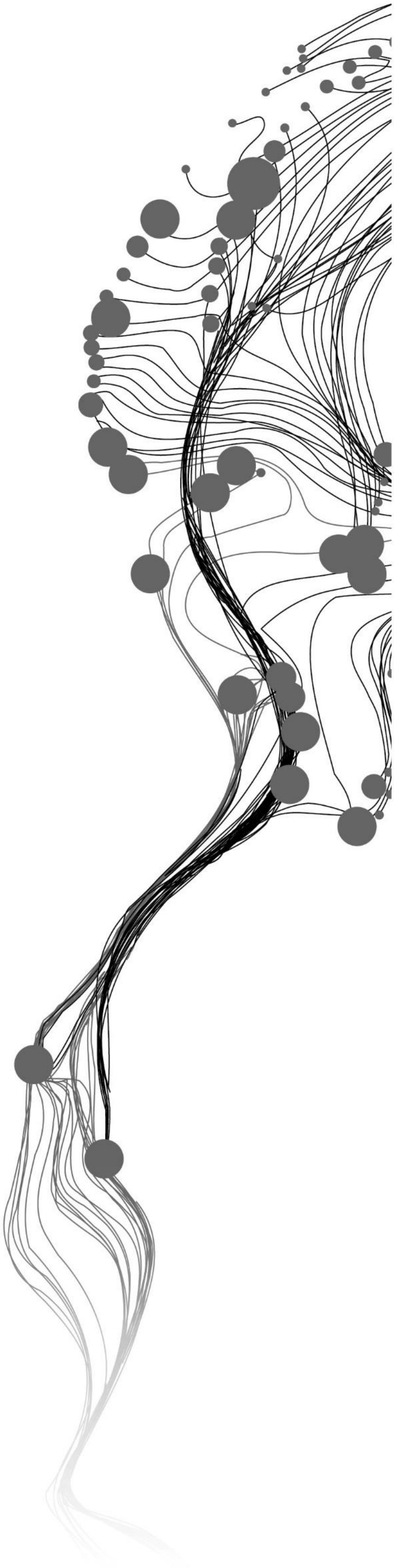
Explaining Variations in Informal Neighborhoods' Consolidation Levels in Dar es Salaam, Tanzania

DOROTH ABSALOM KAAYA
February, 2017

SUPERVISORS:
Dr. R. V Sliuzas
MSc. M. Kuffer



Explaining Variations in Informal Neighborhoods' Consolidation Levels in Dar es Salaam, Tanzania

DOROTH ABSALOM KAAYA
Enschede, The Netherlands, February, 2017

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.

Specialization: Urban Planning and Management

SUPERVISORS:
Dr. R.V. Sliuzas
MSc. M, Kuffer

THESIS ASSESSMENT BOARD:
Prof.dr.ir. M.F.A.M. van Maarseveen (Chair)
Pr.dr.-ing. S. Baumgart (External Examiner, Technische Universitat Dortmund)
Dr. R.V. Sliuzas (1st Supervisor)
MSc. M, Kuffer (2nd Supervisor)

ABSTRACT

Informal neighbourhoods continue to develop in many cities either by physical consolidation or expansion as a result of urbanisation. Although most rapid changes are in peri-urban areas, the more centrally located and the older neighbourhoods also continue to develop. This results in the increase in a number of the built-up area of a city termed as consolidation. Consolidation has been gradually increasing within central parts of the developing cities due to changes in time and the need of people for shelter. Informal neighbourhoods (INs) are associated with social, physical, economic and environmental problems yet they provide habitation and livelihood for a large percentage of urban population. Reliable spatial data on the location and extent of INs is an important foundation for coordinating and implementing different actions at local, national and international levels. However, due to different reasons such as limited expertise, failure to catch up with high INs development dynamics and weakness in governance systems, there is lack and limitation of spatial data on the location and extent of INs. Open Street Map (OSM) has a potential to generate data which can quantify the main drivers and spatial variability of informal neighbourhood development. The purpose of this thesis was to determine the main drivers behind the process of informal neighbourhood consolidation in the central Dar es Salaam from 1992-2015.

Dar es Salaam, the major commercial city of Tanzania has been facing problems and challenges to manage and monitor the development of INs due to lack/limited spatial data. In 2015 Dar es Salaam launched a project on OSM data collection, which can be utilised as the source of data to study consolidation in the central part of the city. The OSM dataset coupled with historic dataset demonstrate changes in consolidation levels of the central city from 1992- 2015.

The historic buildings footprints of 1992 and 2015 OSM building footprints were used to analyse the Percentage Roof Coverage (PRC) of INs across the years. The average nearest neighbour was used to differentiate infill and edge expansion sub processes of consolidation. Multiple linear regression models were used to study the relationship between INs consolidation and driving forces and explaining their level of importance.

The results showed that the changes of consolidation levels vary from <0 % to 60% affected by socio-economic characteristic, physical characteristics and other developmental decision in specific INs. The middle income INs were found to be less consolidated than those with lower income levels. The distance to major rivers, distance to other INs, distance to minor rivers, distance to other urban areas and distance to planned neighbourhood are main drivers of INs consolidation in the central of Dar es Salaam.

The thesis concluded that INs consolidation in Dar es Salaam in not only influences by physical factors but also with other factors such as socio-economic characteristic and upgrading of INs. These drivers contribute to the variations of INs consolidation levels in the central Dar es Salaam. It was also concluded that since 1992 to 2015 the more dangerous areas are becoming potential areas for INs consolidation in the central of Dar es Salaam.

ACKNOWLEDGEMENTS

My precious thanks to Almighty God Jehovah Yahweh, for His love, peace, grace and energy throughout my studies at ITC and The Netherlands. He gave me energy even when I did not know what to do. He taught, lead and support me in His amazing grace. Thanks and Glory to GOD!

I give my heart appreciation to my supervisors, Dr Richard and Ms Monika. They supported me a lot and never gave up on me. They have given me continues directions, guidance and patience throughout my work. Their professional guidance has created a new researcher in this world and thus me. The appreciation is extended to Feringa and Eduardo for their extra time in strengthening my cartographic and regression modelling respectively. I would like to thank all ITC staff for in one way or the other have contributed to my finishing of this work. The grateful of my heart goes to the Netherlands Fellowship Program (NUFFIC) and the Government of The Netherlands for their financial support in my studies.

I am grateful to my mother Jane, and my daddy Absalom, for taking care of my little son Juan Antonio I left him with only one year. They have raised him and send him to school. Thanks to, mama and baba.
My lovely husband Emiliano, for his unconditional love and support. I express thanks for taking care of our beautiful daughter Mercy Egla. You did not consider my studying abroad and separation of our lovely kids as a bad idea. He gave me all the support, love and care even with such a distance he was still there for me. I extend my gratefulness to my daughter Mercy Egla (7) and my son Juan Antonio (2) for being so patient and adoptive to leave without me (their mom) for such a long time.
I also extend my thanks to my sisters Esther, Gerda and Glory for their prayers and support to my little ones. The heart giving appreciation to my chosen mum Aikande Mmari., for taking care of my home, husband and daughter. She has been a nice and faithful grandma.

The support I got from my classmate, all 2015-2017 UPM (especially Chucks and Benson) will never be forgotten, I appreciate their contributions and challenges throughout the course which in the end succeeded this work.

Lastly but not least, I would like to appreciate the support of my field assistant Joachim Marwati and all the Government official in MLHHSD, Kinondoni, Ilala and Temeke Municipalities during my fieldwork. I would like to give special thanks to Prof Kessy, Prof Kombe and Dr. Tatu of ARDHI University for their professional and guidance during my fieldwork in Dar es Salaam.

Dorothy, February 2017

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ACRONYMS

CBD	Centre Business District
DEM	Digital Elevation Model
ESDA	Exploratory Data Analysis
GPS	Global Positioning System
ILO	International Labour Organisation
INs	Informal Neighbourhoods
MKURABITA	Mpango wa Kurasimisha Rasimali na Biashara za Wanyonge Tanzania
MLHHSD	Ministry of Lands, Housing and Human Settlements Development
NBS	National Bureau of Statistics
OSM	Open Street Map
PRC	Percentage Roof Coverage
SSA	Sub Saharan Africa
UAV	Unmanned Aerial Vehicle
URT	United Republic of Tanzania

1. INTRODUCTION AND BACKGROUND

1.1. Introduction

Informal neighbourhoods continue to develop in many cities either by physical consolidation or expansion as a result of urbanisation (Amado, Ramalhete, Amado, & Freitas, 2016). Although most rapid changes are in peri-urban areas, the more centrally located and the older neighbourhoods also continue to develop (Abbott & Douglas, 2001; Kohli, Sliuzas, Kerle, & Stein, 2012). Urbanisation causes the increase in population which stimulates the need for more building construction in central parts of a city (Lombard, 2014). The increase in the number of buildings within the existing neighbourhoods of a city is termed as consolidation. Consolidation has been gradually increasing within central parts of the developing cities due to changes in time and the need of people for shelter. Central cities in developing countries offer shelter and livelihood which leads to different types of INs based on consolidation level. Informal neighbourhoods (INs) are associated with social, physical, economic and environmental problems yet they provide habitation and livelihood for a large percentage of urban population (Huchzermeyer, 2011).

Mapping of INs can help to produce accurate and reliable spatial data for the urban planning and management (Kohli et al., 2012; Kuffer, Pfeffer, Sliuzas, & Baud, 2016) and information about the main drivers of their development (Sliuzas, 2004). Reliable spatial data on the location and extent of INs are the important foundation for coordinating and implementing different actions at local, national and international levels. However, due to different reasons such as limited expertise, failure to catch up with high INs development dynamics and weakness in governance systems, there is lack and limitation of spatial data on location and extent of INs (Lupala, 2002; Sliuzas, 2004).The emergence of Open Street Maps in recent years has helped to fill the gap of spatial data availability where there was no data including in INs (Chakraborty, Wilson, Sarraf, & Jana, 2015; Goodchild, 2007).

Open Street Map (OSM) have a potential to generate data which can quantify the main drivers and spatial variability of informal neighbourhood development. OSM is one of the Volunteered Geographic Information (VGI) which acts as a repository for contributed data as well as a platform for mapping and visualisation (Chakraborty et al., 2015).OSM are invariably available data which can tell about local activities and life at the local level (Goodchild, 2007). An increasing number of cities in the global south have OSM based projects such as Nairobi, Johannesburg and Dar es Salaam (Siebritz, 2014; Uithol, 2015).

Dar es Salaam, the major commercial city of Tanzania has been facing problems and challenges to manage and monitor the development of INs due to lack/limited spatial data. In 2015 Dar es Salaam launched a project on OSM data collection, which can be utilised as the source of data to study consolidation in the central part of the city. The project is named "Dar Ramani Huria" meaning "Dar open map", the project aimed at preparing spatial data for planning flood resilience in Dar es Salaam (Uithol, 2015). According to World Bank Dar Ramani Huria project representative in Tanzania, originally the project was aimed at mapping flooding INs in the city the project started by Red Cross. Later, more stakeholders came in with the interest of mapping

all INs to solve different challenges associated with these neighbourhoods. The stakeholders involved are American Red Cross, Bill & Melinda Gates, Australian Government and the World Bank a few to mention. Currently, the large part of the central city is covered with the plan to cover the whole city. The generated data provided will be used to study INs consolidation in the central Dar es Salaam.
In this thesis coupling, an existing spatial dataset with OSM dataset will be used to study main drivers of consolidation of the central area of Dar es Salaam 1992-2015.

1.2. Background and justification

The increase in number and enlargement in extent and densities of the informal neighbourhood has become alarming in many cities in the Global South due to rapid urbanisation (Keuk, Abdullah, & Hamdan, 2016). Urbanisation causes an increase in a number of people in cities through either rural-urban migration, population growth or changing of rural areas to urban (Keuk et al., 2016). Urbanisation opens up opportunities to new development in cities. However, developing cities experience difficulties in providing adequate services and infrastructure to a large number of incoming population (Cheng & Masser, 2003). Inadequate provision of affordable houses and land for housing by cities has led to the development of informal neighbourhood (Amado et al., 2016; Vermeiren, Van Rompaey, Loopmans, Serwajja, & Mukwaya, 2012)

According to UN-Habitat, (2015), the population increases in INs limit the capacity of urban practitioners and managers to implement developmental projects in INs. However, deriving population information from INs has been a challenge due to their dynamic nature (Garr, 1996). In his argument, Roy et al., (2014) mentioned that population increase is the major factor which contributes to the emergence of INs but only limited attention has been given on how to estimated population in these neighbourhoods.

Poor conditions in the INs have drawn the world's attention to improve informal neighbourhood (Roy et al., 2014). Different policies and strategies have been set to improve living condition in INs; including site and services (Pugh, 2001), slums upgrading (Abbott, 2002), cities without slums (Cities Alliance, 2003) and others. Global policies and strategies succeeded in reducing people living in INs from 39% in 2000 to 32% in 2010 (UN-Habitat, 2015).Despite, the reduction in percentage, the absolute number of people living in INs in the Global South currently is around one billion (UN-Habitat, 2016). The number of people living in INs in Sub-Saharan Africa (SSA) is expected to reach 62% of the urban population living in this region by 2050 (Schwarz, Flacke, & Sliuzas, 2016; UN-Habitat, 2009) that is, will exceed 1.2 billion (UN-Habitat, 2016)

However, more efforts have been made to deal with symptoms of INs than addressing the various drivers of INs development (Huchzermeyer, 2011). INs development in this context refers to the physical change of the central part of the city, resulting in the processes of consolidation. In consolidation, there is an increase in the number of new buildings or old buildings are extended to fill in open spaces within existing neighbourhood boundaries (Lupala, 2002). The increase in the number of buildings occurs gradually with time until a saturation point where all open spaces have buildings (Abebe, 2011).This causes the gradual increase of buildings at the edges of the neighbourhood which in turn increases the extents of its boundary towards open area outside the neighbourhood boundary, a process referred to as edge expansion (Xu et al., 2007). Both processes of infill and edge expansion of individual neighbourhoods contribute to the consolidation of the central part of the city as shown in figure 2-1 which show INs consolidation process (see also section 2.4 which discusses consolidation process).

Urbanisation in Tanzanian cities is mainly dominated by INs (Kombe, 2005). Dar es Salaam is one of the cities in Tanzania which experience high urbanisation with about 70% of its inhabitant residing on INs (UN-Habitat, 2010). Dar es Salaam, the major commercial city of Tanzania, is facing a number of INs' development challenges (MKURABITA, 2013). The individual land transaction between rural landowners and households seeking to build a house in the city or urban fringe is the major procedure leading to INs development in Dar es Salaam (Sliuzas, 2004). The constructed houses, later on, become owners' homes, which may also be used to rent to the incoming population in the city (Sheuya, 2010; UN-Habitat, 2010). INs in Dar es Salaam are poorly planned, overcrowded and have inadequate infrastructure. As discussed with both Huchzermeyer, (2011) and Kuffer et al., (2016) that main drivers of INs development have been poorly researched at the global level as well as in Africa the situation is the same in Dar es Salaam. Less is known on the drivers that lead to INs development which in one way or the other causes variations in consolidation levels of these neighbourhoods.

INs' management and mapping in Dar es Salaam have been a challenge due to lack of spatial data, local expertise and poor knowledge of the spatial extent and location (Sliuzas, 2004). Census has been the most dominant way of collecting information in Dar es Salaam (Sliuzas, 2004). However, census data does not provide robust knowledge on the spatial location and extent of INs. Poor data limits the reliability of information on the spatiotemporal development of INs (Kuffer et al., 2016) at different levels of the world region, Dar es Salaam is not an exception.
OSM dataset from Ramani Huria provide the opportunity to quantify consolidation of INs. The

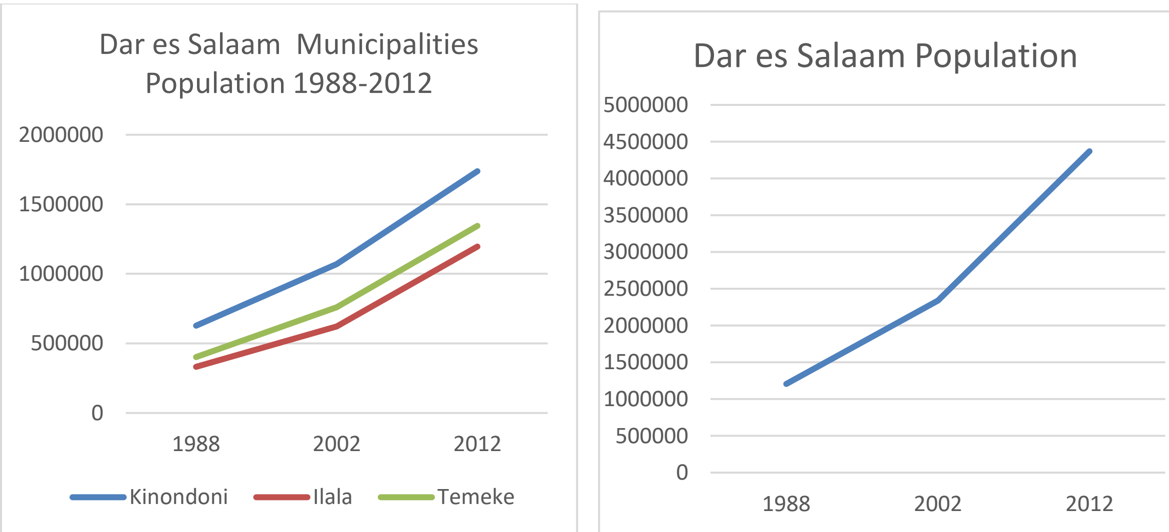


Figure 1-1: Dar es Salaam population by municipalities (left), and by region (right)

Source: Census Tanzania Bureau of Statistics (2016)

OSM dataset coupled with historic dataset allow the analysis of changes in consolidation level of the city from 1992- 2015. The analysis will focus on the consolidation of the existing INs within the central city, in literature also referred to as infill and edge expansion example in Lupala, (2002) and Xu et al., (2007).

1.3. Research problem

Lack of or limited spatial data has led to the limited knowledge of main drivers of the development of INs in Dar es Salaam. This limited knowledge of the spatial variability of the process of consolidation affects planning departments and local authorities' capacity to map, manage and monitor INs in Dar es Salaam.

Much research on the INs development concentrated more at the periphery than the central party of cities analysing expansion of INs. For example, Sirueri, (2015), Young, (2010), Amado et al., (2016) and Osman, Divigalpitiya, & Arima, (2016) who studied INs development in Dar es Salaam, Nairobi and Cairo. The former studies have used modelling techniques to predict the possible drivers of expansion which can easily be extracted from the remotely sensed images. Multiple linear regression being one of the modelling methods used to model urban expansion see for example (Hao, Geertman, Hooimeijer, & Sliuzas, 2013; Simiyu, Swilling, Cairncross, & Rheingans, 2017). Not much research has been conducted on consolidation processes in central areas of cities. Extensive data on buildings formation processes, number and rate of increased buildings within their existing neighbourhood boundaries are crucial in studying INs consolidation in the city centres. Lack of reliable data and information limits studies of consolidation in the central part of cities. The availability of 2015 OSM building footprints data is used as an opportunity which will allow quantifying consolidation in the centre part of Dar es Salaam.

Therefore this thesis aims at demonstrating how large scale topographic building footprints derived from OSM and other historic datasets can be used to study the main drivers of INs consolidation process in the central Dar es Salaam.

1.4. Research objectives

1.4.1. Main objective

To determine the main drivers behind the process of INs consolidation in the central Dar es Salaam from 1992-2015

1.4.2. Specific objectives

1. To measure the amount of physical changes of INs between 1992-2015
2. To identify the main drivers of INs consolidation between 1992-2015
3. To use results of consolidation analysis to recommend improvements in existing policies used in managing INs

1.4.3. Research question

1. To measure the amount of physical changes of INs between 1992-2015
    - What is the positional and semantic accuracy of the 2015 OSM dataset in explaining informal INs consolidation in Dar es Salaam?
    - Where are the hotspots of INs consolidation between 1992 and 2015?
    - What is the change in consolidation from the year 1992 to 2015?
    - What are roof area per person and the total area of buildings in INs?

2. To identify the main drivers of INs consolidation between 1992-2015

- Which factors are potential drivers of INs consolidation?
- How can the most important drivers be determined?
- What are the most important drivers?

3. To use the results of consolidation analysis to recommend improvements in existing policies used in managing INs

- Which areas are most likely to experience more consolidation after 2015?
- What are the planning policies involved in managing INs in Dar es Salaam?
- What policy measures should be taken to improve initiatives in managing INs?

1.5. Conceptual framework

A city is a complex system with INs development as a subsystem which if considered may make suggestions about current and futures interactions particularly as related to resource requirements (Smit, Musango, Kovacic, & Brent, 2016). There are different influential drivers that push or pull development in cities and INs. In order to consider the interaction between these two systems a thoroughly understanding of the sub process and drivers of development are of significant contribution. To understand the main drivers of INs consolidation, there is a need to recognise the development processes taking place in the neighbourhoods. Main drivers of INs development processes supposed to have direct impacts on the levels of consolidation which may lead to different types of INs typologies. INs typologies refer to differentiation of INs based on specific scheme set according to the purpose of the study see for example (Ishtiyaq & Kumar, 2011; Smit et al., 2016).This study identifies INs based on the levels of consolidation levels.
The description of INs development is a combination of building construction, social and economic processes. The social process gives the social characteristics and ties of the society residing (being owners or rental) in a particular neighbourhood. Even though it is difficult separating social and economic processes, the economic process mainly explains the ability to acquire land or rent a room in certain neighbourhoods. Both social and economic processes are important in the physical development taking place in INs, For example, Sliuzas, (1988) and Lombard, (2014) mentioned the importance of social and economic processes in a popular INs ensures an increase in capital benefit to the owner as results of both increases in demand for housing and upgrading of a physical condition of a neighbourhood. The building construction process leads to an increase or decrease in the number of buildings, densities and extent of the built-up area in a neighbourhood. The building construction process causes appearance, consolidation and disappearance or shrinking of INs. The details building process have been discussed in section 2.4, at this stage, it should be noted that it comprises of infill and edge expansion. INs development processes may also undergo diminishing processes called disappearance which may be intentionally caused by human being "eviction" or uncontrolled disaster. Figure1-2 shows INs developments processes which have been described in details in section 2.4 of this thesis.

Main drivers of INs consolidation causes changes in the building construction process. The changes of building processes shapes and defines consolidation level which led to a certain INs typology. The differences in these typologies base on densities, caused by physical characteristics and socio-economic status of the INs dwellers of such neighbourhood. Conceptually understanding of the consolidation process leads to better insight of its main drivers which may distinguish types of INs basing on consolidation level. Understanding the main drivers and their levels of importance, is of most importance, especially when integrating development activities according to similarities and differences in such neighbourhood.

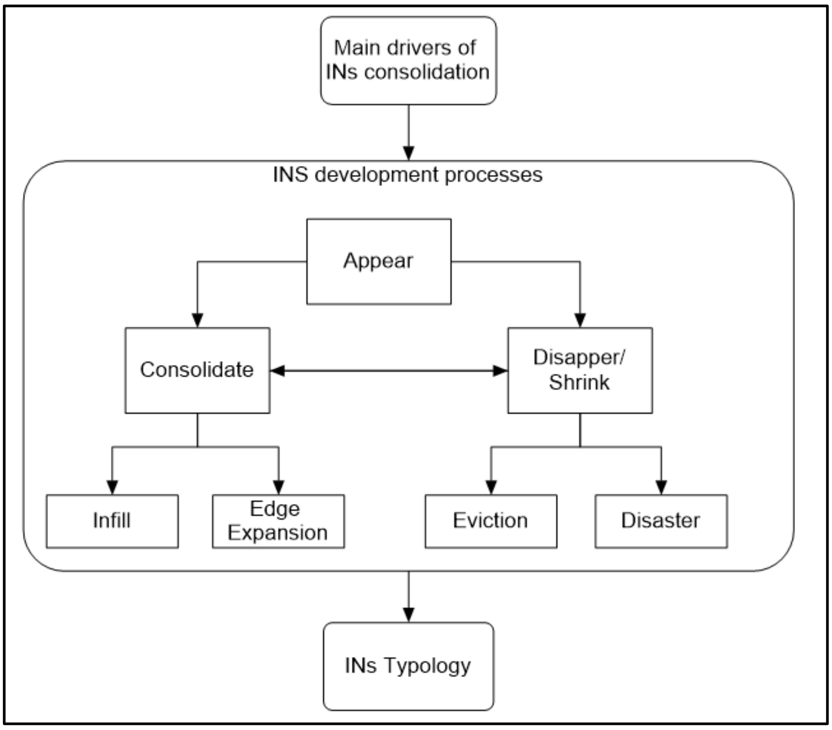


Figure 1-2: Conceptual framework

Source: Author construct, 2016

1.6. Research Outline

This research is divided into five chapters as follows
Chapter 1: Provides the overview of the research issues, the inception of the study, its objective and significance.

Chapter 2: Literature review of the study at global and national level. The chapter provides the meaning of different concepts used in this thesis basing on the literature and author's perspective.

Chapter3: Provide the methodological approach of the study. Different methods used in data collection, both primary and secondary data sources. Methods used for data analysis are discussed in this chapter their advantage over the study and main assumptions are discussed.

Chapter 4: Results and Discussion: in this chapter different finding of the research are mentioned and discussed.

Chapter 5: Conclusion and Recommendation of the research are provided by mentioning different methodological recommendation in managing INs in central Dar es Salaam. The way forward for further research are mentioned as well.

2. LITERATURE REVIEW

2.1. Introduction

This chapter provides insight of INs definition, urban informality and consolidation process based on literature review. The chapter will give an overview of drivers of INs consolidation, OSM accuracy and. the use of different urban growth models.

2.2. Urban informality

2.2.1. Urban informality in Sub-Saharan Africa

Urban informality is an old concept having the history which started back in 1960 when the self-housing program was mentioned to be a solution to shelter provision's (Lombard, 2014; Sliuzas, 2003; Turner, 1969). Evolution of industries and urbanisation are the main causes of urban informality. According to Turner, (1969), urban informality evolved as normal urban growth with a good intention to inhabit the growing population of cities. The illegal status of land tenure and non-adherence to building and infrastructure codes in totality are referred to as urban informality (Sliuzas, 2003). Urban informality occurs as the result of rapid cities expansion in an uncontrolled manner and they grow very fast within a short time (Turner, 1969).

Countries in Sub-Saharan Africa (SSA) experienced an economic decline in the 1980s and 1990s due to political instability and weak urban management which have intensified problems associated with rapid urbanisation (Kombe, 2005; Sliuzas, 2004). According to Schwarz et al., (2016) in the last 40 years SSA countries have experienced rapid urbanisation caused by natural population growth and urban-rural migration. This rapid urbanisation and lack of adequate housing cause many of the poor in SSA to live in informal neighbourhood. The situation of informal housing is complex and to better understand the nature of such a development it is necessary to examine INs characteristics and how they develop and consolidate over time (Sliuzas, 2004). However, preventive and outdated land use plans, regulatory standards and tenure arrangements have declined the success of public urban land managements to manage informal housing in SSA (Fekade, 2000). The INs in SSA have been responsive and adaptive to provide houses to urban dwellers and make up for inefficiency public urban land managements. The existing urban policies and standard have been proved to be outdated, as the result, the informality of the settlement is increasing and become of much urgent research and policy deliberation (Fekade, 2000)

2.2.2. Informal neighbourhoods in Tanzania

Tanzania is one of the fast urbanising countries in East Africa with annual population growth of 2.8 % in 2013 (MKURABITA, 2013). Urban informality in Tanzania has its root in the colonial period where very little was invested in planning except for European areas. The prepared general plans were criticised for their racism, inefficiency and rigidity. Even after independence planning was not a priority for the Government until the externally funded preparation of general plans of eight towns in the country (Armstrong, 1987). Difficulties in economic status, high urbanisation, week administrative system resulted in the failure of the Government to provide houses or formal land for the citizen to construct houses (Sheuya, 2010). Tanzania has been struggling to alleviate urban informality since the 1970's (Kombe, 2005). To date, the informal land sector provides much more land to land seekers (both the urban affluent and poor) and hence provide the opportunity of development of INs (Kombe, 2000). Informal neighbourhoods are the major available cheap source of housing for incoming people in Tanzania cities.

The beginning of intervention goes back to 1960s where the country established a National Housing Cooperation aiming at providing better houses to all citizens. In the first five years, one of the responsibilities of National Housing cooperation was to demolish of all INs. Secondly, the cooperation was aimed at constructing high standard houses to cater for the shortage of shelter. The cooperation built 4,700 houses in Dar es Salaam which was not enough to satisfy the demand in the early 1960s (Magigi, 2013).

Following the failure to satisfy the need of housing the government shifted to site and services programs in the 1980s. This Government strategy was supported by World Bank. Site and services was targeting the low income earners. The scheme was implemented in new unsettled or scarcely settled areas which were surveyed and provided with infrastructures such as water and electricity. The area was located in urban fringe by then examples are Sinza and Tegeta. It was anticipated that low income people will move from INs within the city centre to these serviced plots in which they will build their own house incrementally (Mtwangi, 2010). However, the project did not succeed because the beneficiary turned to be high income earners on one hand. While on the other hand the program largely depended on the external sources (World Bank). Not only that but also the location of sites in urban fringe made low income earners, to refuse the plots and sell them to more affluent who managed transport cost to and from work in the CBD (Kironde, 1992).

The next attempt was INs upgrading projects in the 1990s aiming at two basic things. First, the Government recognised INs as a solution towards the high demand of houses in cities. Secondly, the government decide to tolerance INs existence but investing in upgrading their condition. Therefore with little or no housing demolition, the INs were provided by infrastructures like roads, drainage and water. In Dar es Salaam this was implemented in Manzese. The project shows relative satisfaction. However, due to lack of financial commitment from Local Authorities, lack of community involvement and dependence of the program from the donors the project was not sustained (Kironde, 1992; Magigi, 2013; Mtwangi, 2010).

In the 1990s and 2000s, the strategies involved in environmental planning and management supported by UN- Habitat. These projects were based on community-based upgrading projects in INs. Hanna Nasif is one of the example, where community based upgrading was implemented with the support from International Labour Organisation (ILO) and Ford Foundation. In Hanna Nasif, the community was helped to identify their own environmental problems based on demand. The community members contributed to improving their condition through financial contribution or labour. Community- based projects showed better improvements and impacts on the physical development. Following the satisfaction of community-based INs upgrading program, the country is now following the same processes in the upgrading INs and have introduced a policy in 2007 which guides upgrading programs inter alia. Different policies involved in INs development will be discussed in chapter 4.

2.2.3. Informal neighbourhoods in Dar es Salaam

An informal neighbourhood in Dar es Salaam can be easily understood after understanding its formal background. Urban formality in Dar es Salaam has its history back in 1819 from Germany and British colonialism (Halla, 2007). In this time the approach was to prepare and implement general planning scheme which gave a prearranged city land use pattern which resulted in planned neighbourhoods. The first general planning scheme of Dar es Salaam was produced in 1949, where the city was still young and it's built up area followed legislative, expertise and produced land uses. In 1968s and 1979s the second and third general planning scheme followed. However, the 1949 and 1968 plans, had remained for a long time as strategic plans till 1970 where a foreign-aided program prepared general plans for Dar es Salaam and other Tanzanian towns (Armstrong, 1987). In this time Tanzania had a transitional phase which included a major policy shift to the Arusha Declaration, economic difficulties and damaging war with Uganda. According to Armstrong (1987), this transitional phase led to limitations in the implementation of Dar es Salaam general plan while the city population increased from 69,000 in 1948 to more than 1. 3 million in 1980. Apart from the general plan, managing and controlling of Dar es Salaam physical development involved other planning tools and regulation frameworks such as site and services and regularisation as discussed by Halla (2007); Kironde (2006); Magigi & Majani, (2006) and Sliuzas, (2004). Between 1990 and 2001 out of 243,473 land applications, only 8209 formal plots were available. High demand vs supply of formal plots has resulted to many households both the affluent and the poor decided to build their houses on the informal land. To date, the informal neighbourhood continues to develop in Dar es Salaam and it is estimated that the city population will increase from 3 million people to 5 million in the middle of 2020 (UN-Habitat, 2009; Wehrmann, 2014).This means more population will reside in informal neighbourhoods if there are no strategic plans to create planned neighbourhood and manage the current INs. The increased population will have to reside in INs either by renting houses or construct new buildings. More INs development processes will be witnessed by either infill, edge expansion and or demolition.

2.3. Informal neighbourhoods

INs are defined and analysed along various dimension including 1) physical characteristics pertaining to housing typology, access to services and infrastructure. 2) social characteristics based on income, employment, and economic activity, 3) legal characteristics related to land ownership and adherence to planning and regulations and 4) spatial or geographical characteristics(Amado et al., 2016; Smit et al., 2016). Following these categories, different countries have different ways of defining INs based on the local context and what is missing in these neighbourhoods (Singh & Law, 2016). For example when studying resettlement of INs in Johor Indonesia (Keuk et al., 2016) defined the INs as houses with an unhealthy living situation, harmful locations with hardship and social demoralisation. INs in Dar es Salaam was defined by Wehrmann, (2014) such settlements which were developed without planning designation, survey, land title deeds, provision of service and building permit. This study, however, uses the definition according to UN-Habitat (2004), INs are defined by inadequate access to safe water, inadequate access to sanitation and other infrastructure, poor structural quality of housing, overcrowding and secure residential status (UN-Habitat, 2004)

2.4. INs consolidation process and spatial characteristics

The process of informal neighbourhood development (INs) has two major elements the object level and the settlement level[1]. At the object level, the INs development process starts with a single building structure, in a vacant land. It was noted by Sliuzas, (2004), that at this stage the building may undergo one of three substantial stages appear, evolve and disappear. The stage of appear occurs when a building is constructed on the new land. The evolving stage is when there is enlargement or collapse of a building or part of a building which affects covered floor area. Disappear/shrink occurs when a building is completely destroyed.

At the settlement level, a number of buildings within a specific neighbourhood are considered as one entity. At this level, there are five processes which explain the spatial characteristic of such neighbourhood. The first process occurs when a new neighbourhood is formed. Other scholars such as Xu et al., (2007), have referred to it as when an agricultural land is converted to urban land. The second process is the expansion of such a neighbourhood by increasing its spatial extent by the erection of new building adjacent to existing ones. When the spatial extent of a neighbourhood is reduced this stage has been referred to by Sliuzas, (2004) as shrinking. Other processes are disappearing and densification of the neighbourhoods. The term densification and consolidation has been defined as the same referring to neighbourhood internal growth (Hakuyu, 1995). This thesis uses the term consolidation to refer to the further construction of buildings, storeys, or rooms which lead to an increase in the floor space within the neighbourhood (Hakuyu, 1995; Sliuzas, 2004).

Within a consolidation process, there is an increase in the number of buildings within the neighbourhood until saturation. With time the construction extends INs boundaries to the nearest open land hence forming a new extent of the neighbourhood. Figure 2-1 shows the consolidation process in which it has four imagined INs within a city with dotted blue boundary. Conceptually, the four INs have blue boundaries and blue buildings footprints in 1992. In 2015 two processes occurs within the neighbourhood. The green buildings increased gradually within the blue boundary to INs saturation this process is referred as infill in this thesis. Secondly, the green buildings form new INs extents with green colour, this process referred to as edge expansion in this thesis.

Along with the definition of INs consolidation processes, the use of density in urban planning is very essential. Density changes explicit explains consolidation as at time T_1 the neighbourhood has the density D_1 and at T_2 the neighbourhood has D_2. If $D_2 > D_1$ then we conclude that there is consolidation (Sirueri, 2015). Even though density is defined differently in different countries, it represents the ratio of population size or a number of dwelling units within a given area (Churchman, 1999; Taubenböck, Standfuß, Klotz, & Wurm, 2016). It is also defined as percentage sum of roof area per unit area of a neighbourhood (Sliuzas, 2004).

[1] These paragraph on process of spatial characteristics has been using the study done by (Sliuzas, 2004) in Dar es Salaam.

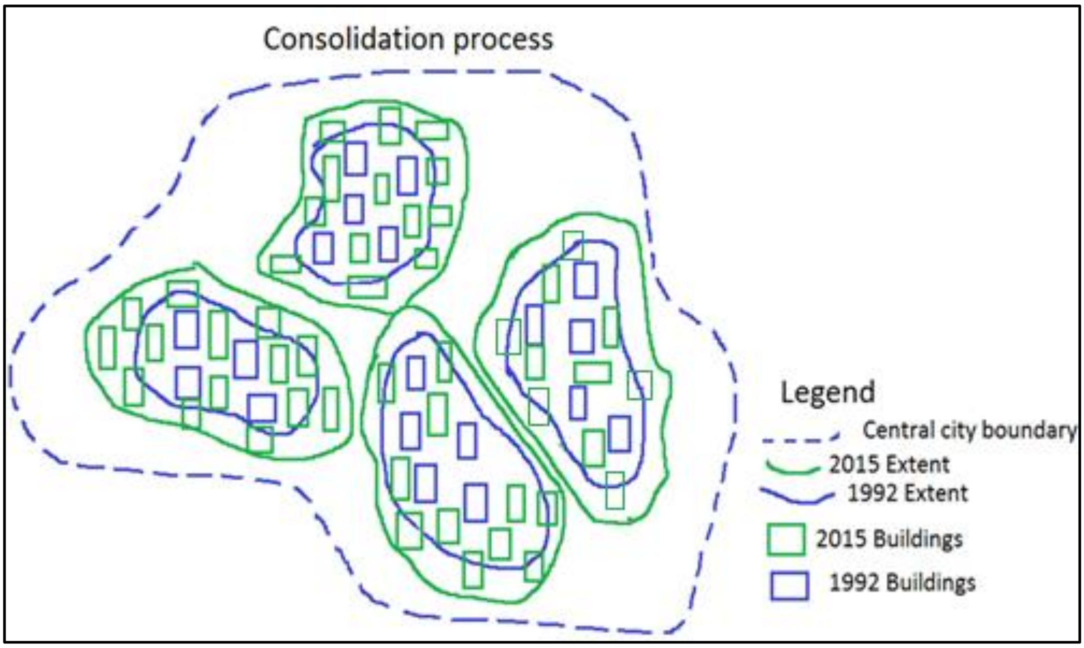


Figure 2-1: Consolidation process

Source: Author construct, 2016

2.5. Measuring physical changes, consolidation and spatial extent

Urban physical changes include carrying any building, engineering or mining or other operation in or under land or making any material changes in the use of land or buildings (Hakuyu, 1995). The physical change is manifested in urban land use changes. Urban land use change is the spatial temporal reflection of urban growth caused by different driving forces such as environment, demographic, economy, transport system (Daoud & Huang, 2013).The most common being that of changing urban agriculture land into urban land also referred to built-up area see for example (Kyessi, 1990; Lupala, 2002; Sheuya, 2010). Land use change is measured by difference or rate of change of urban built-up area and non- built up land across time.

Percentage Roof Coverage (PRC) is a robust way of measuring of physical consolidation of a neighbourhood (Sliuzas, 2004). PRC utilises the roofs area of buildings within a neighbourhood combining with neighbourhood boundary to compute consolidation. PRC is a gross density method that includes public and private buildings with their inclusive spaces but excludes other non-residential and open spaces with larger than one hectare. PRC was used to classify INs with high, medium and low densities in Dar es Salaam (Sliuzas, 2004). It was observed that calculation of PRC relies much on the availability of an up to date mapping system which provides roof area information and boundaries of spatial units (example neighbourhood, settlements or cell) that provide the density area for the density calculation.

2.6. Drivers affecting INs consolidation

In order to understand the location and extent of an informal neighbourhood, one has to identify the main drivers that caused their development and how these factors interact with one another (Roy et al., 2014). INs development can be examined to understand why, where, and how such development takes place and can be attributed to different 'factors' in this thesis referred to as drivers. There are several factors leading to INs consolidation within the central of the city including social, economic, political and spatial factors. INs development drivers may also be derived from morphological and locational characteristics of INs (Kuffer et al., 2016). Other drivers may be biophysical constraints and potential, or spatial policies (Verburg, Ritsema van Eck, de Nijs, Dijst, & Schot, 2004). Even though some of the drivers tends to be more common than others, each INs has its local specific drivers which require a research to be identified and explained (Cheng & Masser, 2003; Githira, 2016).

Urbanisation is the major cause of INs developments as discussed chapter 1. Urbanisation may be due to the natural increase of population or by migration of people from rural to urban area. Factors leading to increasing in population by migration can be divided into two as well, pull and push factors (Bhatta, 2010). The push factors include all factors that cause people decision to move out of their original places. Examples of push factors are unemployment, and lack of services. On contrary pull factors are those encouraging people to move in, examples availability of job opportunities, vacant land and social facilities. The attractiveness towards the neighbourhood basing on factors leading to urbanisation extends its impacts on the decision of such population to construct the building for accommodation and or other activities. (Hao et al., 2013).

Land value affects the decision of people to construct a building in INs. The availability of cheap land that can be bought incrementally attracts more construction. The expectation of an increase in land values invites land speculator to buy land which later on they construct dwelling units for sale (Bhatta, 2010; Hakuyu, 1995). In INs land speculator tends to encroach areas with environmental hazardous with little or no attention from the Government (Kombe, 2000). These areas are later on sold at affordable prices to the population seeking to dwell in central cities.

The decision to undertake construction is determined by the availability of suitable land for construction. This is due to the fact that each location has its own soil type based on climatic condition. The biophysical characteristic of an area, define land suitability for construction (Verburg et al., 2004). It was observed by Kyessi, (1990) that the consolidation occurs faster in highly suitable land compares to the least. The high suitable lands are examples of relative flats plots, with no risks of environmental hazards. The least suitable land are mentioned area with high environmental risks such as those located on river banks and swampy area. According to Verburg et al., (2004), it usually requires more resources to make unsuitable land buildable. Nevertheless, when the high suitable land is saturated or becomes expensive urban population have no choice but construct their homes in fair and bad land sites.

Locational aspects of the neighbourhood in respect to industries and CBD has a major influence on the decision to construct a house. Both Hakuyu, (1995) and Bhatta, (2010) describes that one of the basic needs of the urban population is to access employment and job opportunities to improve their livelihood. Since industries and CBD are sources of employment in cities, more people would like to live near them. They tend to reduce travelling cost by utilising footpath for walking to and from their work. This goes hand in hand with a location of INs near the major and secondary roads. The transportation facilities ensure the access to workplaces and other livelihood activities (Cheng & Masser, 2003; Hao et al., 2013).

The decision to construct houses also depends on social drivers, such as norms cultural values and preferences (Verburg et al., 2004). The need to be near the services stimulate construction of

INs near existing planned neighbourhoods hoping to utilise much of the service. In their studies, Githira, (2016) and Sirueri, (2015) concluded that there was INs development near planned neighbourhood in both Nairobi and Dar es Salaam cities. Population in these areas were accessing their services in the planned neighbourhood.

Previous studies on Dar es Salaam example Hakuyu, (1995) and Mtwangi, (2010) show variations in INs in Dar es Salaam based on the spatial location, building and population densities, land regulations and laws, provision of services, construction materials, infrastructure, distances from the city centre and causative formation of the neighbourhoods.

The main advantage of the drivers is to provide insights into changes of the informal neighbourhood across time and space. Table 2:1 depicts some of driving forces of urban development which are also potential drivers for INs consolidation.

2.7. Urban growth models

Urban growth models and land use change model have been important tools in studying urban growth and development. Both growth models and land use change models have been used within GIS environment to determine the existing situation and to predict future development of urban development.

Different models have been employed to understand land use and urban dynamics. One of the models is cellular automata. For example, Vliet, White, & Dragicevic, (2009) use cellular automata model to aggregate land uses of greater distances to stimulate both regional and local urban growth dynamics. Other common models are agent –based model, for example, Augustijn-Beckers, Flacke, & Retsios, (2011) used to demonstrate a vector implementation of an agent model to simulate INs growth. Analytical models for example, Thapa & Murayama, (2010) used the analytical process to model driving factors of urban growth in Kathmandu valley. Logistic regression models are also common models. For example, Cheng & Masser, (2003) used logistic regression to model major determinants of urban growth in Wuhan China. Dubovyk et al., (2011) used a logistic regression model to analyse driving forces of INs and to predict probable locations of new INs. Multivariate and multiple regression models are used in studies of urban development. For example, Hao et al., (2013) used multivariate to uncover the driving forces of urban village development. Currently, Simiyu et al., (2017) have used multiple linear regression to study determinants of the quality of shared sanitation facilities in INs. Review of these models have been done by different authors to assess their advantages, disadvantages and developments in the modelling technology see for example (Aburas, Ho, Ramli, & Ash'aari, 2016; Roy et al., 2014). The conclusion of the review studies showed that the models are robust in identifying main drivers for the emergence and growth of INs. It was also mentioned that sometimes the combination of more than one model gives better results in case of complexity.

In their study, Cheng & Masser, (2003) depicted that the strength of regression is associated with its strong analytical and explanatory power. It has been observed by (Dendoncker, Rounsevell, & Bogaert, 2007) that the use of regression models provides the opportunity to analyse future patterns based on the existing situations. Table 2: 1 shows the previous application of urban growth models including drivers of development in different cities.

Table 2:1: Main drivers of urban development found in different cities.

Source	Factors	Cheng & Masser (2003) Wuhan	Daoud & Huang, (2013) Delaware	Abebe (2011) Dar es Salaam	Dubovyk et al., (2011) Kathmandu	Githira (2016) Nairobi	Achmad et al., (2015) Indonesia
		The study on urban expansion	The study on urban expansion	The study on INs development	The study on INs development	The study on INs Develop ment	The study on urban expansion
Site specific	Population density	✓	✓	✓	✓	✓	✓
	Soil erosion	✓	✓	✓			✓
	flood		✓	✓			✓
	Slope	✓	✓	✓	✓	✓	
Proximity	Distance to CBD	✓	✓	✓	✓	✓	✓
	Distance to roads (primary and secondary)	✓	✓	✓	✓	✓	✓
	Distance to Industries	✓		✓	✓	✓	
	Distance to markets	✓	✓	✓	✓		✓
	Distance to existing sub centres	✓		✓		✓	
	Distance to markets			✓			
	Distance to minor river	✓		✓		✓	
	Distance to rail lines	✓				✓	
Neighbourhoods	Availability of bare land	✓	✓	✓	✓	✓	
	Availability INs in the surrounding	✓	✓	✓	✓	✓	

Source: Author, 2016

2.8. OSM data accuracy

OSM is one of the most successful VGI-platforms, resulting from the community worldwide who collects geospatial contents that are stored in a spatial database (Kunze & Hecht, 2015). OSM data has recently being used by planners and other urban geographers as either a supplementary data or only source of data where there is no data. According to different scholars such as Girres & Touya, (2010); Haklay, (2010) and Kunze & Hecht, (2015), it has been established that one of the issues when working with OSM data set is the quality of data. In different studies, several ways of assessing the quality of OSM data have been established. In their studies, Haklay, (2010) and Kunze & Hecht,(2015) used geometric and semantic accuracy as the criteria to assess the quality of OSM dataset. In their research Girres & Touya, (2010) used a set of six criteria to assess the quality of OSM namely; geometric quality, semantic accuracy, position accuracy, shape accuracy, logical consistency and temporal. Furthermore some authors decide to use the most common features added by contributors to assess the accuracy of OSM dataset. For example, Haklay, (2010) use street and roads as they were the core contribution provided by the OSM volunteers. Where visual method was used to assess the physical accuracy of OSM of 113 square kilometres in London. The tiles used to assess accuracy were randomly selected from London city. Then 100 samples were taken to evaluate the accuracy between OSM and reference data set.

The mentioned literature assumed that a reference data set is of higher quality and represents the reality and consistency in terms of quality. The reference dataset were therefore used to show shortcoming in the OSM dataset. The characteristics of available reference data set provided the nature of the accuracy assessment. For example, 3D building models were used to assess building footprints both Fan, Zipf, Fu, & Neis, (2014) and Kunze & Hecht, (2015). The availability of reliable dataset which is updated time to time was shown to be important. For example, the mentioned studies have been done in cities with reference dataset; Munich London and Paris. The availability of institutional reference geographic data in these cities gives a better medium for the authors to assess the quality of OSM dataset.

2.9. Concluding remarks

Urbanisation causes the increase in a number of people living in urban areas. The increasing population requires land for housing and livelihood activities. Limited shelter in a planned areas leaves the urban population with no choice rather than constructing/rent a building in the INs. The increased number of buildings increases INs consolidation with the increase in time. However, the increase in consolidation in these INs is not the same. Some neighbourhoods are more consolidated than others. There are different drivers leading to variations in consolidation levels among neighbourhoods. Despite the facts that literature mentions potential drivers, of consolidation, these drivers have different influences depending on the local characteristics of individual INs. The drivers influencing housing construction are given high possibilities of influencing consolidation.

Multiple linear regression gives the opportunity to identify main drivers of INs consolidation. The method is discussed in more detailed in chapter three. The use of building footprints is an added opportunity to quantify the main drivers of INs consolidation.

3. RESEARCH DESIGN AND METHODOLOGY

3.1. Introduction

This study entails to explaining the variation of INs consolidation levels in the central Dar es Salaam from 1992- 2015. The main objective is to determine the main drivers behind the process of INs consolidation. The research has three specific objectives as mentioned in chapter 1.4.2. First, to measure the amount of physical changes in INs in the central of Dar es Salaam in 1992-2015. Second, to identify the main drivers of INs consolidation within the city centre in 1992-2015 years. Third is to use results of consolidation analysis to recommend improvements in existing policies used in managing INs.

To achieve these set objectives the research adopted case study strategy. This chapter introduces case study area, data sources methods used to collect and analyse data. The discussion is arranged such that all objective are covered. Based on its importance more attention is given to multiple linear regression modelling.

3.2. Case study

Dar es Salaam lies between the latitude 6.36 degrees and 7.0 degree to the south of Equator and 39.00 and 33.33 east of Greenwich along the coast of Indian Ocean. The word Dar es Salaam means "*HABOUR (HAVEN) OF PEACE"* (DCC, 2004). Dar es Salaam covers 1,800 square kilometres with three administrative units namely Ilala, Kinondoni and Temeke (DCC, 2004). From July 2016, Kinondoni and Temeke municipalities have been sub dived into two each. This information was obtained in the fieldwork done in September 2016. Kinondoni is subdivided into Kinondoni and Ubungo municipalities while Temeke is sub dived into Temeke and Kigamboni municipalities. To date, the city has five municipalities. However, the opening of new offices started only in October 2016 and mostly of information were not yet prepared accordingly. Therefore this thesis will use the former three municipalities Kinondoni, Ilala and Temeke due to available information. In addition, the division does not affect the study area as its spatial extent and boundaries are not affected by the subdivision. Spatially the city has a four finger-like structure formed by four major roads from the Centre Business District (CBD) spreading outside the city figure 3-1. The major roads include New Bagamoyo road, Old Bagamoyo (Mwaikibaki) road towards the north of the city. Morogoro road is located towards the west, while Kilwa road is found towards the southern part of the city. Sam Nujoma and Nelson Mandela roads make a semi-ring like roads within the city. In between the mentioned roads, there are built up areas divided by the pouches of green fields, river valleys, undulating terrain and swamps. Dar es Salaam has a population of about 4,400,000 (URT, 2013). Figure 1-1 section 1.2 shows the population growth of the city of Dar es Salaam at former Municipal and Regional level.

The central part of Dar es Salaam is the case study of this thesis, the area was delineated following the ring road and it covers about 60 kilometre square of the city figure3-1. Administratively the study area is comprised of 38 wards of which 29 wards have INs. This area is well covered by both historic data and available building footprints. Its spatial extent is the same from 1992 to 2015 and therefore make a good case for studying the change in consolidation across the years. Despite an increase in the spatial extent of the city in the period of twenty years (1982 to 2002) there was an increase in the area covered by INs within one to ten kilometres from the CBD see also Hill, Hühner, Kreibich, & Lindner, (2014), Mtwangi, (2010) and Sliuzas, (2004). The increase in INs coverage within the city centre motivates the need to study INs consolidation processes to identify the main drivers that cause changes in consolidation. The increase in availability of other physical development within the central city and the decreasing of open/vacant land provides that there must be informal development processes going on.

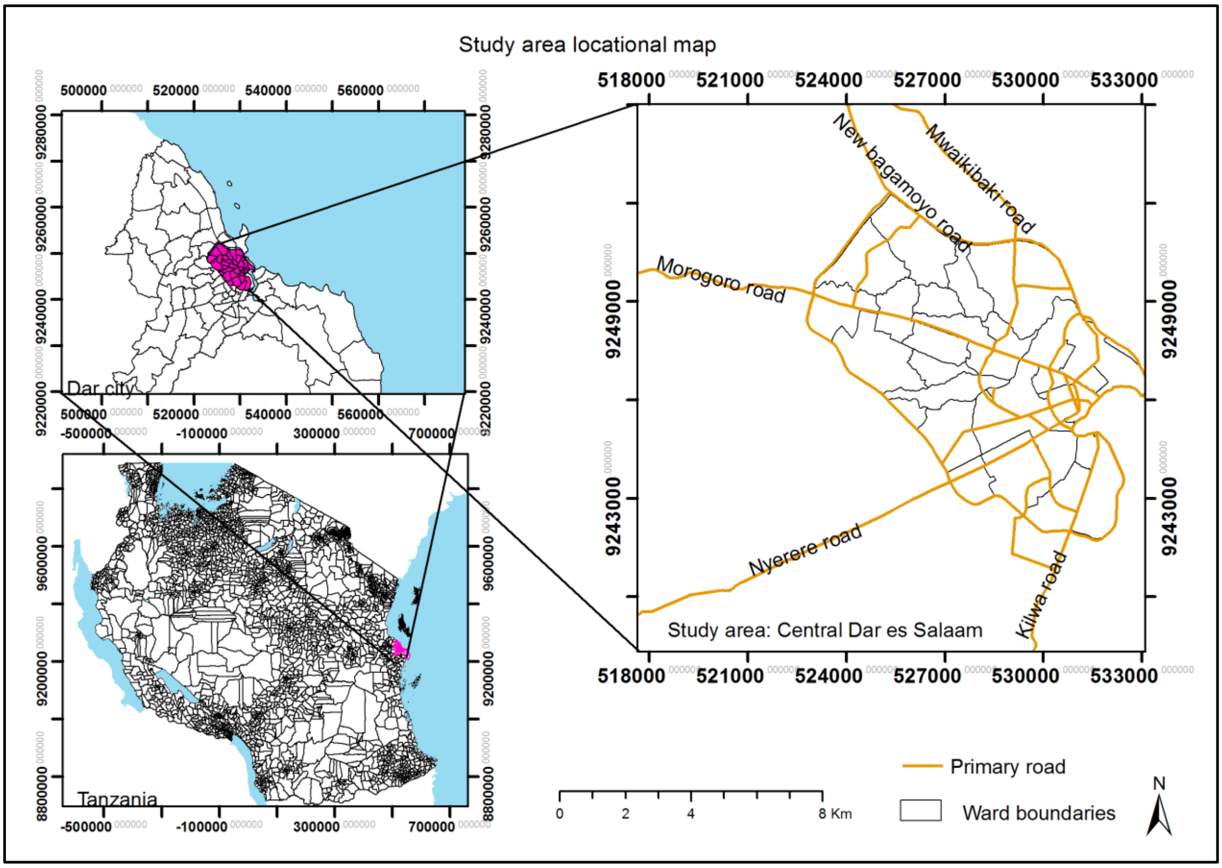


Figure 3-1: Study area: Central Dar es Salaam

3.3. Data sources

Two main datasets sources were used for the study complemented by other data from secondary and primary data collected. The first dataset was 1992 building footprints obtained from Tanzania Ministry of Lands Housing and Human settlement Development (MLHHSD) and collected from ITC archive and the second dataset was 2015 OSM building footprints (downloaded on 15/08/2016 from mapzen.com). Table 3:1 provides description of secondary data available for both 1992 and 2015

3.3.1. OSM data preparation

This paragraph gives an overview of how data was collected as was explained in the interview between the author and data collection representative during field work in October 2016. OSM dataset was prepared by digitising from the UAV image with the resolution of 0.37 m. The area not covered by UAV information was collected from the field work using a hand GPS during data collection project. Later on, they were digitised. The data collection was done by volunteer students from Ardhi University who were trained to undertake data collection and digitisation. Then, these students under the supervision of project management were used to train citizen volunteers who were also involved in data collection. The digitisation of data was supervised by Ramani Huria staffs

3.3.2. Other secondary data

In addition to the 1992 and 2015 building footprints, there were a number of other secondary data collected. These data included documentary sources like statistical data and ward boundaries of Dar es Salaam which were collected from NBS offices originated from the census data of 2012. 2013 drone images were collected from Dar Ramani Huria. The drone images were in Mb tiles format with the resolution of 0.37 m. The drone images were covered only Msasani, Ubungo, Tandale, Magomeni, Buguruni, Mburahati, Ubungo south, Tabata and University of Dar es Salaam; other parts of the city were not available. These images were used to assess the accuracy of OSM data.

3.3.3. Primary Data

Primary data was collected from the field using three techniques expert interviews, household surveys and fieldwork observation.
The semi-structured expert interviews were divided into two groups. The first group was urban planning experts with knowledge and experience in working with INs. These expert interviews were conducted to understand the main drivers of INs consolidation. The prepared interview schedule (Appendix 1: Expert interview schedule) was divided into five section aiming at 1 hour discussion. The sections were divided into different themes; understand the nature INs in the city; characteristics of INs buildings, INs density, INs accessibility and the familiarity and the use of OSM data by the individual expert. In total 15 experts were interviewed in this group; 10 from three Municipalities, 3 from MLHHSD, 2 academicians from ARDHI University. It was planned that experts included have at least 20 years of working experience in the field. However, this was not successful due to expert's transfers which happened in Dar es Salaam Municipalities offices. Therefore, experts who have worked in Dar es Salaam for more than five years were involved.

The second group included the experts participated in the OSM data collection project. These interviews aimed at giving an understanding of the OSM data. A different interview schedule was prepared (see appendix 2: Expert interview data collectors). The schedule was divided into three themes to understand the rules used in classification, accuracy assessment and future plans. Three experts were interviewed in this group UN representative, Kigogo ward executive (during the project he worked with Tandale data collection), and one of the key data collector.
The field observation included; household survey to collect data for population estimation, to verify the accuracy of OSM dataset and to observe INs characteristics. The household survey was done in five subwards where the permission was obtained. At the time of fieldwork, three researchers were burned to death while collecting governmental research data as people claimed that they are taking human blood. With this situation, it was difficult to get the permission to visits different wards to collect data. Furthermore, people did not allow the researcher to map their houses. This also affected photo taking activities which were not possible.
Field observation was done to understand the nature of the selected INs and their differences Selection of INs settlement was done based on the Exploratory Spatial Data Analysis (ESDA). According to Cheng & Masser, (2003), ESDA helps to detect spatial patterns in the data which can further be used in the analysis. The ESDA analysis (on 1992 and 2015 density levels) was done for the whole Dar es Salaam Municipality before going to the field. A total of 8 INs were visited in which 6 selected following the ESDA analysis and two INs proposed by experts. However, the study area was delineated after field work following the physical boundaries and other reasons explained in section 3.2. Therefore some of the visited area are not within the study areas, but they give an insight of the variations of INs consolidation levels in Dar es Salaam.

Table 3:1 Description of secondary data available for 1992 and 2015

Data set	Acquisition year	Scale	Source	Projection	Purpose
Vector					
Buildings footprints	1992	from 1:2500	MLHHSD & ITC	WGS 84	Land use change and modelling consolidation
Building points	1992	from 1:2500	MLHHSD & ITC	WGS 84	Land use change and modelling consolidation
Administrative Boundary	2012		NBS	WGS 84	Delineating study area and INs location
Contour 20m	1992	1: 2,500	MLHHSD & ITC	WGS 84	Modelling consolidation
Landform	1992	1: 2,500	MLHHSD & ITC	WGS 84	Modelling consolidation
Urban Land use	1992	1: 2,500	ITC	WGS 84	Delineating INs and Modelling Consolidation
Urban land use	2012	1:2500	ITC& Ardhi University		
Utilities	2000	1: 2,500	MLHHSD & ITC	WGS 84	Modelling consolidation
Raster		**Resolution**			
DEM 20 X20 m	1999	20	MLHHSD & ITC	WGS 84	Modelling consolidation
DEM 10 X10 m	1999	10	MLHHSD & ITC	WGS 84	Modelling consolidation
OSM Data					
Vector					
Building footprints	2015		**	WGS 84	Land use change and modelling consolidation
Roads	2015		**	WGS 84	
Transport places	2015		**	WGS 84	
Contour 10m	2013		Ilala Mu	WGS 84	
Raster					
UAV image	2013	0.37 m	Ramani Huria	WGS 84	Accuracy assessment

Legend
** https://mapzen.com/data/metro-extracts/.

Source: Author, 2016

3.3.4. Data quality

Data collected from ITC[2] has been provided with the metadata which shows how they were collected and stored. The data used for analysis included DEM of 20m x 20m and 10m x 10m derived from 1:50,000 and 1:2,500 topographical data respectively. 1992 building footprints derived from topographic data of scale of 1:2500 (from 1992 aerial photograph). The 2015 OSM data was digitised from drone images taken in the year 2013 with the resolution of 0.37 m. Parts not covered by drone images were collected from the field and accuracy checked through open source images such as Bing and Google Earth (see section 3.3.1). Land use maps, image data and

[2] For more information on ITC data accuracy refer also (Sliuzas, 2004)

other shapefiles collected from Dar es Salaam were taken from Government offices; their accuracies were checked and corrected accordingly within GIS environment.

3.4. Data analysis methods and unit of analysis

The methodology of this thesis was divided into two major parts according to specific objectives; first, a methodology to measure the amount of physical change and second a methodology to identify main drivers of informal neighbourhood consolidation. Figure 3-2 summarises the methods used in the analysis. The figure shows data preparation and OSM process in part 1, part 2 shows the physical change analysis methods and the separation between Infill and edge expansion processes. Part 3 shows the methods used to determine the main driver of INs consolidation process and determination of future expansion. Section 3.4.1 to 3.4.3 explains the methods in details.

The units of analysis (of PRC) in this thesis was the ward level even though at the beginning it was planned to be subwards level. Due to lack of new subwards boundaries of the city, it was decided to use the ward level. Wards are important connections between the Local Authorities, Central Government, political decision and implementation levels in Dar es Salaam. Therefore an analysis at this level gives the opportunity of replication of the methodology at multi sectoral users such as experts, The National Bureau of Statistics and politicians, a few to mention. For the sake of density comparison the wards level were reduce to one Ha (grid cell of 100m) to map consolidation across time.

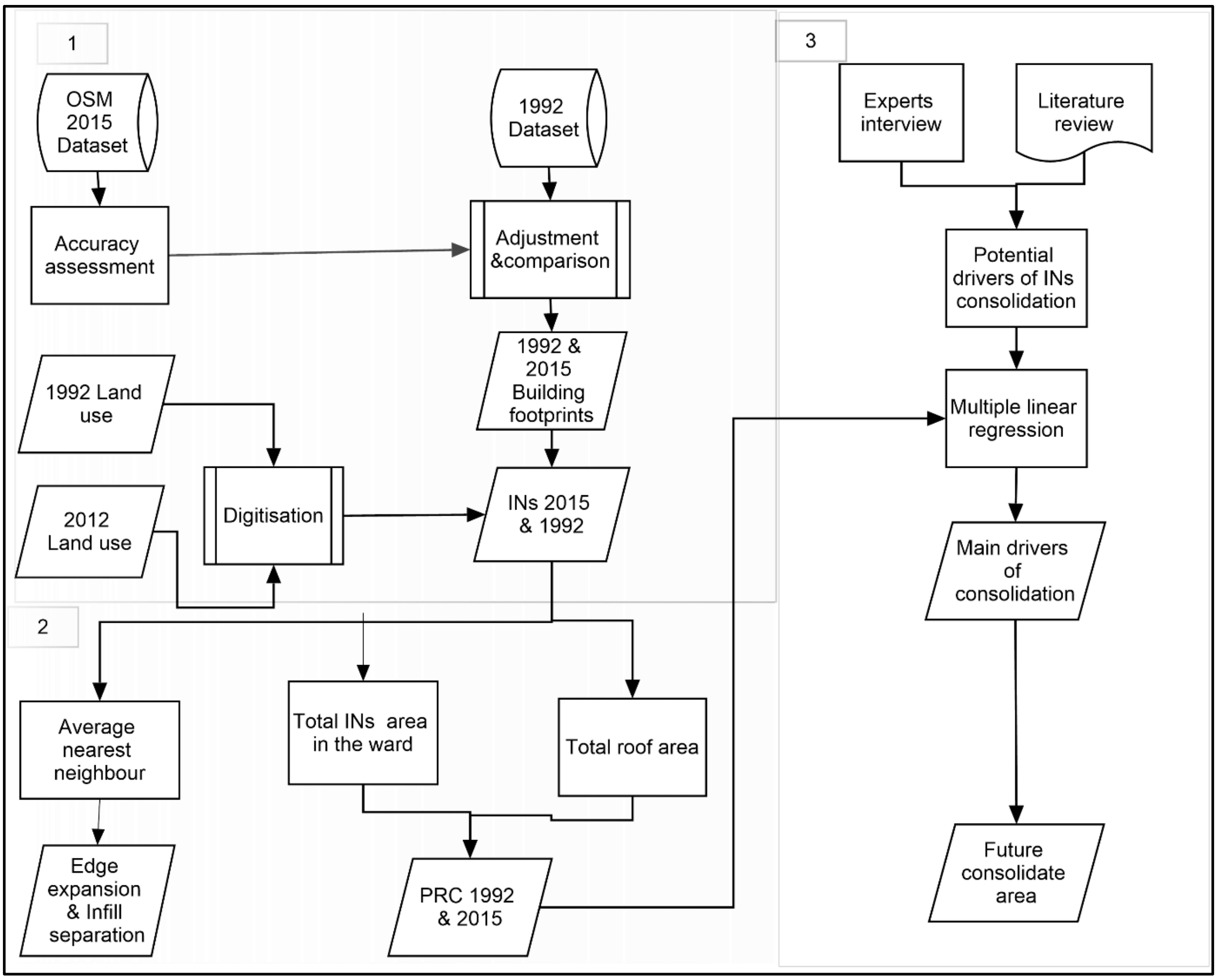


Figure 3-2: Methodology flow chart

Source: Author 2016

3.4.1. OSM accuracy assessment

The aim of accuracy assessment was to assess the *fitness for use* of OSM data in analysing INs consolidation process. Semantic accuracy and positional accuracy of OSM dataset were to assessed. The definition of these two accuracies follows that provided by Fan et al., (2014) that semantic accuracy investigates if the buildings in the real world were recorded as the buildings in OSM dataset. The positional accuracy is defined as how well the coordinate value of building in OSM relates to the reality on the ground. The analysis followed the visual/spatial comparison following Haklay, (2010), the method was used to produce a *fitness for use* assessment of the OSM dataset. Both positional and semantic accuracy of 2015 OSM data were conducted using spatial/visual comparison. The UAV images obtained from World Bank representative were used as reference dataset in case there were no UAV images open street map was used.
Spatial adjustment by rubber sheeting was used to correct positional OSM dataset whenever necessary. Rubber sheeting allows alignment of two layers, by moving the feature stepwise and therefore preserve straight-line (Kasianchuk, 2003).

3.4.2. Physical changes in INs

To detect the hotspot of INs consolidation two major steps were followed. First, the 1992 and 2015 building footprints were spatial joined using one to many relationships with 1992 and 2015 land uses respectively (see appendix: 7 preparation land use data). The 2015 land use was obtained by modifying the available 2012 land use by digitising INs land use. Second, the location of INs were then identified followed by kernel density estimation, by calculating the total building area on one Ha. The resulting density maps were then overlaid with wards boundaries to portray the names of INs. Further analysis to quantify the amount of change in consolidation by calculating Percentage Roof Coverage (PRC) across the time following Sliuzas, (2004). The wards were divided into 100m cell to make sure the whole area is covered and make the comparison of the two years more robust. The total roofs area of 1992 and 2015 within wards were calculated. PRC based on ward boundaries were calculated using equation 1.

To calculate Percentage Roof Coverage (PRC) the following formula was used,

$$PRC = \frac{sum\ of\ roof\ area}{area\ of\ settlement} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 1}$$

Both spatial analysis and spatial statistical methods were used to determine consolidated areas and the amount of consolidation. The average nearest neighbour statistics was used to analyse the pattern of the buildings in INs. The method was used to measure the distance between features centroids, if the observed distance is less that estimated, the measured features are clustered (Mitchell, 2005). The observed minimum distance between buildings centroid was used as the threshold to distinguish infill and edge expansion. The minimum (threshold) distance of 1992 was used as the base distance to detect where the consolidation was an infill or edge expansion from 2015 buildings. Any building of the year 2015 found within 1992 minimum distance was considered to be an infill. Otherwise, the building was considered to be edge expansion. This method was done following the method applied by (Augustijn-Beckers et al., 2011) to simulate the edge expansion of buildings in Manzese. However, in their case it was relative possible to

work by blocks in one ward and calculate the mean distance between building centroids. In this thesis, the average nearest neighbour of a building centroid and other building centroids of INs was used to accommodate variation in distance of small clusters within the neighbourhood.
The roof area per person was calculated using the field work collected data see section 3.3.2 even though the data was not enough to represent the whole city but data provided an overview of the roof area per person and variation among wards and even within wards themselves. The roof area was calculated following the methods used by Dangol, (1998) using equation 2

$$Roof\ area\ per\ person = \frac{Total\ roof\ area}{Total\ population} \ldots \ldots \ldots \ldots \ldots \text{Equation 1}$$

3.4.3. Identify main driver of consolidation

Two important stages were used in this step. One is identifying the factors which may be potential drivers of the INs consolidation. Second, how to identify the main drivers of INs consolidation.
The potential drivers of INs consolidation were identified from the literature review and expert interviews see (section 3.3.2. The expert opinions were counted in a tabular form following the experts ranking schedule. Each mark of the expert was counted on the respective rank and a sum of marks was made. The rank with higher sum (mode) was considered to be the majority expert opinion on the level of significant of a particular driver Then, all drivers were ranked based on their respective mode from the highest which was expected to 15 (same as number of experts) to and the lowest 0. The resulting modes were used to discuss the main drivers according to consolidation models' results. In this way, it was possible to assess the results of the models and identify the main drivers of INs consolidation.
Multiple linear regression was used to model the percentage increase in consolidation across the years with identified potential drivers as the independent variables. Three models were constructed; 1), 1992 density model, 2) 2015 density model and 3) consolidation model across the years. The first two models used the respective PRC levels in INs for each year as the dependent variable. The consolidation model used the increase in PRC from 1992- 2015 as the dependent variable. Different statistics described in section 3.4.3.3 and 3.4.3.4 were used to assess the robustness of the models, and identify the contribution of the influence of independent variables on the results of the models. The following section discusses the steps in the consolidation modelling.

3.4.3.1. Data preparation

Drivers identified by both literature and experts were involved in the preparation of independent variables for the regression models. All factor maps were rasterised to the cell size of 10m x 10m because the available DEM which was derived from large scale data source was in 10mx 10m derived from 1:2500 topographic data. The vector layers for all factors were extracted from their respective shapefile and modified using UAV image and open street maps. These data were then extracted to cells for building the models in SPSS.

3.4.3.2. Factor maps preparation

Factors involved in Dar es Salaam were grouped into three site-specific characteristic, proximity characteristics and neighbourhood characteristics which are explained in details in the subsections below. The socio-economic drivers mentioned by experts were used qualitatively to assess the robustness of the models. The experts mentioned the socio-economic drivers such as, land price, affordability of housing construction, tribesmen, income and employment.

1) Proximity factors

Proximity maps were prepared based on the Euclidean distance to the mentioned factor. According to Cheng & Masser, (2003) proximity is a prime cause of urban expansion, transport and communication change. Euclidean distances in meters were calculated to the major and secondary roads. This is because from the literature review it was concluded that INs settlements tend to grow along the roads see also Hill et al., (2014), Kyessi, (1990) and Mtwangi, (2010). The insight gained from field work gave the experience that INs in the city grows more in secondary roads compared to primary roads. Therefore a Euclidean distance was calculated for primary roads and secondary roads. Availability of public transportation simplified movement to and from working places and other services. It is always an added advantage in the selection of building site for both residential and commercial uses. It was conceptualised that the closer to transport network, the higher the INs consolidation. Therefore all roads used for public transport were used to calculate the Euclidean distances. The most important and potential factor for people choosing residential area is moving to and from CBD for various livelihood activities. The proximity to the CBD increases the consolidation level. From experience, nature of the study area, and explanation from experts the city has two major CBD. One located in Posta area where there are many formal offices and government offices. The other CBD is located at Kariakoo the major commercial centre where different levels of businesses are taking place including both large and small scale (street vendors, and on street vegetable selling). CBD factor maps were prepared for both of them using the Euclidean distance. To study the impacts of different amenities in INs consolidation Euclidean distance to Government clinics were calculated. This is because Government hospital and clinics are not usually changing position (buildings) unlikely the private ones which may be shifted from one building to another based on different reasons such as rent. Four markets located in the study area Buguruni, Chang'ombe, Manzese and Makongo were used in calculating the Euclidean distance to markets.

2) Neighbourhood factors

The neighbourhood variable quantifies the spatial effect of neighbourhood cell due to the influence of the stimulating or constraint of such a cell (Verburg et al., 2004). The presence of planned neighbourhood was expected to attract more consolidation of INs. The planned neighbourhood increases the opportunity of INs to access different services. The distance to the nearest planned neighbourhood was calculated for each ward. Availability of other land uses was used to find out the relationship of INs consolidation with commercial, institutional, recreational activities (see appendix 7: land use preparation). The distance to the nearest other urban land uses was calculated using Euclidean distances. The INs were conceptualised to be consolidating more in the areas where there are other INs. The distance to other INS was also calculated. After all other lands were occupied the INs were conceptualised to be consolidating in any available vacant land. The availability of vacant land use within a 3x3 window size was calculated. All the land use were extracted from land use maps of 1992 for 1992 density and consolidation models. The 2015 land use map was used to extract different land use for the 2015 density model. Neighbourhood characteristics were calculated based on a 3x3 window as suggested by others see for example (Abebe, 2011) the small windows allows the capture of small objects like buildings (Githira, 2016).

3) Site-specific factors

Site-specific characteristics explain the likelihood that the cell will develop or not basing on its own availability of development (Cheng & Masser, 2003). The location of a site in slopes and swamps affects the price of land and suitability (good versus bad land) as well as socio-economic characteristics of individual INs. The lands within swamps and lower slopes was considered to be cheap, taken as the last priority after saturation of better land and hence attracts more INs consolidation. Slope data were calculated from DEM.

3.4.3.3. Multicollinearity analysis

In SPSS, the multicollinearity analysis was done to find how independent variable correlate to each other. The Variance of Inflation Factor (VIF) was calculated determined using equation 5 to determine the level of correlation among the variables following other research examples (Hao et al., 2013; Simiyu et al., 2017). The value of VIF for all factors should not be higher than 10 (Field, 2014) all variables with higher than 10 VIF were removed one by one. However, VIF is an excellent method of quantifying collinearity although it cannot determine which of the other factors are causing collinearity with that factor with a high VIF value (Craney & Surles, 2002). Further analysis using the degree of tolerance was done, with tolerance below 0.2 considered to indicate collinearity see also Dendoncker et al., (2007).All factors with no multicollinearity were therefore considered to be potential factors to explain INs consolidation.

$$R = \frac{1}{1-R_i^2} \quad \dots\dots\dots\dots\dots\dots \text{Equation 2}$$

Where: R_i^2 is the coefficient of determination of variables

3.4.3.4. Model Parameters

The model parameters were defined by the coefficient of independent variable based on maximum likelihood and t statistics. The coefficient of the independent variable gives the contribution of the predictor to the model. If the value is positive, then the relationship between INs consolidation and the predictor is positive. Meaning the higher the distance the higher the consolidation. If the values are negative, it means that the relationship between consolidation and that predictor is negative. The higher the distance the lower the consolidation. The maximum likelihood estimation explains the set of parameters for which the probability of the observed data is the greatest (Czepiel, 2012).The t-test was used to give the level of importance of the variables. Basing on theory t-test associated with significant beta statistics show the predictor which is making a significant contribution to the model. The smaller the value of p values gives the larger the t- values, which means the greater predictor contribution (Field, 2014).The use of two methods were find to be suitable in explaining the level of importance of variables.
The force entry method was used to run the model. The advantage of this method is that it does not utilise the advantages of random sampling by ignoring the variables small difference. Which if considered may results into intensely different with a theoretical importance of the theory of the predictors of the model. Both R-square and F-test to measure the goodness of fit following others for example Hao et al., (2013), Simiyu et al.,(2017) and Field, (2014).

4. RESULTS AND DISCUSSION

4.1. Introduction

This chapter discusses the results of the analysis obtained from both primary and secondary data as described in chapter three. The results are given in a sequential order from research question one to seven. Followed by a discussion in the same structure. A group of research questions, therefore, answers the specific objectives as described in section 1.4.3. Descriptive analysis and synthesis style are adopted to answer the questions. Different figure and appendixes are referred to explain and visualise the respective results. The chapter starts with the fieldwork results on observation of INs and OSM data. The chapter ends with a discussion which leads to chapter five where conclusion and recommendation are presented.

4.2. Field observation results

The aim of the field observation was 1) to verify the accuracy of OSM dataset and 2) to understand the nature of the selected INs and their differences and 3) household survey for roof area per person inputs. Figure 3-3 which shows observed areas and their characteristics are given in Table 3-2. The table provides the differences and similarities of observed INs. The circular marks shows the subwards where household survey was done for population data collection, the roof area results are shown in section4.4.3

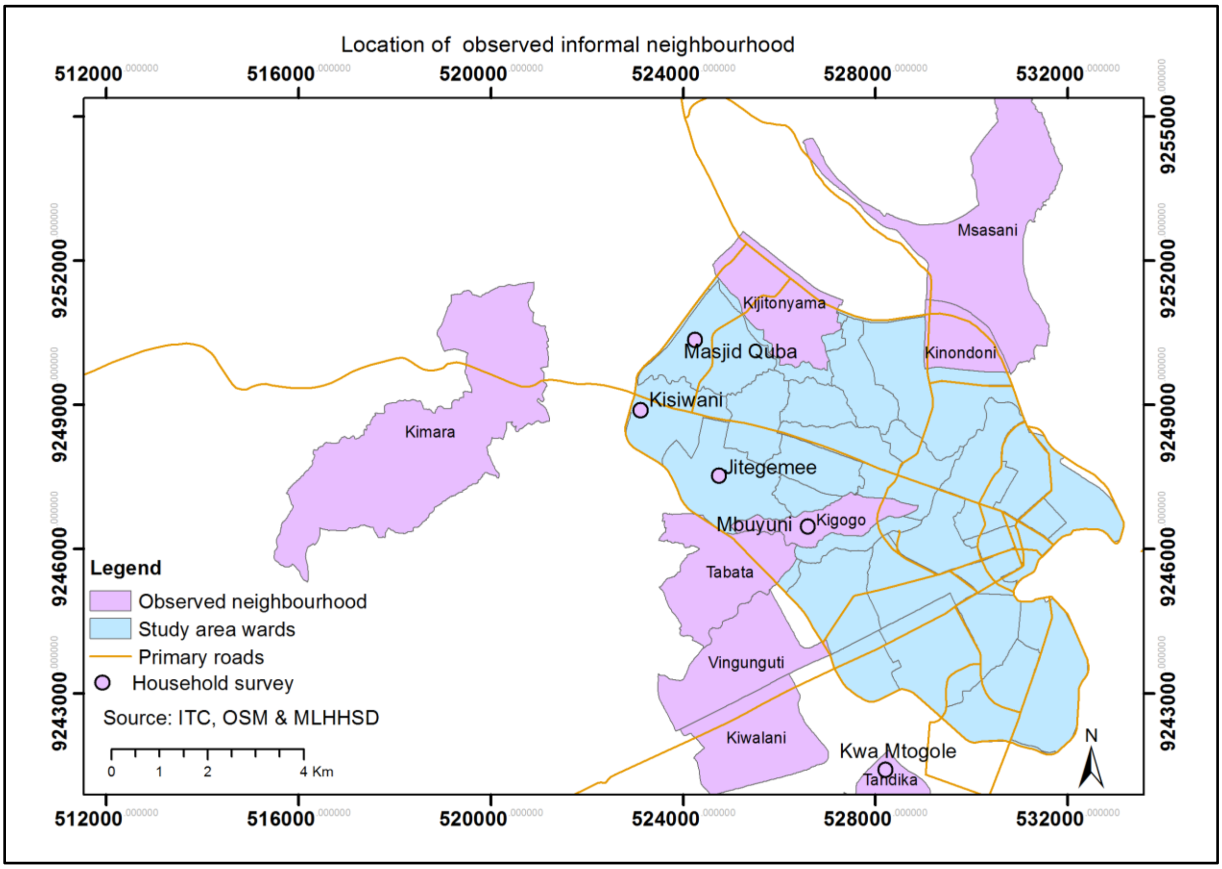


Figure 4-1: Observed neighbourhoods

Table 4:1 General characteristics of INs observed

S/N	Name	Description
1	Ubungo Kimara	It has a river (passing by) which divides the neighbourhood into two areas, one side with INs and the other with the planned settlement. Currently, there are upgrading plans done by MLHHSD. The plans aimed at surveying and improving road accessibility.
2	Kinondoni	Has both planned and unplanned area. In this area there was a swamp called in Swahili "bonde la mkwajuni". This area is located near Hana Nasif upgraded INs It has a number of services like the cemetery, Open University of Tanzania, Churches and both major and secondary roads. The area has high density dominated by dilapidated houses. It has more of unpaved roads with internal circulation provided by footpath.
3	Vingunguti	It is an industrial area. It has major and secondary roads. The area is located near sewerage site. The area is in lowlands with small rivers. The roads are mainly earth roads. The area is characterised by simple and small houses. The area has access to water and electricity services. The area is high density.
4	Kiwalani	It is located near the airport, industrial and near to other INs called Yombo Vituka. Has high to medium density. Water and electricity services are in worse condition than others above. Accessibility is mainly through earth roads and footpath.
5	Kijitonyama	Part of this ward is planned having services such as primary roads, secondary roads schools and industrial areas. Part of the neighbourhood is informal. It has a mixture of tarmac roads and earth roads. It has high access to water and electricity. Houses are in a good condition varying from simple to complex structures.
6	Kigogo	One of INs located near CBD. Located in the mixture of high land (hills) areas and lower slopes. It has some of the bare lands, the building density varies from medium to high. It has good roads, which are upgraded current. It is also located near Kariakoo the major commercial district. Water and electricity services in the area satisfactory according to dwellers found in the water Kiosk.
7	Msasani	Proposed by experts due to the facts that this neighbourhood is surrounded by the planned neighbourhood. This area was used as rice agricultural farm. Therefore it is swampy, called 'Msasani Kisiwani'' the neighbourhood is accessed through primary roads and footpath. Have a mixture of simple and complex building structures.
8	Tabata	Tabata was proposed due to the high rate of building increase as well as its low density characteristic. It resembles Sinza, one of the old planned neighbourhood. Building structures are complex houses and in a good state. The inhabitant are mostly Kariakoo business people with middle and high income society.

Source: Author, 2016

The table shows that INs have varied in socio-economic and physical characteristic. For example, Msasani, Kimara, and Tabata have a better housing condition compared to others. The buildings in these wards are mainly made of better materials and the wards have more internal roads circulation. Vingunguti is characterised by much smaller and poorer condition of houses. The houses have simple shapes and small in size and the ward is characterised by lower income earners.

4.3. OSM dataset accuracy

In order to have a general overview of data accuracy, it was necessary that the whole city data was used to avoid overgeneralisation from a small delineated study area. The accuracy analysis shows that there were some errors in OSM data; data incompleteness and shifting of data from the true position. Figure 4-3, shows different errors in OSM data set in Makumbusho ward. There are three parts in figure A, B and C (appendix 13 shows a relationship between the parts). In part A there is accurate data in terms of digitisation, the buildings are well covered and in the accurate position, no omission or commission of the building. The commission error referred to an inclusion of more buildings as one building while omission occurs when the buildings were not digitised. Part B is located in the western part of part A.

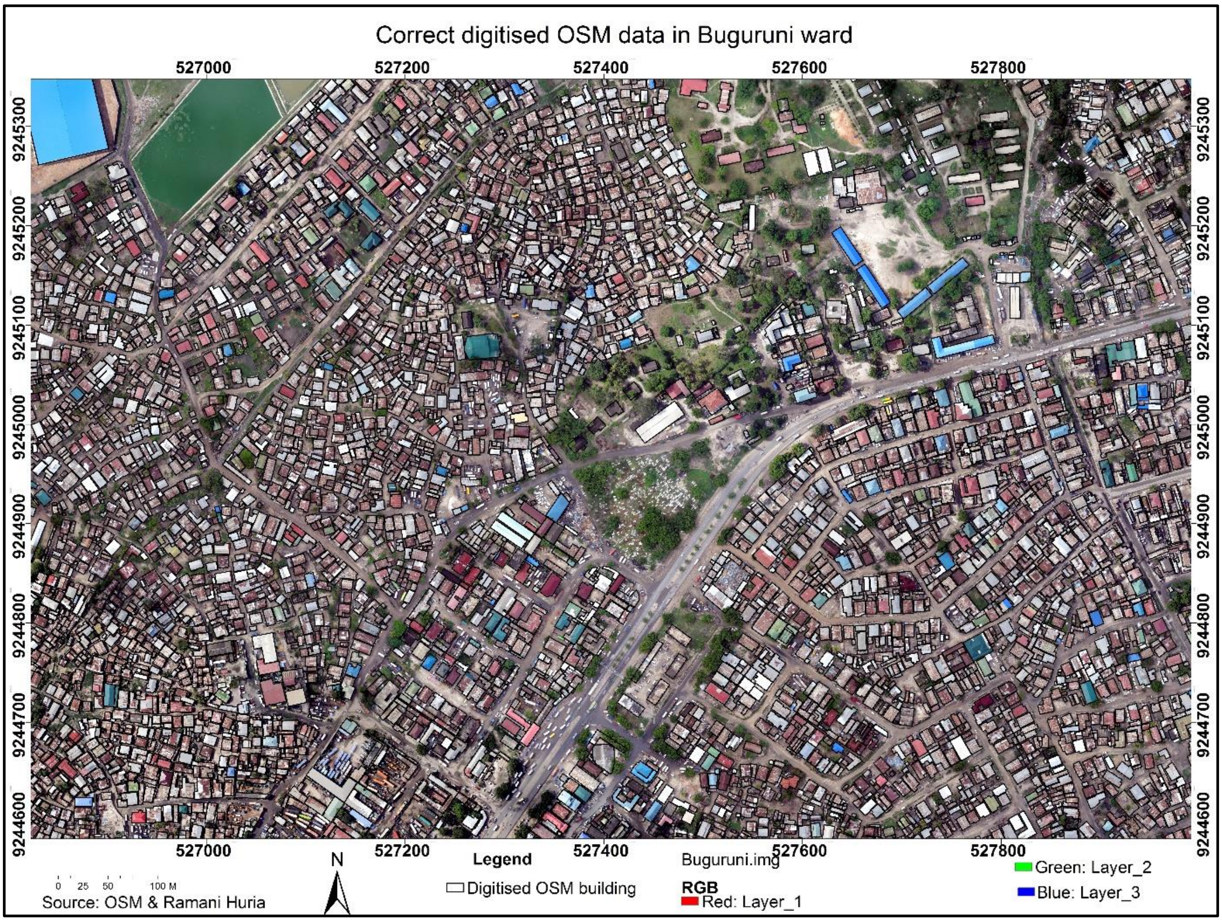


Figure 4-2: Correct digitised OSM data in Buguruni ward

The figure shows that there is a constant shift of the buildings between 2m and 10m towards the north east direction. This may be due to errors associated with GPS during data collection (see section 3.3.1). Part C shows the different types of errors in addition to those mentioned in part B. In this part, the figure shows commission and omission errors. There are a number of buildings which were not digitised, and some of the buildings were digitised as one building while they are more than one buildings. These errors may be caused by the person responsible for digitising. Poor commitment and low experience may account for such low quality data digitation. The results show that there were areas which were correctly digitised see figure 4-2. The figure shows that large part of the buildings were real buildings on the ground and they were in the correct position. In addition, the OSM attribute table naming of the buildings was correct. The attributes provide buildings ID, their uses and location.

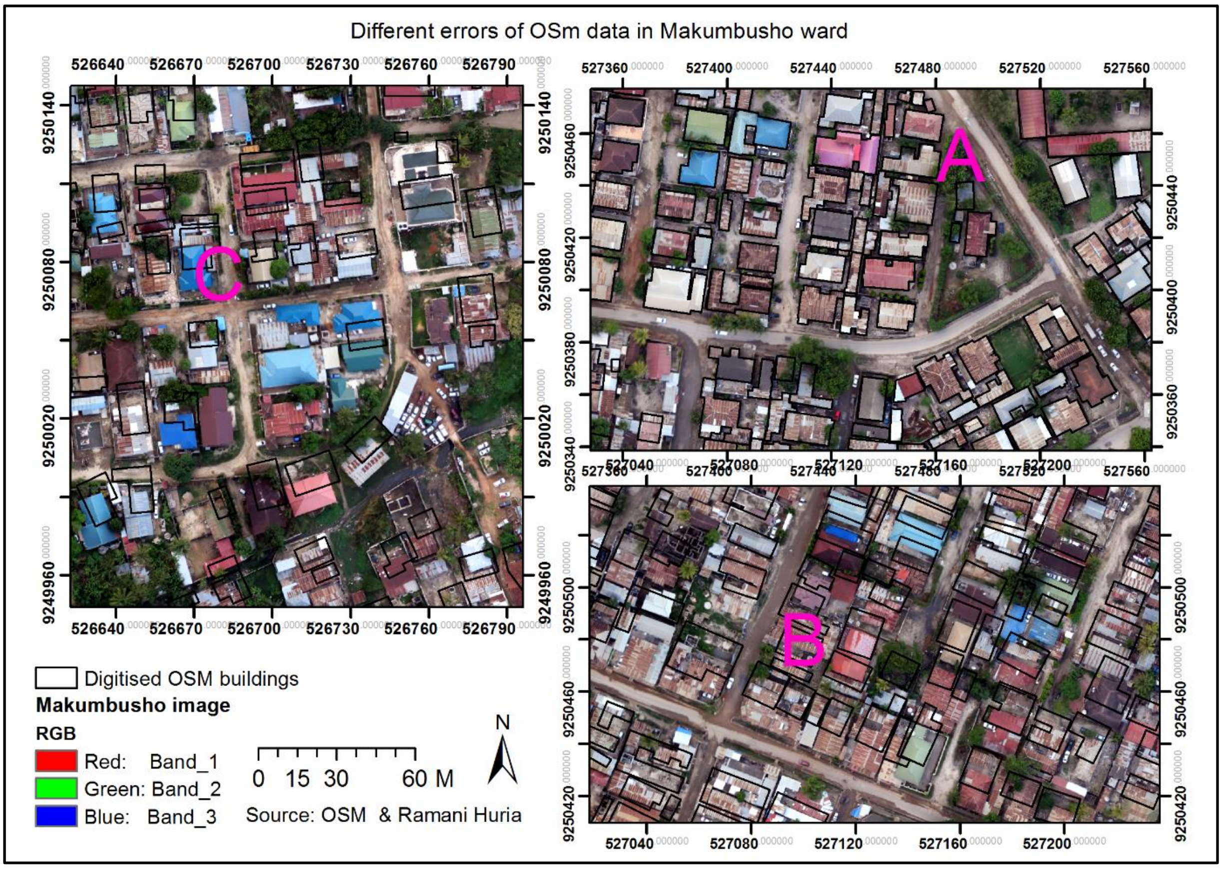


Figure 4-3: Errors of OSM data in Makumbusho ward

4.4. Physical change

According to literature section 2.2.3 one of the indicator that INs consolidation is taking place in Dar es Salaam is the increase of informal land use. The results show that indeed there is INs land use growth see figure 4-4. The figure shows that there is an increase in two major land uses INs and other urban land use. The increase in other urban land use and the decrease in residential may be explained by differences in time and classification of the land uses. Figure 4-4 also shows land uses in both years, in 2015 INs land use has increased for 3 percent making a total of 1680 ha from 1478 ha in 1992. The figure also depicts the locations of INs in the central Dar es Salaam in 1992 and 2015.

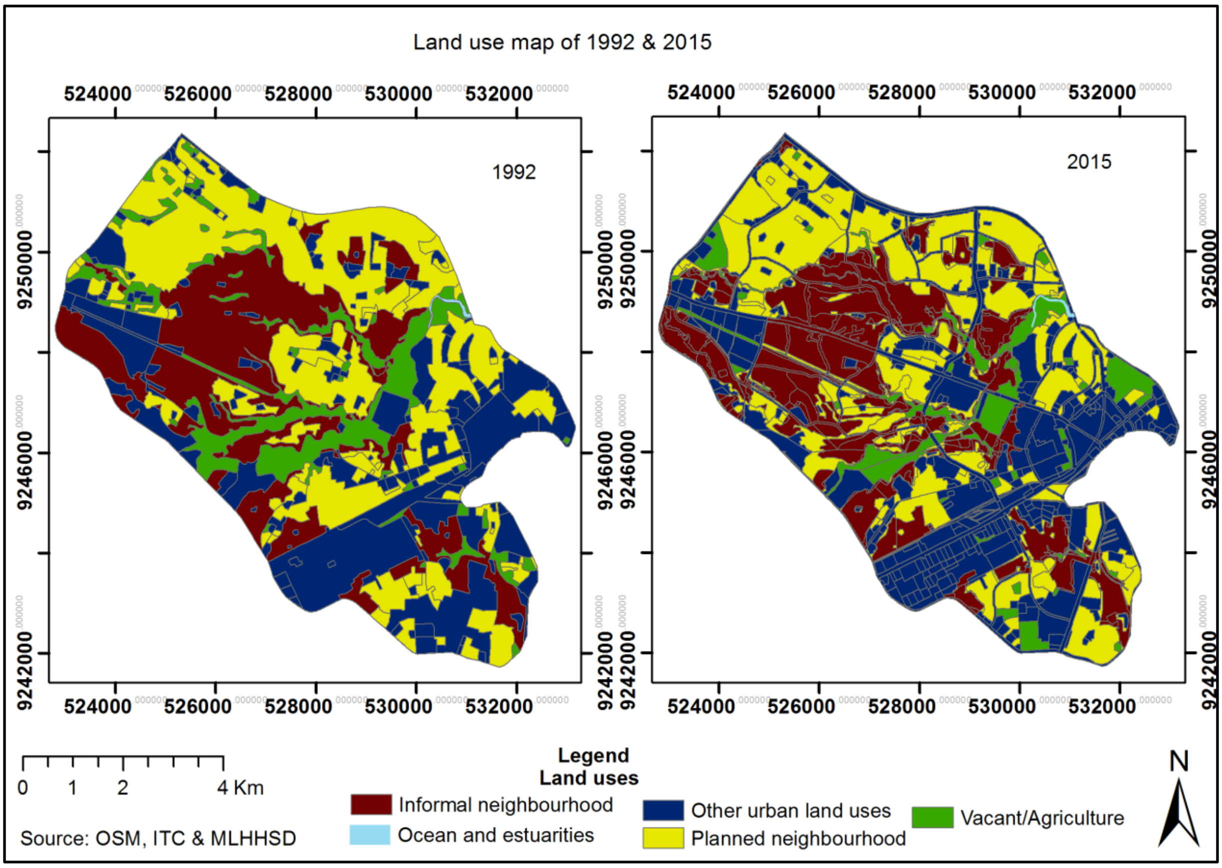


Figure 4-4: Informal neighbourhood location in central Dar es Salaam 1992 -2015

4.4.1. Informal neighbourhood hotspots

The analysis shows that there is an increase of building density across the years Figure 4-5 and table 4.3. Table 4-3 shows the classification of the total building area per Ha into four classes and the amount of area covered per class in each year. The table shows that the lowest density is 936 and 1508, and the highest is 7020 and 10395 square metre per Ha in 1992 and 2015 respectively in their specific class. The natural classification is used to determine the boundaries because it has the nature of minimising the differences within classes and maximising the differences across the classes (ESRI, 2016).

Table 4:2 Increases in density across years in m^2 per Ha

Year	Lowest density	Low density	Medium density	High density
Density per Ha	**< 2000**	**2001-3500**	**3501-5000**	**>5000**
Density as in 1992	936	2175	3359	7020
Density in 2015	1508	3001	4931	9395

Source: ITC, OSM & MLHHSD

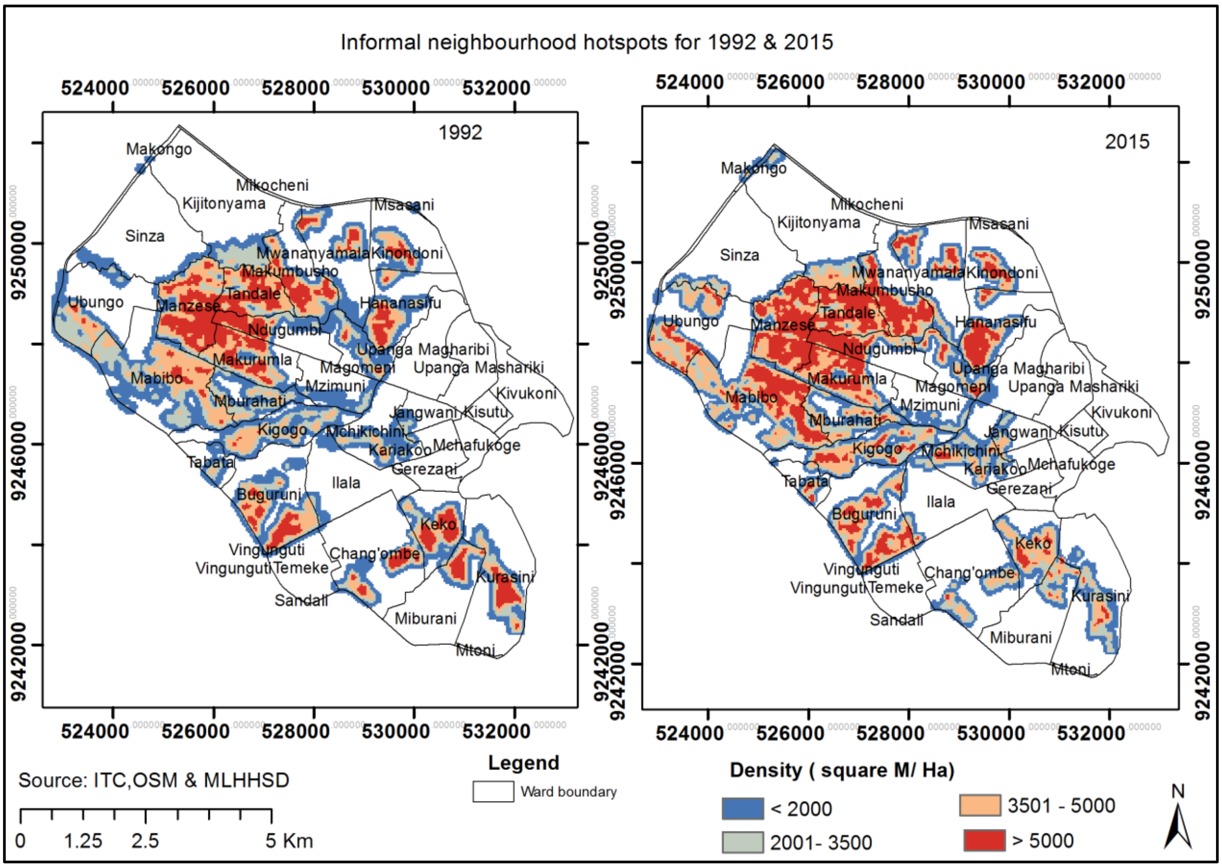


Figure 4-5: Informal neighbourhood hotspots in central Dar es Salaam 1992 & 2015

Figure 4-5 depicts INs consolidation hotspot where large patches of high INs consolidation are found in the northern part of the city compared to the southern part of the city. INs hotspots are found in wards of Manzese, Tandale, and Makurumla which has high building density in 1992 with an increase in 2015. The figure also shows that the southern part of the city is decreasing in building density from 1992 to 2015 from high density to medium density. In 1992 there was a high density in Keko, Chang'ombe and Kurasini which show a decrease in 2015. This may be explained by changes in development processes (Keko and Chang'ombe) and buildings eviction and or data omission in Kurasini. Makumbusho shows all density classes ranging from lowest to the highest in 1992 with an increase in 2015.

4.4.2. INs edge expansion and infill

The results of an average nearest neighbour of the INs shows that in 1992 the buildings make clusters of 9.7 metres as the observed mean distance between building centroids see (appendix 5: Average nearest neighbour 1992). The results of 2015 (appendix 6: Average nearest neighbour 2015) shows a decrease of 2.4 m compared to 1992 making an average observed mean distance between building centroid of 7.3 m. The decrease in distance is explained by the increase in consolidation.

Figure 4-6 shows the infill and edge expansion for the year 2015 over the building existed in 1992. The figure explains how infill was distinguished from edge expansion sub-processes of INs consolidation.

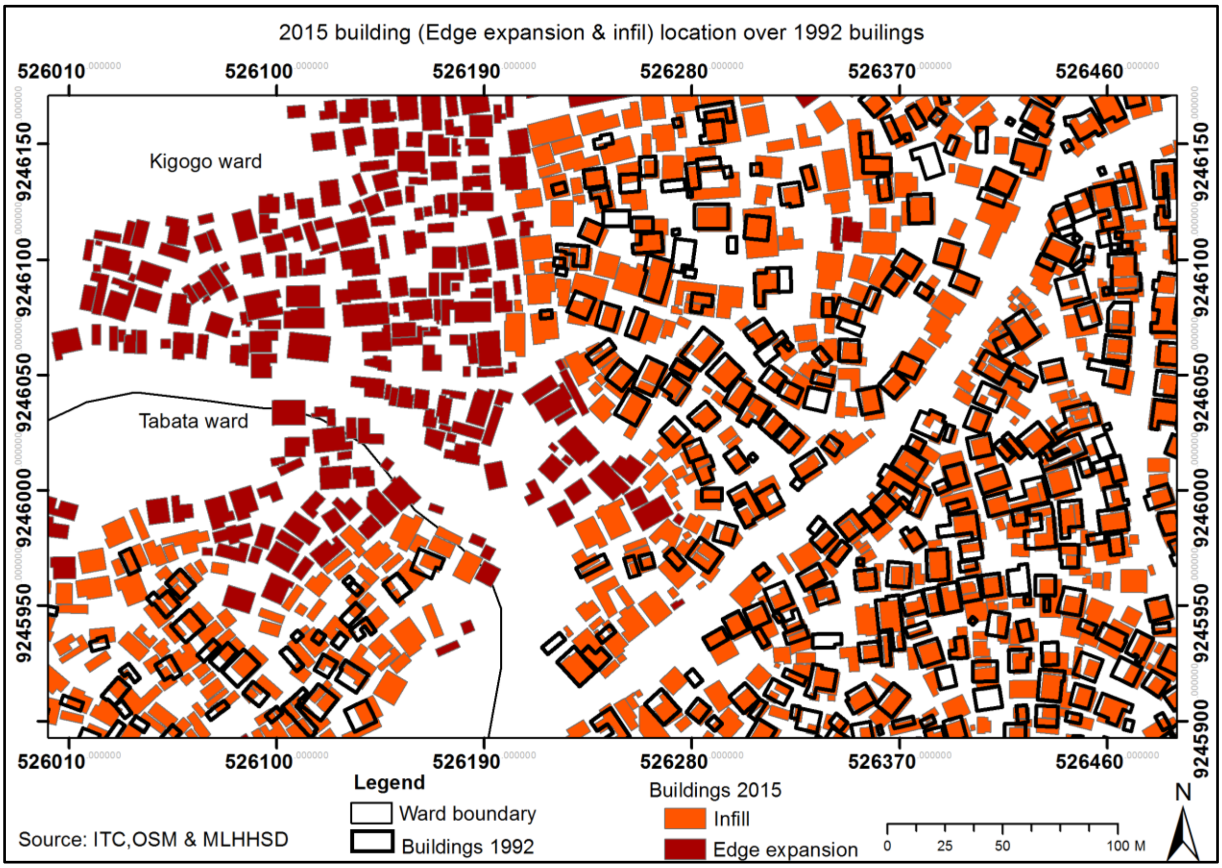


Figure 4-6: 2015 Building (edge expansion and infill) and 1992 buildings

4.4.3. Changes in consolidation from 1992 to 2015

Figure 4-7 visualises the difference in PRC value per 100 m grids. The figure depicts the cells with decreasing values of PRC with a < 0%, and the increased consolidated area with values ranging from 1-60 %. Appendix 12 shows the PRC values in 1992 and 2015, to give the insight of decreasing PRC in Keko, Miburani, Chang'ombe and Kurasini wards. The decrease in generally observed in the southern part of the city where there are cells with the negative values of PRC, Kurasini has a large number of the cell with this nature. The decrease in Keko may be caused by gentrification whereby one or more plots are joined together to form one plot and hence decreasing the density. The decrease in Kurasini is caused by house demolished to extend harbour related activities. Section 4.6.2 discusses this results in details. The figure also showed that generally, the increase in consolidation in the central of Dar es Salaam is between 16-30%.
The high increase in consolidation occurs in Hana Nasif, Jangwani, Mabibo, Makumbusho, Makurumla, Tabata and Ubungo. Figure 4-8 shows the results of the change in consolidation across the years. The figure depicts that Kinondoni and Buguruni have highest PRC in both years with the values 27% and 29% in 1992; and 50% and 44% respectively in 2015. Figure 4-8 also shows that Magomeni, Mabibo, Hana Nasif, Makumbusho, Manzese, and Makurumla are wards which have increase twice in 2015 compare to 1992. This may be explained by the location of the wards, such as Manzese, which is closer to Ubungo bus terminal; Makumbusho is the new dala dala major terminal instead of the former Ubungo; Hana Nasif has been upgraded and Mabibo is

closer to Ubungo bus terminal but also closer to major hostels of the University of Dar es Salaam.

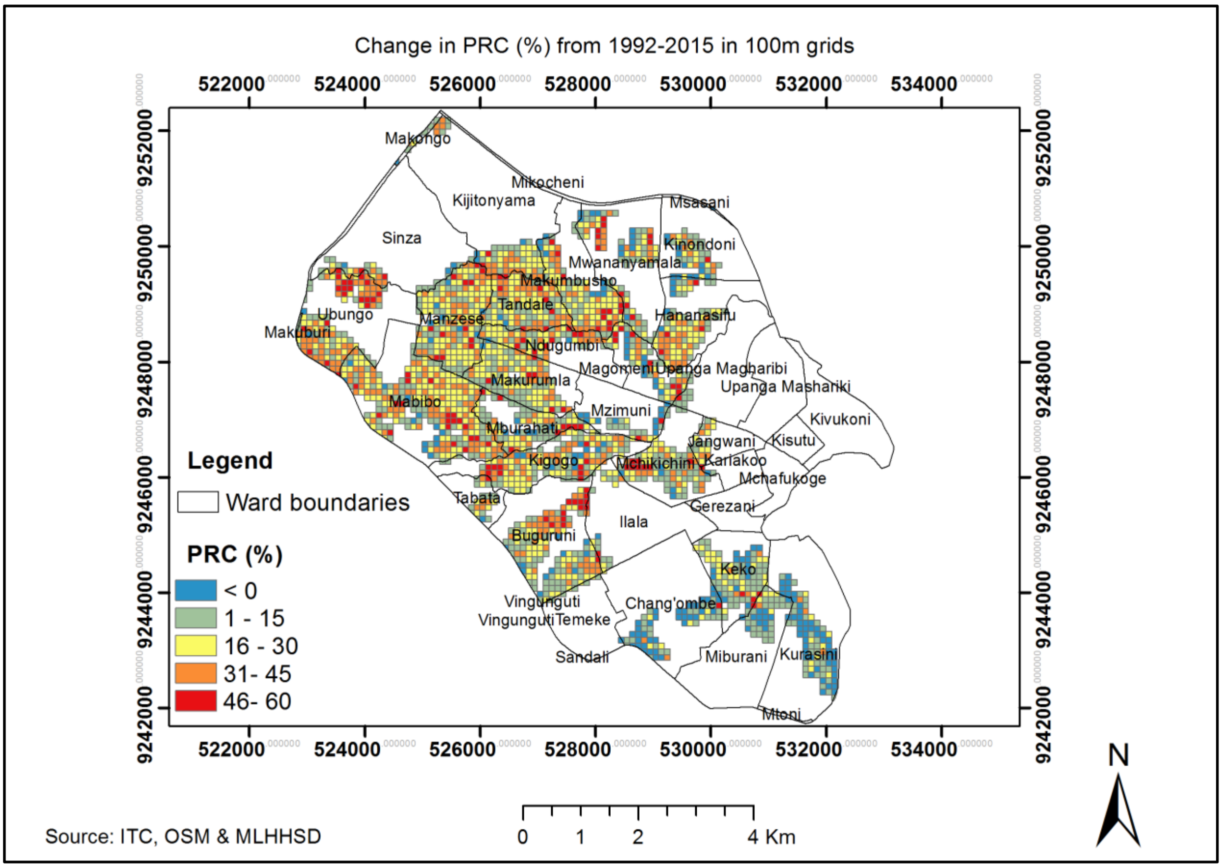


Figure 4-7: Change in Percentage Roof Coverage (PRC) from 1992 to 2015

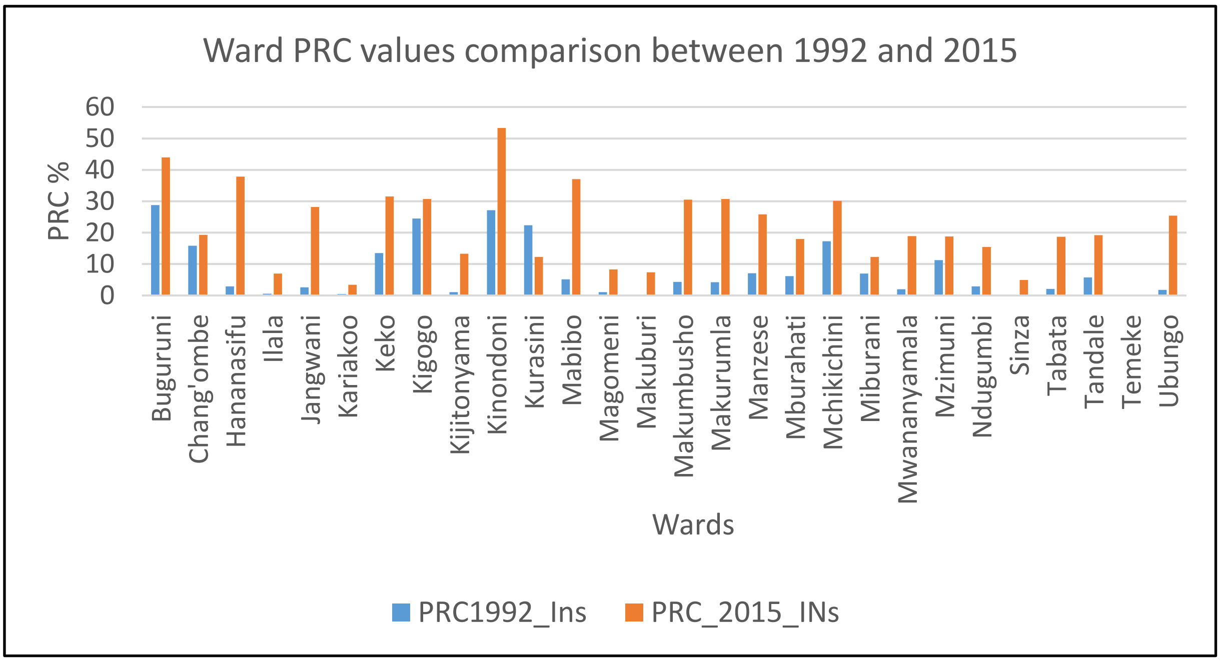


Figure 4-8: Ward Percentage Roof Coverage (PRC) values of 1992 and 2015

Source: ITC, OSM and MLHHSD

4.4.4. Roof area per person

The average roof area per person is 11 for five wards of Kigogo, Tandika, Mabibo, Tandale and Sinza represented by their respective subward. Table 4-4 shows results of roof area per person in different Subwards in the central Dar. Kisiwani is from Ubungo ward, Jitegemee is from Mabibo ward, Masjid Quba is from Sinza ward, Mbuyuni is from Kigogo ward and Kwa Mtogole is from Tandika ward. These results were calculated based on Subwards level. Masjid Quba has the highest average roof area per person meaning that it has lower population density compared to others. The coefficient of variation is higher in Subwards with lower roof area per person compared to others. More of the results have been discussed in section 4.6.2

Table 4:3: Total roof area per person in four subwards within four different ward

Subwards	No. Houses I surveyed	Total No. of occupancy	Total roof area	Total roof area per person			SD	Variance	Coefficient of variation %
				Min	Max	Average			
Jitegemee	9	87	590	4.6	9	6.7	1.6	2.7	24.4
Kisiwani	9	73	1114	4.2	26	14.4	6.0	36.5	41.9
Masjid Quba	10	91	1876	3.8	36	17.3	10.2	104.1	59.1
Mbuyuni	11	83	671	1.5	19	9.9	6.1	36.7	61.4
Kwa Mtogole	10	98	904	3.9	14	8.2	3.5	12.0	42.2
Total Average roof area				3.6	20.8	11			

Source: Author, 2016

4.5. Main drivers of INs consolidation

This section is divided into two section, section one giving the results of the important drivers of INs from expert interviews. Section two gives the results of the main drivers of INs according to the models.

4.5.1. The results of expert interviews

Table 4:4 shows the results of expert interviews and gives the number of ranks marked by experts. The ranks represent the level of importance of each driver. Thus 1 has the highest value of influence and 5 shows the lowest influence. The mode is used for discussion on individual driver. Although experts were marking the table individually, the results show that there are more commonalities in their opinions than the differences.

Expert interview (table 4:4), shows that the availability of vacant land and distance to secondary roads were the most important drivers mentioned by 9 experts out of 15. Followed by the distance to existing INs, primary roads, CBD, as the second important drivers of INs consolidation mentioned by 8 out of 15 experts. The third important factors according to experts included population density, planned neighbourhood, and quantity and quality of infrastructure. The forth included the existing of hazardous lands, such as flood-prone areas, slopes (steep slopes, lower slopes), swamps and rivers banks. Upgrading programs, distance to industries, distance to markets and distance to school had less significant contribution or no importance in influencing INs consolidation.

Table 4:4 Results of experts interviews on main drivers of INs consolidation

S/N	Driver	Ranks of driver (1 is the highest)					Total
		1	2	3	4	5	
1	Distance to existing INN	8	2	4	1		15
2	Distance to primary roads (m)	8	4	3			15
	Distance to secondary roads	9	5	1			15
3	Distance to school	1	3	2	4	5	15
4	Distance to CBD (m)	8	3	4			15
5	Distance to market (m)	4	5	4		2	15
6	Distance to Industries	5	3	4		3	15
7	Distance to Clinics	3	3	2	3	4	15
8	Population density (high, medium, low)	7	2		2	4	15
9	Availability of vacant land	9		3		3	15
10	Existing of planned neighbourhoods	7	2	4	1	1	15
11	Quality and quantity of urban infrastructure	7	4	2	2		15
12	Upgrading program	5	2	4	1	3	15
13	Existing of Flood prune areas, high slopes, swamp and riverbanks	6	2	2	4	1	15

Source: Expert interviews, 2016

4.5.2. Results of the regression models

This section gives the results of main drivers of INs consolidation based on multiple linear regression analysis. The input variables were prepared using potential drivers derived from expert interview and literature review. Table 4:5 shows variables used in the models.

Table 4:5 Potential drivers of INs consolidation used in multiple liner regression model

Category	Variables
Site specific	Slope
	Swamp
Proximity	Distance to CBD
	Distance to clinics
	Distance to primary roads
	Distance to secondary roads
	Distance to markets
	Distance to major river
	Distance to miner river
	Distance to public transport
Neighbourhood	Distance to INs
	Distance to other urban land uses
	Availability of vacant land
	Distance of planned neighbourhoods

Source: Author, 2016

Table 4:6 Models summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1 (1992)	.539[a]	.29	.29	8.9	.29	65	10	1596	.000	1.4
2 (2015)	.574[a]	.33	.33	11.9	.33	71	11	1595	.000	1.6
3 (consolidation)	.443[a]	.20	.19	9.8	.20	44	6	1557	.000	1.6

Source: ITC, OSM and MLHHSD

The model summary table 4:6 depicts R-squares of three models, 1=1992 density model, 2= 2015 density model and 3= consolidation model. The models were built at the cell level. The R-square values are 29%, 33% and 20% for 1992, 2015, and consolidation model respectively. This means that each model is able to explain the respective percentage of variation that happening in the specific model. The adjusted R-square in each model is closed to respective R-square, meaning that each model is good for generalisation.

The Durbin-Watson values are 1.4, 1.6 and 1.6 for 1992, 2015 and consolidation models respectively. These values show that there is no autocorrelation among independent errors, since their independent errors are closer to 2, the optimal value of Durbin-Watson (Field, 2014). Hence the model fulfils the multiple linear assumptions that for each pair of observation the error terms are not correlated. It should be noted that these are the last results after removal of insignificant drivers in each model. However, due to the results of experts interviews (table 4:4), the distance to secondary roads was among the two most important drivers (the other was vacant land); this driver was maintained in order to reveal how it performed poorly from the models. The maintenance was did not affect the general performance of the models.

Table 4:7 ANOVA table for model 1

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	52059	10	5206	65	.000[b]
	Residual	127263	1596	79		
	Total	179322	1606			

Source: ITC, OSM and MLHHSD

Table 4:7 shows ANOVA table for model 1, which gives F value of 65 with the significant value of <0.05 since F it is greater than one means that the predictors contribute to the results of the model with high significant level.

Table 4:8 shows the table of coefficients for model 1, which gives the significant variables that contribute to variation in INs density levels in 1992. The table shows the results after the fourth run to remove the insignificant variable in the model. In the first run; distance to minor river was removed. In the second run, the variable distance to swamp was removed. Followed by removal of distance to primary roads and vacant land in the third and fourth run respectively. All variables have less than 10 VIF values therefore there no correlation between variables. The values of independence error tolerance show no autocorrelation since the values are not low 0.2 nor higher than 2. As it was described by Field, (2014) that the mentioned values are the general threshold of both VIF and independence of errors. Hence there is no issue of multicollinearity in this model.

Table 4:8 shows that slope, distance to clinics, secondary roads and distance to other INs have negative coefficients meaning that they are inversely correlated with density. The low distances to these variables increase density. Other variables show positive correlation meaning that their increases cause an increase in density.
The table also depicts that the major drivers of INs density in 1992 were the distance to clinics, major river, other INs, planned neighbourhood, other urban land uses following the mentioned order. These variables have high t values associated with significant beta values ($p<0.05$). According to this table slope, distance to and CBD are also important with lower significant levels. Except for distance to secondary roads which was maintained to show the differences between experts' opinions and model results over this driver.

Table 4:8 Table of coefficients for model 1

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	15.132	1.235		12.25	.000		
	Slope	-.210	.082	-.056	-2.54	.011	.906	1.104
	Distance to CBD	.000	.000	.066	2.28	.023	.530	1.886
	Distance to clinic	-.006	.000	-.415	-15.45	.000	.615	1.625
	Distance to market	.001	.000	.090	3.72	.000	.768	1.302
	Distance major river	.004	.000	.427	13.96	.000	.475	2.105
	Distance public transport	.002	.001	.067	3.02	.003	.904	1.106
	Distance planned neighbourhood	.008	.001	.199	7.37	.000	.611	1.636
	Distance other urban land uses	.007	.001	.121	5.13	.000	.799	1.252
	Distance INs	-.085	.007	-.294	-12.8	.000	.842	1.188
	Distance secondary roads	-.003	.002	-.030	-1.35	.177	.886	1.129

Source: ITC, OSM and MLHHSD

Table 4:9 shows ANOVA table for model 2, which gives F value of 71 with the significant value of <0.05 since F it is greater than one means that the predictors contribute to the results of the model with high significant level.

Table 4:9: ANOVA table for model 2

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	111982	11	10180	71.3	.000[b]
	Residual	227808	1595	143		
	Total	339790	1606			

Source: ITC, OSM and MLHHS

Table 4:10: Coefficient table for model 2

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	22.578	1.509		14.96	.000		
	Slope_tif1	-.142	.105	-.029	-1.35	.176	.925	1.081
	Distance to CBD	.001	.000	.117	5.03	.000	.777	1.287
	Distance to clinic	-.005	.000	-.222	-9.75	.000	.809	1.236
	Distance primary road	.003	.001	.073	2.98	.003	.703	1.422
	Distance secondary roads	-.003	.002	-.026	-1.24	.215	.939	1.065
	Distance to market	.001	.000	.051	1.98	.048	.629	1.589
	Distance miner river	-.003	.001	-.116	-4.42	.000	.606	1.649
	Distance INs	-.107	.010	-.238	-10.67	.000	.841	1.189
	Distance other urban land uses	.016	.003	.152	6.07	.000	.669	1.494
	Distance vacant land	.007	.001	.125	5.31	.000	.764	1.309
	Distance planned neighbourhood	.018	.003	.158	6.41	.000	.694	1.442

Source: ITC, OSM and MLHHSD

Table 4:10 shows the coefficients for model 2, the significant variables which contribute to variation in INs density level in 2015. The table shows the results after the third run to remove the insignificant variable in the model. Distance to swamps, public transport and major river were removed in consecutively step. All variables have less than 10 VIF values therefore there no correlation between variables. The values of independence error tolerance show no autocorrelation since the values are neither low than 0.2 nor higher than 2. Hence there is no multicollinearity in this mode0l.

The table shows that slope, distance to clinics, secondary roads, minor rivers, and distance to other INs have negative coefficients meaning that they have inversely correlation with density. The low distances to this variables increase density. Other variables show positive correlation meaning that the increase in their value increases density and vice versa.
The table also depicts that the major drivers of INs density in 2015 are the distance to other INs, clinics, planned neighbourhood, other urban land uses, vacant land, CBD minor river and distance to primary road following the mentioned order. These variables have high t values associated with significant beta values.

Table 4:11 ANOVA table for model 3

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	37333.52	9	4148.17	43	.000b
	Residual	153288.15	1597	95.99		
	Total	190621.7	1606			

Source: ITC, OSM and MLHHSD

Table 4:11 shows ANOVA table for model 3, which gives F value of 43 with the significant value of <0.05 since F it is greater than one means that the predictors contribute to the results of the model with high significant level.

Table 4:12: Coefficient table for model 3

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	11.317	1.328		8.52	.000		
	Distance to swamp	-.001	.000	-.040	-1.37	.171	.582	1.719
	Distance to CBD	.000	.000	.054	1.85	.065	.593	1.686
	Distance secondary roads	-.003	.002	-.033	-1.35	.176	.868	1.152
	Distance major river	-.003	.000	-.379	-12.91	.000	.584	1.713
	Distance minor river	-.002	.000	-.093	-3.39	.001	.668	1.496
	Distance public transport	.002	.001	.051	1.93	.054	.730	1.371
	Distance to INS	.026	.005	.131	5.33	.000	.835	1.197
	Distance other urban land uses	.005	.002	.078	3.15	.002	.822	1.216
	Distance planned neighbourhood	.004	.001	.087	3.05	.002	.624	1.603

Source: ITC, OSM and MLHHSD

Table 4:12 shows the table of coefficients for model 3. The table depicts significant variables which contribute to variation in change of INs consolidation level between 1992 and 2015 after the fifth run. Distance to clinics, distance to primary roads, slope, availability of vacant land and distance to market were removed in consecutively step. The VIF and tolerance values show no multicollinearity in the model.

The table depicts 4 variables with negative correlation with consolidation namely; distance to major river, miner river, swamp and CBD. The shorter the distances to these variables the higher the consolidation. Other variables show positive correlation meaning that there is more consolidation with the increase in the distance to these variables.

The table also depicts that the distance to major rivers has highest influence change in INs consolidation across the years. The distance to other INs, miner river, other urban land uses, and public transport are also the major drivers of INs consolidation across the years following the mentioned order. These variables have high t values associated with significant beta values. Distance to CBD is also important even though with lower significant level.

The results of the models on the linearity assumption tests on homoscedasticity and normality of error distributions are given by appendices 9, 10 and 11 show the results of regression plots for the tests. All three models did not violet the assumptions of linear models.

4.6. Discussion on the results

4.6.1. Discussion on OSM Accuracy

The results showed that OSM dataset is *fit* for studying INs consolidation despite the differences in some wards. The shortcoming caused by data collection instruments (handheld GPS) was expected as it was mentioned and proved in other studies in different cities. For example, it was argued that based on the data collection methods the OSM dataset cannot be more accurate that the quality of the GPS receiver which captures a location of 6-10 metres from the actual distance (Haklay, 2010). Therefore it is expected that the OSM data set to be within a region of 20m from the true location under ideal conditions depending on the instrument used.
The results (figure 4-3) showed that the accuracy and attention to details differ between areas. This can be attributed to digitisation, data collection skills and the patience of the person who carried out the work. Again it should be noted that the OSM data was quite well digitised in the central city compared to the periphery. This is a normal phenomenon in many OSM data it was also provided by Girres & Touya, (2010) who found the same in France. Therefore errors found in OSM data were not only found in Dar es Salaam but also with other cities. Therefore this research has revealed the accuracy of OSM data *fitness for use* with the notion that there may be little shortcoming caused by increase or decrease in a number of buildings as the results of omission and commission errors.

4.6.2. Discussion on physical change

The results showed a shifting of the hotspots from the southern part of the city to the northern parts figure 4-5. This is explained by the differences in the socio-economic characteristic of the society living in the southern part against those living in the northern parts of the city. It was revealed in expert interviews that people are more likely to settle along the primary roads which lead to their hometown and villages. People from northern Tanzania are more educated and have the better economic status which gives them the opportunity to move to Dar es Salaam to search for better jobs. In Dar es Salaam they are welcomed by their relatives dwelling in the northern parts of the city and hence causing the increase in density in the course of building their shelter. The shifting of density may also be explained by the changes of nature of INs development activities in Keko, Kurasini, Miburani and Chang'ombe see section 4.4.1. High densities according to the figure are decreasing to medium densities in Keko, Chang'ombe and Miburani wards while the high densities changes to lower densities in Kurasini ward. This is also supported by results of changes in cell consolidation Figure 4-7 which showed that there is a decrease of consolidation to the negative PRC values in Kurasini and some parts of Keko and Miburani. According to the experts Keko is undergoing gentrification where two or more buildings are bought for constructing of one high raised building which may cause a decrease in density. The experts also mentioned a change in land use in Keko from residential to light industries which in turn reduces the density of houses from high to middle levels. Figure 4-7 showed that in Keko consolidation is decreasing up to less than 0% in very few cells whereas the majority of the cells were increasing from 1-30%, with the few number of cells increasing up to 31-60%. The increase in consolidation in Miburani which is a middle income area is mainly 1-15% PRC, these values are lower than Keko. The availability of light industries in Keko such as furniture may be a reason of the increased density compared to Miburani where there is no industries. Thus the availability of jobs and employments attracts more middle and lower income earners in Keko. Kurasini ward has higher decrease < 0% in PRC caused by massive houses demolished by the MLHHSD in 2010 for expansion of harbour activities; although a total number of houses demolished is not known by the author. The analysis showed that there had been some of the demolitions (figure 4-

9) and some parts have evidence of buildings omission in the data. The building omission in this Kurasini may be caused by little or no interest in the community to map this area. Before demolished this ward had middle to high PRC values (between 41-80 % appendix: 12), the availability of harbour activities provided a number of jobs and employment which attracted lower income and middle income to the ward. This also explains the nature of socio-economic status of Miburani ward as the middle class ward. Miburani is located in between Keko and Kurasini wards, therefore, attracts middle income earner who can travel to and from jobs located either in Keko or Kurasini. Although the analysis showed that the increase in consolidation in Miburani is not high (Figure 4-7), the effects of demolished houses in Kurasini might cause the high increase in future by people seeking to live closer to working areas. This is also supports the argument that socio-economic development processes occur in INs contributes to changes of their consolidation levels.

The results of ward consolidation analysis showed that Kinondoni and Buguruni have the highest PRC value per ward (figure 4-8).This may be accounted for by location characteristics of both wards. These two wards similar socio-economic characteristics with few middle income earners and many low income earners. There have been upgrading programs in Buguruni, whereas Kinondoni is close to Hana Nasif one of the early upgraded INs. Also, Kinondoni is located in the area where there was a rice plantation like sharifu shamba, which may have stimulated more consolidation due to the availability of cheap land. Buguruni is bordered by Ilala, Temeke where there are plenty of institutions and industries, therefore the ward is convenient for workers of different socio-economic characteristics. Ilala, Sinza and Kariakoo have the lowest PRC values. Low values of PRC at these wards were expected due to their individual characteristic. Ilala and Sinza are middle income earners areas which are closer to planned neighbourhoods therefore an increase in consolidation may be influenced by the availability of services in planned neighbourhoods. Kariakoo is the central business district where more of land is changing to commercial uses. However, the results of the ward PRC (figure 4-8) showed that there is an increase of PRC in Keko, which is explained by the increase in edge expansion see figure 4-7 and appendix 12. Keko showed edges expansion with an increase of 16-60 % from 1992 to 2015. The accumulation of this increased density may lead to the general increase of the ward consolidation level due to changing of the denominator in calculating density. There are possibilities that the highest density cells are found in Keko which if added changes the total density in ward. Temeke and Chang'ombe showed stability in consolidation across the years due to the fact that these wards are dominated by industries and institutions. The high increase in consolidation occurs Hana Nasif, Jangwani, Mabibo, Makumbusho, Makurumla, Tabata and Ubungo (figure 4-8). These wards have been increasing in consolidation around two times higher in 2015 than 1992. These are wards which have been upgraded previously. The wards have been mentioned in different research as upgraded see for example Magigi, (2013), Magigi & Majani, (2006), Sliuzas, (2004) and UN-Habitat, (2010). Although Jangwani was among the high increased consolidation rate across the years, current the ward is changing to vacant land. This is accounted for the location of the ward on the Msimbazi river valley which provided cheap land for lower income earners. During the field work much of this area was demolished as the reaction towards effects caused by floods in 2012. These people according to the experts were resettled to Mabwepande planned area outside the central of Dar es Salaam.

The results on roof area per person revealed that Masjid Quba and Kisiwani have highest roof area per person (table 4:4).The location and socio-economic status of the inhabitants in these two subwards explain the variation. Masjid Quba is located in the midst of planned neighbourhood of Sinza, having a middle income earner society. Ubungo Kisiwani subwards is located behind Ubungo bus terminal. The area has a number of hotels, hostels and restaurant, there are residential houses of middle income earners. Therefore these two wards have low population density. Comparing these results with the ones obtained by Dangol, (1998), there is a change in the roof area per person. The average roof area per person was about 8.5 square meters in 1998, while current the value is 11square meters. In his/her work, Masjid Quba and Kisiwani were not included. The removal of Kisiwani and Masjid Quba subwards in the empirical data give the average roof area of 8 square meters almost the same as Dangol, (1998) work. This may give an indication that majority of INs in central Dar es Salaam has the average roof area of 8 -9 square metres. However, the high values found in Masjid Quba and Kisiwani explains the variation in INs caused by socio-economic characteristics of an individual INs.

Figure 4-9: Housing demolishment in Kurasini

Source: Author, 2016

The results of average nearest neighbour (section 4.4.2 figure 4-6) showed that there is a decrease in the distance between the buildings which means that INs in the central Dar es Salam are becoming more consolidated. The infill of 2015 buildings describes the former 1992 INs boundaries whereas edge expansion explains new 2015 INs boundaries (refresh section 2.4 figure 2-1)

4.6.3. Discussion on the main drivers of INs consolidation

The results models summary showed that all models had low values of R-square (table 4:7). Low values of R-square explain that the physical drivers involved in the models are not the only explanation of the change in PRC, there are other drivers which were not included. The models did not include socio-economic characteristics of the study area and upgrading programs involved in the study area which could contribute to the variation of PRC in the study area. There are number of cells which were decreasing in density to < 0% which might result to lower values of R-square. The consolidation model (model 3) has the lowest value of R-square because it has a different nature with the other two in terms of the dependent variable. The consolidation model used percentage change in density as the dependent variable while others used respective densities as the dependent variable. The lower values or R-square may be explained by the possibility that the factors influencing density are not necessarily influence consolidation.

Table 4:13: The first five main drivers from the models at <0.05 significant level

S/N	Model 1	Model 2	Model 3
1	Distance to clinic	Distance to INs	Distance to major river
2	Distance to major river	Distance to clinics	Distance to INs
3	Distance to INs	Distance to planned neighbourhood	Distance to minor river
4	Distance to planned neighbourhoods	Distance to other urban	Distance to other urban
5	Distance to other urban land uses	Distance to vacant land	Distance to planned neighbourhood

Source: ITC, OSM and MLHHSD

Table 4:13 shows the first main drivers the main drivers in each model according to the level of influence. The figure shows some similarities and differences in models result. Distance to INs, distance to planned neighbourhoods, and distance to other urban land uses is common in all models, showing that these factors contribute to variation in densities (1992 and 2015) and variation in consolidation across the years in different levels of influence.

The influence of distance to INs to both density and consolidation models may be explained by socio-economic characteristics of the incoming population to the city. The expert interviews mentioned that in reality most of the people in Dar es Salaam are living following their socio-economic ties. INs receive lots of incoming population who seeks accommodation, and they find cheap renting rooms. After a certain period, the newcomers agreed with landowners to buy small subdivided plots at the affordable price to construct their own buildings. Availability of other urban land uses according to the analysis was found to be one of the major influential driver of change in consolidation. This may be explained by the need of people to establish their daily livelihood.

In Dar es Salaam access to planned plots is a challenge. This has been explained in chapter two that the pace of Government and Local Authorities to produce planned plots is lower than the need for housing in the city. Therefore due to few number plots, middle income earners develop their buildings just after the margins of the planned areas where they can access both vacant land and social facilities.

The distance to clinics was important in influencing variation in density for both 1992 and 2015 models. In consolidation model distance to clinics was not important. According to experts distance to clinics was not an important driver of consolidation. Only 3 experts out of 15 ranked distance to clinics as important drivers of consolidation (table 4:4). The experts mentioned that clinics are not drivers of INs because often people have choices where to attend the clinic based on distance and economical status. "*when they have to see the doctor people in Dar es Salaam not necessarily choose the nearest clinic. They may prefer other clinics depending on the services levels and ability to pay*'" said one of the experts. The clinics may be near but expensive or with no services and vice versa. The distance to clinics was the first and second with high significant in 1992 and 2015 density models respectively. The difference between expert opinions and the models' results may be explained by the cause and effect relationship between the distance to clinics and density. It is possible that high density was influencing the location of clinics, and not distance to clinics influencing density. The study done by Amer & Ottens, (2007) showed that spatial distribution of clinics concentrated in the more densely populated areas in the central city. For this reason, distance to clinics is not the main driver of INs. Distance to vacant land was not significant to density model of 1992 and consolidation model while was important in density model of 2015. According to expert interviews, distance to vacant land was the important driver of consolidation (table 4:4). The differences may be explained by the need to construct the buildings for residential and livelihood activities in the vacant land found in 2015. At the early stages of INs consolidation, most of the land is changing from agriculture to residential. Which after saturation there is little possibility of accessing vacant land for construction. Areas with vacant land influences both low and high income earners to constructs their houses. This is also supported by Sheuya, (2010) who explained that INs in Dar es Salaam have a mixture of both the affluent and low income.

Distance to major river was found to be important at the first and second level of influence in consolidation model and 1992 density model. 6 experts out of 15 mentioned distance to river and other hazardous areas as the major drivers of consolidation. This is explained by the lack of vacant land which gives people nor other option than constructing their building along closer to the rivers. It may also be explained by bureaucracy in accessing planned land and failure of the Government to produce enough plots which if produced they become very expensive. The major river banks provide cheap and sometimes not necessarily cheap but access to vacant land for building construction hence increase in INs consolidation.

4.7. Future consolidated INs neighbourhood

According to the consolidation model (table 4:12), the mostly like future consolidated areas will be those INs closer to major river, minor river, INs, Other urban land uses, planned neighbourhoods and public transport. Distance to major river and minor river will provide access to vacant land for construction of buildings.

INs neighbourhood will continue to receive a large number of low and middle income earners. This is because the availability of other INs provides the opportunity of constructing the building by accessing land through the subdivision and informal procedure which are easy to follow than the complicated bureaucratic process to access formal lands see also Kironde, (2006). The socio-economic ties of people living in the INs will stimulate the increase consolidation either through house enlargement or construction of new houses. This was also seen in other studies see for example Mtwangi (2010). While the edges of planned neighbourhood will be potential for the middle and high income earner who looks for better facilities. However, in areas with lower and middle consolidation are expected to increase consolidation in the future. In the areas with high densities already it is expected that consolidation will take place along the hazardous area such as major and minor river. Mabibo, Ndugumbi, Makuburi, Miburani, Kigogo, Ubungo and Mzimuni are among wards located along the river banks which are more likely to be consolidated in the future The increase of consolidation along the major and minor river might probably include all socio-economic groups depending on the availability of vacant land and location of individual INs. The availability of other urban area will continue to influence increase of consolidation where there are the possibility of jobs and employments. For example Miburani ward, which is located between Keko and Kurasini might be potential for middle and lower classes seeking jobs in Keko (light industries) and Kurasini (harbour activities).

4.8. Policies inveolved in managing INs in Tanzania

Tanzania has several policies which are involved in managing INs development in the country. These policies in general aimed at improving the condition of the existing INs and avoiding the formation of new INs. These policies can be divided into two major groups, one which direct involves with land management issues and second those related indirect by dealing with services, location and activities going in INs.

4.8.1. Policies direct involved with land issues in INs

These involved 5 policies; National Land Policy of 1997 section 6, the Land Act of 1999 section 57 to 60. The Human Settlements Policy of 2000 section 4.1.4.1 and 4.1.42, Urban Planning Act of 2007 part IV subsection 23. The Guidelines for Preparing General Schemes, Urban Renewal and Regularisation of Informal Neighbourhoods of 2007, all of these policies aimed at improving INs through regularisation(URT, 1997, 1999, 2000, 2007a, 2007b).

Regularisation is aimed at facilitating the recording, classification and registration of the occupation and use of land by those person living and working in area subject to the scheme of regularisation(URT, 2000, 2007a).

The National Land Policy of 1997 recognised that more than 50 % of urban residents live in poor condition INs characterised by lack or limited access to sanitary and other basic services. Therefore the country is set to prepare planning to all potential areas for urban development in the periphery of all towns. Design special areas for low income housing with simplified building regulations and affordable level of services. It also stipulate that existing INs will not be cleared but will be upgraded and provided with basic facilities except for housing in hazardous areas. Last the policy provide that upgrading plans will be prepared and implemented by local authorities with the participation of residents and their local communities. The resource to accomplish INs upgrading according to the policy will be mobilised locally to finance the plans through appropriate cost recovery systems.

The Land Act of 1999 stipulates the purpose of, criteria and declaring the schemes of regularisation. Where it stipulates that the regularisation schemes can take place if the area is used substantially for habitation, and the user constructs their dwelling of their own or abandoned buildings. The scheme is prepared if the number of people is living in an area where there is no apparent lawful title to their use and occupation of land notwithstanding that they have paid for or are paying for the land they are occupying and manage the land in accordance with the rules generally recognised within the area. The act also provides that the regularisation scheme is prepared if people are living in the area which has been there for a substantial period of time so that the area is a well-established and settled area from a social point of view. The schemes will be prepared if there is evidence that despite the fact that the person living there has no security of tenure and a considerable number of such person appear to be investing in their houses and business and attempting to improve the area through their own initiatives.

The National Human Settlement Policy 2000 also recognised that buildings in INs accounts for most of the new construction in many urban areas, and acknowledge the fact that the formal planning system cannot provide enough surveyed and serviced plots. It also recognises that INs provides informal sector activities and provide employment opportunities on which the majority of urban residents depend for their livelihood and accommodation. It also stipulates that 60% of urban land in TZ are in unplanned, unserviced and or hazardous areas such as steep slopes, valleys and creeks. The policy instructs that INs shall be upgraded by their inhabitant through Community Based Organisation (CBO) and Non-Governmental Organisation (NGO) with government playing a facilitating role by supporting their initiatives. The government shall develop strategies for providing funds for planning and survey of urban plots including plot development revolving funds, cost recovery and cost sharing methods and self-financing for planning and surveying. Designated special area for low income groups. These areas shall be provided with a minimum level of services which the resident can afford.

The Urban Planning Act 2007, recognised that any area intended for regularisation shall be declared as a planning area and that the planning scheme preparation should also involve the community. This law supports the land acts and helps to identify the laws associated with the decision made via land act 1999 and streamline what are the products of such decisions.

The Guidelines for Preparing General Schemes, Urban Renewal and Regularisation of Informal Neighbourhood 2007. These guidelines recognised that development of INs is a process that follows a complex growth path, actions and decisions of different actors especially the urban poor. In these guidelines, detailed explanation on the planning process, form and content of outputs, implementation, monitoring, evaluation and review have been provided. The standards are agreed determined by the LGA in relation with the Ministry.

4.8.2. Other policies indirect involved in INs

These are policies which are not direct involved in the management of planning and management of INs. According to the nature and complexity of INs development process, these policies are in one way or the other are involved. In this category, we found all policies involved with resources utilisation such as National Environmental Policy (URT, 2004), Transport Policy (URT, 2011) and Water Resources Management Policy (URT, 2009).

These policies just like the former group they recognise present of INs. The policies suggest the preparation of integrated planning and improvement of urban centres and designation of urban land uses based on the environmental impacts considerations. The decentralisation of urban development through the promotion of intermediate towns and trade centres, on the basis of a human settlement perspective plan at National, Regional and district levels. Control of indiscriminate urban development, particularly in vulnerable sites such as coastal beaches, flood-prone and hilly areas. However, all policies do not provide any constructive measures in the provision of their respective services to improve or reduce INs development. This has led to the normal provision of services in INs such as water, electricity as in planned neighbourhood provided the service can be paid for.

4.8.3. Lesson from policies and policy gaps

The lesson found from these policies are four. One, the Government recognised its responsibility for the provision of housing to urban dwellers and understand its failure to satisfy housing demand. Second, the recognition of INs as both dwelling places and part of their dweller's livelihood and socio-economic ties. Third, regularisation schemes are the major planning tool set by the government through which INs can be upgraded. Fourth, even though regularisation has been set aside as planning tool for INs, there is no explanation who will provide technical resources such as base maps and other data to upgrade INs.

There are identified gaps which are found in the policies. Despite the recognition of people living in the hazardous area, there is no specific solution of how to limit the increasing number of people in such areas. As it has been stated in the land policy that Tanzanian land is public it is not easy to restrict vacant land ownership by the citizens. In Tanzania, even the hazardous land have owners either as an individual or as a clan. The policies provide rights of compensation to resettle and or acquire such land. This provides an opportunity for informal land subdivision even in hazardous land and thereby increasing INs consolidation.

There are no particular standards to improve INs rather the standard are subject to discussion between the community and the local authority which has to get concern from the Ministry. The willingness of building owners to participate in regularisation program might jeopardise the success and or failure of the regularisation plans. The policy states that these plans will be funded by the citizens themselves and this might affects the possibility of the intervention to take place. Those neighbourhoods with mid-income earners may be the only one ready for upgrading and thereby leaving the poor neighbourhood in severe consolidation risks and challenges associated with high consolidated INs.

Lack of base maps and other dataset required to improve INs is still a challenge. For example, it was revealed in the expert interviews that they are using the images of 2008 as base maps to prepare regularisation schemes of Kimara INs. This takes much of extra resources to update the base maps. Poor working environmental such as lack of strong internet for downloading images is the results of the policy reluctant by assuming that INs dwellers, NGO and CBO will pay for costs of regularisation. No specific time and stage of consolidation have been mentioned to be of action, this leaves an open opportunity for late intervention which is costly and or reduced chances of success. The totality of the shortcoming has resulted to many regularisation projects to take place at the periphery of the city as stated by policies living the inner city with no or minimum attention.

4.8.4. Policy measures be taken to improve initiatives in managing INs

The thesis recommends Policy makers and Local Authorities (as the main policy implementers) to turn an eye over the central located INs taking into consideration that they are not static. There is developmental process occurs in these INs which lead to higher densities over time. The strategic approach towards improving and managing their growth will reduce the probably high costs of dealing with the negative results of highly consolidated INs. For example, most of the sewerage in INs is directed to small drainage and minor rivers, which increases health risk and other environmental pollution related effects. The strategies may include a time to time monitoring of INs in a certain period of time for example once a year. However, lack of data source to monitor development in INs may hinder strategy and or make it complicated and expensive. Thus why the use of alternative open data source such as OSM are recommended to improve the management of INS. Henceforth this study recommends both Centre Government and Local Authorities in Dar es Salaam to ensure a periodic update of OSM data set which are already in place in order to utilise their potential as an alternative data sources.

Secondly, the thesis recommends that the Government should set strategies to relocated people from hazardous areas such as the river valleys. These has always been avoided by the claims of lack of resources to relocate people. This should be considered as a matter of set priorities, for example, there had been a massive house demolished in Kurasini which have cost lots of funds. However, the return from harbour related activity was considered important to implement the house demolishing. Therefore if the cost of solving effects of hazards such flooding is forethought to be avoided by relocating people from the dangerous areas, will have the same profits (compared to harbour activities) in terms of people safety, better livelihood activities provision and environmental sustainability

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The study has shown that building footprints obtained from the OSM data source can be used as an alternative source of data where there are no data or complement the existing data to study INs consolidation dynamics. Both the existing and new OSM building footprints dataset provided required information to study the physical development processes that occur within INs in the central Dar es Salaam. However, due to observed differences in the wards and errors found in data, it is better to assess the quality and completeness of OSM data before using them.

The thesis has shown that changes in different developmental activities affect consolidation of INs, for example, the decreasing in consolidation in Kurasini ward have been caused by the decision to expand harbour activities towards Kurasini. The developmental changes occur in Kurasini might affects the neighbouring INs by increasing their consolidation.

Different socio-economic characteristics have influence in the variation of consolidation level in INs in central Dar es Salaam. It has been observed that Sinza (Masjid Quba) and Ubungo (Kisiwani) have lower population density because of accommodating middle income earners.

Upgrading programs influence changes in the consolidation of INs. Wards like Hana Nasif, Buguruni and Mabibo have shown higher rates of increasing consolidation due to being upgraded. This is supported by the improvement in facilities at least at the basic level as stated in the National Land Policy and National Human Settlement Policy.

The thesis has identified main drivers of INs consolidation and their level of influence through multiple linear regression, with an added local knowledge from local experts. Distance to other INs, distance to major and minor rivers, distance to other urban land uses, distance to planned neighbourhood have been shown to be the main drivers of INs consolidation in the central Dar es Salaam. However, the lower values of R-square have shown that main drivers influencing are not only physical characteristic of INs but also includes other factors such as socio-economic characteristics and upgrading programs. The poor performance of consolidation model suggested that at higher levels of density, the drivers influencing density are not always influence changes in consolidation.

The thesis also concluded that since 1992 the more dangerous areas are becoming potential for INs consolidation. Despite the awareness of the Government of the location of INs in such dangerous areas there are no strategies made to reduce the number of people living in these areas.

5.2. Methodological recommendation

On methodological part, it was clear that the usability of building footprints gave the important information of the development process. However, inconsistency in the definition of buildings may lead to differences in the results. Therefore the common establishment of what is referred to as a building is important before taking further analysis. The level of completeness of buildings footprints data should be determined before going to the field. These will help to capture data incompleteness and omission during the study. In this study, for example, this was not foreseen earlier. As a result it has taken much of time to repeat analysis to detected and prove changes especially in Kurasini where there had been a massive house demolished.

The third methodological recommendation goes to the utilisation of density as the main measure of analysis. As shown by different studies for example Churchman, (1999) the use of different denominators may affect the results obtained in the density based analysis. For instance when calculating PRC values in the wards may be different if calculated using administrative boundaries, cell or block boundaries.

The use of net densities usually gives higher values that the use of gross densities. The administrative boundaries are supposed to give the lowest density than block and cell boundaries. Due to larger sizes of administrative units. Differences in spatial coverage between blocks and cell may lead to higher densities in blocks by 10 % see also (Taubenböck et al., 2016). This has been seen in Keko ward in this thesis where cell calculation showed a decrease in density, while the overall density in informal neighbourhood density has become higher. Which may be explained by an extremely high density in a number of increasing cell which caused tremendous changes in general density.
The advantage of using administrative boundary is that it can be easily understood decision makers who do not have the time to think about block or never bothers about cell calculation. The use of a block analysis is important for experts and normal citizens who want to know exactly where infill and edge expansion occurs. In Dar es Salaam there are no clear definition of blocks in INs, instead of the blocks there are sub ward levels. The coverage of sub wards are inconsistency and changes over time, which makes them not a good option also. The cells analysis use are perfect in academia for they are more of the specification. They provide a consistency in analysis and can be easily described at administrative and blocks levels. However, the aim is not to compare the advantages of the use of units used for denominators of density. The recommendation is for the easiness in decision making and consistency in the results one denominator should be chosen in early stages of the study depending on the purpose and audience concerned.
In determining the most important drivers in regression model it is better to set a cut-off value beforehand this will help to give a straight forwards importance. This was also foreseen in this study as the results table 4:13 has to be created to streamline the decision of the important drivers and discussion.
Lastly every step taken in the analysis need to be recorded which enable to provide exactly results of each step; in this thesis for example number of how many rubber sheeting performed during building data preparation was overlooked.

5.3. Further studies

The study recommends further detailed studies in Keko because the cell analysis shows decreasing in densities in some of the cells while the administrative boundaries showed a general increase in consolidation. A thorough study at ward level will give more insight of the changes in consolidation levels.

LIST OF REFERENCES

Abbott, J. (2001). Use of spatial data to support the integration of informal settlements into the formal city. *International Journal of Applied Earth Observation and Geoinformation*, *3*(3), 267–277. doi.org/10.1016/S0303-2434(01)85033-9

Abbott, J. (2002). An analysis of informal settlement upgrading and critique of existing methodological approaches. *Habitat International*, *26*(3), 303–315. doi.org/10.1016/S0197-3975(01)00049-2

Abbott, J., & Douglas, D. (2001). *A methodological approach to the upgrading, in-situ, of informal settlements in South Africa.* (No. Report No 786/2/01). Cape Town. Retrieved from http://www.ircwash.org/sites/default/files/205.42-17337.pdf

Abebe, F. K. (2011). *Modelling informal settlement growth in Dar es Salaam, Tanzania*. MSc thesis,University of Twente Faculity of Geo-information and Earth Observation Science (ITC). Enschede,The Netherlands. Retrieved from http://www.itc.nl/library/papers_2011/msc/upm/abebe.pdf

Aburas, M. M., Ho, Y. M., Ramli, M. F., & Ash'aari, Z. H. (2016). The simulation and prediction of spatio-temporal urban growth trends using cellular automata models: A review. *International Journal of Applied Earth Observation and Geoinformation*, *52*, 380–389. doi.org/10.1016/j.jag.2016.07.007

Amado, M. P., Ramalhete, I., Amado, A. R., & Freitas, J. C. (2016). Regeneration of informal areas: An integrated approach. *Cities*, *58*, 59–69. doi.org/10.1016/j.cities.2016.05.015

Amer, S., & Ottens, P. D. H. F. L. (2007). *Towards spatial justice in urban health services planning: A spatial-analytic GIS-based approach using Dar es Salaam, Tanzania as a case study*. Institute for Geo-Infromation and Earth Observation. Retrieved from http://www.itc.nl/library/papers_2007/phd/amer.pdf

Armstrong, a. (1987). Master plans for Dar es Salaam, Tanzania: The shaping of an African city. *Habitat International*, *11*(2), 133–145.

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. doi.org/10.1016/j.compenvurbsys.2011.01.001

Bhatta, B. (2010). Analysis of urban growth and sprawl from remote sensing data. *Analysis*, 49–63. doi.org/10.1007/978-3-642-05299-6

Chakraborty, A., Wilson, B., Sarraf, S., & Jana, A. (2015). Open data for informal settlements: Toward a user' s guide for urban managers and planners. *Journal of Urban Management*, *4*(2), 74–91. doi.org/10.1016/j.jum.2015.12.001

Cheng, J., & Masser, I. (2003). Urban growth pattern modeling: a case study of Wuhan city, PR China. *Landscape and Urban Planning*, *62*(4), 199–217. doi.org/10.1016/S0169-2046(02)00150-0

Churchman, A. (1999). Disentangling the concept of Density. *Journal of Planning Literature*, *13*(4), 389–411. doi.org/10.1177/08854129922092478

Cities Alliance. (2003). *Cities without slums*. Annual Report. Retrieved from https://scholar.google.nl/scholar?q=cities+without+slums+&btnG=&hl=en&as_sdt=0,5

Craney, T. A., & Surles, J. G. (2002). Model-dependent variance inflation factor cutoff values model. *Quality Engineering*, *14*(3), 391–403. doi.org/10.1081/QEN-120001878

Czepiel, S. A. (2012). Maximum likelihood estimation of logistic regression models: Theory and implementation. *Class Notes*, 1–23. Retrieved from papers3://publication/uuid/4E1E1B7E-9CAC-4570-8949-E96B51D9C91D

Dangol, P. (1998). *Estimating population of unplanned residential areas (Dar es Salaam)*. International Institute for Aerospace Survey and Earth Sciences.

Daoud, M., & Huang, J. X. (2013). Mining query-driven contexts for geographic and temporal search. *International Journal of Geographical Information Science*, *27*(8), 1530–1549. doi.org/10.1080/13658816.2012.756883

DCC. (2004). *Dar es Salaam city profile*. (D. es S. C. Council, Ed.). Dar es Salaam.

Dendoncker, N., Rounsevell, M., & Bogaert, P. (2007). Spatial analysis and modelling of land use distributions in Belgium. *Computers, Environment and Urban Systems*, *31*(2), 188–205. doi.org/10.1016/j.compenvurbsys.2006.06.004

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. doi.org/10.1016/j.isprsjprs.2010.10.002

ESRI. (2016). Arc GIS for desktop. Retrieved from http://pro.arcgis.com/en/pro-app/help/mapping/symbols-and-styles/data-classification-methods.htm

Fan, H., Zipf, A., Fu, Q., & Neis, P. (2014). Quality assessment for building footprints data on OpenStreetMap. *International Journal of Geographical Information Science*, *28*(4), 700–719. doi.org/10.1080/13658816.2013.867495

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. doi.org/10.1016/S0197-3975(99)00034-X

Field, A. (2014). *Discovering statistics*. (M. Carmichael, Ed.) (4th ed.). London.

Garr, D. J. (1996). Expectative land rights, house consolidation and cemetery squatting: Some perspectives from central Java. *World Development*, *24*(12), 1925–1933. http://doi.org/10.1016/S0305-750X(96)00077-0

Girres, J.-F., & Touya, G. (2010). Quality assessment of the French OpenStreetMap dataset. *Transactions in GIS*, *14*(4), 435–459. doi.org/10.1111/j.1467-9671.2010.01203.x

Githira, D. N. (2016). *Growth and eviction of informal settlements in Nairobi*. MSc thesis,University of Twente Faculty of Geo-information and Earth Observation Science (ITC). Enschede,The Netherlands. Retrieved from http://www.itc.nl/library/papers_2016/msc/upm/githira.pdf

Goodchild, M. F. (2007). Citizens as sensors: the world of volunteered geography. *GeoJournal*, *69*(4), 211–221. doi.org/10.1007/s10708-007-9111-y

Haklay, M. (2010). How good is volunteered geographical information? A comparative study of OpenStreetMap and ordnance survey datasets. *Environment and Planning B: Planning and Design*, *37*(4), 682–703. doi.org/10.1068/b35097

Hakuyu, T. (1995). *Unpalnned urban development: Spatial growth and typology of unplanned settlements: Dar es Salaam Tanzania*. International Institute for Aerospace Survey and Earth Sciences.

Halla, F. (2007). A SWOT analysis of strategic urban development planning: The case of Dar es Salaam city in Tanzania. *Habitat International*, *31*(1), 130–142. doi.org/10.1016/j.habitatint.2006.08.001

Hao, P., Geertman, S., Hooimeijer, P., & Sliuzas, R. (2013). Spatial analyses of the urban village development process in shenzhen, china. *International Journal of Urban and Regional Research*, *37*(6), 2177–2197. doi.org/10.1111/j.1468-2427.2012.01109.x

Hill, A., Hühner, T., Kreibich, V., & Lindner, C. (2014). Dar es Salaam, megacity of tomorrow: Informal urban expansion and the provision of technical infrastructure. In F. Kraas, S. Aggarwal, M. Coy, & G. Mertins (Eds.), *Megacities* (pp. 165–177). Dordrecht: Springer Netherlands. doi.org/10.1007/978-90-481-3417-5_12

Huchzermeyer, M. (2011). *Cities with Slums : From Informal Settlement Eradication to a Right to the City in Africa*. Claremont: Juta Academic. Retrieved from ezproxy.utwente.nl:2200/patron/FullRecord.aspx?p=991016

Ishtiyaq, M., & Kumar, S. (2011). Typology of informal settlements and distribution of slums in the NCT of Delhi. *Journal of Contemporary India Studies: Space and Society, Hiroshima University*, *1*, 37–46. Retrieved from home.hiroshima-u.ac.jp/hindas/PDF/Ishtiyaq_and_Kumar(2011).pdf

Kasianchuk, P. (2003). Spatial adjustment tools in ArcGIS. *ArcUser*, (March), 48–49.

Keuk, J. N., Abdullah, Y. A., & Hamdan, H. (2016). Eradicating Squatters through Resettlement Programme: A Conceptual Paper. *MATEC Web of Conferences*, *66*, 23. doi.org/10.1051/matecconf/20166600023

Kironde, L. (1992). Creations in Dar es Salaam and extensions in Nairobi. *Cities*, *9*(3), 220–231. doi.org/10.1016/0264-2751(92)90017-Y

Kironde, L. (2006). The regulatory framework, unplanned development and urban poverty: Findings from Dar es Salaam, Tanzania. *Land Use Policy*, *23*(4), 460–472. doi.org/10.1016/j.landusepol.2005.07.004

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. doi.org/10.1016/j.compenvurbsys.2011.11.001

Kombe, W. (2000). Regularizing housing land development during the transition to market-led supply in Tanzania. *Habitat International*, *24*(2), 167–184. doi.org/10.1016/S0197-3975(99)00036-3

Kombe, W. (2005). Land use dynamics in peri-urban areas and their implications on the urban growth and form: the case of Dar es Salaam, Tanzania. *Habitat International*, *29*(1), 113–135. doi.org/10.1016/S0197-3975(03)00076-6

Kuffer, M., Pfeffer, K., Sliuzas, R., & Baud, I. (2016). Extraction of slum areas from VHR imagery using GLCM variance. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, *9*(5), 1–11. doi.org/10.1109/JSTARS.2016.2538563

Kunze, C., & Hecht, R. (2015). Semantic enrichment of building data with volunteered geographic information to improve mappings of dwelling units and population. *Computers, Environment and Urban Systems*, *53*, 4–18. doi.org/10.1016/j.compenvurbsys.2015.04.002

Kyessi, A. (1990). *Urbaniation of fringe villages and growth of squatters, the case of Dar Es Salaam Tanzania*. International Institute for Aerospace Survey and Earth Scinces.

Lombard, M. (2014). Constructing ordinary places: Place-making in urban informal settlements in Mexico. *Progress in Planning*, *94*, 1–53. doi.org/10.1016/j.progress.2013.05.003

Lupala, J. M. (2002). *Urban types in rapidly urbanising cities: Analysis of formal and informal settlements in Dar es Salaam , Tanzania. Analysis.* Royal Instiute of Technology,Stockholm.

Magigi, W. (2013). Community involvement in informal settlements upgrading: Evidence from Dar Es Salaam metropolitan city, Tanzania. *Research on Humanities and Social Sciences*, *3*(12), 75–90.

Magigi, W., & Majani, B. B. K. (2006). Community involvement in land regularization for informal settlements in Tanzania: A strategy for enhancing security of tenure in residential neighborhoods. *Habitat International*, *30*(4), 1066–1081. doi.org/10.1016/j.habitatint.2005.12.002

Mitchell, A. (2005). The ESRI guide for GIS Analysis. Retrieved November 1, 2016, from pro.arcgis.com/en/pro-app/tool-reference/spatial-statistics/average-nearest-neighbor-distance-spatial-st.htm

MKURABITA. (2013). Mkurabita property and business formalisation program Tanzania. Retrieved May 23, 2016, from www.mkurabita.go.tz/resource_centre/view_news_item.php?id=209&intVariationID=1&szTitle=Current

Mtwangi, T. (2010). *Exploring social cultural expalanations for residential location choices*. Stockholm Univesrity.

Osman, T., Divigalpitiya, P., & Arima, T. (2016). Driving factors of urban sprawl in Giza Governorate of Greater Cairo Metropolitan Region using AHP method. *Land Use Policy*, *58*, 21–31. doi.org/10.1016/j.landusepol.2016.07.013

Pugh, C. (2001). The Theory and Practice of Housing Sector Development for Developing Countries, 1950-99. *Housing Studies*, *16*(4), 399–423. doi.org/10.1080/02673030120066527

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. doi.org/10.1016/j.envsoft.2014.05.004

Schwarz, N., Flacke, J., & Sliuzas, R. (2016). Modelling the impacts of urban upgrading on population dynamics. *Environmental Modelling and Software*, *78*, 150–162. doi.org/10.1016/j.envsoft.2015.12.009

Sheuya, S. A. (2010). *Informal settlements and finance in Dar es Salaam, Tanzania.* Nairobi: UN-HABITAT.

Siebritz, L.-A. (2014). *Assessing the accuracy of openstreetmaps data in South Africa for the purpose of intergrating it with authoritative data.* University of Cape Town. Retrieved from open.uct.ac.za/handle/11427/9148

Simiyu, S., Swilling, M., Cairncross, S., & Rheingans, R. (2017). Determinants of quality of shared sanitation facilities in informal settlements: case study of Kisumu, Kenya. *BMC Public Health*, *17*(1), 68. doi.org/10.1186/s12889-016-4009-6

Singh, B. N. (2016). KAAV International journal of arts, humanities & social sciences socio-economic conditions of slums dwellers: a theoretical study, *3*(3), 5–20.

Sirueri, F. O. (2015). *Comparing spatial patterns of informal settlements between Nairobi and Dar Es Salaam*. MSc thesis,University of Twente Faculty of Geo-information and Earth Observation Science (ITC). Enschede,The Netherlands. Retrieved from http://www.itc.nl/library/papers_2015/msc/upm/sireuri.pdf

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*, (November).

Sliuzas, R. (2003). Opportunities for enhancing communication in settlement upgrading with geographic information technology-based support tools. *Habitat International*, *27*(4), 613–628. doi.org/10.1016/S0197-3975(03)00008-0

Sliuzas, R. (2004). *Managing informal settlements: a study using Geo-Information in Dar es Salaam Tanzania. ITC Dissertation 112*. International Institute fro Geo-information Science and Earth Observation (ITC).

Smit, S., Musango, J. K., Kovacic, Z., & Brent, A. C. (2016). Conceptualising slum in an urban African context. *Proceedings of the 22nd Annual International Sustainable Development Research Society Conference*, *62*, 107–119.doi.org/10.1016/j.cities.2016.12.018

Taubenböck, H., Standfuß, I., Klotz, M., & Wurm, M. (2016). The physical density of the city—deconstruction of the delusive density measure with evidence from two European megacities. *ISPRS International Journal of Geo-Information*, *5*(11), 206. doi.org/10.3390/ijgi5110206

Thapa, R. B., & Murayama, Y. (2010). Drivers of urban growth in the Kathmandu valley, Nepal: Examining the efficacy of the analytic hierarchy process. *Applied Geography*, *30*(1), 70–83. doi.org/10.1016/j.apgeog.2009.10.002

Turner, J. F. C. (1969). Uncontrolled urban settlement: problems and policies. *The City in Newly Developing Countries: Readings on Urbanism and Urbanization*, (1), 107–128.

Uithol, P. (2015). Dar ramani huria - Dar open map. Retrieved July 29, 2016, from hotosm.org/projects/tanzania?page=1

UN-Habitat. (2004). *The Challenge of Slums: Global Report on Human Settlements 2003/2004*. *Management of Environmental Quality: An International Journal* (Vol. 15). London: Emerald Group Publishing Limited. doi.org/10.1108/meq.2004.15.3.337.3

UN-Habitat. (2009). *World Cities*. (G. L. Ooi & B. Yuen, Eds.). London: Co-Published With World Scientific Publishing Co. Pte. Ltd. doi.org/10.1142/9789814280730

UN-Habitat. (2010). *Informal settlements and finance in Dar es Salaam, Tanzania*. Nairobi: UN-HABITAT.

UN-Habitat. (2015). *Habitat III Issue Papers 22 – Informal Settlements* (not edited, Vol. 2015). New York: UN-HABITAT.

UN-Habitat. (2016). *Slum Almanac 2015/2016 Tracking improvement in the lives of slum dwellers*. Nairobi: UN-HABITAT.

URT. (1997). *The National land policy*. (URT, Ed.) (2nd ed.). Dar es Salaam: The Ministry of lands and Human Settlements.

URT. (1999). *The National land Act*. Dar es Salaam: URT.

URT. (2000). *The National human settlement policy*. Dar es Salaam: URT. Retrieved from histories.cambridge.org/extract?id=chol9780521441957_CHOL9780521441957A003

URT. (2004). *The environmental management Act,2004*. (URT, Ed.). Dar es Salaam: URT.

URT. (2007a). *Ministry of Lands, Housing and Human Settlements Development Guidelines for the preparation of general planning schemes and detailed schemes for new area,urbanrenewal, and regularisation of informal settlements*. (URT, Ed.). Dar es Salaam: URT.

URT. (2007b). *The urban planning act, 2007*. (URT, Ed.). Dar es Salaam: URT.

URT (Ed.). (2009). *The National water policy*. Dar es Salaam: URT.

URT. (2011). *The National transport policy*. (URT, Ed.). Dar es Salaam: URT.

URT. (2013). The United Republic of Tanzania. 2012 population and housing census: Population distribution by administrative areas. and office of chief Government statistician President's office, finance, economy and development planning. National Bureau of Statistics , 211.

Verburg, P. H., Ritsema van Eck, J. R., de Nijs, T. C. M., Dijst, M. J., & Schot, P. (2004). Determinants of land-use change patterns in the Netherlands. *Environment and Planning B: Planning and Design*, *31*(1), 125–150. doi.org/10.1068/b307

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. doi.org/10.1016/j.landurbplan.2012.03.006

Vliet, J. van, White, R., & Dragicevic, S. (2009). Modeling urban growth using a variable grid cellular automaton. *Computers, Environment and Urban Systems*, *33*(1), 35–43. doi.org/10.1016/j.compenvurbsys.2008.06.006

Wehrmann, B. (2014). *Megacities*. (F. Kraas, S. Aggarwal, M. Coy, & G. Mertins, Eds.). Dordrecht: Springer Netherlands. doi.org/10.1007/978-90-481-3417-5

Xu, C., Liu, M., Zhang, C., An, S., Yu, W., & Chen, J. M. (2007). The spatiotemporal dynamics of rapid urban growth in the Nanjing metropolitan region of China. *Landscape Ecology*, *22*(6), 925–937. doi.org/10.1007/s10980-007-9079-5

Young, G. (2010). *Socioeconomic analysis of informal settlement growth in Dar es Salaam : The concept for an agent based model socioeconomic analysis of informal settlement growth in Dar es Salaam*. University of Twente facult of ITC.

LIST OF APPENDICES

Appendix 1: Expert interview schedule (for experts with experience in working with INs)

FORM No: 1
(This form is aimed at all other experts except data collection experts)
Introduction

This research aimed at determining the main drivers behind the process of consolidation of informal neighbourhoods in the central Dar es Salaam. The main objective of research is to gain experts knowledge and opinions understanding of main drivers of informal neighbourhood consolidation in the city. On the analysis phase the revealed drivers will be model to explain variation of informal neighbourhood consolidation in the central of Dar es Salaam. The coupling of 1992 and 2015 OSM data set will be used to quantify informal neighbourhood consolidation level.

ID …………………………………………………………………………………
Researchers……………………………..Office…………………………..Private sector…………………………..
Position at your organisation……………………………
Experience in Urban planning (years)…………………………
Experience in Dar es Salaam (years)………………………………………………

A: Informal neighbourhood growth

1. What are the mostly dynamic informal Neighbourhoods and what are causes of such changes.
2. What are the locational factors that attracts informal neighbourhoods?
3. In you experience how can you explain growth of informal neighbourhood in Dar es Salaam in the last 20-24 years (are they changing in location, shape, extent and densities)

B: Informal neighbourhood buildings

1. In your experience, what is the shape of buildings in informal neighbourhood if you compare 1992 to 2015? Are the shape getting more complexity or simpler.
2. What do you define as a building in an informal neighbourhood?
3. What is approximate the dimension of a dwelling in an informal neighbourhood in square meters?

C: Informal neighbourhood density

1. In general what are the density characteristics of informal neighbourhoods in Dar es Salaam?
2. Which part of Dar es Salaam consolidate more than others and why?
3. Do you remember if there had been changes in open area/ vacant land that has disappear because of urban changes?
4. How the built up area was changes over time?

D: Accessibility

1. What are types of roads in the neighbourhoods?
2. What is the approximate percentage of roads of paved roads in informal neighbourhoods?

E: OSM data use

1: Are you familiar the 2015 OSM data project in Dar es Salaam
2: Have you tried to use the OSM data as source of data? Yes

3: If yes: what is your experience in using OSM data accuracy?

In the following list may you rank the main drivers of informal neighbourhood consolidation?

Note:
1=Very strong drivers
2=Moderate
3=Week
4=Very week
5=Not a driver

Main drivers of informal neighbourhood Consolidation

S/n	Driver	Ranks				
1	Distance to the existing INs (m)	1	2	3	4	5
2	Distance to primary roads (m)					
3	Distance to secondary roads (m)					
4	Distance to school					
5	Distance to CBD (m)					
6	Distance to market (m)					
7	Distance to Industries					
8	Distance to Hospital					
8	Population density (high, medium, low)					
9	Availability of vacant land					
10	Existing of planned neighbourhoods					
11	Quality and quantity of urban infrastructure					
12	Upgrading programs					
13	Flood areas, high slopes, swamp and riverbanks					

Appendix 2: Expert interview schedule (for OSM data collectors)

FORM No: 2

Interview schedule to data collection stakeholders (The Data collection consultancy and Local Authorities involved in data collection)

Introduction:

This research aimed at determining the main drivers behind the process of consolidation of informal neighbourhoods in the central Dar es Salaam. The main objective of research is to gain experts knowledge and opinions understanding of main drivers of informal neighbourhood consolidation in the city. On the analysis phase the revealed drivers will be model to explain variation of informal neighbourhood consolidation in the central of Dar es Salaam. The coupling of 1992 and 2015 OSM data set will be used to quantify informal neighbourhood consolidation level.

ID:……

Professional:…………………………….. Experience:…………………………………………….

Position at your organisation:……………………………………………………………………………..
Responsibility in the project:……………………………………………………………………………
Experience in Dar es Salaam (years):…………………………………………………………………

F: The rules used in classification

1. What were the rules used to define a building: Were toilet and kitchen considered separate or as part of the main building.
2. What is the minimum area of the building counted as building in metres
3. What are the criteria used to in road classification
4. Was it part of the project to classify informal neighbourhoods from formal neighbourhoods? If yes: which criteria were used for this classification?

G: Accuracy assessment

1. What methods did you use to assess data accuracy of the data produce and what were the results?

H: Future plans

1. What is the plan to complete data collection on other parts of the city
2. Are there any plans to regularly update the data?
3. If yes which methods will you use for updating and what are the intervals?

Appendix 3: House hold survey

FORM No: 3

Household surveys

Introduction

This research aimed at finding out differences in informal neighbourhoods in Dar es Salaam. The information we get from you will help us to know number of people living in informal neighbourhoods. We have few questions and takes 5-10 minutes.

Age: …………………………..
Ownership: Owner☐
Other: ………………………………………………………..Explain……………………………………………..
GRID No: …………………..House number: ………………………..Mtaa Name:…………………………..

1. How many person are living in this house?
2. How long have been living here?
3. Approximate roof area:
   The shape of the Building (sketch below)

Appendix 4: INs observation form

FORM No: 4
Field work observation form

This research aimed at determining the main drivers behind the process of consolidation of informal neighbourhoods in the central Dar es Salaam. The main objective of research is to gain experts knowledge and opinions understanding of main drivers of informal neighbourhood consolidation in the city. On the analysis phase the revealed drivers will be model to explain variation of informal neighbourhood consolidation in the central of Dar es Salaam. The coupling of 1992 and 2015 OSM data set will be used to quantify informal neighbourhood consolidation level.

Accuracy assessment data

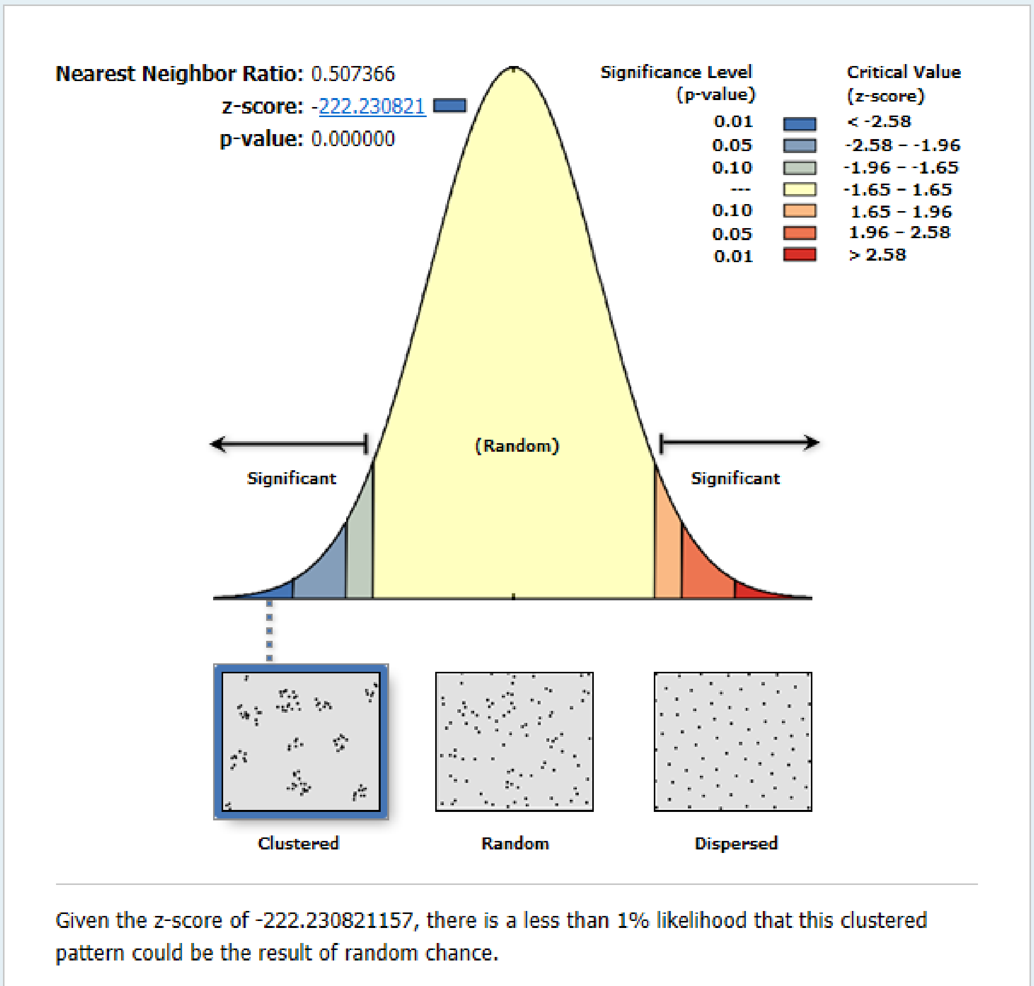
Informal neighbourhood characteristics: 10 informal neighbourhood were selected based on hotspot analysis.

S/n	Area	No. of points	Feature (Road, Building, Open space, water body)	Ground x	Ground Y	Notes
	Name of the Mtaa	Types of Neighbourhood	Amenities	Roads types	Building shape,	Bare land
1	Mabibo					
2	Tabata					
3	Kimara					
4	Makongo					
5	Msasani					
6	Kinondoni					
7	Vingunguti					
8	Kiwalani					
9	Kijitonyama					
10	Sinza					

Amenities: 1=school; 2=CBD, 3=market; 4=industries, 5=Hospital.
Roads types: 1=major and paved; 2=major and not paved; 3= Minor and paved; 4=minor and not paved; 4=footpath.
Building: 1=complex shape, 2=simple shape.
Vacant land: 1: available 2: not available
1: Formal
2: Informal

Appendix 5: 1992 Average nearest neighbour

Average Nearest Neighbor Summary



Average Nearest Neighbor Summary

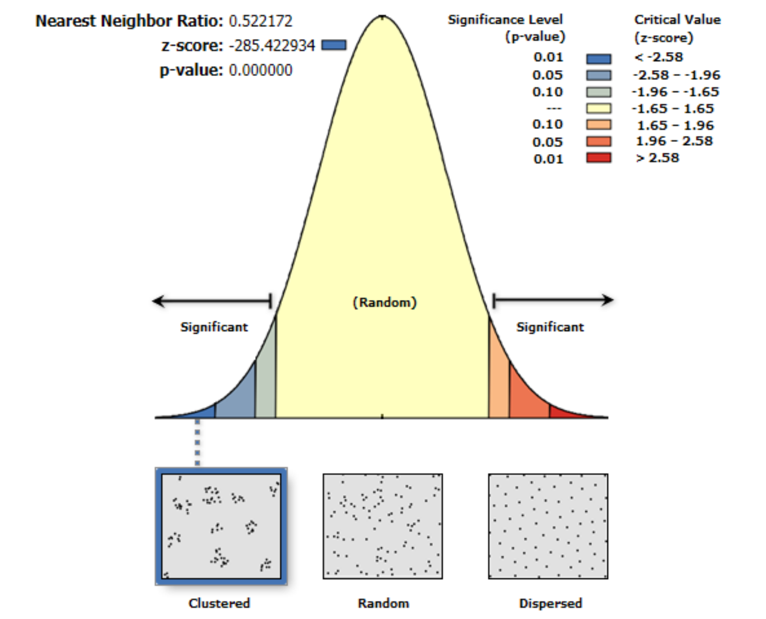
Observed Mean Distance:	9.7565 Meters
Expected Mean Distance:	19.2298 Meters
Nearest Neighbor Ratio:	0.507366
z-score:	-222.230821
p-value:	0.000000

Dataset Information

Input Feature Class:	wards_build_landuse92_spatialjoin selection
Distance Method:	EUCLIDEAN

Appendix 6: Average nearest neighbour 2015

Average Nearest Neighbor Summary



Given the z-score of -285.422933836, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

Average Nearest Neighbor Summary

Observed Mean Distance:	7.2822 Meters
Expected Mean Distance:	13.9460 Meters
Nearest Neighbor Ratio:	0.522172
z-score:	-285.422934
p-value:	0.000000

Dataset Information

Input Feature Class:	wards_build_landuse15_spatialjoin selection
Distance Method:	EUCLIDEAN

Appendix 7: Preparation of land use data

Land use Updating

There was inconsistence of the land use found from Ilala and Temeke Municipality, Kinondoni Municipality had no land use at all. The 2012 land use map was modified by using UAV image and building footprints to form a 2015 land use. Then the land use was aggregated into the same structure as 1992 land use. These land uses were grouped as followed.

1992 land use was grouped into five classes

1. Informal settlement: (> 25 dwellings/Ha, Medium density (12-24 dwellings/Ha) and Low density (>12 dwellings/Ha)
2. Ocean & estuaries
3. Other urban
4. Planned residential: High density (>25 dwellings/Ha, Medium density (12-24 dwellings/Ha) and Low density (6-12 dwellings/Ha)
5. Vacant and agriculture

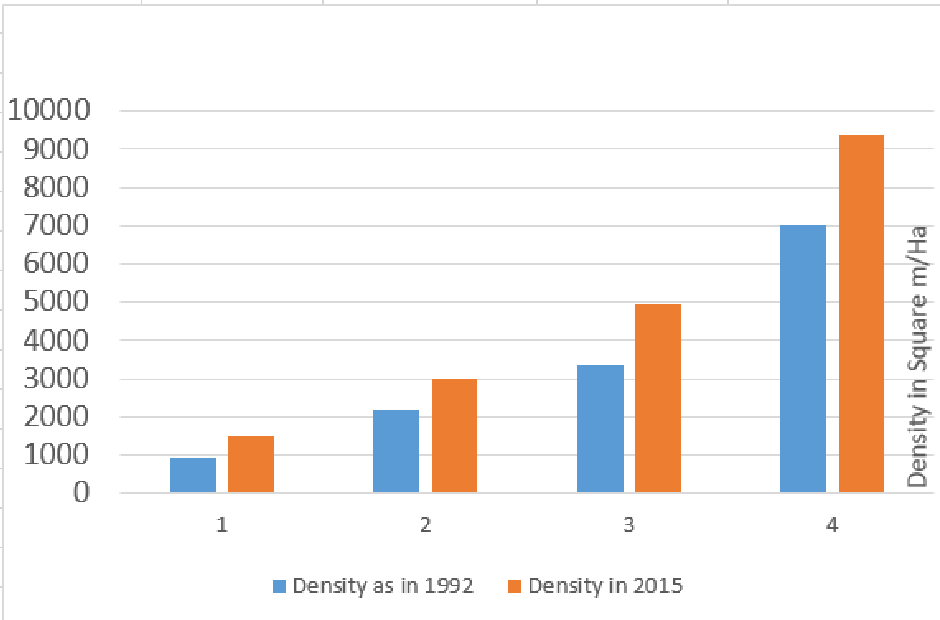
The 2012 were 10 classes (Before aggregation)

1. Agriculture
2. Commercial
3. Educational
4. Industrial
5. Informal settlements
6. Recreational
7. Residential
8. Special purpose
9. Transportation
10. Water body

New 2012 land use aggregated land use

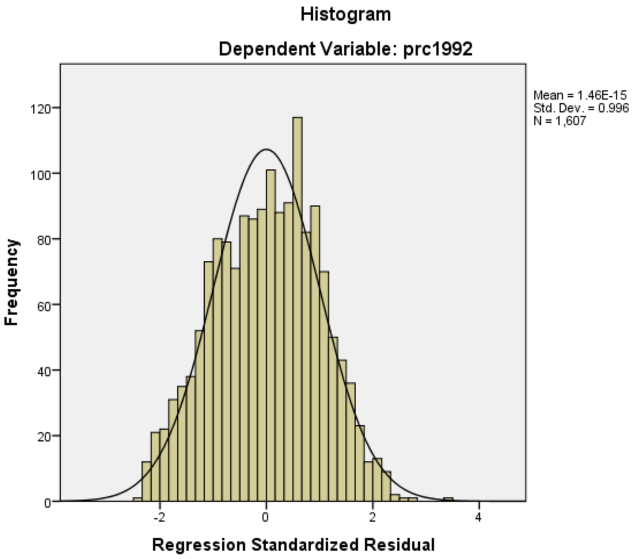
1. Informal settlements
2. Planned residential: from residential
3. Vacant agriculture: this includes all forest, water bodies
4. Other urban: educational, industrial, recreational, special purpose, transportation
5. Ocean & estuaries

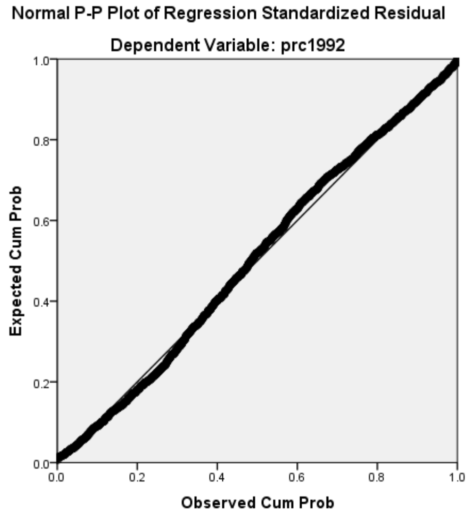
Appendix 8: INs density description in m square / ha in 1992 and 2015

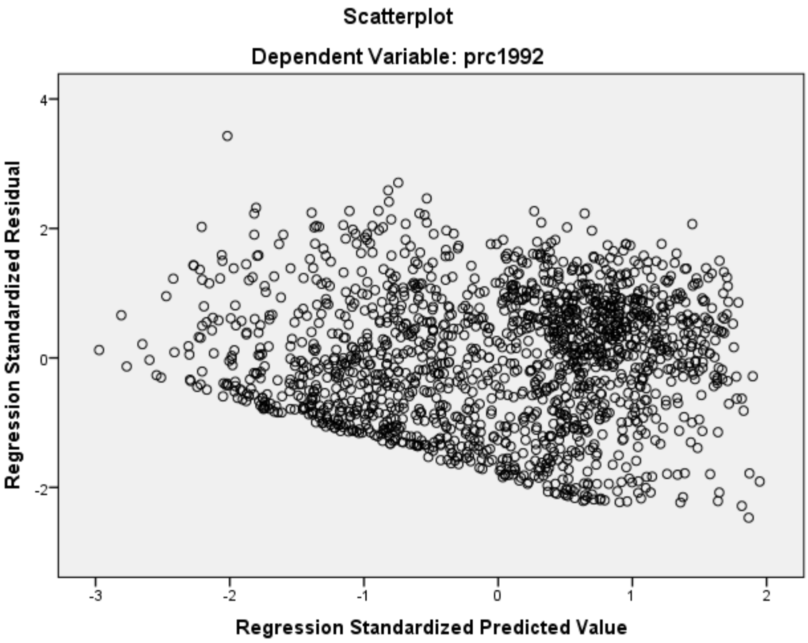


Density per Ha	< 2000	2001-3500	3501-5000	>5000
Density as in 1992	936	2175	3359	7020
Density in 2015	1508	3001	4931	9395

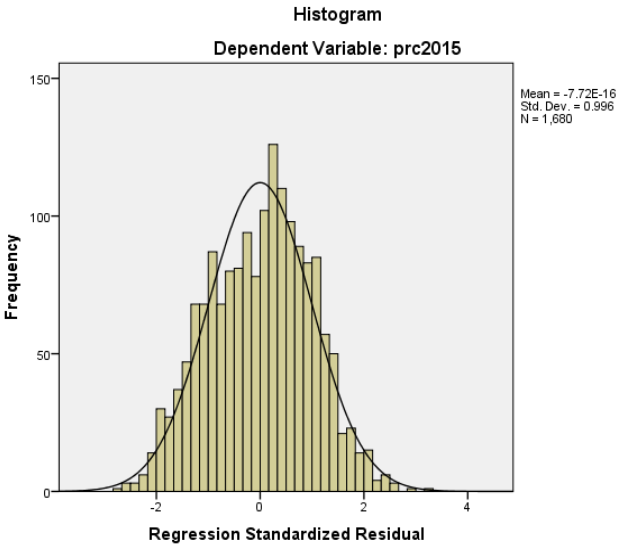
Appendix 9: Regression plots for model 1

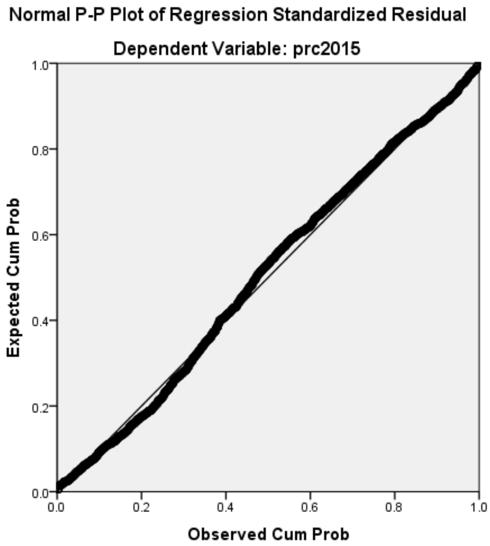


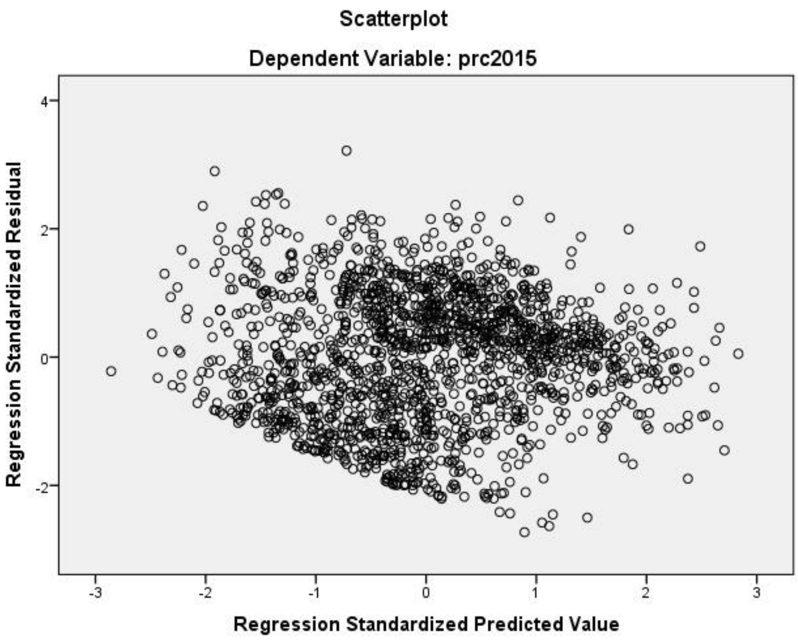




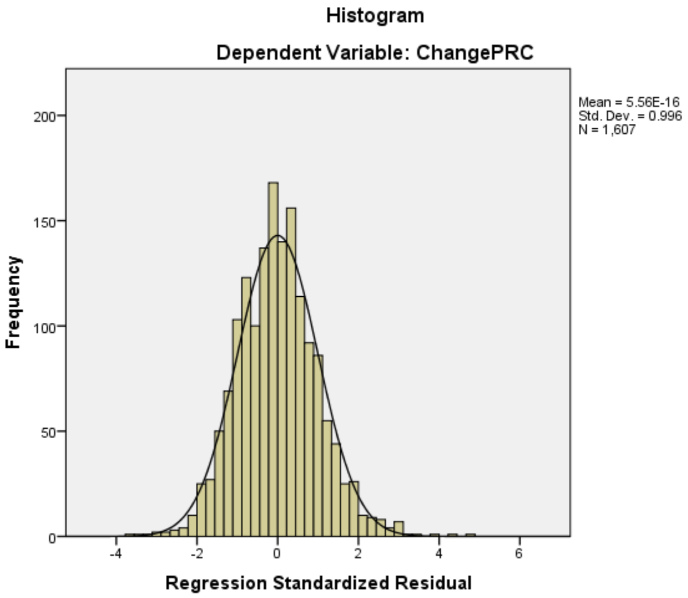
Appendix 10: Regression plots for model 2

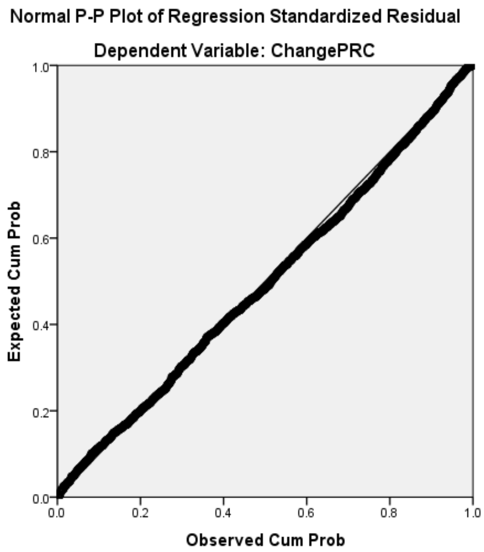


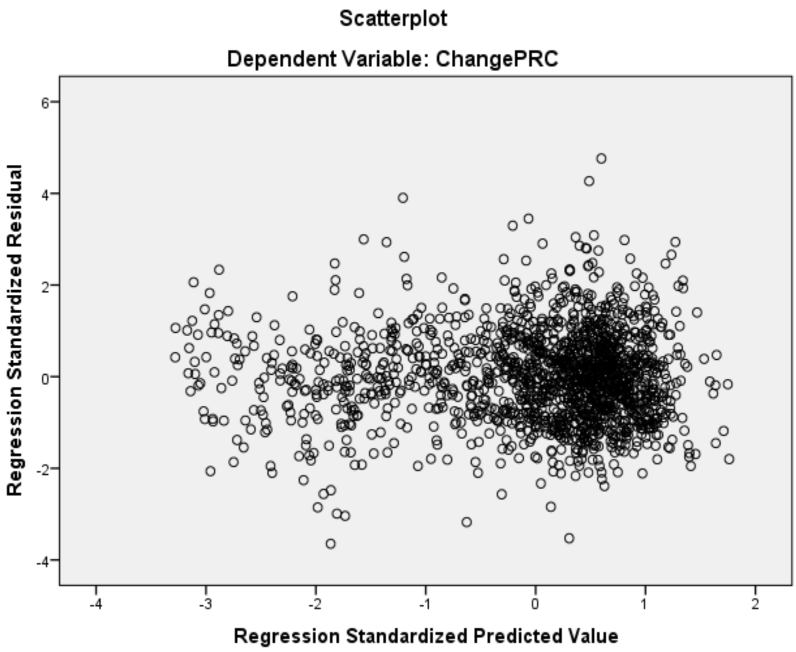




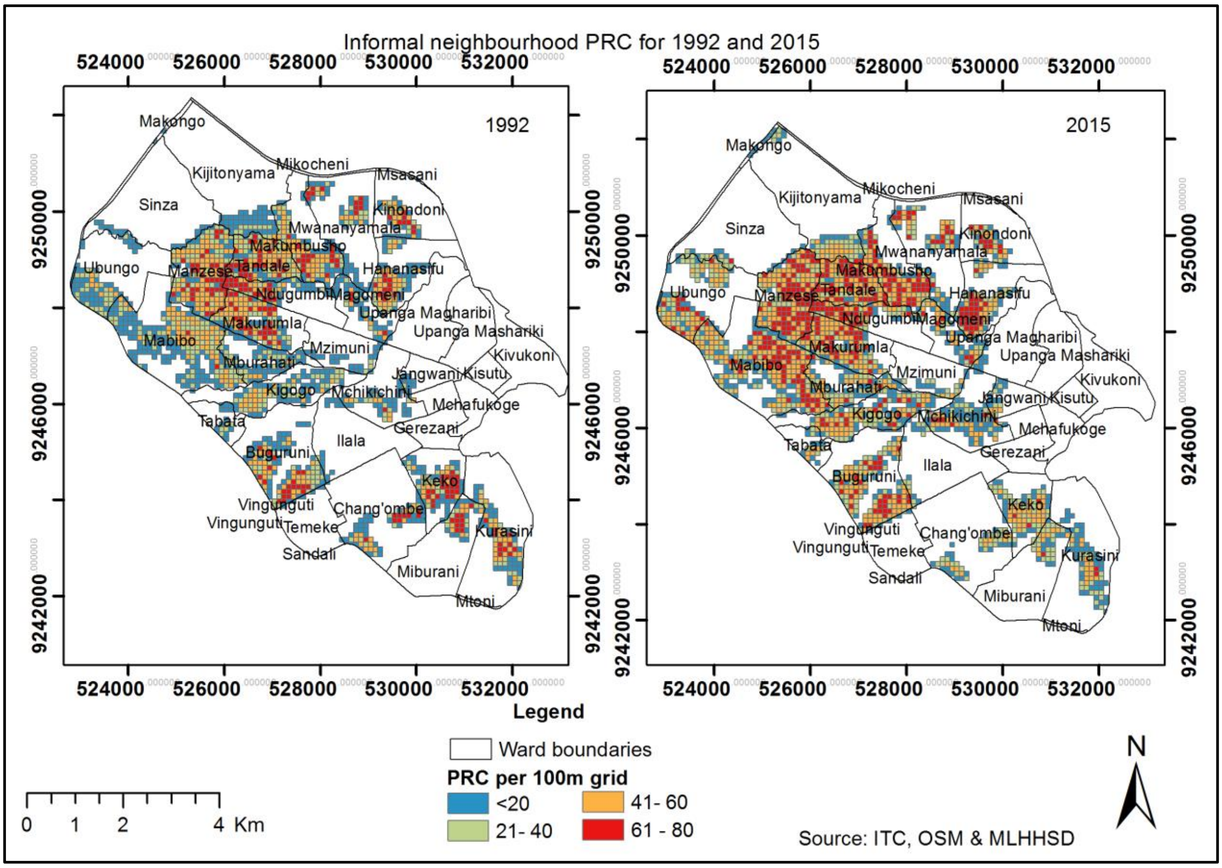
Appendix 11: Regression plots for model 3







Appendix 12: PRC per 100m grids



Appendix 13: Different errors of OSM data in Makumbusho ward