review)***

Chapter 5 discusses the third objective of this study, which explores the coupling of logistic regression with cellular automata SLEUTH, to simulate scenarios of future growth pattern of slums in Lagos. The driving forces of slum development in Lagos were analyzed and the correlated spatial drivers compiled to build a probability map of slum development in Lagos, using the logistic regression model. The probability map was combined with the exclusion layer of the modified SLEUTH (in XULU) to simulate scenarios of slum growth in Lagos until 2035. Three scenarios were designed based on the modification of the exclusion layer and the transition rules. The scenario 1, business-as-usual, is based on slum development similar to the present trend. The scenario 2, excessive growth, is based on the future population projection for the city, while the scenario 3 is based on limited interference by the government in slum development in the city. This chapter has been submitted for publication in Computers, Environment and Urban Systems, a peer reviewed journal that focus on computer-based analysis to understand the urban system better, as: **Badmos, O., Rienow, A., Callo-Concha, D., Greve, K., & Jürgens, C. Exploring coupling of logistic regression with SLEUTH to simulate slum growth in Lagos *(Under review).***

Chapter 6 gives the summary, conclusions and outlooks for further research in the field of integrating spatial and social sciences to study slum dynamics.

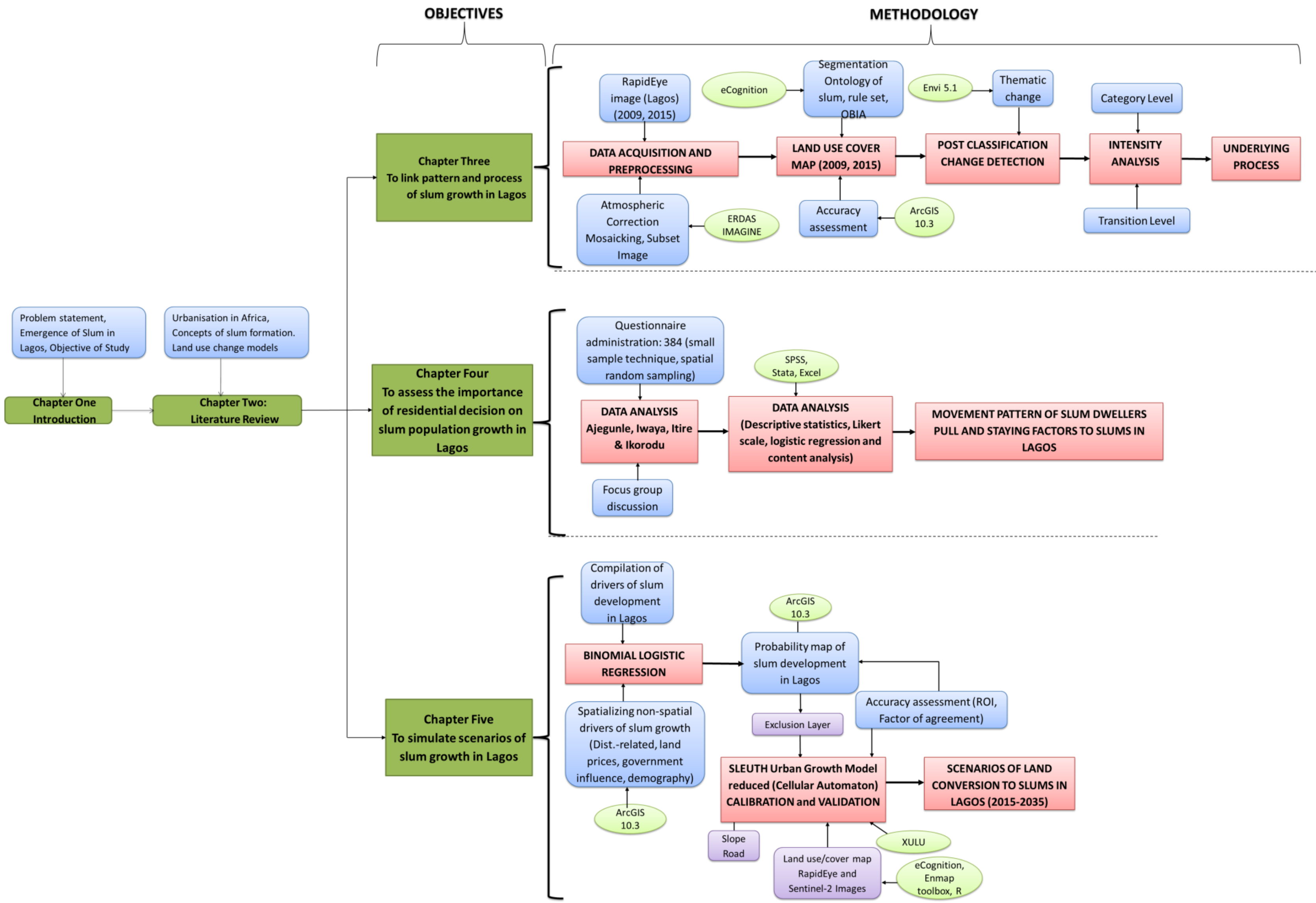


Figure 1.5: Thesis structure

2. LITERATURE REVIEW

2.1 Urbanization in Africa

According to the United Nations, more than 50% of the projected global population growth between 2017 and 2050 is expected to take place in Africa. Out of the 2.2 billion people projected to be added globally, 1.3 billion will be added in Africa, making Africa the highest contributor to the future population growth (United Nations Department of Economic and Social Affairs Population Division, 2017: Figure 2.1). Most of this population growth will be in urban areas of African countries (Cohen, 2006; United Nations Population Division, 2011 in Linard, Tatem, & Gilbert, 2013). Although the world population is expected to continue to grow until the end of the 21st century, however the rate at which the growth will occur is expected to decline (Figure 2.1 and 2.2). Presently, Africa has the highest growth rate of about 2.6 % compared to other major areas in the world, which is expected to continue in the future (United Nations Department of Economic and Social Affairs Population Division, 2017: Figure 2.1).

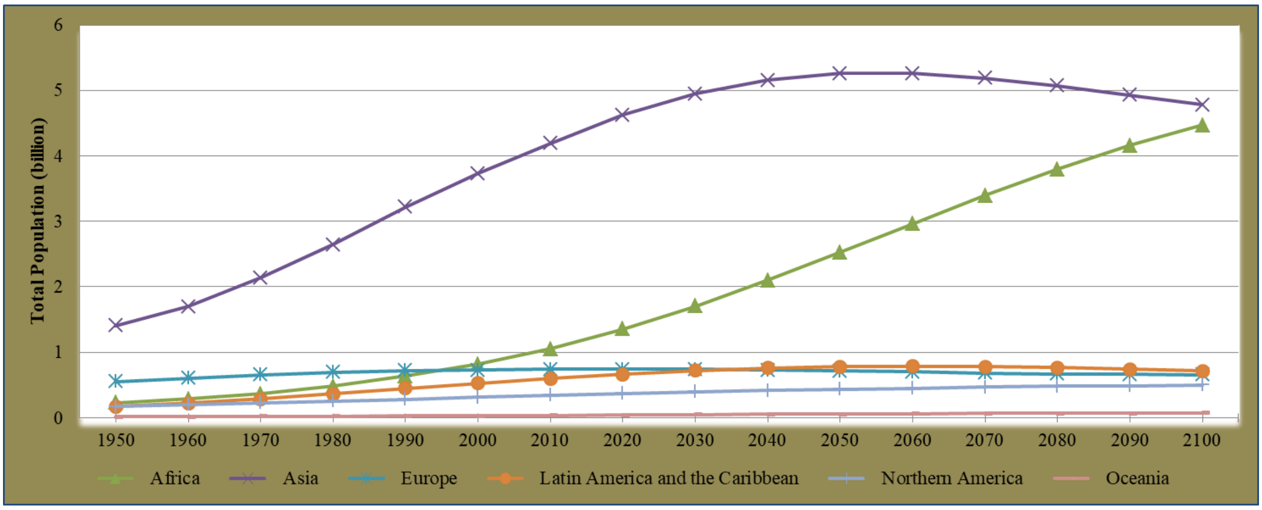


Figure 2.1: Population by region: estimates 1995-2015, and medium-variant projection 2015-2100

Source: United Nations Department of Economic and Social Affairs Population Division, (2017)

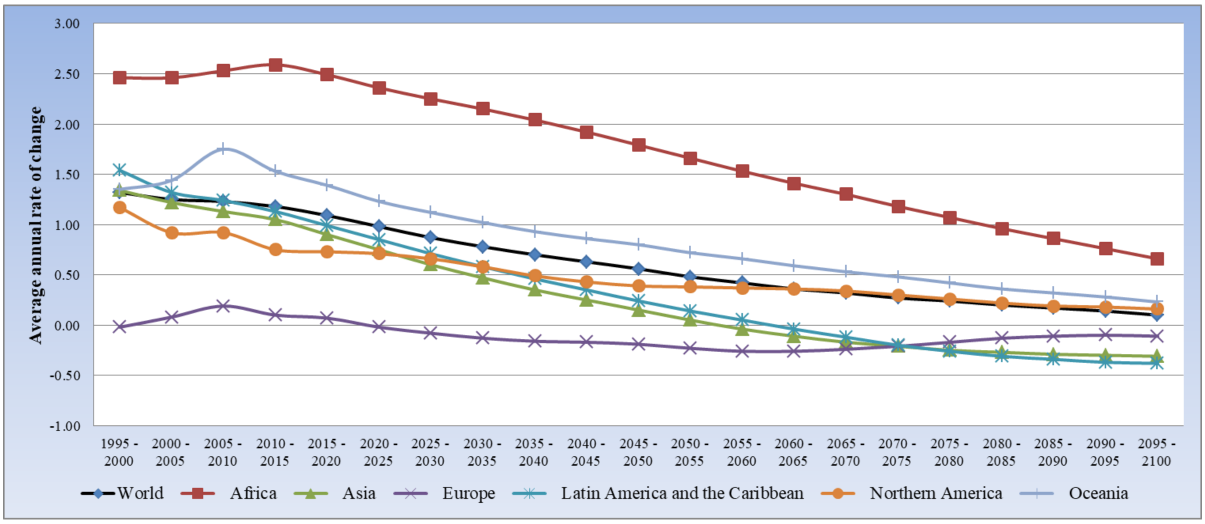


Figure 2.2: Average annual rate of population change for the world and by region: estimates 1995-2015, and medium-variant projection 2015- 2100

Source: United Nations Department of Economic and Social Affairs Population Division, (2017)

Urbanization is define as "the process whereby a large number of people become permanently concentrated in relatively small areas to form cities" (UNSTAT, 2005). Urbanization leads to a distinct change in the size and structure of an urban population (Bobadoye & Fakere, 2013). Urbanization is considered a good process because many countries generate the bulk of their gross domestic product from the cities (Arimah, 2010). But with the high rate of urbanization experienced in sub-Saharan African countries, the economy of these countries has been considered immature and marginalized (Cohen, 2006; Africa Fact Sheet, 2010). This is associated with the high growth of informal activities in these countries (Africa Fact Sheet, 2010), and poor governance, high poverty rate and non-coherent urban planning policies present in most of these cities have exacerbated the situation (Davis, 2004; Cheru, 2005).

Unlike other developing countries where urbanization is accompanied by growth, sub-Saharan African countries have experienced rapid urbanization, which has led to limited or even no development (Cheru, 2005; Barrios, Bertinelli, & Strobl, 2010). According to Daniel, Wapwera, Akande, Musa and Aliyu (2015), it is difficult to establish a positive relationship between urbanization and economic growth in African cities, because the urbanization experienced in Africa has created hardships for its urban residents. Davis (2004) also observed that the cause of urbanization, economic growth and slumming in Western cities such as Manchester, Berlin and Chicago, etc., was as a result of industrial revolution, while the African countries' experience of rapid urbanization and slumming cannot be totally attributed to industrialization. This is because many of these countries have experience limited or no industrialization. Despite the poor economic performance and no significant direct foreign investment in many African cities, these cities continue to grow (Cohen, 2006). The question remains what causes urbanization in African cities?

Fay and Opal (1999) observed that in general there is a strong association between level of urbanization and level of income, but when negative economic growth occurred, urbanization still persisted, and this seems to be the case for many African countries where distorted economic growth has not reduced rate of urbanization. Hence, the authors conclude that other factors such as education, differences in rural-urban wages, ethnic tensions and civil disturbances contributed to urbanization in African countries. Fox (2012) also argued that the rapid urban growth experienced in Africa after 1960 was due to decline in mortality rate and improved access to surplus food supply. This was made possible through technological and institutional changes introduced after World War II by colonialism, trade and international development.

The conversion of rural to urban settlements has been reported to be a cause of urban growth in Africa (Parnell & Walawege, 2011). According to McGranahan, Mitlin, Satterthwaite, Tacoli and Turok (2009), between 1950 and 1980, more than 26% of the overall rate of urbanization recorded in Africa was due to this conversion, which has not necessarily lead to any type of development. Further, the cause of urban growth in many African countries can be traced back to the colonial era, when the colonial governments established centers for administration, cultural, economic and recreational activities where the country's population drifted to (Hope, 1998). After the colonial era, these centers became the focal point for many Africa countries (e.g. Lagos in Nigeria, Accra in Ghana, etc.), and people did not stop migrating to these places even when economic incentives no longer existed. Considering some of the causes stated above, urbanization in Africa is sometimes referred to as "parasitic urbanism, urbanization of poverty or premature urbanism" (Obeng-Odoom, 2010:13).

The consequence of this type of urbanization experienced in Africa is high slum prevalence, which has become the dominant residential land-use type in many African cities (Hofmann et al., 2015; Simon et al., 2013). With the future population projection that expects African cities to experience massive population growth (United Nations Department of Economic and Social Affairs Population Division, 2017), there is the expectation of high slum proliferation in the future. In addition, future migrants to these cities are assumed to be mostly poor, and if the present trends continue, these migrants are expected to follow their predecessors' way of securing shelter by either living in the existing slums or occupying vacant plots (Akom, 1984; Garau, Sclar, & Carolini, 2005).

Urbanization is here to stay and needs to be integrated into city development processes (Shekhar, 2012b). Even if all rural areas are developed, people will still migrate to cities. This is because cities are not just a focal point of the economy, they are also a driver of societal development (Odufuwa, Fransen, Bongwa, & Gianoli, 2009), and therefore curtailing urbanization might not be possible. Hence, governments need to stop regarding over-urbanization as a cause for slum formation and expansion, but rather need to look for ways to utilize land-use policies to manage urban growth (Aguilar, 2008). They should also consider the uniqueness of cities while planning their future development (Angel et al., 2011 in Agunbiade, Rajabifard, & Bennett, 2012).

2.2 Concept of slums

Slums are illegally developed residential areas with limited or inadequate infrastructure and services (Davis, 2004). They are part of the city where the housing and the resulting social arrangement has developed through processes which are different from the general growth of the city (Stokes, 1962). Slums are old residential areas left to decay without any adequate maintenance (Omole, 2001). A slum is also a group of buildings in an urban area that is overcrowded with no access to infrastructural facilities such as potable water, school, health facilities, drainage, etc. (George, 1999). It is also defined as an area containing a group of older housing units that have deteriorated and overcrowded (UNSTAT, 2005). According to Akinbode (2002), slums emerge as a result of the concentration of poor people in unplanned settlements. George (2002) is of the opinion that the emergence of slum environments is due to the interaction of different forces which give rise to a larger community with a devalued physical and social image. Slums are seen as the manifestation of urban poverty in developing countries and are home to different social vices such as unemployment, crime, poverty, urban decay, etc. (Simon et al., 2013; Adedayo & Malik, 2015; Peter Hofmann et al., 2015). Considering some of the definitions given above, it can be infer that slums is not just about the buildings but also about the combination of different criteria related to the socioeconomic characteristics of the residents and the physical characteristics of the environment (Figure 2.3).

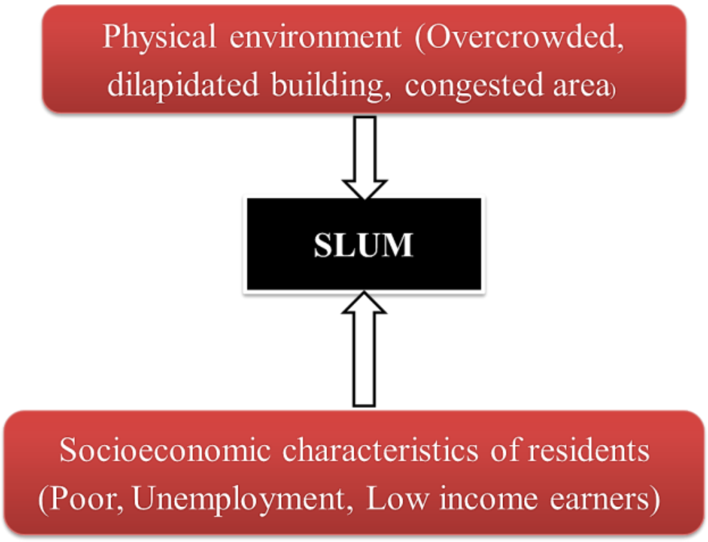


Figure 2.3: Concept of Slum

Informal settlements, squatter settlements, and shanty towns are synonyms commonly used for slums in literature (UN-Habitat, 2013). But Hofmann et al. (2015) states that informal settlements are different from slums, as informal settlements are settlements that do not conform to the planning standards or are illegal. However, when considering the characteristic of slums given by the UN-Habitat (2003), which is a neighborhood characterized by inadequate access to safe water, sanitation and infrastructural facilities, poor structural quality of housing, overcrowding and insecure residential status, then all informal settlements fulfill at least one of the given characteristics. Furthermore, slums, shanty towns, informal settlements, etc., exhibit, at least partially, similar characteristics, which include poor sanitary surroundings, dilapidated structures, high occupancy ratio, haphazard architectural design, and general features of vandalism (George, 2002). Accordingly, the UN-Habitat (2015:1) definition of slum "as the most deprived and excluded form of informal settlements characterized by poverty and large agglomerations of dilapidated housing often located in the most hazardous urban land" identifies slum as a type of informal settlement. Combining informal settlements and slums together is not implausible, as their physical manifestation is quite similar though their origin may differ.

Slums are heterogeneous in nature, and consist of all kinds of buildings, e.g. shacks, well-maintained building structures, etc., as well as people of diverse origin (Bobadoye &

Fakere, 2013). No two slums are the same, as they tend to differ in their history, growth and development, opportunities and challenges (Dung-Gwom, 2007). Garau et al. (2005) defended this point by identifying three alternatives to location and characteristics of slums: (i) to find shelter in existing inner city slums or informal settlements, (ii) to occupy vacant land in vulnerable areas (floodplains, river banks, hill slopes, dump sites, etc.), and (iii) to move to semi-legal settlements managed by self-proclaimed landlords that subdivide the existing plots of land. These alternatives determine the uniqueness and characteristics of a slum, which is key for providing effective slum management measures.

Slum development processes take different forms. These can be gradual degradation of the formal housing sector or through informal housing development (Sliuzas et al., 2008). The former is common within the city, while the latter occurs around the fringe of the cities. Slums include high-density squalid settlements in city centers and squatter settlements along the edge of cities. The inner-city slums are usually older than the cities themselves, while those in the peripheral are due to urbanization and failure of effective planning (Olthuis, Benni, Eichwede, & Zevenbergen, 2015). According to Agbola (1995), there are two types of slums in Nigeria, i.e. the traditional and the spontaneous slum. The former result from the decay of existing structures, while latter emerges through squatters living on illegally acquired land (in Ajayi, Oviasogie, Azuh, & Duruji, 2014). The inner-city slums are found in the traditional residential core center of the cities, which is very close to the business center, and in most cases are legal as they conform to the past planning standard but have deteriorated and are also overcrowded (Pugalis et al., 2014).

Slums have been known to be home to deprivation since the 19th century (Friedman, 1968 in Pugalis et al., 2014). They are an expression of deep poverty, poor economic factors, unrealistic regulatory frameworks as well as resilience by marginal people to survive in cities (Mehta et al., 2008). But it is important to note that well-maintained building structures with legal rights can also be found in slums. This is common in some areas identified as slums in Lagos (e.g. Shomolu), where a few well-maintained building structures exist in the midst of old and decaying buildings (Figure 2.4).

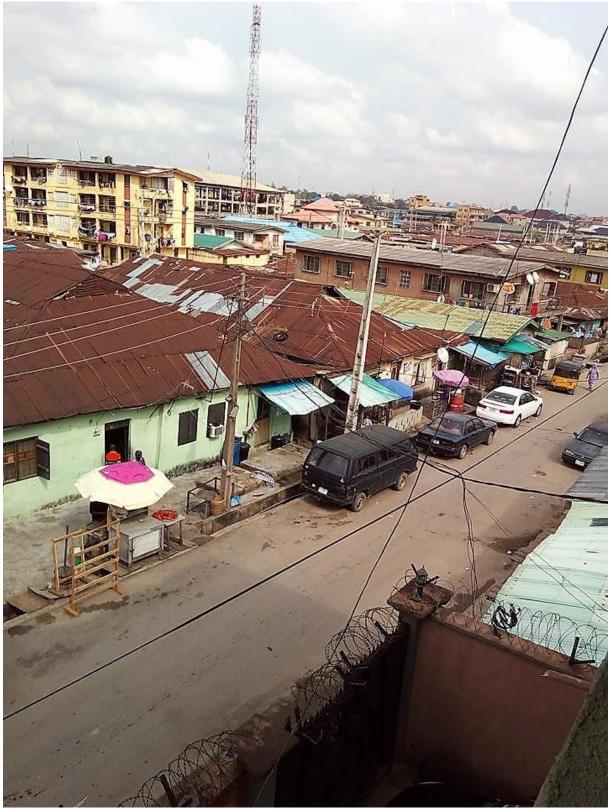


Figure 2.4: Slum community in Lagos, 2016

Although the negativity accredited to slums is very high, slums nevertheless provide shelter at low cost for the poor especially when the city administration is unable to plan and provide affordable housing (Gulyani & Talukdar, 2008; Ooi & Phua, 2007). Davis (2004:28) refers to slums as "a solution to warehouse the twenty-first century surplus humanity, especially in the global south where housing is limited". In the same line, Augustijn-Beckers, Flacke and Retsios (2011) stated that informal settlements arise due to the need for shelter by migrants who migrate into the cities for better opportunities. This implies that slums also have roles in a city (Andavarapu & Edelman, 2013), and may continue to grow if their functionality is not considered during urban planning.

2.2.1 Slums in Africa

A survey conducted by the UN-Habitat (2016) estimated that 55.9% of urban dwellers in sub-Saharan African countries live in slums. In Asia, numbers are between 25% and 31% and in Latin America and Caribbean countries 21.1%. While the percentage of urban populations in sub-Saharan African countries living in slums has decreased, the absolute number of urban population has increased (Figure 2.5). This number has followed the observed population growth in the region i.e. as the region population increases, the slum population also increases.

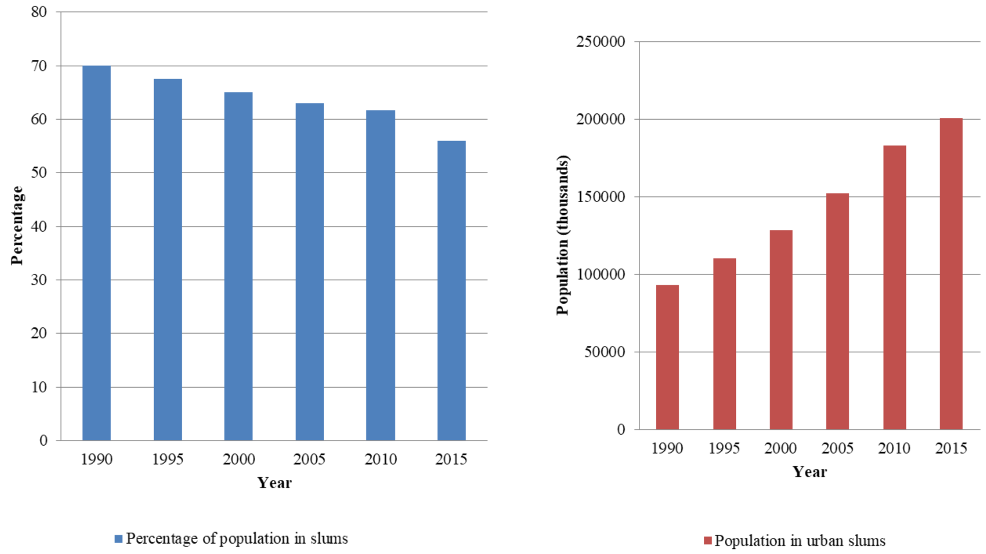


Figure 2.5: Percentage of urban population in slums and population in urban slums in sub-Saharan African countries
Source: UN-Habitat, 2016

According to Owusu (2004), the development of squatter settlements in Africa is slow and in three stages with undefined boundaries: formation, transitional and maturity. The population is very small at the formation stage, and most of the residents are usually migrants from nearby cities. At this stage, the migrants stay in this settlement while they look for employment and better accommodation. At the transitional stage, the settlement gains greater recognition, and experiences increases in population and economic bases; particularly in the area of informal activities. Migrants from other parts of the country migrate in large numbers to the settlements. At the transitional stage, information flow will begin as migrants send information on job opportunities and housing situation in the settlements to relatives and friends (prospective migrants) in other parts of the country. In the last stage of the development, the population is higher compared to the available land area, i.e. the settlement becomes saturated. This leads to deterioration of living standards causing a decline in the population growth of the settlement. At the maturity stage, the settlement experiences low or no population growth.

Many studies have predicted future urban growth in many sub-Saharan African countries (e.g. Barredo, Demicheli, Lavalle, Kasanko, & McCormick, 2004; Mundia & Aniya, 2007; Vermeiren, Van Rompaey, Loopmans, Serwajja, & Mukwaya, 2012). Can we now say the predicted urban growth in most of these countries is related to slum growth, as there seems to be a close correlation between urban growth and slum growth in Africa (Marx et al., 2013; UN-Habitat, 2016)? As Davis (2004) stated, about 40-70% of the urban dwellers in developing countries live in slums, and this is expected to increase with the projected influx into the cities. Therefore, studies and polices on urban growth management need to integrate slum management policies in the agendas to eliminate slums and the associated problems especially in developing countries with high slum prevalence.

2.3 Approaches to slum management

Slum management involves effective upgrading of the existing slums and prevention of new ones from emerging. This practice is categorized broadly into an adaptive and a proactive approach (Mehta et al., 2008).

Adaptive measures occur when slum manifestation has evolved with the associated problems (Bobadoye & Fakere, 2013). The adaptive approach helps to improve the situation of existing slum dwellers by finding ways to integrate them into the city (Mehta et al., 2008). It involves slum upgrading, which could be in form of in-situ upgrading, total slum clearance and partial clearance. The three methods involve provision of facilities such as roads, water, electricity, etc., but differ in how the housing units are managed. In in-situ slum upgrading, the housing units are mostly left untouched while facilities are provided. In partial clearance, some of the housing units are demolished while facilities are provided. In total clearance, all housing units are demolished and the site is redeveloped. These approaches may be combined, for instance, in-situ upgrading and partial clearance are sometimes employed together in Lagos. With in-situ upgrading, welfare intervention provided for slum dwellers can also spill over to non-slum dwellers in the neighborhood (Kapoor, Lall, Lundberg, & Shalizi, 2004).

In-situ slum upgrading with community participation is considered to be one of the most promising slum-upgrading approaches (Patel, 2013), as it allows slum dwellers to have a say on how their community is redeveloped. In the same vein, it is the least expensive approach especially when dealing with urban poor (Werlin, 1999). But many cities find it difficult to achieve, as in most cases governments do not recognized the slum dwellers' opinions during the upgrading practices. For instance, the Lagos Metropolitan Development and Governance Project (2006), whose mandate was to upgrade subprojects in nine of the largest slums identified in 1984 (Agege, Ajegunle, Amukoko, Badia , Iwaya, Makoko, Ilaje, Bariga, Ijeshatedo/Itire), was rated unsatisfactory due to factors such as lack of transparency, corruption, non-participation of slum dwellers, etc. (World Bank, 2014), though it did help to restore harmonious space and improved transport management within the slum communities (Iweka & Adebayo, 2010) (Figure 2.6).

Figure 2.6: New road in Itire Slum, 2016
Constructed by Lagos state Government under the LMDGP

Slum clearance is suggested if the slum is built on land that is unsafe, and in such cases a negotiated relocation is the best option. But in most cases, slums are on lands that are well located with easy access to opportunities such as jobs, social activities, etc. (Cities Alliance, 2013). In cities where land is scarce, for example Lagos where most of the city consists of water bodies, the government forcefully evicts slum dwellers to develop the area into a prime real estate. For instance, after the demolition and clearance of the Maroko[4] slum in Lagos in 1990, the land was developed to a high-income residential apartment (Agbola & Jinadu, 1997).

Slum clearance could be an alternative, but when no resettlement plan is available for the evictees, it results only in displacement of slums and creation of new ones in another

[4] Maroko is a squatter community cleared in 1990 while Makoko is still in existence

area (Arimah, 2010). For instance, the demolition of the Maroko slum led to the development of new slums along Ikota village in Lagos Island (Sule, 1990). Slum clearance means high social and economic costs, e.g. problems of re-settlement, payments of compensation, etc., and should be avoided as a slum management strategy wherever possible (Akom, 1984). Furthermore, when relocation has to take place, it is crucial that the whole community is relocated to prevent disruption of social networks, as many slum dwellers prefer to stay close to those sharing common socio-demographic factors such as language, religion, etc. (Kapoor et al., 2004)

The proactive approach involves prevention of slum formation through proactive measures. Here, governments develop policies and programs that can help to prevent slum formation. This can be in form of provision of low-cost housing for the projected influx close to the city center, or through adequate development control to monitor development within the city (Mehta et al., 2008; UN-Habitat, 2016). This approach is based on prior knowledge of slum development and its drivers (Abbot& Douglas, 2003 in Sietchiping, 2005). Proactive approach is considered a better slum management approach to prevent slum growth, but it is difficult for many developing countries to implement as they have little or no information about the growth pattern and spatial expansion of slums within their cities (Shoko & Smit, 2013).

In the past, interest has been more in slum upgrading than in slum prevention. But recent findings (from MDG to SDG) show that only through the integration of adaptive measures with proactive measures could total slum eradication be achieved. Marx et al. (2013) also suggested that not only sound housing policies are necessary for any meaningful slum development programme, but also a holistic approach which addresses health and sanitation issues, local governance, private savings and investments, and land market institutions. This involves understanding the existing situation in the slums, what drives slum growth, and how to prevent new slums from springing up in the future (Figure 2.7).

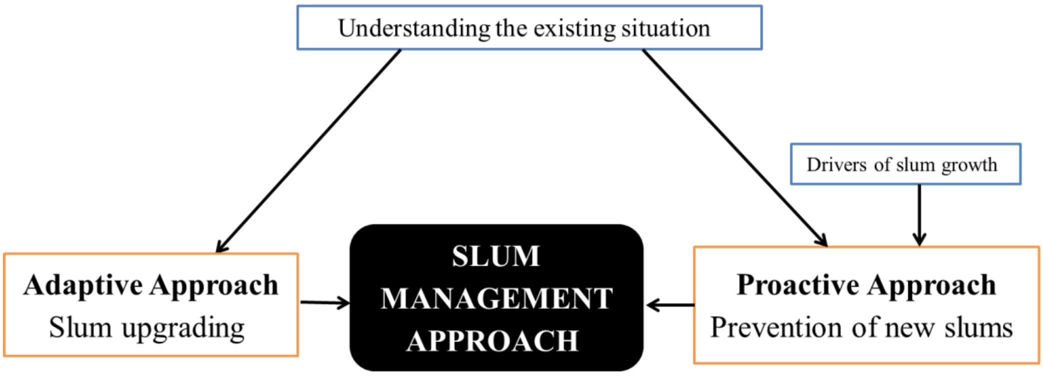


Figure 2.7: Concept of slum management

2.4 Mapping of slums

Effective slum management processes will require a methodology that can link historic trends of slum patterns with the driving forces (Arimah, 2010). This entails first identifying and mapping of existing slums. Census-based approach, participatory approach and remote sensed-based approach can be utilized to identify and map slums and informal settlements (Kohli et al., 2012).

The census-based approach uses data obtained from census surveys to delineate deprived areas. Mapping is based on aggregating slum household data according to the enumeration areas (EA). Any EA with more than 50% of its population deprived of the indicators given by the UN-Habitat (2003) is declared a slum (Sliuzas et al., 2008). This method does not consider other variables such as location of slums, condition of roads, etc. (Sliuzas et al., 2008). Also, some countries do not have recent data for each EA, and where they do have data, this is only partially reliable as it does not recognize slum settlements (Arimah, 2010). For instance, the last census conducted in Nigeria (2006) was characterized by many controversies, as some state governments (e.g. Lagos) rejected the result of the census given by the Nigeria federal government (Akoni, 2013).

In the participatory approach, stakeholders (experts, government, slum dwellers, etc.) are involved in the mapping of the slums. Joshi, Sens and Hobson (2002) showed how slum dwellers and non-governmental organizations (NGOs) worked together to map slums in Pune and Sangli, India, through the collection of information at household level in slum settlements. Lemma, Sliuzas and Kuffer (2006) used the rapid urban appraisal method in form of focus group discussions with experts supported by GIS tools to map and analyze slums in Ethiopia. Also Slum Dwellers International (SDI), a transnational network of urban poor communities, used the slum dwellers to count and map the slum residents in some slum communities in over 32 countries, as a means to transform slums into resilient neighborhood and inclusive cities (Slum Dwellers International, 2016). However, gaining detailed information through the participatory approach is time consuming, especially in cities with many slums (Kohli et al., 2012), hence the need to identify another strategy to map slums in cities.

Although slum dwellers may have influence how slums look, defining a slum neighborhood is also a function of the physical and infrastructural environment (Weeks, Hill, Stow, Getis, & Fugate, 2007). Slums, like any other land-use type, have their own spatial location and characteristics which are different from non-slum environments (Sietchiping, 2005). Weeks et al. (2007) showed that slums have footprints that can be detected from satellite imagery and can be utilized as an alternative to socioeconomic data collection (census-based approach). Some characteristics of slums such as haphazard high density building pattern, flood-prone area, structure, size and condition of road network, etc., can be detected using high-resolution satellite imageries (Shekhar, 2012a). Hence, remote sensed data can be utilized to delineate and analyze slum patterns when detailed census data is not available. It can also provide information on the spatial distribution and heterogeneity of slums, which can be used for the analysis of the location and physical composition, which are challenging for the traditional data collection method such as census data (Olthuis et al., 2015). A slum map produced from remote sensed data can be an input for urban planning, modeling, growth monitoring, etc.

Remote sensing has some advantages when used to map slums in urban areas, nevertheless there are some limitations associated with this approach. When Gruebner et al. (2014) mapped slums in Dhaka, Bangladesh, it was observed that pre-existing knowledge of Dhakar was required to visually interpret the very high resolution satellite imagery. According to Rhinane, Hilali, Berrada and Hakdaoui (2011), mapping different classes (e.g. slum, commercial, industrial, open space, etc.) in urban spaces is challenging, and this was attributed to the similar spectral and textural properties of different classes in an urban space. For instance, misclassification could be due to slum-like areas having a similar micro-structure, overlapping rooftops, and irregularly shaped buildings like in slums (Veljanovski, Kanjir, Pehani, Otir, & Kovai, 2012). Kuffer and Barros (2011) also observed that segmentation at object level sometimes does not give an explicit representation of real life. Considering some of these limitations, it can be inferred that the challenge of the application of remote sensing in slum mapping is in form of over- and under representation of slums on the ground.

Nevertheless, many studies have effectively incorporated the remote sensing data to detect slums in many cities. Hofmann, Strobl, Blaschke and Kux (2008) utilized IKONOS image to detect informal settlements in Rio de Janeiro using a fuzzy-logic rule-base as a basic classifier for the generated segments. Busgeeth, van den Bergh, Whisken and Brits (2008) used Quickbird images of Soweto, South Africa, to illustrate how informal settlements could be monitored in countries without complimentary census data or cadastral maps. Stoler et al. (2012) used medium-resolution satellite imagery from ASTER to show slum presence in Accra, Ghana, and compared the results with socioeconomic data obtained from census data of Ghana and obtained similar 'slum indices'. Marghany and Genderen (2014) utilized a fuzzy B-spline algorithm to detect slums in Cairo from ENVSIAT ASAR and Google Earth imagery. Kuffer, Sliuzas, Pfeffer and Baud (2015) were also able map slums in built-up areas from WorldView-2 images of Mumbai, India, using co-occurrence matrix (GLCM) and NDVI.

2.5 Spatio-temporal pattern of slum dynamics

Slum formation or disappearance is a gradual process that does not change overnight. The studies discussed above were able to utilize one time period of satellite imagery to identify slums and their features within a city. But considering the dynamic nature of slums, it is important to also consider the multi-temporal dimension of slums to manage its growth effectively. It is surprising that there are limited studies that focused on the multi-temporal dynamics of slums. This was due to the high costs of high-resolution temporal satellite imagery and the imperfectness of automated slum identification methods (Kit & Lüdeke, 2013). Also, most of the sensors with high-resolution imagery were established around the year 2000, and identifying slums before that time proved to be a challenge, due to non-existent or limited data availability, especially in sub-Saharan African countries.

Yet, a few studies have attempted to study slum growth. Hurskainen and Pellikka (2004) used black and white and true-colour aerial photography to study the growth and change of informal settlements in VOI, south-east Kenya, between 1985 and 2004. Kit and Lüdeke (2013) captured the spatiotemporal dynamics of slum-related land-use change in the whole city of Hyderabad, India, between 2003 and 2010. Adepoju et al. (2013) mapped and monitored slum development in Abuja, Nigeria, between 2005 and 2012 using the pixel-based classification method to classify the slums, before studying their temporal growth. Veljanovski et al. (2012) utilized QuickBird and GeoEye imagery to study settlement growth and changes in the Kibera slum, Kenya, between 2006 and 2009. These studies show that integrating remote sensing techniques into identifying and studying the growth of slums could also be done in countries with insufficient data, however the time gap for most of these studies was less than 10 years, attributed to unavailability of high resolution satellite imageries and recent development of remote sensing techniques for slum delineation.

2.6 Temporal dynamics of land-use and land-cover change

The interaction between humans and the biophysical environment has been described as the main driver of land-use and land-cover changes - LULCC (Manandhar, Odeh, & Pontius, 2010; Brown, Walker, Manson, & Seto, 2012; Raphael, Hambati, & Ato Armah, 2014). Due to the importance of LULCC and the advancement of remote sensing and geographical information systems (GIS), various techniques have been developed to detect these changes (Lu, Mausel, Brondízio, & Moran, 2004; Rimal, 2011). The objective of LULCC is to identify land transition, measure the area extent of change, and assess the spatial pattern of change (Macleod & Congalton, 1998). Further, the interest in land-use change models has necessitated the application of techniques that can characterize initially observed land-use change, which can then be used to identify driving forces and causes of land-use change, to assess the effect of the changes on humans and environment as well as predict future land-use patterns (Aldwaik & Pontius, 2012). It is against this background that intensity analysis was developed to quantitatively analyze maps of land categories from several points in time for a single site (Aldwaik & Pontius, 2012). As observed by Pontius et al. (2013) in their study of land-use change in Kalimantan, Indonesia, inclusion of a single large dormant category can influence the result of other categories. They further showed that intensity analysis is sensitive to selection of domain. Hence, it is imperative to consider these limitations while utilizing intensity analysis to quantify LULCC.

Yet, with these challenges, it has been successfully applied in many LULCC studies, due to its ability to integrate patterns and processes of land-use changes. Yang, Liu, Xu and Zhang (2017) applied intensity analysis to evaluate spatio-temporal change in LULCC in Zhenlai County, north-east China, from 1932 to 2005, and identified the driving forces, which included policies, institutional and political factors and natural disasters. Raphael et al. (2014) combined in-depth interviews and focus group discussions with intensity analysis to assess the spatial distribution of different categories of land uses and land covers in the high- and low-altitude zones in the northern highlands of Karatu, Tanzania, between 1976 and 2008. With the transition level of the intensity analysis they were able to conclude that the main cause of the fast change in the use of land in the region was due to the villagization policy in the 1970s. Zhou, Huang, Pontius and Hong (2014) applied the three levels of intensity analysis to examine the temporal difference in coastal watersheds of south-east China from 1986 to 2010. They showed that land-use transformation had been accelerating, and identified the land-use types systematically targeted by other land-use types.

It can be observed that application of intensity analysis to study temporal change of different land-use types could help to link patterns and processes of land-use change, which will assist in understanding LULCC dynamics. Since slums also have distinct spatial characteristics like other land-use types (Sietchiping, 2005), applying intensity analysis to study spatiotemporal changes of slums could help to better understand slum dynamics and also prevent future slum growth. The methodology applied in the intensity analysis is discussed in the next section.

2.6.1 Intensity Analysis

Intensity analysis was developed by Aldwaik and Pontius (2012:101), and they defined it as a "quantitative method to analyze maps of land categories from several points in time for a single site by considering cross-tabulation matrices, where one matrix summarizes the change in each time interval". Intensity analysis compares the annual uniform rate of change with the observed annual rate of change among different categories (Pontius et al., 2013), where the annual uniform rate of change is the rate that will exist if the annual changes have been distributed uniformly across the entire time period. The method is based on the availability of maps of different time periods for the same site containing the same categories (land-use types). These maps are overlaid to develop a cross-tabulation matrix where the row and column show categories from initial and final time, respectively. The entries on the diagonal show no change while those off the diagonal indicate land change. This cross-tabulation matrix is the basis for most LULCC studies. Although the matrix helps to identify the pattern of LULCC, it does not give information on the how the pattern of change was derived. The intensity analysis helps to solve this by formulating the following three questions: i) In which time intervals is the annual rate of overall change relatively slow versus fast? ii) Which land categories are relatively dormant versus active in a given time interval, and is this pattern stable across time intervals? iii) Which transitions are intensively avoided versus targeted by a given land category in a given time interval, and is this pattern stable across time intervals (Aldwaik & Pontius, 2012:103)? Intensity analysis consists of three levels, i.e. interval level, category level and transition level (Aldwaik & Pontius, 2012).

Interval Level: This provides information on the size and speed of change across different time intervals. At this level, the annual rate of change for each time interval (S_t) is compared to the annual uniform rate of change (U). When S_t is greater than U, the rate of change at that interval is considered fast and vice versa. Equation 2.1 and 2.2 give the annual rate of change for each time interval (S_t) and annual uniform rate of change (U), respectively.

$$S_t = \frac{\{\sum_{j=1}^{J}([\sum_{i=1}^{J} C_{tjj}] - C_{tjj})\}/(\sum_{j=1}^{J}[\sum_{i=1}^{J} C_{tij}])}{Y_{t+1} - Y_t} \times 100\% \qquad (Equation\ 2.1)$$

$$U = \frac{\sum_{t=1}^{T-1}\{\sum_{j=1}^{J}([\sum_{i=1}^{J} C_{tjj}] - C_{tjj})\}/(\sum_{j=1}^{J}[\sum_{i=1}^{J} C_{tij}])}{Y_t - Y_1} \times 100\% \qquad (Equation\ 2.2)$$

Category Level: This level examines the size and speed of loss and gain for each land-use type within a time interval. It also provides information on which land-use category is dormant or active during that time interval. The intensity of a category annual gain (G_{tj}) and loss (L_{ti}) during a time interval is given in Equation 2.3 and 2.4, respectively.

$$G_{tj} == \frac{\left[\left(\sum_{i=1}^{J} C_{tij}\right) - C_{tjj}\right]/Y_{t+1} - Y_t}{\sum_{i=1}^{J} C_{tij}} \times 100\% \qquad (Equation\ 2.3)$$

$$L_{ti} == \frac{\left[\left(\sum_{j=1}^{J} C_{tij}\right) - C_{tii}\right]/Y_{t+1} - Y_t}{\sum_{j=1}^{J} C_{tij}} \times 100\% \qquad (Equation\ 2.4)$$

Transition level: This level provides information on whether a category is being targeted or ignored during a time interval. The transition level is in two parts: transition **to** and transition **from**. The transition "**to"** examines transitions to category **"n"** during a time interval (Equation 2.5: R_{tin}). Equation 2.6 (W_{tn}) shows the uniform intensity of transition **"to"**. The second part is the transition **"from"**, which examines how other categories transition from category **"m"** (Equation 2.7; Q_{tmj}). The uniform intensity of transition **"from"** is also derived using equation 2.8 (V_{tm}).

$$R_{tin} = \frac{C_{tin}/(Y_{t+1} - Y_t)}{\sum_{j=1}^{J} C_{tij}} \times 100\% \qquad (Equation\ 2.5)$$

$$W_{tn} = \frac{\left[\left(\sum_{i=1}^{J} C_{tin}\right) - C_{tnn}\right]/(Y_{t+1} - Y_t)}{\sum_{j=1}^{J}\left[\left(\sum_{i=1}^{J} C_{tij}\right) - C_{tnj}\right]} \times 100\% \qquad (Equation\ 2.6)$$

$$Q_{tmj} = \frac{C_{tmj}/(Y_{t+1} - Y_t)}{\sum_{i=1}^{J} C_{tij}} \times 100\% \qquad (Equation\ 2.7)$$

$$V_{tn} = \frac{\left[\left(\sum_{j=1}^{J} C_{tmj}\right) - C_{tmm}\right]/(Y_{t+1} - Y_t)}{\sum_{i=1}^{J}\left[\left(\sum_{j=1}^{J} C_{tij}\right) - C_{tim}\right]} \times 100\% \qquad (Equation\ 2.8)$$

Where J =Number of categories; i=Index for a category at the initial time point for a particular time interval; j=Index for a category at the final time point for a particular time interval; m=Index for the losing category in the transition of interest; n= Index for the gaining category in the transition of interest; T=Number of time points; t=Index for the initial time point of interval [Y_t, Y_{t+1}], where t ranges from 1 to T−1; Y_t=Year at time point t; C_{ij} =Number of pixels that transition from category i at time Y_t to category j at time Y_{t+1}; G_{tj}=Annual intensity of gross gain of category j for time interval [Y_t,Y_{t+1}]; L_{ti}=Annual intensity of gross loss of category i for time interval [Y_t,Y_{t+1}]; R_{tin}= Annual intensity of transition from category i to category n during time interval [Y_t,Y_{t+1}] where i≠n; Wtn= Value of uniform intensity of transition to category n from all non-n categories at time Yt during time interval $[Y_t,Y_{t+1}]$; Qtmj=Annual intensity of transition from category m to category j during time interval $[Y_t,Y_{t+1}]$ where j≠m; Vtm=Value of uniform intensity of transition from category m to all non-m categories at time $[Y_{t+1}]$; during time interval $[Y_t,Y_{t+1}]$ (Aldwaik & Pontius, 2012:107)

2.7 Drivers of slum growth

It is important to first understand the causes of slum formation and growth to improve the lives of slum dwellers and provide alternatives to new slum formation (Arimah, 2010). Most attention has focused on urbanization as the main cause of slum proliferation in developing countries, but there seem to be other factors contributing to slum growth. Although urbanization leads to slum growth, it does not give information on where the slums will be located. Hence, location attributes are considered very important when addressing determinants of slum growth (Olthuis et al., 2015).

According to Davis (2004), slum development is enhanced in locations where religious activities are found. Debnath and Naznin (2011) observed in their study of the Dhakar metropolitan development plan in Bangladesh that there is spatial dependence between slum agglomeration and industrial concentration. In addition, a close correlation is observed between informal economies and informal settlements (Kengne, 2000). This is because, unlike formal economy or the public sector that require professional skills or knowledge, most informal economies do not, e.g., market (Happe & Sperberg, 2003). In many developing countries, more than 70% of the migrants to urban areas are employed within the informal economic sector (Kengne, 2000). The implication is that the location of certain activities could lead to the development of slums nearby. For instance, Ajegunle and Ijora Badia are slums close to the Apapa wharf, a major sea port in Lagos.

The manifestation of a slum within a location may also be a function of family linkage (Olajuyigbe, Popoola, Adegboyega, & Obasanmi, 2015). Migrants will prefer to settle in neighborhoods that share similar socio-cultural backgrounds (Malpezzi & Sa-Adu, 1996 in Sietchiping, 2005). Also, most of these migrants are brought to the city by their relatives, with whom they live while they find their footing or secure accommodation within the slum community or move to another one (Owusu, 2004). This can be observed in Lagos, where people of the same cultural background live in the same slum sub-community (Bariga water front, Ago in Iwaya, etc.).

The economic status of people is also considered to be a determinant factor of slum growth, as many low-income earners cannot afford to live in the overpriced houses (Adedayo & Malik, 2015), hence they look for alternative shelter which in most cases is in the least desirable part of the city. This is a common phenomenon in many cities where the cost of living is very high, and alternative shelter for the migrants is usually around hazardous areas where the value of land is low or there is no government influence. These areas include riverbanks, steep slopes, close to dump sites, along transportation routes, etc.

A high population growth in a city does not necessarily lead to expansion of slums, rather slum expansion has to do with the failure of the government and city planners to effectively plan and provide infrastructural facilities for their residents (Morka, 2007). Most urban planners tend to overlook a possible expansion of the slums in the city (Sietchiping, 2005), and do not even recognize slums as an integral part of the city. For instance, Makoko slum dwellers living on the lagoon in Lagos were exempted from the 2006 census in Nigeria.

Weak institutional factors, such as planning policies (which are either rigid or archaic), poor zoning laws and building codes combined with poor governance, corruption and nepotism have led to housing shortages, weak housing rights and inaccessibility to land in many urban areas in African countries, and also adoption of coping strategies by the low-income urban households, which leads to degradation of the environment (Fekade, 2000; Ajibade & McBean, 2014). The inability of the governments to invest and proactively manage rapid urban development is considered a driving force of slum growth (Fox, 2012). In many mega-urban regions, there is no efficient coordination between different authorities within the city, and their policies are sometimes conflicting (Ooi & Phua, 2007). The consequence is the proliferation of slums, as many low-income urban households have to look for alternative shelter, which in most cases does not conform to the policies of the city.

The concentration of economic development in larger cities of developing countries is a pull factor for many migrants (Roy et al., 2014). People migrate to these cities for better opportunities, and within a short time the city becomes congested and resources become limited or unavailable of catering for this population boom. Furthermore, most of these cities cannot provide the necessary economic opportunities required by the migrants, thus many look for livelihood alternatives, which in most cases do not conform to the city development plan. As this process is still ongoing, many people still continue to migrate to the city even when there are limited or no opportunities.

Concluding, the drivers of slum growth can be broadly categorized into three factors: institutional, socioeconomic and biophysical. The institutional driver is a function of government policies in the cities, which directly drives the growth of slums as a whole. The socioeconomic factors (e.g. economic status of people, closeness to religious centers and industrial areas, cultural affinities) as well as biophysical characteristics of the environment (flood-prone zone, dump sites, etc.) influence the location of slums in urban areas.

2.8 Land-use change models

Development in geographic information systems (GIS) and remote sensing has enhanced monitoring and studying of urban growth dynamics (Alsharif & Pradhan, 2014). This development provided tools (e.g. land-use change models) that can predict and model the direction of urban growth (Al-shalabi, Billa, Pradhan, Mansor, & Al-Sharif, 2013). Land-use change models are tools that help in analyzing causes and effects of land-use change to gain a better understanding of land-use systems, and also support land-use planning policies (Verburg, Schot, Dijst, & Veldkamp, 2004; Al-shalabi et al., 2013). These models can show the complex relationship of socioeconomic and biophysical factors and the rate at which these factors influence spatial patterns of land-use change, which can help in simulating future scenarios (Verburg et al., 2004).

Since the last three decades, agent-based modeling (ABM) and cellular automata modeling (CA) are the two major techniques mostly utilized in modeling urban growth. These models serve as the basis for other land-use change models (e.g. ISGM, SLEUTH, CLUES, MAS, etc.). CA and ABM are bottom-up models that model performance of a system at the basic level (Clarke, 2014). CA is based on the spatial dynamics of land-use change. It is mostly suitable for land-use change and urban growth (Clarke, 2014). It captures and simulates the complexity observed in urban areas (Mundia & Aniya, 2007). The basic principle of ABM is that decisions of agents or objects (e.g. human, government, countries, etc.) influence the change in the process and use of land (Barros, 2012). It studies behaviors of agents with other agents as well as with their environment (Roy et al., 2014).

Many studies have criticized CA and considered ABM a better choice. This is because ABM allows movement of agents within the environment, unlike CA where agents are mostly static and only interact with their neighbors (Augustijn-Beckers et al., 2011; Clarke, 2014; Patel, Crooks, & Koizumi, 2018). According to Manzo (2014), ABM also has some limitations. It is dependent on input values and internal structure; there is uncertainty in the ABM simulation and also challenges with respect to the reproducibility of ABM simulations. The data required for ABM is sometimes not available, especially in sub-Saharan African countries. For instance, it was observed in ABM modeling of slum formation in Ahmedabad, India (Patel et al., 2018), that most of the required data were not readily available in cities such as Lagos, Nigeria. Further, if the aim of a study is to simulate spatially distributed processes such as spread and dispersal, CA is considered a better option (Clarke, 2014). This makes it a better alternative in this study, as the focus is on the simulation of the pattern of slum growth in Lagos.

To improve the CA model, Clarke, Hoppen and Gaydos (1997) developed the SLEUTH model: "a CA that incorporated weighting of probabilities and self-modification, feedback from the aggregate to the local" (Clarke, 2014:1223). SLEUTH can be used to simulate urban/non-urban dynamics and also urban land-use dynamics (Dietzel & Clarke, 2007). SLEUTH is an acronym for the data input required by the model: slope map, land-use map, exclusion map, transportation map and hill-shade map. The data required are produced within a GIS environment and converted to graphics interchange format (GIF) as input. The model has been criticized because of its reliance on biophysical drivers of land-use change, as it does not give sufficient attention to socioeconomic and institutional factors, which are usually the prime drivers of land-use changes (Ahmed & Bramley, 2015). Hence, the shift to hybrid models that couple empirical methods with spatial models. In this type of model, the probability of a land use to change is based on different driving factors, which are computed using empirical methods. One of the empirical methods is the logistic regression model, which examines the relationship between urban land uses and independent variables (Jat, Choudhary & Saxena, 2017). It also determines the weight of independent variables and their respective functions. Through logistic regression, demographic and socioeconomic factors can be integrated into many models (Alsharif & Pradhan, 2014). But it is important to note the challenges of autocorrelation and multi-collinearity in logistic regression, which could affect the results (Lin, Chu, Wu, & Verburg, 2011; Nong & Du, 2011).

2.9 The Modeling Framework (XULU)

The eXtendable Unified Land Use modeling platform (XULU), developed at the university of Bonn and implemented in java 1.5, is a generic modeling framework that allows the integration of different land use and land cover models to simulate scenarios of future state of land use and land cover under different boundary conditions, irrespective of the spatial scale of the test area (Schmitz et al., 2007). It eases the work of a developers as it separates the model implementation from the XULU framework, to enable the independence of the application functionalities (data pool, I/O routines for data import and export, data structures and internal memory management, model flow control and data visualization), which are usually the same for all models (Schmitz et al., 2007: Figure 2.8). It can be executed in any operating system: LINUX and Windows.

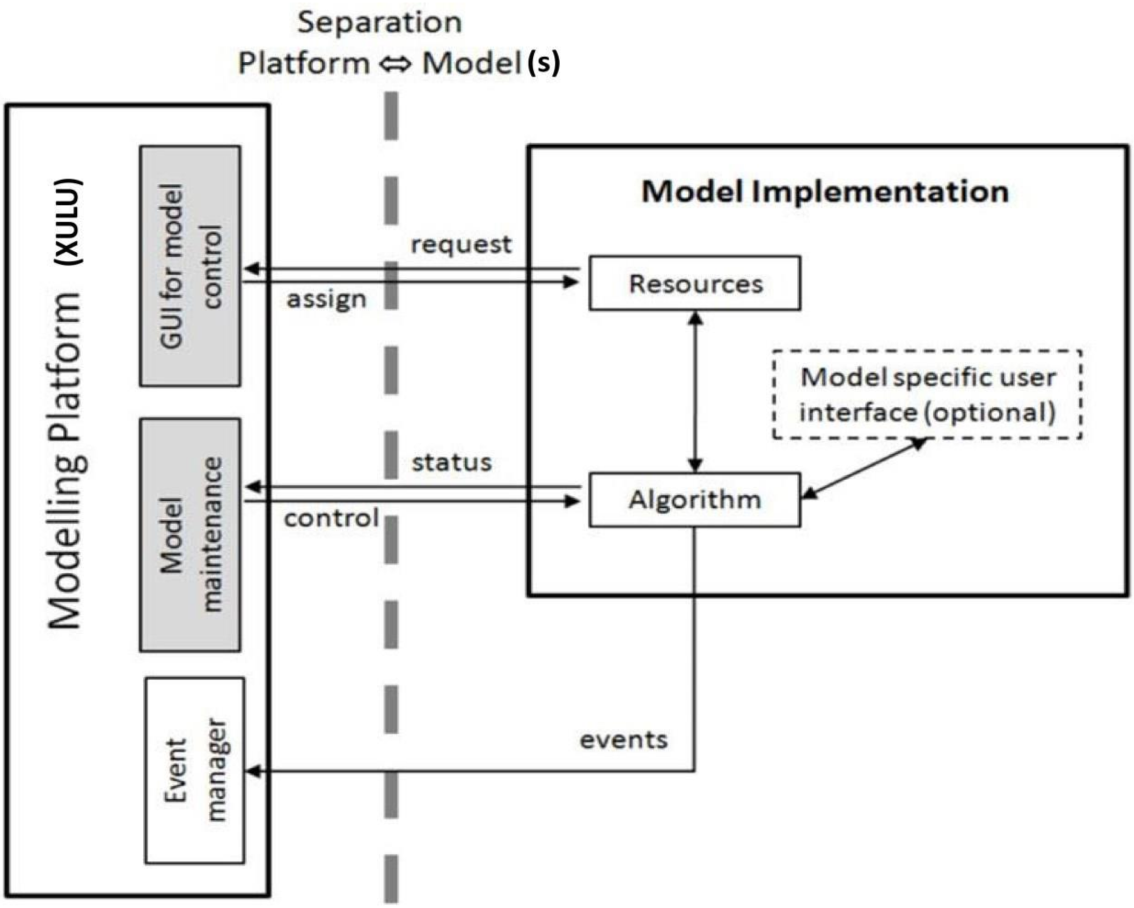


Figure 2.8: Separation between the XULU model platform and a model implementation
Source: Goetzke (2011)

It is difficult to acquire the quantity of data required for the calibration of urban growth models (Rienow & Goetzke, 2015), thus Goetzke (2011) reprogrammed the Clarke Urban Growth model (UGM), a sub-component of SLEUTH (Clarke et al., 1997), and coupled it with CLUE-s (Verburg et al., 2002), implemented it in XULU, to simulate scenarios of future urban development in Nordrhein-Westfalen region, Germany. The reprogrammed urban growth model, implemented in XULU, has been applied to simulate scenarios of urban growth in some regions. For instance Mubea (2014) simulated scenarios of urban growth in Nairobi and Nakuru, in Kenya, using the modified urban growth. Rienow, Stenger and Menz (2014) coupled the modified UGM with support vector machine and combine it with multi-agent system to simulate urban growth and population decline in Ruhr by 2025. Unlike the UGM that requires at least four different land use maps for calibration purposes (Silva & Clarke, 2002); the modified urban growth model, implemented in XULU, requires only two, i.e., map of the starting year of the calibration phase and the reference map at the end year. This makes it a good alternative for data scarce regions such as sub-Saharan African countries.

2.10 Application of land-use change model in the simulation of slum patterns

Informal settlements have complex structures with irregularities that can be quantified through their spatial patterns (Sobreira & Gomes, 2001). Although slums appear disorganized, their growth is not random but rather a geometry of distinct spatial patterns possibly influenced by physical, economic and social factors (Sliuzas, 1988; Augustijn-Beckers et al., 2011). Furthermore, slum formation is a spatial phenomenon, thus the need for tools that can model its dynamics (Vincent, 2009 in Shoko & Smit, 2013; Patel et al., 2018).

Land-use change models can help to determine slum patterns, which planners can use for proactive slum management, decision making as well as to prevent settlements in risk-prone areas (Shoko & Smit, 2013; Roy et al., 2014). Also, models can show historical trends of slums as well as simulate possible hotspots of future slum patterns (Abbot, 2002 in Sietchiping, 2005). Modeling also allows exploration of associated slum theories in a controlled computer environment, which can be used to understand urban phenomena through analysis and experimentation (Batty, 2005).

It is important to note that land-use change models cannot account for political will, legal and policy impediments or funding issues, which are important drivers of slum growth (Sietchiping, 2005). Nevertheless, research has shown that it is possible to predict the formation and expansion of slums in urban areas. Many of these studies utilize remote sensing data, CA, ABM and GIS to predict slum patterns. (Shekhar, 2012b) used multi-criteria evaluation and CA to determine the suitability of lands for slum formation by considering biophysical criteria, which include accessibility, hill slopes, canals, etc., and predicted future slum growth in Pune, India. Patel et al. (2018) integrated agent-based modeling and GIS to explore how the interaction between different agents (slum dwellers, governments etc.) and their spatial environment leads to emergence of slums in Ahmedabad, India. Augustijn-Beckers et al. (2011) utilized an ABM to develop a vector-based housing model to simulate the growth of informal settlements in Dar es Salaam, Tanzania. Dubovyk et al. (2011) used a logistic regression model to analyze the driving factors of informal settlements to predict probable locations of new informal settlements in the Sancaktepe district in Istanbul, Turkey. Sietchiping (2005) adopted an informal settlement growth model to predict the growth of slums in Yaoundé, Cameroon.

In studies by Augustijn-Beckers et al. (2011) and Patel et al. (2018), the objective was to model agent behavior (households) leading to slum growth, while Sietchiping (2005) and Shekhar (2012b) focus was to predict the spread of slums using location attributes, hence ABM and CA were utilized. The definition of slum as encompassing both the physical environment and people living within the community made application of these two methods possible. Hence, it can be concluded that the objective of the study will determine the appropriate land-use change model that could be utilized in slum modeling and prediction.

2.11 Summary of chapter

This chapter presents the relevant literature on slum dynamics and application of remote sensing to slum growth modeling. The type of urbanization experience in African was discussed and how this causes slum growth. The concept of slum and how it relates to other type of blighted areas (informal settlement, squatter etc.) and slums in Africa were also discussed. Slum management is categorized into adaptive and proactive, and it was shown how the two approaches intertwine. The different drivers of slum growth with emphasis on locational drivers were reviewed, and the drivers were categorized into institutional, socioeconomic and biophysical. The different methods of mapping slums and studies on temporal patterns of slums were presented. Furthermore, the potential of intensity analysis as a technique to examine LULCC is discussed. The chapter concludes by discussing application of remote sensing and land-use change models to investigate slum dynamics, i.e. ABM and CA, and that the objective of study will determine the best approach to utilize when modeling slum growth.

3. LINKING PATTERNS AND PROCESSES OF SLUM GROWTH IN LAGOS USING REMOTE SENSING DATA AND INTENSITY ANALYSIS

Source: Badmos, O., Rienow, A., Callo-Concha, D., Greve, K., & Jürgens, C. (2018). Urban Development in West Africa—Monitoring and Intensity Analysis of Slum Growth in Lagos: Linking Pattern and Process. Remote Sensing, 10(7), 1044.

Abstract: Upgrading all slums in Lagos by 2030 is an ambitious task given that more than 70% of its residents live in slums. Furthermore, there is no recent study identifying the slums or their temporal growth/development pattern in Lagos that can support slum management initiatives. This study aims to contribute by applying object-based image analysis and intensity analysis to map and link patterns and processes of slum growth in Lagos. RapidEye imagery from 2009 and 2015 were used to create maps for each time point for six land-use categories (water, vegetated area, open space, road, slum, and other urban). Intensity analysis was applied to quantify the annual intensity of changes at the category and transition level. An overall accuracy (and kappa coefficient) of 94% (0.9) and 89% (0.86) were achieved for the 2009 and 2015 land-use and land-cover maps, respectively. The results of the study showed that slums in Lagos have increased spatially during the time interval studied, with a total net gain of 9.18 km^2, influenced by the increase in population, mainly due to in-migration to Lagos. However, it was also revealed that slums were actively losing and gaining land area between 2009 and 2015, with an annual gain and loss intensity of 10.08% and 6.41%, respectively, compared to the uniform intensity of 3.15%. The gain was due to poor maintenance of buildings and encroachment onto available spaces (water and open space), while the loss was attributed to gentrification and demolition processes. A systematic process of transition was observed between slums and other urban and open space areas in the interval studied, and this process was mainly influenced by the Lagos state government. This analysis is crucial for designing policy interventions to manage slum growth in Lagos.

Keywords: S*lum; object based image analysis; intensity analysis; Lagos*

3.1. Introduction

Rapid urbanization with limited development has led to slum proliferation in many Sub-Saharan African cities (Davis, 2004; Cheru, 2005; Barrios et al., 2010; Bobadoye & Fakere, 2013). Slums are part of the city where the housing and resulting social arrangements diverge from the general growth of the city (Stokes, 1962). Slums emerge due to the interaction of forces which give rise to communities with a devalued physical and social image (George, 2002). Thus, slums are seen as a manifestation of urban decay, poverty, crime, and unemployment in developing countries (Simon et al., 2013; Hofmann et al., 2015; Adedayo & Malik, 2015). Although the negativity attributed to slums is very high, nevertheless, they provide shelter at low cost for the poor, especially when the city government is unable to plan and provide affordable housing (Gulyani & Bassett, 2007; Ooi & Phua, 2007). In addition, Davis (2004:28) refers to slums as "a solution to warehouse the twenty-first century surplus humanity, especially in the global south where housing is limited". Similarly, informal settlements arise due to the need for shelter by migrants, who migrate into the cities for better opportunities (Augustijn-Beckers et al., 2011). Therefore, slums have roles in cities (Andavarapu & Edelman, 2013) and may continue to grow if their functionality is not considered during urban planning process.

Slums are unique in terms of their history, growth and development, opportunities, and challenges, but often similar in their characteristics and physical manifestations (George, 2002; Dung-Gwom, 2007). Experts find it difficult to reach an agreement on what criteria to use in defining slums (Pratomo et al., 2017), resulting in many slums being invisible to the world (Mahabir, Croitoru, Crooks, Agouris, & Stefanidis, 2018). Furthermore, understanding the intricacies of slum dynamics will require linking historical trends of slum patterns with their underlying process (Arimah, 2010). This starts by identifying and mapping existing slums and their temporal changes. Mapping/identifying slums is very important to assist governments in providing the necessary services, such as housing, health, infrastructural facilities, etc. (Kit, Lüdeke, & Reckien, 2012). However, slums are, in many cases, not recognized as an integral part of the city or in the overall growth of the urban economy, because many urban planners tend to overlook its growth during urban planning process (Sietchiping, 2005; Davis, 2006; Kumar Swami, 2017). In addition, many donors or non-governmental organizations interested in slum management are only interested in slum improvement and not in their mapping (Sliuzas et al., 2008).

Like other land use types, slums have distinct spatial characteristics that can be identified and mapped with Earth observation technology (Sietchiping, 2005; Weeks et al., 2007; Shekhar, 2012a). While mapping of slums is important, their multi-temporal dimension is also necessary to understand their evolution and observe their general growth trends (Olthuis et al., 2015). This would then be used to support planning policies, to improve the existing slums or prevent new ones from springing up. Although, Kuffer, Pfeffer and Sliuzas (2016) showed that there are several studies that have utilized remote sensing to identify and map slums, studies on slum temporal dynamics are few (Hurskainen & Pellikka, 2004; Veljanovski et al., 2012; Adepoju et al., 2013; Kit & Lüdeke, 2013). This is due to the high cost of high-resolution temporal satellite imagery, and the imperfection of automated slum identification methods (Kit & Lüdeke, 2013). Additionally, most of the sensors with high-resolution imagery were established around the year 2000, the reason why identifying slums before that time proved to be a challenge, due to the nonexistence or limited availability of spatial data, especially in sub-Saharan Africa.

The interaction between humans and the biophysical environment has been pointed out as the main driver of LULCC (Manandhar et al., 2010; Brown et al., 2012; Raphael et al., 2014), nevertheless, it is important to link the patterns of land use and land cover changes (LULCC) with their underlying processes, and bridging the gap between social science and remote sensing (Rindfuss & Stern, 1998). Further, LULCC entails computation of a land cover/use transition matrix. However, this matrix does not provide sufficient information on the quantitative and systematic signals of land use and land cover changes (Huang, Pontius, Li, & Zhang, 2012). In many cases, the transition matrix is analyzed at a broad level and may fail to reveal the total changes on the landscape; for instance, zero net change due to simultaneous gain and loss within the landscape (Braimoh, 2006). Additionally, discriminating significant signals during land use shifts is important in LULCC (Pontius, Shusas, & McEachern, 2004) and it is difficult to establish from a transition matrix. Purposefully, Aldwaik and Pontius (2012) developed the intensity analysis, a type of change detection, to quantitatively analyze changes in different land-use categories from time to time for a single site, by utilizing cross-tabulation matrices to summarize changes for each time interval. Although intensity analysis is sensitive to domain selection and the size of land-use categories (Pontius et al., 2013), it has been successfully utilized to integrate patterns with processes of LULCC (Raphael et al., 2014; Zhou et al., 2014; Yang et al., 2017).

Lagos developed from a small farming and fishing village in the fifteenth century to become one of the fastest growing cities in the world (Filani, 2012). Lagos Bureau of Statistics (2013) projected the population of Lagos metropolitan area as 21,324,114 in 2015. Lagos is projected to be the ninth most populous city by 2030 (United Nations, 2014), and its population is expected to double by 2050 (World Population Review, 2015). Amidst these projections is a city where more than 70% of its resident lives in slums (UN-Habitat, 2003; World Bank, 2006; Adelekan, 2010). Furthermore, Marx et al. (2013) observed that slum growth accounts for most of the urban growth experienced in Nigerian cities. In the past, scant attention was paid to urban planning in Lagos, but change in the government in 1999 led to the development of new reforms, including new policies to curb slum growth in Lagos through slum upgrading and redevelopment (Filani, 2012). Yet, there is still need for improvement if the city hopes to be "free of slums by 2030", such as utilizing remote sensing techniques to improve our understanding on the spatial and temporal dynamics of slum in Lagos; this can then be used to create knowledge repositories of these slums. These repositories can provide important information on the existing situation and also assist to devise a tailored slum management approach (either proactive or adaptive) for the city of Lagos. Presently, there is no study identifying slums or their growth patterns in Lagos. Hence, this chapter aims to contribute by applying remote sensing techniques and intensity analysis, to map and link patterns and processes of slum growth in Lagos from 2009 to 2015. The objectives of this study are:

- To delineate slums from other land use types in Lagos;
- To determine how slums in Lagos developed over time;
- To quantify the patterns of change observed between 2009 and 2015; and
- To identify the underlying processes leading to the observed change.

This chapter is structured as follows: section 3.1 gives the rationale and objective of this study; section 3.2 discusses the study area and data utilized for this study; section 3.3 gives the methodology utilized; section 3.4 gives the result; section 3.5 gives the discussion; while section 3.6 gives the conclusion.

3.2. Study Area and Data

3.2.1. Study Area

The study was conducted in six local government areas (Apapa, Ajeromi-Ifelodun, Amuwo-odofin, Surulere, Lagos Island, and Lagos Mainland) of Lagos metropolis, constituting a section of the older part of the city. The population densities (persons km^{-2}) of Apapa, Ajeromi-Ifelodun, Amuwo-odofin, Surulere, Lagos Island, and Lagos Mainland was 18,016; 137,102; 3892; 62,552; 123,290; and 42,598, respectively in 2015 (Lagos Bureau of Statistics, 2013) (Figure 3.1). Most of the unplanned settlements (slums and squatter communities) are located within this area because of its proximity to Lagos lagoon and the central business district (World Bank, 2006).

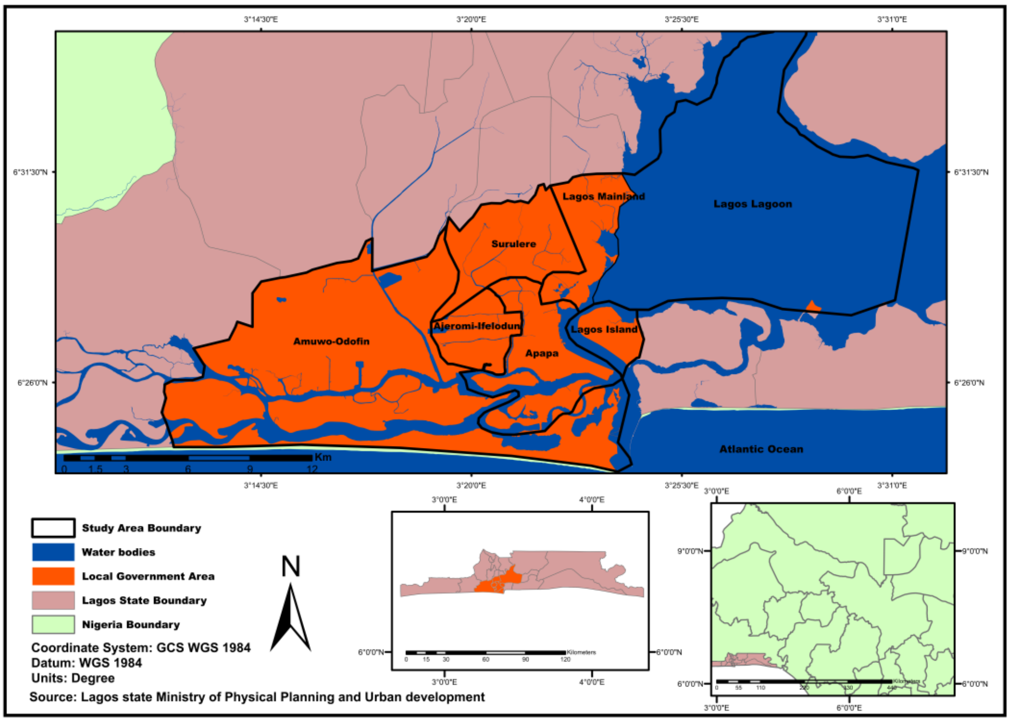


Figure 3.1: Study area in Lagos State, Nigeria.

The study area covers approximately 395 km^2, and lies between 3°12′E and 3°24′E longitude and 6°24′N and 6°31′N latitude. Elevations range from 38m below sea level to 52m above sea level. Four dominant land-cover categories were identified using a RapidEye image (20/12/2015) which included vegetated area (20.1%), water (47.9%), open space (8.5%), and built-up area (23.5%) (Figure 3.2).

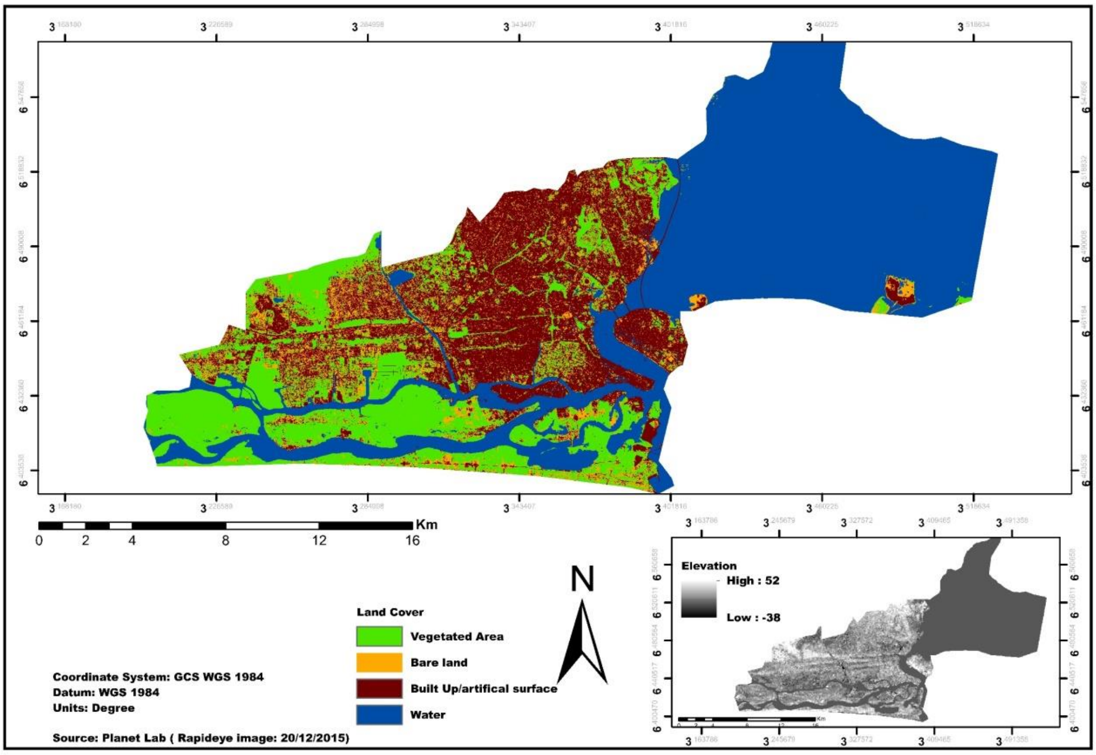


Figure 3.2: Land-cover map and digital elevation model of the study area. The map is based on classified RapidEye data acquired on 20 December 2015.

According to Onokerhoraye (1995), there are two types of deprived urban areas in Nigeria: squatter communities and slums. Squatter communities are uncontrolled or temporary dwellings inhabited by migrants from within and outside the city, while slums are old residential areas built long ago in line with the then-prevailing urban planning, zoning, and construction standards, but now dilapidated and overcrowded. The research conducted by Lagos-State/UNCHS (1984) shows that Lagos has the two deprived areas (Figure 3.3). Further, the Lagos state government sometimes includes squatter under the category of slums due to the similar physical characteristics, as observed in the Lagos Metropolitan Development and Governance Project (2006) where water, roads, and electricity were provided to nine blighted communities (Agege, Ajegunle, Amukoko, Badia, Iwaya, Makoko, Ilaje, Bariga, Ijeshatedo/Itire) without considering if these were a squatter community or slum. In this study, squatters and slums were equally considered to prevent bias, as they all need to be monitored and improved.

Figure 3.3: Squatter (A) and slum (B) communities in Lagos (2017)

3.2.2. Data

The satellite images utilized in this study were from RapidEye, through the RapidEye science archive, acquired on 29 November 2009 and 20 December 2015 (Table 3.1). Other data utilized were vector data (roads, water, land-use maps, etc.) obtained from the Lagos State Ministry of Physical Planning and Urban Development. The imagery was not radiometrically calibrated because it was a Level 3A product (radiometric, sensor, and geometrically corrected). However, atmospheric correction and haze removal was done using ATCOR 2 on all the scenes. The corrected scenes were mosaicked and the study area subset was derived using its shapefile.

Table 3.1: Satellite imagery description.

Data Source/Type	**Acquired Scene**	**Spatial Resolution**	**Acquisition Date**
RapidEye/Level 3A	3142015_2009-11-29_RE2_3A_412557	5	29 November 2009
RapidEye/Level 3A	3142016_2009-11-29_RE2_3A_412557	5	29 November 2009
RapidEye/Level 3A	3142017_2009-11-29_RE2_3A_412557	5	29 November 2009
RapidEye/Level 3A	3142116_2009-11-29_RE2_3A_412557	5	29 November 2009
RapidEye/Level 3A	3142117_2009-11-29_RE2_3A_412557	5	29 November 2009
RapidEye/Level 3A	3142015_2015-12-20_RE4_3A_412557	5	20 December 2015
RapidEye/Level 3A	3142016_2015-12-20_RE4_3A_412557	5	20 December 2015
RapidEye/Level 3A	3142017_2015-12-20_RE4_3A_412557	5	20 December 2015
RapidEye/Level 3A	3142116_2015-12-20_RE4_3A_412557	5	20 December 2015
RapidEye/Level 3A	3142117_2015-12-20_RE4_3A_412557	5	20 December 2015

3.3. Overview of Methodology

This section presents the methodology applied in this study. The flowchart represents the successive steps taken (Figure 3.4)

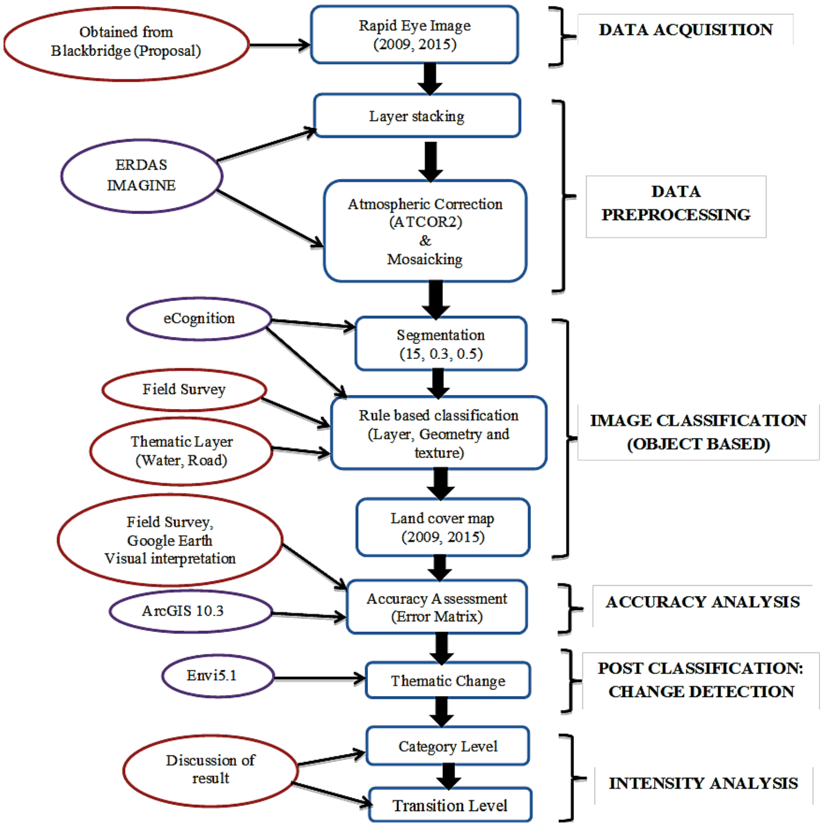


Figure 3.4: Work flow of study.

3.3.1. Data Processing

Change detection from satellite imageries can be from pre-classification or post-classification. This study applied the post-classification techniques to detect changes in the land-use maps developed from the satellite images acquired at different dates. This technique includes data pre-processing, image classification, accuracy assessment, and change detection (Huang et al., 2012). Post-classification is widely utilized because it provides a matrix of land transition among different categories (Manandhar et al., 2010), which serves as the input data for the intensity analysis. The thematic change workflow in the ENVI software package was applied to detect spatial changes in the extent of slums and other identified LULCC in the maps produced for 2009 and 2015.

3.3.2. Classification of Imagery

The images were analyzed using the object-based image analysis (OBIA). This analysis is conducted in two stages, i.e., segmentation of the image into homogenous objects based on their spectral and spatial/contextual properties, and classification of identified objects into different land-use or land-cover categories (Blaschke, 2010; Duro, Franklin, & Dubé, 2012). The subset images were segmented using the multi-resolution segmentation algorithm in the eCognition Developer software using scale factor, shape, and compactness values of 15, 0.3, and 0.5, respectively. Additionally, a weight of 2 was assigned to band 3 (red) of the image, because the reflectance of built-up areas is high in this band. Existing road and water layers were used as predefined boundaries for the segmentation process. The classification of the segmented image was carried out using the rule set classification method, which allows the combination of OBIA with expert knowledge and integration with GIS data to produce a better result, especially in the extraction of slums from other land-use types in urban areas (Sliuzas et al., 2008).

Before classifying the image, a reconnaissance survey and review of the literature were used to develop slum ontology (Kohli et al., 2012), to serve as a comprehensive basis for the object-based image classification of the slums in the study area. This includes:

At the environs level:

- Nearness to water bodies could not be used as some of the planned communities were also located close to the water bodies
- Some of the slums were located close to employment opportunities in Lagos (markets, central business district, industrial sites, etc.)
- Need to combine the slums and squatter communities as they have similar manifestation in Lagos
- Most of the squatter communities along the express road have been demolished by previous governments
- In some parts of the city, there were no distinct boundaries between the planned communities and the slum communities.

At the settlement level:

- Most of the slums were highly compacted

- The shapes of the slums were irregular.

At the object level:

- Roof type could be used to determine the use of some buildings in the study area
- Although some of the slum communities have paved roads, unpaved roads and footpaths were important observations to identify slums.

The implication of these observations was that some of the rules applied in the extraction of slums from satellite images, e.g., closeness to rivers or roads, were not entirely applicable in Lagos. Hence, extractions of most of the slum buildings were based on the textural properties of objects at the settlement level. Table 3.2 presents the categorization and analysis of the observations listed above based on the ontological framework and its OBIA parameterization.

Table 3.2: Adaptation of generic slum ontology concepts to an ontology for Lagos, with OBIA parameterization at environs, settlements, and object level

Level	Indicator	Observation (Lagos)	OBIA Parameterization
Environs	Location	Located on river banks and marshy areas	Vector layer water: Min. overlap on water bodies
	Neighborhood characteristics	Close to employment opportunities (central business district, industries etc.)	Not used due to absence of spatial data on economic opportunities
		No defined boundaries between planned and slum communities.	Not used due to absence of spatial data on different types of residential land use in the city
		Some public buildings were poorly maintained and needed to be extracted to prevent misclassification	Vector layer of public buildings to extract those buildings
Settlement	Density	Denser than the planned communities	Texture—GLCM
	Shape	Irregular	Not used
Object	Building	Roof materials: corrugated iron sheets, concrete and plastic	Spectral—Layer mean values
	Access network	Unpaved roads and footpaths	Not used

Using trial and error techniques and studies (Mhangara, Odindi, Kleyn, & Remas, 2011; Shekhar, 2012a; Sori, 2012; Kohli, Warwadekar, Kerle, Sliuzas, & Stein, 2013), rule sets were developed to classify the images into classes, i.e., background, water bodies, slum, road, open space, vegetated area and other urban areas. The 2015 image was classified first, and the rule set transferred to the 2009 image with minor changes in some of the values. Tables 3.3 and 3.4 describe the parameters used for the classification, and summarize what each class represents and the rule set utilized for their extraction from other land use types in the study area, respectively.

Table 3.3: Parameters used in the image classification of the study area

Parameter	Description
Normalized difference vegetation index NDVI	Index used to measure vegetation
Mean Blue	Mean intensity of all pixels forming an image in blue band
Mean NIR	Mean intensity of all pixels forming an image in NIR band
Density	Distribution in space of the pixels of an image object
Brightness	Mean intensity of all pixels forming an image object
Relative border to road	The ratio of the shared border length of an image object (with a neighboring image object assigned to road) to the total border length
Minimum overlap with a thematic polygon	Computes the maximum value of the overlap between an image object and a selected vector layer in percent
$GLCM_{BLUE\_CONTRAST}$	Measure of the amount of local variation in the image in blue band
$GLCM_{RED\_CONTRAST}$	Measure of the amount of local variation in the image in red band
Red ratio	Enhancement of red band

Source: Trimble Documentation: reference Book, 2014

Table 3.4: Land-use classes and rule sets used for classification in eCognition.

	Land-use class	**Description**	**Rule Set for 2009**	**Rule Set for 2015**
1	Background	Black background	Mean blue = 0	Mean blue = 0
2	Water	Lagoon, rivers, ponds, reservoirs, swamps, waterways	Mean NIR ≤ 840	Mean NIR ≤ 1075
3	Vegetated area	Sparse and dense vegetation, forest, grassland	NDVI ≥ 0.34	NDVI ≥ 0.34
4	Road	Roads (primary and secondary), tarred road	Road layer map Density ≤ 1 and Relative border to road ≥ 0.5	Road layer map Density ≤ 1 and Relative border to road ≥ 0.5
5	Other urban areas	Other built-up areas (residential, public, commercial, industrial, etc.) except slums	Brightness ≥ 1700 $GLCM_{BLUE\_CONTRAST}$ ≥ 400 $Ratio_{RED}$ ≥ 0.207 Min. overlap (old industrial and public space) ≥ 20	Brightness ≥ 1700 $GLCM_{BLUE\_CONTRAST}$ ≥ 400 $Ratio_{RED}$ ≥ 0.219 Min. overlap (old industrial and public space) ≥ 20 $GLCM_{RED\_CONTRAST}$ ≥ 420
6	Slum	Slum and squatter communities	Min. overlap water ≥ 95% 210 ≥ $GLCM_{BLUE\_CONTRAST}$ ≥ 65 $GLCM_{RED\_CONTRAST}$ ≤ 200 1050 ≥ Mean red ≥ 900	Min. overlap water ≥ 95% 210 ≥ $GLCM_{BLUE\_CONTRAST}$ ≥ 65 $GLCM_{RED\_CONTRAST}$ ≤ 200 1050 ≥ Mean red ≥ 900
7	Open space	Exposed soil, concrete floor, dump sites, etc.	0.34 ≥ NDVI ≥ 0.245 $GLCM_{BLUE\_CONTRAST}$ ≤ 65	0.34 ≥ NDVI ≥ 0.23 $GLCM_{BLUE\_CONTRAST}$ ≤ 65

The first step was the classification of the non-built up area, which includes background, water, vegetated area, open space, and road. The *background* was classified as anything with a mean blue value of zero. The existing water polygon could not be utilized because of the encroachment of other land-use categories on the water bodies, hence a mean NIR value of less than 1075 for 2015 and 840 for 2009 was used to classify *water*. The thematic layer of road available was a line vector map, which was only able to classify the object under it, and to classify the exempted part, the density and relative border to the already-classified *road* was utilized. Normalized difference vegetation index (NDVI) values above 0.34 were used to classify *vegetated area*. *Open space* was classified using an NDVI value less than 0.34 but greater than 0.23. Additionally $GLCM_{BLUE\_CONTRAST}$ below 65 was classified as *open space*.

Brightness, $GLCM_{BLUE\_CONTRAST}$, $GLCM_{RED\_CONTRAST}$, and $Ratio_{RED}$ values greater than 1700, 400, 420, and 0.219, respectively, were used to classify *other urban areas*. The available thematic layer for the public and old industrial buildings was also utilized to classify *other urban area*. *Slum* was classified using the min. overlap of the water layer on the remaining unclassified objects; $GLCM_{BLUE\_CONTRAST}$ between 210 and 65; $GLCM_{RED\_CONTRAST}$ above 200, and mean red between 1050 and 900. The remaining unclassified objects were assigned to the *other urban area* class. The classified objects were exported from eCognition to ArcGIS for accuracy assessment

3.3.3. Accuracy Assessment

A thematic map derived from a classification is considered accurate if it provides an unbiased representation of the land cover it portrays (Foody, 2002). An extensive field survey was conducted in the study area for verification of the developed LULCC maps. Although 600 points (100 from each local government) were randomly selected using ArcGIS Random points, only 449 and 455 reference points were utilized for the 2009 and 2015 images respectively (Table 3.5). This was due to inaccessibility to some of the sites and the unstable nature of some of the reference points. The assessment was complemented with the support of the *historical view* tool in Google Earth for 2009 and 2015, especially for the 2009 classification of *water* and *vegetated area*. Using these reference points, an error matrix was generated in ArcGis 10.3 to calculate the producer, user, and overall accuracy of the LULCC maps. Finally, a concordance analysis was implemented, and the Cohen kappa statistic computed (Congalton, 1991).

Table 3.5: Sample sizes allotted to the targeted land-use class in 2009 and 2015.

Land-use	**Verified Reference Points**	
	2009	**2015**
Vegetated area	129	117
Open space	54	59
Other urban area	69	71
Road	42	49
Slum	77	80
Water	78	78
Total	**449**	**455**

3.3.4. Intensity Analysis

Since slums have distinctive spatial characteristics (Sietchiping, 2005), intensity analysis can help to understand the underlying processes leading to their observed growth pattern. Intensity analysis compares the predicted annual uniform rate of change, the rate that will exist if the annual changes were distributed uniformly over the entire time extent, against the observed annual rate of change among categories (Pontius et al., 2013). It is based on the availability of maps of different time periods for the same sites containing the same land-use categories. The application and limitations of intensity analysis have been discussed in several studies (see Pontius et al., 2004; Aldwaik & Pontius, 2012; Huang et al., 2012; Zhou et al., 2014; Yang et al., 2017).

As this study focused on one time interval (2009–2015), the category and transition levels of the intensity analysis were employed. The category level examines the size and speed of loss and gain for each land-use category within a time interval, implying the gain (Gtj) or loss (Lti). It also gives information on which land-use category is dormant or active during that time interval (*Equation 3.1 and 3.2*). The transition level informs whether a land-use category is being targeted or ignored during a time interval. It is calculated in two parts, i.e., transition "to" and transition "from". (i) The transition "to" examines transition of other categories to a land-use category "n" during a time interval (*Equation 3.3*) and the expected uniform intensity of transition "to" (*Equation 3.4*), and (ii) the transition "from", which examines how other land-use categories transit from category "m" (*Equation 3.5*). The uniform intensity of transition "from" is also calculated (*Equation 3.6*).

Category level:

$$G_{tj} == \frac{\left[\left(\sum_{i=1}^{J} C_{tij}\right) - C_{tjj}\right] / Y_{t+1} - Y_t}{\sum_{i=1}^{J} C_{tij}} \times 100\% \qquad (Equation\ 3.1)$$

$$L_{ti} == \frac{\left[\left(\sum_{j=1}^{J} C_{tij}\right) - C_{tii}\right] / Y_{t+1} - Y_t}{\sum_{j=1}^{J} C_{tij}} \times 100\% \qquad (Equation\ 3.2)$$

Transition level:

$$R_{tin} = \frac{C_{tin} / (Y_{t+1} - Y_t)}{\sum_{j=1}^{J} C_{tij}} \times 100\% \qquad (Equation\ 3.3)$$

$$W_{tn} = \frac{\left[\left(\sum_{i=1}^{J} C_{tin}\right) - C_{tnn}\right]/(Y_{t+1} - Y_t)}{\sum_{j=1}^{J}\left[\left(\sum_{i=1}^{J} C_{tij}\right) - C_{tnj}\right]} \times 100\% \qquad (Equation\ 3.4)$$

$$Q_{tmj} = \frac{C_{tmj}/(Y_{t+1} - Y_t)}{\sum_{i=1}^{J} C_{tij}} \times 100\% \qquad (Equation\ 3.5)$$

$$V_{tn} = \frac{\left[\left(\sum_{j=1}^{J} C_{tmj}\right) - C_{tmm}\right]/(Y_{t+1} - Y_t)}{\sum_{i=1}^{J}\left[\left(\sum_{j=1}^{J} C_{tij}\right) - C_{tim}\right]} \times 100\% \qquad (Equation\ 3.6)$$

Symbol	Definition
J	Number of categories
i	Index for a category at the initial time point for a particular time interval
j	Index for a category at the final time point for a particular time interval
m	Index for the losing category in the transition of interest
n	Index for the gaining category in the transition of interest
T	Number of time points
t	Index for the initial time point of interval $[Y_{t,}Y_{t+1}]$, where t ranges from 1 to T − 1
Y_t	Year at time point t
Cij	Number of pixels that transition from category i at time Y_t to category j at time Y_{t+1}
G_{tj}	Annual intensity of gross gain of category j for time interval $[Y_t,Y_{t+1}]$
L_{ti}	Annual intensity of gross loss of category i for time interval $[Y_t,Y_{t+1}]$
R_{tin}	Annual intensity of transition from category i to category n during time interval $[Yt,Y_{t+1}]$ where i ≠ n
W_{tn}	Value of uniform intensity of transition to category n from all non-n categories at time Yt during time interval $[Y_t,Y_{t+1}]$
Q_{tmj}	Annual intensity of transition from category m to category j during time interval $[Y_t,Y_{t+1}]$ where *j ≠ m*
V_{tm}	Value of uniform intensity of transition from category m to all non-m categories at time $[Y_{t+1}]$;during time interval $[Y_t,Y_{t+1}]$

Mathematical notation for intensity analysis
Source: Aldwaik & Pontius, 2012*:107*

3.4. Results

3.4.1. Production of Land-Use and Land-cover Maps and Accuracy Assessment

Based on the integration of OBIA with expert knowledge and GIS data, a LULCC map of the study area was developed for 2009 and 2015. Six LULCC (water, vegetated area, open space, other urban areas, roads, and slums) were derived from the RapidEye images (Figure 3.5 a and b). Overall accuracies of 94% and 89% were estimated for the produced LULCC maps of 2009 and 2015, respectively. Kappa coefficients of 0.9 and 0.86 were achieved for the 2009 and 2015 classified map respectively. Furthermore, user and producer accuracies for each land-use category were above 75% for the two maps, except for *open space*, which reached 66.1%, and could be attributed to the heterogeneous nature of the land-use category (Table 3.6).

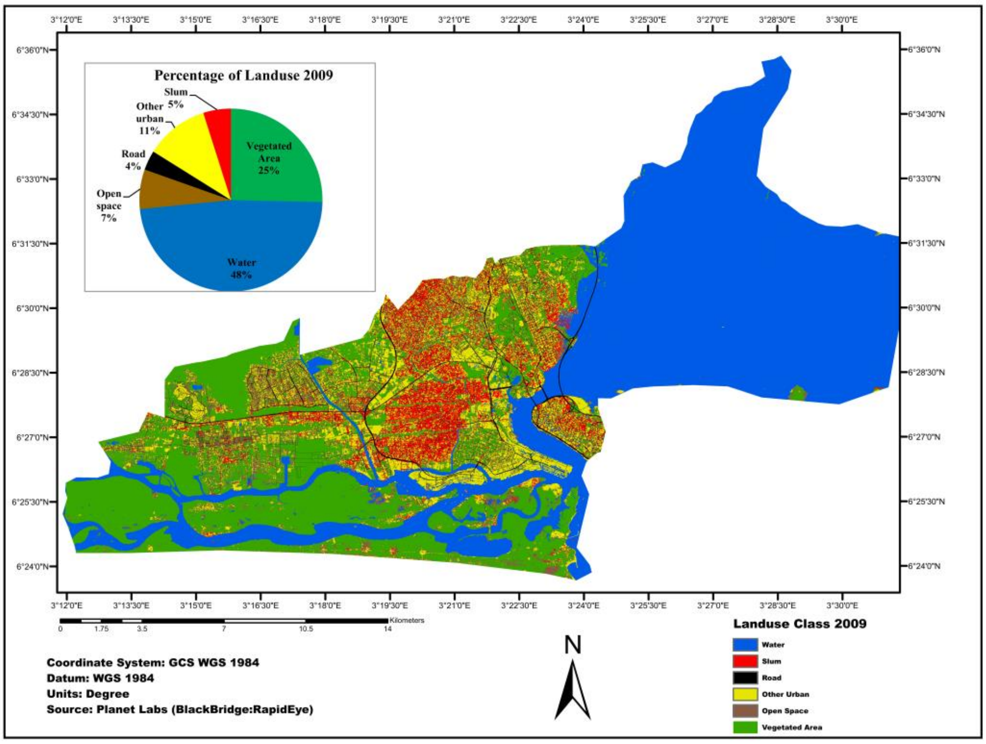


Figure 3.5a: Land-use/cover map of study area in 2009

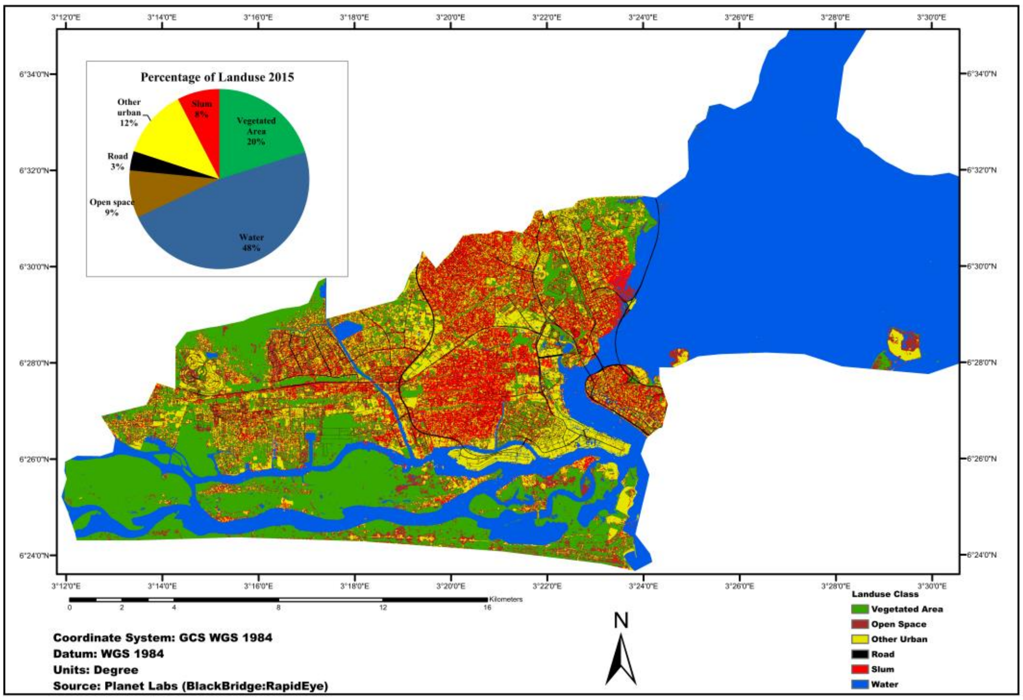


Figure 3.5b: Land-use/cover map of study area in in 2015

Table 3.6: Summary of land-use/cover map accuracies (%) for 2009 and 2015

	2009		2015	
Land Use	**User Accuracy (%)**	**Producer Accuracy (%)**	**User Accuracy (%)**	**Producer Accuracy (%)**
Water	98.7	100.0	100.0	100.0
Vegetated Area	100.0	100.0	100.0	100.0
Open	88.0	77.0	78.0	66.1
Slum	88.0	86.0	76.7	85.0
Other urban	83.0	91.0	77.5	87.3
Road	100.0	98.0	98.0	79.6
Overall Accuracy	**94.0**		**89.0**	
kappa coefficient:	**0.9**		**0.86**	

3.4.2. Observed Patterns of Land Use and Land Cover Change Dynamics

3.4.2.1. Visual Interpretation

Figure 3.6 presents a map showing the detected changes in the land-use pattern in the study area during the time interval studied. The map gives information on the final state of the use of the land area. Transitions in all land-use categories were observed during this time interval. Changes were observed in the proportion of areas covered by each land category, except *water*, though small changes may have occurred. Furthermore, the area of change increased for *slum*, *open space*, *road*, and *other urban areas*, while it decreased for *vegetated area*. Although the share of land area occupied by slums (Figure 3.5 a,b) was smaller than that of other categories, its total net gain was higher compared to the others (Figure 3.7).

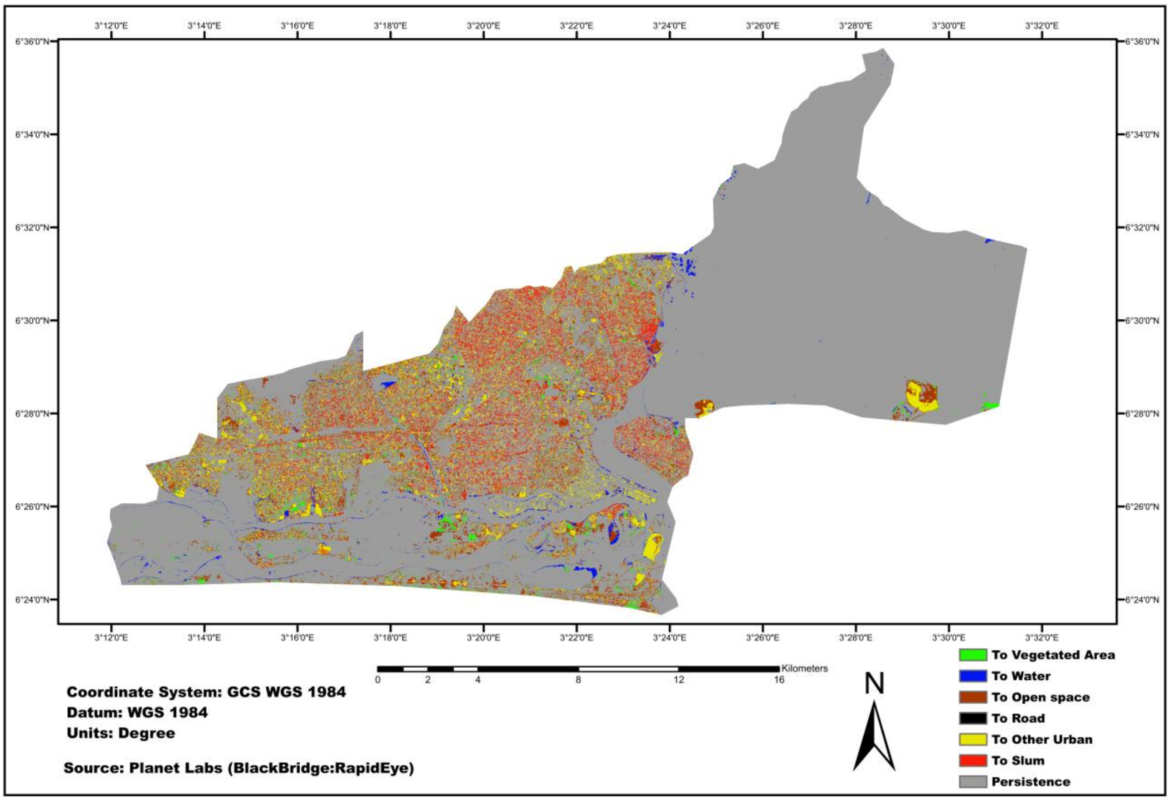


Figure 3.6: Detected changes in the research area from 2009 to 2015

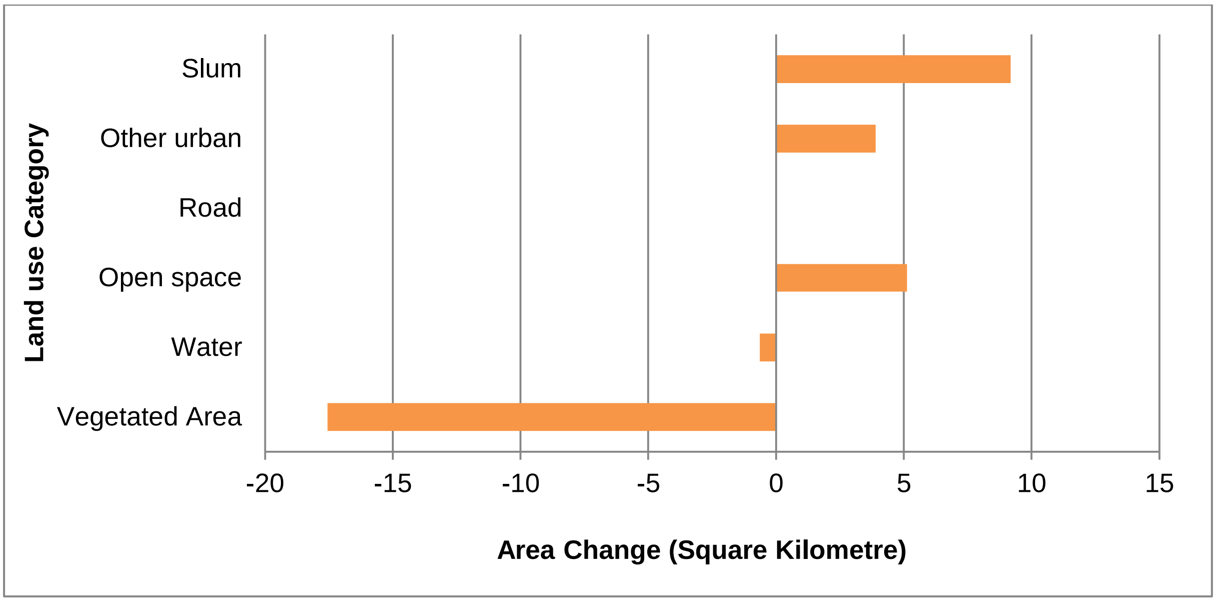


Figure 3.7: Area change of land-use categories in the research area from 2009 to 2015

3.4.2.2. Quantification

Table 3.7 presents the pattern of LULCC in the study area. Water is the dominant land-cover category accounting for 47–48% of the two time points, followed by vegetated area

(20–25%). These two categories contributed to the high percentage of persistent land use observed during this time interval (81.1%). Vegetated area suffered the highest loss among the land-use categories with a net loss of about 6%. This is common in urban areas, where the vegetated area is usually encroached upon during urban expansion, especially when it is near urban areas (Song & Deng, 2015). Overall, a swapping of land area was observed in all land-use categories, indicating simultaneous loss and gain by all categories except roads. However, the swap change is larger than the net change for slums, other urban areas, water, and open spaces, implying spatial reallocation rather than net quantity changes for these land-use categories.

Table 3.7: Land-use and land-cover changes in the period 2009–2015 (%)

Land Use	Total 2009	Total 2015	Persistence	Gain	loss	Total Change	Swap	Absolute Value of Net Change
Vegetated area	25.34	20.14	18.62	1.52	6.73	8.25	3.05	** 5.20
Water	48.08	47.90	46.92	0.98	1.17	2.15	1.96	** 0.19
Open space	6.99	8.51	2.37	6.14	4.62	10.77	9.25	1.52
Road	3.47	3.46	3.46	0.00	0.01	0.01	0.00	0.01
Other urban	11.22	12.38	6.73	5.64	4.49	10.13	8.98	1.16
Slum	4.89	7.61	3.01	4.60	1.88	6.48	3.76	2.72
Total	100	100	81.11	18.89	18.89	37.78	26.99	10.79

***net loss.*

3.4.3. Intensity Analysis

3.4.3.1. Category Level

The interval level of intensity analysis required at least two time intervals in order to compare the size and speed of change across different time intervals. However, this study utilized only one time interval (2009–2015) due to the unavailability of data; hence, the interval level was excluded. The category level of the intensity analysis gives information about which land-use category is relatively dormant or active during a particular time interval. Category loss and gain maps are illustrated in Figure 3.8 a and b.

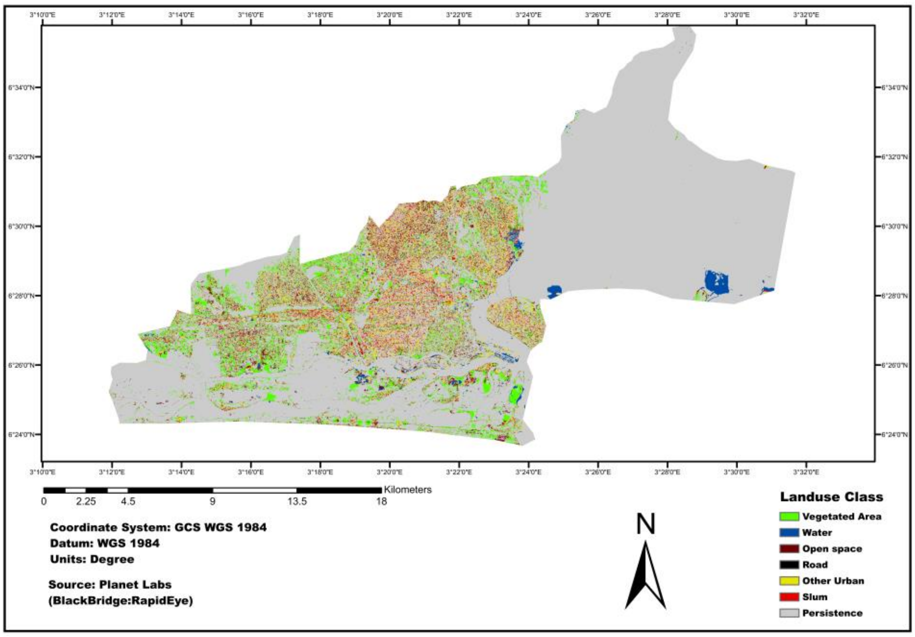


Figure 3.8a: Land-use category loss intensity analysis

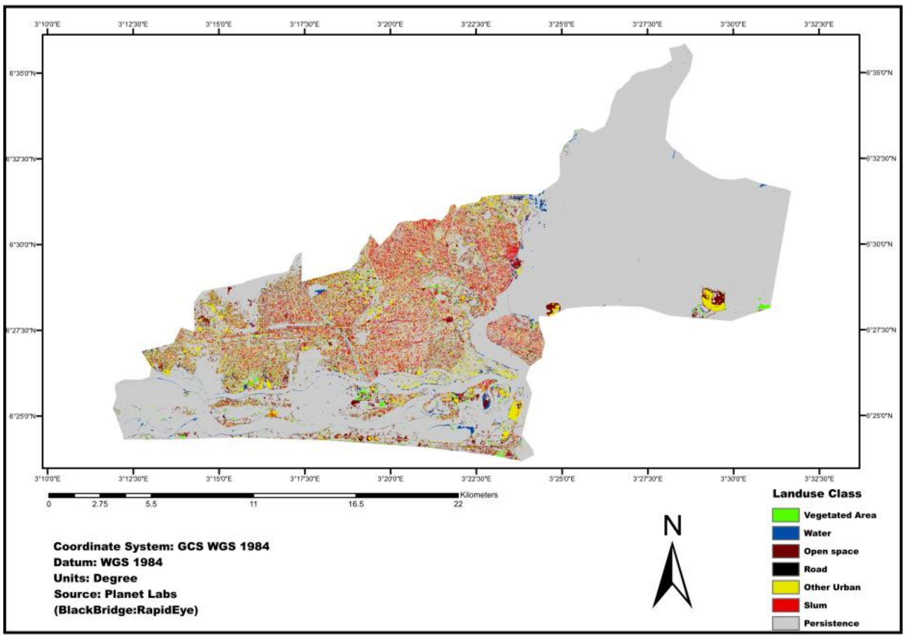


Figure 3.8b: Land-use category gain intensity analysis

The graphical representation of the intensity analysis of loss and gain for the land-use categories from 2009 to 2015 is given in Figure 3.9 a and b. The bar to the left gives the area of changes (pixel), while the right gives the intensity of the changes (percent). The dotted vertical line gives the uniform intensity. If an intensity bar extends beyond the uniform intensity line, the category is considered to be active, and if it is within the line, the category is considered dormant during the given time interval.

It could be observed that *vegetated area, slum, other urban areas*, and *open space* were actively losing their land areas to other land-use categories from 2009-2015 (Figure 3.9a). Although the right side of the bar shows that *water* was dormant, the left side shows that it also lost some of its land area during this time interval. The dormant state of water bodies during this time interval could be attributed to their large size, and if the size included in the domain is reduced, it could also become an active class. As Pontius et al. (2013) noted in their study in Central Kalimantan, Indonesia, the large size of a persistent land-use category could influence the result of the intensity analysis. Hence, it is important to also consider the area change of the bar to get a better insight into intensity changes of different land-use categories. Furthermore, while *slum*, *other urban areas*, and *open space* were actively losing, they were also actively gaining (Figure 3.9b), making them the most active land-use categories in the study area between 2009 and 2015.

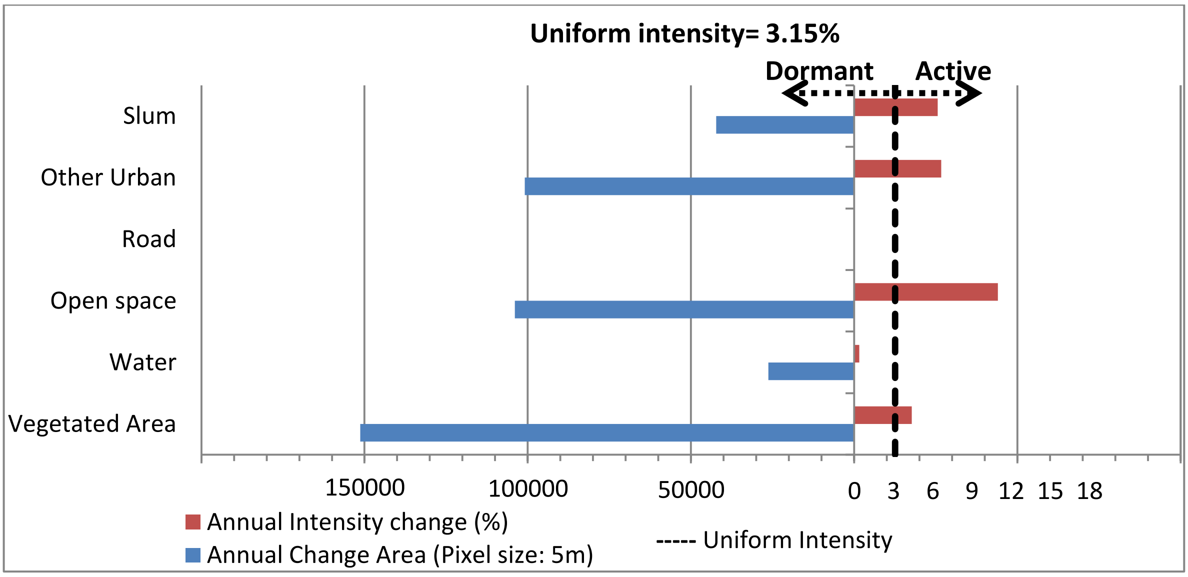


Figure 3.9a: The category loss intensity for 2009–2015 in the research area

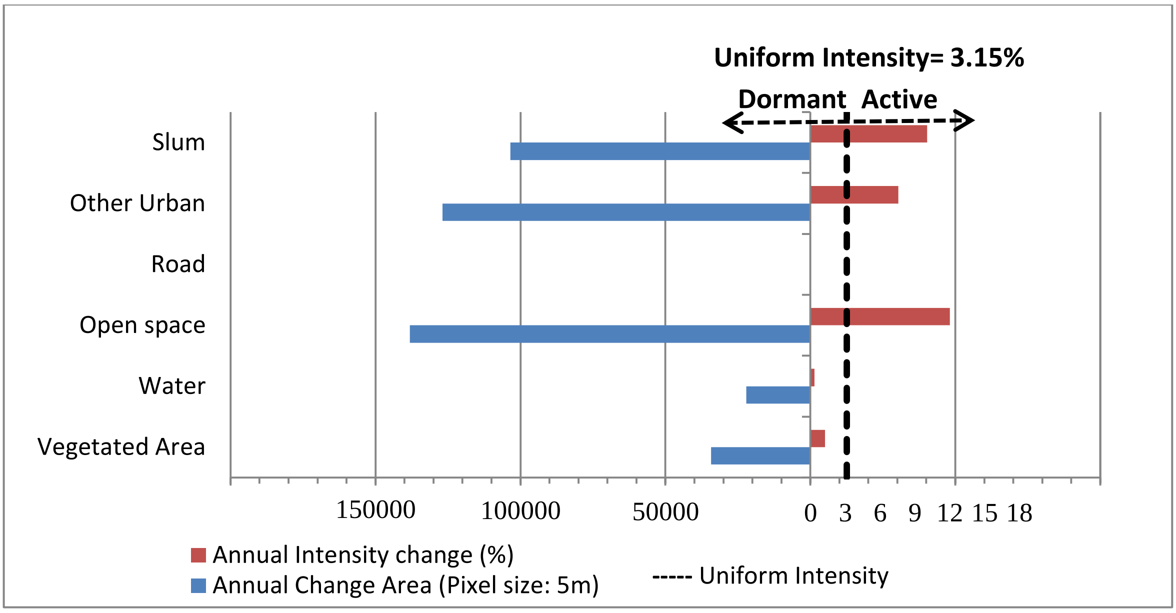


Figure 3.9b: The category gain intensity for 2009–2015 in the research area.

3.4.3.2. Transition Level

As described above, slums were active (losing and gaining) during the studied time interval. This leads to the next question: Which land category were slums losing to and gaining from? Figure 3.10 presents the map of the transition and examples of the transition observed in the research area.

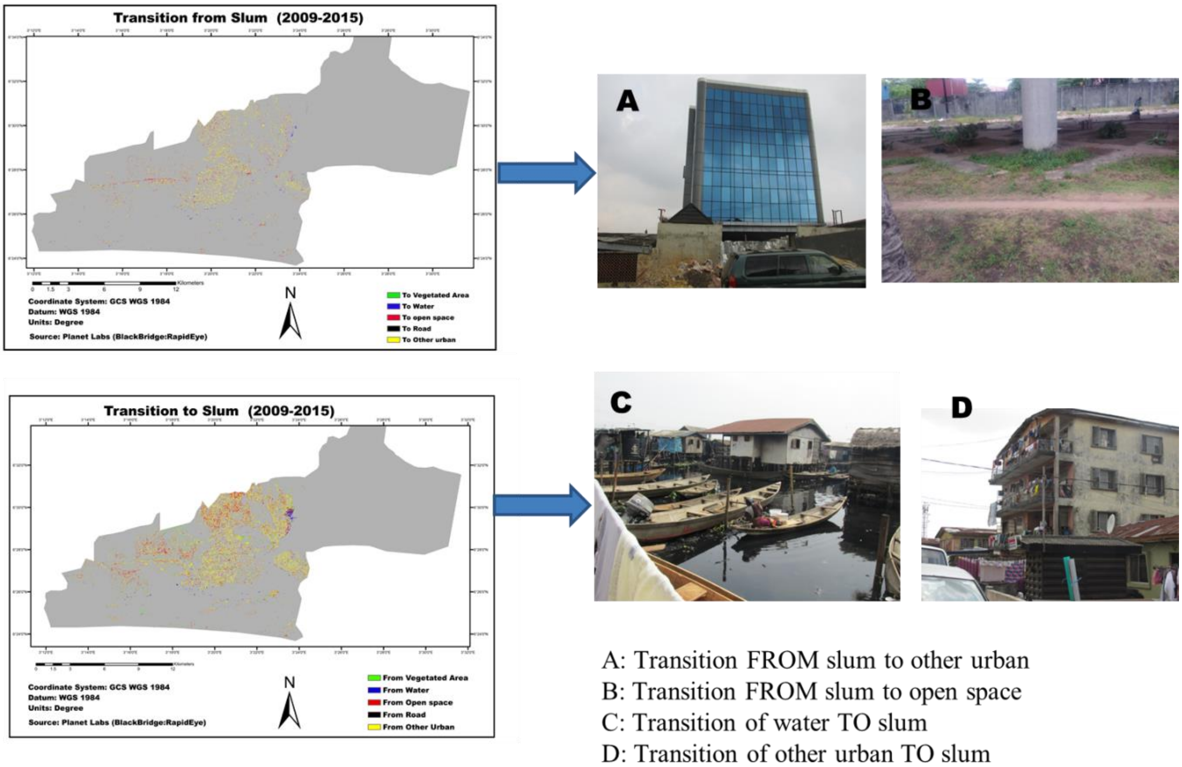


Figure 3.10: Transition of land-use categories in the research area 2009-2015

Figure 3.11 presents the graphical representation of transition **from** slum (a) and transition **to** slum (b). The bar extending to the left on the vertical axis shows the size of each transition (pixel), while the right side of the vertical axis gives the intensity of transition. The dotted vertical line is the uniform transition intensity, and any bar that extends beyond the uniform line denotes targets, while a bar within the uniform line means a target is being avoided.

Figure 3.11a presents the transition from *slum* to other land-use categories. During this time interval, *other urban area* and *road* were targeting *slum*, so *slum* experienced high rates of conversion into *other urban areas* and *open space*. However, *slum* avoids conversion to *water* and *vegetated area* during this time interval. *Slum* also targeted *other urban* and *open space* (Figure 3.11b). On the one hand, *slum* was targeted by both *open space* and *other urban areas;* while on the other hand, *slum* also targeted both *other urban areas* and *open space*. Hence, the transition observed between slums and other urban areas is a systematic process of transition (Aldwaik & Pontius, 2012). Further, the rate at which other land-use categories transition to *slum* is higher than the rate of transition of *slum* to other land-use categories (Figure 3.12). This implies that slum growth is faster than its decline. Although the results show that *water* is avoided by *slum*, this is actually not the case, as it was observed during the field survey that *slum* encroached on *water body* (Figure 3.10). This omission was due to the large size of water in the study area.

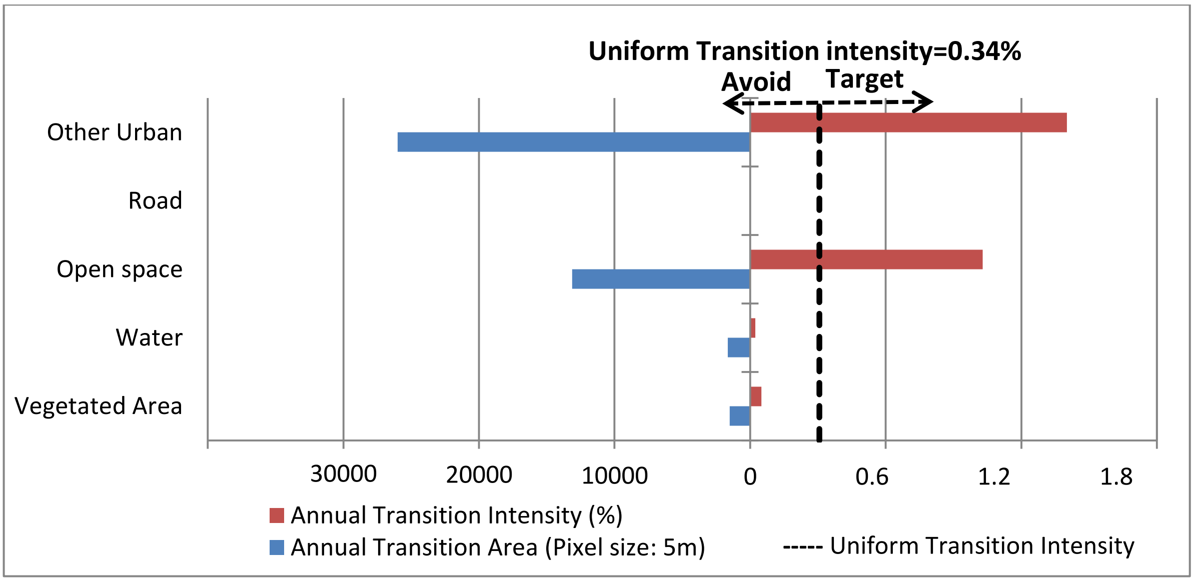


Figure 3.11a: Transition intensity analysis "from" slum (2009–2015)

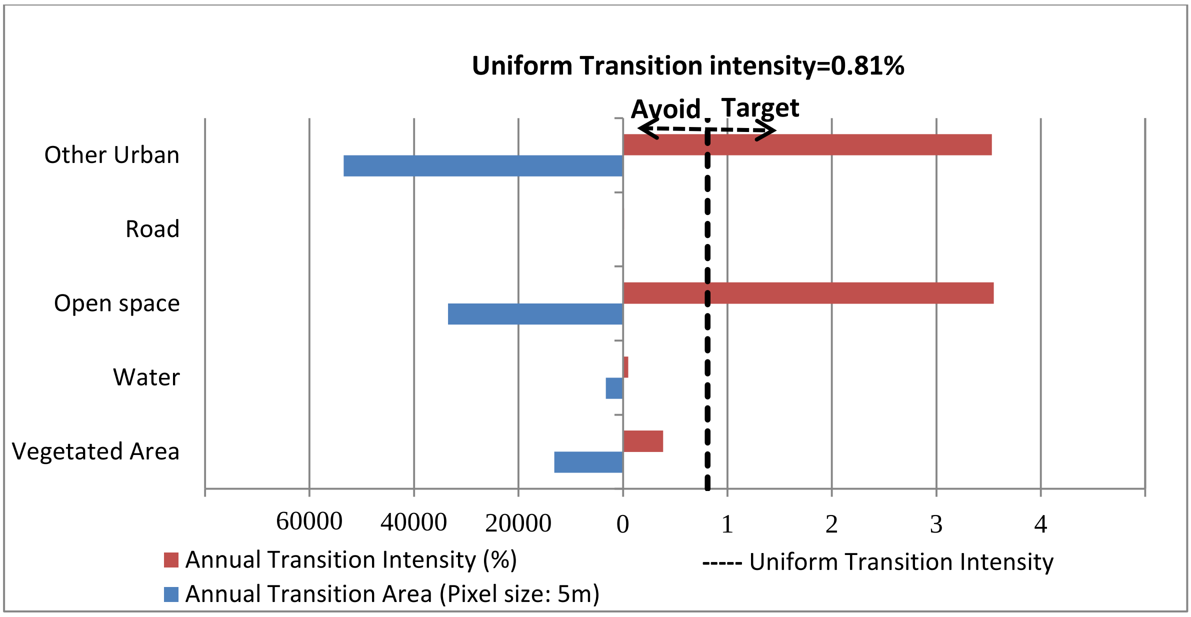


Figure 3.11b: Transition intensity analysis "to" slum (2009–2015)

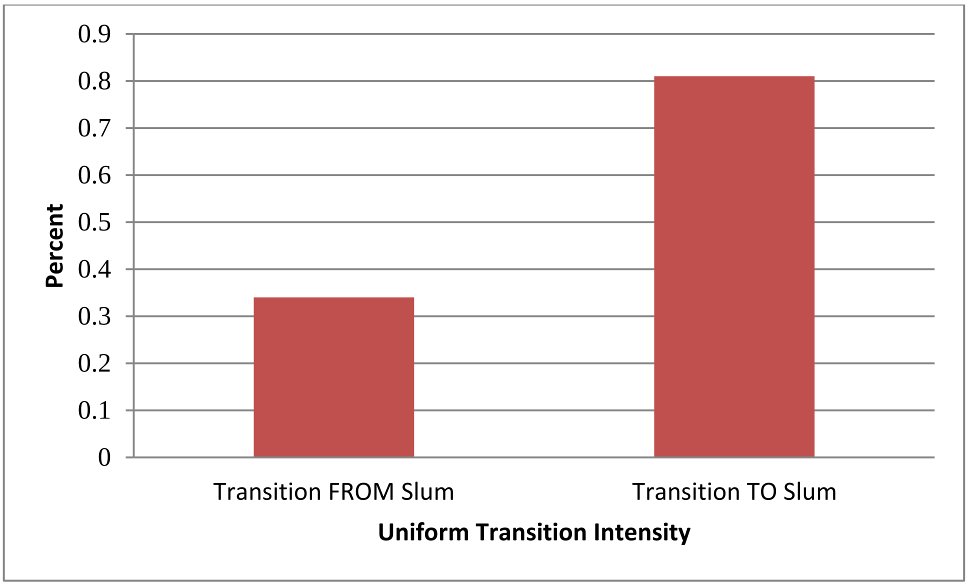


Figure 3.12: Comparison of uniform transition intensity of slum 2009-2015

3.5. Discussion: From Pattern to Process

Overall Change: This study utilized RapidEye imagery and intensity analysis to classify and quantitatively analyze the pattern and process of slum growth in Lagos from 2009 to 2015. The overall results show an area increase in the intensity of land utilized by *open space*, *other urban* and *slum*, and a decrease in that of the *vegetated area* (Figure 3.7). According to Adepoju, Millington and Tansey (2006), the reduction in vegetated areas in Lagos, through conversion to other land-use categories, was due to the rapid population growth. This was attributed to in-migration rather than to natural increase (Immerwahr, 2007; Aluko, 2010). The city is the economic hub and former capital of Nigeria, and continues to be a pulling factor for many migrants with little or no livelihood experience in large cities. Migrants only consider the benefits of moving and not the challenges that might be experienced through moving (Aworemi, Abdul-Azeez, & Opoola, 2011). The implication is that many migrants were absorbed into the already established slum communities, which led to their growth.

Process involved in the transition of slum to other land-use categories. Though the overall results show a net increase in the *slum* area, it can be seen that some of the initial land area covered by *slum* in 2009 had been converted to other land-use categories in 2015 (*open space* and *other urban areas*). Demolition of existing slums (e.g., Badia, Makoko, Iwaya, Ilubirin) by the Lagos state government contributed to the transition of *slum* to other land-use categories in this interval. Some of these demolitions were documented by Amnesty International (2017) in their report "The human cost of a megacity, forced evictions of the urban poor in Lagos, Nigeria". The Lagos state government's response to reducing slum proliferation is mostly slum clearance, after eviction of the slum residents, as a means to maintain city standards. However, Nwanna (2012) argued that most of the observed slum clearance in Lagos is for profit maximization, as most of these slums are located on prime development land. For instance, Ilubirin, formerly a squatter community, is currently being converted to a high-income residential apartment area. Such measures are common in squatter communities in Lagos, primarily due to the illegality of these communities. However, in the case of slums where residents have a legal right to the land that their buildings were constructed upon, dwellers lease out or sell their land to private developers, who then convert them to high-priced rental houses. Such an example can be seen in the Onike and Itire environs. Slum clearance and its redevelopment to high-income residential areas is a form of gentrification in Lagos. Furthermore, squatter communities along major roads (e.g., Obalende axis) were demolished by the Lagos state government as part of their agenda to beautify the city. Thus, the transition of slums to other land-use categories in the study area was due to demolition and gentrification processes.

Process involved in the transition of other land-use categories to slum. According to Olthuis et al. (2015), slums tend to evolve into hazardous sites such as water bodies. This trend was also observed in the study area, where slum communities were found to have encroached on water bodies (Figure 3.10). Slums near water bodies have a high tendency to encroach on water bodies. Although the transition level in the intensity analysis showed that water bodies were avoided by slums during the study period, this omission was associated with the large size of the water bodies in the study area.

The transition from *other urban areas* to *slum* comprises buildings that have been poorly maintained (Figure 3.10). This study focused on the older section of Lagos where the colonial style of houses was still common. Most of the colonial housing in Lagos is difficult to maintain because of inadequate technical knowhow and unavailability of foreign materials, leading to poor maintenance (Adejimi, 2005). In addition, poor maintenance of existing buildings is attributed to the poverty level in the city. Approximately 66.9% of Lagos residents live below the poverty line (Lagos Bureau of Statistics, 2014) and, according to Oduwaye and Lawanson (2007), poverty is a cause of environmental stress in the city. Many house owners lack the required financial resources to maintain/improve their homes.

Furthermore, the Lagos state government concentrated development in other sections of the city (Lagos Island axis) during 2009-2015. Hence, expansion of squatter communities was observed especially close to the existing ones. Slum upgrading measures by the Lagos state government (e.g., Lagos Metropolitan Development and Governance Project, 2006) were primarily through the provision of infrastructural facilities and not through the improvement of housing structures. Hence, many buildings from spaces still had similar textural properties.

3.6. Conclusions

The results of this study contributes to slum mapping in West Africa, as not many studies focus on Nigeria or Lagos, though Lagos had been infamously referred to as a megacity of slums. The study uses object-based image analysis building on the generic slum ontology. Its main contribution is the use of intensity analysis to link pattern and process of slum growth in Lagos. It is shown that through integration of object-based image analysis with expert knowledge and geographical information system data, slums could be delineated from other land-use categories in Lagos using RapidEye imagery. An overall accuracy of 94% and 89%, and kappa coefficients of 0.9 and 0.86, were achieved for the 2009 and 2015 land-use and land-cover maps, respectively. The results show that from 2009 to 2015, the spatial extent of slums increased, with a net gain of about 9.14 km^2. This was attributed to population growth due to in-migration to the city.

Category and transition level of the intensity analysis was applied to quantitatively analyze the pattern of slum growth in Lagos. The annual gain and loss intensity of slums from 2009-2015 was 10.08% and 6.41%, respectively, compared to the annual uniform intensity of 3.15%, thus making slums an active land-use category in Lagos in this time interval. At the transition level of intensity analysis, a systematic process of transition was observed between slums and other urban areas, as well as slums and open space, which were influenced by the Lagos state government. When the government exerts its power in the study area, slums are converted to other land-use categories, and vice versa. Furthermore, the calculated uniform transition intensity "to" slum (0.81) was higher than the uniform transition intensity "from" slum (0.34). This implies that slum growth was faster than slum decline in the interval studied.

Demolition and gentrification were the major processes contributing to the loss of slum land area to other land-use categories in the study area. Transition of other urban areas to slums was attributed to poor maintenance of existing building structures due to poverty and unavailable resources. Further, slums encroached on water bodies; however, the transition level of the intensity analysis could not capture this process as an active process, because of the size of the water bodies in the study area. Slums in prime locations were often demolished; while new ones emerged in the least desirable areas, e.g., close to water bodies, partly due to the scarcity of land in the study area.

Slums will continue to be a major challenge to the urban landscape if the status quo persists. It is hoped that the findings presented in this paper will assist in policy-driven initiatives on slum management such as monitoring of land-use categories targeted by slums to prevent further slum expansion, and contribute to the body of knowledge on slum dynamics in emerging economies, especially in data-scarce countries. Although this study captures the applicability of object-based image analysis and intensity analysis to map and quantitatively link the pattern and process of slum growth in Lagos, there is scope for further improvement. The remotely-sensed data utilized in this study was for only two periods due to the limited availability of data covering the older section of Lagos, thus leading to the exemption of the interval level of intensity analysis. A broader coverage, including the whole city with more years of remotely-sensed data can provide further insights into slum dynamics in Lagos, Nigeria.

4. ASSESSING THE IMPORTANCE OF RESIDENTS' DECISIONS ON SLUM POPULATION GROWTH IN LAGOS

Source: Badmos, O., Callo-Concha, D., Agbola, B., Rienow, A., Badmos, B., Greve, K., & Jürgens, C. (2018). Determinants of Residential Location Choices by Slum Dwellers in Lagos Megacity (Under Review)

Abstract: The complexity of slums has made them an important phenomenon in city development planning, especially in African countries where slum growth is on a par with urban growth. However, our knowledge on the residential choice of slum dwellers, which contributes to population growth in slums, is limited. This is the case in Lagos, a megacity reportedly dominated by slum dwellers. This study thus aims to investigate the factors influencing the residential choices and reasons of the people to remain in the Lagos slums. Data was collected through questionnaires and focus group discussions in slums in Lagos. Descriptive statistics was used to analyze and describe the factors influencing the residential location choice, and logistic regression was used to determine the extent to which the neighborhood and household attributes influence slum dwellers' decisions to remain in the slums. The findings show that movement to Lagos was the main causes of population growth in the slums; most of the migrants were from nearby geopolitical zones in Nigeria. Furthermore, the movement patterns observed in this study support two theories of human mobility in slums: a slum as a sink and a slum as a final destination. Also, the factors that attract most of the slum dwellers to the slums (cheap housing, proximity to job opportunities, etc.) differ from those that made them wish to stay (duration of stay, housing status, etc.). We conclude that residential choice and intention to stay are the major contributors to population growth in Lagos slums. It is therefore important for the Lagos state Government to incorporate these elements in their slum management policies if the city is to be free of slums by 2030.

Keyword; Migration, population growth, residential decision, slum, Lagos

4.1. Introduction

Urbanization in Africa is sometimes described as “parasitic urbanism”, “urbanization of poverty” or “premature urbanism” (Obeng-Odoom, 2010:13). The motives and forms of urbanization in most African cities differ from those of the planned cities, characteristics of Western countries (Hope, 1998; Fay & Opal, 1999; Fox, 2012). The consequence of this type of urbanization is a high slum proliferation, making slums the dominant residential land-use type (Simon et al., 2013; Hofmann et al., 2015). Coupled with this, the demographic forecasts predict that some African countries will experience a massive population growth (United Nation Population Division, 2011), which will possibly lead to further slum growth if the status quo persists, as urban population growth is on a par with slum growth in Africa (Davis, 2004; Marx et al., 2013).

Although slums are broadly described using four major criteria: i.e. socioeconomic based on income, employment and economic activities of slum dwellers; physical based on housing typology, access to services and infrastructure; legal based on land ownership; and spatial location (Kohli et al., 2012; Srinivas, 2015), experts still finds it difficult to reach a consensus on a unified description of slums (Pratomo et al., 2017). However, the UN-Habitat (2010) portrayal of slum as a physical and spatial manifestation of urban poverty and intra-city inequality shows how crucial its growth should be curbed during city planning, especially in cities aiming to be free of slums by 2030, either through upgrading of existing slum or preventing new ones from springing up.

Slum growth could either be defined as area or as population growth. While the advancement of remote sensing and geographical information systems had eased the possibility to study the spatio-temporal dynamics of slums (Shekhar, 2012b; Kit & Lüdeke, 2013; Badmos, Rienow, Callo-Concha, Greve, & Jürgens, 2018), studying the slum population dynamics, with respect to slum dwellers movement pattern, is complicated (Wesolowski & Eagle, 2009). This can be attributed to the diversity in the origin, development and challenges of these slums (Dung-Gwom, 2007).

Theories on human mobility in slum can be summarized into four: i) movement of people from rural area to urban slums, work and then move to the outskirt of the city due to improvement in their socioeconomic status (upward housing mobility of migrants); ii) movement of people from rural area to urban slums, work and then move to other slums, due to inability to improve their socioeconomic status (slum as a sink); iii) movement of people from rural areas to urban slums, work and stay in the same slum all their lives (slum as final destination); and iv) movement of people from rural area to urban slums, work and move back to the rural area (Wesolowski & Eagle, 2009: Figure 4.1). Although it would have been expected that migration to urban slums will follow the first theory, however, shortage of affordable housing in developing country cities (Wu, 2006) may permanently put many migrants in the same or similar slums, even if their income level increases. For instance Wesolowski and Eagle (2009) shows that slum dwellers in Kiberia, Nairobi move within the slums following the third theory. Also the study conducted by Sanford School of Public Policy at Duke University shows that slum dwellers in Karnataka, India follows the second theory (Bengaluru, 2018). This implies that slums are probably not a transition stage for prospective migrants, rather permanent throughout their lifetime.

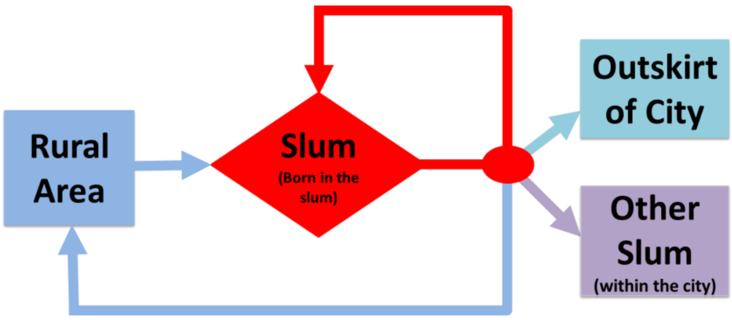


Figure 4.1: Theories of human mobility in slums
Source: Adapted from Wesolowski & Eagle, 2009

The characteristics of different locations are important determinants of slum growth (Olthuis et al., 2015). For instance, Lall, Lundberg and Shalizi (2008) observed that in addition to housing quality, neighborhood amenities and community structures, classical housing location choices, i.e., commuting cost, local public goods and neighborhood composition, were also contributory factors determining the choice of location by slum dwellers in Pune, India. According to Davis (2004), presence of religious activities in a location attracts slum growth. Debnath and Naznin (2011) also observed in their study of the Dhakar metropolitan development plan in Bangladesh that there is a spatial dependence between slum agglomeration and industrial concentration. Location of slum may also be a function of tribal affiliation and family linkage (Olajuyigbe et al., 2015). Migrants will prefer to settle in neighborhoods that share similar socio-cultural backgrounds

(Malpezzi & Sa-Adu, 1996 in Sietchiping, 2005). Most of these migrants are brought to the city by their relatives, with whom they live while they find their footing or secure accommodation within the slum community or move to another one (Owusu, 2004). Hence, it appears key to go beyond migration to study the contributing factors of slum proliferation. Factors leading to choice of residential location by slum dwellers as well as factors responsible for their decision to remain in the slum after moving in should also be considered. In addition, when a resettlement is planned, a community structure can still be maintained based on the location decision choices of slum dwellers, as many slum dwellers prefer to stay close to those sharing common socio-demographic characteristics such as language, religion, etc. (Kapoor et al., 2004).

Residential decision is based on the decision to move and the location choice, provided there is intention to move (Kim, Pagliara, & Preston, 2005). Though the pull factor to the urban area for many migrants is considerable due to social and economic reasons, factors leading to prolonged stay of migrants in their new residence in the urban area, especially slums, is difficult to ascertain (De Jong, 1994; Mudege & Zulu, 2011). For instance low income might dissuade some migrants from moving out of their residence while "tied" migrants (wives) might not be able to move because they do not drive the decision to move or stay(Marsden & Tepperman, 1985; Chepngeno-Langat & Ezeh, 2007). The attachment to neighborhood have also been identified as a causative to prolong stay in a locality, but the aged had a stronger attachment than the working class and migrants, attributed to long time commitment to their neighborhoods (Wu, 2012). Additionally, migrants who stay away from their place of origin for a long period might be reluctant to go back, especially when they feel unsatisfied with their lives; hence becoming trapped in the slums (Mudege & Zulu, 2011). Further, satisfaction in a particular residence prolong migrants stay in a residence, but dissatisfaction will not make them leave, especially when there is no alternative (Chepngeno-Langat & Ezeh, 2007; Mudege & Zulu, 2011).

Although there are many studies on migration in the context of slum dynamics(e.g. Beguy, Bocquier, & Zulu, 2010), but only few studies on the residential decisions of slum dwellers, especially in Africa, with high slum proliferations. Contributing to this was the fact that many of the classical theories/models used in residential location studies (e.g. Alonso, 1964; Muth, 1969; etc.) were developed after studies carried out in Western cities (Phe &

Wakely, 2000). Moreover, these studies were carried out in the context of well-developed housing policies and programs (Limbumba, 2010). Africa, by the features that characterize its urbanization, e.g., complex urban structures, high poverty rate, unemployment, inadequate housing, etc., likely drifts away from some of the determinants identified in these studies and theories, making these at least only partially applicable.

A few studies have attempted to bridge the gap on residential location choices in Africa. Acheampong and Anokye (2013) utilized the Alonso model of access-space-trade-off to explain household decisions to live in peri-urban Kumasi, Ghana; they observed that relatively low land price and house rents were the contributing factors for living in the peri-urban area. Limbumba (2010) qualitatively explored the factors contributing to the residential location choices by urban residents in Dar es Salaam, Tanzania, and reported that the information passed through informal channels on available accommodation, free rent, proximity to relatives and people of the same socioeconomic status were the key determinants. Mudege and Zulu (2011) also examined how satisfaction with slum life affects migrants' decisions to stay or move away from slum communities in Nairobi, Kenya, and reported that land tenure, age group of migrants, and dissatisfaction with their environment were the major factors contributing to their satisfaction in slum life. Further, Ige and Nekhwevha (2014) explores how the level of deprivation can predicts slum dwellers willingness to relocate in Badia, Nigeria, and reported that slum dwellers are willing to relocate based on their socio-demographic characteristics and not on the level of deprivation. These studies separately analyzed decision to move and location choices, but not their relationship or their influence on the population growth.

In the past, the Lagos state government had a laissez-faire attitude to the slum situation, which contributed to its growth over several decades. Before 1999, slum settlements were conspicuously located along major roads, coastlines and under the bridge of Lagos metropolis. But changes in Government and the neoliberal approach adopted to governance since 1999, towards the regeneration of Lagos into a befitting megacity, led to new slum management approaches, such as: increasing slum clearances (e.g. Ilubiri, Otodo-Gbame), relocation of slum dwellers (e.g. Adeniji-Adele) and limited slum upgrading (e.g. Lagos Metropolitan Development and Governance Project). Although, reasons given for such approaches, especially slum clearance, was security and health, Nwanna (2012) argues that it was for profit maximization, as many slums in Lagos are located on prime development land. Despite this, slums in Lagos have increased in area and population, mainly due to slum displacement (Sule, 1990; Morka, 2007).

Badmos et al. (2018) demonstrated that slums in Lagos have grown in area, however the intricacies behind the slum growth cannot be determined based on Earth observation technology. Furthermore, while it is important to curb slum growth, the approach utilized is also crucial. Smit, Musango, Kovacic, and Brent, (2017:110) advocates the need for sustainable system approach where slums are considered as “i) integral part of the city; ii) affecting the living standards and opportunities of their inhabitants; and (iii) influencing and being influenced by the developmental perspectives of the cities and societies in which they occur“. This will involve understanding the system, i.e. city, as whole; the sub-systems, e.g. slums, in particular; and their relationship (Clayton & Radcliffe, 1996). As there is a link between residence and pattern of social interaction and socialization(Wu, 2006), this study therefore seek to analyze the; (i)movement pattern of slum dwellers in Lagos; (ii) factors influencing the residential choices of slum dwellers; and (iii)factors influencing slum dwellers decision to stay/or move from their residence in Lagos.

This paper is structured as follows: section 4.1 presents the rationale and aim of the study; section 4.2 presents the study areas; section 4.3 gives the methodology; section 4.4 presents the results and discussion; and section 4.5 gives the conclusions.

4.2. Study area

The study was carried out in the city of Lagos, located in south-western Nigeria, and lies between longitude 2°42’E and 3°42’E and latitude 6°22’N and 6°52’N. The region covers approximately 1,171km^2 of which about 20% are water bodies. It is the second fastest growing city in Africa with an annual population growth rate of 3.4% (United Nations Department of Economics and Social Affairs Populations Division, 2018). This growth is mainly due to its location on the western coast of Africa, which profits from the development of trade in its hinterland and the neighboring countries, and its role as the first administrative capital of Nigeria (Adelekan, 2010). It is one of the most chaotic and least planned mega cities in the world (Hartley et al., 2013), hence infamously called the megacity of slums (IRIN, 2006).

In 1984, the United Nation Development Program identified forty-two degraded communities in Lagos, classified as slums and squatter communities, based on their level of decay and tenancy (Lagos-State/UNCHS, 1984). Tenancy is defined based on the legality of land the communities were built upon. Squatters are communities dominated by illegal buildings structures while slums communities is dominated by legal buildings but dilapidated and overcrowded (Onokerhoraye, 1995) Four of these communities were selected for this study, i.e., Ajegunle and Iwaya (squatter), and Ikorodu and Itire (slums) (Figure 4.2).

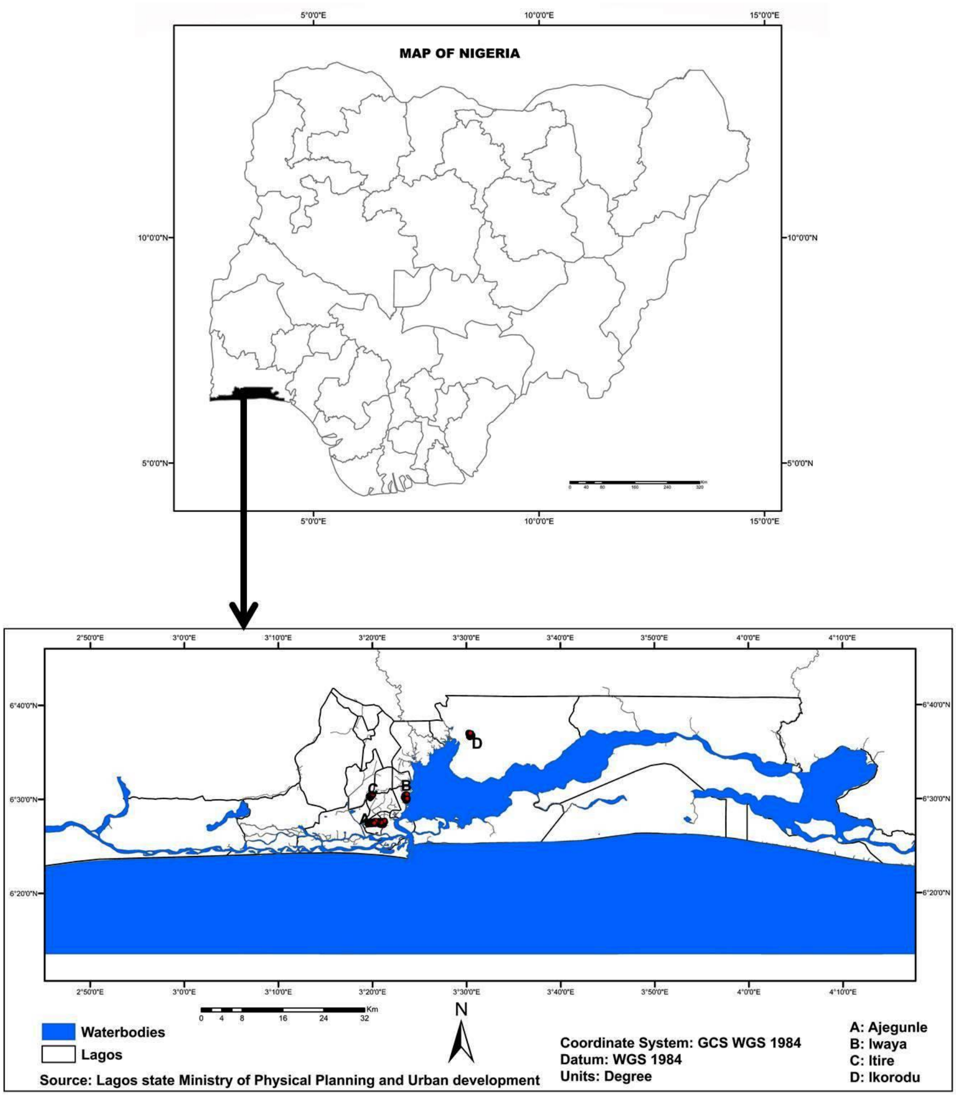


Figure 4.2: Map of study areas and sample points in Lagos

Ajegunle

Ajegunle (meaning place where riches dwell), colloquially called “AJ” or “jungle city”, is located in the Ajeromi Ifelodun local government area. It is a cosmopolitan squatter community that comprises different ethnic groups (Yoruba, Hausa, Igbo, Ijaw, etc.). Although its population was estimated to be 156,000 based on the 1995 projection, the Lagos state Government estimated it to be 500,000 based on occupancy rates, tenement rates and properties assessed for property taxes leading to a population density of about 750 people per hectares (Agbola & Agunbiade, 2009). It is the largest blighted community in Nigeria. In the past, Ajegunle served as the boundary between the Lagos colony and the western region (New Telegraph, 2015). Its proximity to the two biggest seaports in Nigeria (Apapa Wharf and Tincan Island) contributed to its popularity and growth, as it hosted the workers who worked there. Its growth led to encroachment on the water bodies as buildings were built on silt deposits. Majority of the residents of this community engage in trading and other informal activities including tailoring, barbing, bricklayer, hairdressing etc. (Figure 4.3).

Figure 4.3 A*jegunle (2016)*

Iwaya

Iwaya is a squatter community located in Lagos mainland local government area. The population was estimated to be 58,000 with population density of 725 persons per hectares in the 1995 projection (Agbola & Agunbiade, 2009). It has continued to grow because of its proximity to the University of Lagos, Lagos Island and Lagos Lagoon. It has also encroached on water bodies, which can be observed from the Lagos third mainland bridge. Several ethnic groups live in Iwaya, but are segregated in sub-communities such as Iwaya Central, Ago Egun, Pedro/Shogunro, etc. It harbors a high concentration of poor people (Action Health Incorporated, 2011), but some of the residents are blue-collar workers (Kunnuji, 2015). Some of the residents also engage in fishing, trading, carpentry etc. Iwaya has experienced several demolition exercises and forceful eviction of its residents. In August 2017, more than 200 houses were reported to be demolished by the Lagos state Government (Sahara Reporters, 2017) (Figure 4.4).

Figure 4.4: Ago Area, Iwaya (2016)

Itire

Itire is a slum community located in Surulere local government area. The population was estimated to be 41,769 with a population density of 663 persons per hectare in the 1995 projection (Agbola & Agunbiade, 2009). The community is dominated by the Yoruba ethnic group, followed by the Ibo. In the past, Itire was a village on the fringe of Old Lagos city, which was later, absorbed through the city's expansion. Itire experienced population growth after the resettlement of Lagos Island residents to the Surulere Government Reserved Area and its environs as a result of the slum clearance in Lagos Island following the bubonic plague (1925-1928). Itire has become attractive to many people of different socioeconomic status because it is centrally located and bordered by major express roads. Some of the residents engage in activities such as trading, mechanical work, tiling, catering, office work etc. (Figure 4.5).

Figure 4.5: Itire (2016)

Ikorodu

Ikorodu slum is located in the Ikorodu local government area, a peri-urban area in Lagos State (Table 4.1). The population was estimated to be 40,194 with a population density of 638 persons per hectare in the 1995 projection (Agbola & Agunbiade, 2009). It is dominated by the Yoruba ethnic group. The site comprises the oldest section of Ikorodu town. Many rather refer to it as "agboole" (family compound) rather than a slum community (King of Ikorodu, personal communication). The community still exhibits the characteristics of a traditional Yoruba town, as most of the houses are of mud type. The acquisition of land for industrial uses, dualization of the Lagos-Ikorodu road, and the establishment of secondary and tertiary activities led to population and economic growth in the local government area (Dekolo & Olayinka, 2013). The occupation of the residents includes trading, tailoring, barbing, pottery etc. (Figure 4.6).

Figure 4.6: Ikorodu (2017)

Table 4.1: Characteristics of the study communities

Communities	**Local government area**	**Area (ha)**	**Size**	**Legality status**	**Location and boundaries**	**Biophysical characteristics**
Ajegunle	Ajeromi-Ifelodun	208*	Large	Squatter	Central	Land and water
Iwaya	Lagos Mainland	80*	Medium	Squatter	Central	Land and water
Itire	Surulere	63*	Medium	Slum	Central	Land
Ikorodu	Ikorodu	63*	Medium	Slum	Peripheral	Land

Adapted from *SNC-Lavalin, (1995); UN-Habitat, (2003)

4.3 Methodology

4.3.1 Data Collection

This study utilized a mixed methods approach, which combines quantitative and qualitative data, to determine the movement pattern of slum dwellers, factors influencing the residential choices and reasons of the people to remain in Lagos slums/squatter communities. Quantitative data was collected via questionnaires, while qualitative data was collected during focus group discussions (FGD) with residents of the sampled slums/squatter communities (Figure 4.7)

First, a reconnaissance survey was carried out to understand the social and spatial structure of the communities. As people of similar ethnic groups were observed to cluster together, the participants for the FGD were subsampled from the observed ethnic clusters. In addition, the fishnet tool of ArcGIS 10.3 was used to randomly select the buildings where questionnaires were administered to guarantee the coverage of all sections of the community. The data collected during the survey included the socioeconomic characteristics, settlement history, reasons for choice of location of respondents, and physical characteristics of the buildings/neighborhood. During the FGD, various issues relating to the respondents' choice of residential location were discussed. The aim of the FGD was also to perform a quality control of the administered questionnaires. This study received ethical clearance and all ethical process of confidentiality and informed consent were followed. All the names used in this study are pseudonyms.

Questionnaire administration

Focus group discussion

Figure 4.7: Data Collection in the study communities 2016 (left) and 2017 (right)

4.3.2 Sample Size

The last reliable reference of the population size for the slum communities in Lagos is twenty-one years old (SNC-Lavalin, 1995) and the city is growing very fast (World Population Review, 2015). Thus, the sample size was based on scientific representatives rather than statistical one (Rothman, 2012), and was calculated using the small sample technique (Krejcie & Morgan, 1970; Equation 4.1).

$$S = \frac{X^2NP(1-P)}{d^2(N-1)+X^2P(1-P)} \quad (Equation\ 4.1)$$

Where:

S= required sample size

X^2= table value of chi-square for 1 degree of freedom at the desired confidence level (3.841)

N= population size (estimated to be 1,000,000)

P= population proportion (assumed to be 0.50 since this provides the maximum sample size)

d = degree of accuracy expressed as a proportion (0.05).

The number of questionnaires administered in each community was based on their proportionate fraction in the projected population for 2016 calculated after the SNC-Lavalin (1995) baseline population (Table 4.2). The sample unit was a household, and the respondent was generally the household head, or alternatively the oldest family member available older than 18 years.

Table 4.2: Sample size

Community	Estimated population (2016)	Number of households	Proportion	Number of questionnaires
Ajegunle	321271	53545	0.529	203
Iwaya	119447	19908	0.195	75
Itire	86020	14337	0.141	54
Ikorodu	82777	13796	0.135	52
Total	609516	101586	1.000	384

Source: Projected from SNC-Lavalin (1995)

4.3.3 Data Analysis

4.3.3.1 Socioeconomic characteristics and movement pattern of dwellers of slums/squatter communities

Descriptive statistics was applied to summarize the socioeconomic characteristics of the respondents as well as the inter- and intra-movement pattern. Further, a chi-square test was applied to assess the sample fitting and Cramer's V for the strength of the association. Finally, correlations between the socioeconomic characteristics of the respondents in the communities were determined.

4.3.3.2 Slum Index

In order to characterize the sampled household buildings, a slum index was calculated using parameters which included overcrowding, building characteristics, and availability of facilities such as water, toilets and roads (Olajuyigbe et al., 2015).

Overcrowding is one of the attributes of slum households (UN-Habitat, 2003). According to WHO (2005) and UN-Habitat (2008), it occurs when more than two people share the same dwelling unit (in Olajuyigbe et al., 2015). We estimated the average size of a dwelling to be less than 9 m^2 in the sampled communities. Overcrowding was calculated by dividing the number of bedrooms by the number of household members (Equation 4.2). A result of above two was considered overcrowded.

$$Overcrowding = \frac{Number\ of\ household\ members}{Number\ of\ bedrooms} \quad (Equation\ 4.2)$$

Roofs and walls can be used for characterization of a slum building (Kohli et al., 2012). For instance, sagging and patched roofs were mostly found in the old and poorly constructed houses. Moreover, buildings constructed with wood were considered to be temporary, while those constructed with bricks and blocks were considered to be permanent. Any building with a sagging or patched roof was rated low.

Availability of facilities such as water, toilets and roads are important criteria to define a slum household (UN-Habitat, 2003), and buildings without access to water or precarious facilities, e.g. open wells, were deemed to lack water facilities. Buildings without toilets or with pit latrines were also considered lacking toilet facilities. In the case of roads, footpath or no defined access to buildings were considered as inaccessible, while buildings with paved and unpaved road were considered accessible.

Each attribute was scored 0 or 1 to represent it's absent or presence respectively. The total score for each building was summed up to provide the decay severity score. A building with a score of six (6) was considered optimal, while zero (0) meant decayed

4.3.3.3 Residential location choices

The pull factors to the slum were summarized in charts, which were complemented with content analysis based on the transcript of the FGD. Further, a Likert scale (Likert, 1932) was applied to explore the respondents' perception of the most important factors influencing their choice of residential location. The selected drivers utilized in the Likert scale were based on previous studies (Davis, 2004; Sietchiping, 2005; Debnath & Naznin, 2011; Olajuyigbe et al., 2015).

4.3.3.4 Decision to remain in slum

The decision to remain in a particular community is crucial to residential studies (Kim et al., 2005). A household will decide to move if there is dissatisfaction with the present neighborhood, change in family structure, or due to institutional policies (Wong, 2002; Clark & Huang, 2003). The focus of this study is on the importance of neighborhood and household characteristics regarding slum dwellers' decision to stay in/move from the community. A logistic regression was applied to estimate the factors contributing to the slum dwellers intention to stay. Some of the parameters in the regression model were based on previous studies (Walker, Marsh, Wardman, & Niner, 2002; Clark & Huang, 2003; Kim et al., 2005; Wu, 2006). Here, the intention to stay/move is hypothesized to be a function of the socioeconomic characteristics of respondents, dwelling type and neighborhood affinity (Equation 4.3). A variance inflation factor was used to test for multicollinearity among the predictor variables leading to the exemption of age, employment, and education from the logistic regression model.

$$Intention\ to\ stay = f(GENDER, MAR\_STAT, HOU\_OWN, NBH, NUR, BIRT, FPT\_CAL, DUR\ , PLA\_WRK, INCM, AFF\_HOU, QU\_BU, TOLT, NEI\_ATT)\ (Equation\ 4.3)$$

Table 4.3: Description of parameters incorporated in the logistic regression

Parameters	Symbol	Definition
Dependent Variable	Stay (1) or Move (0)	
socio-economic characteristics of respondents	Gender	Gender
	MAR_STAT	Marital status
	HOU_OWN	Housing Ownership (owned or rented)
	NBH	Number of people in household
	BIRT	Place of birth in community
	FPT_CAL	First point of call
	DUR	Duration of stay
	PLA_WRK	Place of work
	INCM	Monthly income
Dwelling type	NUR	Number of bedrooms occupied
	AFF_HOU	Affordable housing
	QU_BU	Quality of building (roof, wall)
	TOLT	Toilet facilities
Neighborhood attachment	NEI_ATT	Neighborhood attachment

Source: Walker, Marsh, Wardman, & Niner, 2002; Clark & Huang, 2003; Kim et al., 2005; Wu, 2006

4.4 Results and discussion

4.4.1 Socioeconomic profile of dwellers of slums/squatter communities

Most of the respondents were male, as in most Nigerian homes males perform as household heads. It was observed that the Ikorodu community profile deviates from the other three. More than 50% of the respondents in Itire, Ajegunle and Iwaya were tenants, while this only applied to 38.5% of the respondents in Ikorodu. Here, 69.2% of the respondents originated from Lagos, while less than 30% from the other communities came from Lagos. Further, the house rental price is lower in Ikorodu compared to the other surveyed communities. This is a motivating factor for many people who live but works in Lagos metropolis. This may likely also be the cause of the low overcrowding experienced in Ikorodu compared to the other communities, as people can afford to pay for more rooms because it is cheaper (Table 4.4).

Table 4.4: Socioeconomic characteristics of respondents

Characteristics	Respondent	Community				Total (%)
		Ajegunle(%)	Iwaya (%)	Itire (%)	Ikorodu (%)	
Gender	Male	60.6	68.0	51.9	55.8	60.2
	Female	39.4	32.0	48.1	44.2	39.8
Age (years)	18-24	10.8	12.0	16.7	13.5	12.2
	25-40	48.8	60.0	31.5	25.0	45.3
	41-65	28.6	24.0	44.4	48.1	32.6
	Above 65	11.8	4.0	7.4	13.5	9.9
State of origin	Lagos	9.9	29.3	18.5	69.2	22.9
	Not Lagos	90.1	70.7	81.5	30.8	77.1
Ethnic group	Yoruba	51.2	50.7	61.1	96.2	58.6
	Hausa	4.9	1.3	3.7	0.0	3.4
	Ibo	19.7	18.7	18.5	1.9	16.9
	Ilaje	2.5	1.3	0.0	0.0	1.6
	Egun	9.4	20.0	0.0	1.9	9.1
	Ijaw	1.5	2.7	0.0	0.0	1.3
	others	10.8	5.3	16.7	0.0	9.1
Marital status	Single	29.1	32.0	25.9	15.4	27.3
	Married	64.5	65.3	68.5	78.8	67.2
	Divorced	1.5	2.7	1.9	0.0	1.6
	Widow	4.9	0.0	3.7	5.8	3.9
Household size	1 person	3.4	2.7	3.7	3.8	3.4
	2 persons	6.9	4.0	7.4	3.8	6.0
	3-4 persons	38.4	26.7	33.3	55.8	37.8
	5- 7 persons	38.9	40.0	38.9	32.7	38.3
	Above 7 persons	12.3	26.7	16.7	3.8	14.6
Crowding status	Yes	70.4	60.0	63.0	26.9	61.5
	No	29.6	40.0	37.0	73.1	38.5
Religion	Islam	36.9	16.0	35.2	55.8	35.2
	Christianity	62.1	84.0	61.1	40.4	63.3
	Traditional	0.5	0.0	3.7	3.8	1.3
	Others	0.5	0.0	0.0	0.0	0.3
Education level	Primary	13.8	8.0	13.0	17.3	13.0
	Secondary	59.1	52.0	63.0	57.7	58.1
	Higher education	22.2	28.0	18.5	19.2	22.4
	None	4.9	12.0	5.6	5.8	6.5
Housing status	Tenant	76.8	62.7	70.4	38.5	86
	Owned	23.2	37.3	29.6	61.5	24
Monthly income	Below ₦10,000	10.8	8.0	7.4	23.1	11.5
	₦10,000-20,000	35.0	30.7	31.5	26.9	32.6
	₦20,000-80,000	34.0	41.3	38.9	26.9	35.2
	Above ₦80,000	7.9	10.7	11.1	13.5	9.6
	No income	12.3	9.3	11.1	9.6	11.2
House rent per year	Below ₦24,000	11.8	4.0	7.4	5.8	8.9
	₦24,000-48,000	43.3	20.0	27.8	23.1	33.9
	Above ₦48,000	20.7	32.0	35.2	7.7	23.2
	Not applicable	24.1	44.0	29.6	63.5	34.1

A significant association was observed between the deviating parameters (i.e., housing status, crowd status, and state of origin) and the location of the communities, Ajegunle, Itire and Iwaya are located within Lagos metropolis while Ikorodu is at the outskirt of the metropolis. Based on the Cramer's V, the association is stronger between location of slum and origin of the people living in the community (Table 4.5). This implies that location of a slum is a contributory factor influencing the result obtained from the different communities sampled.

Table 4.5: Test of association between location of study areas and deviating indices

		Location of communities
State of origin	Chi-square	73.032*
	Cramer's V	0.436
Crowding status	Chi-square	30.284*
	Cramer's V	0.281
Housing status	Chi-square	24.053*
	Cramer's V	0.250

** Chi-square is significant at the .001 level*

Although the Nigerian minimum wage is set at ₦18,000 per month (~ € 43), but Guzi, Kabina and Tijdens (2016) have shown that a family of four in Lagos will require a minimum living wage between ₦54,000 - ₦72,500 (€ 129-172). However, more than 50% of the respondents earn less than that and also a have a household size exceeding four members, implying possible deprivation in the study area (Table 4.5).

There is correlation between informal economies and informal settlements in developing countries Kengne (2000). Informal economy, a form of unregulated economic activities (Webb, Tihanyi, Ireland, & Sirmon, 2009), was predominant in the study area, as 72% of the total surveyed respondents engaged in such activities e.g. trading, fishing, carpentry, barbing, security, traditional medicine etc. (Figure 4.8). In addition, 63% of the respondents worked in their respective slum community (Figure 4.9). This is because most of the respondents owned their private businesses that allow them to locate their shops at their preferred locations, which in most cases is within their respective community.

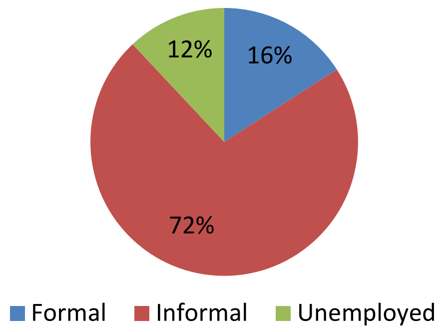


Figure 4.8: Employement type

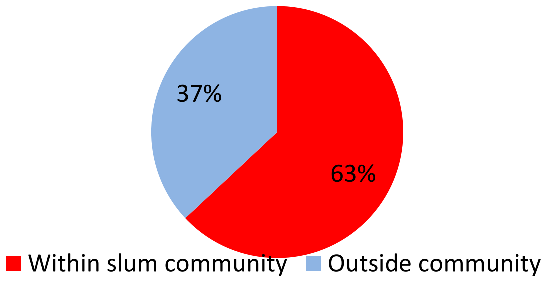


Figure 4.9: Location of employment

Table 4.6: Correlation matrix of indices measuring the economic characteristics of slum dwellers

	Education	Monthly income	Rent
Education	1.000	0.179**	0.095
Monthly income	.179**	1.000	0.149**
Rent	.095	0.149**	1.000

***Correlation significant at the 0.01 level (2-tailed).*

A positive correlation was observed between the highest educational level attained and the monthly income. Similar findings were observed by Adedayo and Malik (2015), thus presuming that the education determines income. Also, a positive correlation was observed between income and rent paid (Table 4.6). This could be explained that as income level increases, people will be willing to secure a better accommodation with a higher rent outside the slum. However, because of the limited housing availability in the city, rents paid in Lagos are mainly influenced by housing availability and not by income level. The housing deficit in Lagos is estimated at five million housing units, which is about 31% of the national estimated deficit in Nigeria (Oshodi, 2010). This leads to higher costs of housing, which are unaffordable for the poor households in Lagos (Opoko & Oluwatayo, 2014).

4.4.2 Slum decay

Only 4.9%, 9.3%, 5.6% and 11.5% of the sampled buildings in Ajegunle, Iwaya, Itire and Ikorodu, respectively, comply with all attributes applied in the scoring. This implies that most of the buildings sampled in this study show slum characteristics (Table 4.7).

Table 4.7: Characterization of slum conditions in the study area

Slum index	Ajegunle (%)	Iwaya (%)	Itire (%)	Ikorodu (%)	Total (%)
0	7.4	24.0	0.0	0.0	8.6
1	20.7	20.0	3.7	9.6	16.7
2	21.2	13.3	20.4	23.1	19.8
3	22.2	6.7	9.3	23.1	17.4
4	11.3	14.7	31.5	9.6	14.6
5	12.3	12.0	29.6	23.1	16.1
6	**4.9**	**9.3**	**5.6**	**11.5**	**6.8**
Total	100.0	100.0	100.0	100.0	100.0

None of the sampled buildings in Ikorodu or Itire were deficient in all the six attributes, which was likely due to their legal status (Table 4.1). Many slums in Lagos, especially those that emanated from villages to become part of the city, had modicum of planning, which allowed them to have certain attributes; these were deficient in the squatter communities. It was also observed that slum dwellers, especially migrants, were not willing to improve their housing structures. According to one of the dwellers in the squatter community:

"I do not see the need to improve this house as you can see I made it with wood and the government can come any time to evict us, so it's ok for me as it is."

(Steve, FGD, Iwaya, November 30, 2016)

Whereas an inhabitant from a slum said:

"This house belongs to my father, so we always try to improve it to the best of our ability."

(Femi, FGD, Ikorodu, February 10, 2017)

The implication is that people are willing to improve their living conditions if they have security of tenure. A similar situation was observed by Agbola and Agunbiade (2009), who found that the threat of forceful eviction deterred slum dwellers from improving their housing quality and environment. Furthermore, they also observed that insecurity of tenure is a major cause of slum formation in Lagos. But obtaining a land title in Lagos is expensive and time consuming (Braimoh & Onishi, 2007), consequently deterring Lagos residents from applying for land ownership titles, thereby affecting their security of tenure.

4.4.3 Migration pattern of slum dwellers in Lagos

Nigeria is divided into six geopolitical zones (North-central, North-east, North-west, South-east, South-south and South-west) based on similar culture, ethnic groups and common history. It was found that more than 70% of the respondents migrated to Lagos from other parts of Nigeria (Figure 4.10). Hence, population growth in the sampled communities was due to in-migration rather than to a natural increase, which also applies to the whole city of Lagos (Immerwahr, 2007; Aluko, 2010). The closer regions, i.e. South-west, South-south, and South-east, contributed higher percentages of migrants to slums in Lagos. This is demonstrated by their influence on the spoken languages, i.e., Yoruba and Pidgin English and also to the ethnic enclaves e.g. Egbas in Abule Egba, the Ibos in Festac, Hausas in Agege etc. in the city (Oduwaye, 2008). The lower turnout from North-west and North-central may be attributed to their proximity to Abuja, the federal capital territory of Nigeria.

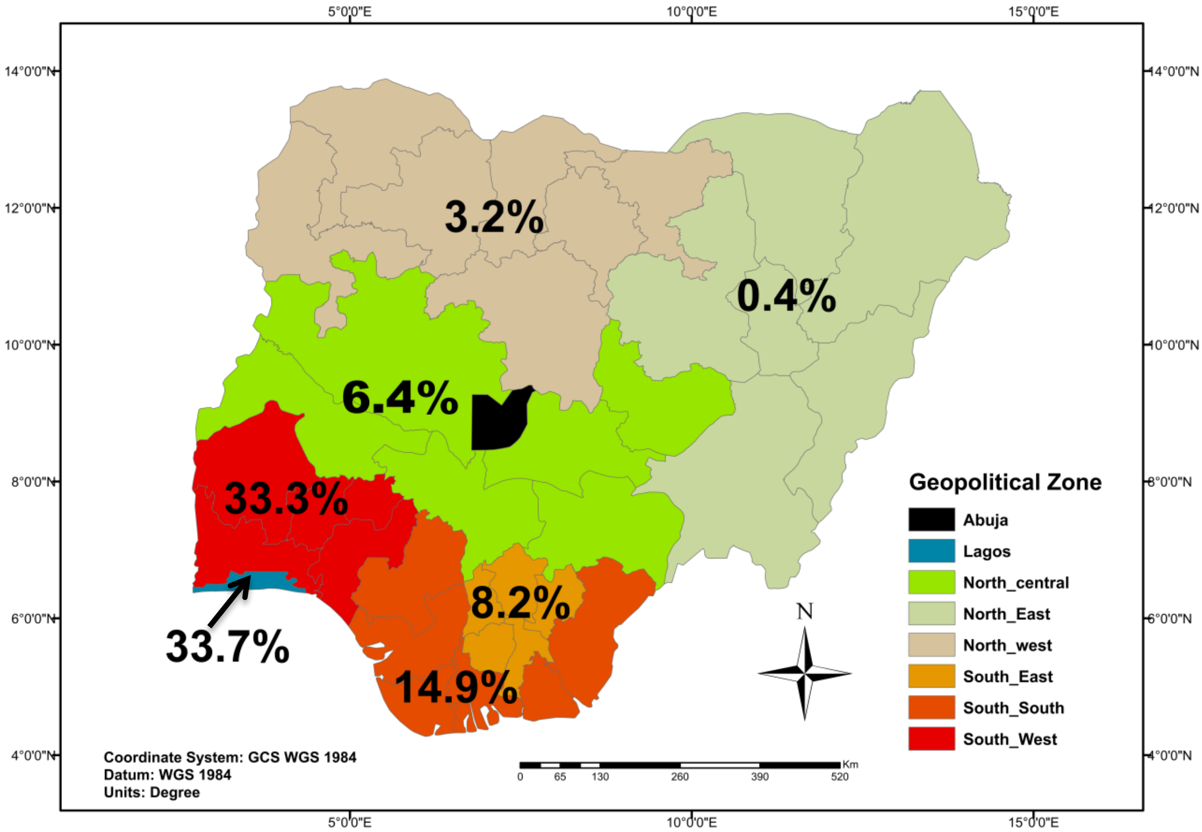


Figure 4.10: Inter-migration pattern of slum dwellers in Lagos

The dynamics of intra-migration show that 48.7% of the respondents that migrated to Lagos, first stopped in the study communities, while 51.3% had previously lived in other communities in Lagos. 81.1% of the respondents that moved from one residential area in Lagos to the four communities relocated from high-density residential areas such as Ebute-Metta, Amukoko, Makoko, Oshodi, etc. However, referring to their former residence as a slum is difficult because no recent official document exists to back up this claim. However, according to an official of Lagos State Urban Renewal Agency, all slums in Lagos metropolitan area are categorized as high-density residential areas; hence it can be assumed that those former dwellings exhibit slum-like characteristics (Table 4.8).

Table 4.8: Intra-migration pattern of slum dwellers in Lagos

Theme	Response	Frequency (%)
Was this community the first place you moved into when you came to Lagos?	Yes	48.7
	No	51.3
If not, did you move within the same community?	Yes	33.2
	No	66.8
Density of former house of respondent	Low	15.3
	Medium	3.6
	High	81.1

When residents changed their homes, they often moved to housing within their settlement or to places in the settlement next to it. For instance, there were some respondents that relocated from Makoko to Iwaya while some moved from Badia to Ajegunle. These communities share the same geographical boundaries. This implies an interaction between neighboring slums in Lagos. Thus, the observed movement patterns support two theories of human mobility in slums: i) slum as a sink where slum dwellers move from one slum to another within an urban area, and ii) final destination where slum dwellers stay within one slum but move from one dwelling to another within the same slum.

4.4.4 Residential decisions

4.4.4.1 Residential location

Respondents provided various reasons for moving to slums/squatter communities. However, 65.8%, 51.7%, and 44.9% of the slum dwellers considered family ties, cheap housing, and proximity to work, respectively, as the most important factors for moving to their respective communities (Figure 4.10). The FGD corroborated the influence of family ties and proximity to jobs.

One of the old participants said

"Our forefathers came from Badagry and Idi-Iroko to settle here because of water due to their occupation which is fishing. After our forefathers settled down, they brought their family and since then many of us have been coming here to live and work. Although, I still go to Idi-Iroko for visits but this community is my home now."

(Ayoade, FGD, Iwaya, November 30, 2016)

Another participant said:

"I live here because of my family. I was born here and even if government offers me a highbrow area, I will not leave this community, because anywhere I go I will be a visitor, but this place is my home, my ancestral home."

(Moses, FGD, Itire, December 19, 2016)

A participant who was a migrant to the community said:

"I live here because it is well connected and very easy to get to work and other places that I need to go in Lagos."

(John, FGD, Itire, December 19, 2016)

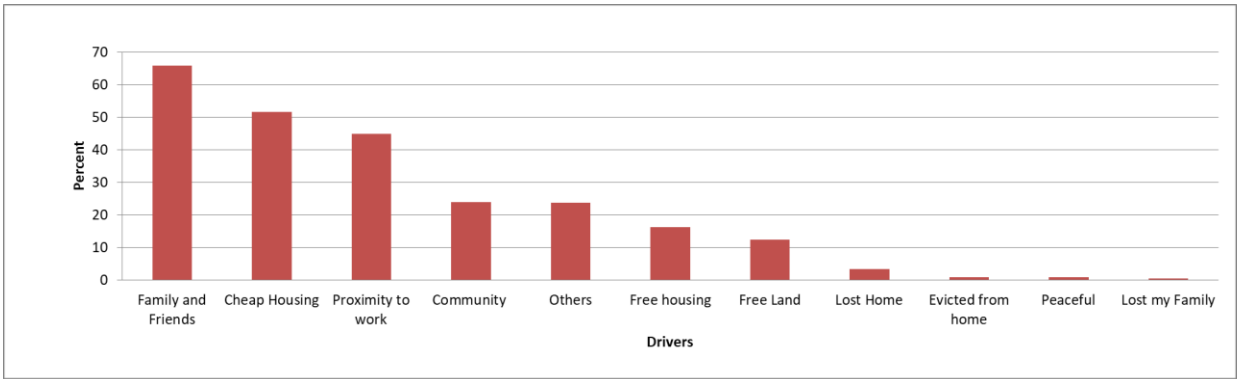


Figure 4.11: Location decision factors in the study area

The Likert scale shows that all drivers except closeness to religious center were ranked important in all communities (Figure 4.11). However, slum dwellers ranked affordability, cultural and family ties and closeness to market higher than other factors.

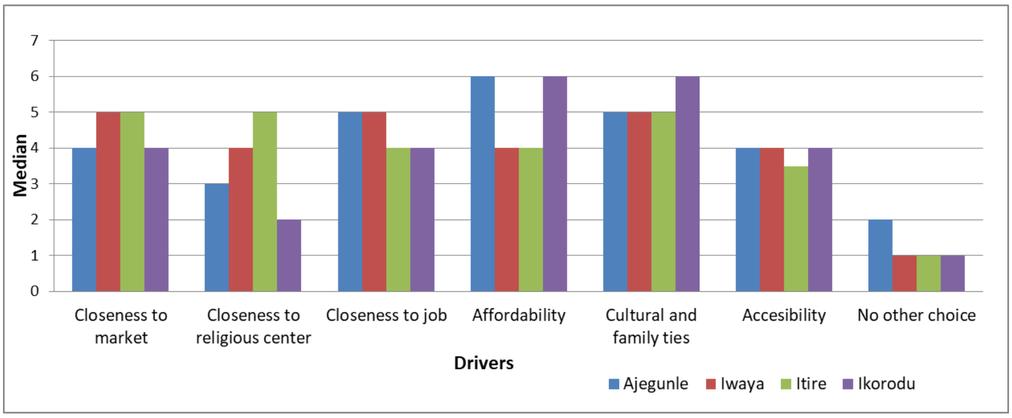


Figure 4.12: Respondents preference based on ranking of drivers

Respondents underlined that they had moved to a particular settlement because they had family members living there and also many people who shared their cultural characteristics (Figure 4.12). When migrants move to Lagos, they are usually accommodated by their relatives or friends. In most cases, these relatives pass information on the available opportunities in the city through informal channels to prospective migrants, and also assist in their integration into the system. After successful integration, the migrants also search for accommodation closer to their relatives/friends and the cycle continues (Oduwaye, 2008). This cycle leads to concentration of the same ethnic groups in the same section of a community. For instance, Ijaws (Niger-Delta) dominates the Ogbowankwo section of Ajegunle while the Eguns clustered in Ago Egun in Iwaya.

While social factors contributed to the residential location choices, economic reasons determined the affordability of housing. As said before, this is because of inadequate housing in Lagos resulting in high rents of the available housing, hence the respondents, especially the migrants or low-income earners, search for cheaper accommodation, which in most cases is found in slum communities (Ademiluyi & Raji, 2008).

4.4.4.2 Decision to Stay

Based on the calculated slum index (section 4.4.2), an assumption could have been that slum dwellers only live in the sampled buildings for a short time. However, more than 50% of the respondents have lived in their respective communities for more than sixteen years (Figure 4.13), implying that other factors might have influenced their decision to stay.

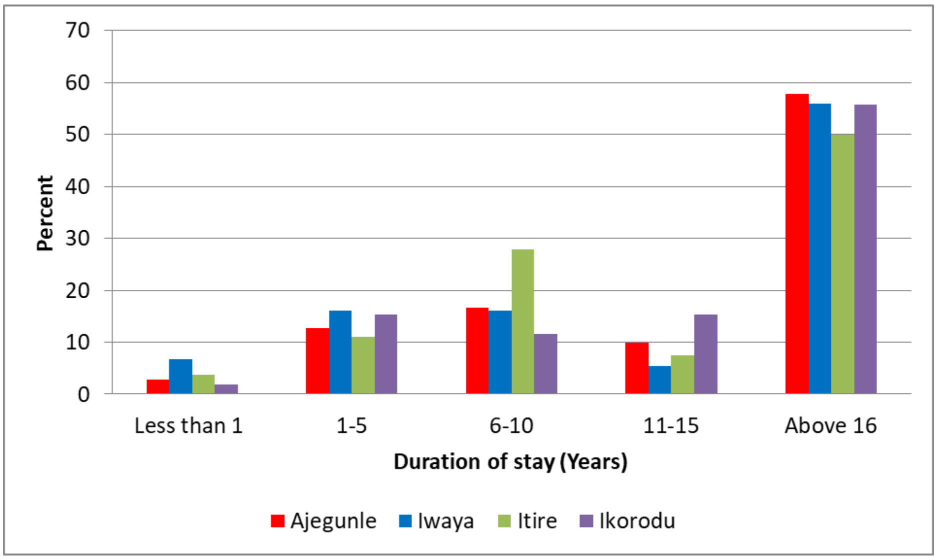


Figure 4.13: Duration of stay in slum/squatter community

Gender, housing status, household size, marital status, cheap housing, place of work, number of bedrooms occupied by the household and attachment to neighborhood are significant factors that incentivize dwellers to stay in a community (Table 4.9). Estimates show that the odd ratio for females to stay in a slum is 0.60 times greater than that of males, which may be due to the differences in sample size (lower number of female respondents than male). Nevertheless, the findings are consistent with those in studies on gender and migration, where males were considered to be more migration-prone than females (Chant, 1992; Kim et al., 2005). Also, the odd ratio of respondents with families to remain in the slum is 0.42 times greater than that of single respondents. This is because families are less mobile than singles, and in most cases decisions are made by more than one person. Other factors, such as location of schools, job, and shopping area are included in family migration decisions (Mincer, 1978), which makes moving difficult.

Table 4.9: Logistic regression, intention to stay and odd ratio

Variable	**Coefficient**	**Odd ratio**
Stay (1) and Move (0)	Dependent Variable	
Gender (Female=0, Male=1)	-0.505* (0.294)	0.603* (0.177)
Marital status: (With Family =0, Single =1)	-0.859** (0.427)	0.424** (0.181)
Housing ownership (Rented=0, Owned=1)	1.048*** (0.334)	2.853*** (0.954)
Number of people in household	-0.142** (0.064)	0.867** (0.055)
Number of bedrooms occupied	0.215* (0.129)	1.240* (0.160)
Place of birth in community	0.299 (0.409)	1.348 (0.552)
First point of call	-0.050 (0.354)	0.952 (0.337)
Duration of stay	0.021* (0.013)	1.021* (0.013)
Place of work (within slum =0, outside slum= 1)	-0.722** (0.320)	0.486** (0.155)
Monthly income	0.126 (0.169)	1.134 (0.192)
Affordable housing (No= 0 Yes =1)	0.576** (0.290)	1.779** (0.517)
Quality of building (roof, wall)	-0.294 (0.315)	0.745 (0.235)
Toilet facilities	-0.789* (0.476)	0.454* (0.216)
Neighborhood attachment	1.829*** (0.443)	6.227*** (2.759)

*p<*0.1, p<**0.05, p<***0.01*
Standard errors in parentheses
Number of observations = 384
Log pseudolikelihood = -162.948
Pseudo R^2 = 0.2454

Furthermore, the likelihood of slum dwellers that own their houses to remain in a slum is 2.85 times greater compared to slum dwellers that pay rents, as the former have a stronger attachment to their neighborhood than the latter. This agrees with the study of (Mudege & Zulu, 2011) of slums in Nairobi. The phenomenon was also confirmed during the FGD:

"My house is here so I cannot leave here."

(Joshua, FGD, Itire, December 3, 2016)

"When I came to Lagos, I rented a house here, and when I had money I bought land and built my own house because I like this place, so I cannot leave here."

(Fiyin, FGD, Ikorodu, January 21, 2017)

"This house was built by my father, but it is mine now, so this is home."

(Kolapo, FGD, Ikorodu, January 21, 2017)

The analysis shows that an additional bedroom increases the odd of slum dwellers to remain by a factor of 1.24, while an additional member to the slum dwellers household reduces the odd of staying by a factor of 0.87. This implies that respondents will continue to stay in their respective residence as long as there is enough space for the household members. Slum dwellers also considers place of work as an important reason to remain in the slum. Dwellers whose place of work is located within the slum communities are more likely to remain than those whose place of work is outside. During the FGD, some of the participants (especially artisans) highlighted the fact that their shops are located in the same community, which makes the community the best choice for them (Figure 4.14).

Boat maker working and living in Iwaya

Tailor working and living in Ikorodu

Figure 4.14: Location of work contributing to reasons for staying in slum (2016)

Interestingly, income was not a significant predictor for remaining in the slum. As mentioned before, this was due to the limited housing availability in the city of Lagos (Oshodi, 2010). However, affordable rent was an important predictor to remain in these communities. This implies that even with high income, slum dwellers in Lagos will still prefer to stay in the slums because of the lower costs for housing. The odd to remain in a slum building reduces by 0.4 with the absence of toilet facilities, as people like to live in a home with sanitary facilities.

Finally, satisfaction with the neighborhood is a factor contributing to the wish to remain in a slum: the odds increase by 6.22 for dwellers who liked their neighborhood against those who did not. However, it is important to note that the satisfaction mainly refers to the human interaction, as dissatisfaction with the environment might not necessarily lead to moving out, especially when there is no alternative (Chepngeno-Langat & Ezeh, 2007).

As observed, the reasons for staying in a slum are complex. Contradicting general beliefs, income alone is not a significant reason, so referring to slums as a home for the poor (Akinbode, 2002; Adedayo & Malik, 2015) is likely not correct with respect to Lagos. In contrast, the strong attachment to the communities seems to be the main reason for remaining in a slum. Moreover, some of the respondents reported that although they owned other houses in another part of the city, they were still not willing to leave the slum. The above-described factors imply that the slum management approach of the Lagos state government that focuses on redeveloping slum communities and relocating dwellers from slums to new places is likely not appropriate for Lagos. Hence, slums will continue to grow in the city.

4.5 Conclusions

This study was conducted in four communities (Ajegunle, Iwaya, Ikorodu and Itire) in Lagos to identify the factors influencing residential location choices of slum dwellers. The results show that intra-migration to Lagos is the major contributor to population growth in the slums, and that most of the migrants move from geopolitical zones closer to the city of Lagos, which influences the local languages spoken and the ethnic enclaves in the city. Also, slum dwellers move within and among slum communities in Lagos. The movement patterns observed support two theories of human mobility in slums: slum as a sink, and slum as a final destination, which also shows that slums in Lagos are not transitional phases for its residents rather permanent.

Regarding the conundrum of moving to a slum and staying in a slum, the results of this study shows that the factors bringing dwellers into slums might not necessarily be the same factors contributing to their stay. In the residential location choices, it is important to include both aspects, as people will continue to stay in the slums as long as their needs are met. With no regulations on the influx to slums, the population will continue to grow; adding numbers of people to those who do not intend to leave the slum. Hence, future studies on slum dynamics should include parameters contributing to the intention to stay or leave as a contributory factor to population growth in a slum. Furthermore, the type of factors (i.e. socio-demographic) identified as contributors to staying in the slums reveals the need for new policies for slum management in Lagos, especially if it is necessary to relocate slums dwellers to another neighborhood.

Although this study analyzed the movement pattern of slum dwellers in Lagos and their residential decisions, there is scope for further studies. Since slums are unique, a broader coverage including more of such communities in Lagos can provide further insight into the importance of the residential decisions of slum dwellers with respect to slum dynamics in Lagos.

5. SIMULATING SCENARIOS OF SLUM GROWTH IN LAGOS

Exploring coupling of logistic regression with SLEUTH to simulate slum growth in Lagos. Olabisi S Badmos[1, 3], Andreas Rienow[2], Daniel Callo-Concha[1], Klaus Greve[3], Carsten Jürgens[2] (preparation)

[1]Center for Development Research, University of Bonn, Genscherallee 3 - D-53113 Bonn, Germany; s7olbadm@uni-bonn.de (O.B); d.callo-concha@uni-bonn.de (D.C)
[2]Department of Geography, Ruhr-University Bochum, Universitätsstr. 150 / D-44801 Bochum, Germany; andreas.rienow@ruhr-uni-bochum.de (A.R); carsten.juergens@ruhr-uni-bochum.de (C.J)
[3]Department of Geography, University of Bonn, Meckenheimer Allee 166, 53115 Bonn, Germany; klaus.greve@uni-bonn.de (K.G)
* Correspondence: s7olbadm@uni-bonn.de; Tel.: +49228734976

Abstract: The demographic forecast put Lagos as one of the cities with the highest population growth. Past trends show correlations between urban growth and slum growth, thereby creating a major challenge for sustainable city planning. This study explores the drivers of slum development in Lagos, and simulates scenarios for their growth through coupling logistic regression with the cellular automata-based SLEUTH model. The driving forces of slum development in Lagos were analyzed, and the correlated spatial drivers compiled to create a probability map of slum development using the logistic regression model. The probability map was combined with the exclusion layer of the modified SLEUTH to simulate scenarios of slum growth in Lagos by 2035. Three scenarios were designed based on the modification of the exclusion layer and the transition rules. The Scenario 1'business as usual', depicts slum development following the present trend; the scenario 2 'excessive growth', considers the demographic projection for the city; while the scenario 3 'limited government influence', dealt with limited interference by the government in slum management/control. Factors including distance to markets, distance to shoreline, distance to local government administrative buildings, land prices, etc. were predictors of slum development in Lagos. The prediction model, based on the logistic regression, reached an overall accuracy of 79.17% and a relative operation characteristics value of 0.85. The three scenarios show further densification of the existing slums, and increase in their area by 1.18 km^2 (scenario 1), 4.02 km^2 (scenario 2), and 1.28 km^2 (scenario 3). New slums are predicted at the fringe of the south-eastern part of the city. The predicted limited spatial growth of the slums is due to the high density of the city, thus new slums may likely develop in the neighboring zones to Lagos when land in the city is no longer available.

Keywords: Slum growth, logistic regression, cellular automata, SLEUTH, Lagos

5.1 Introduction

More than 50% of the projected global population growth until 2050 is expected to take place in Africa, where out of the 2.2 billion global increase, 1.3 billion will be in Africa (United Nations, 2017). This is of great concern as urban growth in Africa correlates with slum growth (Davis, 2004; Marx et al., 2013). Slums are perceived as the manifestation of urban decay, poverty, crime, and unemployment (Simon et al., 2013; Adedayo & Malik, 2015; Peter Hofmann et al., 2015). Nevertheless, it provide low-cost shelter for the increasing city populations, especially in the global south, where housing is limited (Davis, 2004; Gulyani & Bassett, 2007; Ooi & Phua, 2007). Thus, slums continue to be a conspicuous part of many cities in developing countries.

Informal settlements and slums are used interchangeable in literature, due to their similar physical manifestation (UN-Habitat, 2003, 2013). However, some argues that there is a distinct difference between them, with respect to their origins, for instance informal settlements are described as settlements that do not conform to the planning standards or are illegal and mostly dominated by migrants while slums are described as old residential areas built long ago in line with the then prevailing urban planning, zoning, and construction standards, but now dilapidated and overcrowded (Onokerhoraye, 1995; Dung-Gwom, 2007; Hofmann et al., 2015; Mahabir, Crooks, Croitoru, & Agouris, 2016, for further discussion see Gilbert, 2007). Many studies on slums have centered on the informal settlements, especially in the application of remote sensing to study slum dynamics (e.g. Sietchiping, 2005; Hofmann, Strobl, Blaschke, & Kux, 2008; Shekhar, 2012a), probably due to its characterization as illegal and in most cases cleared rather than upgraded by the Government (Amnesty International, 2017; Badmos et al., 2018). This study focus on the informal settlements and used interchangeably with slums throughout this paper.

Land-use models can help to analyze the causes and effects of land-use change to better understand the land-use system and also support planning policies (Verburg et al., 2004; Al-shalabi et al., 2013). Land-use models can be categorized into rule-based and empirical estimation models (Aspinall, 2004; Hietel, Waldhardt, & Otte, 2007; for further typology see Verburg et al., 2004). Rule-based models imitate processes and often address the interaction of components forming a system, while empirical estimation models utilize regression techniques to relate the influence of potential drivers and their degree of confidence with respect to their contribution to land-use change based on historical data (Hu & Lo, 2007; Nong & Du, 2011).

Cellular Automata (CA), a type of rule-based model, focuses on the spatial dynamics of land-use change and is mostly suitable to analyze land-use change and urban growth (Clarke, 2014). As it can capture and simulate the complexity observed in urban areas (Mundia & Aniya, 2007). However, it has been criticized because its cells are static and can only interact with neighboring cells (Augustijn-Beckers et al., 2011; Clarke, 2014; Patel et al., 2018). However, if the goal is to simulate spatially distributed processes e.g. spread and dispersal, CA is considered a better option (Clarke, 2014).

Clarke et al. (1997) developed the SLEUTH model, i.e., "a CA that incorporates weighting of probabilities and self-modification feedback from the aggregate to the local" (Clarke, 2014: 1223). SLEUTH, stands for the acronym of the data input required by the model, i.e., Slope map, Land-use map, Exclusion map, Transportation map and Hill-shade map, is used to simulate urban/non-urban land-use dynamics (Dietzel & Clarke, 2007). SLEUTH had been criticized because of its reliance on biophysical drivers of land-use change, as it underplays socioeconomic and institutional factors, which are usually the prime drivers of land-use changes (Ahmed & Bramley, 2015). Those limitations have led to the onset of hybrid models that couple empirical estimation models with rule-based models (e.g., Jokar Arsanjani, Helbich, Kainz, & Darvishi Boloorani, 2013; Rienow & Goetzke, 2015). In hybrid models, the probability of a land-use change is based on different driving factors, which are computed using empirical statistical models. Logistic regression (LR), an example of empirical statistical model, examines the relationship between urban land uses and their driving forces (Jat et al., 2017), as well as determines the weight of the drivers and their respective functions. Through LR, demographic and socioeconomic factors can be integrated into rule-based models (Alsharif & Pradhan, 2014). However, these have to be corrected to prevent autocorrelation and multicollinearity (Lin et al., 2011; Nong & Du, 2011).

Past policies on slum management have been ineffective in the prevention of new slum development (Sietchiping, 2005; Arimah, 2010; Roy et al., 2014). This occurred because proactive planning to prevent slums, requires prior knowledge of slum development and its main drivers, which is a challenge for many developing countries, especially where census data is either unavailable or inaccurate (Dubovyk et al., 2011; Shoko & Smit, 2013). Since slums have their own spatial location and characteristics (Sietchiping, 2005), modeling techniques based on geographic information systems (GIS) can be used to bridge this gap, through analyzing the spatial and temporal pattern of slums, identifying the factors of slum development, and predicting pathways of slum development. Models allow scientist explore and test different theories and practices of slums in a control computer environment, to improve understanding of urban phenomenon (Batty, 2005), and assist in the development of tailored slum management policies. However, the applicability of these techniques is still in its infancy, especially in sub-Saharan African countries, where data availability is a major issue. Also, based on the uniqueness of different slums, adopting other studies without gauging the existing situation will definitely fail, as slums tends to manifest differently between cities and even within cities (Sliuzas, Mboup, & de Sherbinin, 2008; Mahabir, Croitoru, Crooks, Agouris, & Stefanidis, 2018). Hence, studies on slum dynamics must be case specific.

In this regards, few studies have been carried out. Shekhar (2012b) utilized multi-criteria evaluation and cellular automata to determine the proneness of lands for slum formation in Pune, India, by considering biophysical criteria that included hill slopes, canals, etc., and predicted their future growth. Patel et al. (2018) integrated agent-based modeling and GIS to explore how the interaction between different agents (slum dwellers, governments, etc.) and their spatial environment, lead to the emergence of slums in Ahmedabad, India. Augustijn-Beckers et al. (2011) utilized an agent-based model to develop a vector-based housing model to simulate the growth of informal settlements in Dar es Salaam, Tanzania. Dubovyk et al. (2011) used a logistic regression model to analyze the driving factors of informal settlements, to predict the probable location of future informal settlements in the Sancaktepe district in Istanbul, Turkey. Sietchiping (2005) adopted an informal settlement growth model to predict the growth of slums in Yaoundé, Cameroon.

If the current trend persist, Lagos, might not meet the demands of the United Nations Sustainable Development Summit (2015) for cities to be free of slums by 2030. Slums in Lagos have increased in number from 42 in 1984 to over 100 (Lagos-State/UNCHS, 1984; Morka, 2007). Over 70% of the city’s residents live in slums, and this will increase based on the demographic projections for the city, as urban growth leads to the emergence of slums in Nigerian cities (UN-Habitat, 2003; World Bank, 2006; Adelekan, 2010; Marx et al., 2013; World Population Review, 2015). Until now, slum management in the city has been mostly based on forceful eviction (e.g. in Maroko, Badia etc.), and very limitedly slum upgrading (e.g., Lagos metropolitan development governance project), which has not reduced slum growth, but has rather led to their displacement (Agbola & Jinadu, 1997).

To date, there is no study predicting the formation and expansion of slums in Nigeria, neither has there been any study that adopts the SLEUTH model to simulate scenarios of slum growth in a city. Therefore, this study aims to contribute by answering the following questions:

- What factors determine slum development in Lagos?
- How can you spatialize non-spatial processes and include them into urban land use change models?
- How can the spatial patterns and rates of slum growth be predicted with an urban land use change model?
- How is the future growth pattern of slums in Lagos based on the simulation of different scenarios?

This chapter is structured as follows: Section 5.1 introduces this study; Section 5.2 discusses the study area and data utilized for this study; Section 5.3 gives the methodology utilized; Section 5.4 gives the result and discussion; while Section 5.5 gives the conclusion.

5.2 Study Area and Data

5.2.1 Study Area

This study covers the whole of Lagos state, which consists of Lagos metropolitan area (16 local governments) and the peri-urban area (4 local governments). It lies between longitude $2^0$42’E and $3^0$42’E and latitude $6^0$22’N and $6^0$52’N. Elevations range from 37 m below sea level to 73 m above sea level. Lagos State covers an area of 3,577 km^2 of which approximately 22% are wetlands. Lagos has a diverse and fast growing population due to in-migration from other states and neighboring countries (Abiodun et al., 2011). Its population was projected to be 23,305,91 in 2015 (Lagos Bureau of Statistics, 2013) (Figure 5.1).

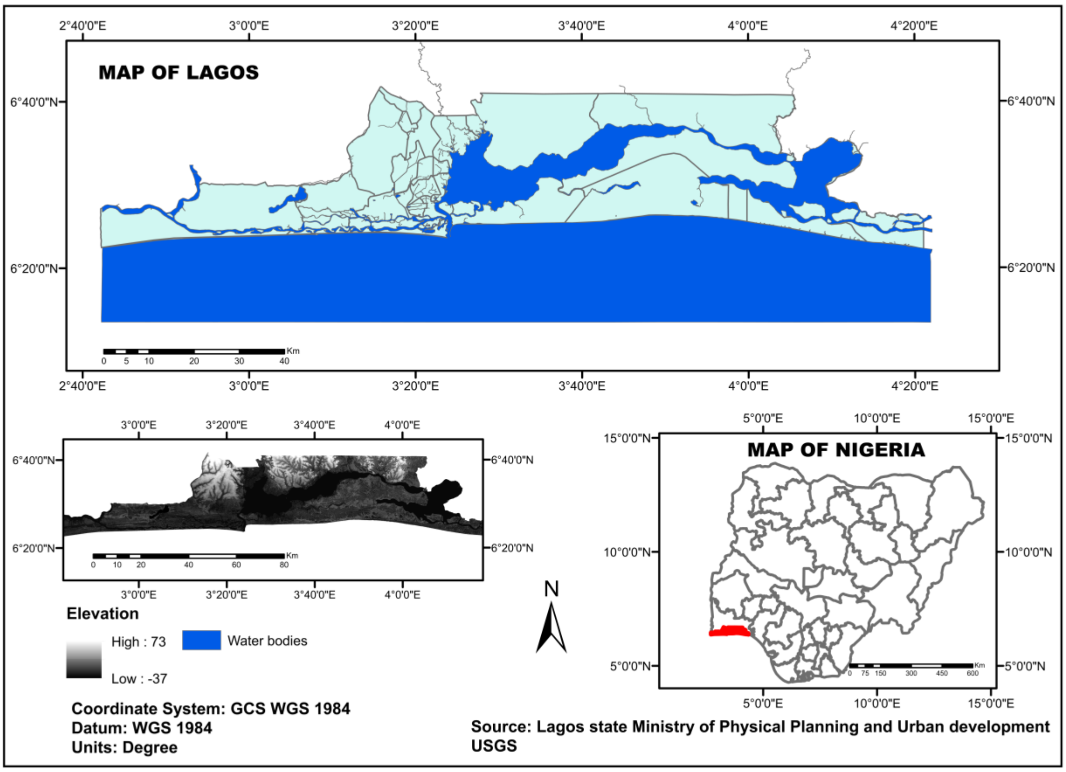


Figure 5.1: Study Area

5.2.2 Data

The satellite data utilized in this study were from Sentinel-2 imagery acquired on 8 December of 2015 and RapidEye imagery acquired on 29 November of 2009 and 20 December of 2015. The images were used to generate land-use maps for those years. The land-use maps derived from the RapidEye images were utilized to calibrate and validate the model, while the map from the Sentinel-2 image, served as the base layer for the simulation. The ASTER digital elevation model (DEM), was downloaded from United States Geological Survey (USGS) website, and used to generate elevation and slope map of the study area. Vector data including water-bodies, road network and existing land-uses were obtained from the Lagos State Ministry of Physical Planning and Urban Development. Complementary, a dataset on income level of 242 communities in Lagos was obtained through questionnaires administered to experts in the built environment (urban planners, architects, etc.), to rank the settlers income level (high, medium and low income), later used to generate a spatially explicit map of economic wealth in Lagos (Table 5.1).

Table 5.1: Description of Data

Data Type	Description	Spatial Resolution	Acquisition Date	Source
RapidEye/Level 3A	Multispectral satellite data	5	29/11/2009	Planet Lab/ RapidEye Science Archive (See Badmos et al., 2018)
RapidEye/Level 3A		5	20/12/2015	
Sentinel-2	Multispectral satellite data	10	08/12/2015	European Space Agency
Digital elevation model	Raster	30		United States Geological Survey (USGS)
Land-use map of Lagos: road network, water-bodies etc.	Vector			Lagos State Government
Census data	Population of Lagos state		2006	National population Census
Economic status of communities in Lagos	quantitative data		2017	Online questionnaire

5.3 Methodology

This study coupled the cellular automata-based model, SLEUTH, with logistic regression; the process was carried out in three stages, 1) image classification, 2) compilation, analysis of driving forces and generation of probability map of slum development, and 3) simulation of future slum development pattern. The Sentinel-2 and the RapidEye images were classified using random forest classifier and object-based image analysis, respectively, to delineate slums from other land-use types. The driving forces of slum development were identified based on previous studies, then analyzed and the significant spatial drivers compiled to create a probability map of slum development in Lagos using the LR model. The probability map was combined with the exclusion layer of the modified SLEUTH to simulate scenarios of slum growth in Lagos by 2035. For the calibration of the SLEUTH models, the land-use data of 2009 and 2015 were applied as base layer and reference layer, respectively, generated from the RapidEye images. Due to computing time, the transition rule was implemented on the whole of Lagos using the land-use data generated from the Sentinel-2 images to predict the future slum pattern in Lagos (Figure 5.2).

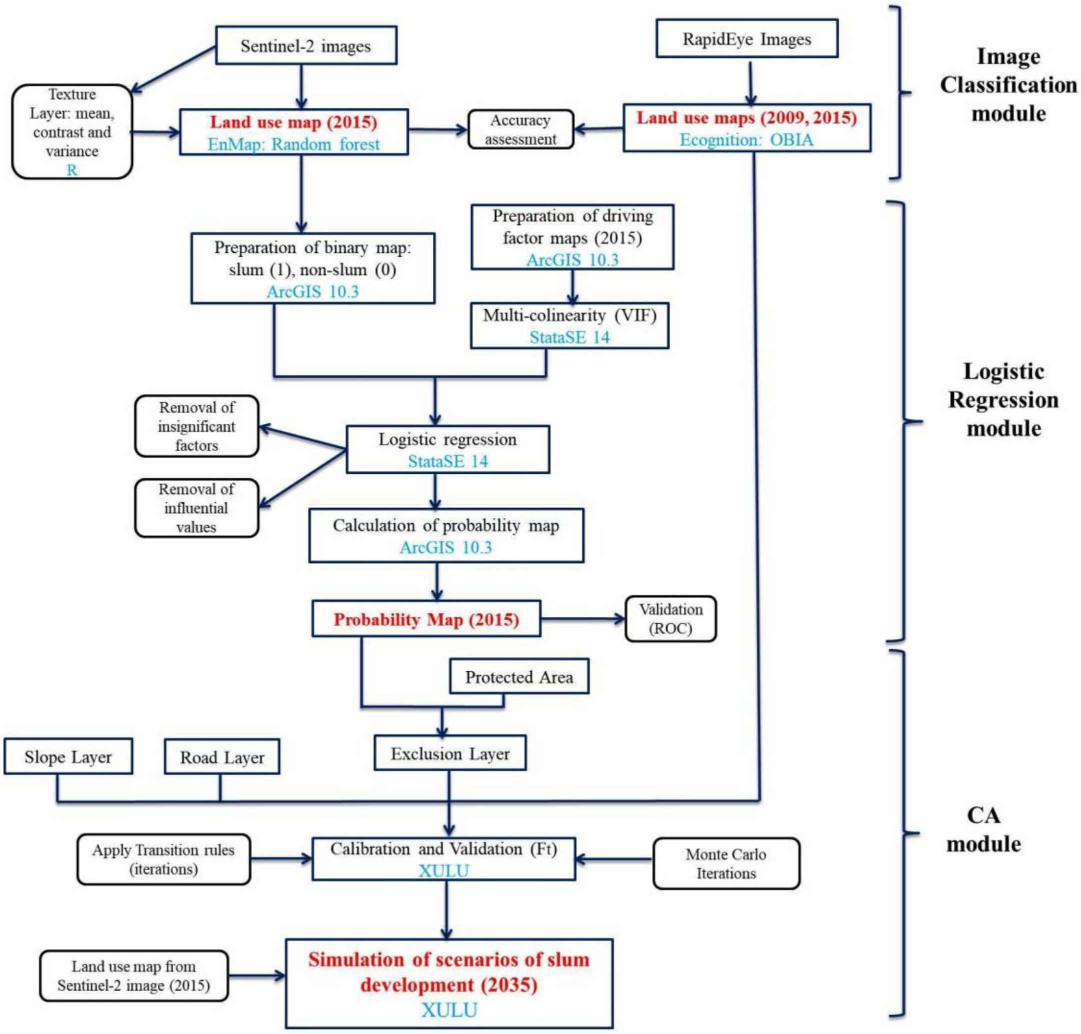


Figure 5.2: Work flow for modeling slum development in Lagos

5.3.1 Data Pre-processing

The bands 2, 3, 4, and 8 of the Sentinel-2 image were utilized due to their spatial resolution (10 m) and the imagery was radiometrically calibrated in QGIS. Simultaneously, texture layers (mean, contrast and variance) were created using the R software, to improve the accuracy of the classification (Wurm, Weigand, Schmitt, Geiss, & Taubenbock, 2017). The radiometrically calibrated bands (2, 3, 4, and 8) and the texture layers were stacked and utilized for the classification procedure. The RapidEye images were not radiometrically calibrated because it was a Level 3A product (radiometric, sensor, and geometrically corrected). However, atmospheric correction and haze removal was done using ATCOR 2 on all the scenes (see Badmos et al., 2018 for the RapidEye classification procedure).

5.3.2 Classification of imagery and accuracy

The RapidEye images (2009 and 2015) were classified using the rule set classification method, which allows the combination of object-based image analysis with expert knowledge and integration with GIS data (see Badmos et al., 2018). The stack obtained from the Sentinel-2 image was classified using the random forest classifier, a supervised ensemble learning methods that generates many independent identically distributed random classifiers, and then aggregate their results based on the popular class vote (Breiman, 2001; Liaw & Wiener, 2002), by applying a decision tree of 1000 in EnMap. The training data/classifiers (for each land use classes) and the reference data, utilized in the classification and the accuracy assessment of the Sentinel-2 image, respectively, were obtained from field work and complemented by Google Earth. Because of the moderate resolution of the Sentinel-2 image (10 m), some of the smaller slums were excluded during the automated classification (Table 5.2), and to improve this, manual editing was done using Google Earth as a reference. The images were initially classified into five classes: bare soil, other urban, slum, vegetated area and water, and later merged into two (slum and non-slum).

Table 5.2: Land-use/land-cover map accuracies (%) 2015 (Sentinel-2 images)

Land Use	**2015**	
	User Accuracy (%)	**Producer Accuracy (%)**
Water	99.98	99.97
Vegetated area	99.92	99.97
Bare soil	92.99	92.99
Slum	72.41	60.00
Other urban	72.50	73.42
Overall accuracy	**99.83**	
kappa coefficient	**99.66**	

5.3.3 Driving factors of slum development in Lagos

Logistic regression was applied to identify and analyze the relationship between the driving factors of slum development, and also to generate a probability map of slum development in Lagos. The input data for the logistic regression model was given in form of factor maps, which represent the independent variables (drivers of slum development in Lagos), based on those in previous studies (Kengne, 2000; Morka, 2007; Debnath & Naznin, 2011; Dubovyk et al., 2011; Roy et al., 2014; Adedayo & Malik, 2015; Olajuyigbe et al., 2015); and expert interviews. The selected driving forces were transformed into a raster grid format (10 m x 10 m cell) to form factor maps through a set of standardization procedures. All input files have the same spatial extent, projection and coordinate system (Table 5.3: Figure 5.3).

Table 5.3: Predictor variables incorporated in the logistic regression modeling

Type	**Variable**	**Description**	**Justification**	**Data type**
Dependent Variable	y	Slum (1) and Non-slum (0)		Binary
Accessibility characteristics	x_1	Cost-weighted distance to central business district (CBD)	Slums tend to develop close to job opportunities (Kengne, 2000; Happe & Sperberg, 2003; Debnath & Naznin, 2011)	Continuous
	x_2	Cost-weighted distance to markets		Continuous
	x_3	Cost-weighted distance to industrial/public land use		Continuous
	x_4	Euclidian distance to shoreline	Slums develop in hazardous areas (Sliuzas, 2004); Shorelines are prone to flooding	Continuous
	x_5	Euclidian distance to rail	Provision of infrastructural facilities leads to urban development	Continuous
	x_6	Euclidian distance to manmade canal		Continuous
	x_7	Euclidian distance to express roads		Continuous
	x_8	Euclidian distance to access roads		Continuous
	x_9	Euclidian distance to local government administrative building	Government influences slum development in Lagos (Badmos et al., 2018) and will be a able to monitor development close to them	Continuous
Site-specific characteristics	x_{10}	Inverse distance-weighted for land price	Economic status of people is a determinant factor of slum development, as many low-income earners cannot afford to live in the overpriced houses/lands (Adedayo & Malik, 2015)	Continuous
	x_{11}	Population density (persons/km^2)	Slums in Lagos are located in high density residential areas	Continuous
	x_{12}	Elevation	Low slopes and elevation are hazardous areas (Sliuzas, 2004) prone to flooding in Lagos	Continuous
	x_{13}	Slope		Continuous

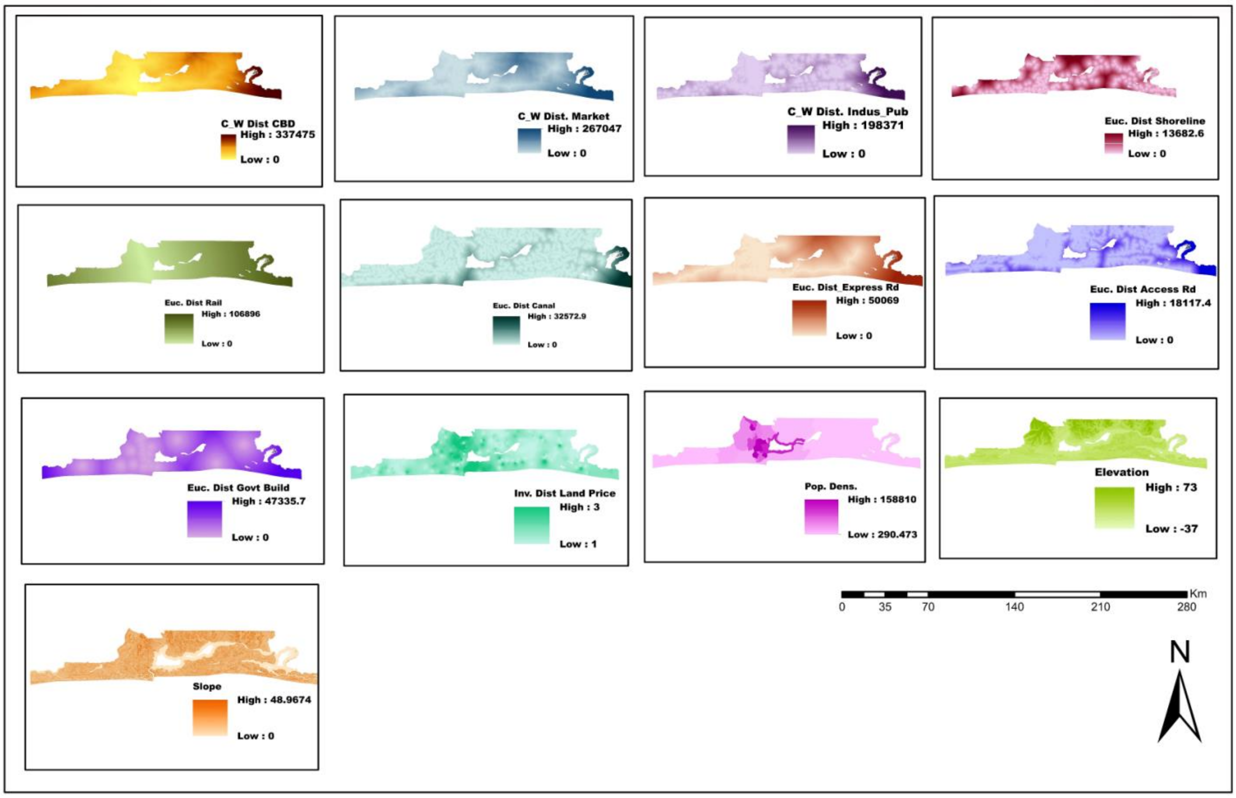


Figure 5.3: Factor maps for logistic regression

Distance can be define in terms of proximity or accessibility. Majority of studies on slum growth modeling have utilized proximity to describe distance (e.g. Sietchiping, 2005; Shekhar, 2012b; Shoko & Smit, 2013), however the influence of some drivers of land-use change is based on accessibility rather than proximity (Rienow & Goetzke, 2015), which can be expressed in terms of money, time, preference, etc. (Deichmann, 1997; Braimoh & Onishi, 2007). In this study, travel time to reach the central business district, open markets and industrial/public land uses, was used to measure their accessibility and generated using cost-weighted distances, “a deterministic least-cost path between a source point and a target point, based on the friction layer, which is a raster map where each cell expresses the relative difficulty (or cost) of moving through that cell for a given species” (Ray, 2005:178). The friction layer used comprises of the different tiers of roads in Lagos (people close to the express road will reach the target faster than those farther away and vice versa). Other distance related drivers (shoreline, rail, canal, express road and access road) were based on proximity and calculated using the Euclidian distance function in ArcGIS.

Complementary, experts were asked to rank the selected 242 communities in Lagos based on the socioeconomic characteristics of their residents (high, medium and low income) using an online survey, to serve as proxy for the hierarchy of land prices in Lagos. The assumption was that high-income residents can afford to pay high prices for land e.g., in Victoria Island, Ikeja, etc., while low-income residents cannot. A mean value for each settlement was calculated based on the rankings of the experts and then interpolated, using inverse distance weighting, to the point data representing each of the settlements on the map of Lagos, to generate spatially explicit map of economic wealth in Lagos.

Badmos et al. (2018) identified that the government influences slum development in Lagos. Therefore, spatially explicit maps of the distance to the geographical location of the administrative buildings of the 20 local Governments in Lagos, existing prior to 2002, and man-made canals constructed by the Lagos state government were generated, to serve as proxy of government influence on slum development. The assumption was that slums will not develop close to where government buildings and infrastructures are located.

5.3.4 Logistic regression model/validation

The dependent variable in a LR model is a binary variable (slum=1, non-slum=0) and was extracted from the land-use map created from the Sentinel-2 image. It was assumed that the probability of a cell (P/z/) to be a slum follows the logistic curve as described in equation 5.1 (Christensen, 1997 in Dubovyk et al., 2011):

$$P(z) = \frac{1}{1 + exp^{-(\beta_0 + \sum_{i=1}^{n} \beta_i x_i)}} ------(Equation. 5.1)$$

Where z is a binary variable representing the occurrence of slum development (z=1) or nonoccurrence (z=0), x_1……x_n represents the independent variables (i.e., drivers of slum development), β_0 is the intercept of the model, and β_i represents the parameter to be estimated, which is the coefficient of the independent variables. β_i is estimated in the model using the maximum likelihood algorithm, which interprets how the drivers affect slum development. All statistical operations were carried out in Stata.

Multicollinearity and autocorrelation among independent variables and dependents variables, respectively, may affect the result of logistic regression models. The variance inflation factor was calculated to eliminate correlated predictors, leading to the removal of cost-weighted distance to CBD, distance to rail, and distance to express roads. In addition, statistically insignificant predictors were removed using backward stepwise regression. Also, systematic random samples containing 4009 pixels of slum and non-slums were utilized to calibrate the model to solve the problem of sample size and autocorrelation (Xie, Huang, Claramunt, & Chandramouli, 2005). Influential values were also removed from the sampled dependent variables using Cook's distance (Cook, 1977). The final LR model was generated using the remaining dependent and independent variables. The coefficients of the independent variables were then used to generate the probability map of slum development in Lagos in 2015 in ArcGIS, to enhance the performance of the cellular automata-based SLEUTH model.

30,000 independent samples (for slums, and non-slums) was used to validate the predicted probability map of slum development in Lagos and the accuracy assessed using the contingency table (using a cut value of 0.5) and relative operating characteristics (ROC). The ROC technique, used for two land use types, can be applied to any model that predicts a homogenous category in each grid cell (Pontius & Schneider, 2001). It combines the probability that an event occurs with the existence of an event, in this case slum development, by plotting rate of true positive identified to positive classified against the rate of false positive to negative classified (Tayyebi et al., 2010). The result of ROC is a curve and is measured by the area under the curve (AUC), which range from 0-1. A model that acts randomly will have an AUC of 0.5, while perfectly will be 1.

5.3.5 Cellular Automata-SLEUTH model in XULU

The limitation of many urban growth models is that they can only simulate one land-use type at a time and in one direction (i.e., growth) (Goetzke & Judex, 2011). Although slums may lose and gain land area (Badmos et al., 2018), its growth is of more relevance to urban planning in Lagos, considering the demographic forecast for the city (World Population Review, 2015), hence this study can still utilize a one-direction urban growth model.

The SLEUTH model, developed by Clarke et al. (1997) consist of two sub-models, however scientific literature focus more on the Clarke Urban Growth model (UGM) rather than its other component, the Land Cover Deltatron Model (Rienow & Goetzke, 2015), which is not used in this study. Unlike the UGM model that requires at least four different land use maps for calibration purposes (Silva & Clarke, 2002); the modified UGM, referred to as urban growth model reduced: UGMr (Rienow & Goetzke, 2015), reprogrammed by Goetzke (2011), implemented into XULU, a java-based modeling platform eXtendable Unified Land Use Modeling Platform (For detailed description of XULU, see Schmitz et al., 2007), requires only two, i.e., map of the starting year of the calibration phase and the reference map at the end year. This makes it a good choice for this study due to limited data availability of slums in Lagos.

The UGMr requires four spatial input parameters, i.e., map of land use (expressed in two classes: “slum” and “non-slum”), transportation (road network), slope (in percent) and exclusion (areas resistant to growth and areas where growth is possible). The exclusion layer is used to incorporate constraints (i.e. areas resistant to growth) and drivers of slum development in Lagos into the model, based on the probability map created from LR model. Furthermore, the road layer was assigned weight based on the class of the road, i.e., 1, 2 and 27 to express road, access road and no road, respectively. The assumption is that non-slum pixels far from road will attract slum development in the future. All input files have the same resolution, coordinates and spatial extents (Table 5.4).

Table 5.4: Input parameter for UGMr

Data Layer	Source	Description
Land-use maps (slum extent)	RapidEye Image	Slum extent for calibration and validation extracted from the land-use maps: 2009 and 2015
	Sentinel-2 image	Slum extent for the simulation extracted from land-use map of 2015
Slope	Digital elevation model	Derived from the digital elevation model from USGS
Exclusion	Survey and logistic regression	Probability map of slum development, policies and survey of Lagos state
Road	Road network	Vector layer of road network in Lagos

After the compilation of the required input data, the next phase was the calibration of the model. Here, transition rules were set based on the five growth coefficients: dispersion, breed, spread, road growth and slope resistance, which defines the four growth rules in the model. The spontaneous growth is influenced by the dispersion coefficient, the new spreading growth is determined by the breed coefficient, the edge growth is influenced by the spread parameter, the road influenced growth is determined by the road growth and the slope parameter influences all growth types to capture the effects of slope resistance (Jantz, Goetz, & Shelley, 2004: Table 5.5). The model treats space and time discreetly, where one growth cycle denotes one year of slum growth based on the four aforementioned growth types (Figure 5.4). Each proposed new slum cell is compared to the local slope, exclusion layer and a random value, before it can be converted to a slum cell.

Table 5.5: Growth type simulated in the UGMr

Growth cycle order	**Growth type**	**Parameter**	**Description**
1	Spontaneous	Dispersion	Randomly selects potential new growth cells
2	New spreading	Breed	Growing urban centers from spontaneous growth
3	Edge	Spread	Old or new urban centers spawn additional growth
4	Road influenced	Road gravity	Newly urbanized cells spawn growth along transportation network
Throughout	Slope resistance	Slope	Effects of slope on reducing probability of urbanization
Throughout	Excluded layer	User-defined	Users specify areas of resistant or excluded development

Source: Jantz et al. (2004: 254)

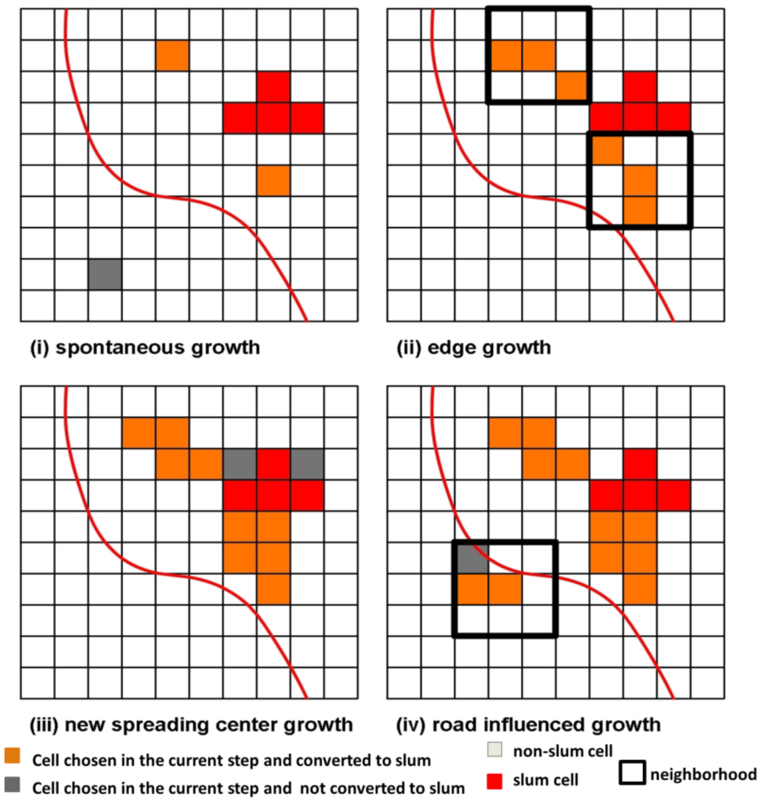


Figure 5.4: Growth types of a growth cycle in UGMr
Source: Adapted from Rienow & Goetzke (2015)

CA models aims to capture the self-organizing nature of complex urban system (Benenson & Torrens, 2004). It does not require prior knowledge about the parameters, so they are determined inductively during model calibration. Thus, UGMr uses the brute force Monte Carlo calibration techniques. The values for each coefficients (from 1 to 100, where 0 indicates no influence and 100 indicates maximum influence) were initially set at 1, 50 or 100, for the starting year of the slum extent (2009), to achieve a coarse calibration, and later refined in subsequent steps to achieve the best set of model combination, mimicking reality, based on the quantitative comparisons of simulated data to observed data (land-use map of Lagos, 2015 derived from the RapidEye image). After several runs, 7, 4, 13, 50 and 30 were chosen for dispersion, breed, spread, road gravity and slope resistance, respectively, as the best combination to forecast slum growth in Lagos, based on the factor of agreement of the validation (F_t=0.985).

5.3.6 Scenarios of slum growth in Lagos

Scenarios help to describe how a future event could likely unfold based on certain factors, and to suggest suitable alternatives to prepare and manage these future events. However, it is important to note that scenarios are not predictions, but rather an approach to help decision makers interpret the qualitative description of alternative futures translated into quantitative scenarios (Petrov, Lavalle, & Kasanko, 2009).

After successful calibration of the model, the obtained combination set for dispersion, breed, spread, road gravity and slope resistance were used to simulate future patterns of slum development in Lagos by 2035. To complete the prediction of the simulations, 100 Monte Carlo iterations were implemented. The result is a probabilistic map of each cell being converted to slum in the future based on various scenarios (Rafiee, Mahiny, Khorasani, Darvishsefat, & Danekar, 2009). The iterations also help to dampen the effect of stochasticity (Wegener, 2011).

Three scenarios were explored in this study, based on the modification of exclusion layer and growth coefficients. The Scenario 1 ‘business as usual’, depicts the slum development following the present trends. The present trend of development in Lagos shows that some section of Lagos Island axis (Victoria Island, Lekki Peninsula, Ikoyi, etc.) are resistible to slum growth, based on the monitoring of development by Government, thus included in the exclusion layer, together with the probability map of slum development in Lagos (from LR model). The scenario 2 ‘excessive growth’ depicts slum development based on the predicted population growth in Lagos (World Population Review, 2015), here the exclusion layer is the same with the scenario 1, however the growth coefficients was increased by a factor of 3 as a proxy for rapid population growth. And lastly, in scenario 3 ‘limited government influence’, the growth coefficient for scenario 1 was utilized, while the exclusion layer was modified in such a way that all land areas in the city could be converted into slums based on the probability map (LR model) (Table 5.6).

Table 5.6: Model parameters utilized for scenario of slum growth in Lagos (20 years)

Scenario	Dispersion	Breed	Spread	Road	Slope	Exclusion layer
1	4	13	7	50	30	Probability map (incl. zoning) & section of Lagos Island
2	12	39	21	50	30	Probability map (incl. zoning) & section of Lagos Island
3	4	13	7	50	30	Probability map (no zoning)

5.4 Results and Discussion

5.4.1 Drivers of slum development in Lagos (logistic regression)

Distance to markets, distance to industrial/public land use, distance to shoreline, distance to canal, distance to access roads, distance to local government administrative buildings, land price, population density, elevation and slope were significant drivers of slum development in Lagos (Table5.7).

Table 5.7: Estimated coefficients and odd ratios for logistic regression on drivers of slum development in Lagos

Variable	Definitions of Variables	Coefficient	Odd ratio
x_1	Cost-weighted distance to central business district (CBD)	Eliminated due to multicollinearity	
x_2	Cost-weighted distance to markets	-8.77e-05*** (4.85e-06)	0.999***(4.84e-06)
x_3	Cost-weighted distance to industrial/public land use	-5.88e-05***(9.34e-06)	0.999***(9.34e-06)
x_4	Euclidian distance to shoreline	- 4.61e-4***(2.68e-05)	0.999***(2.68e-05)
x_5	Euclidian distance to rail	Eliminated due to multicollinearity	
x_6	Euclidian distance to canal	9.88e-4***(5.03e-05)	1.000*** (5.04e-05)
x_7	Euclidian distance to express roads	Eliminated due to multicollinearity	
x_8	Euclidian distance to access roads	1.21e-3*** (1.50e-4)	1.001*** (1.51e-4)
x_9	Euclidian distance to local government administrative buildings	1.511e-4***(1.00e-05)	1.000*** (1.00e-05)
x_{10}	Inverse distance-weighted for land price	-2.509***(0.131)	0.0814***(0.0107)
x_{11}	Population density (persons/km^2)	3.73e-06***(1.31e-06)	1.000***(1.31e-06)
x_{12}	Elevation	-0.0849***(0.00322)	0.919***(0.00296)
x_{13}	Slope	-0.150***(0.0160)	0.861***(0.0138)
Constant		5.213 (0.2231)	

Dependent variable: slum/non-slum
*p<*0.1, p<**0.05, p<***0.01*
Standard errors in parentheses
Number of observations= 7616
Pseudo R^2 = 0.4023

Slum development tends to occur close to markets. An odd ratio of 0.999, meaning that the probability of slums to develop in an area increased as one moves closer to the markets. This could be explained by the fact that many slum dwellers in Lagos are artisans and thus work in the informal economy (Agbola & Agunbiade, 2009; Chapter 4), and unskilled job opportunities are common in the open markets. Furthermore, when tracing the origin of some slum settlements in Lagos, one will always detect a market not too far from them, e.g. boundary market in Ajegunle, however in some cases it is the slums, especially the old ones, that leads to the creation of the open markets e.g. Ikorodu slum and market.

As Lagos is the economic hub of Nigeria and West Africa. Many people move to Lagos for job opportunities, which can be found in industrial/public areas. The estimated odd ratio for distance to industrial/public land is 0.999, signifying that slums will likely develop closer to this land-use type than further away. An example is the proximity of Ijora-Badia slum to Apapa Wharf, a major seaport, and NIPCO, a major oil deport in Nigeria (Morka, 2007).

Slums will likely develop further away from the man-made canals. The Lagos state government constructed these canals to reduce flooding in the city. Many squatter communities around the canals were demolished during canal construction (Adelaja, 2011), and the government still monitors them, thereby discouraging new slum development close to these canals. Also, the odd ratio of distance to local government administrative buildings is 1.00, indicating that the probability of slum developing close to these buildings is null. Furthermore, based on the estimates, slums will probably not develop close to the access roads. Informal settlements are usually not planned as they are illegal (Onokerhoraye, 1995). A consequence of their illegality is the absence of a good road network within them.

In Lagos, slums tends to develop close to the shoreline, low slopes and elevations. Although the city harbors more than 10% of Nigeria's population, its landmass is considerably small, the smallest state in Nigeria with respect to land mass, consequently leading to high land and housing prices, which many cannot afford due to the high poverty in the city (Lagos Bureau of Statistics, 2014; Adedayo & Malik, 2015). The alternative for many people is usually the hazardous areas where the land value is low. However, the recent slum clearances in Lagos (eg Otodo Gbame, Ilubirin) have shown that some of these sites, especially those close to the shorelines, are now prime locations for formal housing development in Lagos, which might dissuade slum development in such locations in the future.

Slums tend to develop in areas with high population density. But, a considerable part of the study area is highly densified, leading to the low odd ratio observed in the logistic regression. Areas close to land with high prices will not develop into slums. This is because these areas also have the tendency to be expensive, thereby reducing their attractiveness for future slum development. Additionally, slums closer to these high income areas are usually demolished by the government after a certain period of time, to enable the development of high-income condominiums. An example is Maroko, a squatter community close to the Victoria Island and Ikoyi, demolished by the Lagos state government in 1990 and converted to a high-income residential area.

The analysis reveals the influencing character of the government on slum development. Slums tends to develop in areas where the government has limited or no access, e.g. low elevations and slope areas; while areas close to roads, man-made canals, and government buildings, discourage slum development. This is because slums that are accessible to the government tend to be cleared, being that the main slum management approach of the Lagos state government, to reduce slum proliferation in the city (Amnesty International, 2017).

5.4.2 Land-use and land-cover maps

Five dominant classes, i.e., bare soil, other urban, slum, vegetated area and water were derived from the land-use/cover maps of Lagos state for 2009 and 2015, and later merged into the slum and non-slum classes (where non-slum class includes all other classes) (Figure 5.5).

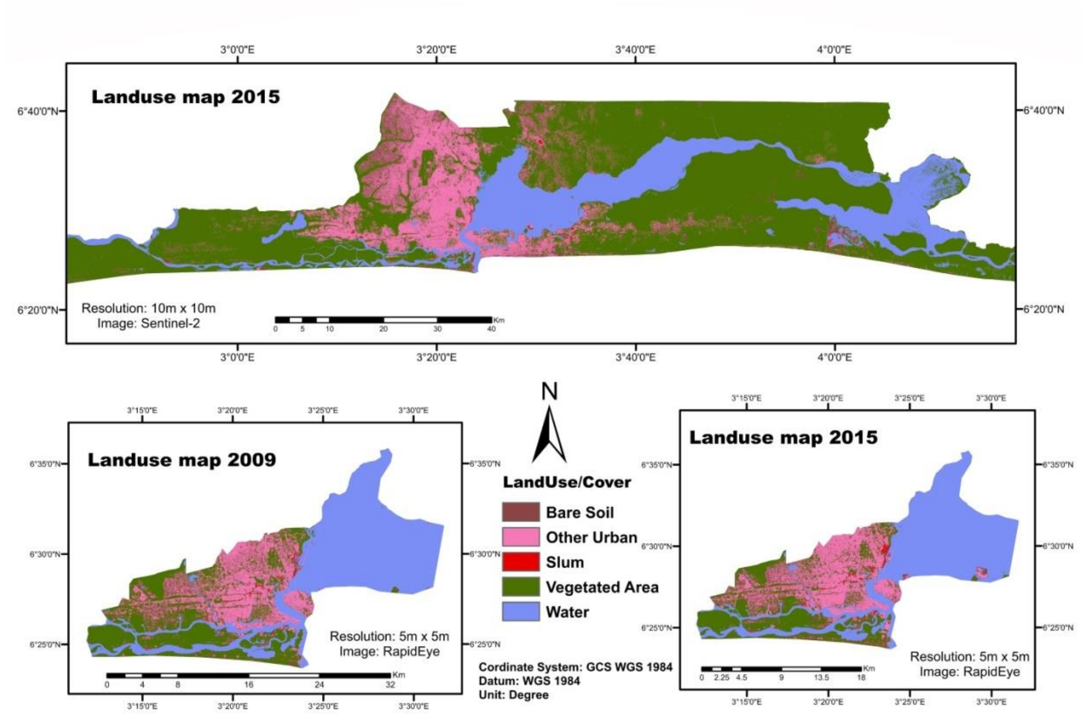


Figure 5.5: Land-use/cover map of Lagos state 2015

5.4.3 Probability Map of Slum development in Lagos (logistic regression)

The performance of fitting the LR model with the coefficients of the drivers of slum development was assessed using contingency table and ROC. The LR model achieved an overall accuracy of 79.17% (using a cut value of 0.5) and a ROC value of 0.85, symbolizing a good performance of the model based on the drivers utilized (Table 5.8; Figure 5.6).

Table 5.8: Validation of prediction done with the logistic regression model

		Predicted (%)	
		Non-slum (0)	Slum (1)
Observed (%)	Non-slum (0)	75.58	17.24
	Slum (1)	24.42	82.76
Overall accuracy (%)		79.17	

Note: cut value is 0.5

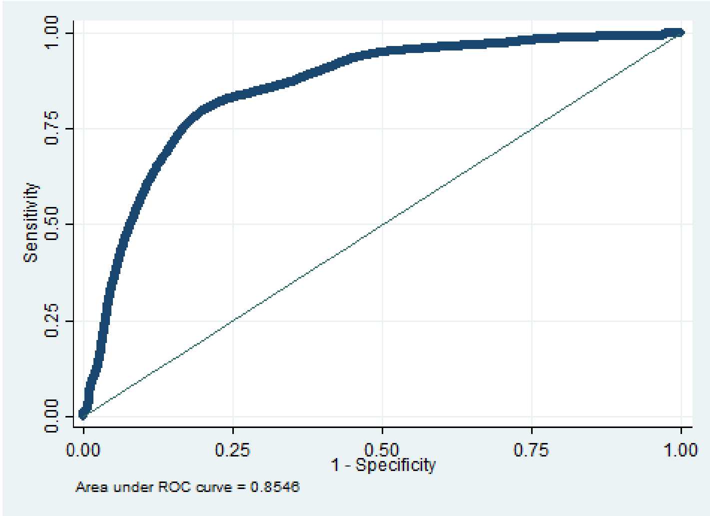


Figure 5.6: Relative operation characteristic curve (ROC)

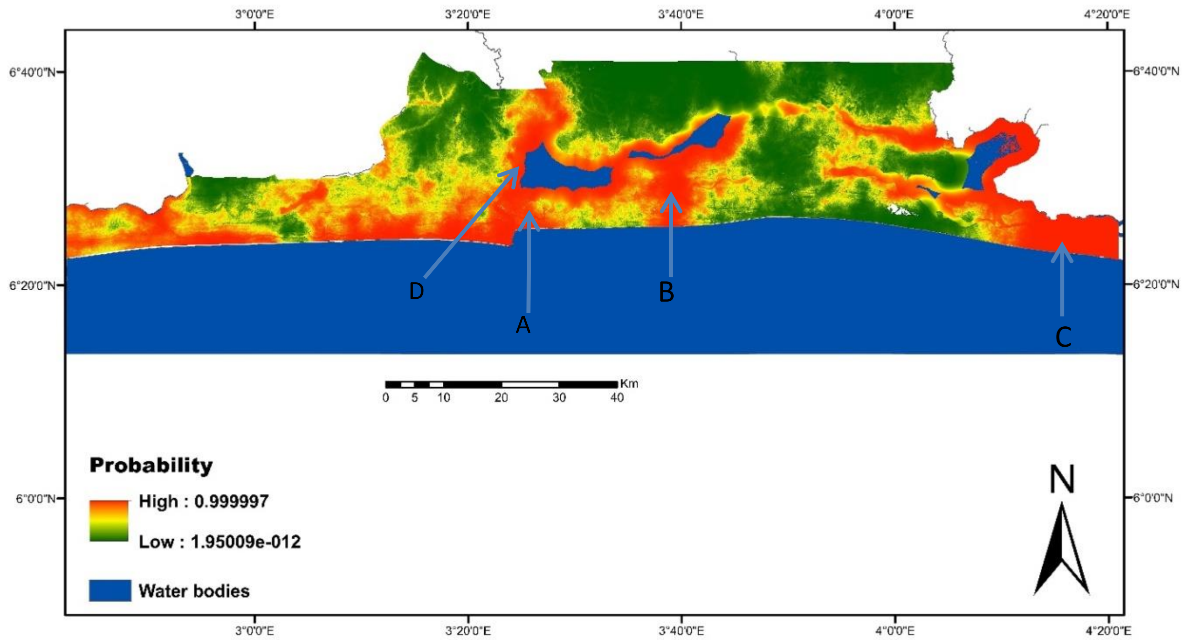


Figure 5.7: Probability map of slum development in Lagos 2015

The probability map shows that slums tend to be located within the city and on the fringe. This is consistent with Ajayi et al. (2014) who classified slums based on their location in: the core area (Figure 5.7.A), along the margins of the planned sections of the city (Figure 5.7.B), in the outskirts of the city (Figure 5.7.C). The scattering of probable location of slums can be attributed to the bilateral development, where slums developed concurrently with planned settlements, in Lagos. In addition, slums located at the margin of the planned areas are due to the job opportunities available for many slum dwellers in these areas (Morakinyo, Ogunrayewa, Olalekan, & Adenubi, 2012), however after short time, they are usually cleared. Furthermore, slums have the tendency to develop close to/on water bodies in the study area, which can be attributed to the nature of jobs done by the residents of this type of slums, for instance, most of the residents of Ago, Iwaya (a riverine slum community) are fishermen (Figure 5.7.D). Although the probability map reveals Lagos Island as a probable location of slum development in 2015, but the current trend shows gradual gentrification process in this area (Figure 5.7.A and 5.8).

Figure 5.8: Gentrification on Lagos Island

5.4.3 *Scenarios of future slum development in Lagos*

The simulations predict the slum area will increase by 1.18 km^2 (scenario 1), 4.02 km^2 (scenario 2), and 1.28 km^2 (scenario 3) by 2035. While the increased areas are similar, differences can be observed in their patterns of growth. For instance, scenarios 1 and 2 forecasted new slum development at the south-eastern fringe of Lagos, attributed to the development of the trade fair zone by the Lagos state government there (Figure 5.9.D), while scenario 3 predicted that existing slums in the excluded area will expand by 2035 (Figure 5.9.E).

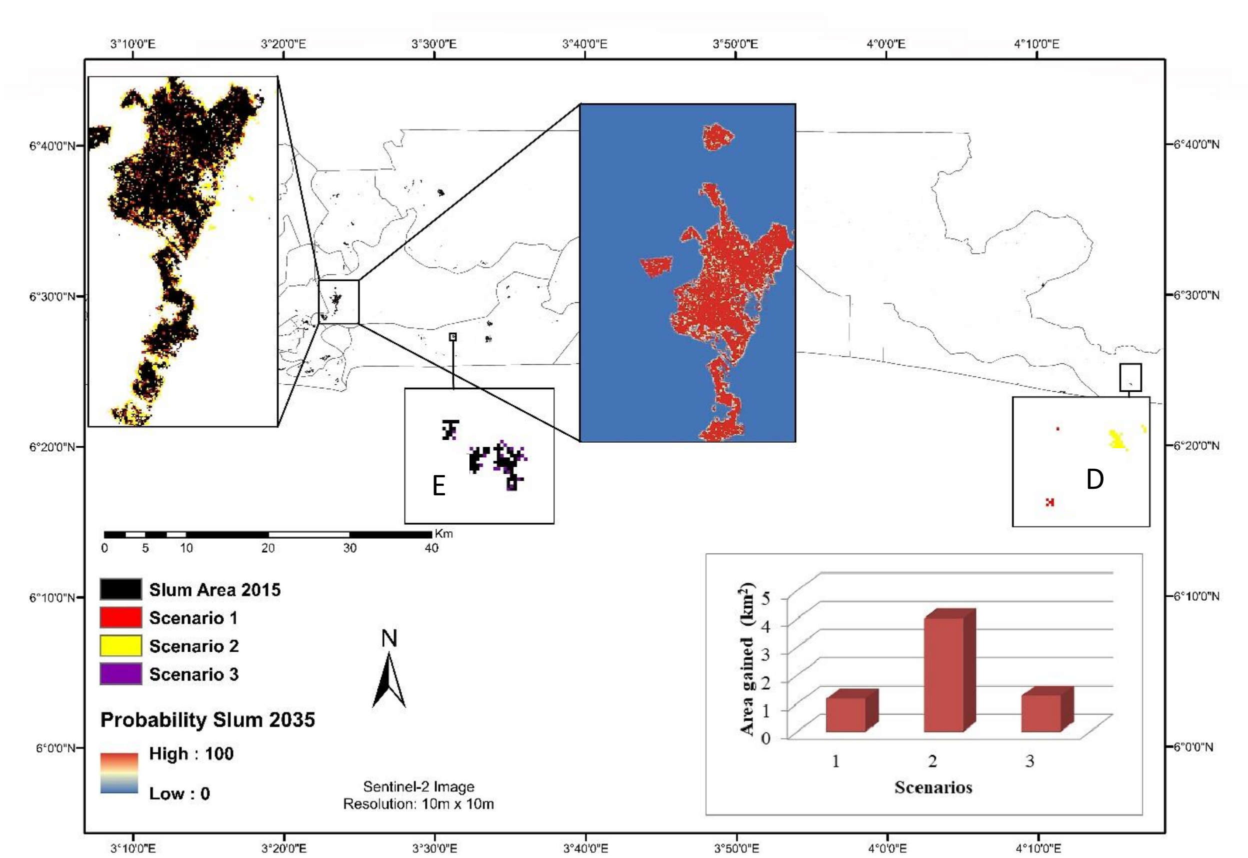


Figure 5.9: Simulation of slum development in Lagos in 2035

Although the exclusion layers utilized in scenarios 1 and 3 were different, the predicted slum areas were very similar. This could be attributed to the new vision for the city of Lagos to turn it into Africa's model megacity (Vanguard, 2018). At present, the master plan of the city is being developed at regional levels, as the previous one was not effective (LMPPUD/Asiyanbi, 2005). The master plan developed for each region would allow monitoring of development at the local scales. Also, the state government recently commissioned a waterway terminal to facilitate transportation within the city, which may also prevent illegal dwellings on the shorelines, as slums tend to grow there (Badmos et al., 2018). These two practices could make the scenarios 1 and 3 probable by 2035, as all sections of the city may become accessible to the government. As discussed above, slums in Lagos grow in places that are difficult to access by the government. Scenario 2, that depicts what could happen if the government would not plan for the demographic forecast, predict the development of new slums at the fringe of the south-eastern part of the city.

Areas closer to the existing slums have a higher tendency to change into slums than those farther away. Although this is a limitation of CA-based models, as the influence of growth decreases the farther you move away from the existing developed cells, however, it was able to show the type of growth expected in the Lagos slums. For instance, the simulations predicted increased densification of the existing slum communities. Furthermore, smaller neighboring slums will likely expand and merge to become bigger in the future.

5.5 Conclusions

This study explores the coupling of a logistic regression model with SLEUTH to simulate scenarios of future slum development in Lagos. Various drivers of slum development in Lagos were identified, analyzed and converted to spatial datasets. The results reveal that distance to markets, distance to industrial/public land, distance to shoreline, distance to canal, distance to access roads, distance to local government administrative buildings, land price, population density, elevation and slope contributed to the development of slums in Lagos. Also, the identified drivers was used to train the logistic regression model, and subsequently, constructed probability map to enhance the performance of the modified cellular automaton SLEUTH, known as urban growth model reduced. An overall accuracy of 79.17% (using a cut value of 0.5) and relative operation characteristics value of 0.85 was achieved for the probability map. The visualization of the probability map shows that slums can develop within and at the fringe of Lagos city and in places that are mostly inaccessible to Lagos state government (close to shoreline, on low slopes, no road, etc.).

Three scenarios were simulated based on the modification of the transition rules and the exclusion layer. The scenario 1 was business as usual, which allows slum development similar to the present trend. The scenario 2 was based on the future population projection for the city, while scenario 3 was based on limited interference by the government in slum development in the city. The scenarios predicted that the slum area will increase by 1.18 km^2 (scenario 1), 4.02 km^2 (scenario 2), and 1.28 km^2 (scenario 3), by 2035. New slums are predicted to develop on the south-eastern fringe of the city, and also further densification and merging of the existing slums by 2035. This implies that there is still room for future growth within the existing slum communities in Lagos.

The area gained in each scenario is relatively small, compared with the historical growth of slums in Lagos, attributed to the high density of Lagos, leading to a strong competition between slum and non-slum development on the limited available land. The present urban growth pattern in Lagos already shows the city´s expansion to neighboring towns e.g. Ibafo, Sango Ota, and these towns have started exhibiting slum like characteristics, thus the need for strategic planning. While it might be difficult to dissuade people from to moving to Lagos, it is important to develop adequate planning policies to manage the consequences of this movement, which must be jointly developed by the Lagos state government and that of the affected neighboring states.

The model was based on Cellular automata, which has a difficulty to model mobile entities. As it is in many simulation modeling, variables such as political will and unforeseen forces could not be integrated into the model. Limited data availability, a challenge for many sub-Saharan African countries, also reduces the detailed calibration and validation of the model. Nevertheless this study contributed to the modeling of slums in emerging economy, as its result can support planning decisions in Lagos. Further, the study also shows the importance of integrating socioeconomic drivers of slum development into cellular automaton SLEUTH model, as it helps to significantly reduce the bias in the prediction.

6. SUMMARY, CONCLUSIONS AND OUTLOOK

6.1 Summary

Urban planning aims to cater for the needs of people in a city at the right time and in the right place, irrespective of the peoples' socioeconomic status. However, achieving this is a pending task, especially in sub-Saharan African countries, where there are limited or unavailable data on the baseline situations, and a proactive slum management continues to be a herculean task. But this should not be a deterrent for conducting research in such situations, especially if the goal is to create cities without slums. To compensate for some of these limitations, this study contributes with ground information and a spatial planning tool, put together to support urban planning, and better management of slum formation in Lagos, a megacity in sub-Saharan Africa dominated by slum dwellers. To the best of the author's knowledge, this is the first study of its kind in a city in Nigeria, where remote sensing techniques, social science method (ethnographic survey) and spatially explicit urban land use models were integrated to study slum dynamics. The remote sensing techniques involved the use of object-based image and intensity analyses, to analyze and quantify the spatial growth of slums. Ethnographic surveys, through questionnaire administration and focus group discussion, were used to assess the influence of the residential choices of the slum dwellers on population growth. And finally, a hybrid land-use model, that coupled logistic regression and SLEUTH, was applied to simulate scenarios of future slum growth pattern in Lagos.

The introduction section of this thesis outlines three objectives with underlying sub-questions, which are answered in Chapter 3 (objective I), Chapter 4 (objective II) and Chapter 5 (objective III). A brief overview is given below before concluding with an outlook discussing the need for further research.

6.2 Objective I: Linking patterns and processes of slum growth in Lagos

Most slum management programs have been criticized because they do not consider the historical trends before their implementation. This was the motivating factor for the first objective where the patterns and processes of slum growth in Lagos were analyzed. This study utilized object-based image analysis building on generic slum ontology, to delineate slums from other land-use types in Lagos using RapidEye images of two time periods (2009 and 2015). Furthermore, it applied intensity analysis, at the category and transition level, to quantify the pattern of slum growth within the city. Finally, the underlying processes leading to the observed growth pattern were discussed.

An overall accuracy (kappa) of 94% (0.9) and 89% (0.86), were achieved for the 2009 and 2015 land-use and land-cover maps, respectively. From 2009 to 2015, the spatial extent of the slums increased, with a net gain of 9.14 km^2. This was attributed to population growth due to in-migration. Furthermore, the annual gain and loss intensity of the slums in the studied interval was 10.08% and 6.41%, respectively, compared to the annual uniform intensity of 3.15%, thus making slum an active land-use category. At the transition level of the intensity analysis, a systematic process of transition was observed between slum and other urban areas and open space, which were influenced by actions of the Lagos state government. The calculated uniform transition intensity “to” slum (0.81) was higher than the uniform transition intensity “from” slum (0.34), implying slum growth was faster than decline in the interval studied. Furthermore, slums encroached on water bodies. However the intensity analysis did not capture the process as active, due to the large size of water in the study area, which reveals the limitation of intensity analysis for studying the pattern and process of land-use changes in Lagos. Demolition and gentrification were the major reasons for loss of slum land area to other land-use types, while poor maintenance of existing building structures due to high poverty and unavailable resources contributed to the transition of other land-use types into slums. This chapter identified the land-use types that are susceptible to conversion to slums (open space, water and other urban areas), and if monitored, by the government can help reduce slum proliferation in Lagos.

6.3 Objective II: Assessing the importance of residential decisions on slum population growth in Lagos

The complex processes underlying slum growth, such as population growth dynamics, cannot be determined using earth observation technology. Therefore, the second objective was to assess: the movement pattern of slum dwellers; the residential decisions of slum dwellers in Lagos; and why they remain in the slums, and the influence of these decisions on the population growth in the slums. Ethnographic survey, via questionnaire administration and focus group discussion were used to solicit information on the socioeconomic characteristics, settlement history, reasons for choice of location of respondents in the sampled communities (Ajegunle, Iwaya, Itire and Ikorodu), which was then analyzed using descriptive statistics and logistic regression.

Movement to Lagos was the main cause of population growth in the slums, as over 70% of the respondents migrated to Lagos; most of the migrants were from nearby geopolitical zones in Nigeria, thus influencing the spoken languages and the ethnic enclaves in the city. Further, the movement pattern of slum dwellers in in Lagos supports two theories of human mobility in slums: slum as a sink where slum dwellers move from one slum to another within an urban area, and slum as a final destination where dwellers stay within one slum but can move from one residence to another within the same slum community, thus slums are not transitional phases in Lagos, rather permanent for the slum dwellers. Also, the factors that attracted most of the slum dwellers to the slums (family connection, cheap housing, proximity to work, etc.) differ from those that made them stay (duration of stay, housing status, affinity for neighborhood, etc.). People will continue to stay in slums as long as their needs are met, and with no rule on the influx to the slums, the population will continue to grow, adding to the number of people who do not intend to leave the slum. Most of the identified factors (pull and stay) were socio-demographic factors, hence appear keys to integrate them in the slum management practices, especially when it is necessary to relocate slum residents.

6.4 Objective III: Simulating scenarios of slum growth in Lagos

Unlike the first two objectives that focused on understanding the existing situation of slums in Lagos, the third objective focused on the exploration of land-use change models to develop scenarios of future slum growth patterns. A hybrid model, involving the coupling of an empirical statistical model (logistic regression), which allows the integration of other drivers of slum development, with a rule-based model (cellular automata based SLEUTH), was applied to simulate scenarios of slum growth in Lagos. The driving forces of slum development were analyzed and the correlated spatial drivers compiled to build a probability map of slum development in Lagos. The probability map was combined with the exclusion layer of the modified SLEUTH to simulate three different scenarios: i) business as usual, ii) excessive population growth and iii) limited government interference, of slum growth in Lagos by 2035.

Based on the estimates in the logistic regression, distance to markets, distance to shoreline, distance to local government administrative buildings, and land prices, etc., were identified as predictors of slum development in Lagos. An overall accuracy of 79.17% and a relative operation characteristics value of 0.85 were achieved for the prediction of slum development, based on the logistic regression model. The probability map shows that slums can develop within Lagos city and at the fringe, and also in places that are mostly inaccessible to Lagos state government. The three scenarios reveal further densification of the existing slums in Lagos with the slum area increasing by 1.18 km^2 (scenario 1), 4.02 km^2 (scenario 2) and 1.28 km^2 (scenario 3). New slum development was predicted at the fringe of the south-eastern part of the city, attributed to the development of the new trade fair center, by the government, in that location. The limited growth observed in the city was due to the highly densified nature of the city and some of the new policies put in place by the Lagos state, e.g., development of master plans at regional levels. It is assumed that new slums will develop in the neighboring areas close to Lagos. Therefore, neighboring state governments need to work together to prevent a spillover from Lagos turning these areas into slums.

6.5 Conclusion and Outlook

The results of this study show that the integration of remote sensing, social science method and spatially explicit land-use model can improve our understanding of slum dynamics, especially in sub-Saharan African countries with high slum proliferation and limited existence of data. However, there is still room for improvement. Availability of cloud-free very high resolution satellite images that cover the entire Lagos at different time points could help in the identification of all types of slums in Lagos and the analysis of the growth trend. This could support the creation of a base map, which could serve as a basis for monitoring development in the city and for other scientific studies. Furthermore, while integrating logistic regression in the model helps to reduce some of the shortfalls of cellular automata-based models, some limitations were still observed, such as the static nature of cells in these models. Although the study focused more on the simulation of the spread of slums, which cellular automata based models are good for, using other types of models such as agent-based models could help to understand how interactions of different actors (environment, government, slum dwellers, developers, etc.) have led to the observed growth of the slums in Lagos.

The observed limitations show the need for further studies on the integration of remote sensing in studies relating to slum dynamics. However, before incorporating relatively new methodologies, it is crucial to focus more on studies that can develop techniques to gather the data needed for the analyses, especially in sub-Saharan African countries where data are scarce. Otherwise, this approach will not provide sound findings on slum dynamics in sub-Saharan African countries.

REFERENCES

Abiodun, J. O. (1997). The Challenges of Growth and Development in Metropolitan Lagos. In C. Rakodi (Ed.), *The Urban challenge in Africa: Growth and Management of Its Large Cities*. New York: United nations University Press.

Abiodun, O. E., Olaleye, J. B., Dokai, A. N., Abiodun, O. E., Olaleye, J. B., & Dokai, A. N. (2011). Land Use Change Analyses in Lagos State From 1984 to 2005 Land Use Change Analyses in Lagos State From 1984 to 2005. In *FIG Working week, Bridging the Gap between Cultures* (p. May 18-22). Marrakech, Morocco. Retrieved from http://www.fig.net/resources/proceedings/fig_proceedings/fig2011/papers/ts09c/ts09c_abiodun_olaleye_et_al_5142.pdf

Acheampong, R. a, & Anokye, P. a. (2013). Understanding Households' Residential Location Choice in Kumasi's Peri-Urban Settlements and the Implications for Sustainable Urban Growth. *Research on Humanities and Social Sciences*, *3*(9), 60–70.

Action Health Incorporated. (2011). *A Promise to Keep: Supporting Out-Of- School Adolescent Girls to Reach Their Potential*. Lagos, Nigeria.

Adedayo, A. F., & Malik, N. A. (2015). Factors influencing the growth of slums in Lagos metropolis, Nigeria. *Ethiopian Journal of Environmental Studies and Management*, *8*(2), 113–119. https://doi.org/10.4314/ejesm.v8i2.1

Adejimi, A. (2005). Poor Building Maintenance in Nigeria : Are Architects Free from Blames? In *Proceedings of ENHR International Conference on Housing: New Challenges and Innovations in Tomorrow's Cities, Iceland, 29 June-3 July* (pp. 1–16). Iceland.

Adelaja, B. (2011, September 7). Flooding: Illegal structures give way to canal in Lagos. Retrieved September 11, 2018, from https://www.vanguardngr.com/2011/09/flooding-illegal-structures-give-way-to-canal-in-lagos/

Adelekan, I. O. (2010). Vulnerability of poor urban coastal communities to flooding in Lagos, Nigeria. *Environment and Urbanization*, *22*(2), 433–450. https://doi.org/10.1177/0956247810380141

Ademiluyi, I. A., & Raji, B. A. (2008). Public and private developers as agents in urban housing delivery in Sub-Saharan Africa: The situation in Lagos State. *Humanity and*

Social Sciences, *3*(2), 143–150.

Adepoju, M., Halilu, S., Ozigis, S., O, M. S., Idris, I., A, A. S., & Eta, J. (2013). Mapping and Monitoring of Slum Development in Abuja, Nigeria with Satelite Remote Sensing and Geographical Information System. *International Journal of Geosciences and Geomatics*, *1*(2), 69–76.

Adepoju, M. O., Millington, A. C., & Tansey, K. T. (2006). Land use/land cover change detection in metropolitan Lagos (Nigeria): 1984-2002. In *American Society for Photogrammetry and Remote Sensing, Annual Conference* (pp. 1–5). Reno, Nevada. Retrieved from http://www.asprs.org/a/publications/proceedings/reno2006/0002.pdf

Africa Fact Sheet. (2010). Main Economic Indicators. Retrieved July 11, 2017, from http://www.un.org/en/africa/osaa/pdf/policybriefs/2011_ecoindicators.pdf

Agbola, T., & Agunbiade, E. M. (2009). Urbanization, Slum Development and Security of Tenure: The Challenges of Meeting Millennium Development Goal 7 in Metropolitan Lagos, Nigeria. *Urban Population-Environment Dynamics in the Developing World: Case Studies and Lessons Learned*, 77–106. https://doi.org/http://www.populationenvironmentresearch.org/workshops.jsp#W2007

Agbola, T., & Jinadu, A. M. (1997). Forced eviction and forced relocation in Nigeria: the experience of those evicted from Maroko in 1990. *Environment and Urbanization*, *9*(2), 271–288. https://doi.org/10.1177/095624789700900214

Aguilar, A. G. (2008). Peri-urbanization, illegal settlements and environmental impact in Mexico City. *Cities*, *25*(3), 133–145. https://doi.org/10.1016/j.cities.2008.02.003

Agunbiade, M. E., Rajabifard, A., & Bennett, R. (2012). The dynamics of city growth and the impact on urban land policies in developing countries. *International Journal of Urban Sustainable Development*, *4*(2), 146–165. https://doi.org/10.1080/19463138.2012.694818

Ahmed, S., & Bramley, G. (2015). How will Dhaka grow spatially in future?-Modelling its urban growth with a near-future planning scenario perspective. *International Journal of Sustainable Built Environment*, *4*(2), 359–377.

https://doi.org/10.1016/j.ijsbe.2015.07.003

Ajayi, O. O., Oviasogie, F. O., Azuh, D. E., & Duruji, M. M. (2014). Urban Design and Sustainable Development: a Case of Makoko Area of Lagos State, Nigeria. *European Scientific Journal*, *10*(10), 90–97. Retrieved from http://www.eujournal.org/index.php/esj/article/view/3697

Ajibade, I., & McBean, G. (2014). Climate extremes and housing rights: A political ecology of impacts, early warning and adaptation constraints in Lagos slum communities. *Geoforum*, *55*, 76–86. https://doi.org/10.1016/j.geoforum.2014.05.005

Akinbode, A. (2002). *Introductory Environmental Resources Management*. Ibadan: Daybis.

Akom, A. A. (1984). Development strategies for the slums of Lagos. *Habitat International*, *8*(3–4), 159–171. https://doi.org/10.1016/0197-3975(84)90049-3

Akoni, O. (2013, August 31). 2006 Census: Tribunal declares Lagos exercise illegal. *Vanguard Nigeria*. Retrieved from https://www.vanguardngr.com/2013/08/2006-census-tribunal-declares-lagos-exercise-illegal/

Al-shalabi, M., Billa, L., Pradhan, B., Mansor, S., & Al-Sharif, A. A. A. (2013). Modelling urban growth evolution and land-use changes using GIS based cellular automata and SLEUTH models: the case of Sana'a metropolitan city, Yemen. *Environmental Earth Sciences*, *70*(1), 425–437. https://doi.org/10.1007/s12665-012-2137-6

Aldwaik, S. Z., & Pontius, R. G. (2012). Intensity analysis to unify measurements of size and stationarity of land changes by interval, category, and transition. *Landscape and Urban Planning*, *106*(1), 103–114. https://doi.org/10.1016/j.landurbplan.2012.02.010

Alonso, W. (1964). *Location and Land Use*. Cambridge: Harvard University Press.

Alsharif, A. A. A., & Pradhan, B. (2014). Urban Sprawl Analysis of Tripoli Metropolitan City (Libya) Using Remote Sensing Data and Multivariate Logistic Regression Model. *Journal of the Indian Society of Remote Sensing*, *42*(1), 149–163. https://doi.org/10.1007/s12524-013-0299-7

Aluko, O. (2010). The Impact of Urbanization on Housing Development: The Lagos Experience, Nigeria. *Ethiopian Journal of Environmental Studies and Management*, *3*(3), 64–67. https://doi.org/10.4314/ejesm.v3i3.63967

Amnesty International. (2017). *The human cost of a megacity forced evictions of the urban poor in Lagos, Nigeria*. London, UK: Amnesty International. Retrieved from https://www.amnesty.org/download/Documents/AFR4473892017ENGLISH.PDF

Andavarapu, D., & Edelman, D. J. (2013). Evolution of Slum Redevelopment Policy. *Current Urban Studies*, *1*(4), 185–192. https://doi.org/10.4236/cus.2013.14021

Arimah, B. C. (2010). The Face of Urban Poverty: Explaining the Prevalence of Slums in Developing Countries. In *Urbanization and Development* (pp. 143–164). Helsinki: Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199590148.003.0008

Aspinall, R. (2004). Modelling land use change with generalized linear models—a multi-model analysis of change between 1860 and 2000 in Gallatin Valley, Montana. *Journal of Environmental Management*, *72*(1–2), 91–103. https://doi.org/10.1016/j.jenvman.2004.02.009

Augustijn-Beckers, E.-W., Flacke, J., & Retsios, B. (2011). Simulating informal settlement growth in Dar es Salaam, Tanzania: An agent-based housing model. *Computers, Environment and Urban Systems*, *35*(2), 93–103. https://doi.org/10.1016/j.compenvurbsys.2011.01.001

Aworemi, J. I., Abdul-Azeez, I. A., & Opoola, N. A. (2011). An Appraisal of the Factors Influencing Rural-Urban Migration in Some Selected Local Government Areas of Lagos State Nigeria. *Journal of Sustainable Development*, *4*(3). https://doi.org/10.5539/jsd.v4n3p136

Badmos, O., Rienow, A., Callo-Concha, D., Greve, K., & Jürgens, C. (2018). Urban Development in West Africa—Monitoring and Intensity Analysis of Slum Growth in Lagos: Linking Pattern and Process. *Remote Sensing*, *10*(7), 1044. https://doi.org/10.3390/rs10071044

Barredo, J. I., Demicheli, L., Lavalle, C., Kasanko, M., & McCormick, N. (2004). Modelling Future Urban Scenarios in Developing Countries: An Application Case Study in Lagos, Nigeria. *Environment and Planning B: Planning and Design*, *31*(1), 65–84. https://doi.org/10.1068/b29103

Barrios, S., Bertinelli, L., & Strobl, E. (2010). Trends in Rainfall and Economic Growth in

Africa: A Neglected Cause of the African Growth Tragedy. *Review of Economics and Statistics*, *92*(2), 350–366. https://doi.org/10.1162/rest.2010.11212

Barros, J. (2012). Exploring Urban Dynamics in Latin American Cities Using an Agent-Based Simulation Approach. In *Agent-Based Models of Geographical Systems* (pp. 571–589). Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-90-481-8927-4_28

Batty, M. (2005). *Cities and complexity: understanding cities with cellular automata, agent-based models, and fractals.* Cambridge: MIT.

Beguy, D., Bocquier, P., & Zulu, E. M. (2010). Circular migration patterns and determinants in Nairobi slum settlements. *Demographic Research*, *23*, 549–586. https://doi.org/10.4054/DemRes.2010.23.20

Benenson, I., & Torrens, P. (2004). *Geosimulation: Automata-based modeling of urban phenomena.* Chichester: John Wiley & Sons.

Bengaluru. (2018, June 23). Very little upward mobility in slums: study. Retrieved October 11, 2018, from https://www.thehindu.com/news/cities/bangalore/very-little-upward-mobility-in-slums-study/article24496406.ece

Bigon, L. (2008). Between Local and Colonial Perceptions: The History of Slum Clearances in Lagos (Nigeria), 1924-1960. *African and Asian Studies*, *7*(1), 49–76. https://doi.org/10.1163/156921008X273088

Blaschke, T. (2010). Object based image analysis for remote sensing. *ISPRS Journal of Photogrammetry and Remote Sensing*, *65*(1), 2–16. https://doi.org/10.1016/j.isprsjprs.2009.06.004

Bobadoye, S. A., & Fakere, A. A. (2013). Slum Prevalence in Nigeria : What Role for Architects ? *World Environment*, *3*(2), 45–51. https://doi.org/10.5923/j.env.20130302.02

Braimoh, A. K. (2006). Random and systematic land-cover transitions in northern Ghana. *Agriculture, Ecosystems and Environment*, *113*(1–4), 254–263. https://doi.org/10.1016/j.agee.2005.10.019

Braimoh, A. K., & Onishi, T. (2007). Spatial determinants of urban land use change in Lagos, Nigeria. *Land Use Policy*, *24*(2), 502–515.

https://doi.org/10.1016/j.landusepol.2006.09.001

Breiman, L. (2001). Random forests. *Machine Learning*, *45*(1), 5–32.

Brown, D. G., Walker, R., Manson, S., & Seto, K. (2012). Modeling Land - Use and Land - Cover Change. In *Land change science* (pp. 395–409). Dordrecht: Springer. https://doi.org/10.1007/978-1-4020-2562-4_23

Busgeeth, K., van den Bergh, F., Whisken, J., & Brits, A. (2008). Potential application of remote sensing in monitoring informal settlements in South Africa where complimentary data does not exist. In L. Liu, X. Li, K. Liu, & X. Zhang (Eds.), *Geoinformatics 2008 and Joint Conference on GIS and Built Environment: Geo-Simulation and Virtual GIS Environments*. Guangzhou, China. https://doi.org/10.1117/12.813211

Chant, S. (1992). A framework for the Analysis of Gender-Selective Migration. In S. Chant (Ed.), *Gender and Migration in Developing Countries*. New York: Belhaven Press.

Chepngeno-Langat, G., & Ezeh, A. (2007). Between a rock and a hard place': perception of older people living in Nairobi city on return-migration to rural areas. *Issues & Action*, *4*(3), 67–78.

Cheru, F. (2005). Globalization and uneven urbanization in Africa: the limits to effective urban governance in the provision of basic services. Retrieved March 10, 2017, from http://www.international.ucla.edu/cnes/article/107324

Cities Alliance. (2013). About Slum Upgrading. Retrieved January 10, 2017, from https://www.citiesalliance.org/sites/citiesalliance.org/files/CA_Images/SUFactsheet_English_0.pdf

Clark, W. A. V, & Huang, Y. (2003). The Life Course and Residential Mobility in British Housing Markets. *Environment and Planning A*, *35*(2), 323–339. https://doi.org/10.1068/a3542

Clarke, K. (2014). Cellular automata and agent-based models. In *Handbook of regional science* (pp. 1217–1233). Berlin Heidelberg: Springer.

Clarke, K. C., Hoppen, S., & Gaydos, L. (1997). A self-modifying cellular automaton model of historical urbanization in the San Francisco Bay area. *Environment and Planning B:*

Planning and Design, *24*(2), 247–261. https://doi.org/10.1068/b240247

Clayton, A., & Radcliffe, N. (1996). *Sustainability. A systems approach* (1st ed.). London: Routledge.

Cohen, B. (2006). Urbanization in developing countries: Current trends, future projections, and key challenges for sustainability. *Technology in Society*, *28*(1–2), 63–80. https://doi.org/10.1016/j.techsoc.2005.10.005

Congalton, R. G. (1991). A review of assessing the accuracy of classifications of remotely sensed data. *Remote Sensing of Environment*, *37*(1), 35–46. https://doi.org/10.1016/0034-4257(91)90048-B

Cook, R. D. (1977). Detection of Influential Observation in Linear Regression. *Technometrics*, *19*(1), 15–18. https://doi.org/10.1080/00401706.1977.10489493

Daniel, M. M., Wapwera, S. D., Akande, E. M., Musa, C. C., & Aliyu, A. A. (2015). Slum Housing Conditions and Eradication Practices in Some Selected Nigerian Cities. *Journal of Sustainable Development*, *8*(2), 230–241. https://doi.org/10.5539/jsd.v8n2p230

Davis, M. (2004). Planet of slums. *New Left Review*, *26*, 5–34.

Davis, M. (2006). *Planet of slums*. London, UK; New York, NY, USA,: Verso.

Debnath, A. K., & Naznin, S. . (2011). Industrial Concentration as Predictor of Slum Agglomeration in Dhaka Metropolitan Development Plan Area: A Spatial Autocorrelation Approach. *Journal of Bangladesh Institute of Planners*, *4*, 1–13.

Deichmann, U. (1997). *Accessibility indicators in GIS*. New York.

DeJong, G. (1994). *Choice processes in migration intentions and behavior* (Population Research Institute Working Papers No. 95-04). Pennsylvania.

Dekolo, S. O., & Olayinka, D. N. (2013). Monitoring peri-urban land use change with multi-temporal Landsat imagery. In C. Ellul, S. Zlatanova, M. Rumor, & R. Laurini (Eds.), *Urban and Regional Data Management: UDMS Annual* (pp. 145–159). London: CRS, Taylor & Francis.

Dietzel, C., & Clarke, K. (2007). Toward Optimal Calibration of the SLEUTH Land Use Change Model. *Transactions in GIS*, *11*(1), 29–45. https://doi.org/10.1111/j.1467-

9671.2007.01031.x

Dubovyk, O., Sliuzas, R., & Flacke, J. (2011). Spatio-temporal modelling of informal settlement development in Sancaktepe district, Istanbul, Turkey. *ISPRS Journal of Photogrammetry and Remote Sensing*, *66*(2), 235–246. https://doi.org/10.1016/j.isprsjprs.2010.10.002

Dung-Gwom, J. Y. (2007). Urban Renewal in Jos-Bukuru Metropolis. *WORLD*, *31*, 714–972.

Duro, D. C., Franklin, S. E., & Dubé, M. G. (2012). A comparison of pixel-based and object-based image analysis with selected machine learning algorithms for the classification of agricultural landscapes using SPOT-5 HRG imagery. *Remote Sensing of Environment*, *118*, 259–272. https://doi.org/10.1016/j.rse.2011.11.020

Fay, M., & Opal, C. (1999). *Urbanization without Growth: A Not-So-Uncommon Phenomenon*. The World Bank. https://doi.org/10.1596/1813-9450-2412

Fekade, W. (2000). Deficits of formal urban land management and informal responses under rapid urban growth, an international perspective. *Habitat International*, *24*(2), 127–150. https://doi.org/10.1016/S0197-3975(99)00034-X

Filani, O. M. (2012). *The Changing face of Lagos: From vission to reform and transformation*. *Cities Alliance*. Brussels, Belgium.

Foody, G. M. (2002). Status of land cover classification accuracy assessment. *Remote Sensing of Environment*, *80*(1), 185–201. https://doi.org/10.1016/S0034-4257(01)00295-4

Fox, S. (2012). Urbanization as a Global Historical Process: Theory and Evidence from sub-Saharan Africa. *Population and Development Review*, *38*(2), 285–310. https://doi.org/10.1111/j.1728-4457.2012.00493.x

Garau, P., Sclar, E. D., & Carolini, G. Y. (2005a). *A Home in the City: Improving the lives of slum dwellers*.

Garau, P., Sclar, E. D., & Carolini, G. Y. (2005b). *A Home in the City: Task Force on Improving the Lives of Slum Dwellers: achieving the Millennium Development Goals*. London: Earthscan.

George, C. (1999). *Basic Principles and Methods of Urban and Regional Planning* (1st ed.).

Nigeria: Libra – Gen Limited.

George, C. (2002). *Basic Principles and Methods of Urban and Regional Planning* (2nd ed.). Lagos: Librogem Books.

Gilbert, A. (2007). The Return of the Slum: Does Language Matter? *International Journal of Urban and Regional Research*, *31*(4), 697–713. https://doi.org/10.1111/j.1468-2427.2007.00754.x

Goetzke, R. (2011). *Entwicklung eines fernerkundungsgestützten Modellverbundes zur Simulation des urban-ruralen Landnutzungswandels in Nordrhein-Westfalen*. Verlag. Retrieved from http://hss.ulb.uni-bonn.de/2011/2577/2577.htm

Goetzke, R., & Judex, M. (2011). Simulation of urban land-use change in North Rhine Westphalia (Germany) with the Java-based modelling plat- form Xulu. In P. Mandl & A. Koch (Eds.), *Modeling and Simulating Urban Processes* (pp. 99–116). Munster: LIT-Verlag.

Gruebner, O., Sachs, J., Nockert, A., Frings, M., Khan, M. M. H., Lakes, T., & Hostert, P. (2014). Mapping the Slums of Dhaka from 2006 to 2010. *Dataset Papers in Science*, *2014*(1), 1–7. https://doi.org/10.1155/2014/172182

Gulyani, S., & Bassett, E. M. (2007). Retrieving the Baby from the Bathwater: Slum Upgrading in Sub-Saharan Africa. *Environment and Planning C: Government and Policy*, *25*(4), 486–515. https://doi.org/10.1068/c4p

Gulyani, S., & Talukdar, D. (2008). Slum Real Estate: The Low-Quality High-Price Puzzle in Nairobi's Slum Rental Market and its Implications for Theory and Practice. *World Development*, *36*(10), 1916–1937. https://doi.org/10.1016/j.worlddev.2008.02.010

Guzi, M., Kabina, K., & Tijdens, K. G. (2016). *Living Wages in Nigeria– Lagos State*. Amsterdam.

Happe, B., & Sperberg, J. (2003). Social structures and living conditions. In D. Berg-Schlosser & N. Kersting (Eds.), *Poverty and Democracy* (pp. 76–92). London: Zed Books.

Hartley, J., Potts, J., Flew, T., Cunningham, S., Keane, M., & Banks, J. (2013). *Key concepts in creative industries*. London: Sage.

Hietel, E., Waldhardt, R., & Otte, A. (2007). Statistical modeling of land-cover changes based on key socio-economic indicators. *Ecological Economics*, *62*(3–4), 496–507. https://doi.org/10.1016/j.ecolecon.2006.07.011

Hofmann, P., Strobl, J., Blaschke, T., & Kux, H. (2008a). Detecting informal settlements from QuickBird data in Rio de Janeiro using an object based approach. In *Object-Based Image Analysis* (pp. 531–553). Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-77058-9_29

Hofmann, P., Strobl, J., Blaschke, T., & Kux, H. (2008b). Detecting informal settlements from QuickBird data in Rio de Janeiro using an object based approach. In *Object-Based Image Analysis* (pp. 531–553). Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-77058-9_29

Hofmann, P., Taubenbock, H., & Werthmann, C. (2015). Monitoring and modelling of informal settlements - A review on recent developments and challenges. In *2015 Joint Urban Remote Sensing Event (JURSE)* (pp. 1–4). IEEE. https://doi.org/10.1109/JURSE.2015.7120513

Hope, K. R. (1998). Urbanization and urban growth in Africa. *Journal of Asian and African Studies*, *33*(4), 345–358.

Hu, Z., & Lo, C. P. (2007). Modeling urban growth in Atlanta using logistic regression. *Computers, Environment and Urban Systems*, *31*(6), 667–688. https://doi.org/10.1016/j.compenvurbsys.2006.11.001

Huang, J., Pontius, R. G., Li, Q., & Zhang, Y. (2012). Use of intensity analysis to link patterns with processes of land change from 1986 to 2007 in a coastal watershed of southeast China. *Applied Geography*, *34*, 371–384. https://doi.org/10.1016/j.apgeog.2012.01.001

Hurskainen, P., & Pellikka, P. (2004a). Change detection of informal settlements using multi-temporal aerial photographs–the case of Voi, SE-Kenya. In *5th African Association of Remote Sensing of the Environment conference*. Nairobi, Kenya. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.112.127&rep=rep1&type=pdf

Hurskainen, P., & Pellikka, P. (2004b). Change detection of informal settlements using multi-temporal aerial photographs–the case of Voi, SE-Kenya. In *5th African Association of*

Remote Sensing of the Environment conference. Nairobi, Kenya.

Ige, K., & Nekhwevha, F. (2014). Economic Deprivation and Willingness to Relocate among Urban Slum Dwellers in Lagos. *J Hum Ecol*, *45*(1), 25–39. Retrieved from http://www.krepublishers.com/02-Journals/JHE/JHE-45-0-000-14-Web/JHE-45-1-000-14-Abst-PDF/JHE-45-1-025-14-2501-Ige-K-E/JHE-45-1-025-14-2501-Ige-K-E-Tx[4].pmd.pdf

Ilesanmi, A. O. (2010). Urban sustainability in the context of Lagos mega-city. *Journal of Geography and Regional Planning*, *3*(10), 240–252. https://doi.org/10.1016/S0169-2046(01)00233-X

Immerwahr, D. (2007). The politics of architecture and urbanism in postcolonial Lagos, 1960–1986. *Journal of African Cultural Studies*, *19*(2), 165–186. https://doi.org/10.1080/13696810701760450

IRIN. (2006). Lagos, the mega-city of slums. Retrieved July 9, 2018, from http://www.irinnews.org/ news/2006/09/05/lagos-mega-city-slums

Iweka, C. O., & Adebayo, A. (2010). Improving housing durability in deprived settlements of Lagos megacity through ingenuous use of sustainable indigenous materials. *International Journal of Sustainable Construction Engineering & Technology*, *1*(1), 99–111.

Jantz, C. A., Goetz, S. J., & Shelley, M. K. (2004). Using the Sleuth Urban Growth Model to Simulate the Impacts of Future Policy Scenarios on Urban Land Use in the Baltimore-Washington Metropolitan Area. *Environment and Planning B: Planning and Design*, *31*(2), 251–271. https://doi.org/10.1068/b2983

Jat, M. K., Choudhary, M., & Saxena, A. (2017). Application of geo-spatial techniques and cellular automata for modelling urban growth of a heterogeneous urban fringe. *Egyptian Journal of Remote Sensing and Space Science*, *20*(2), 223–241. https://doi.org/10.1016/j.ejrs.2017.02.002

Jokar Arsanjani, J., Helbich, M., Kainz, W., & Darvishi Boloorani, A. (2013). Integration of logistic regression, Markov chain and cellular automata models to simulate urban expansion. *International Journal of Applied Earth Observation and Geoinformation*, *21*, 265–275. https://doi.org/10.1016/j.jag.2011.12.014

Joshi, P., Sens, S., & Hobson, J. (2002). Experiences with surveying and mapping Pune and Sangli slums on a geographical information system (GIS). *Environment and Urbanization*, *14*(2), 225–240. https://doi.org/10.1177/095624780201400218

Kapoor, M., Lall, S. V, Lundberg, M. K. A., & Shalizi, Z. (2004). *Location and welfare in cities: Impacts of policy interventions on the urban poor* (No. Paper No. 3318.). Retrieved from https://ssrn.com/abstract=610363

Kengne, F. F. (2000). À travers le temps et l'espace: l'irresistible expansion du secteur informel dans les pays du Sud. In F. F. Kengne & A. Metton (Eds.), *Economie Informelle et Développement dans les pays du Sud à l'ère de la Mondialisation.* (pp. 21–37). Yaoundé: UGI/PUY.

Kim, J. H., Pagliara, F., & Preston, J. (2005). The intention to move and residential location choice behaviour. *Urban Studies*, *42*(9), 1621–1636. https://doi.org/10.1080/00420980500185611

Kit, O., & Lüdeke, M. (2013). Automated detection of slum area change in Hyderabad, India using multitemporal satellite imagery. *ISPRS Journal of Photogrammetry and Remote Sensing*, *83*, 130–137. https://doi.org/10.1016/j.isprsjprs.2013.06.009

Kit, O., Lüdeke, M., & Reckien, D. (2012). Texture-based identification of urban slums in Hyderabad, India using remote sensing data. *Applied Geography*, *32*(2), 660–667. https://doi.org/10.1016/j.apgeog.2011.07.016

Kohli, D., Sliuzas, R., Kerle, N., & Stein, A. (2012). An ontology of slums for image-based classification. *Computers, Environment and Urban Systems*, *36*(2), 154–163. https://doi.org/10.1016/j.compenvurbsys.2011.11.001

Kohli, D., Warwadekar, P., Kerle, N., Sliuzas, R., & Stein, A. (2013). Transferability of object-oriented image analysis methods for slum identification. *Remote Sensing*, *5*(9), 4209–4228. https://doi.org/10.3390/rs5094209

Krejcie, R. V., & Morgan, D. W. (1970). Determining sample size for research activities. *Educational and Psychological Measurement, 30*(3), 607–610.

Kuffer, M., & Barros, J. (2011). Urban morphology of unplanned settlements: The use of spatial metrics in VHR remotely sensed images. *Procedia Environmental Sciences*, *7*, 152–157. https://doi.org/10.1016/j.proenv.2011.07.027

Kuffer, M., Pfeffer, K., & Sliuzas, R. (2016). Slums from space-15 years of slum mapping using remote sensing. *Remote Sensing*, *8*(6). https://doi.org/10.3390/rs8060455

Kuffer, M., Sliuzas, R., Pfeffer, K., & Baud, I. (2015). The utility of the co-occurrence matrix to extract slum areas from VHR imagery. *2015 Joint Urban Remote Sensing Event, JURSE 2015*, 3–6. https://doi.org/10.1109/JURSE.2015.7120514

Kumar Swami, S. (2017). An Empirical Study of Growth of Slum Population in India. *International Journal of Political Science*, *3*(1), 10–13. https://doi.org/10.20431/2454-9452.0301002

Kunnuji, M. O. N. (2015). Experience of Domestic Violence and Acceptance of Intimate Partner Violence Among Out-of-School Adolescent Girls in Iwaya Community, Lagos State. *Journal of Interpersonal Violence*, *30*(4), 543–564. https://doi.org/10.1177/0886260514535261

Lagos-State/UNCHS. (1984). *Identification of Urban Renewal Areas in Metropolitan Lagos*. Lagos.

Lagos Bureau of Statistics. (2013). Lagos State Government Digest of Statistics. Retrieved August 24, 2017, from https://mepb.lagosstate.gov.ng/wp-content/uploads/sites/29/2017/01/2013-Digest-of-Statistics.pdf

Lagos Bureau of Statistics. (2014). *Poverty Profile for Lagos State*. Lagos, Nigeria.

Lagos state Government. (2016). Year 2017 Lagos state Budget. Retrieved March 19, 2018, from https://lagosstate.gov.ng/blog/2017/01/19/budget-presentation-by-his-excellency-mr-akinwunmi-ambode-governor-of-lagos-state/

Lall, S. V., Lundberg, M. K. A., & Shalizi, Z. (2008). Implications of alternate policies on welfare of slum dwellers: Evidence from Pune, India. *Journal of Urban Economics*, *63*(1), 56–73. https://doi.org/10.1016/j.jue.2006.12.001

Lemma, T., Sliuzas, R., & Kuffer, M. (2006). A participatory approach to monitoring slum conditions: an example from Ethiopia. *IIED Publications Database. Participatory Learning and Action*, *54*(1), 67–89.

Liaw, A., & Wiener, M. (2002). Classification and Regression by randomForest. *R News*, *2*(December), 18–22. https://doi.org/10.1023/A:1010933404324

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology*, *22*(140), 55.

Limbumba, T. M. (2010). *Exploring social-cultural explanations for residential location choices: The case of an African city-Dar es Salaam*. Royal Institute of Technology, Stockholm, Sweden.

Lin, Y.-P., Chu, H.-J., Wu, C.-F., & Verburg, P. (2011). Predictive ability of logistic regression, auto-logistic regression and neural network models in empirical land-use change modeling – a case study. *International Journal of Geographical Information Science*, *25*(1), 65–87. https://doi.org/10.1080/13658811003752332

Linard, C., Tatem, A. J., & Gilbert, M. (2013). Modelling spatial patterns of urban growth in Africa. *Applied Geography*, *44*, 23–32. https://doi.org/10.1016/j.apgeog.2013.07.009

LMPPUD/Asiyanbi. (2005). *Report on the review of the Lagos state regional plan (1980-2000), Executive summary*. Lagos.

Lu, D., Mausel, P., Brondízio, E., & Moran, E. (2004). Change detection techniques. *International Journal of Remote Sensing*, *25*(12), 2365–2401. https://doi.org/10.1080/0143116031000139863

Macleod, R. D., & Congalton, R. G. (1998). A Quantitative comparison of change-detection algorithms for monitoring eelgrass from remotely sensed data. *Photogrammetric Engineering and Remote Sensing*, *64*(3), 207–216. https://doi.org/10.1088/0004-637X/743/2/135

Mahabir, R., Croitoru, A., Crooks, A., Agouris, P., & Stefanidis, A. (2018). A Critical Review of High and Very High-Resolution Remote Sensing Approaches for Detecting and Mapping Slums: Trends, Challenges and Emerging Opportunities. *Urban Science*, *2*(1), 8. https://doi.org/10.3390/urbansci2010008

Manandhar, R., Odeh, I. O. A., & Pontius, R. G. (2010). Analysis of twenty years of categorical land transitions in the Lower Hunter of New South Wales, Australia. *Agriculture, Ecosystems & Environment*, *135*(4), 336–346.

https://doi.org/10.1016/j.agee.2009.10.016

Manzo, G. (2014). The Potential and Limitations of Agent-based Simulation. *Revue Française de Sociologie*, *55*(4), 433–462.

Marghany, M., & Genderen, J. v. (2014). Three-dimensional slum urban reconstruction in Envisat and Google Earth Egypt. *IOP Conference Series: Earth and Environmental Science*, *18*, 012166. https://doi.org/10.1088/1755-1315/18/1/012166

Marsden, L. R., & Tepperman, L. J. (1985). The migrant wife: The worst of all worlds. *Journal of Business Ethics*, *4*(3), 205–213. https://doi.org/10.1007/BF00705621

Marx, B., Stoker, T., & Suri, T. (2013). The Economics of Slums in the Developing World. *Journal of Economic Perspectives*, *27*(4), 187–210. https://doi.org/10.1257/jep.27.4.187

McGranahan, G., Mitlin, D., Satterthwaite, D., Tacoli, C., & Turok, I. (2009). *Africa's urban transition and the role of regional collaboration. Human Settlements Working Paper Series Theme: Urban Change – 5*. Retrieved from https://s3.amazonaws.com/academia.edu.documents/30920105/10571IIED.pdf?AWSAccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1540820525&Signature=bMmlQD7%2FcWc0bguP0MNmE3%2FKNbQ%3D&response-content-disposition=inline%3Bfilename%3DAfricas_urban_transition_and_the_r

Mehta, B. E., Dastur, A., & Janus, S. (2008). *Approaches to Urban Slums: A Multimedia Sourcebook on Adaptive and Proactive Strategies*. (B. E. Mehta & A. Dastur, Eds.). The World Bank. https://doi.org/10.1596/978-0-8213-7354-5

Mhangara, P., Odindi, J., Kleyn, L., & Remas, H. (2011). Road Extraction Using Object Oriented Classification. Retrieved March 3, 2016, from http://www.ee.co.za/wp-content/uploads/legacy/posit11/PositionIT_nov-dec11-Vis_45-50.pdf

Mincer, J. (1978). Family Migration Decisions. *Journal of Political Economy*, *86*(5), 749–773. https://doi.org/10.1086/260710

Morakinyo, K. O., Ogunrayewa, M. O., Olalekan, K. B., & Adenubi, O. O. (2012). Urban Slums as Spatial Manifestations of Urbanization in Sub- Saharan Africa: A Case Study of Ajegunle Slum Settlement, Lagos, Nigeria. *Developing Country Studies*, *2*(11/12), 1–10.

Morka, F. C. (2007). A place to live: A case study of the Ijora-Badia community in Lagos, Nigeria. *Enhancing Urban Safety and Security: Global Report on Human Settlements 2007*.

Mubea, K. W. (2014). *Scenarios of Urban Growth in Kenya Using Regionalised Cellular Automata based on Multi temporal Landsat Satellite Data*. Retrieved from http://hss.ulb.uni-bonn.de/diss_online elektronisch publiziert

Mudege, N. N., & Zulu, E. M. (2011). In their own words: Assessment of satisfaction with residential location among migrants in Nairobi slums. *Journal of Urban Health*, *88*(SUPPL. 2), 219–234. https://doi.org/10.1007/s11524-010-9467-z

Mundia, C. N., & Aniya, M. (2007). Modeling and predicting urban growth of Nairobi City using cellular automata with geographical information systems. *Geographical Review of Japan*, *80*(12), 279–290.

Muth, F. R. (1969). *Cities and Housing*. Chicago: University of Chicago Press.

New Telegraph. (2015). History about Ajegunle In Lagos, Nigeria. Retrieved July 12, 2018, from http://voiceofajegunle.blogspot.com/2015/11/history-about-ajegunle-in-lagos-nigeria.html

Nong, Y., & Du, Q. (2011). Urban growth pattern modeling using logistic regression. *Geo-Spatial Information Science*, *14*(1), 62–67. https://doi.org/10.1007/s11806-011-0427-x

Nsorfon, I. F. (2015). *Exploring Social Vulnerability to Natural Disasters in Urban Informal Settlements - Perspectives from Flooding in the Slums of Lagos, Nigeria*. Universitz of Cologne. Retrieved from http://kups.ub.uni-koeln.de/6367/

Nwaka, I. G. (2005). the Urban Poor, the Informal City and Environmental Health Policy in Nigeria. *Epidemiology*, *16*(5), S121–S122. https://doi.org/10.1097/00001648-200509000-00306

Nwanna, C. R. (2012). Gentrification in Lagos State: Challenges and prospects. *British Journal of Arts and Social Sciences*, *5*(2), 163–176.

Obeng-Odoom, F. (2010). Abnormal Urbanization in Africa: A Dissenting View. *African Geographical Review*, *29*(2), 13–41.

Obono, O. (2007). Lagos Thing, A-Rules and Realities in the Nigerian Megacity. *Georgetown Journal of International Affairs*, *8*(2), 31–37.

Odufuwa, B. O., Fransen, J., Bongwa, A., & Gianoli, A. (2009). Cities, theories and reality. *Journal of Geography*, *2*(10), 243–248.

Oduwaye, A. O., & Lawanson, T. O. (2007). Poverty and Environmental Degradation in the Lagos Metropolis. Retrieved May 12, 2018, from https://www.africaportal.org/publications/poverty-and-environmental-degradation-in-the-lagos-metropolis/

Oduwaye, L. (2008). Planning Implications of the Ethnic Structure Of Residential Areas of Metropolitan Lagos. *Asian Social Science*, *4*(8), 129–136.

Oduwaye, L. (2009). Challenges of Sustainable Physical Planning and Development in Metropolitan Lagos. *Journal of Sustainable Development*, *2*(1), 159–171.

Okwuashi, O., & Beulah, O. (2012). Historical Perspective of Urbanization and Urban Planning Lagos, Nigeria. *International Journal of Science and Research*, *3*(8), 1994–1998.

Olajuyigbe, A. E., Popoola, O. O., Adegboyega, S. A.-A., & Obasanmi, T. (2015). Application of Geographic Information Systems to Assessing the Dynamics of Slum and Land Use Changes in Urban Core of Akure, Nigeria. *Journal of Sustainable Development*, *8*(6). https://doi.org/10.5539/jsd.v8n6p311

Olotuah, A. O., & Bobadoye, S. A. (2009). Sustainable Housing Provision for the Urban Poor: A Review of Pubic Sector Intervention in Nigeria. *The Built & Human Environment Review*, *2*, 51–63.

Olthuis, K., Benni, J., Eichwede, K., & Zevenbergen, C. (2015). Slum Upgrading: Assesing the importance of location and a plea for a spatial approach. *Habitat International*, *50*, 270–288. https://doi.org/10.1016/j.habitatint.2015.08.033

Olukoju, A. (2008). 09 Local and Global Dynamics in the Transformation of the Port-City of Lagos Since the Nineteenth Century, 1–8.

Omole, F. K. (2001). *Basic Issues in Housing Development*. Ondo, Nigeria: Femo Bless.

Omole, K. F. (2010). An Assessment of Housing Condition and Socio-Economic Life Styles of Slum Dwellers in Akure , Nigeria. *Contemporary Management Research*, *6*(4), 273–290. https://doi.org/10.7903/cmr.2980

Onokerhoraye, A. G. (1995). *Urbanization and Environment in Nigeria: Implications for Sustainable Development* (Benin Social Science Series for Africa). Benin, Nigeria.

Ooi, G. L., & Phua, K. H. (2007). Urbanization and slum formation. *Journal of Urban Health*, *84*(SUPPL. 1), 27–34. https://doi.org/10.1007/s11524-007-9167-5

Opoko, A. P., & Oluwatayo, A. (2014). Trends in Urbanisation: Implication for Planning and Low-Income Housing Delivery in Lagos, Nigeria. *Architecture Research*, *4*(1A), 15–26. https://doi.org/10.5923/s.arch.201401.03

Oshodi, L. (2010). Housing, Population and Development in Lagos, Nigeria. Retrieved July 9, 2018, from https://oshlookman.wordpress.com/2010/11/24/housing-situation-in-lagos-nigeria/

Owusu, T. (2004). Urban Migration and the Growth of Squatter Settlements in African Cities : Some Theoretical and Empirical Observations. *National Social Science Journal*, *21*(2), 68–78.

Parnell, S., & Walawege, R. (2011). Sub-Saharan African urbanisation and global environmental change. *Global Environmental Change*, *21*, S12–S20. https://doi.org/10.1016/j.gloenvcha.2011.09.014

Patel, A., Crooks, A., & Koizumi, N. (2018). GeoComputational Analysis and Modeling of Regional Systems, 121–141. https://doi.org/10.1007/978-3-319-59511-5

Patel, K. (2013). A successful slum upgrade in Durban: A case of formal change andinformal continuity. *Habitat International*, *40*, 211–217. https://doi.org/10.1016/j.habitatint.2013.05.005

Patel, S., & Baptist, C. (2012). Editorial: Documenting by the undocumented. *Environment and Urbanization*, *24*(3), 12.

Petrov, L. O., Lavalle, C., & Kasanko, M. (2009). Urban land use scenarios for a tourist region in Europe: Applying the MOLAND model to Algarve, Portugal. *Landscape and Urban Planning*, *92*(1), 10–23. https://doi.org/10.1016/j.landurbplan.2009.01.011

Phe, H. H., & Wakely, P. (2000). The Donald Robertson Memorial Prizewinner 2000 Status , Quality and the Other Trade-off : Towards a New Theory of Urban Residential Location. *Quality*, *37*(1), 7–35.

Pontius, R. G., & Schneider, L. C. (2001). Land-cover change model validation by an ROC method for the Ipswich watershed, Massachusetts, USA. *Agriculture, Ecosystems & Environment*, *85*(1–3), 239–248. https://doi.org/10.1016/S0167-8809(01)00187-6

Pontius, R., Gao, Y., Giner, N., Kohyama, T., Osaki, M., & Hirose, K. (2013). Design and Interpretation of Intensity Analysis Illustrated by Land Change in Central Kalimantan, Indonesia. *Land*, *2*(3), 351–369. https://doi.org/10.3390/land2030351

Pontius, R., Shusas, E., & McEachern, M. (2004). Detecting important categorical land changes while accounting for persistence. *Agriculture, Ecosystems & Environment*, *101*(2–3), 251–268. https://doi.org/10.1016/j.agee.2003.09.008

Pratomo, J., Kuffer, M., Martinez, J., & Kohli, D. (2017). Coupling Uncertainties with Accuracy Assessment in Object-Based Slum Detections, Case Study: Jakarta, Indonesia. *Remote Sensing*, *9*(11), 1164. https://doi.org/10.3390/rs9111164

Pugalis, L., Giddings, B., & Anyigor, K. (2014). Reappraising the World Bank responses to rapid urbanisation: Slum improvements in Nigeria. *Local Economy*, *29*(4–5), 519–540. https://doi.org/10.1177/0269094214541377

Pugh, C. (2000). Squatter settlements: Their sustainability, architectural contributions, and socio-economic roles. *Cities*, *17*(5), 325–337. https://doi.org/10.1016/S0264-2751(00)00029-9

Rafiee, R., Mahiny, A. S., Khorasani, N., Darvishsefat, A. A., & Danekar, A. (2009). Simulating urban growth in Mashad City, Iran through the SLEUTH model (UGM). *Cities*, *26*(1), 19–26. https://doi.org/10.1016/j.cities.2008.11.005

Raphael, J. L., Hambati, H., & Ato Armah, F. (2014). An Intensity Analysis of land-use and land-cover change in Karatu District, Tanzania: community perceptions and coping strategies. *African Geographical Review*, *33*(2), 150–173. https://doi.org/10.1080/19376812.2013.838660

Ray, N. (2005). pathmatrix: a geographical information system tool to compute effective distances among samples. *Molecular Ecology Notes*, *5*(1), 177–180. https://doi.org/10.1111/j.1471-8286.2004.00843.x

Rhinane, H., Hilali, A., Berrada, A., & Hakdaoui, M. (2011). Detecting Slums from SPOT Data in Casablanca Morocco Using an Object Based Approach. *Journal of Geographic Information System*, *03*(03), 217–224. https://doi.org/10.4236/jgis.2011.33018

Rienow, A., & Goetzke, R. (2015). Supporting SLEUTH – Enhancing a cellular automaton with support vector machines for urban growth modeling. *Computers, Environment and Urban Systems*, *49*, 66–81. https://doi.org/10.1016/j.compenvurbsys.2014.05.001

Rienow, A., Stenger, D., & Menz, G. (2014). Sprawling cities and shrinking regions - Forecasting urban growth in the RUHR for 2025 by coupling cells and agents. *Erdkunde*, *68*(2), 85–107. https://doi.org/10.3112/erdkunde.2014.02.02

Rimal, B. (2011). Application of remote sensing and GIS, land use/land cover change in Kathmandu metropolitan city. *Journal of Theoretical & Applied Information Technology*, *23*(2), 80–86.

Rindfuss, R., & Stern, P. (1998). Linking Remote Sensing and Social Science: The Needs and the Challenge. In D. Liverman, E. F. Moran, R. R. Rindfuss, & P. . Stern (Eds.), *People and Pixels* (pp. 1–27). Washington, DC, USA: National Academy Press.

Robertson, S. A. (2009). Access to water in the slums of the developing world. *Development Policy Review*. https://doi.org/10.1016/j.neuroscience.2014.07.042

Rothman, K. J. (2012). *Epidemiology: An Introduction* (2nd ed.). London: Oxford University Press.

Roy, D., Lees, M. H., Palavalli, B., Pfeffer, K., & Sloot, M. A. P. (2014). The emergence of slums: A contemporary view on simulation models. *Environmental Modelling & Software*, *59*, 76–90. https://doi.org/10.1016/j.envsoft.2014.05.004

Sahara Reporters. (2017, August 19). Lagos State Government Demolishes 200 Houses At Iwaya. Retrieved from https://secure.saharareporters.com/2017/08/19/ lagos-state-government -demolishes-200-houses-iwaya

Schmitz, M., Bode, T., Thamm, H. P., & Cremers, A. B. (2007). XULU - A generic JAVA-based platform to simulate land use and land cover change (LUCC). In L. Oxley & D. Kulasiri (Eds.), *MODSIM 2007 International Congress on Modelling and Simulation* (pp. 2645–2649). Modelling and Simulation Society of Australia and New Zealand. https://doi.org/10.1117/1.JRS.11.035015

Shekhar, S. (2012a). Detecting Slums From Quick Bird Data in Pune Using an Object Oriented Approach. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XXXIX-B8*(8), 519–524. https://doi.org/10.5194/isprsarchives-XXXIX-B8-519-2012

Shekhar, S. (2012b). Modeling the probable growth of slums by using Geoinformatics. *Innovation Development Indian Journal*, *1*(8), 588–598.

Shoko, M., & Smit, J. (2013). Use of Agent Based Modelling in the Dynamics of Slum Growth. *South African Journal of Geomatics*, *2*(1), 54–67. Retrieved from http://sajg.org.za/index.php/sajg/article/view/70/31

Sietchiping, R. (2005). Prospective Slum Policies: Conceptualization and Implementation of a Proposed Informal Settlement Growth Model. *"Land Development, Urban Policy and Poverty Reduction*, 4–6. Retrieved from https://pdfs.semanticscholar.org/948f/1acf79ba85df2173142fa8063123d45dd6a4.pdf

Sietchiping, R., & Yoon, H.-J. (2010). What drives slum persistence and growth? Empirical evidence from sub-Saharan Africa. *International Journal of Advanced Studies and Research in Africa*, *1*(1), 1–22.

Simon, R. ., Adegoke, A. K., & Adewale, B. A. (2013). Slum Settlements Regeneration in Lagos Mega-city: an Overview of a Waterfront Makoko Community. *International Journal of Education and Research*, *1*(3), 1–16. Retrieved from http://eprints.covenantuniversity.edu.ng/id/eprint/5586

Sliuzas, R. (1988). *Problems in monitoring the growth of a squatter settlement: The housing process in Manzese, Dar es Salaam*. *Department of Urban Survey and Human Settlement Analysis*. University of Twente.

Sliuzas, R. (2004). *Managing Informal Settlements: A Study Using Geo-Information in Dar es Salaam, Tanzania*. *Urban Planning and Geoinformation Management*. Utrecht University. Retrieved from https://www.itc.nl/library/Papers_2004/phd/sliuzas.pdf

Sliuzas, R., Mboup, G., & de Sherbinin, A. (2008). *Report of the expert group meeting on slum identification and mapping*. *Report by CIESIN, UN-Habitat, ITC*.

Slum Dwellers International. (2016). *Annual Report, 20th Anniversary Edition*. Retrieved from http://knowyourcity.info/wp-content/uploads/2016/11/SDI-Annual-Report-2016.pdf

Smit, S., Musango, J. K., Kovacic, Z., & Brent, A. C. (2017). Conceptualising slum in an urban African context. *Cities*, *62*, 107–119. https://doi.org/10.1016/j.cities.2016.12.018

SNC-Lavalin. (1995). *Report on Community Infrastructure Upgrading Programme for Metropolitan Lagos*. Lagos.

Sobreira, F., & Gomes, M. (2001). *The Geometry of Slums: boundaries, packing and diversity* (No. 30). London, UK. Retrieved from http//www.casa.ucl.ac.uk/paper30.pdf

Song, W., & Deng, X. (2015). Effects of Urbanization-Induced Cultivated Land Loss on Ecosystem Services in the North China Plain. *Energies*, *8*(6), 5678–5693. https://doi.org/10.3390/en8065678

Sori, N. D. (2012). *Identifying and classifying slum development stages from spatial data*. University of Twente, Netherland.

Srinivas, H. (2015). *Defining Squatter Settlements*. *Urban Squatters and Slums, Concept Note Series E-036*. Retrieved from http://www.gdrc.org/uem/squatters/define-squatter.html

Stokes, C. J. (1962). A Theory of Slums. *Land Economics*, *38*(3), 187. https://doi.org/10.2307/3144581

Stoler, J., Daniels, D., Weeks, J. R., Stow, D. A., Coulter, L. L., & Finch, B. K. (2012). Assessing the Utility of Satellite Imagery with Differing Spatial Resolutions for Deriving Proxy Measures of Slum Presence in Accra, Ghana. *GIScience & Remote Sensing*, *49*(1), 31–52. https://doi.org/10.2747/1548-1603.49.1.31

Sule, R. A. (1990). Recent slum clearance exercise in Lagos (Nigeria): victims or beneficiaries? *GeoJournal*, *22*(1), 81–91. https://doi.org/10.1007/BF02428541

Tayyebi, A., Delavar, M. R., Yazdanpanah, M. J., Pijanowski, B. C., Saeedi, S., & Tayyebi, A. H. (2010). A Spatial Logistic Regression Model for Simulating Land Use Patterns: A Case Study of the Shiraz Metropolitan Area of Iran. In *Advances in Earth Observation of Global Change* (pp. 27–42). Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-90-481-9085-0_3

Trimble Documentation: reference Book. (2014). eCognition Developer: Release 9:

Reference Book. Munich Germany: Trimble Germany GmbH.

Turner II, B. L. (1998). Frontiers of Exploration: Remote Sensing and Social Science Research. In *Pecora 13 Symposium, Humannteaction with the Environment: Perspectives from Space* (pp. 15–19). Souix Falls, SD.

UN-Habitat. (2003). *Global report on Human Settlements 2003: The Challenge of Slums*. London and Sterling: Earthscan.

UN-Habitat. (2010). The challenge of slums. Global report on Human settlements: revised and updated version. Retrieved November 5, 2018, from https://unhabitat.org/wp-content/uploads/2003/07/GRHS_2003_Chapter_01_Revised_2010.pdf

UN-Habitat. (2013). *Urban planning for Leaders*. (V. Quinlan, Ed.) (2nd ed.). Nairobi.

UN-Habitat. (2015). HABITAT III Issue Papers: Informal settlements. *United Nations Conference on Housing and Sustainable Urban Development*, *2015*(May), 0–8. https://doi.org/http://dx.doi.org/10.3402/gha.v5i0.19065

UN-Habitat. (2016). *State of the world's cities 2016*. London: Earthscan.

United Nation Population Division. (2011). *World Urbanization Prospects: The 2011 Revision*. New York.

United Nations, Department of Economic and Social Affairs, P. D. (2015). Summary for Policymakers. In Intergovernmental Panel on Climate Change (Ed.), *Climate Change 2013 - The Physical Science Basis* (pp. 1–30). Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9781107415324.004

United Nations. Department of Economics and Social Affairs. Populations Division. (2015). *World population prospects: The 2015 revision, key findings and advance tables*.

United Nations Department of Economic and Social Affairs Population Division. (2014). *World Urbanization Prospects: The 2014 Revision, Highlights* (No. ST/ESA/SER.A/352). Rome, Italy.

United Nations Department of Economic and Social Affairs Population Division. (2017). *World Population Prospects: The 2017 Revision, Key Findings and Advance Tables* (No. ESA/P/WP/248). New York. Retrieved from https://population.un.org/wpp/Publications/Files/WPP2017_KeyFindings.pdf

United Nations Department of Economics and Social Affairs Populations Division. (2018). The World's Cities in 2018, Data booklet. Retrieved November 7, 2018, from http://www.un.org/en/development/desa/population/publications/pdf/urbanization/the_worlds_cities_in_2018_data_booklet.pdf

United Nations Sustainable Development Summit. (2015). *Transforming our world: the 2030 Agenda for Sustainable Development*. Retrieved from A/RES/70/1http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&referer=/English/&Lang=E

UNSTAT. (2005). Environmental Glossary Retrieved. Retrieved March 23, 2015, from https://unstats.un.org/unsd/environmentgl/gesform.asp?getitem=665

Vanguard. (2018, March 6). Lagos will be Africa's model mega-city by 2025 – Ambode. Retrieved September 11, 2018, from https://www.vanguardngr.com/2018/03/lagos-will-africas-model-mega-city-2025-ambode/

Veljanovski, T., Kanjir, U., Pehani, P., Otir, K., & Kovai, P. (2012). Object-Based Image Analysis of VHR Satellite Imagery for Population Estimation in Informal Settlement Kibera-Nairobi, Kenya. *Remote Sensing - Applications*, (May 2016). https://doi.org/10.5772/37869

Verburg, P. H., Schot, P. P., Dijst, M. J., & Veldkamp, A. (2004). Land use change modelling: current practice and research priorities. *GeoJournal*, *61*(4), 309–324. https://doi.org/10.1007/s10708-004-4946-y

Verburg, P. H., Soepboer, W., Veldkamp, A., Limpiada, R., Espaldon, V., & Mastura, S. S. A. (2002). Modeling the spatial dynamics of regional land use: The CLUE-S model. *Environmental Management*, *30*(3), 391–405. https://doi.org/10.1007/s00267-002-2630-x

Vermeiren, K., Van Rompaey, A., Loopmans, M., Serwajja, E., & Mukwaya, P. (2012). Urban growth of Kampala, Uganda: Pattern analysis and scenario development. *Landscape and Urban Planning*, *106*(2), 199–206. https://doi.org/10.1016/j.landurbplan.2012.03.006

Walker, B., Marsh, A., Wardman, M., & Niner, P. (2002). Modelling Tenants' Choices in the

Public Rented Sector: A Stated Preference Approach. *Urban Studies*, *39*(4), 665–688. https://doi.org/10.1080/00420980220119516

Webb, J. W., Tihanyi, L., Ireland, R. D., & Sirmon, D. G. (2009). You Say Illegal, I Say Legitimate: Entrepreneurship in the Informal Economy. *Academy of Management Review*, *34*(3), 492–510. https://doi.org/10.5465/amr.2009.40632826

Weeks, J. R., Hill, A., Stow, D., Getis, A., & Fugate, D. (2007). Can we spot a neighborhood from the air? Defining neighborhood structure in Accra, Ghana. *GeoJournal*, *69*(1–2), 9–22. https://doi.org/10.1007/s10708-007-9098-4

Wegener, M. (2011). From Macro to Micro—How Much Micro is too Much? *Transport Reviews*, *31*(2), 161–177. https://doi.org/10.1080/01441647.2010.532883

Werlin, H. (1999). The Slum Upgrading Myth. *Urban Studies*, *36*(9), 1523–1534. https://doi.org/10.1080/0042098992908

Wesolowski, A. P., & Eagle, N. (2009). Inferring human dynamics in slums using mobile phone data. Santa Fe, NM: Santa Fe Institute. Retrieved October 23, 2017, from http://samoa.santafe.edu/media/cms pagemedia/264/AmyWesolowskiREUFinalPaper.pdf

Wong, G. K. M. (2002). A Conceptual Model of the Household's Housing Decision-Making Process: The Economic Perspective. *Review of Urban and Regional Development Studies*, *14*(3), 217–234. https://doi.org/10.1111/1467-940X.00055

World Bank. (2006). *Project Appraisal Document to the Federal Republic of Nigeria for the Lagos Metropolitan Development and Governance Project*. Washington DC.

World Bank. (2014). *Nigeria - Lagos Metropolitan Development and Governance Project.* Washington DC. Retrieved from http://documents.worldbank.org/curated/en/872021468290442515/Nigeria-Lagos-Metropolitan-Development-and-Governance-Project

World Population Review. (2015). Lagos Population. Retrieved March 19, 2018, from http://worldpopulationreview.com/world-cities/lagos-population/

Wu, F. (2012). Neighborhood Attachment, Social Participation, and Willingness to Stay in China's Low-Income Communities. *Urban Affairs Review*, *48*(4), 547–570.

https://doi.org/10.1177/1078087411436104

Wu, W. (2006). Migrant intra-urban residential mobility in urban China. *Housing Studies*, *21*(5), 745–765. https://doi.org/10.1080/02673030600807506

Wurm, M., Weigand, M., Schmitt, A., Geiss, C., & Taubenbock, H. (2017). Exploitation of textural and morphological image features in Sentinel-2A data for slum mapping. In *2017 Joint Urban Remote Sensing Event (JURSE)* (pp. 1–4). IEEE. https://doi.org/10.1109/JURSE.2017.7924586

Xie, C., Huang, B., Claramunt, C., & Chandramouli, C. (2005). Spatial logistic regression and gis to model rural-urban land conversion. *Proceedings of PROCESSUS Second International Colloquium on the Behavioural Foundations of Integrated Land-Use and Transportation Models: Frameworks, Models and Applications*, (December 2015), 12–15.

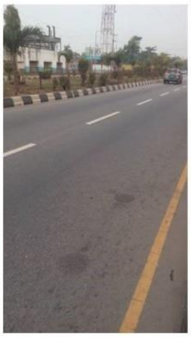
Yang, Y., Liu, Y., Xu, D., & Zhang, S. (2017). Use of intensity analysis to measure land use changes from 1932 to 2005 in Zhenlai County, Northeast China. *Chinese Geographical Science*, *27*(3), 441–455. https://doi.org/10.1007/s11769-017-0876-8

Zhou, P., Huang, J., Pontius, R., & Hong, H. (2014). Land Classification and Change Intensity Analysis in a Coastal Watershed of Southeast China. *Sensors*, *14*(7), 11640–11658. https://doi.org/10.3390/s140711640

APPENDICES

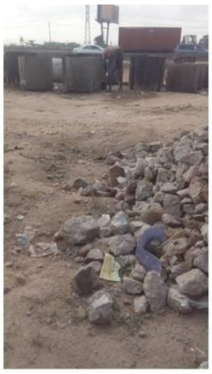
```
- Segmentation
- Classification
    unclassified with Mean Blue = 0  at  New Level: Background
    unclassified at  New Level: assign class by thematic layer using "OWNERSHIP1"
    unclassified at  New Level: assign class by thematic layer using "Thickness"
    unclassified with Mean NIR <= 1100  at  New Level: water
    unclassified with NDVI > 0.2  at  New Level: Greenland
- LANDUSE_15_OLD
    - Segementation
        15 [shape:0.3 compct.:0.5] creating 'Level1'
    - Classification
        unclassified with Mean Blue = 0  at  Level1: Background
        unclassified at  Level1: assign class by thematic layer using "OWNERSHIP1"
        unclassified with Mean NIR <= 1075  at  Level1: water
        unclassified with NDVI >= 0.34  at  Level1: Greenland
        unclassified with Density <= 1  and Rel. border to Road >= 0.5  at  Level1: road2
        SLUM_M, unclassified with NDVI <= 0.34  and NDVI >= 0.23  at  Level1: open ground
        unclassified with Brightness >= 1700  at  Level1: Other urb1
        unclassified with GLCM Contrast (quick 8\11) Blue (all dir.) <= 65  at  Level1: open ground2
        unclassified with GLCM Contrast (quick 8\11) Blue (all dir.) >= 400  at  Level1: Other urb2
        unclassified with RED RATIO >= 0.219  at  Level1: Other urb3
        unclassified with Min overlap [%]: Tincan >= 20  at  Level1: Other urb4
        unclassified with Min overlap [%]: Industrial >= 20  at  Level1: other urban 2a
        unclassified with Min overlap [%]: Public >= 20  at  Level1: Other urban 2b
        unclassified with Min overlap [%]: open remove >= 20  at  Level1: open3
        unclassified with Min overlap [%]: Water >= 95  at  Level1: slum1a
        unclassified with GLCM Contrast (quick 8\11) Red (all dir.) >= 420  at  Level1: other urb5
        unclassified with GLCM Contrast (quick 8\11) Blue (all dir.) <= 210  and GLCM Contrast (quick 8\11) Blue (all dir.) >= 65  at  Level1: Slum
        unclassified with GLCM Contrast (quick 8\11) Red (all dir.) <= 200  at  Level1: Slum2
```

Sample of rule sets utilized in the classification of RapidEye Image in Ecognition



Road

Vegetated Area



Open space

Other urban area

Slum

Samples of reference data set for the accuracy assessment of slum delineation in Lagos

CENTRE FOR DEVELOPMENT RESEARCH

REFERENCE DATA FORM

DATA OBTAINED BY: ____

LOCAL GOVERNMENT: _________________________________

S/N	Coordinates	If Point is a building, is it accessible by road (Y/N) (T/UnT)	If point is a building what is the quality of building (roof, wall and age)	If Point is a building what is its use (residential, mixed, commercial, industrial)	Any other physical characteristics of the points	What is the number on the picture taken for the point	Point Identified as (slum, other urban, water, Green land, road)

Centre for Development Research
An Integrated Remote Sensing and Urban Growth Model Approach to Curb Slum Formation in a Megacity (Lagos)

Questionnaire Survey for Residents of Slum Communities in Lagos (Iwaya, Ajegunle, Ijeshatedo/Itire and Agboju)

1. Coordinates________________________
2. Name of slum ______________________

A. Socio-Economic Characteristics of Respondents

3. Gender a)Male b)Female
4. Age a)18-24 b)25-40 c)41-65 d)above 65
5. State of origin____________
6. Ethnic group a)Yoruba b)Hausa c)Ibo d)Ilaje d)Egun e)Other_________
7. Marital status a)Single b)Married c)Divorced d)Widow
8. Number of people in the household___________________
9. Number of rooms occupied___________________________
10. Who lives with you a)Spouse b)Children c)Grandchildren d)Friends e)Parents f)Other relatives
11. Religion a)Islam b)Christianity c) Traditional d)Others
12. Education a)Primary b)Secondary c)Higher institution d)None
13. Employment a)Formal sector b)Informal sector c)Unemployed
14. If Informal, please specify________________________________
15. Place of work a)Within Slum Community b)Outside Slum Community
16. If Outside Slum Community, where? ______________________________
17. How do you get to work a)Trekking b)Personal car c)Motorcycle d)Bicycle e)Public transport
18. Monthly Income a)Below ₦10,000 b) ₦10,000-₦20,000 c) ₦20,000-₦80,000 d) above ₦80,000 e)No income
19. Housing status a)Tenant b)Staying with friends/families c)Owned d)Others___________
20. If Owned, Do you have land title (c/o)? a) Yes b)No
21. If Yes how did you get it?_____________________________________
22. If No, why?____
23. If Owned, do you have a building permit a) Yes b)No
24. If Yes how did you get it?_____________________________________
25. If No, why?____
26. If you are a tenant, how much do you pay for rent(room per year) a)Below ₦24,000 b) ₦24,000-₦48,000 c)Above₦48,000

B. Settlement History of Respondents

27. How long have you been living in Lagos_________________
28. How long have you been in this settlement_________________
29. Were you born in this settlement? a)Yes b)No,
30. If No, where____________(Town/state)
31. Before moving to this settlement, where were you ____________(Town/state)
32. If Lagos, where in particular were you living?____________________________
33. Do you intend to leave this settlement a)Yes b)No
34. If Yes where do you want go and why? ____

____

____

35. If No, why?____

36. Do you like this place? a)Yes b)No

37. Please give reasons your response ____

____

38. How will you rate this community/environment a)Very Poor b)Poor c)Average d)Good e)Excellent

39. Please give reasons for your response _____________________________________

____

C. Choice of Location for Respondents

40. Why do you live in this settlement__________________

Positive	**Negative**
Family/friend ties	I was evicted from-------
Cheap Housing	I had no other options
Free housing	No place to live
Free Land	I lost my place
Communities live here	
Proximity to work	

41. If you are asked to relocate, which area will you prefer___________________

42. Why?____

43. If you are forced to leave, where will you prefer
    a) Ikorodu b) Epe c) Badagry d) Ibeju-Leki

44. Why?____

45. Rank the following in their order of importance 1(low) – 7(high) for living in this community

Closeness to market	
Closeness to religious centre	
Closeness to job	
Affordability	
Cultural reasons/Family ties	
Accessibility (road, rail, river)	
No other choice	

Why?____

____

D. Housing and Environmental Profile

46. Location of building a)Land b)beside water c)On Water/Cannal
47. Building Type a)Block of flats b)Bungalow c) Face-to-face d)Others
48. Use of Building a)Residential b)Commercial c)Mixed used d)Others
49. Nature of building a)Permanent b)Temporary
50. Material of construction (Foundation) a)Stone b)Stud c)Sandcrete block d)Others______________
51. Material of construction (Wall) a))Wood b)Stone c)Sandcrete block d)stone e)Others______________
52. Material of construction (Roof) a)Thatched b)Corrugated Iron sheet c)Concrete d)Others______________

53. Condition of Roof a)Sagging b)Patched c)Fair d)Good e)Very Good
54. Presence of Toilet a)Yes b)No
55. Type of Toilet a)Water closet b)Pit Latrine c)VIP d)Pour flush e)Others_____
56. Toilet Facilities a)Private b)Shared with co-Tenants c)Community shared
57. Presence of potable Water a)Yes b)No
58. Water Facilities a)Private b)Shared with co-Tenants c)Community shared
59. Source of water for the house a)Well b)Tap water (public) c)borehole (public) d)borehole (private) e)others
60. Is the building accessible by road a)Yes b)No
61. Type of accessibility a)Footpath (dirt) b)Footpath (plank) c)Paved road d)Tarred road e)River

E. Slum Management Practices

62. Who heads this Community?________________________________
63. How do you manage this Community? _____________________________________ ____
64. Do you have a Community Development Association (CDA)? a)Yes b)No
65. If Yes, what are their role in the management of this Community? ____ ____
66. If No, Why not?____
67. Do you pay any dues to the CDA? a)Yes b)No
68. If Yes, How much per month__________________________
69. If No, Why not?____
70. Do you pay any money to the government for Community Development activities? a)Yes b)No
71. If No, Why not?____
72. If Yes, How much per month____
73. What community projects were or have been undertaken? (Please list them) ____
74. Has the government helped you in the management of your Community a)Yes b)No
75. If Yes, how____
76. If No, Why____
77. How will you rate government assistance in the management of your community a)Very Poor b)Poor c)Average d)Good e)Excellent
78. Give your reason for the rating ____ ____
79. Are you aware of any Project done through partnership between your community and Government a)Yes b)No
80. If Yes, can you list them?____ ____
81. How will you rate Government/CDA collaboration on Community Management a)Very Poor b)Poor c)Average d)Good e)Excellent
82. Give your reason for the rating ____ ____
83. Are you aware of any collaboration on slum management practices between your Community and other Slum Communities in Lagos a)Yes b)No
84. If Yes, Can you list some?____
85. If No why?____
86. What can be done to improve your Community?______________________________

Center for Development Research (ZEF)

University of Bonn, Germany
An Integrated Remote Sensing and Urban Growth Model Approach to Curb Slum Formation in Lagos Megacity

Guide for Focus Group Discussion for Residents of Slums Communities in Lagos

A. Existing Situation in Slums

1. Lagos state government classified this community as a slum. Do you agree with this classification? Please give reason
   ____
2. What is your perception of this community in respect to environment, building, facilities, health, people etc ____
3. Are you aware of other communities that have the same characteristics like your community? (Yes/No)

a) If yes, kindly identify them by name and location.____________
b) If No why? ____

B. Factors contributing to Slum Growth

4. Why do you live in this community?
   ____
5. If you are asked to move to another community which area will you prefer? Why?
   ____

C. Slum Management Practices

6. What is the role of Community Development Association in your communities? ____
7. Do you think CDA is effective in your community? Please give reasons ____
8. Is there any collaboration between CDA and Lagos state Government during slum upgrading? (Yes/No)
   a) If Yes, can you please explain how you have collaborated in the past and how effective it was?____
   b) If No why?____
9. Are you aware of slum management approach for this community by the Lagos state Government?
   ____
10. If Yes can you discuss some of the approaches you know
11. What is your opinion on the slum management approach utilized by the Lagos state government? (Effective or non-effective). Please give reasons
   ____
12. Do you have suggestions on how slums should be managed?
   ____

D. Future of Slums in Lagos

13. How do you perceive this community to look like in the next 15 years?____
14. Do you think slum proliferation should be curbed? If yes why and how? If No why?
   ____