Identifying and Classifying Slum Development Stages from Spatial Data

NEGERA DINSA SORI
February, 2012

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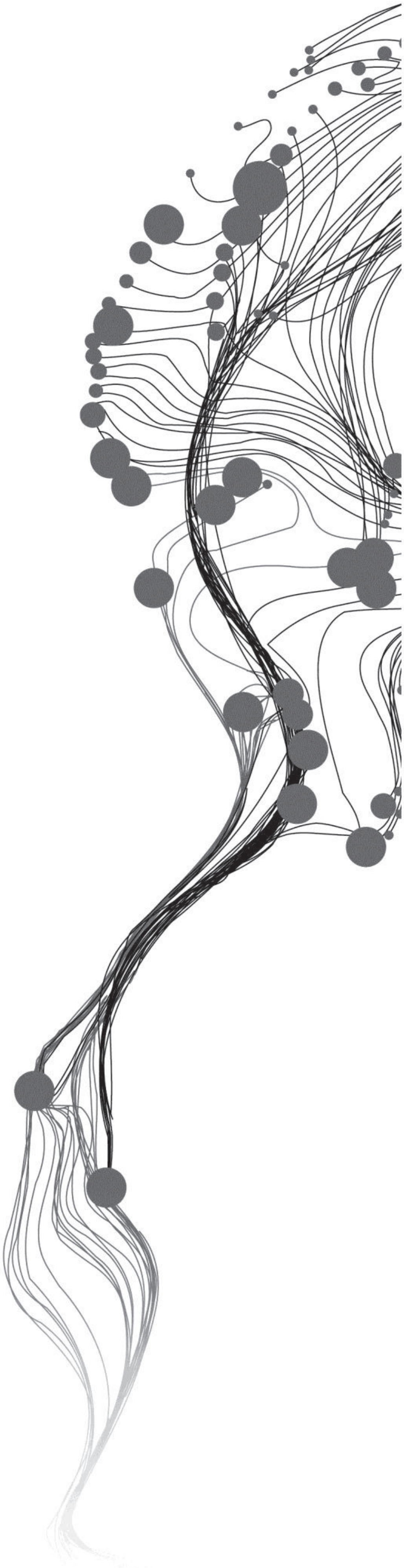

Identifying and Classifying Slum Development Stages from Spatial Data

NEGERA DINSA SORI
Enschede, The Netherlands, February, 2012

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.
Specialisation: Urban Planning and Management

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ABSTRACT

The current existence and continued formation as well as expansion of slums at unprecedented rate is one of the challenges encountering cities in Sub-Saharan African (SSA) countries. Although international, national, and local initiatives have made significant efforts to tackle the problem of the growth of slums, unfortunately, the rapid growth of urbanisation and the actual trend of population growth in SSA has eclipsed their efforts. While slum formation can be attributed to several factors, the absence of adequate knowledge on the evolution and subsequent development of slums over the course of time in SSA countries has resulted in ineffective urban planning and prevented the initiatives from alleviating the problem. Knowledge gap has been correlated with lack of relevant theories and concepts developed from empirical analysis to explain the evolution, growth and spatial characteristics of Slum Development Stages (SDS). However, the little study of SDS in the context of rapidly urbanising city of SSA has also contributed to this problem.

This study was an attempt to contribute to addressing the global and escalating problem of slum formation and expansion. It proposed innovative methods for classification and analysis of SDS using VHR imagery, demonstrating that RS and GIS technology can provide wealth of spatial information that cover large areas with high detail and temporal frequency. It then analysed key socio-economic characteristics of the case study area in order to relate with SDS. Finally, the applicability of the approach to identify SDS from spatial data was examined. Furthermore, SDS in a 3D context was briefly discussed as proliferations of multistory residential buildings have also started to emerge in slum settlements in some cities of developing countries. Kisumu city, which is among the rapidly urbanising centres in Kenya and also an UN Millennium city was selected as a case study area. Two neighbourhoods, Manyatta A and Manyatta B together form the specific study area.

The study explored the theoretical framework for classification and analysis of SDS. The relevance of this framework was examined as per the study area context. The concept of object-based image analysis and rule-based classification techniques was utilised to extract feature classes from GeoEye imagery. Six feature classes were extracted and accuracy assessment was met through the use of an error matrix. The density of vegetation, impervious surface and bare soil were computed at one hectare unit of analysis in GIS environment. Thresholds that are appropriate contextually were defined to classify the physical development process of Manyatta slum settlement into infancy, consolidated and saturated neighbourhoods.

The analysis of SDS revealed that around one-fifth of Manyatta A is already saturated and nearly two-third, and one-fifth of the settlements is consolidated and at infancy stage respectively. In the case of Manyatta B, which is relatively young and rural slum settlement, more than half of the settlements are at early stages while around two-fifth are consolidated. The employed methods and the results of the study can improve the analytical capabilities in similar context of SSA where reliable, up-to-date and high spatial and temporal information pertaining to slums at local level are hardly available. This can potentially enhance better understanding about the characteristics of SDS thereby help urban planners and policy makers to develop informed systematic interventions which will eventually improve the living and the economic conditions of slum dwellers. These, in turn, are expected to contribute to the efforts being made to minimize slum formations.

Key terms: Slum development stages, object-based image analysis, VHR imagery, density, Manyatta, Kisumu

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Negera Dinsa Sori,

Enschede, The Netherlands, February 2012

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LIST OF ABBREVIATIONS AND ACRONOMYS

2D	Two-dimensional
3D	Three-dimensional
AOI	Area of interest
DSM	Digital Surface Model
EO	Earth Observation
FAR	Floor Area Ratio
GIS	Geographic Information Systems
HH	Household
KCC	Kisumu City Council
LiDAR	Light Detection And Ranging
NDVI	Normalised Difference Vegetation Index
MDG	Millennium Development Goal
NGOs	Non-governmental organizations
OBIA	Object Based Image Analysis
RS	Remote Sensing
SDS	Slum Development Stages
SSA	Sub-Saharan Africa
UN Habitat	United Nations Human Settlements Programme
VHR	Very High Resolution
V-I-S	Vegetation, impervious surface and bare soil

1. INTRODUCTION

This introductory chapter explains the background and justification of the research; leading to the research problem. It also includes the identification of the research objectives and the corresponding research questions that need to be answered, and the significance of the outcome of the study. The section also presents the scientific pillars pertinent to the research topic or the domain in which the study tries to attain the research objectives.

1.1. Background and Justification

The current existence of slums is a reality which cannot be ignored. More than one billion people live indecent areas without access to basic needs; adequate sanitation, improved water supply, durable housing, adequate living space, and secure tenure (Amnesty International, 2011). Lack of one of these basic conditions has direct consequences on the physical and psychological well-being of the urban population (Sclar et al., 2005). For example, infectious diseases like diarrhea, cholera, typhoid and other water borne diseases, malarial and, tuberculosis are major problems affecting slum dwellers. On the other hand, the economic circumstances of the slum dwellers render them unable to access health care services. This severely affects their safety and security. According to UN Habitat, (2010b) the number of slum dwellers worldwide continues to grow at the rate of 10 percent every year, hence increasing the problem. As a result, future urban development will show further expansion and sprawling of slums and the spread of urban problems if no remedial action is taken in the coming years (UN Habitat, 2010b).

To address this global and escalating problem of slum formation and expansion, many city governments as well as international institutions have programmes aimed at lowering the rate of future slum formation. It is undeniable that lot of efforts have been made to improve the living and the economic conditions of slum dwellers by United Nation (UN), Non-Governmental Organizations (NGOs), and other stakeholders since 1970's. For instance, according to new estimates, governments have together surpassed the Millennium Development Goal (MDG) number 7 Target 11 (improving the lives of 100 million slum dwellers by 2020) by at least a multiple of two (UN Habitat, 2010b). However, this improvement is highly skewed towards the more advanced emerging economies, while developing countries, particularly in sub-Saharan Africa (SSA) much remain to be done. This is mainly caused by the rapid growth of urbanisation and the actual trend of population explosion in SSA that has prevented the initiatives from alleviating the problem and eclipsed their efforts as well. While the proportion of slum dwellers is decreasing, their absolute number is actually increasing, particularly in the world's poorest regions such as SSA.

Though slum formation can be attributed to rapid urbanisation and population growth trends, the general little knowledge on evolution and the subsequent development of slums over the course of time in SSA countries has limited effective urban planning and management. Knowledge gap has been correlated with lack of relevant theories and concepts developed from empirical analysis to explain the evolution, growth and spatial characteristics of slum development stages (SDS). However, the existence of little studies of SDS in the context of rapidly urbanising city of SSA has also contributed to this problem.

There is a need to develop informed systematic interventions to improve the well-being of slum dwellers and, better yet to reduce the continued formation and expansion of slums at unprecedented rate. Developing of systematic interventions requires reliable, up-to-date and high spatial and temporal information pertaining to slums at local level which are commonly unavailable in many developing countries (Khadr et al., 2010). It is unclear which types of interventions are most effective to yield maximum benefit with minimum effort. Local authorities also invariably lack the expert capacity and reliable data to carry out the work needed to address the global and escalating urban slums problems (Ooi & Phua, 2007). Similar constraints are faced by numerous NGOs, which work at the national and local scale among poor urban neighbourhoods. Consequently, low-income housing programmes and provision of basic amenities and facilities fail to keep pace with rapid population growth and the tremendous demand for basic needs. Given the actual trend of population growth, the inevitability of urbanisation, and the proportion of slum dwellers without access to improved social and physical services coupled with their vulnerability raises, efficient methods are required for better understanding of SDS that can be utilised in targeting slum alleviation programmes.

Spatial information is essential for several aspects of urban development, planning and management, including identifying and observing changes in slum settlements (Hofmann et al., 2008; Lemma et al., 2006). Without spatial information, it is difficult to monitor and identify slum areas, their physical development process and their impacts. For example, the lack of up-to-date, objective and accurate city specific data related to slums remain a challenge in SSA countries resulting in uninformed policy making and imposing additional burdens on the majority of urban residents (UN Habitat, 2010a).

Accordingly, obtaining reliable spatial information is the basis for any actions of enhancing the well-being of urban slum dwellers (Hofmann, et al., 2008). Spatial information has traditionally been acquired through field surveys which are time consuming and limited to capture urban dynamic process (Niebergall et al., 2008). Currently, very high resolution (VHR) satellite imagery integrated with geographic information systems (GIS) provides spatially consistent datasets that cover large areas with high detail and temporal frequency. These tools are preferable to field surveys, as they are cheaper to build, easier to use, and more robust and flexible in their application (Sliuzas et al., 2004) thereby providing a wider range of information that is more up-to-date. With these tools it should be possible to develop reliable methods to identify, classify and analysis the physical development process of slums.

1.2. Research Problem

Earth Observation (EO) has been used in various studies as a basis to identify and monitor slum settlements. For example, Hofmann et al. (2008) demonstrated how slum settlements can be detected from VHR satellite image data using an object-based image analysis approach. Busgeeth et al. (2008) discussed the potential application of Remote Sensing (RS) in monitoring slum settlements in developing countries. Similarly, Lemma, et al. (2006) developed a methodology through the integration of local knowledge and geographic information technology (GIT) for monitoring slum condition. Recently, Mathenge (2011) developed a conceptual framework for slum identification and mapping based on domain expert knowledge from VHR imagery. Generally, slum identification has already been carried out in different ways. However, the identification, classification, and analysis of SDS in the context of rapidly urbanising city of SSA is rarely investigated.

Understanding the evolution and the subsequent development stages of slums over the course of time is vital to support appropriate policy intervention and prevent their further development (Sliuzas, et al., 2004). According to the author, generally slums evolve from sparsely settled rural areas and settlements into consolidated and physically saturated neighbourhoods that largely determine the spatial structure of rapidly urbanising SSA cities. This indicate the continuous process of transformation and change of slum settlements from one stage to another, which is triggered by change in building materials used, change in socio-economic condition and tenure status (Agnihotri, 1994). Similarly, due to cultural and socio-economic differences, slums are not the same, and some provide better living conditions than others. For example, within one city many different manifestations of slums may be found, each of which may require specific methodological adjustments for identification and mapping (Sliuzas et al., 2008). These multiple faces of slums and their multidimensional nature, often varying widely between countries and within countries and cities indicates to understand the slum development process itself. Consequently, according to the author, the development stage of slum settlements should be considered when deciding how it is to be identified and mapped from VHR imagery.

Hence, developing a method to identify and classify SDS will need to explicitly consider how the spatial characteristics of slum settlements may change. RS data may not provide all the information needed for mapping SDS. Other spatial attributes from various sources such as socio-economic data may be needed. For example, indicators like access to improved water, access to improved sanitation, and access to secure tenure cannot be extracted from RS data. Certainly, VHR imagery has the potential to provide wealth of spatial information that covers large areas with high detail and temporal frequency. Hence, a simple but reliable method to extract and analysis SDS from VHR imagery with the integration of local expert knowledge, and combined analysis in GIS environment are useful, convincing and generate a wealth information, which is easier for institutional embedding. This can be a systematic approach to identify, classify and analysis SDS which will be more transparent and updated continuously and can better target slum areas, thus yield maximum benefit with minimum effort (Sliuzas, et al., 2008).

The current existence and continued formation as well as expansion of slums at unprecedented rate and the existence of inadequate rigorous studies of SDS in the context of rapidly urbanising city of SSA calls for the analysis of the physical and socio-economic development process of slums. While slum formation can be attributed to several factors, the absence of adequate knowledge has been correlated with lack of relevant theories and concepts developed from empirical analysis to explain the evolution, growth and spatial characteristics of SDS. Hence, this study is an attempt to contribute in slum mapping approaches specifically identifying, classifying and analysing the physical and socio-economic development process of slum settlements from spatial data. To achieve this goal, the study tries to attempt to use RS and Geo-information based information. Generally, to make a substantial alleviation of the slum dwellers, it is wise to look at the physical development process of slums which could be an alternative approach toward improving the living and the economic conditions of slum dwellers and, better yet to reduce continued slum formation and expansion.

1.3. Research Objective and Quessions

This study aims to identify and classify SDS from spatial data in its effort to improving the analytical capabilities in similar context of SSA where reliable, up-to-date and high spatial and temporal information pertaining to slums at local level are typically not available. Specifically, it attempts to extract features from VHR imagery using the concept OBIA for further classification and analysis of SDS. In addition, this study attempts to analyses key socio-economic characteristics of slum settlements and evaluate the applicability of the approach to identify SDS from spatial data.

1.3.1. General Objective

To identify and classify SDS from spatial data that can be utilised in targeting slum alleviation programmes relevant to SSA.

1.3.2. Specific Objectives

1. To identify slum development stages from VHR imagery
2. To analyse key socio-economic characteristics of the case study

3. To evaluate the applicability of the approach to identify SDS from spatial data

1.3.3. Research Questions

1. To identify slum development stages from VHR imagery
   1.1. What are the spatial and contextual characteristics of slums?
   1.2. What kind of spatial indicators can be detected from VHR imagery?
   1.3. How can these spatial indicators be translated into image based parameters?
   1.4. What is the appropriate spatial analytical level?
   1.5. How to define thresholds that are appropriate contextually to differentiate SDS?
2. To analyse key socio-economic characteristics of the case study
   2.1. What are the socio-economic characteristics of slum dwellers?
   2.2. Are socio-economic characteristics related to SDS?
   2.3. Can socio-economic characteristics be used to differentiate SDS?
3. To evaluate the applicability of the approach to identify SDS from spatial data
   3.1 How to evaluate the applicability of the approach?
   3.2 What are the strengths and weakness of the approach?
   3.3 What are the possible recommendations to improve the limitations?

1.4. Conceptual Framework

This sub-section highlights the causes and effects of slum formation in a broader context and limits the scope of the study to slum development stages. The conceptual framework gives a quick overview of inter-relation of concepts, sources, approaches, and tools that is utilized to identify and classify slum development stages.

1.4.1. Causes and Effects of Slum Formation

There are many factors that contribute to the continued formation and expansion of slums. Among these are rapid rural-to-urban migration, policy failure, increasing urban poverty and inequality, population growth and globalisation. While more people are migrating from rural areas to towns and cities, urban areas are not expanding enough, there are not enough affordable houses, and municipalities are not being able to provide enough accommodation. Therefore, the in-migrants are forced to occupy illegal settlements on marginal lands at the urban periphery, along railways and riversides, or on other hazardous areas that is not suitable for development leading to expansion of slums. Not only rural-urban migration, urbanisation or population growth etc. that is the cause of slum formation, but also the failure of governments, failed policies, corruption, inappropriate regulation, dysfunctional land markets, unresponsive financial systems etc. to provide low income people with essential public infrastructure and services (UN Habitat, 2003).

Result of lack of basic public services and facilities to sustain slum dwellers exposed them to many problems related to health (Alberti & Waddell, 2000). For instance, water-borne diseases, such as malaria, cholera, typhoid, and malnutrition, child mortality are common in slum settlements. There are also wide range of social problems and psychological burdens on slum dwellers which often leads to homelessness and social exclusion. In addition, slum dwellers are prone to polluted and hazardous areas, for example, next to toxic plants, on areas threatened by landslip or waste disposal areas, flood, and environmental hazardous and they are vulnerable to risks. Generally, the causes and effects of slum formation are manifold and are not the focus of this study. The focus is to explore the theoretical framework for classification and analysis of SDS as per the study area context which could improve analytical capabilities and potentially enhance better understanding about slums for informed interventions thereby improve the well-being of slum dwellers and better yet to reduce continued slum formation and expansion.

1.4.2. Infancy, Consolidation and Saturation

In many cities slums evolve from sparsely settled rural areas and settlements into urban slum neighbourhoods and develop further over time into densely packed and physically saturated neighbourhoods as illustrated in figure 1.1 (Sliuzas, et al., 2008). Figure 1.1 shows incremental and unstructured type of slum development process; however, there are other types of development also possible. Slum developments may happen at the expense of prime agricultural land, with the destruction of natural landscape or public open space. Every slum passes through various stages during its development. This process includes formation of various nuclei, expansion of older nuclei and intensification of the oldest (Agnihotri, 1994). In this study, three stages of slum development are considered, namely, infancy, consolidation and saturation stages.

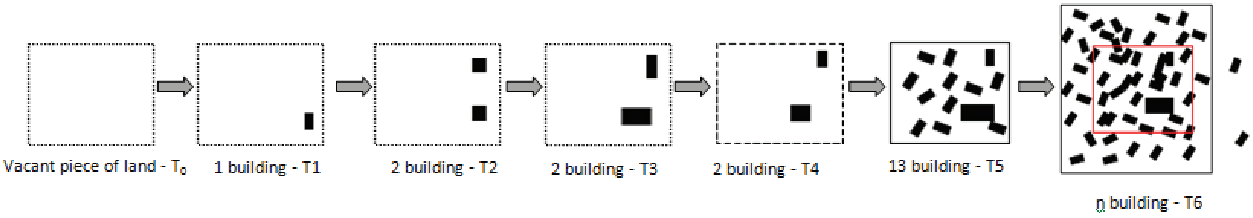


Figure 1.1: Physical process of slum development stages
Source: Sliuzas, et al. (2008)

Infancy is the initial occupancy stage where patches of vacant land like on steep sided land, swamps, near river banks, hazardous areas, conserved areas, etc. become available to the slum dwellers. They can also occur on suitable lands. Also there is the possibility of slum formation decaying from formal areas. Due to the job insecurity slum dwellers prefer to live on hazardous areas than to live on suitable land at faraway places. In this stage public amenities and services are quite inadequate, for example, supply of water is the main problem. Consolidation stage is the intermediate stage between infancy and saturation. There is fast outward expansion and the available land will be reduced by filling up additional building. Saturation stage is the stage at which the expansion stops as the vacant lands gets filled up. At this stage overcrowding is highest and lowers the living standards of slum dwellers.

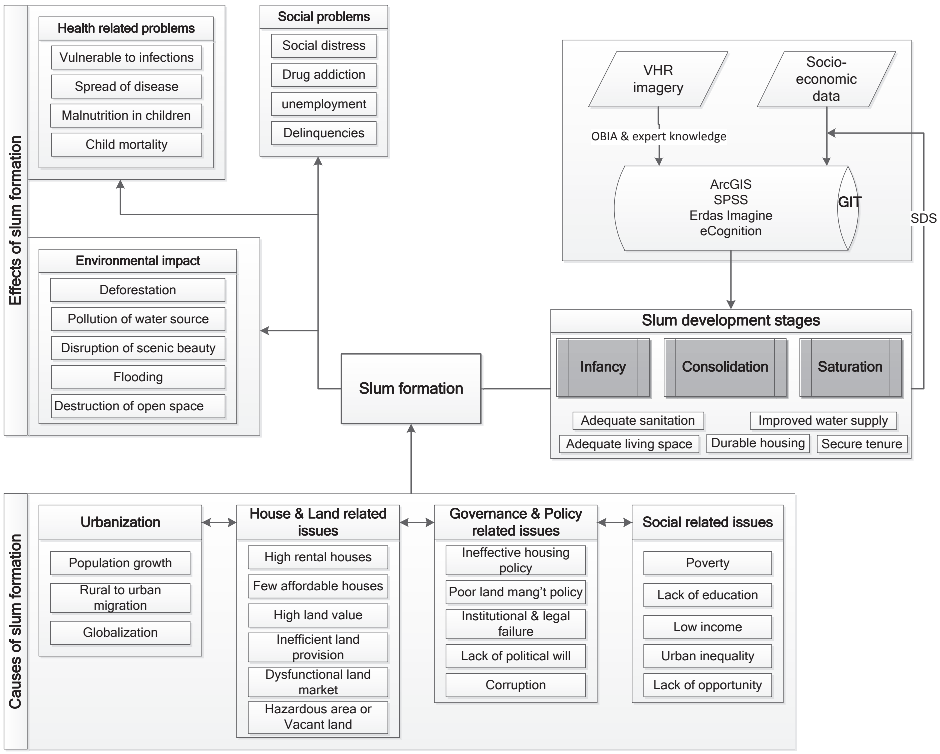


Figure 1.2: Conceptual framework

Analysis of the location of slums is a typical variable in understanding how slum develops. This is because factors such as the location of city centre and availability of marginal lands may be important factors for slum dwellers. Hence the study of slum location shows both the spatial pattern of slums and the process of physical change of slum development stages. Generally, the speed of slum growth is not uniform: faster at one time and not in another (Agnihotri, 1994). According to the author, spatial change in slum areas is the result of change in construction materials, change in socio-economic state and tenure status. Figure 1.2 illustrates some of the causes and effects of slum formation and concentrate on stages of slum development which is the focus of the study (conceptual framework).

1.5. Research Design Matrix

The research design matrix gives an overview of the sequence of the research including methods to be carried out and the required data for analysis.

General objective: To identify and classify SDS from spatial data that can be utilised in targeting slum alleviation programmes relevant to SSA.

Table 1.1: Research design matrix

Research sub objectives	The respective research questions	Techniques of Analysis	Required data and software
To identify slum development stages from VHR imagery	• What are the spatial and contextual characteristics of slum? • What kind of spatial indicators can be detected from VHR imagery? • How can these spatial indicators be translated into image based parameters? • What is the appropriate spatial analytical level? • How to define thresholds that are appropriate contextually to differentiate SDS?	Literature review, expert consultation, visual interpretation, OBIA, GIS spatial analysis,	Literature, Expert knowledge, VHR imagery, ArcGIS, Erdas Imagine, eCognition Developer,
To analyse key socio-economic characteristics of the case study	• What are the socio-economic characteristics of slum dwellers? • Are socio-economic characteristics related to SDS? • Can socio-economic characteristics be used to differentiate SDS?	Literature review, expert consultation, Descriptive analysis, GIS spatial, analysis	Literature, Expert knowledge, Socio-economic data, SPSS, ArcGIS
To evaluate the applicability of the approach to identify SDS from spatial data	• How to evaluate the applicability of the approach? • What are the strengths and weakness of this approach? • What are the possible recommendations to improve the limitations?	Literature review , Expert consultation, Result analysis and discussion	Literature, Expert knowledge, Result of classification of SDS

1.6. Significance of The Study

This study is an attempt to classify slum development stages and analyse their socio-economic characteristics within Kisumu city context. Quite often the physical development processes of slum settlement are multidimensional in nature, often varying widely between countries and within countries and cities. The methods employed in this study provide a basis for analysing other slum settlements in other SSA contexts that have similar socio-economic and cultural conditions. In addition to this, the result of the study can provide information on slum development stages that will help the local authorities and other stakeholders to clearly understand stages of slum development and their characteristics for their respective cities. This could also help to answer questions like: Where are the emerging/saturated slum areas in a city? What are their characteristics? Which stage would require minimum effort and easy to apply interventions and yield maximum benefit? In fact they need to know the types of interventions that may be needed for the different slum development stages. Furthermore, this study can provide an opportunity for future research. Generally, the study provides up-to-date baseline information that would inform interventions on housing and related basic urban services including water and sanitation facilities among others for Manyatta slum settlements.

1.7. Structure of the Thesis

This thesis has been organised into six chapters as summarised below:

Chapter 1: Introduction

This chapter introduces and explains the background and research problem area; leading to the identification of the research objectives and the corresponding research questions. It also presents the conceptual framework and research design matrix pertinent to the research topic in which the study tries to attain the identified research objectives.

Chapter 2: Slum Formation and Their Development Stages

Chapter two discusses the theoretical and empirical background information to the topic of slum formation and their development stages in general and in the context of SSA countries. The chapter reviews on some of the concepts, thoughts, and ideas of the formulated problem and relates the concepts with approaches and methods that have addressed similar problem.

Chapter 3: Study Area

Chapter three provides background information about the study area. The chapter reviews the urbanisation and population trend growth and illustrates the economic activity and the general profile of the existing slum settlements of the case study area. Similarly, it gives the general overview of slum upgrading programmes of a case study area along with the overall nature of basic services and infrastructure provisions.

Chapter 4: Data Source and Research Methodology

This chapter describes the bases and processes within which this study is conceived and executed. It describes the data source, tools, and approaches employed for identifying, classifying and analysing the physical and socio-economic development process of the case study slum neighbourhoods. Generally, it outlines the overall research design and methodology underpinning the study to attain the pre-defined objectives.

Chapter 5: Results and Discussion

Chapter five presents results analysis of the physical development process of SDS process along with the general discussion. It also presents the analyse of key socio-economic characteristics of the case study area along with the conceptual and operational framework on how a more integrated analysis can be conducted. The chapter further discusses the applicability of the approach to identify, classify and analysis SDS from spatial data. Furthermore, the chapter presents some discussion about SDS in 3D context.

Chapter 6: Summary of Findings, Conclusion and Recommendations

The last chapter provides the general conclusion, summary of key findings and recommendations on the approach to identify SDS from spatial data and drawing inferences from empirical investigation. It also highlights some of the limitations faced during the course of carrying out this study along with possible recommendations to improve the limitations and finally proposes possible future research areas related to SDS. In generally, figure 1.3 shows the work steps that the study goes through from the research identification to conclusion, recommendation and compilation of the thesis.

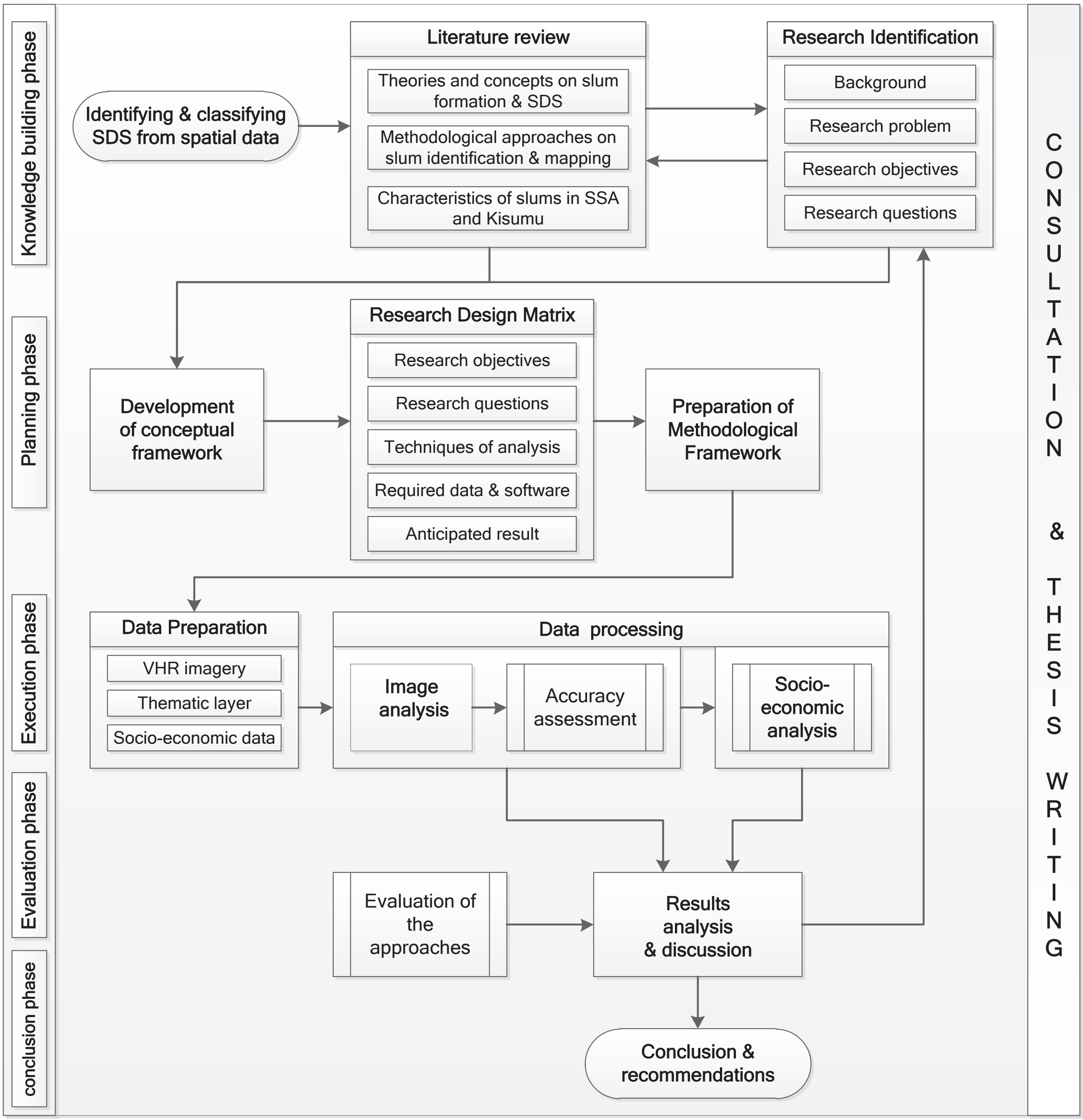


Figure 1.3: Thesis workflow

2. SLUM FORMATION AND THEIR DEVELOPMENT STAGES

This chapter is a compilation of background literature to the topic of slum formation in general and in the context of sub-Saharan Africa. The section reflects on some of the concepts, thoughts, and ideas of the formulated problem. It also relates the concepts with approaches that have addressed similar problem and the methods that are being used for this study. It is also important to be acquainted to the concepts and definitions bring about in this section so as to have a clearer understanding of the subsequent sections and the analysis of the information.

2.1. Theories and Concepts on Slum Formation

Scientific theories are concerned with how and why of the empirical phenomena and at the same time help to explain and predict about a phenomenon (Nachmias & Nachmias, 1996). A theory is a collection of concepts which together provides an understanding of how a phenomenon is built up and how it can be classified and used. Concepts are abstractions of a phenomenon from which meaning or a way of seeing the world can be grasped. Concepts provide a common language to communicate with other scientists and define a theory's content and attributes. Theories and concepts are tools for human thinking. According to these authors, theory and concepts are the basis of the researchers' attempts to understand, explain, predict and propose measures that relate the phenomenon being investigated. In the following section concepts, thoughts and ideas for identifying, classifying and analysing SDS is reviewed.

2.1.1. Population Growth and Rapid Urbanisation

Many people believe that slums are inevitable as long as population growth and rapid urbanization are there. However, the existence and/or formation of slums are neither an inevitable consequence of population growth nor an inevitable result of rapid urbanization (Ooi & Phua, 2007; Taubenböck et al., 2009). One is to recognize that urbanization and further population growth is going to happen. Urbanization and emergence of mega cities themselves are not problems in themselves. Rather urbanization is necessary for the wealth generation and economy of most nations. However, the benefits of urbanization do not come suddenly; they need well-designed public policies that can lead to healthy economies, and ensure equitable distribution of resources. When public policies benefits only political or economic elites, urbanization will almost inevitably result in instability, as cities become unlivable for rich and poor alike (UN Habitat, 2010a). Furthermore, the limited capacity of the local authorities to supply improved social and physical infrastructure services for the residents and in-migrants coupled with the rapid growth pace of urbanisation and the actual trend of population growth are contributory factors to growth of slum settlements.

2.1.2. Governance and Its Impact on Slums

As mentioned above, urbanisation by itself is not a problem. The real problem is rooted in out-dated institutional structures, government policies, inappropriate legal systems, incompetent national and local governance, and short-sighted urban development policies, and operational dysfunction (Share The World's Resources, 2008). It seems that institutions of government leave improving the living conditions of slum dwellers to international aid agencies. The exceptions are times of political elections, where the basics of the human condition are sometimes publicly raised and debated. There are many examples where public officials and politicians treat slum dwellers for political reasons, which only worsen and extend the problem (Shackelford & Davis, 2003). Understandably, a common consensus that seems to emerge from many initiatives and authors is that slums cannot be exempted in any form, or under any conditions. This is because their rapid expansion means that society has no effective control over them, thereby projecting a miserable image of the human future.

2.1.3. The Economic, Social and Environmental Challenges of Slums

Addressing the problems of slum settlements needs a better understanding of the physical development process of slum as well as recognition of its interrelated economic, social and environmental challenges. As discussed by Gabriel (2007), slum expansion is not simply an urban planning problem, but a rather more complex and intractable phenomenon. The processes of slum formation are multidimensional in nature, often varying widely between countries and within countries and cities. Slum expansion is associated with the economic, social and environmental challenges.

In economic terms, slum settlements actuate considerable public and private investments, which remain outside of the formal economy and investment cycles (De Soto, 2003). Furthermore, they are correlated with large public sector costs, explicit and implicit. According to Tsenkova (2008), slum settlements often conquest public land, shifting the cost burden to local governments and public institutions. Slum settlements also impact on the government's ability to manage, monitor and plan land use. Owners usually do not pay property taxes or user fees; often connect illegally to infrastructure, thus reducing the revenue available to government to provide basic services.

Slum settlements are a key element of the informal economy and real estate market. Since there is no tenure security in most of the cases, the investment is constantly under threat of being lost. For example, due to environmental hazards such as floods, landslides, earthquakes or demolition in cases of road widening and other major infrastructure developments. Informal practices remain the only affordable option for low income groups to access housing and land. "Although there is still disagreement whether informality is part of the problem or a possible solution, informal strategies play an essential role in supporting the livelihood of the marginalized groups (Tsenkova, 2008, p. 30)." According to Huchzermeyer (2006, p. 9), "… the slums are often referred to as large open air markets." The author discussed the challenge to understand the complexity of economic interests linked to the slum environment from the distant. Given this complexity, one cannot accurately foresee from outside how an intervention will impact on slum dwellers, their income generation and their access to basic services. Thus it is importance to explore the impact an intervention will have in the context of deprivation, vulnerability and fragile livelihoods.

According to Tsenkova (2008), the variety of spatial manifestations of slum settlements across the region is associated with several different social dimensions to the problem. Slum dwellers are often poor and disadvantaged facing unemployment, social exclusion and tenure insecurity. In several countries, one of the worst consequences of living in slum settlement is not the lack of secure tenure, but lack of access to basic amenities and social services such as schools, improve water and sanitation etc.

Slum settlements along with planning and management deficiencies affect the city's livability and environmental quality. For example, urban run-off, downstream pollution from garbage and sewer discharged directly in rivers create serious environmental threats. In addition to this, some settlements (e.g. low land slum settlements) are directly exposed to environmental hazards associated with landslides, flooding, poor drainage, environmental pollution and exposure to various environmental hazards. In general, slum settlement expansions contribute to environmental degradation at many levels and create environmental hazards through development in natural reserves and protected areas.

2.1.4. Concepts and Definitions of Slum

Until 2002, there was no internationally agreed definition and concept of slum even if international aid agencies such as UN, NGOs and others begin to improve life of slum dwellers in 1970s. Many cities in the world tend to define slums differently, although efforts have been made for years to establish objective measures with which to delineate the major problem areas. For example, favela (Brazil), Barrio or tugurio (Latin America), Basti (Bangladesh), Bidonville (France/Africa), Kampung (Indonesia), Katchi abadi (Pakistan), Masseque (Angola), Ghetto (USA), Shantytown, Squatter cities, etc. (Cities Alliance for Cities Without Slums, 2000). These various names indicate that there is no universal name for slum. This is because it is viewed differently from place to place and what might be considered to be a slum in one country might be regarded as an acceptable accommodation in another. The UN Expert Group Meeting has tried to come to a more acceptable definition of slum. They define slum as a group of individuals living under the same roof, in urban area that lack at least one of the following housing conditions: access to improved water, access to adequate sanitation, access to secure tenure, housing durability, and sufficient living area (UN Habitat, 2003).

The word slum is also a relative concept and the concept is not constant over time. Because urban areas are dynamic; change through time; like many neighbourhoods in a city, some slums are gentrified, some formerly decent areas decay. This is because what is a slum at one point in time may improve, what was once an area of decent living may worsen. To be logical, the definition of a slum, like poverty, has to be both absolute and relative. The only common consensus over time has been that slums have always been perceived to be undesirable places in which poor people live. In this study the term informal settlements and slums will be used interchangeably since informal settlements are often referred to as slums (Cities Alliance for Cities Without Slums, 2000; UN Habitat, 2003). Hereof, slum area or informal settlement is an area that encompasses, to various extents, the following physical characteristics: high spatial heterogeneity, complex shape; substandard housing; high building density; small building size; irregular pattern of road network in poor condition; poor connectivity with infrastructure; no or little vegetation (open space); prone to hazardous locations (Niebergall, et al., 2008). Thus, it should be possible to identify these settlements from other settlement areas from VHR satellite image data (Hofmann, et al., 2008). It is assumed that the identification of one or more of these indicators in the VHR image could be an indication for locating slum areas. However, these indicators are context wise and need local tuning.

2.1.5. Slum Development Stages

Different authors classified the physical development stages of slum into different stages. For example, Eyre (1972) classified slums into four stages based on their characteristics (the initial occupancy, the transitional, the stage of attainable secure tenure, and the stage of absorption). Miller (1965) classified slums into the same categories based on familial stability and job security (the unstable, the copers, the strained and the stable poor). Similarly, Turner (1966) also classified slums into four in terms of development levels and security of tenure (the transient, provisional, incomplete and incipient, complete). Recently, Abebe (2011) described informal settlements into three phase (infancy, consolidation and saturation) based on the availability of open space in the neighborhood. According to Abebe (2011), infancy is the starting stage at which 50 percent of the settlement area would be built-up; consolidation stage refers to booming stage at which up to 80 percent of the land would be used for housing construction; and saturation stage is the stage whereby further construction is mainly continued through vertical densification. However, the potential limitations in adapting these thresholds (Abebe) lie in the differences in context from where this concept draws their origin. This is because density (percentage of building) is relative and different country has different physical development standaards. In this case, the thresholds that is appropriate culturally and environmentally to distinguish between SDS should be locally tuned and apparent. For more explanation see the concept of urban density, apparent thresholds and spatial unit of analysis under section 4.3.

The changing stage of slum settlement from initial occupancy to the stage of absorption and saturation may be interrupted by eviction or may be influenced by flood, fire and landslide. Sometimes political attitude and administrative exertion tend to be the main controlling forces (Agnihotri, 1994). Hence, the consequential slum development stages till saturation may not be mono-directional. The general characteristics of the stages of slum development (infancy > consolidation > saturation has been discussed under conceptual frame section.

2.2. Methodological Approaches on Slum Identification and Mapping

There have been a number of studies discussing identification and mapping of slum settlements. Satellite imagery has the advantage of providing the physical coverage of urban land. However, choosing the appropriate method to collect up-to-date and reliable spatial information about slums settlements is challenging. Several approaches are used in urban areas to extract spatial information from spatial data. For example, Hurskainen and Pellikka, (2004) integrate RS and GIS methods for change detection of informal settlements using multi-temporal aerial photographs in Voi, SE-Kenya. Stasolla and Gamba (2007) introduced a semi-automatic procedure to detect informal settlements in arid environments exploiting spatial patterns. Abbott (2003) developed GIS based spatial data management framework for informal settlement upgrading in South Africa. Similarly, Sartori et al. (2002) used GIS to monitor the evolution of informal settlements and population estimation from aerial photography and satellite image in Nairobi, Kenya.

Choosing one method over another is not easy and depends on data availability and purpose of the study. Also, urban space, by its very heterogeneous and dynamic nature, becomes more complex to study by the presence of many objects different by their shape, direction, size, roof material depending on the type of habitat (Busgeeth, et al., 2008). The combination of semantic information certainly improve the quality of image classification and will make easier the identification of the slums among other objects with similarities and which can lead to confusion in interpretation. Recently, OBIA approach has been employed for detecting and mapping slum settlements through the integration semantic information (Benz et al., 2004; Hofmann, 2001; Nobrega et al., 2006) hence its adoption for this study. This approach will be explained further in the following section.

2.2.1. Object Based Image Analysis

Although pixel based classifiers are simple and economical, they are not capable of exploiting semantic information like shape, pattern, texture, neighbourhood context, etc. particularly in urban system context where many features have similar spectral reflectance. In addition, important information for image understanding is not represented in single pixels but in meaningful images objects and their mutual relations (Blaschke, 2003). OBIA instead does utilize spectral and contextual information in an integrative way (Blaschke, 2010). By looking at VHR images it is possible to see several features that can be described based on their characteristics. For example, although river and lake have similar spectral values they can be identified based on their form and shape; informal settlements have irregular patterns that could distinguish them from formal settlements without much effort. One way to make use of this semantic information is segmenting the image into objects that represent regions of similar pixel prior to the classification (Campbell, 2002). The effect of salt-and-paper (reduction of noise) can be also overcome by segmentation followed by classification. Accordingly, the work step process of the same classification tasks could be automated to a certain extent, for working on similar image. In addition, the achieved classification results can be exported to GIS in the form of vector layers for further analysis and visualization (Shackelford & Davis, 2003). Generally, OBIA can give the benefit of classification scheme or hierarchical network that can be exported and reused on more than one data set having similar context (Niebergall, et al., 2008). Similarly, OBIA has advantage of improving the quality of classification which cannot be accomplished by traditional, pixel based approach (Benz, et al., 2004). Due to these advantages utilized in image analysis, OBIA is commonly considered as the bridging element between RS and GIS (Lang & Blaschke, 2006).

2.2.2. Image Classification

After an image has been segmented into appropriate image objects, the image is classified by assigning each object to a class based on features and criteria set by the user (Lang et al., 2006). In eCognition software environment features usually define the upper and lower limits of range measures of characteristics of image objects. Image objects within the defined limits are assigned to a specific class. Image objects outside of the feature range are assigned to a different class, (or left unclassified). Commonly used features are: Colour (mean or standard deviation of each band, mean brightness, band ratios), size (area, length to width ratio, relative border length, shape (roundness, asymmetry, rectangular fit), texture (smoothness, local homogeneity), class level (relation to neighbours, relation to sub-objects and super-objects) etc.

Commonly, image objects can be classified based on samples (nearest neighbour) and using prior external knowledge stored in rule bases (rule-based classification). Though, the former one requires less training samples, the later one is more transparent and better transferable approach and has the advantages in incorporating of expert knowledge in the classification and formulation of complex class descriptions (Lang, et al., 2006). Integrating knowledge is a way to overcome the spectral similarity of different geographical features and results are more capable of expressing uncertain human knowledge about the world and thus lead to better classification results. Like the segmentation process, there is no "best" method, or combination of methods. The most appropriate method depends on objectives, image characteristics, a priori knowledge, as well as experience and preference of the user. Classes can be sorted in semantic grouping of classes or inheritance of class descriptions of child classes' hierarchies. The former one enable reduction of redundancy and complexity in the class descriptions while the later one combine classes previously separated by the classification in a common semantic meaning (Lang, et al., 2006). Generally, there are many different image classification methods (e.g., supervised, unsupervised, or sub-pixel classification). OBIA is generally considered a type of supervised classification strategy because knowledge of the user is imposed on the image as part of the input for the resulting classification.

2.3. The Slum in sub-Saharan Africa

According to the UN Population Division in 1970, only 37 percent of the world's population lived in urban areas. This proportion increased to 47 percent by 2000, and it reached 49 percent in 2005. The latest UN population projection also indicates that the proportion of urban population will rise to 60 percent by 2030, which means that about 4.9 billion people out of 8 billion are expected to be urban dwellers in 2030. Of these urban dwellers, about 4 billion (80 percent) would be living in the developing countries of Asia and Africa. That means rapid urbanisation and population growth trend is occurring currently in developing countries.

Understandably the rapid growth of urbanisation in developing countries is resulting in escalating problem of slum formation and expansion. African cities have been growing rapidly since the time of independence. For example, annual urban population growth rate in sub-Saharan Africa is estimated at 4.58 percent, which is the highest compared to other developing regions (UN Habitat, 2003). In sub-Saharan Africa slum formation has increased rapidly during the past decades (see figure 2.1).

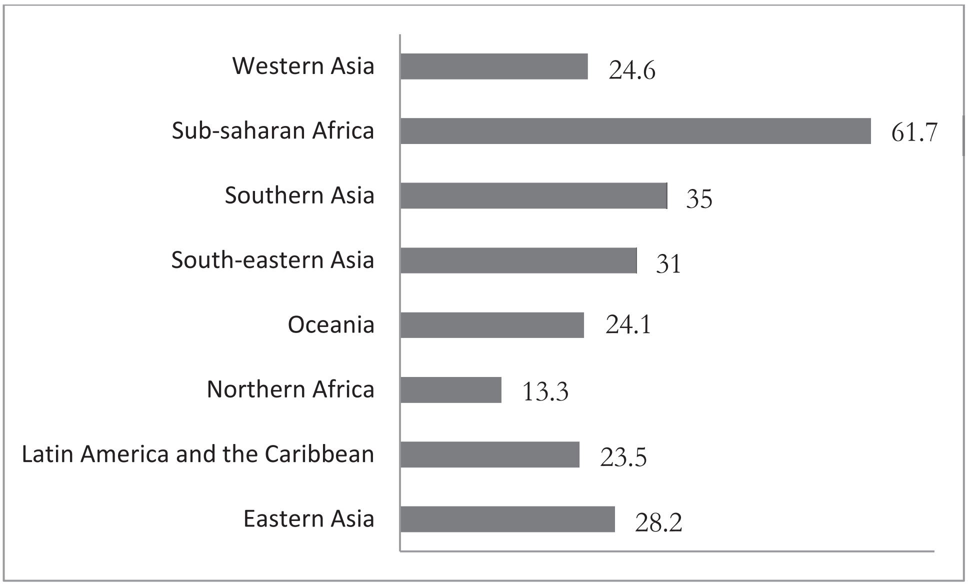


Figure 2.1: Percentage of slum dwellers by region, 2005
Source: Adapted from UN Habitat (2010b)

As figure 2.1 illustrates, in sub-Saharan Africa region, nearly two-thirds of city dwellers live in a slum (UN Habitat, 2010b). This means that a significant majority of the urban inhabitants in the sub-Saharan region of the world are slum dwellers. On top of this, the number of slum dwellers is growing at the rate of 10 percent every year. It is projected that if current growth rates persist and urban poverty rises at the same pace, there would be a clear majority of people living in urban slum areas in Africa and nearly 2 billion people in the world by 2030 (UN Habitat, 2003).

The rapid process of urbanization has led to severe urban problems, where existing urban services are quite insufficient to serve all its city and new inhabitants. Among the many problems facing urban slum dwellers, lack of access to improved services such as water, sanitation, waste removal, health services, etc. are some of the most striking difficulties. Overcrowding, unemployment, high mortality and insecure tenure are other severe disadvantageous factors typical of slum areas.

Several urban interventions have been initiated or implemented in developing countries with the purpose of working towards the goal of improving the lives of slum dwellers. Despite many efforts made in different cities across the world there are still regions where the situation is static or worse than at the beginning of the millennium (Berger, 2006). This is particularly the case for sub-Saharan Africa region where the overall progress towards improved living conditions for slum dwellers is showing the least positive results(Berger, 2006).

2.4. The slum in Kenyan Context

Kenya is one of the most rapidly urbanising countries in the region; with an annual urban population growth rate of 4.4 percent (UN Habitat, 2007). According to UN Habitat (2007), 60 to 80 percent of Kenya's urban population lives in slums with limited access to water and sanitation, housing social services and secure tenure. For example, in Nairobi, 60 percent of the population lives in slums where only 22 percent of slum households have water connections. Kibera, which is situated within the city boundaries of Nairobi, is the second largest slum settlements in Africa and characterised by lack of basic urban services and infrastructure. In Mavoko city, more than 50 percent of the inhabitants have no access to basic amenities. In Mombasa, 44 percent of the city inhabitants live below the poverty line. In Kisumu, more than 60 percent population are slum dwellers, in which half of the inhabitants live in absolute poverty. According to UN Habitat report, Kisumu is the poorest cities in Kenya. The slum upgrading programme in Kisumu and the general profile of Kisumu's slum settlements will be reviewed in the proceeding chapter 3.

2.5. Summary

This chapter focused on highlighting the concept and definition of slum settlements, the main factors attributed to slum formation and expansion, and the general nature of SDS. Similarly, the role of RS and GIS technology in detecting and analysing slums as well as various approaches and methods utilised to map and monitor slum settlements has been discussed. In summary, the rapid growth of urbanisation and the actual trend of population growth is associated with a proliferation of slum settlements in the developing countries. Slum settlement growth is also influenced by a number of other factors: poverty and inequality, limits in housing availability, and affordability being perhaps the most significant. In other words, when government low-income housing programmes and provision of basic amenities and facilities fail to keep pace with urban growth, rapidly expanding slum settlements also escalate. Little research has focused on analysis of SDS in the contexts of SSA where slum settlements are burgeoning and remain the only viable housing options for the majority of low-income urban residents and new in-migrants despite the poor service provision, inadequate housing, and vulnerable environments in these areas. These gaps, hence, present key avenues for this study. The next chapter reviews the urbanisation and profile of case study slum settlements as well as the overall nature of service and infrastructure provision in settlement areas, before introducing the research design and methodology underpinning the study.

3. STUDY AREA

This chapter provides a general description of the study area. It also gives an overview of the area such as physical setting of the area, population trend growth, economic activity, existing land use, and the general profile of slum settlements and slum upgrading programmes.

3.1. Physical Setting

The study area for this research is the city of Kisumu, located in western part of Kenya, Nyanza province, Kisumu district. Kisumu lies at the east-coast of Lake Victoria which is the largest fresh water lake in Africa and source of River Nile; yet the city is characterized by prolonged water shortages. Kisumu is the third largest city in Kenya. Kisumu has developed gradually from a railway terminus and internal port in 1901, to become the foremost commercial and industrial as well as communication and administrative centre in the Lake Victoria basin and for the Great Lakes region (Kisumu City Council, 2004, p. 8). The sugar belt and the extensive Kano irrigation scheme to the east border the city. "Kisumu is a name derived from a Luo word, "kisuma" – meaning a place where the hungry get sustenance; this could have been due to its role as a regional centre for barter trade" (UN Habitat, 2005, p. 13).

Kisumu city is divided into two topographical regions: the hilly North and the southern plain. The southern plain is liable to flooding during the rainy season, primarily because of the topography and soils. The city of Kisumu sits on the arm of tertiary lava, which covers southwards overlooking the plains to the east, and Winam gulf of the Lake Victoria to the west (Kisumu City Council, 2004). The city is situated at an altitude of approximately 1,100 meter (m) above sea level with an area around 417 square kilometre (sq. km) of which 297 sq. km is dry land and approximately 120 sq. km under water.

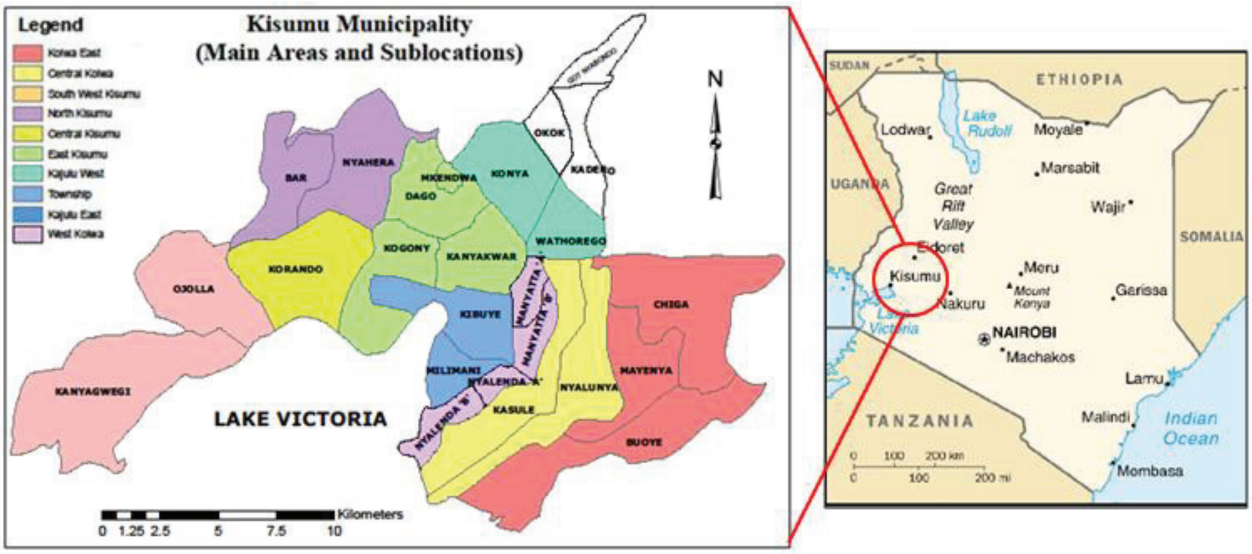


Figure 3.1: Map of Kisumu, location of case study area
Source: Adapted from (Maoulidi, 2010)

Figure 3.1 shows Map of Kisumu City which consists 25 sub-locations that can be grouped into 10 main locations (Maoulidi, 2010). According to the author, residents of Kisumu can also be broadly divided into the following three categories: urban centre, informal settlements (slums surrounding the urban centre), and peri-urban areas located on the outskirts of the city.

The city falls within the hot humid climate, with an average annual rainfall of 1245mm and a relative humidity of 70 percent. Kisumu city experiences long rains between March and June and short rains between October and November. The annual average minimum and maximum temperatures are 17.3˚C and 28.9˚C, respectively. The choice of Kisumu as a case study was motivated by the fact that the city is one among the rapidly urbanising centres in the country. In addition, Kisumu is the poorest city in Kenya and may reveal great variations in socio-economic condition. Furthermore, the city was on a global spotlight since the declaration of Kisumu as a Millennium City. Apart from the above criteria, there exist data sources, GeoEye imagery 2009 for analysis of physical development process of slum settlements.

3.2. Population Growth Trends

Population distribution and growth trends can assist the city in planning for the future needs of its citizens, such as schools, health centre, market centres, residential houses or generally physical and social infrastructures. Kisumu grew from new settlements since the beginnings of railway station for Uganda in 1901. According to UN Habitat (2005), Kisumu has around 500,000 populations (as of 1999 population census data) of which about 60% of the population live in slums. Kisumu is one of the rapid growing cities in Kenya with an urban growth rate estimated at 2.8 percent and has around 828 per Sq. Km population density. Kisumu city is undergoing rapid urbanization as more and more people in-migrate to the area in search for employment, settlement area, education, etc. According to KCC report (2004), the city was experiencing many development challenges, e.g. rapid population growth, solid waste management problems, rising poverty levels, HIV/AIDS pandemic, decaying infrastructure, high unemployment, mushrooming of slums, poor and inefficient services among others.

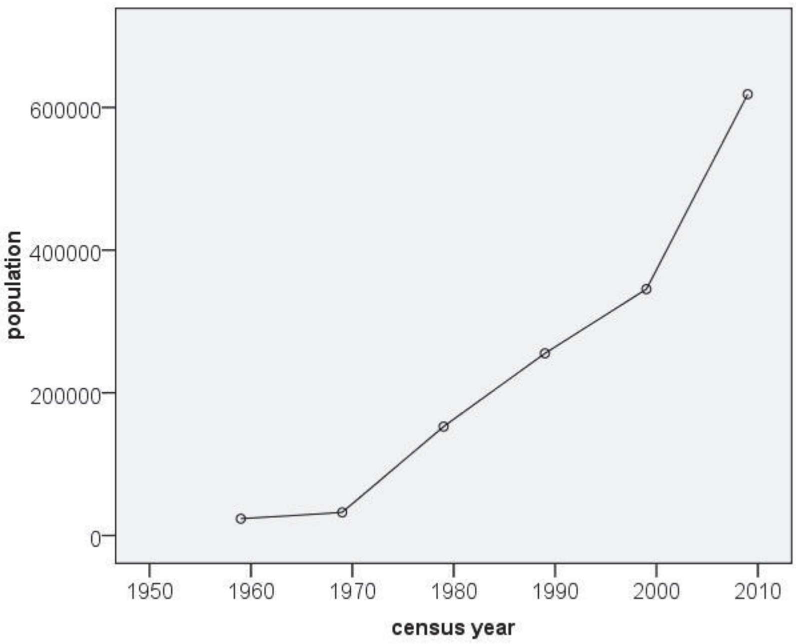


Figure 3.2: Population trend of Kisumu (1959 – 2009)
Source of data: Kenya population census 2009

Figure 3.2 shows the population trends of Kisumu city since 1950s. As the figure illustrates, the population of Kisumu has increased steadily between 1970 and 2000. The size of population of the year 2009 is almost twice as of 1999. This has been partly caused by in-migration mainly in search of job opportunities. This rapid population growth is one of the driving forces of slum formation because of social and physical infrastructure services are not keeping pace with the rapid population growth.

3.3. Major Economic Activities

Economic activities can be an indicator of the types of jobs in the city and can provide general information on the local workforce. Employment opportunities can also affect the growth rate of cities and allow people to settle in the city. If residents cannot find work in the city, then they will most probably move elsewhere or move into slum settlements since opportunities for rental housing in slum areas are relatively affordable.
Currently, Kisumu is the third largest urban centre acting as a commercial, industrial, communication and transportation hub for the Victoria Lake basin region (Kisumu City Council, 2004). Its economic significance comes primarily from its location on the shores of the Lake Victoria, which connects it to Uganda and Tanzania. Over the past decade (1960s and 1970s), Kisumu was a successful economy and large manufacturing hub with well-developed sugar, cotton and fishing industries. However, according to KCC report (2004), several industries and plants performance have scaled down rather than growth and expansion. The decline of railway and shipping services which is the major source of transport and jobs is also increasing the growing urban poverty.

According to KCC report (2004), Kisumu experiences the highest average urban poverty levels at 48 percent against a national average of 29 percent. It was indicated that, the city also experiences one of the highest incidences of food poverty with 53.4 percent in the country (compared to 8.4 percent for Nairobi, 30 percent for Nakuru and 38.6 percent for Mombasa), which makes it the poorest city in Kenya. It is estimated that 60 percent of the city's population live in slum areas (UN Habitat, 2005). The city has high levels of skilled and unskilled unemployment with a 30 percent unemployment rate, 52 percent of the working populations engaged in the informal activities (Kisumu City Council, 2004).

The main sources of income for the poor people are employment in manufacturing and processing plants, informal trades, fish trade, sale of briquettes and water vending services, urban livestock and agriculture at the subsistence level, public transportation (non-motorized e.g. 'Boda boda') among others. Inadequate and unreliable rainfall pattern has affected agricultural activities which is the main source of livelihood of the population. In addition, Kisumu is facing high HIV/Aids infection, malaria and water borne diseases such as cholera and typhoid contributing to high child mobility rate (Kisumu City Council, 2004).

3.4. Existing Land Use

Existing land use patterns is important in order to assess the city's current land uses, and then determine future land use needs. Growth and development occurring within the city in the future may require the conversion of some vacant and agricultural land to more intensified urban uses. This conversion process will determine the community's future urban form, and in turn, its attractiveness and desirability. The associations of existing and future land uses will not only have an impact on economy, but will also shape the character and livability of the community in the years to come.

In Kisumu land use in the hinterland includes small-scale rain-fed mixed farming, large-scale sugar cane farming, fishing, small-scale river irrigation, and settlement infrastructure (Kisumu City Council, 2004). "However, agriculture does not provide enough livelihood support due to frequent droughts alternating with severe floods and poorly drained, intractable soils of the flat plains. The result has been rapid rural-urban migration with a consequence of unplanned and uncontrolled urban expansion (Kisumu City Council, 2004, p. 9)." According to UN Habitat, (2005, p. 14), Kisumu's residential land use falls into five groups, namely:

- The high-class residential areas of Milimani (the former European residential area)
- The high-income residential areas of Tom Mboya-Kibuye (the former Indian residential area)

- Low and middle-income public housing (Municipal, railways, Kenya Post, Kenya Power, etc.).
- The Kanyakwar residential area, peri-urban unplanned and slum settlements and
- Rural extended boundary areas.

3.5. Slum Settlement in Kisumu and Its Challenges

Slum formation in Kisumu has been associated with the rapid growth of urban population caused by in-migration from the countryside (UN Habitat, 2005). These people come in search for improving their living standard and are usually not aware of the situation in slums and they leave the countryside with biased pictures and ideas about the life in cities. When they arrive in the city, they discover that the housing, jobs, incomes and amenities they aspired for are not available or are inaccessible. Due to this, in Kisumu, the number of slum dwellers increases by 6 percent every year. The slum belt forms the outer ring of the old city and cuts across the peri-urban areas of Mantyatta and Nyalenda neighbourhoods. Beyond the slum belt is rural land that was included into the city boundary as part of the extension.

The report by UN Habitat, (2010a) showed that access to improved water and sanitation facilities are the main challenges for slums of Kisumu in which only 40 percent of the population accessing piped water, 10 percent sewerage and 20 percent solid waste coverage. Consecutively, during the rainy season persistent flooding causes water and sanitation related disease contributing to high child mobility rate. In addition, housing provision remains one of the key challenges for the local authorities, with approximately 75 percent of the peri-urban inhabitants residing in temporary and semi-permanent structures without basic infrastructure (Kisumu City Council, 2004). It was also indicated that poor environmental management, high prevalence of HIV/Aids, malaria and infectious diseases, poor access to health services are other highly ranked challenges for Kisumu slum dwellers. On top of this, low income and job insecurity is the prime challenge for Kisumu slum residents (UN Habitat, 2005).

Since the main focus of this study is to classify and analysis SDS, other residential areas (formal areas) are not considered. Indeed, UN Habitat has identified eight slum settlements of Kisumu. These include: Nyalenda A, Nyalenda B, Manyatta A, Manyatta B, Obunga, Bandani, Manyatta Arab and Kaloleni (figure 3.3).

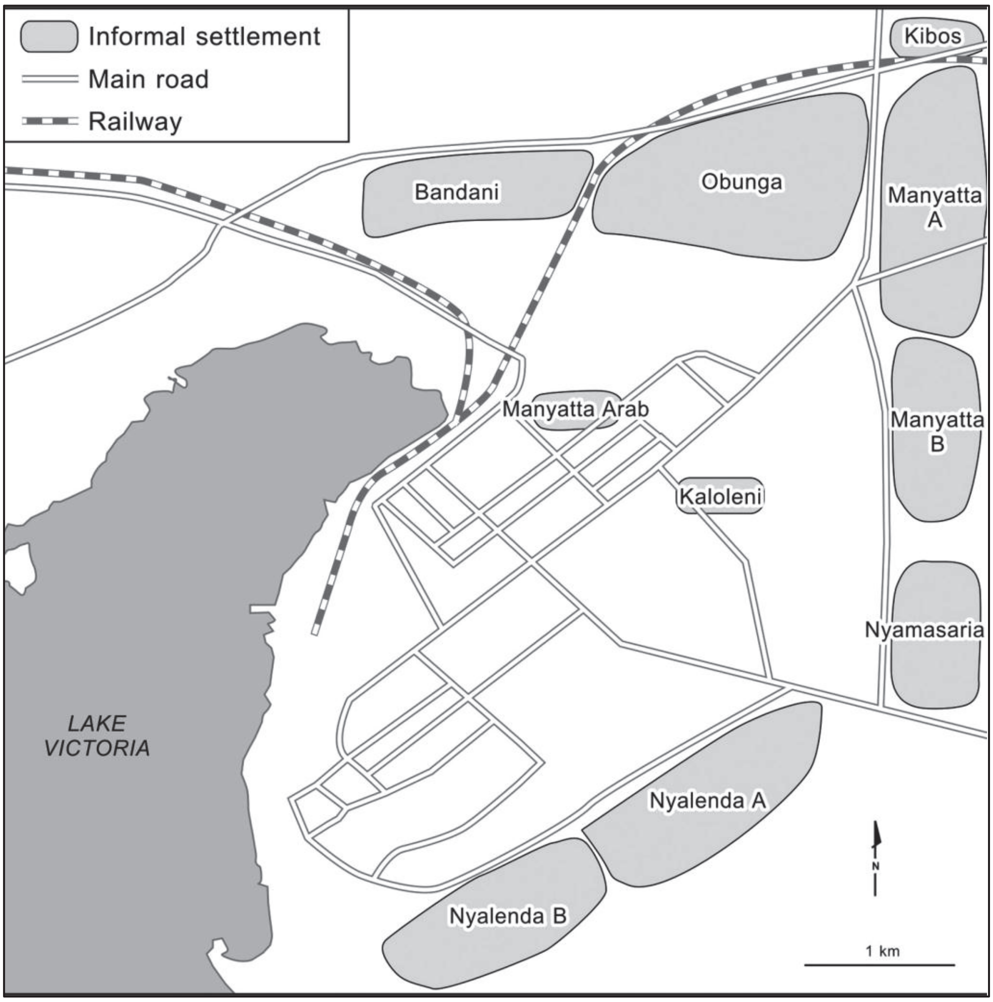


Figure 3.3: Location of Kisumu slum settlements and their boundaries
Source: Pamoja Trust

Table 3.1: Land ownership status and facilities in eight Kisumu slum settlements in 2010

Kisumu's slum settlements	% of HH without land ownership	% of HH with water	% of HH with toilet	% of HH with electricity
Bandani	74.2	2.9	47.6	2.3
Kaloleni	42	18.1	80.3	30.8
Manyatta A	81.3	22.4	57.6	24.9
Manyatta Arab	96.3	4.8	18	6.4
Manyatta B	63.6	10.3	65.9	10.1
Nyalenda	68.2	26.4	57.5	15.6
Nyawita	57.1	6.1	66.1	29.8
Obunga	80.5	2.3	12.3	2

Source: Pamoja Trust

Table 3.1 shows details of the proportion with evidence of land ownership and other services such as the proportion with water, toilets and electricity in their house or plot. Some of the characteristics of slum settlements in Kisumu are summarised below. The summary is based upon an enumeration finding of the households living in Kisumu, implemented by Karanja (2010) who is a senior research and advocacy programme officer at Pamoja Trust in Kenya.

As table 3.1 shows, more than 50 percent of Nyawita dwellers have no evidence of land ownership. Very few households have water available on their plot, although the main water pipe supplying Kisumu runs through Nyawita (Karanja, 2010). Nearly one third of households have no toilet on their plot. One third of households have electricity but most households have no connection. There are no schools in the Nyawita settlement and no government health facilities. The only health service available in the settlement is a private dispensary and a chemist set up by a women's group with support from the NGO World Vision, to help local residents get access to medicine.

According to Karanja (2010), in Obunga settlement, very few households have water connections, electricity or toilets on their plots and many use the bush for defecation. Obunga faces serious problems with flooding during the long rains and many areas are waterlogged. There is no primary or secondary school nor health care facility in the settlement.

In Nyalenda settlement, most households do not have water on their plots; more than two-fifths of the inhabitants do not have toilets on their plots and many rely on open defecation. There is little provision for drainage and parts of the settlement flood during the long rains. According to the author, there is good provision for schools; seven primary schools and two secondary schools and there is a public hospital and various private health services.

In Manyatta Arab settlement, the inhabitants feel insecure; nearly all the dwellers do not have evidence of secure tenure. Very few households have provision for water and electricity on their plot. Almost one-fifth of the households have a toilet on their plot. There are no government schools; although there are two private primary schools and one private secondary school. For health care, there is one dilapidated dispensary owned by the municipal council. The settlement was overlooked by the land adjudication process in 1976.

According to the enumeration by Karanja (2010), Bandani settlement had around 14,000 inhabitants living on a 13.1 square kilometre. The area is poorly drained and forms a bowl through which storm water runoff drains from the hills to the lake. Usually several houses in the settlement are destroyed whenever are heavy rains. Part of Bandani is swampy and provides a breeding ground for malarial mosquitoes. There is very few electricity and formal provision for water on their plot. Around half of the dwellers have pit latrines on their plots. According to the author, there is a primary school that serves both Bandani and adjacent settlements, but a number of residents take their children to more distant schools because of overcrowded classrooms, staff shortages and poor performance. There are no public health care facilities within the settlement and secondary school.

In Manyatta A and Manyatta B four out of five and nearly two-third of the slum dwellers have no evidence of land ownership respectively. In both settlement around two-fifth of the households has no toilet in their plot. Only one-fifth of Manyatta B settlements have provision of water and electricity while in Manyatta A the proportion increases nearly to one forth. Since both Manyatta A and Manyatta B are selected as a study area for this study, the analysis of their physical and socio-economic characteristics will be discussed in section 4.

Generally, due to rapid urbanization and population growth trend coupled with lack of basic services extensions, Kisumu has experiencing enormous pressure on the urban environment. With an annual population growth rate estimated at 2.8% and densities of 828 persons per sq. Km, Kisumu records one of the highest urban population densities in the country, bringing with it the associated complexities in urban planning. Consequently, there has been an increase in urban poverty, slum formation, informal activities, and disease infection rates largely associated with limited access to health facilities, as well as, indecent environmental conditions (Kisumu City Council, 2004).

3.6. Kisumu Slum Upgrading Programme

Since 2003 slum upgrading projects are underway in Kenya with international aid agencies through UN Habitat, Cities Without Slums Sub-regional Programme for Eastern and Southern Africa of Cities Alliance and in collaboration with the government of Kenya. The city of Kisumu is identified as one of the international pilot projects of the Cities Alliance's Cities Without Slums initiative. The Programme aims at improving the lives of slum dwellers through targeted interventions to address shelter, infrastructure services, land tenure and employment issues, as well as the impact of HIV/AIDS in slum settlements. It is estimated that around 60% of Kisumu's residents live in areas classified as slums with little or inadequate access to improved water and sanitation facilities (UN Habitat, 2005).

However, lack of coordination between governmental and the non-governmental slum upgrading stakeholders limited the effectiveness of the slum upgrading (Global Land Tool Network, 2008). In addition, according to this report, only marginal resources were set aside for slum upgrading by the Kenyan government and the Kisumu Municipal Council, therefore only a few interventions were implemented on a piecemeal basis.

Kisumu city has been given the status of a regional center for economic growth. Yet has substantial bottlenecks in social infrastructure and services. Pamoja Trust is tasked by UN Habitat to undertake the Kisumu slum enumeration and mapping and organizing communities into savings groups as well as settlement executive committees. Generally, according to Global Land Tool Network (2008), there is improved overall awareness on lack of service delivery to Kisumu's slums, and of intra-city inequalities.

3.7. Summary

Although it is difficult to relate the characteristics of slum formation with only a few factors, it seems however, that rapid urbanisation play a major influencing role especially on the expansion of slum settlements in Kisumu. This factor is in turn associated with the limited capacity of the local authorities to supply social and physical infrastructure services and to facilitate formal provision of housing for the low-income residents and new in-migrating population. However, as noted in the preceding sections, one of the compelling factors for the present slum settlements of Kisumu has been the rapid growth of urban population. The proliferation of slum settlements and its outward expansion in newly peri-urban areas and on-going consolidation within the relatively old settlements play a major role in shaping the city structure and the emerging slum settlement of Kisumu city. Having outlined some factors that influence the growth and of the ensuing slum settlements of Kisumu, in the subsequent chapter an attempt to identify and classify stages of slum development from spatial data on the basis of the proceeding discussion being made. The main variables in this classification are density of buildings, vegetation and bare lands, spatial unit of analysis, and thresholds to distinguish the physical development process of slum settlements. The methodology underpinning the study is now detailed.

4. DATA SOURCES AND RESEARCH METHODOLOGY

In the preceding chapters, theories and concepts about slum formation and general profile of study area has been presented. This chapter presents the bases and processes within which this study was conceived and executed. It describes the data source, tools, and approaches employed for identifying, classifying and analysing slum development stages. Generally, it outlines the overall study strategy. The work steps carried out is explained in the proceeding sections and the workflow is displayed in figure 4.1 for a better understanding. The figure shows the work steps that lead from the initial data preparation to the analysis of physical and socio-economic development processes of slum settlements within the context of Kisumu city.

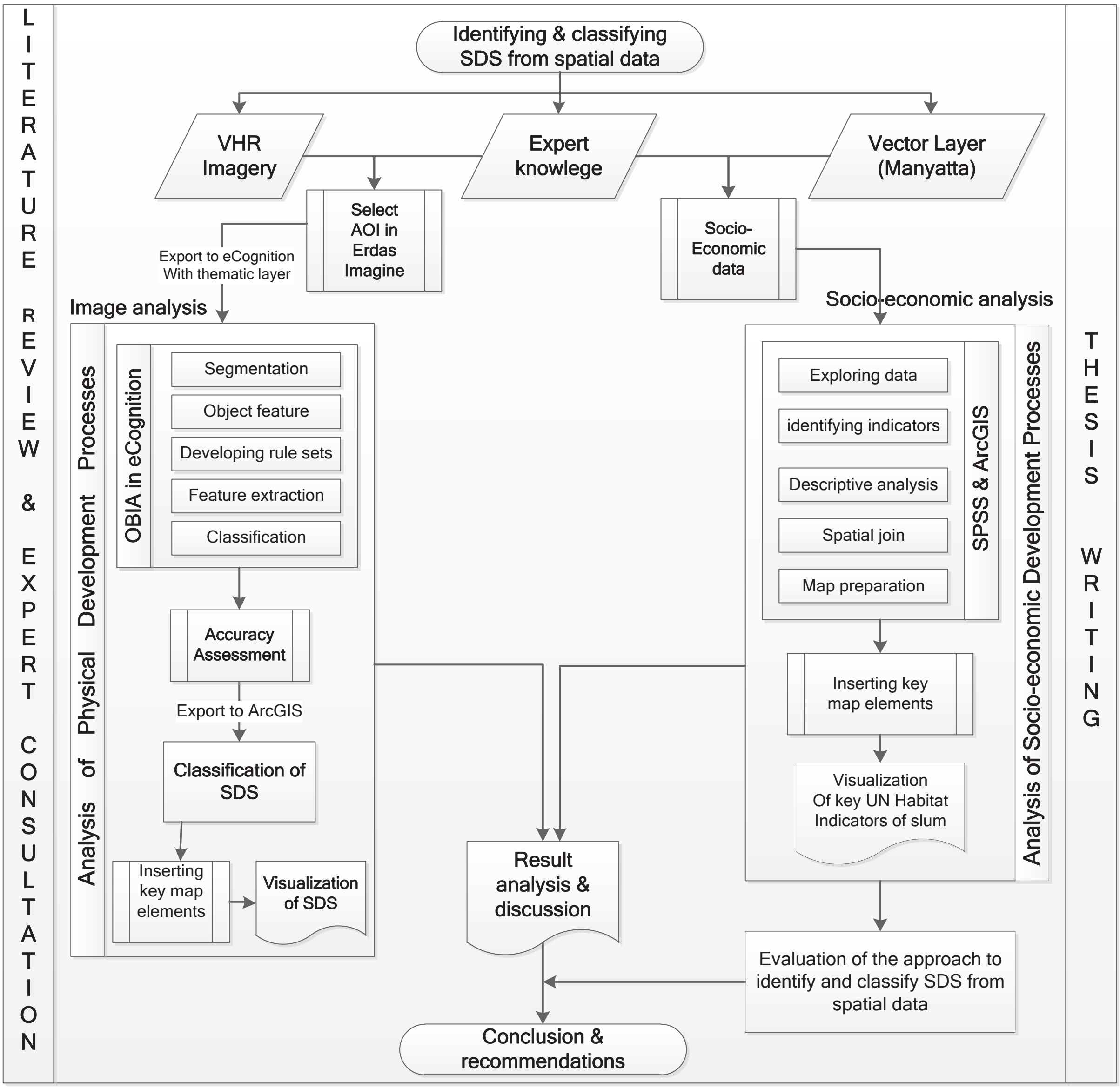


Figure 4.1: Methodological framework

4.1. Data Sources and Software Requirement

In this study, GeoEye 2009 VHR imagery (0.5 meter spatial resolution) covering part of Kisumu city is used. The image has two datasets, panchromatic and multispectral (blue, green, red and NIR band) which provide highest resolution and more land cover information. The image was acquired on 23 May 2009 at 08:21 GMT with 45.4300 and 60.711967 degree sun angle azimuth and elevation respectively. In addition to the RS data, the draft enumeration report of Manyatta slum settlements, which was provided by Pamoja Trust, was used for analysis of key socio-economic characteristics based on the defined indicators of slum settlement in section 4.4. Unfortunately, the aspired geo-referenced socio-economic data from Pamoja Trust was not obtained. Nevertheless, apart from the key socio-economic analysis, it has been briefly discussed on how analysis could have brought into the issue of SDS, if georeferenced socio-economic data at household level would have been available.

To classify and analysis SDS several software packages such as eCognition Developer 8.64, ERDAS IMAGINE 2010, ArcGIS 10 were utilized. Segmentation and classification process of the GeoEye imagery, in eCognition software were carried out on a powerful computer (high resolution). This is because eCognition Developer 8.64 software is expensive software, very computer intensive, requiring substantial processing power and large amounts of available memory which are some of the limitations of the software. In general, in this study, GIS acts as a key tool for the integration and analysis, and visualization of the spatial information about the physical and socio-economic development process if slum settlements.

4.2. Image Analysis

The image analysis approach is an object based image analysis (OBIA) approach which makes use of image objects instead of single pixels as the building blocks for image classification. As explained in section 2.2, segmentation algorithm based upon homogeneity criteria is done as a pre-classification step since the result image objects tend to be composed of spatially clustered pixels having similar gray value (Blaschke, 2003). Generally, the OBIA approach is transparent, reproducible, to a high degree comprehensible, and technically transferable to other scenes as it offers valuable methodological assets in breaking down scene complexity into meaningful image primitives (Lang, et al., 2006). The modified relevant steps of OBIA approach is depicted in figure 4.2. The proceeding sections describe the steps that have been followed to extract features from the VHR imagery in eCognition software till accuracy assessment.

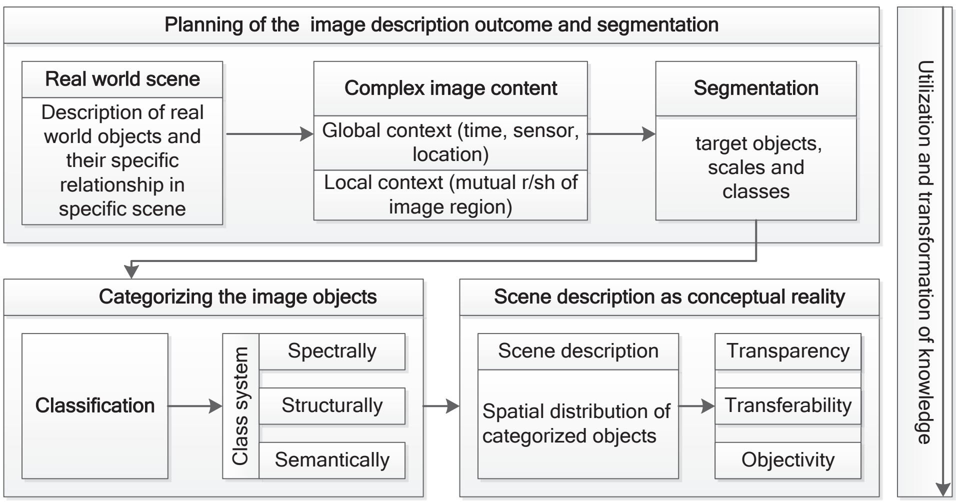


Figure 4.2: Relevant steps of OBIA approach
Source: Adapted from Lang, et al. (2006)

4.2.1. Selection of AOI and Data Preparation

Any attempt to identify and classify SDS in a city such as Kisumu ought to take into consideration a number of factors and local context some of which have been discussed in the preceding section. Basically, the first step is to distinguish between formal and informal settlements in Kisumu. Indeed, as explained under section 3.5, UN Habitat has identified 8 slum settlements in Kisumu and there is a clear boundary between formal and informal settlements. Since the focus of this study is to classify and analysis SDS within the context of Kisumu city, two slum settlements (Manyatta A and Manyatta B) has been considered as an appropriate strategy to analysis slum development stages. Manyatta A was selected as a relatively old slum settlement and consolidated case study area. Manyatta B was selected as a newly developing slum settlement. In addition, Manyatta A and Manyatta B were selected with the expectation of socio-economic data provision by Pamoja Trust. It was also considered that results from these settlements would provide a basis for further analysis of SDS in other SSA cities having similar context.

Manyatta settlement is located to the East of Kisumu's City Centre. The settlement is further divided into two, Manyatta A and Manyatta B with a total of 9 administrative units (figure 4.4). Manyatta A comprises Kondele, Meta Meta, Kona Mbuta, Flamingo, Gonda and Magadi while Manyatta B comprises Upper Kanyakwar, Lower Kanyakwar and Kuoyo. Manyatta has a total of 11,571 households, with Manyatta A having 6,424 households and Manyatta B having 5,143 households (Pamoja Trust, 2010). According to situation analysis, Manyatta A and Manyatta B have a population density of about 20,955 and 6,372 people per square kilometre respectively. Manyatta A is approximately 2 square kilometres area while Manyatta B is around 3.3 square kilometres area.

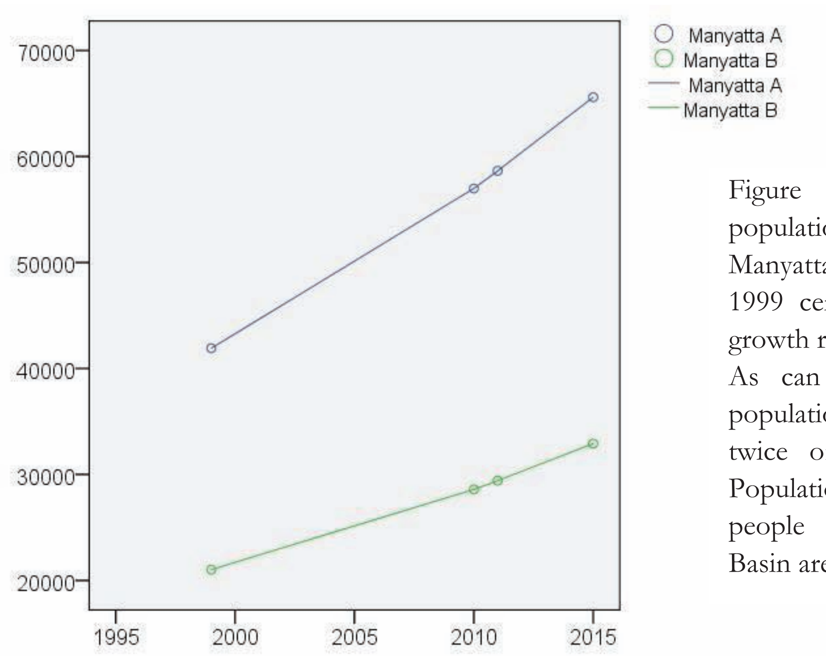


Figure 4.3 illustrates projected population of Manyatta A and Manyatta B settlements based on the 1999 census data and recommended growth rate.
As can be seen from the figure, population of Manyatta A is more than twice of Manyatta B as of 2009. Population is expanding rapidly as people from the surrounding Lake Basin area move into the city.

Figure 4.3: Population growth trend of Manyatta A and Manyatta B
Source of data: Kenya CBS (1999) and Millennium Cities Initiative (MCI)

The building footprint and road networks of the year 2005 were used to guide segmentation process. Some buildings were digitized manually since there are new buildings in the image acquired in the year 2009 (figure 4.4). The thematic layer (building footprints and road networks) were used in segmentation process alone to reduce the complexity of image classification in eCognition environment. Figure 4.6 shows the general steps to extract the feature classes using OBIA in eCognition software till visualization of the image classification result in ArcGIS.

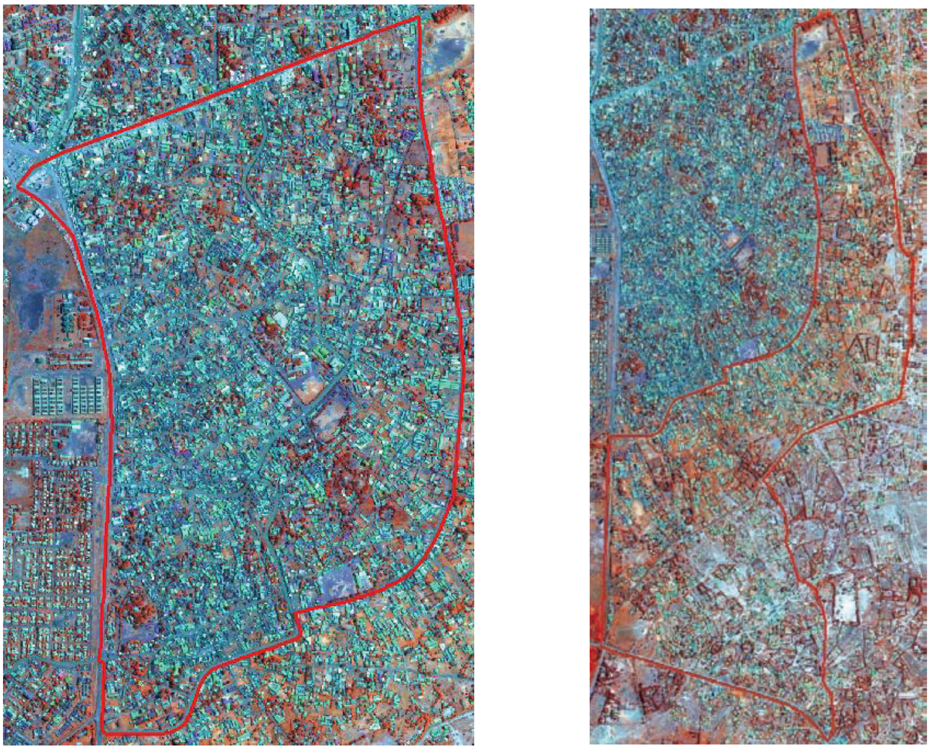


Figure 4.4: VHR GeoEye 2009 image of Manyatta A (left) and Manyatta B (right)

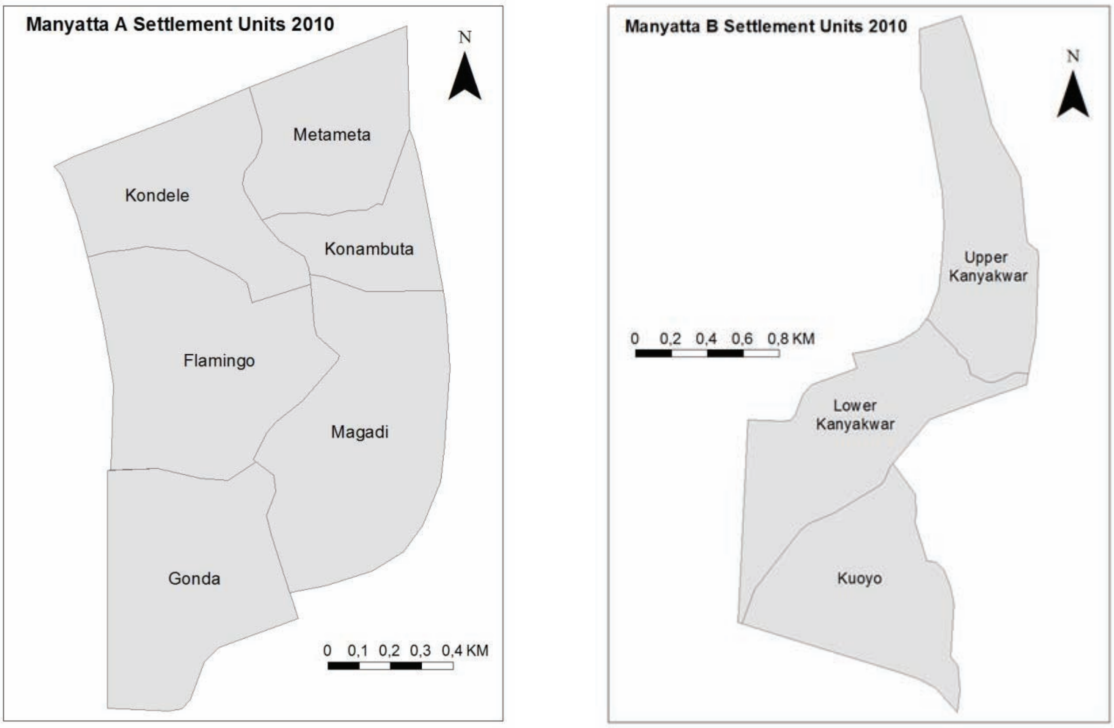


Figure 4.5: Manyatta A and Manyatta B administrative units

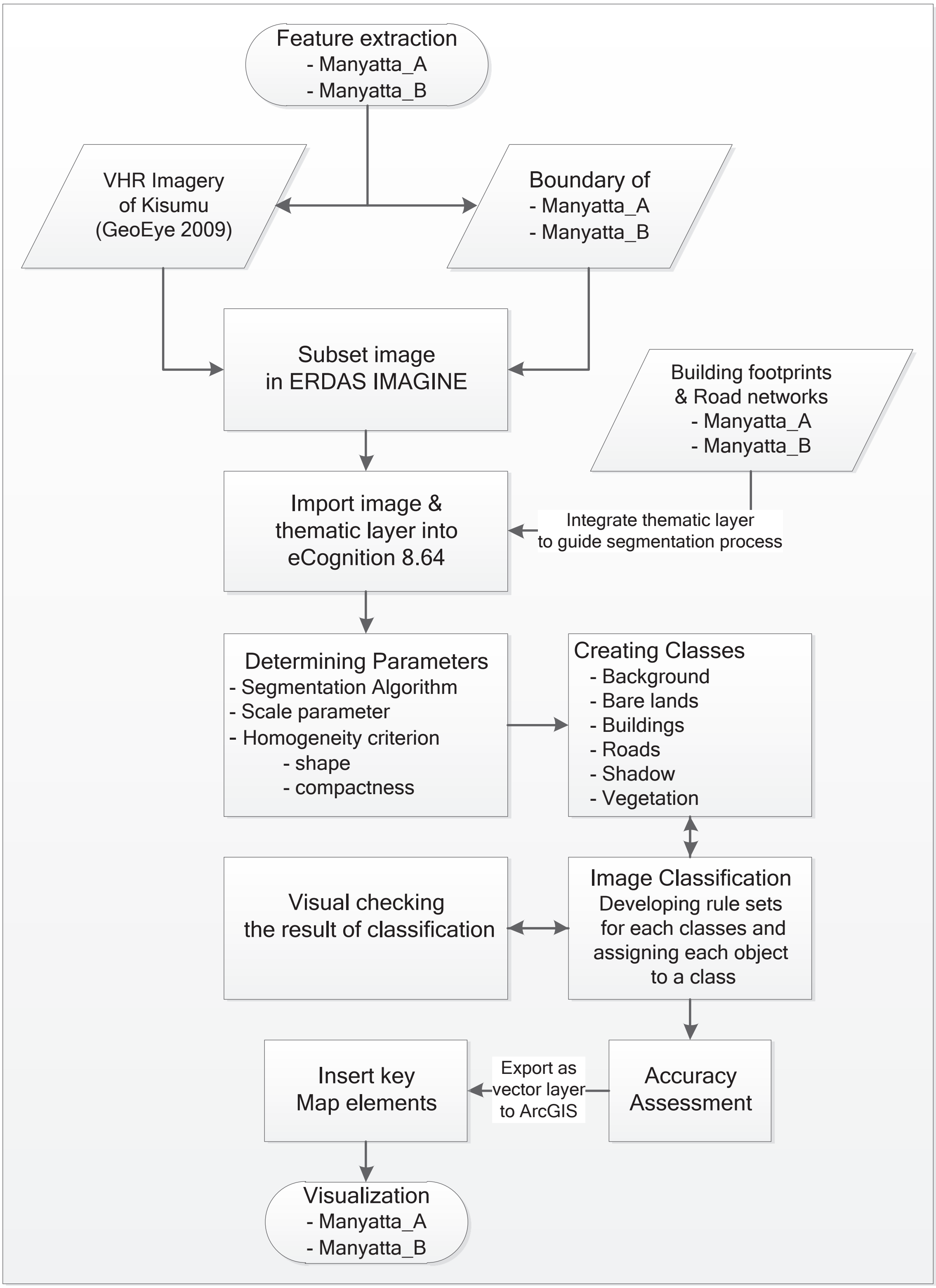


Figure 4.6: General steps of feature extraction using eCognition software

4.2.2. Visual Image Interpretation

When using a computer for classifying an image, structural knowledge is transferred to the computer and making it trying to imitate certain characteristics of the human way of image interpretation. Visual interpretation therefore is the interface between RS and GIS. Thus, this traditional, qualitative way of visual interpretation is an ultimate benchmark, still kept its significance in many RS applications and undefeated in analysing complex scene contents with ease (Lang, et al., 2006). In many cases, image interpretation is often applied to evaluate and visually check the results of more automatic methods for accuracy assessment and the most successful method to obtain reliable and accurate information from RS imagery.

However, visual interpretation is highly user-dependent process, which is carried out based on the skills and experience of interpreter to detect, identify, describe and assess object information (Lang, et al., 2006). It may also be time-consuming for less experienced interpreters, may not be cost-effective for large areas. In addition, problems like selection of appropriate levels of generalization, placement of boundaries when there is a graded transition etc., may occur with visual interpretation that may be solved via segmentation (Lang, et al., 2006).

In this study, visual image interpretation has been applied in accuracy assessment to see whether image objects are classified, misclassified or unclassified according the respective rules. However, the content of image appears in several scales. Human eyes perceive shapes, texture and spatial arrangement of certain elements and/or experience influences image interpretation. The analysis is based on the elements of visual interpretation which include location, size, shape, shadow, tone and colour, texture, pattern, and association.

4.2.3. Multiresolution Segmentation

The first step in the OBIA is the segmentation of the image into image objects. Segmentation starts with one pixel size and merges them in numerous loops iteratively in pairs to larger units until an upper threshold of homogeneity is not exceeded locally. The seed looks for its best fitting neighbour for a potential merger. If best fitting is not mutual; the best candidate image object becomes the new seed image object and finds its best fitting partner. When best fitting is mutual, image objects are merged. The loops continue until no further merger is possible. Most of the time large object primitives are good for successful image analysis, yet small enough to be used as building blocks for the objects to be detected in the image.

In this study, multiresolution segmentation was applied on the four pan-sharpened GeoEye image with different scale parameter. Multiresolution segmentation is a global region growing method based on a pairwise region merging technique (Trimble Germany, 2010). It minimizes the average heterogeneity and maximizes their respective homogeneity of the segments to be created. The homogeneity criterion is defined as a combination of both colour and shape homogeneity. The colour homogeneity is based up on the standard deviation of the spectral colours, whereas the shape homogeneity is constituted by weighting compactness vs. smoothness. Shape criterion determines to what extent shape influences the segmentation compared to colour. For example, a shape weighting of 0.4 results in a colour weighting of 0.6. Compactness is defined by the ratio of a segment‘s perimeter to its area; smoothness is defined by the ratio of the object‘s perimeter to the perimeter of its minimum bounding box parallel to the image grid. Both together form the shape homogeneity form by weighting them to the sum of one. Figure 4.7 shows the segmentation result at two different levels. Essentially segmentation result is depending upon the scale parameter. On the other hand scale parameter is determined based upon try-and-error and purpose of the segmentation which is further explained in the following section.

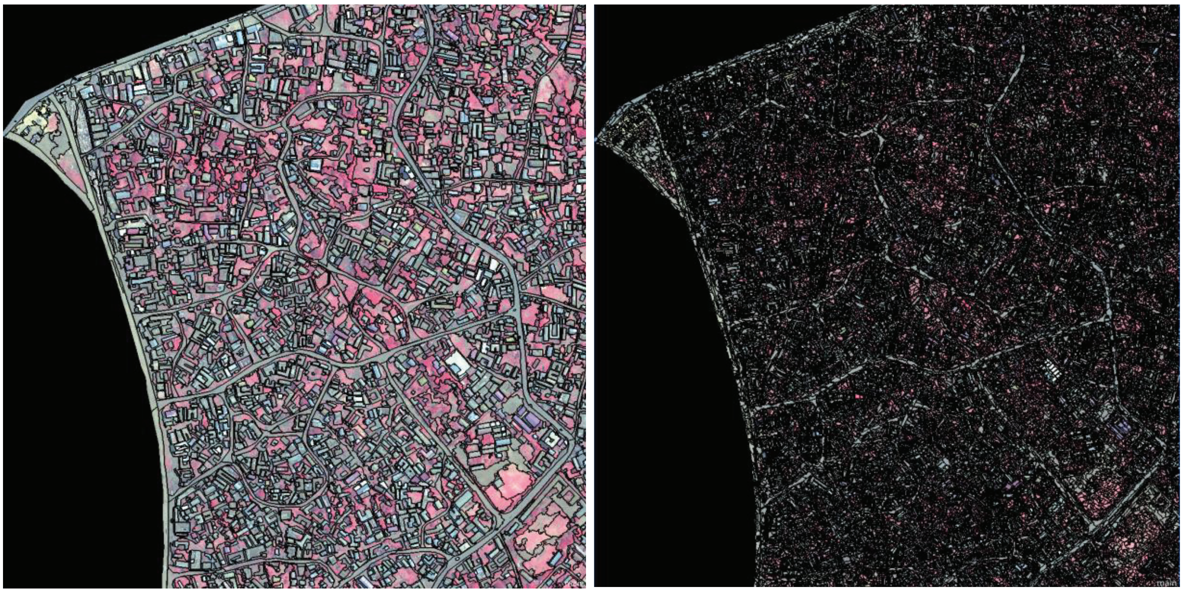


Figure 4.7: Part of Manyatta A segmentation result at level 1 and level 2

4.2.4. Scale Parameter

In the segmentation process, the selection of appropriate scale parameter is crucial. It directly influences the accuracy of classification. Determining the most suitable scale for image segmentation is challenging, since there is no objective method exists for setting the scale parameter in segmentation algorithms (Kim et al., 2008). In addition, it is difficult to determine appropriate scale parameter with a one fit all approach to represent all feature of interest as objects are either under-segmented or over-segmented. Consequently, the determination of appropriate scale parameters settings is often based upon subjective trial-and-error methods (Meinel & Neubert, 2004). Besides the scale parameter, shape and compactness weighting might highly influence the segmentation results, mainly in classifications of spectrally similar objects (Drǎ guţ et al., 2010). Figure 4.8 shows multiresolution concept flow diagram and the algorithms behind scale parameter and composition of homogeneity.

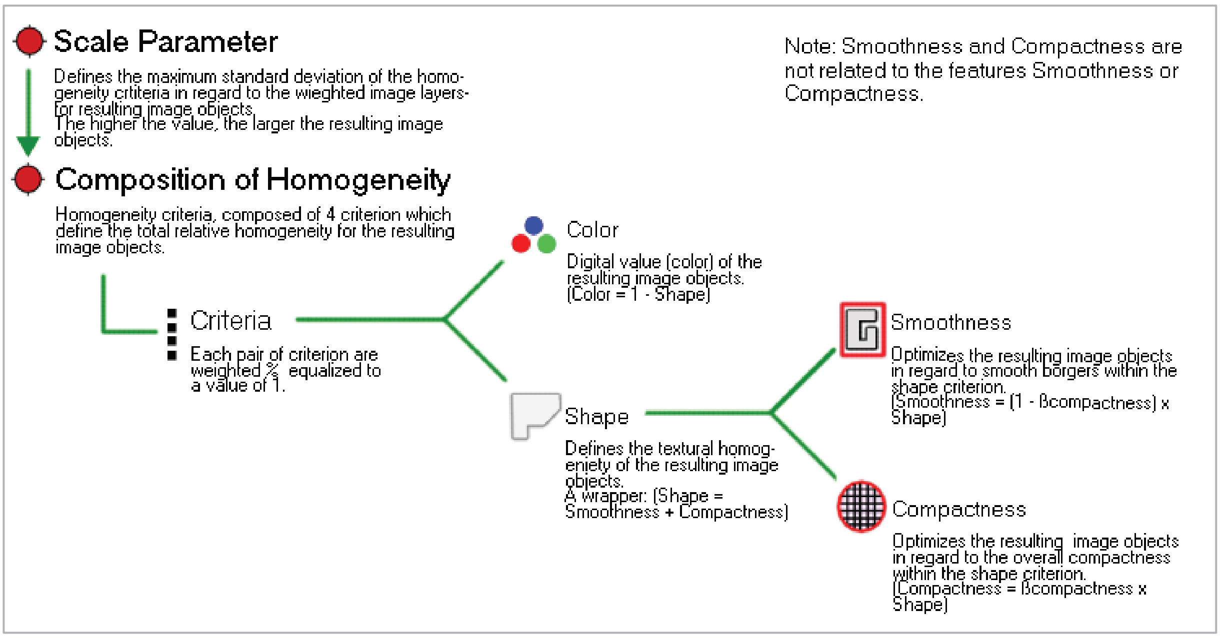


Figure 4.8: Multiresolution concept flow diagram
Source: eCognition Developer 8.64.0

4.2.5. Image Classification

The image objects that suit the purpose are produced using different scale, smoothness and compactness parameter. Then, the classification algorithms analyse image objects in line with the formulated rule sets. Subsequently objects are assigned to a class that best meets the specifications of the defined rule sets and according to their similarity to samples taken. In this study, area of interest (Manyatta A and Manyatta B) was selected in Erdas imagine and exported to eCognition software package. Thematic layer (building footprint and road networks) was used as pre-defined boundaries for segmentation process alone. Multiresolution segmentation was applied on the imagery at two levels of hierarchy using different scale parameter to extract features of interest (table 4.1).

Table 4.1: Multiresolution segmentation parameter

	Segmentation Algorithm	Scale parameter	Composition of homogeneity criterion	
			Shape	Compactness
Level 1	multiresolution segmentation	100	0.5	0.3
Level 2	multiresolution segmentation	14	0.5	0.3

Since thematic layer restricts segmentation to the edge of buildings and roads, image objects for buildings and roads require large scale parameters. If the scale is too small, the segmentation will generate many fragmentations. Hence, through trials and error, 100 scale parameter at level 1 is used to classify background, roads and buildings whereas 14 scale parameter at level 2 is used to extract shadow, vegetation and bare lands.

Background is classified as anything with a brightness value of zero. Shadow is classified based on their mean of brightness values less or equal to 265. Basically the determination of the threshold was done based on trial-and-error techniques. Then roads and buildings were classified according to the specifications of the defined rule sets (figure 4.9). Ratio of length to width, rectangular fit and asymmetry were used to extract roads from other features. For building extraction, rectangular fit and smaller area were used to classify from other features. At level 2, objects having greater or equal to 0.56 NDVI value are classified as vegetation. Finally, the remaining unclassified image objects were assigned to the bare land class. The classifications were adjusted through refinements that addressed some of misclassified and unclassified image objects.

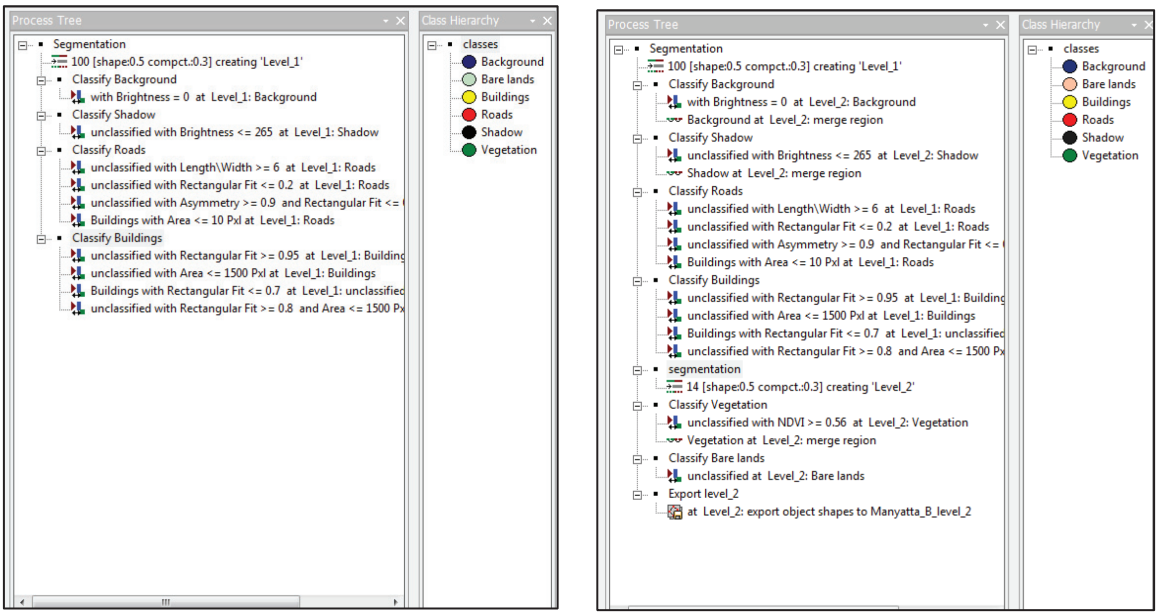


Figure 4.9: List of rule set at level 1 and 2

4.2.6. Accuracy Assessment

Accuracy assessment is an essential component in image analysis to assess level of possible confusion, reliability of the class assignments and the overall accuracy of the results. Image classification is not complete till its accuracy is assessed (Tso & Mather, 2009). To perform accuracy assessment, reference area (ground truth) is required. However, "ground data do not necessarily represent reality, due to observation and recoding errors, mislocation of test data sites, differences caused by changes in land cover between the time of observation and the date of imaging, and so forth (Tso & Mather, 2009, p. 69)." Besides, in this study, there was no field campaign and on-site samples. Therefore, samples from the image have been used to estimate the quality of the classification results as long as these samples are not used to classify the images objects. In other words, there are no samples taken for training data set in order to classify or extract feature. Samples are taken randomly for the six classes that later converted to a Training and Test Area masks (TTA). Basically, during classification process, results for each class have been checked visually, as explained in visual image interpretation section.

According to Tso and Mather (2009), the most common tool used for the classification accuracy assessment is in terms of a confusion (or error) matrix. An error matrix is a square array of dimension $n \times n$, where n is the number of classes. The columns in an error matrix represent sample data, while rows represent the classification result. In eCognition software package, error matrix based on TTA mask can be estimated where several accuracy measures can be displayed. Several indices of classification accuracy such as overall accuracy, producer's accuracy, user's accuracy, and Kappa coefficient can be derived from the error matrix.

Overall accuracy treats the classes as a whole and does not provide specific information about the accuracy of each individual class. Furthermore, the overall result can be misleading. The producer's accuracy estimates the proportion of pixels in the sample data set that are correctly classified. Actually it is a measure of omission error. User's accuracy represents the probability that a classified pixel actually represents that information class on the ground (in this study sample data set). User's accuracy is a measure of commission error.

The overall accuracy, producer's accuracy, and user's accuracy, while quite simple to use, are mainly based on either the main diagonal, columns, or rows of the error matrix only, which does not use the information from the whole error matrix (Tso & Mather, 2009). However, Kappa coefficient uses all of the information in the error matrix to estimate the accuracy of the classification. It should be noted that sample size and sampling scheme are important for the above accuracy assessments. According to Tso and Mather (2009), simple random sampling is required and minimum sample size is needed in order to ensure level of accuracy. In this study, the sample data sets are enough to represent the characteristics of each class and all samples were taken randomly. For example, more than 136837 sample building pixels having different roof colour have been taken in Manyatta B (figure 4.10).


Figure 4.10: Part of Manyatta B sample buildings for accuracy assessment

4.3. Spatial Analysis

Subsequent to image classification and accuracy assessment, all feature classes are exported as vector layer. The focus of this study is not only the feature extraction or recognition itself but rather the classification and analysis of SDS in the neighbourhoods using the result of classified image. In GIS environment, it is possible to play around GIS functionality to classify slum development stages. Basically slum settlements are defined mainly by their physical and infrastructural environment, instead of the demographic conditions of inhabitants, while it can be certain that the inhabitants have some impact on the physical environment (Weeks et al., 2007).

According to the authors, the important aspect of a slum is that it is a characteristic of place, not specifically of the people residing there. Similarly the UN Habitat definition of a slum refers to an environment where every place is composed of individual housing units. Thus, every neighbourhood will exhibit some variability with respect to its slumness and that slum is a continuum, rather than a dichotomy (Weeks, et al., 2007). Hence, thresholds along this continuum might be required in order to classify slum settlements into SDS, but the arbitrariness of such thresholds should be apparent and in line with the physical planning standards of the city (study area). Therefore, it is possible to identify SDS from satellite imagery, thus improving our analytical capabilities in similar context of the world where detailed census data at the local level are typically not available.

4.3.1. Spatial Characteristics of Slum Development Stages

The main theme and contribution of this study is the identification and classification of SDS from spatial data, which is rarely investigated in SSA. Features of interest have been extracted from satellite imagery using the concept of OBIA in eCognition software. The process of classifying SDS continues by identifying spatial characteristics of SDS and defining thresholds that is appropriate contextually to differentiate slum development stages in to infancy, consolidation and saturated stages and basic spatial unit in which analysis can be carried out.

In this study, the bases of classification of SDS rely on the proportion of vegetation, impervious surface and bare lands. According to Ridd (1995), among many elements vegetation, impervious surface, and bare soil are the three fundamental component of urban areas. Figure 4.11 illustrates the general land cover composition to simplify heterogeneous urban areas to simple combinations of three basic ground components based upon Ridd's V-I-S model. In the figure, each axis represents one component and the percentage of that corresponding component. According to the author, urban areas evolve internally and at the periphery, where there is an associated change in composition of vegetation, impervious surface and bare soil.

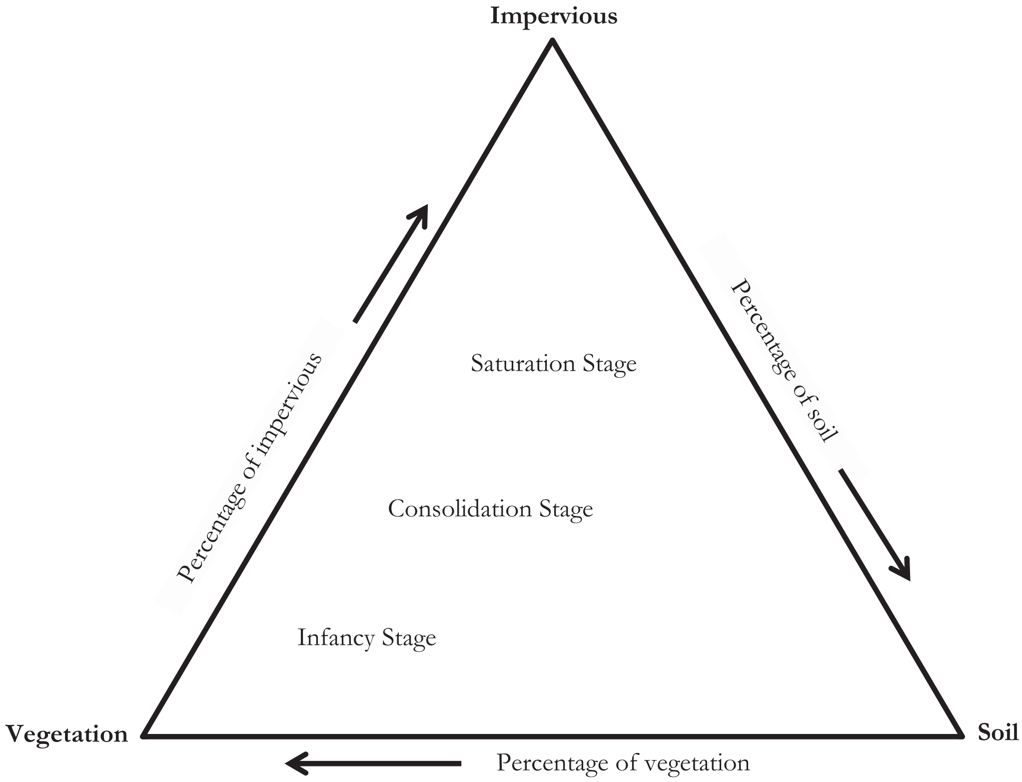


Figure 4.11: The general urban land cover composition
Source: Adapted from Ridd's (1995) V-I-S model

In this study, among the three land cover composition, the proportion of buildings in the neighbourhood is the main variable playing a role in classifying SDS. On the other hand, according to Netzband et al., (2009), existing vegetation and other open areas are considered as positive urban structure elements in terms of their ecological functions of biodiversity and production of oxygen. For example, social functions for individual recreational purposes and social meeting points. Hofmann, et al (2011) also describe that, in urban areas, vegetation play a critically important role in the quality of life and they have remarkable impact on the local microclimate and the regional climate of the city. According to the author, vegetation affects urban climate by moderating temperature, increasing humidity, influencing wind speed and reducing noise. Further desirables are reduction of solar radiation, view screening and visual amenity.

However, green spaces are not distributed evenly throughout the neighbourhood. Therefore, the spatial distribution and density of urban vegetation is of interest for city planners as well as for real estate developers and of course for individuals looking for attractive residential and business locations. For example, if the neighbourhood have trees, there are shadows and consequently the environment is pleasant and vice versa.

In cities located within hot humid coastal tropical climates like Kisumu, the presence of shadows from plants is of vital importance to improve the microclimate and enhance comfort living within dwellings environments. For example, outdoor life in a warm humid climate is only pleasant if there is a breeze, shadow and protection from extreme weather conditions. Shadow tree filters the sunlight, reduce air temperatures and protect smaller plants. Environmental qualities are determined to some extent by the degree of exposure to shadow from trees to buildings and open spaces.

Generally, the inclusion of vegetation and bare lands to classify SDS is important to generally examine the environmental quality and for provision of infrastructure and redevelopment. In this paper, vegetation includes trees and grass lands. Impervious surface refers to roofs of residential buildings. Bare soil refers to bare lands. The assumption is that the spatial composition of slum areas can be classified by the proportional abundance of vegetation, impervious surface and bare lands. In other words, percentage of each of these types of surface materials could be indicator to classify SDS within a context of Kisumu city.

4.3.2. Concept of Urban Density

There has been varying perceptions among professionals to the concept density in different disciplines such as planners, economists, psychologists and ecologists. For example, a psychologist or a sociologist may concentrate on the effects of perceived density on mental well-being. According to (Alexander, 1993), there is no simple, clear definition of perceived density. Rather, it is a complex concept involving the interaction of perception with the concrete realities. According to this author, in the field of planning, a misunderstanding arises because of the different kinds of density used such as neighbourhood density, net density, gross density etc. Another ambiguity arises from the use of the concept without clearly defining it. In many studies, density has been referred to as high or low, without a definition of what is a high or a low one. High and low densities are relative measures. They differ between countries and communities, and they are dependent on which perspective density is being discussed.

Density is a term that represents a relationship between number of units, people, trees, buildings, etc. in a given physical area. For example, population density refers to the number of persons per unit ground area of development, whereas physical density refers to land use ratios. The former one which viewed as a matter of number of people per unit area is not a very useful concept. This is because neighbourhood having the same number of people may therefore have different perceived densities and areas with fewer people may be perceived as dense due to physical settings to perceived experiences of density. Most times people see low perceived densities as one of the characteristics of a high quality environment and vice versa.

There is a common understanding that higher densities is efficient regarding infrastructure provision and maintenance, efficient utilisation of land, high levels of access and increased surveillance in the use of spaces (Acioly & Davidson, 1996). However, it is worth noting that if higher densities are not well guided, they create problems of congestion, overloaded infrastructure, and urban inefficiencies (Figure 4.12). Generally, infrastructure cost for installation and operation is inversely proportional to increased density as long as it is not extremely high and unguided density.

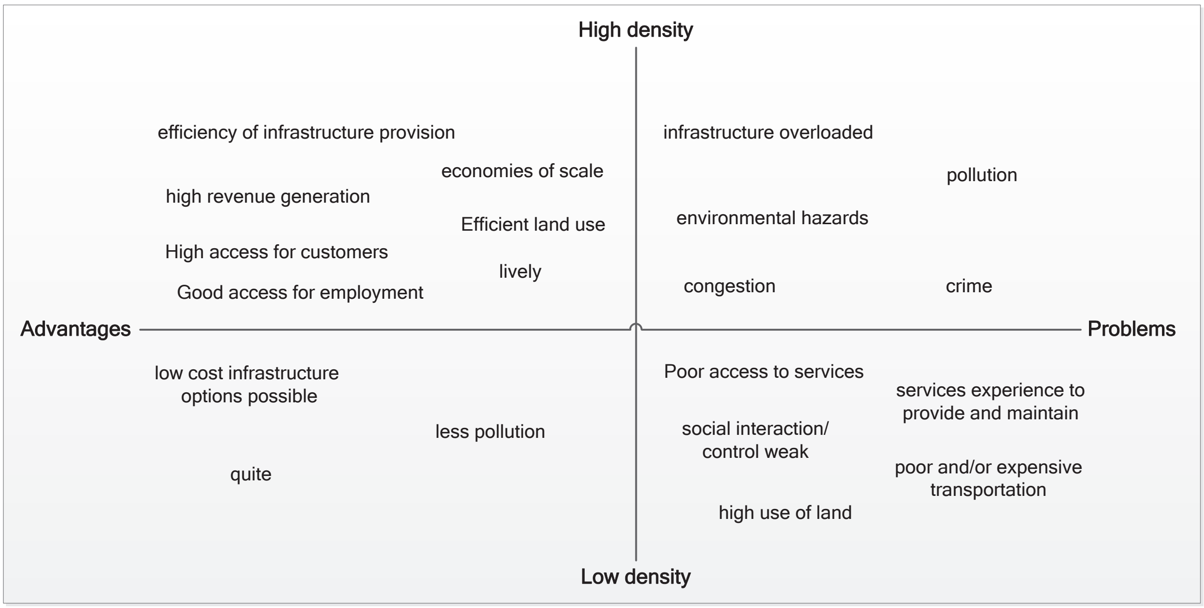


Figure 4.12: Advantages and disadvantages of high and low density
(Source: Acioly & Davidson, 1996)

Pont and Haupt (2007) have discussed different categories of physical density. Net residential density includes the area occupied by the housing itself, any services and facilities for its immediate benefit, private gardens, children play areas and incidental open spaces. It includes parking spaces, access roads within the site and half the width of surrounding roads. Net density refers to the actual lots used for development after allowance to roads, parklands, local shops, primary schools, open spaces and other types of development and non-development land excluded from calculation. Gross residential density (neighbourhood density) includes, in addition to the above, open spaces serving a wider area and other landscaped areas, primary schools, local health centres, distributor roads and transport networks, small scale employment, services and mixed use. It does not normally include secondary schools, town parks, town centres, large industrial and commercial areas or major roads and transport interchanges. Town or overall density represents to population related to all urban activities and uses of the whole town. Site/ plot density represents to the density on a specific site excluding public roads and public open space. Gross and net residential density, which are typically expressed as dwelling units per hectare, are widely used methods to determine density (Pont & Haupt, 2007). Dwelling unit sounds much better because it reveals number of dwelling units per unit area and gives a general overview of the physical density of the environment, whereas population is variable based on household size. Consequently, area that is being considered needs to be specified. Saying net or gross density is not enough. It is important to specify what is included and what is excluded to make density figures truly comparable.

In this study, net physical density (building footprint, vegetation and bare land) has been employed to classify and analyse SDS in Manyatta A and Manyatta B. While people evaluate their environments as perceived, it is the net physical density that provides a basis to objectively assess spatial characteristics of a place. Net density is of great relevance because it shows the actual intensity of development of the settlement at a lower scale levels. In density calculation road networks and shadow were excluded in because in Manyatta slum settlements (in Kisumu context), roads are irregular and unevenly distributed and their boundaries are not clear. The ambiguities influence the conventional definition of net density and seem to be biased to settings with well-defined roads. In the case of shadow, since there is no shadow feature class in reality, it is challenging to aggregate it to other feature classes. This is because trees, buildings, or other features having height, either cast their shadow on buildings, grasses, trees, or roads.

By taking into account the time of image acquisition (08:21 am), it is challenging to aggregate which shadow to which feature classes. In summary, building footprint, vegetation and bare lands are features being considered excluding the non-residential areas such as schools and their respective vegetation and bare lands. General operational steps to compute the percentage of these features per hectare and classify SDS have been shown in figure 4.14.

4.3.3. Spatial Unit of Analysis

A slum is a cluster of houses, a slum is an area, and therefore, an individual house is not considered as a slum (Agnihotri, 1994). Thus, how many houses: 2 or 7 or 11 that make an area a slum? Hence, defining the smallest cluster size is difficult and demarcation of slum in such case is not always easy as the slums may extend to larger space in the course of time. On the other hand, aggregation of data at the city level may hide the spatial variation of the urban structure and thus, of slums. Thus, a standardized geometry is required to support longer-term monitoring as well as planning applications as image analysis produces a high resolution map of the land cover features of interest (Hofmann, et al., 2011). An alternative approach is to define slums as geographic areas which are likely to capture the specific needs of that community and is easier and cost-effective way to improve the spatial characteristics of that particular area.

According to Patton (1987), the units of analysis depend on prior decision on the focus of the study. According to Weeks, et al. (2007), spatial units of analysis at the contextual level vary rendering the scales of investigation (global, regional, and local) and criteria (social, political-administrative, ecological). Units of analysis may include individual persons, small groups, household, communities, administrative neighbourhoods, census tracts, cities, states or regions if the focus is on international programmes. In identifying the units of analysis Patton argues as follows: "The key factor in selecting and making decisions about the appropriate unit of analysis is to decide what unit is that you want to be able to say something about at the end of the evaluation (Patton, 1987, p. 51)."

Since one of the main interests of this study is to use density of buildings, vegetation and bare land to classify SDS, units of analysis for this study is 100 meter resolution (see figure 4.13). This unit of analysis would decrease the residential and socio-economic heterogeneity in the neighbourhood. In addition, the regular grid is well suited as a common framework for integration of data sets from different sources and lends itself easily to a broad range of analysis techniques as well as visualization approaches (Hofmann, et al., 2011).

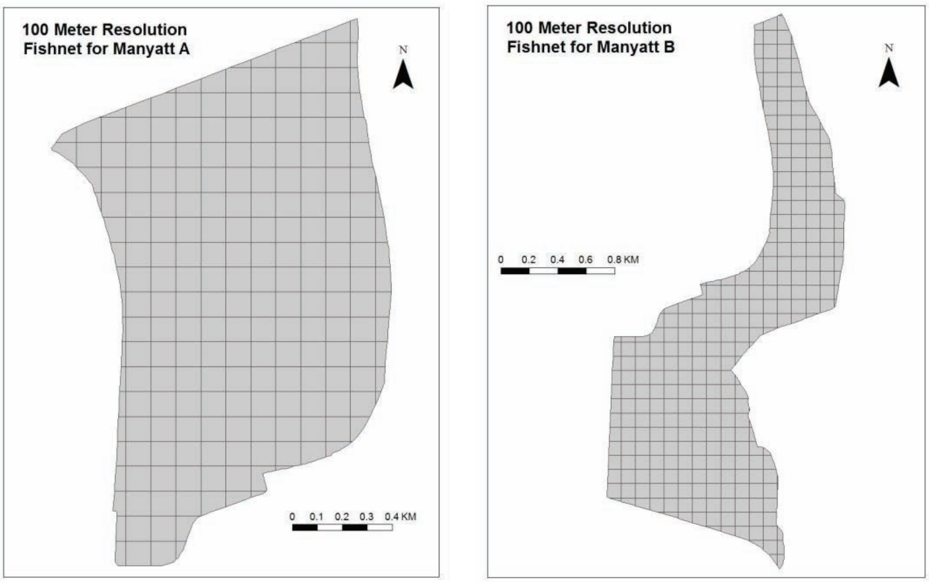


Figure 4.13: 100 x 100 meters resolution fishnet for Manyatta A and Manyatta B

4.3.4. Creating Thresholds to Distinguish SDS

As discussed in section 4.3.1 urban areas can be represented as a set of combinations of impervious surface, vegetation and bare soil. As it can be seen from figure 4.11, each SDS yields a range, not a point. The challenge is defining thresholds that are appropriate culturally and environmentally. This is because proportion of land cover features varies from place to place. The reliability of threshold also depends on the spatial analytical unit.

Quite often people talk about low, medium, and high densities while there are no agreed upon standards for what constitutes high, medium, and low densities. For example, a high density in Kisumu might be medium or even low density in Delhi. Generally, high levels of impervious surface along with low vegetation would be indicative of dense and saturated slum areas, while high levels of vegetation would be indicative of infancy stage or low-density residential neighbourhood. Bare soil may be associated with initial stage of slum areas relatively with little impervious surface.

Kisumu is in tropical zone and the imagery was acquired in the fourth week of May (Kisumu city experiences long rains between March and June), in which vegetation flourishes naturally and relatively dynamic land cover class. Thus, the proportional abundance of vegetation and bare soil could be interrelated to each other. This means that high proportional abundance of vegetation and low proportional abundance of bare soil or vice-versa would be indicative of infancy. Saturated slum areas are most likely associated with less vegetation and high impervious surface.

If the percentage of buildings is high and the percentage of either vegetation or bare lands is low, the neighbourhood is most likely at saturation stage. If the percentage of buildings is low or the percentage of vegetation is high and the percentage of bare lands is low, the neighbourhood is most likely at infancy stage. If the neighbourhood does not fall into either of the above two categories, it is most likely classified as consolidation stage. However, the above categories holds true within the context of study area because the proportion of land cover features varies from place to place even within the city.

Generally, high density residential areas refer to areas with small amount of vegetation and bare lands. Medium-density residential areas refer to areas with moderate amount of vegetation and relatively low bare lands. Low density residential neighbourhood refer to areas with individual housing units and large amount of vegetation and low bare lands. However, to determine the thresholds that are appropriate contextually, it is wise to look at the physical development planning standards of country in which the study is being conducted.

4.3.5. Physical Development Planning Standards in Kenya

Kenya's physical planning department has been preparing a guidelines and minimum standards on the process and practice of physical planning. According physical planning handbook (2007), a study of ten towns done in 1971 to establish the average land use percentages. These percentages have been used to determine land use allocations during planning. Another study on the same town carried out in 2004 has shown that the percentages have increased in some cases like in residential areas. These percentages can be used as a guide when planning new towns or assessing whether land allocations are reasonable. Categorization of the residential land use should be based on development density and level of services. Residential areas are seen as integral parts of the overall built-up area (dwelling plots) together with day-to-day services, recreation and communication network. In this study, plot ratio and density of residential development standards has been considered to classify SDS.

Plot size and plot coverage give the dimensions of the most visible aspect of density and culturally bound phenomenon and therefore varies from country to country (Acioly & Davidson, 1996). Plot coverage provides a sound basis for analysing of built spaces in relation to size of plots, for example, for enough space that would allow adequate ventilation and natural lighting for hot and humid climatic conditions like Kisumu. According to the handbook, plot coverage is the portion of horizontal area of the site of the building permitted to be built. The essence of fixing plot coverage is to ensure a healthy environment and allow for expansion and improvement of social and infrastructural amenities and comfortable living in general. According to physical planning handbook (2007), the maximum plot coverage recommended is shown in table 4.2.

Table 4.2: Maximum plot coverage recommended

Type of residential development	maximum percentage plots coverage		
	detached housing	semi detached	row housing
1. Slum rehabilitation upgrading	50	65	65
2. Low cost housing	50	60	65
3. Normal housing	40	50	60

Source: Kenya physical planning handbook (2007)

The intensity of development is determined by availability of services such as water, sewerage, size of roads, etc., and the zoning recommendation. The intensity of development may be varied depending on the type of waste disposal, availability of piped water, and the level of building technology to be applied. According to physical planning handbook of Kenya, recommended number of dwelling per hectare for low, medium and high density semi-detached housing is 20, 32, and 70 respectively.

Commensurate with these recommendations, it is possible to create thresholds to classify SDS. Usually, in slum settlements semi-detached housing are dominant; a house with two dwelling units sharing a common wall. Therefore, it is possible to calculate the maximum plot coverage per hectare for low, medium and high density for semi-detached and row housing. In Kisumu slum settlements these types of residential houses are dominant. Hence, in calculating intensity of development detached housing types are not considered.

Table 4.3: Intensity of development per hectare for semi-detached and row housing

	No. of dwelling per hectare	maximum percentage plots coverage per dwelling unit	maximum percentage plots coverage per hectare
Low density	20	65	13
Medium density	32	65	20.8
High density	70	65	45.5

4.3.6. Classification of SDS

So far a conceptual framework (thresholds) for classifying SDS has been discussed. In analysing SDS, these thresholds need to be considered contextually within the scale at which analysis is being carried out. The process of classifying SDS involves the identification of settlements that depict similar physical characteristics within pre-defined classification criteria. For example, in this study, density or proportional abundance of buildings, vegetation and bare land surface materials plays as classifying variables.

Slum settlements depict some characters that are not uniform across the settlements. In some settlements one finds saturated or consolidated patterns while in other cases sparsely built houses (infancy stage). This is because no planning guidelines have been put in place to guide housing development in slum settlements which indicate that house develop from individual's intuitive designs and construction methods.

In order to classify SDS, first the vegetation, buildings, and bare land layers need to be intersected with 100 metre grid fishnet net and go through different steps till the estimation of proportion of the three feature classes (figure 4.14).

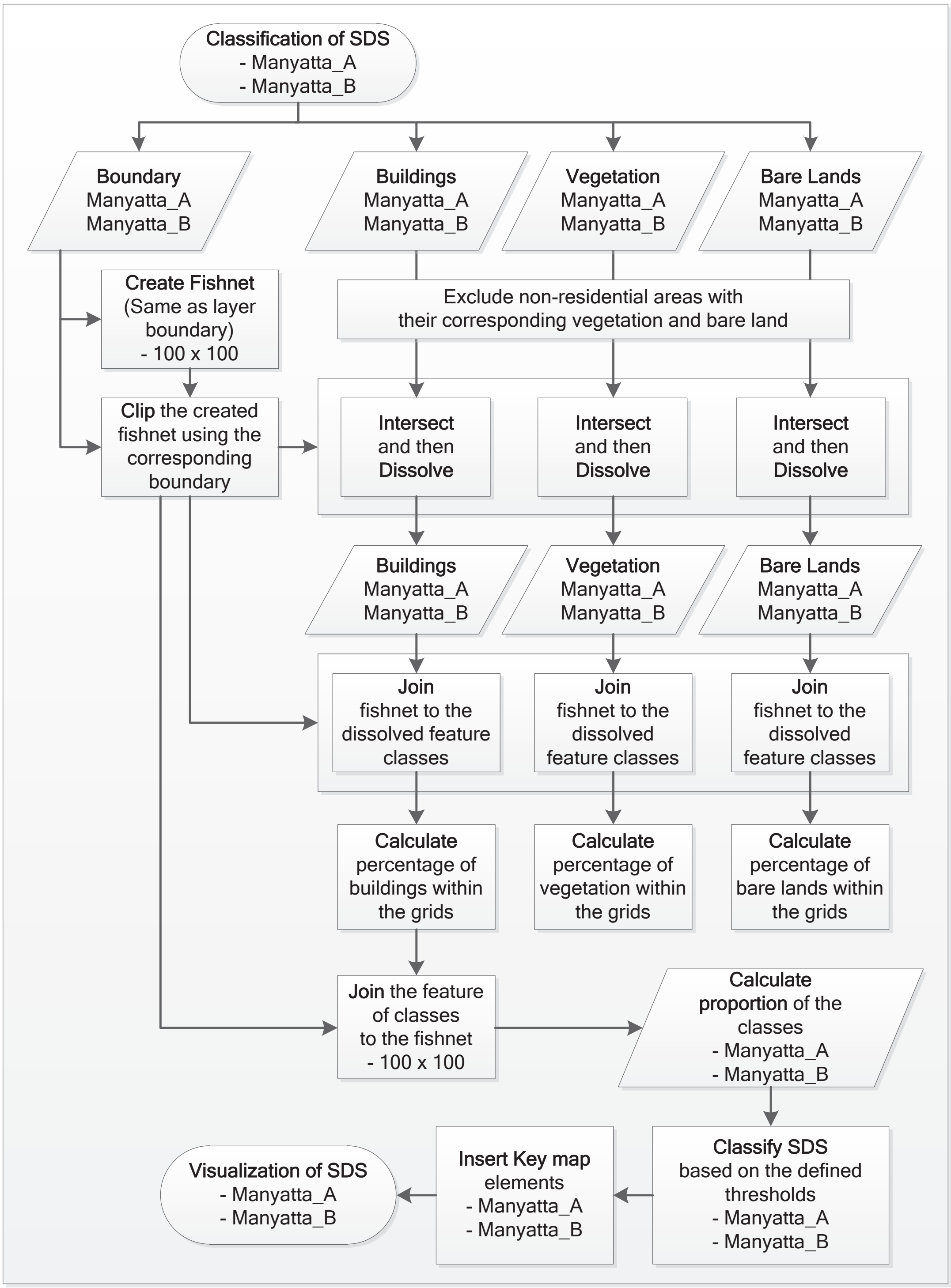


Figure 4.14: General steps to compute percentage of V-I-S and classify SDS

4.4. Socio-economic Analysis

This section examines basic urban amenities, the absence of which illustrates some of the most fundamental vulnerabilities faced by the slum dwellers. For example, insufficient provision of improved social and physical services such as water, sanitation, durable housing, overcrowding and secure tenure is some of the very common feature of the slum settlements in Kisumu. Water and sanitation can be considered two of the most fundamental critical urban facilities upon which the management of health and well-being in cities depend (Beall & Fox, 2009). Meanwhile lack of electricity in fact has significant environmental and health impacts as people are forced to depend on burning fuels (e.g. charcoal) that contribute to both indoor and outdoor pollution. In this section, UN Habitat slum indicators are considered for both Manyatta A and Manyatta B. It should be noted that in this section a unit of measure for analysis of socio-economic characteristics of SDS is a household that is later aggregated to settlement units.

4.4.1. Key Socio-economic Characteristics of Slum Settlements in Kisumu

Urban poverty is indissolubly linked with the process of rapid urbanisation in the city, which means that it is likely to continue to increase as the city urbanises unless sufficient measures are put in place. In Kenya, while urban poverty has been decreasing according to some measures, statistics indicate that the proportion of the urban populations that are poorest of all has been on the rise (Oxfam GB, 2009). In the preceding section it has been discussed that, in Kisumu, over 60 percent of the populations live in slum area and levels of inequality are dangerously high, with negative implications for both human security and economic development. According to UN Habitat (2008), income disparities in the urban areas of Kenya have increased even the country has exceeded the 'international alert line-inequality threshold.' Recent studies show that levels of inequality in the Kenyan towns around Lake Victoria like Kisumu are considerably higher than the National. These high levels of inequality have not only contributed to conflict in the city but are also bad for development more generally. Feelings of insecurity in many of the city's slum settlements have heightened considerably and poverty in the city is worst amongst those with low levels of education, another cause for concern given that many slum settlements have few or no public schools.

The slum dwellers often pay more times as much for water as the rich and being at risk from contaminated water, and the lack of sanitation facilities in the slums breeds disease and contributes to poor drainage, exacerbating flood hazards through obstruction of natural water channels and rivers. Most slum dwellers feel at risk from crime and violence in their settlements, and this sense of insecurity is exacerbated by insecurity of tenure. Another major aspect of vulnerability relates to the dramatically increased cost of food in recent years pushing people into high-risk livelihood activities in order to meet their basic needs.

Quite often high proportion of urban poor live in slum settlements, however, it should be noted that not all poor people live in slum settlements and not all people living in slum settlements are poor. But the overlap between the urban poor and slum dwellers is so great that for this study it can be assumed that in the vast majority of cases they are one and the same. In addition, even those who are not poor in income/expenditure terms but live in slum settlements can be considered qualitatively poor by virtue of living in poor quality housing lacking basic services.

4.4.2. Access to Improved Water and Sanitation Facilities

Quite often the quantity, quality and affordability of water in slum settlements falls significantly short of globally acceptable standards (UN Habitat, 2006). Though the city of Kisumu is located on the shores of Lake Victoria, the second largest fresh water lake in the world, yet the city is characterized by prolonged water shortages. Recent study on the water sector in Kisumu City shows that water and sanitation services are not keeping pace with the rapid population growth (Maoulidi, 2010). Particularly, many slum dwellers lack access both to clean water and to safe and environmentally sound sanitation facilities. For example, unreliable water supply, high water prices, poor solid and liquid waste management with no apparent system of designated dumping sites, and poor quality of water from sources such as shallow wells are some of water and sanitation problems facing slum dwellers. In addition, differences exist between the quantity and quality of water supply available to the rich and poor within the city. According to Maoulidi (2010), water vendors supplying piped water to slum settlements typically charge rates 50 percent higher than those provided by the water utility. As a result, many slum dwellers rely on shallow well water, which is often contaminated because of a high density of pit latrines near to the wells, poor wastewater management and inadequate drainage systems. Limited access to pure water supply and inadequate sanitation is also linked to increased rates of waterborne diseases and sever health effects especially among women and children. Particularly, during the rainy season, outbreaks of water borne diseases such as diarrhea, cholera, typhoid, dysentery and malaria contribute to numerous deaths every year. Generally, Kisumu city faces challenges such as increasing water production to meet the demands of a growing population, improving revenue collection, reducing water loss, expanding solid waste collection, developing recycling activities and rehabilitating sewers (Maoulidi, 2010).

According to UN Habitat (2003, p. 243), "a household is considered to have access to improved water supply if it has sufficient amount of water for family use, at an affordable price, available to household members without being subject to extreme effort, especially to women and children. A household is considered to have adequate access to sanitation, if an excreta disposal system, either in the form of a private toilet or a public toilet shared with a reasonable number of people, is available to household members." However, since the definition is more general and difficult to measure distance to such water sources, an alternative working definition is given by WHO/ UNICEF Joint Monitoring Programme (JMP) which is adapted for this study. A household in urban areas is considered to have access to improved water supply and adequate access to sanitation based on the indicator listed in table 4.4. In the table, bottled water is not considered as improved drinking water sources because of concern for the quantity of supplied water, not quality.

Table 4.4: Improved and unimproved drinking-water sources and sanitation facilities

	Drinking Water Sources	Sanitation Facilities
Improved	• Piped water into house • Piped water to yard/plot • Public tap or stand pipe • Protected well/spring • Rain water harvesting	• Flush/pour-flush toilet connected to: - public sewer - septic tank - pit latrine • Ventilated improved pit (VIP) latrine • Pit latrine with slab
Unimproved	• Unprotected well/spring • Vendor provided water • Tanker-truck provided water • Cart with small tank/drum • Bottled water (quantity) • Surface water (e.g. river, dam, lake, pond, stream, canal)	• Flush/pour flush to elsewhere • Pit latrine without slab/ open pit • Bucket latrine • Public or shared latrine • Flying toilets • No facilities or bush or field

Source: Adapted from http://www.wssinfo.org/definitions-methods/watsan-categories/

In line with the MDG indicator definition, which stipulates "use of improved facilities" to measure "access to improved facilities", this study also measures and analysis the actual use of facilities. This is because the definition of access can vary widely within and among countries and regions and involves many additional criteria. Table 4.4 lists the improved and unimproved sources of water and sanitation facilities as defined by the JMP. It is worth noting that "improved" provision of water does not always mean that the provision is safe, sufficient, affordable or easily accessible (UN Habitat, 2006).

Kisumu slum Settlements obtain water from kiosks supplied by KIWASCO (Kisumu Water and Sewerage Company), shared yard connections, shallow well (boreholes), piped water, door-to-door water vendors, rain water harvesting. KIWASCO is the largest provider of piped water and sewerage services in Kisumu. Although some slum dwellers have access to piped water, most slum dwellers rely on water kiosks, water vendors and boreholes for their drinking water supply. The reliance on shallow wells and boreholes in these slum settlements is problematic because water from these sources is of poor quality. Kisumu has high water tables; consequently, shallow wells are easily contaminated by overflowing pit latrines, poor wastewater management and inadequate drainage systems. According to recent study, it is found that 96 percent of the sampled shallow wells had medium or high levels of contamination. Even water from vendors had fecal contamination confirming that populations in slum settlements without access to piped water are ingesting contaminated water. These shallow wells situated in close proximity to the pit latrines, thereby increasing the chances of cross-contamination, especially during the rainy season. As a result, this contaminable water sources contributes to dangerous outbreaks of water borne diseases such as diarrhoea, cholera, typhoid, dysentery and malaria. Therefore, in this study, piped water, kiosks, shared yard connections and rain water harvesting are considered as improved water source while shallow wells and water vendors are considered as unimproved water sources.

The main sanitation facility in Kisumu slum settlements is the pit latrine. However, black cotton soil areas are not conducive to pit latrine construction, as they are loose, and latrines built on them are prone to collapse during the long rains (Maoulidi, 2010). According to the author, therefore, pit latrines are often less than six meters deep and therefore tend to fill up quickly and/or overflow. VIP latrines are a better alternative than open pit latrines because they are less odoriferous. In this study, VIP latrine and pour-flush latrine is considered as improved sanitation while pit latrine is considered as unimproved sanitation. Generally, access to safe drinking water and basic sanitation facilities is measured by percentage of population using an improved drinking water source and percentage of population using an improved sanitation facility respectively.

4.4.3. Overcrowding and Lack of Durable Housing

Overcrowding is a dominant characteristic of the urban slum dwellers. If room occupancy is employed as a measure of overcrowding, overcrowding is interpreted as the number of persons per room. Overcrowding is defined as when three or more people have to share one bedroom (UN Habitat, 2006). In other words, a house is considered to provide a sufficient living area for the household members if no more than two people share one bedroom. According to UN Habitat (2006), overcrowding also compromises the health of the occupants. That means overcrowding is positively correlated with a range of illnesses, diseases, overall child mortality and an increase in negative social behaviour. They are thus susceptible to contacting infections such as tuberculosis, skin infections and other diseases. The indoor environment is worsened by the use of crude energy such as wood, charcoal, and kerosene for cooking and lightening.

Majority of slum dwellers, build their own shelter with materials that are classified as non-durable. The UN Habitat (2003) describes a house as durable if it is built on a non-hazardous location and has a structure permanent and adequate enough to protect its inhabitants from the extremes of climatic conditions. Since the socio-economic data has no information about the compliance with local building codes, the geography of locations and associated hazards that constitute part of the definition of housing durability, in this study, the housing durability is based primarily on permanence of physical structures. The estimate is made taking into account only the nature of the construction (building) materials. Construction (building) materials have always been the cornerstone of structural quality and durability of housings. In the context of Kisumu, permanent structure means when housing unit is made of clay-fired bricks (matofali) or concrete blocks while semi-permanent structures are made of mud and wattle with cement finish and iron sheet. Therefore, housing quality is defined as percentage of permanent and semi-permanent structures in settlement units.

4.4.4. Lack of Secure Tenure

A key determinant of slum dwellers is the lack of secure tenure. According to UN Habitat, security of tenure is becoming increasingly precarious, particularly in SSA where mass evictions of residents are commonplace. Secure tenure is defined as the rights of all individuals and groups to effective protection from the State against forced eviction (UN Habitat, 2006). Most slum dwellers in SSA do not have security of tenure; they can be evicted at any time. The scale of insecure tenure is rising worldwide and only likely to worsen (UN Habitat, 2007). Security of tenure can range from home ownership which is typically regarded as the most secure, to the precariousness of living under constant threat of eviction (UN Habitat, 2006), which is quite clearly a state of very insecure tenure.

Security of tenure is associated with a number of benefits for residents. Some of the benefits of property titling include gains from the trade in land, increased investment incentives, and improved access to credit. Ward (2003), summarises the benefits of legal title as providing security against eviction; bringing people into formal property markets where they can receive full market prices through free sale; increasing property values; stimulating investment in house improvement and consolidation; encouraging access to credit; introducing residents into the formal property-owning democracy and citizenry; and integrating settlements into the formal tax collection and regulatory sector of the city.

However, it is not yet proven that formal or regularised markets are more efficient and productive than informal or unregularised markets. Secondly, it remains unclear whether a more formal land market will actually benefit or harm the slum dwellers. For example, according to Gulyani & Bassett (2007), efforts were far more complex and difficult than expected and, in general, unsuccessful often hindered by unexpected outcomes. Overall, extending the range of tenure options, and general slum upgrading are viable options for increasing security of tenure. However, perhaps the single most important means to increased perceived security of tenure is to remove residents' fear of eviction (UN Habitat, 2007). After all, it is forced evictions that are the extreme consequence of tenure insecurity (UN Habitat, 2006). In summary, there is still insufficient understanding between the strength and indeed direction of the relationship between security of tenure and housing consolidation and improvement (Kiddle, 2011).

UN Habitat has now come to recognise that security of tenure is not always equated with titling and ownership of land and housing (a far too common misconception), and they now explicitly state that ownership is not always the solution (UN Habitat, 2006). The UN Habitat also recognises that security of tenure has as much to do with perception as legal status (UN Habitat, 2007). As many examples throughout the world discloses titling does not often facilitate access to credit or prevent new slum formation (UN Habitat, 2006). Similarly, legal titles are not always necessary, for it is increasing residents' security of tenure that is key; or more correctly increasing residents' perceived security of tenure (Kiddle, 2011).

Generally, the importance of secure tenure cannot be underestimated as UN Habitat (2007) summarises, secure tenure is a major contributor to poverty alleviation, advancing sustainable livelihoods, improving choices and opportunities, accessing services, and for the general recognition of citizenship rights of the urban poor. However, security of tenure may not guarantee long-term remedy to the continued formation and expansion of slums. In this study, proportion of population with housing ownership and without (tenants) is measured and analysed.

4.5. Summary

This chapter described the conceptual and operational framework as well as the methods that were employed in this study. The feature extraction from VHR GeoEye imagery in eCognition Developer 8.64 software using the concept of OBIA was first implemented. This was followed by accuracy assessment which is an important part in image analysis, in order to assess about the level of potential confusion, the reliability of the class assignments and the overall quality of the results. Furthermore, accuracy assessment is important in providing a guide to its fitness for a particular analysis and to inform the user how much confidence in image classification and valid as a basis for scientific research.

As noted in the preceding sections, the classification of the physical development process of slum settlements rely on the concept of Ridds' conceptual model. Understandably, a slum is an area. This indicates that slum settlements are defined mainly by their physical and infrastructural environment, instead of the demographic structures of inhabitants, while it can be certain that the inhabitants have some impact on the physical environment. The UN Habitat definition of a slum also refers to an environment or a characteristic of place, not specifically of the individuals residing there. Specifically, density of buildings, vegetation, and bare soil at one hectare resolution with thresholds that is appropriate contextually has been defined to distinguish SDS. Generally, the preceding section has provided a theoretical and methodical framework for identification, classification and analysis of SDS and variables employed for this study. Finally the chapter has also described the analyses of key socio-economic characteristics of Manyatta slum settlements. Displaying the result of the physical and socio-economic development process of the case study along with discussion are subjects of proceeding chapter.

5. RESULTS AND DISCUSSION

This chapter presents the main findings and results of the study. In this chapter three main issues are being discussed, namely: feature extraction from GeoEye imagery using the concept of OBIA and rule-based classification techniques, classification of SDS in GIS environment and analysis of key socio-economic characteristics. Three categories of slum settlements have been identified and classified. These include: saturated or high density slum settlements, consolidated or medium density slum settlements, infancy or low density slum settlements.

5.1. Spatial and Contextual Characteristics of Slum Settlements

Any attempt to identify and classify SDS in a city such as Kisumu ought to take into consideration a number of factors some of which have been discussed in the preceding sections. For instance, in this study, the starting point was to define slum and employing this definition in local context and identifying slum settlements. Indeed, UH Habitat has identified around eight slum settlements in Kisumu and there is a clear boundary between formal and informal settlements. Since the focus of this study is to classify and analysis development stages of slum within the realm of local context, two neighbourhoods, Manyatta A and Manyatta B, has been considered as it was discussed in section 4.2.

Generally, slum settlements tend to group into two broad types of location: inner city and peri-urban areas. The centrality of location often implies older, more established formations close to the old city. Residents benefit from the proximity of employment opportunities, but often inhabit substandard housing on sites that are exposed to environmental and health risks. Some of these settlements originally developed as planned areas; they gradually have lost their attractiveness over time and become indecent areas. For example, Manyatta Arab is among the eight slum settlements located nearly in centre of Kisumu city. Further subdivision of houses and shared facilities might contribute to the degraded of the housing. However, security of tenure in these types of slum settlements might not be a problem.

In most cases, slum settlements, especially large scale formations concentrate in the periphery because land values tend to be lower. Most of these settlements are the result of illegal subdivision and selling of the agricultural lands but some others have rural nuclei that have been growing over time and were subsequently absorbed by the city. For example, in Kisumu except Manyatta Arab and Kaloleni the rest are located around the old city making slum belt. The quality and standards of housing are generally better and there might be some illegal connections to existing infrastructure. Figure 5.1 provides a summary of the statistical mean of some of the facilities and land ownership of Kisumu slum settlements based upon table 3.1.

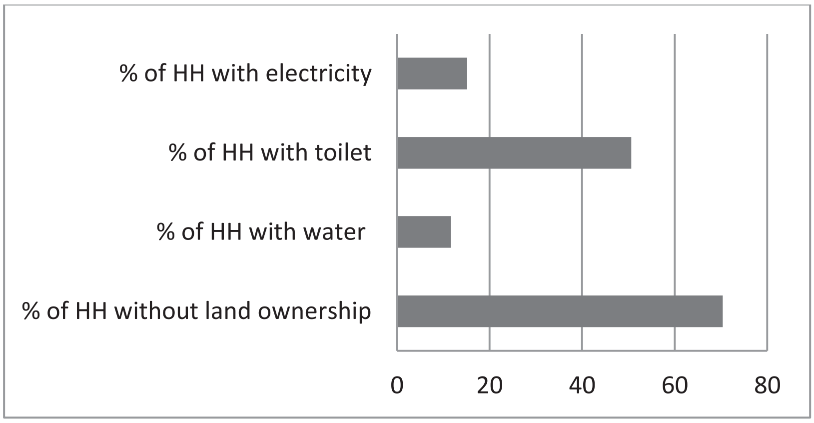


Figure 5.1: Statistical mean of land ownership and other facilities for Kisumu slum settlements 2010

It should be noted that figure 5.1 highlight the general profile of eight slum settlements in Kisumu based on table 3.1. As the figure shows for nearly 71 percent there was no evidence of land ownership where threats and fear of eviction are commonplace either by the government or by private developers. Resettlement schemes rarely work, because the old land often is convenient to work opportunities in the city centre, and new areas tend to be farther out on the periphery. Overall, it can be seen that around 85 percent of the plots lacked electricity and around 88, and 50 percent lacked improved drinking-water sources and sanitation facilities on their plot. Though those are in fact the general socio-economic characteristics of Kisumu slum settlements at aggregated level, it is may not allow to observe the extent to which each slum settlement units are different in physical as well as socio-economic status. Thus the proceeding sections present the result analysis of the physical and socio-economic development process of both Manyatta A and Manyatta B at one hectare and household level unit of analysis.

5.2. Image Classification

Multiresolution segmentation was implemented in eCognition Developer 8.64.0 software in which a 4 meter multispectral GeoEye 2009 imagery was utilised. Methodologically, the classification result was based on the concept of OBIA and rule-based classification techniques. Six feature classes were extracted and accuracy assessment was met through the use of an error matrix (Figure 5.2). Figure 5.2 shows the image classification result of both Manyatta A and Manyatta B. It has been explained that the recognition of these feature classes is of special importance in distinguishing slum settlements in the neighbourhoods. As can be seen from the figure 5.2, feature classes, namely, roads, vegetation, buildings, shadows, bare lands, and background were classified. The integration of thematic layer in the segmentation process significantly improved the classification and statistical accuracy of both roads and buildings. In addition, the edges of the roads and buildings in the extraction become relatively smooth.

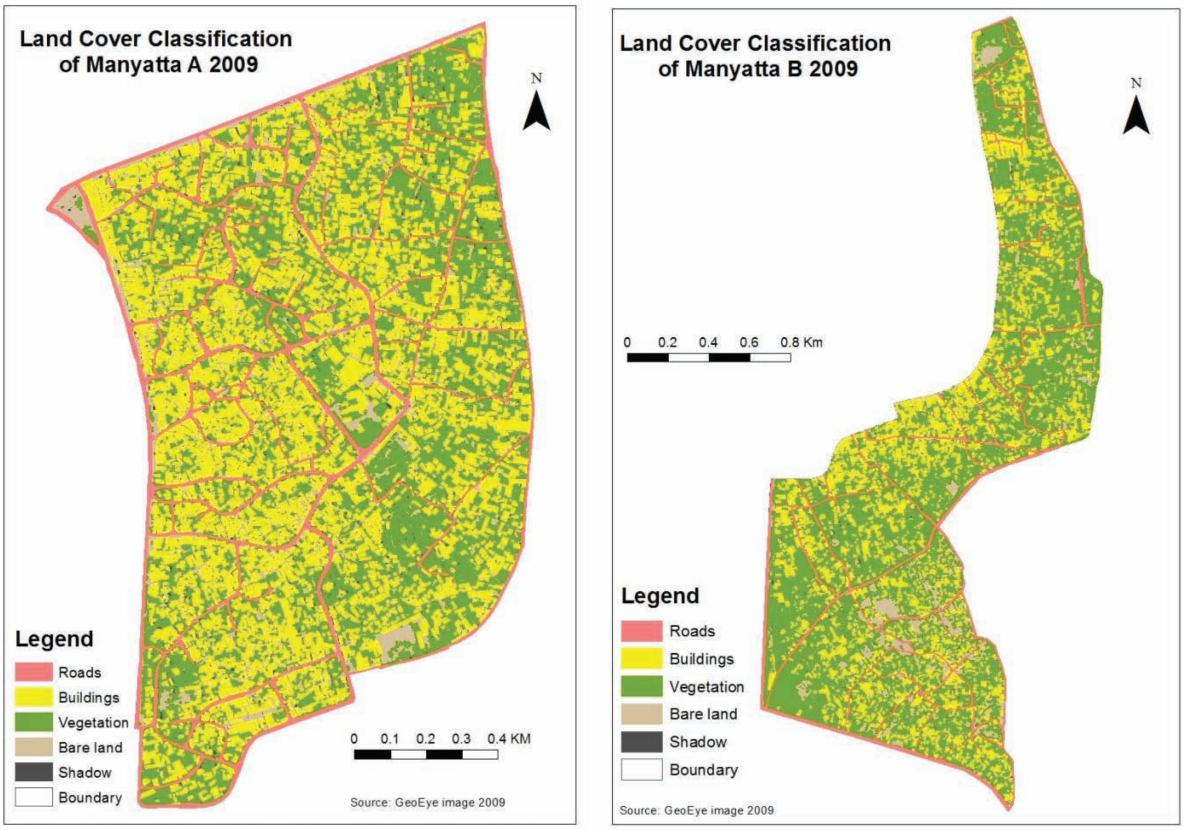
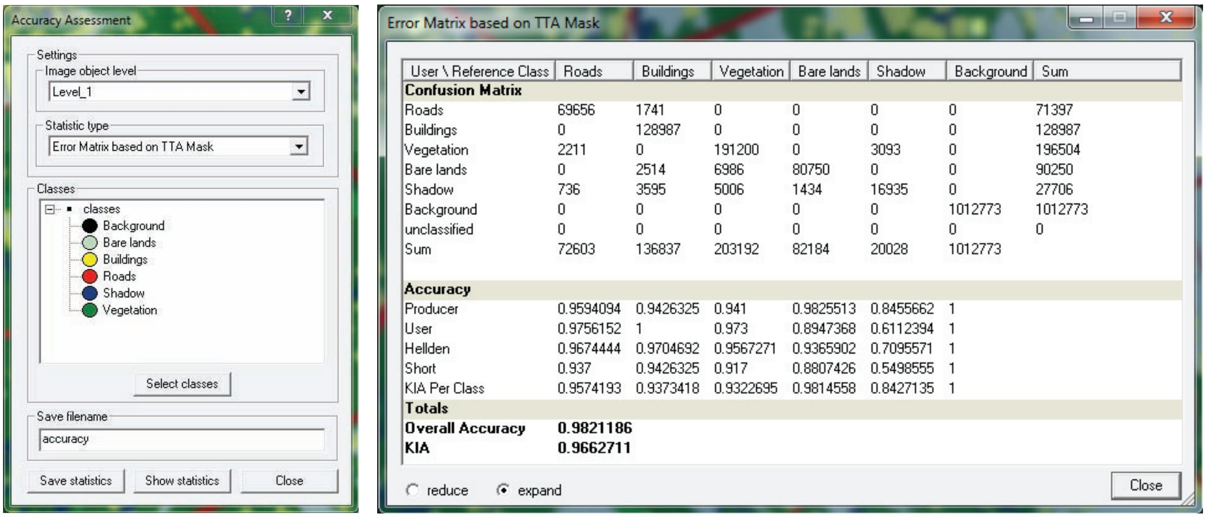


Figure 5.2: Result of image classification for both Manyatta A and Manyatta B

Generally, the accuracy assessments indicated that the classification result was to the required level and sufficient for further analysis (figure 5.3). For example, around 98 percent overall accuracy and around 97 percent kappa index of agreement accuracy have been achieved for Manyatta B. This kind of result was reached because of the integration of thematic layer in the segmentation process alone. As explained in image segmentation section, segmentation plays a key role in classification accuracy. That means roads and building have been classified accurately which also, in turn, increased the classification of other features. In other words, the confusion between the spectral reflectance of roads, some roofs and bare lands were significantly reduced. There is no surprise at the accuracy of background (100 percent) because it has only zero brightness value. The accuracy of shadow (85 percent producer's accuracy and 61 percent user's accuracy) is relatively low from the rest of the feature classes. This is because different features cast different shadow illumination. Even the same categories, for example, trees have different leave density which cast different shadow intensity. Hence, it was challenging to determine a threshold that includes all shadow within the scene. The estimated accuracy assessment of Manyatta A is similar to Manyatta B. Among these classified feature classes buildings, vegetation and bare land were used for classification and analysis of slum development stages as discussed in the preceding sections 4.3.



User \ Reference Class	Roads	Buildings	Vegetation	Bare lands	Shadow	Background	Sum
Confusion Matrix							
Roads	69656	1741	0	0	0	0	71397
Buildings	0	128987	0	0	0	0	128987
Vegetation	2211	0	191200	0	3093	0	196504
Bare lands	0	2514	6986	80750	0	0	90250
Shadow	736	3595	5006	1434	16935	0	27706
Background	0	0	0	0	0	1012773	1012773
unclassified	0	0	0	0	0	0	0
Sum	72603	136837	203192	82184	20028	1012773	
Accuracy							
Producer	0.9594094	0.9426325	0.941	0.9825513	0.8455662	1	
User	0.9756152	1	0.973	0.8947368	0.6112394	1	
Hellden	0.9674444	0.9704692	0.9567271	0.9365902	0.7095571	1	
Short	0.937	0.9426325	0.917	0.8807426	0.5498555	1	
KIA Per Class	0.9574193	0.9373418	0.9322695	0.9814558	0.8427135	1	
Totals							
Overall Accuracy	**0.9821186**						
KIA	**0.9662711**						

Figure 5.3: The estimated accuracy assessment for Manyatta B

5.3. Characteristics of SDS and Their Classification

Several characteristics might be used to identify and classify development stages of slum: size, location, socio-economic conditions of residents, level of consolidation, spatial pattern and etc. Despite multiple faces of slums and their multidimensional nature, in this study, three SDS (infancy stage, consolidated stage and saturated stage) have been considered and classified on the basis of the proportional abundance of V-I-S as discussed in section 4.2.

One of the most continuing manifestations of slum settlements consists mainly of scattered housing (infancy) on public or private land. It is built on illegally occupied land, usually through self-help. The settlements are mainly the result of in-migration, changes in the urban economies, or a gradual process of occupation and incremental growth. Located in peri-urban areas and on public or private land, the settlements have grown to become housing hundreds of thousands of residents. The land, sometimes public or private, is unsuitable for urban development and has limited services and access to essential infrastructure. These peripheral slum settlements are often make-shift and built their houses with temporary materials. At the initial occupancy stages source of improved water is the main challenge for the neighbourhood. At this stage public amenities and services are generally inadequate. Infrastructure and facilities provided by local authorities are too late and too little. The dwellers are also people with lowest income. This stage may serves as an initial base for the rural in-migrants due to the lowest possible housing price.

The early stages of slum developments may happen at the expense of prime agricultural land, with the destruction of natural landscape or public open space. Most of the time many land owners retain their ownership but construct extra houses/ rooms for tenants to supplement their income. The standard of infrastructure is low and the land subdivision often does not meet planning standards for right-of-way, road access and provision of public spaces.

Consolidation stage is the transitional stage where the process of filling up a piece of land by in-migrants continues. At this stage there is rapid outward expansion with every flow of in-migrants. The slum expansion influences demographic structure, economic activity, the problem of public amenities and services. Commonly, within the slum settlements across the city, there is a variety of settlement patterns and historic circumstances. Some that have started as initial occupancy stage in the peri-urban areas in the past decades have evolved into more established and saturated neighbourhood. Diversity also exists in the legal status of these settlements: while most begin with an illegal occupation of land, through time some security of tenure is acquired with a formally recognized legal title of land. Some infrastructure, such as piped water, electricity and sewer might be provided.

Some of the slum settlements in saturated categories are not necessarily poor quality, substandard housing areas. From the external it may appear that the dweller is of lower economic status while from the inside some slum dweller haves a comparatively better off. Some of the residents in these settlements have a title to the land, but the housing is built without a planning and/or building permit. Socio-economic status is relatively higher at this stage. The rate of both incoming and outgoing people is slowed down. Overcrowding is highest at this stage. Generally, the growth of slums can be faster at one time and not in another. The process of slum growth stops as vacant areas get filled up. As it has been discussed in section 1.4, change of slum from one stage to another are due to change in building materials used, change in socio-economic condition, and occupancy status, among others.

In this study, after image classification and accuracy assessment has been done, the proportion of buildings, vegetation and bare lands for both Manyatta A and B at 100 meters resolution (one hectare) were calculated. As explained in preceding section the non-residential areas, for example public schools and their respective vegetation and bare land and road networks were excluded from the calculation.

Figure 5.4 shows the result of classification of SDS. The physical development planning standard of Kenya was employed to define threshold that is appropriate contextually to differentiate development stages of slum settlements. The recommended maximum plot coverage and number of dwelling units per hectare for slum rehabilitation upgrading type of residential development and semi-detached and raw housing type were considered as discussed in section 4.3.5.

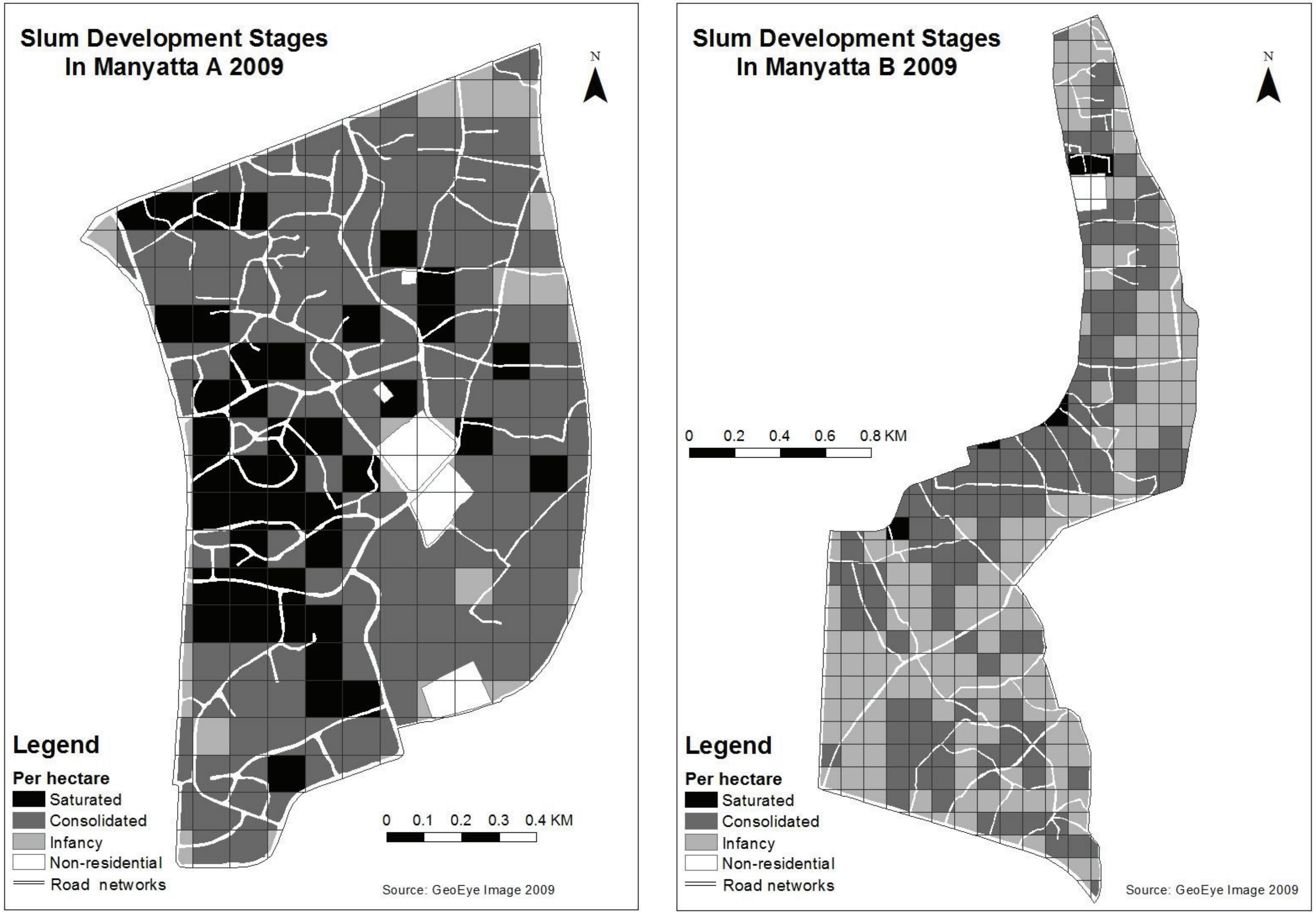


Figure 5.4: Classification of SDS at one hectare resolution for Manyatta A and Manyatta B

Figure 5.4 shows the classification result of SDS for both Manyatta A and Manyatta B. As discussed in section 4.3.3 the spatial unit of analysis is one hectare. It is shown in table 4.3 that the recommended plot percentage per hectare for low, medium and high slum settlements is 13, 21, and 45 percent respectively. These figures have been cut in to three equal parts (33.33% and 66.67%) to create thresholds to distinguish SDS within the neighbourhood at one hectare resolution (figure 5.5). Hence, those neighbourhoods having 16 percent or below plot coverage were classified as infancy stage while those neighbourhoods fall between 16 and 37 percent were classified as consolidated neighbourhoods. Those neighbourhoods having 37 percent or more were classified as saturated neighbourhoods.

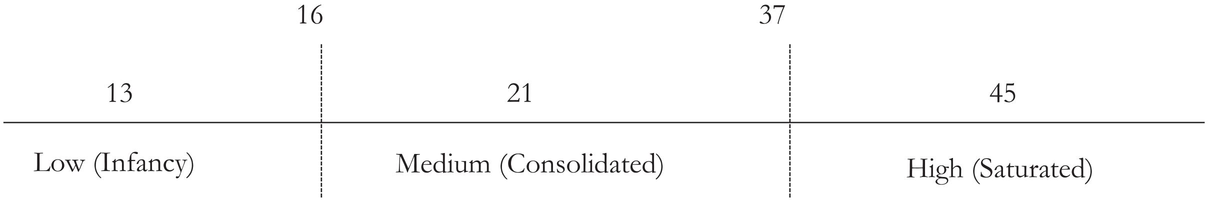


Figure 5.5: Maximum percentage plots coverage per hectare to classify SDS

Table 5.1 shows summary of frequency table of SDS of Manyatta A and Manyatta B. When percentage of buildings at one hectare is taken into consideration, approximately one-fifth of Manyatta A is already saturated and nearly two-third is consolidated. Although the external environment of Manyatta A depicts a characteristic density which has been perceived to be high, implicitly including the internal environment, around one-fifth of the settlements are at infancy stage. In case of Manyatta B, which is relatively young and rural slum settlement, around 54 percent of the settlements are at early stages. Around 42 percent of the settlements are consolidated stage.

Table 5.1: Frequency table of SDS for Manyatta A and Manyatta B

SDS	Manyatta A		Manyatta B	
	Frequency	Percent	Frequency	Percent
Saturated	42	18.8	7	2.2
Consolidated	139	62.1	131	41.5
Infancy	41	18.3	169	53.5

Generally, it has been observed that the proportion of vegetation is higher than the proportion of bare lands in both Manyatta A and Manyatta B across the three stages. In addition, the proportion of vegetation in Manyatta B is generally higher than Manyatta A at each stage. However, this proportion is influenced by the time of acquisition of the imagery due to relatively dynamic land cover class. This issue has been raised and discussed in section 4.3.4.

5.4. Socio-economic Analysis

A key challenge in analysing the socio-economic status of the residents of Manyatta slum settlements was the lack of geo-referenced data sets at household level which would have been useful to relate to the analysis of the physical development processes status. In other words, there is no shape file depicting each household within the settlements except their socio-economic status which is not spatially referenced. This issue has been briefly discussed in proceeding section on how a more integrated analysis could have been achieved if appropriate geo-referenced socio-economic data at HH level for Manyatta settlements would have been obtained. Nevertheless, analysis of the UN Habitat slum indicator of the socio-economic situation has been done for the nine administrative units of Manyatta as shown in figure 4.5. The analysis covered all residential housing units within the nine settlement units where Manyatta A and Manyatta B comprise of 6 and 3 administrative units respectively. As it can be understood from Pamoja Trust enumeration draft report, the data collection was carried out by the trained community members within their respective settlements that would therefore be instrumental in generation of more realistic information.

The analysed key socio-economic characteristic of Manyatta settlements was based on the UN Habitat slum indicator and their respective working definition given in section 4.4. For this purpose, each housing characteristics was computed in SPSS statistical software and as per the defined working definition and operational framework which were later exported to GIS for visualisation (figure 5.6 and 5.7). Generally, on the housing durability, the analysis revealed that around two-fifth of the residents live in clay-fired bricks and concrete blocks (permanent structure) while the rest of the residents live in dwellings made of non-durable materials such as mud and wattle structure. Nearly two-third of the residents are tenants. It was further revealed that more than half of the settlement's population use unimproved drinking water sources such as shallow wells and water vendors. Up to 93 percent of residents use communal pit latrines (unimproved sanitation) where their proximity to shallow wells affects water quality in the area due to the high water table. Only 7 percent of the residents use improved sanitation facilities such as VIP latrine and pour-flush latrine connected to sewer and septic tanks.

Figure 5.6 and 5.7 shows proportion of households with improved drinking water sources, sanitation facilities, house ownership and permanent structures. Among the five UN Habitat indicators of slum settlements overcrowding which is the typical characteristic of the urban slum dwellers is not considered due to lack of information on the number of persons per room.

As it has been discussed in section 4.4.1, residents obtain water from individual connections, Kiosk, yard tap connections, shallow wells, handcart vendors and rain water harvest. For instance, one-fourth of residents of Flamingo, which was classified as saturated neighbourhoods, had access to an improved water source, while around three-fourth relied on unimproved water sources, including water vendors, shallow wells (the top figure 5.6). The figure also illustrates that, there is general trend that the coverage of improved water sources in Mantyatta B is relatively greater than that of Mantyatta A. To some extent this indicates that as neighbourhoods become developed from infancy through consolidation to saturation the quality of water sources is becoming less. This might be due to lack of rehabilitation and improvement of water supply facilities which did not keep pace with increasing water demand.

The bottom figure 5.6 shows that, there are relatively very few improved sanitation facilities such as VIP latrine and pour-flush latrine in both Manyatta settlements. More than 90 percent of the residents use unimproved pit latrines which are often less than six meters deep and therefore tend to fill up quickly and prone to collapse during the long rains season (March-June). According to Maoulidi (2010), frequent sewer bursts and blockages are common, resulting in groundwater contamination, environmental pollution and outbreaks of water related diseases such as malaria, typhoid and cholera. In addition to this, according to the author, the sewers were built more than four decades ago, and there has been no rehabilitation or extension of the sewer system, except for the Kibos Trunk sewers, which were built in 1980.

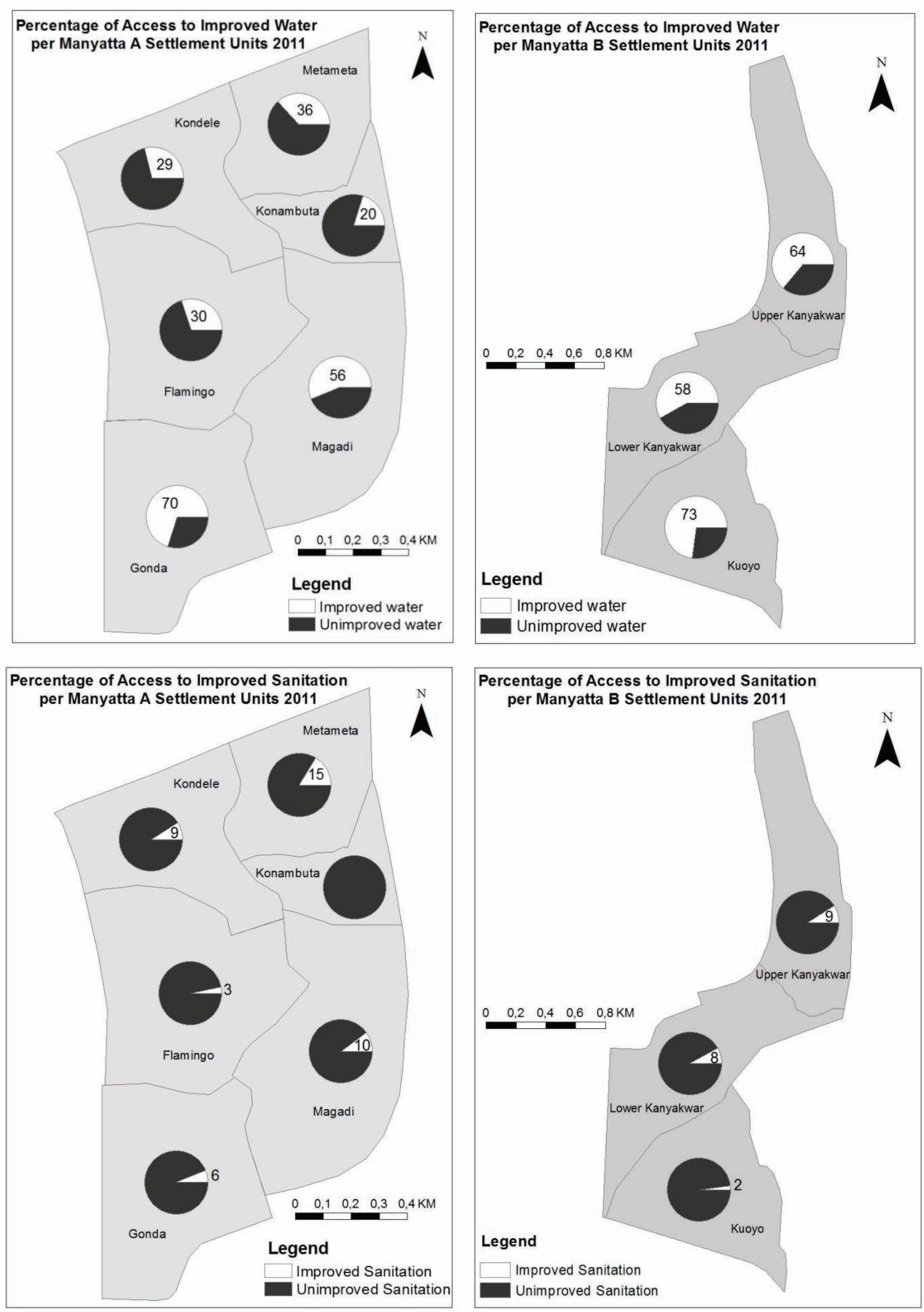


Figure 5.6: Proportion of HH with access to improved drinking water sources and sanitation facilities

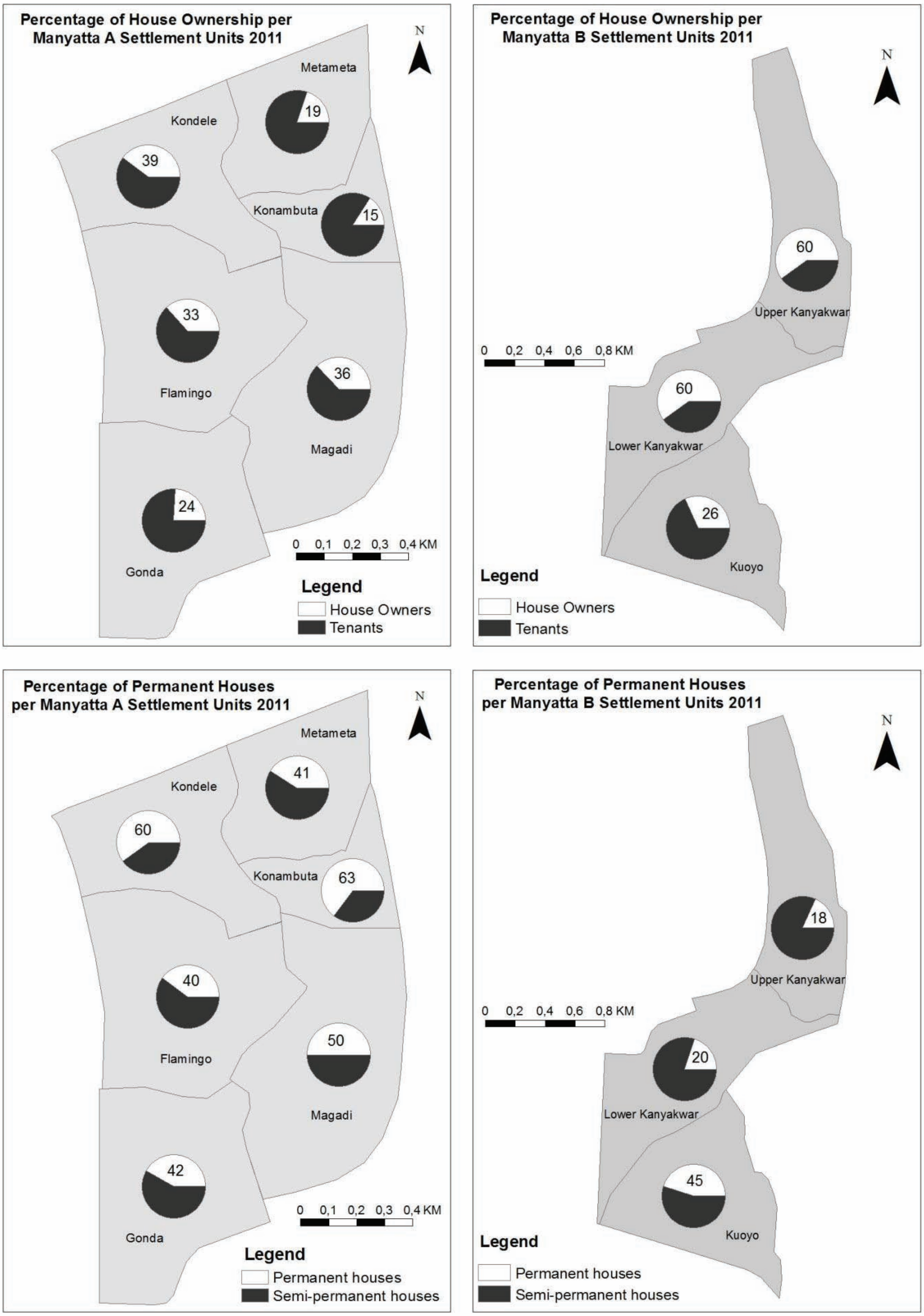


Figure 5.7: Proportion of HH with house ownership and permanent structures

Nearly one-fourth and half of slum dwellers in Manyatta A and Manyatta B respectively are house ownership while the rest of the residents are rent-paying tenants (the top figure 5.7). There are residents who are sub tenants and relatives of homeowners. Home owners are mostly landlords who provide poor housing units, which are mostly illegal and sub-standard in quality, often being constructed of semi-permanent materials such as mud and wattle, re-used iron sheets for roofing, polythene bags and iron sheets roofing. Furthermore, as tenants, households have no titles over the land on which the houses are built, and live under the threat of eviction either by the government or by private developers. There is a general trend that the proportion of tenants is higher in Manyatta A which is relatively old and more saturated and consolidated slum settlements than Manyatta B which is relatively young and rural slum settlement.

As regards building materials, about half of the houses in Manyatta A are built of local permanent structures such as clay-fired bricks (matofali) and concrete blocks and while the proportion of permanent structures in Manyatta B reduced to one-fourth (the bottom figure 5.7). As the results indicated that there is a general trend that the proportion of permanent structure is higher in Manyatta A than in Manyatta B settlements.

5.5. Are Socio-economic Characteristics Related to SDS

If geo-referenced socio-economic data at HH level had been available, the socio-economic situation of Manyatta slum settlements would have been analysed based on the UN Habitat slum indicator and their respective working definition given in section 4.4. For this purpose, each housing characteristics will be computed in SPSS statistical software based on the following operational techniques.

- If the HH does not have improved drinking-water sources, then slum1 (S_1) = 1 (else 0);
- If the HH does not have improved sanitation facilities, slum2 (S_2) = 1 (else 0);
- If three or more people share one room, slum3 (S_3) = 1 (else 0);
- If the housing unit is not made of permanent structure, slum4 (S_4) = 1 (else 0);
- If the resident of housing unit is tenant, slum5 (S_5) = 1 (else 0);

Then it is possible to visualise the distribution of housing units by each of these defined characteristics with their respective spatially referenced housing unit in GIS environment. This helps to observe those housing units that do not have improved basic services. It is also possible to compare housing unit within the result classification of SDS. For example, it is possible to quantify housing units that do not have improved drinking-water sources within saturated slum areas. The same can be applied to the other indicators and SDS. Similarly it is also possible to identify the socio-economic characteristics that can better differentiate SDS.

Apart from analysing the housing condition based on the above operational indicators separately, it is also possible to analysis in a combined fashion to observe whether there is a relationship between SDSs and multiple deprivation. This is because it is expected that majority of housing units in slum areas will have a combination of slum characteristics (multiple deprivation) that would indicate spatial variability. For example, a housing unit deprived of improved sanitation alone may experience a lesser degree of deprivation than a housing unit that lacks any improved basic services at all. Basically not all slum dwellers are equality deprived. Deprivation is thus taken to mean lack of the stipulated improved basic services whereas multiple deprivation relates to the occurrence of several forms of deprivation concurrently.

Here two different situations might exist. At the infancy stage more instances of multiple deprivation might expected as starters in the area need time to get settled and create infrastructure and enough living space of good quality. At later stages less instances of multiple deprivation might be found as initial occupancy stage have evolved into more established and consolidated neighbourhood. But in the saturation stage things may worsen as high numbers of poorer tenants create overcrowded conditions and shared facilities might be heavily over utilised. Generally, the hypothesis that could be tested is whether there is a relationship between SDSs and multiple deprivation that would be explained by the combination of these defined socio-economic characteristics.

Having calculated the above defined indicators for each housing units, their combination can then be calculated as the sum value for each housing units to relate with the result of the physical development process of slum settlements. That means each housing unit in the settlements have the value of the summation of the above five key indicators.

$$S_{HH} = S_1 + S_2 + S_3 + S_4 + S_5$$

Based on the above defined indicators the most possible minimum and maximum value of S_{HH} is 0 and 5 respectively. For example, if housing unit has 0 value of S_{HH}, this indicates that the housing unit does not show slum characteristics. This can be expected because not all people living in slum settlements are poor. If the housing unit has around 3 values of S_{HH}, the housing unit show some slum characteristics. In this case there might be high frequency of lack of improved sanitation facilities among others since only 7 percent of the residents of Manyatta settlements use improved sanitation facilities such as VIP latrine and pour-flush latrine connected to sewer and septic tanks as shown in key socio-economic analysis. Similarly, if the housing unit has maximum value 5, this shows that the housing unit does not have the above defined improved basic services. This housing unit exhibit severe slum characteristics.

Though the spatial unit of analysis for the physical and socio-economic development process is not necessarily the same (one hectare and HH), yet it is possible to identify the spatial location of each housing units within one hectare resolution as well as their housing conditions. This could have explained whether there is significant spatial variability in the neighbourhoods with respect to the physical development process of slums. This also enables to locate the worst and the better off housing units in the neighbourhoods to explore less advantaged housing units and how does this impact their well-being. It should be noted that a composite of the above five different indicators, may not contribute equally to its overall combination and show socio-economic variability. However, it would highlight the extent to which slum dwellers are different in deprivation and level of access to basic improved services as well as their vulnerability to many problems related to health. Variability among SDS in Manyatta might be associated with some variability in socio-economic characteristics of slums.

From overall perspective, then, it could be possible to verify whether there is significant correlation between multiple deprivation and SDS and further to conclude if socio-economic characteristics can be used to differentiate SDS with reference to the result of empirical evidence that would have been achieved. Generally, such more integrated analysis would have brought up reliable information that could therefore facilitate targeted discussions around key development issues such as basic social and physical services and state of service delivery to the slum dwellers in Manyatta settlement. Consequently, holistic development out of integrated analysis and informed systematic interventions programmes can be attained to secure the wellbeing of slum dwellers. Therefore, the above discussion has to be understood as a conceptual and operational framework on how a more integrated analysis can have been conducted, if appropriate geo-referenced socio-economic data at HH level for Manyatta settlements would have been obtained.

5.6. Evaluation of The Approach to Identify and Classify SDS from Spatial Data

In order to be able to evaluate the applicability of the approach to identify and classify the physical development process of slum from spatial data some evaluation criteria were used. These criteria include reliability, validity, and efficiency, utility and generality.

5.6.1. Reliability

Reliability aims at demonstrating that if the methods are repeated under similar conditions similar results will emerge. For the purpose of ensuring reliability of results from this study three strategies were conducted. Firstly, a classification of accuracy assessment was done for feature extraction whereby level of possible confusion, reliability of the class assignments and the overall accuracy of the results were assessed. Samples from the image were used to estimate the quality of the classification results provided that these samples were not used to classify the images objects. Secondly, in order to ensure the thresholds that are appropriate culturally and environmentally to distinguish SDS, net physical density and physical development planning standards of the case study (Kenya) were considered. These thresholds are apparent and in accordance with slum rehabilitation upgrading of Kenya where the respective plot coverage and intensity of buildings for semi-detached and raw type of house were employed. The third strategy was the adoption of a coherent unit of analysis. As it has been discussed, the unit of analysis (one hectare) would decrease the residential and socio-economic heterogeneity in the neighbourhoods and is well suited as a common framework for integration of data sets from different sources and lends itself easily to a broad range of analysis techniques. Furthermore, this unit of analysis support longer-term monitoring as well as planning applications and is easier and cost-effective way to improve the spatial characteristics of that particular neighbourhood. However, spatial unit of analysis might depend on the type of information needed to be conveyed, the extent and characteristics of the geographical case study area to be analysed, and the availability of ancillary data, among others.

Generally, the approach has performed properly and generated expected results based on the recommended plot coverage and intensity of development per hectare. The density calculation does not, however, take into consideration other features such as roads and shadow which could have improved classification if clear boundary of roads and aggregation of shadow to other feature classes had been possible. Despite this, the employed methods and the results of the classification could potentially enhance better understanding about the characteristics of SDS thereby help urban planners and policy makers to develop systematic interventions which would eventually improve the well-being of slum dwellers for their respective cities.

5.6.2. Efficiency, Utility and Generality

Efficiency refers to the classification result precision given time, equipment and expertise limitations, whereas utility assesses the effect, usefulness of the approach. Generality is the extent to which an approach can be successfully applied, with minor modifications, to other slum settlements in other SSA contexts that have similar socio-economic and cultural conditions. How to generalise results from one case to a broader context has been one of the challenges of a case study research. Many authors have discussed how generalisation from a case study can be made (Patton, 1987; Yin, 1994). A consensus that seems to emerge from the authors is that results from case study research are not generalizable as is the case is for statistical samples. However, in analytical generalization, case study findings can be related or transformed to other context given that conditions are similar. This is because, in analytical generalisation, the researcher attempts to generalise a particular set of results to some broader theory or a set of concepts. Thus, results from case studies have been presented towards serving mostly as bases for reliability with specific contexts where prevailing conditions are more or less the same as those found in these cases. The central idea is that analytical results established from this study can be related with other cases with similar socio-economic conditions.

Certainly, the developed rule-set in eCognition environment can be exported and reused on more than one data set having similar context (Niebergall, et al., 2008). Moreover, the reliability of the class assignments and the overall quality of the results of feature extraction is to the required level and sufficient for categorisation of development stages of slum. Generally, the OBIA approach is transparent, reproducible, to a high degree comprehensible, and technically transferable to other scenes (Lang, et al., 2006) where GIS acts as a key tool for the integration and analysis, and visualization of the spatial information.

The approach to identify SDS from spatial data is generally fast to adapt and quite flexible in defining thresholds. In terms of equipment, the approach is versatile and it can be implemented on powerful computer for feature extraction and on standard computer platform with GIS environment for classification. Furthermore, visual checking of the classification result of SDS with the image clearly showed that, with threshold contextualisation, the approach has the potential to be successfully used to classify and analyse the SDS in other cities of SSA. As the case study of Manyatta indicated, the approach serves to improve the analytical capabilities in similar context of SSA where detailed census data pertaining to slums at local level are mostly not available. This is of paramount importance for proactive strategic decision making and slum upgrading to improve the living and the socio economic status of slum dwellers. In general, the study provide a basis to further identify the driving forces for change of slum from one stage to another and types of interventions for each slum development stages which are the questions that ought to be raised. On the methodological aspect, it has been noted that the employed methods in this study, in general, were not time-consuming and challenging, as well as they have the advantage of making the results more practical and user-oriented.

5.6.3. Validity

Validity assesses how the result agrees with the reality on the ground. As it has been discussed in section 4.2.6, "ground data do not necessarily represent reality, due to observation and recoding errors, mislocation of test data sites, differences caused by changes in land cover between the time of observation and the date of imaging, and so forth (Tso & Mather, 2009, p. 69)." Therefore, accuracy assessment which is an important part in image analysis, in order to assess about the level of potential confusion, the reliability of the class assignments, and the overall quality of the results has been carried out based on randomly taken samples data set from the image. In addition, accuracy assessment is important in providing a guide to its fitness for a particular analysis and to inform the user how much confidence in image classification and valid as a basis for scientific research. Though there is no single universally acceptable measure of accuracy, currently, the confusion or error matrix that has been used is, the most common tool of accuracy assessment because it identifies not only overall errors for each feature classes, but also misclassifications due to confusion between the feature classes.

It is important to mention that due to the analytical nature of this study the defined thresholds to distinguish SDS could only be based on the physical development planning standards of Kenya, specifically for slum upgrading scheme to be appropriate contextually. That means, the classification results of SDS (infancy, consolidation, saturation) could not be compared with other results, only because such similar classification of SDS does not exist. For instance, there are no other sources of evidence like maps that exactly depict the location of SDS that are classified as infancy, consolidated and saturated. Hence, the computed density, the defined thresholds is a result of these exploratory studies. Nevertheless, the classification result of SDS is validated by comparing visually with the GeoEye 2009 imagery. This traditional, qualitative way of visual interpretation is an ultimate benchmark and is often applied to evaluate and visually check the overall results of more automatic methods. Future SDS classification could well benefit from the incorporation and strengthening of the approach to analyse physical slum development process.

5.7. SDS In A 3D Context

The analysis of the physical development process of slum settlements in Kisumu was based on a two-dimensional basis (2D) approach in which SDS is basically analysed by roof coverage. It was assumed that Manyatta slum settlements are mainly characterized by flat habitable neighbourhoods or one story residential buildings. In this case 100 percent roof coverage is the most that can be achieved. However, a clear future trend will be to explore the third dimension (3D) in analysing slum development stages in those cities where multistory residential buildings are common. This is especially true in metropolitan cities of developing countries such as in India, Brazil, Hong Kong and China, where it is common to have high rise residential buildings in slums.

In many of the rapidly urbanising cities in developing countries, it has been observed that there is a struggle for scarce urban space. Consequently, there has been a growing of high rise residential buildings in central and peripheries of metropolitan cities, medium and small cities as well. Currently, the proliferation of multistory buildings also takes place in slum settlements with high occupation densities in some cities of developing countries such as Cairo, Mumbai, Rio de Janeiro, Sao Paulo, and Shenzhen etc.

The essence of high density high rise building is generally to save land grabbing. Taking into account the rapid urbanisation and population growth trends, constructing high rise buildings or vertical expansion seems important for economically and demographically viable development and concurrently to reduce horizontal expansion of cities. Similarly, it minimizes operation and maintenance costs of infrastructures such as water supply, sanitation facilities, transport, drainage etc. There is also a tendency for gradual reduction of air pollution.

However, experience show that high density high rise building is challenging and sometimes even deteriorates. In many cities, governments seek to relocate slum dwellers into high rise houses in order to retain more lands and build condominiums or others and draw investment on the large slum areas. On the other hand, this type of relocation is not as efficient as it could be; potentially leading to congestion and vertical slums rise. In addition, the costs of maintenance of high rise building are unaffordable for slum dwellers and conceivably they enjoy little daylight and natural ventilation. Furthermore, high rise buildings do not provide much ground open space for slum dwellers to operate small businesses to supplement their incomes. Consecutively, slum dwellers rehabilitated into high rise buildings move back to the slum settlements as they disconnected from their critical social, familial and economic networks where only do exist in dense, ground level neighbourhoods. Generally, densities may be very high, with narrow streets, little open space, inadequate cross ventilation, and perhaps no areas for public amenities.

In 3D situation roof coverage, which is the equivalent of plot ratio in planning terms, provides only a partial measure of development and the floor space density (floor area ratio in planning terms) is more relevant. In planned areas floor area ratio (FAR) and plot ratio are mutually dependent. In areas with high FAR, plot ratio tends to be lower – i.e. high rise development requires more open space around the buildings to ensure adequate circulation space, green area, light etc. However, this is not the case particularly in multistory developments in informal settlements of developing countries.

Floor area ratio (FAR) is a unit of density referring to the floor space in relation to plot area (figure 5.8). It is the ratio of built-up floor area on a plot to the size of the plot – i.e. the total covered area on all floors of the building on a plot divided by size of the plot. Plot coverage is the size of the footprint of a building.

It is used to determine the intensity of development in a given unit area. According to Acioly and Davidson (1996), plot size, plot coverage and FAR give the dimension of the most visible aspect of density. Basically, these variables should be in accordance with the conditions stipulated in physical development planning standards of the respective city or country.

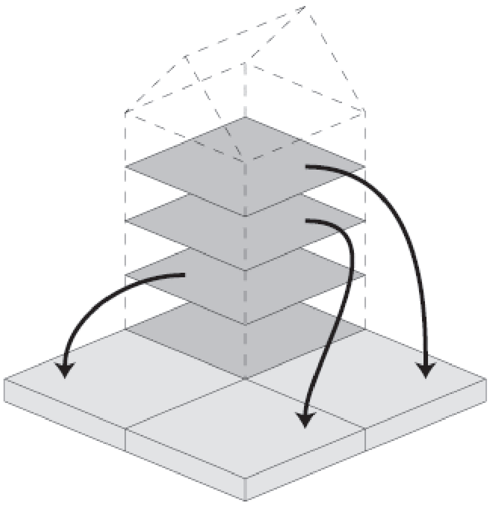


Figure 5.8: A Floor Area Ratio (FAR) of 1.0.
Source: http://www.carfree.com/far.html

Figure 5.8 shows a Floor Area Ratio (FAR) of 1.0. For example, if the size of the plot is 100 square meters and four story building covering one-fourth of the plot size was built, then FAR is 1.0 ($4 \times 0.25 = 1.0$).

If the recommended plot coverage of the site and FAR is known, the recommended number of story building can be easily computed from these variables using the formula shown below.

Plot coverage = FAR/Number of story buildings

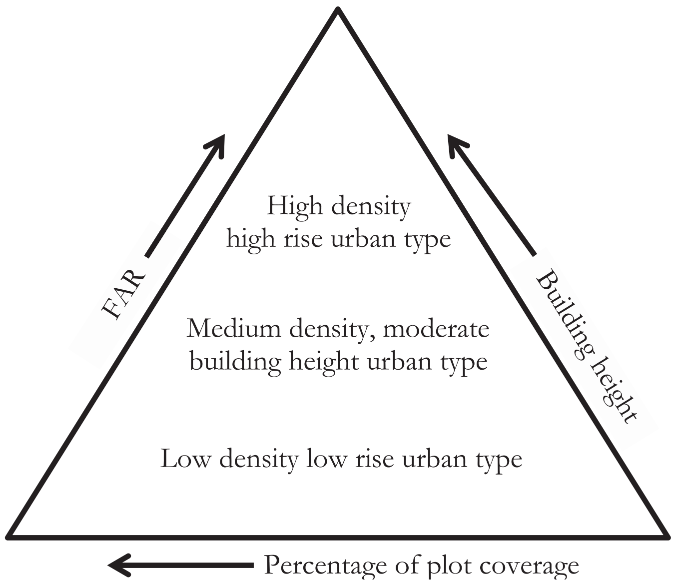


Figure 5.9: Conceptual urban density in terms of FAR, building height and percentage of plot coverage

If FAR, building height and plot coverage are taken into consideration there are different urban categories. Figure 5.9 generally illustrate different categories of urban type. As can been seen from the conceptual diagram, high density high rise urban type with a relatively higher FAR is located at the upper level. The middle level shows mixed density moderate building height and FAR urban type with different range of building height. The lower level shows low density low rise urban type characterised by relatively lower plot coverage and FAR. Basically, due to the cultural and socio-economic differences from place to place and variations in plot size, house size and soil type, the recommended number of storeys also varies considerably with subsequent variations in terms of plot coverage and FAR. Most of the cities of developed countries have FAR less than 1.0 ensuring more environmental and social benefits such as

streets, gardens, open spaces around the building, sufficient natural light and cross ventilation to reduce the total amount of built environment and its impacts onto the macro climate.
To analysis SDS in 3D slum settlements, OBIA with the integration of digital surface model (DSM) methods could be used for image classification process and thereby to investigate how 3D approach might be implemented. This methods offer up-to-date, reliable and accurate results, and can be continuously updated with minimum effort especially in developing countries where detailed spatial information related to slum settlements is hardly available. Basically, there are various methods for measuring the height of buildings using VHR imagery or aerial photography in order to estimate the number of floor space of a set of high rise residential buildings in the neighbourhoods. The numbers of floors space of the building is required to compute the FAR with the integration of plot coverage of the buildings. Most of the time, height of each floor space of the buildings is approximately 3 meters. In principle there might be different categories of roof buildings (flat or gable roof etc.) and viewing configurations (various local aspect and incidence angles) in the scene depending on the case study in which the research will be conducted. Similarly, interference between different buildings (shadow cast) might also arise if they are built close enough and the space around the building is not flat. To improve height estimation results for buildings that are affected by objects in the neighbourhood, combining different height estimation method from different aspects maybe required.

Generally, given the growing global availability of VHR satellite data and the rapid urbanisation trends, it is promising to analysis the vertical development stages of slums where proliferations of multistory residential buildings have also started to emerge in informal urban areas with high occupation densities. However, due to the scope of this study and the limited time frame, this approach has not been implemented and thoroughly examined how such issues could be brought into identifying development stages of slums in 3D informal settlements which are common in some cities. Nevertheless, the section highlighted key variables in general and it would seem promising to study 3D approach so as to explore the development stages of slum and how dwellers in these multistory residentially buildings cope with the changing lifestyles. Thus, this approach could be a key avenue for future research area in its effort to developing more consistent methods for analysis of the vertical physical development process of slums.

5.8. Summary

This chapter presented key results of the analysis along with the general discussion, particularly focussing on addressing the first and the main objective of the study, identifying and classifying the physical development process of stages of slum development process. It then presented the second sub-objective, analyse of key socio-economic characteristics of Manyatta slum settlement along with the conceptual and operational framework on how a more integrated analysis can have been conducted, if appropriate geo-referenced socio-economic data at HH level for Manyatta settlements would have been obtained. The chapter also discussed the applicability of the approach to identify, classify and analysis SDS from spatial data which is the third objective of the study. In addition, some issues have been briefly discussed on how to measure SDS in 3D context where proliferation of multistory buildings takes place in slum settlements with high occupation densities in some cities of developing countries.

6. SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

This chapter presents the general conclusion, summary of key findings, and recommendations from the results highlighting the nature of the physical and socio-economic development process slums in Manyatta settlement and drawing inferences from empirical investigation. The section, firstly, reiterates and discusses main themes applicable to Manyatta slum settlements and summarises briefly the outcome this study. It then discusses some limitations faced during execution along with possible recommendations to improve the limitations and finally proposes possible future research areas related SDS.

6.1. Sumary of Findings and Conclusion

The study first presented the pervasiveness of the formation and expansion of slum settlements using literature review. It has been explained that the formation and outward expansion of slums is associated with the rapid urbanisation and population growth trend mainly due to in-migration from rural to urban areas in search for livelihood opportunities. While slum formation can be attributed to rapid urbanisation and population growth trends, the general little knowledge on slum evolution, the limited capacity of the local authorities to supply improved social and physical infrastructure services for the residents and in-migrating population growth are contributory factors to the growth of slum settlements. The study has discussed that successful alternative strategies require not only relocation or slum upgrading programme but also understanding of the development stage of slums from sparsely settled rural areas and settlements into densely packed and physically saturated neighbourhoods. It was shown that local authorities and institutions are unlikely to be able to keeping pace with the tremendous demand for low cost housing due to rapid population growth and economic situation.

This study has empirically demonstrated the identification, classification and analysis of SDS from spatial data within the city context of Kisumu, Manyatta slum settlements. The result analysis of SDS revealed that around one-fifth of Manyatta A is already saturated and nearly two-third and one-fifth of the settlements is consolidated and at infancy stage respectively. In the case of Manyatta B, which is relatively young and rural slum settlement, more than half of the settlements are at early stages while around two-fifth are consolidated. It has also been shown that improved basic services and infrastructure provision, particularly improved sanitation facilities, has proved to be largely inadequate in the old Manyatta A slum settlement and in newly developing settlement of Manyatta B. This has resulted into numerous cases of water and sanitation related diseases such as malaria, cholera and typhoid.

On the methodological aspect, it has been noted that the methods employed in this study have the advantage of making the results more practical and user-oriented and provide reliable, up-to-date and high spatial and temporal information about spatial and contextual characteristics of slum settlements thereafter could be continuously updated with minimum effort to monitor and observe changes in slum settlements. Hence this study could provide a basis for further investigations of SDS and other related issues towards addressing the global and rising problem of slum formation and expansion and its associated effects.

6.1.1. Feature Extraction

This study has demonstrated how features from VHR GeoEye imagery has been extracted using the concept of OBIA and the developed rule-based classification in eCognition Developer 8.64.0 software environment. Six feature classes were extracted and their accuracy assessment was made which later exported as vector layer for classification of SDS. The accuracy assessment of the classifications was met through the use of an error matrix and reporting accuracies associated with each features. Overall, due to the integration of thematic layer as pre-defined boundaries for segmentation process alone, the accuracy assessment result was good and sufficient for further analysis. According to Bhaskaran et al. (2010), the accuracy of image classification using the concept of OBIA depends directly on the segments and an erroneous segmentation will result in inaccurate classification. Likewise segmentation result is depending upon the scale parameter which is determined by subjective try-and-error techniques. After segmentation, the classification algorithms analyses image objects according to the formulated rule-sets and subsequently objects are assigned to a class that best meets the specifications of the defined rule-sets. Generally, the full functionality for hierarchical classification available in eCognition software allows for classes to be defined in steps rather than through one training exercise, it may however take a significant amount of time spent to familiarise with the available functionality and to come up with appropriate scale parameter and classification rule-sets.

Kisumu is in hot and humid tropical zone. The GeoEye imagery was acquired during long rainy season in which vegetation flourishes naturally and relatively dynamic land cover class. If the image had been acquired during winter season the proportional abundance of vegetation and bare soil would have been changed. It has been discussed that, existing vegetation and other open areas are considered as positive urban structure elements, for example, in terms of their ecological functions of biodiversity and social functions. Overall, vegetation is important to generally examine the spatial quality as well as for provision of infrastructure and redevelopment. Though V-I-S are the fundamental components of urban areas and their densities were the bases of classification of SDS in this study, however, it might be enough to look at only the percentage of buildings. But the question which is relevant here is: What methods can only provide buildings without extracting other urban features within the scene? In other words, this is to question what kind of urban features should be considered along with buildings as far as reliable, up-to-date and high spatial and temporal information is concerned?

It has been also described that RS and GIS technology have a potential source of reliable, up-to-date and wealth of spatial information and spatially consistent datasets that cover large areas with high detail and temporal frequency. These technologies are cheaper to build, easier to use, and more robust and flexible in their application. The acquired high spatial and temporal information from RS and GIS could then help to solve and manage environmental and social problems particularly in SSA where detailed information pertaining to slum settlements is hardly available at local level.

6.1.2. Classification of SDS

The classification of the physical development process of slums was made based on the density of buildings, vegetation and bare soil at one hectare unit of analysis. The question that surrounds the three main variables to distinguish SDS has been raised and discussed in section 4.3. Generally, density is one of the most significant indicators and design parameters in the field of housing and human settlement planning (Lupala, 2002). However, according to the author, there is no such thing as the perfect density that is acceptable across cultures and countries. What people observe and feel is subject to their own background, and to some extent on the layout, building, and land use of the neighbourhoods. For example, a layout that satisfies certain specific society might sometimes inappropriate for other society; environments having the same number of people may as well be perceived to have different densities.

The question to define thresholds that are appropriate contextually and spatial unit of analysis that someone wants to be able to say something about at the end of the investigation was also raised and discussed. The primary unit of analysis for classification of SDS that has been determined was 100 x 100 meters resolution (one hectare). This unit of analysis would decrease the residential and socio-economic heterogeneity in the neighbourhood and well suited as a common framework for integration of data sets from different sources. It would also support longer-term monitoring as well as planning applications and might be easier and cost-effective way to improve the spatial characteristics of that particular neighbourhood.

The question of apparent thresholds to differentiate SDS is rather related to the plot coverage and number of dwelling units. As mentioned in section 4.3.4 the physical development planning standard of Kenya for slum upgrading programme was taken into consideration. It is indicative therefore that high, medium, and low density neighbourhoods were categorized based on the recommended plot size and number of dwelling units per hectare for semi-detached and row type of houses that dominate the present Manyatta slum settlement.

Overall, when percentage of buildings at one hectare is taken into consideration, approximately one-fifth of Manyatta A is already saturated and nearly two-third is consolidated. Although the external environment of Manyatta A depicts a characteristic density which has been perceived to be high, around one-fifth of the settlements are at infancy stage. In the case of Manyatta B, which is relatively young and rural slum settlement, around 54 percent of the settlements are at early stages. Around 42 percent of the settlements are consolidated.

It seems logical to conclude that the dynamic nature of rapidly urbanising cities and the relative location of slum settlements within cities renders SDS classification time dependent. This is due to the continuous process of transformation and change of slum settlements from one stage to another, which is triggered by change in building materials used, change in socio-economic condition and occupancy status, among others. This indicates that a neighbourhood that is classified as infancy stage would be at saturation stage over a course of time. This also implies that categorisation that has been done in this study is, toward serving mostly as bases for reliability with specific contexts and at specific time. Classification results from the case study areas are therefore context specific. The central idea is that the methods and analytical results established from this study could be related with other cases with similar cultural and socio-economic conditions in SSA. Generally, the results suggest that SDS can be identified, classified and analysed from spatial data but the proportion of buildings, vegetation and bare land may vary from country to country and even within the same country and city.

6.1.3. Socio-Economic Analysis and Applicability of the Approach

Finally, the analysed key socio-economic characteristics of Manyatta settlement and the applicability of approach to identify SDS from spatial data was examined and discussed. The five UN Habitat slum indicators except overcrowding were chosen and analysed for nine slum settlement units found in Manyatta. In Kisumu city where over 60 percent of its population lives in slum settlements, has an overall population density of about 1,052 people per square kilometre. The population density increased to 20,955 and 6,372 people per square kilometre in Manyatta A and Manyatta B respectively (UN Habitat, 2005). Although these figures may be comparable to some extent with other SSA countries, when compared with figure from other slum settlements of Kisumu, they are rather high. Particularly, population densities in Manyatta A have been noted to be nearly triple of the rest of slum settlements. The fact that the growth of Manyatta slum settlements is largely characterised by semi-detached and row house types, particularly Manyatta B, has the potential to expand horizontally limiting effective provision of improved basic infrastructure and social facilities.

In general, despite the location of Kisumu city at the east-coast of Lake Victoria, water supply in Manyatta is not regular. It was noted from Pamoja Trust enumeration report households pay exorbitant rates to access what can only be described as unimproved drinking water from shallow wells and door-to-door water vendors. The housing condition in Manyatta slum settlements has a mix of permanent made of clay-fired bricks (matofali) or concrete blocks structure and semi-permanent housing units with mud and wattle with cement finish and iron sheet structures. Most housing structures in the settlement were observed to be structurally deficient which might be due to insufficient drainage or low uptake of appropriate building technology. Manyatta B for example, mud and wattle structures accounts for averagely around three-fourth of the building materials in the neighbourhoods. The footpaths and road networks in Manyatta B are non-motorable in most cases and they are impassable, especially during rainy seasons because the ground is predominantly waterlogged. In contrast, Manyatta A is comparatively more developed and has some facilities such as schools, health centres, markets and a network of tarmac roads. The majority of households, more than 90 percent, in both Manyatta A and Manyatta B do not have improved sanitation facilities that are connected to either sewer or septic tank (figure 5.6). Indeed, the vast majority of households have pit latrine that is defined as an unimproved sanitation facilities. Nearly two-third of the households in Manyatta A and more than half of the households in Manyatta B are tenants.

One of the major observations in this study is the pattern of slum development which is from sparsely settled rural areas and settlements into consolidated and physically saturated neighbourhoods that largely determine the spatial structure of rapidly urbanising SSA cities. A close examination of the result of the physical development process of slum confirms that the pattern of development stages of slums is toward the location of the city centre as it was expected and theoretically explained. It has been observed that about 80 present of the neighbourhoods in Manyatta A are currently consolidated and saturated while more than half of Manyatta B is at infancy stage. Manyatta is primarily dominated by the semi-detached and row houses types, with multiple deprivation in terms of infrastructure and other basic services. Unless effective measures are established along with strong local partner to address these deprivations, the rapid growth and expansion of slum settlements will continue to augment the lack of social and physical infrastructure and other basic services.

Understandably, one of the reasons for ineffective planning interventions could be attributed to the general little knowledge on evolution of SDS. Furthermore, low capacity of the local authorities in terms of manpower, financial resources and equipment to deal with the large number of slum settlements and to capture the speed and direction of slum growth in the city has also contributed to this global and escalating urban problem. The identification and classification of SDS from VHR imagery within the city context of Kisumu, for example, could provide a basis for studying the development processes of slums in the context of SSA. As contribution to knowledge, this study has generated a methodology to discuss the concepts of SDS and provides a grounding base for further investigations to contribute to the efforts being made to minimize slum formations. The question that is worthy raising here is, what kind of interventions are needed that required minimum effort and yield maximum benefit for improving the living and the economic conditions of slum dwellers concurrently ensuring optimal use of land and infrastructure without compromising spatial qualities and yet to reduce slum formation. This question together with other key issues might be further research areas which is the subjects of discussion in the proceeding recommendation section.

Finally, this study has demonstrated that the developed rule-based classification techniques, the employed variables and unit of analysis as well as the defined thresholds to classify and analysis SDS has also been examined based upon reliability, usability, generality, and validity. These frameworks have generally indicated that the employed methods and the results of the study can improve the analytical capabilities in similar cultural and socio-economic characteristics that would ultimately expected to contribute to the efforts being made to minimize slum formations and expansion. However, the developed methods has possibility for further improvement, especially by applying the entire developed methods to new slum settlements which would also enable stronger assertions about the applicability and transferability of the methods if time had been available.

6.2. Limitations and Areas For Further Research Recommendation

The employed methods in this study enabled a thorough investigation of the first research objectives which was the centre of the study; essentially identifying and classifying slum development stages from VHR imagery. The lack of geo-referenced socio-economic data set, however, only allowed limited investigation around the last research questions under second research objective aiming to explore the relation between the physical and socio-economic development process of slums in Manyatta settlement. Obviously further research exploring correlation between socio-economic characteristics and SDS and further to conclude if socio-economic characteristics could be used to differentiate SDS, need to investigate and identify other important variables apart from the conceptual and operational framework that has been discussed in section 5.5. The proceeding last section highlights some of the challenges and limitations faced during the course of carrying this study along with possible recommendations to improve the challenges and the limitations as well. Concurrently, future research areas that could therefore be considered as general benchmarks toward addressing the problems emanating from the continued formation and expansion of slums, via understanding the characteristics of SDS were proposed.

6.2.1. Feature Extraction

The use of VHR imagery is steadily increasing in urban-related applications such as for monitoring human settlements. It offers detailed view and large coverage of land cover that can be able to utilise the wealth of information coming from this VHR data. However, it is true that, there are some challenges related to the fine spatial resolution and the relative course spectral resolution of VHR data. For example, the confusion between many spectral reflectance especially urban areas is the major challenges in extracting different urban features (Herold et al., 2003). This is because, urban space, by its very heterogeneous and dynamic nature, becomes more complex to study by the existence of various objects different by their shape, direction, size, roof material, to list few among others, depending on the type of habitat (Busgeeth, et al., 2008). Consequently, sole use of VHR imagery for urban feature identification yields less satisfactory results (Kokje, 2011). Integration of additional data such as Light Detection And Ranging (LiDAR) products (elevation and slope) at same resolution could be an alternative method to overcome these practical limitations. The assumption for image segmentation and classification is that, all features classes within the scene can be distinguished into ground and non-ground objects based upon elevation, slope and normalised Digital Surface Model (nDSM) extracted from LiDAR data in eCognition Developer software environment (Kokje, 2011). This early attempt to differentiate image segments into ground feature classes, for example water, grass, roads and above ground feature classes, for example trees, buildings yields clear boundaries of various features resulting in more accurate segmentation. Therefore, Normalised Difference Vegetation Index (NDVI) threshold in combination with nDSM values could be used to discriminate vegetation (grass and trees) which was one of the main challenges faced during feature extraction phase in this study. In addition, nDSM, slope and elevation parameters obtained from 3D LiDAR data could be used to identify buildings from above ground classes.

6.2.2. Evaluation of the Approach

Two neighbourhoods, Manyatta A and Manyatta B, together were considered to be an appropriate strategy as case studies to investigate SDS since they are relatively consolidated and newly developed slum settlements from across eight Kisumu slum settlements. These selected settlements allowed to some extent both a holistic and contextualised investigation of stages of slum development processes. The research methodology utilised, however, only limited investigation and use of qualitative method of evaluation, around the third research objective aiming to assess the applicability of the developed methods, could not been carried out due to the limited time. Further work, the transferability of the approach, perhaps applying the entire sufficiently described classification process to a new slum settlement with similar socio-economic condition, would also enable stronger assertions about the applicability and reusability of the methods. It is expected that adjustments and slight changes to the methods will occur when it is applied into another slum settlements.

6.2.3. Summary

Generally further research area looking at development stages of slums could focus on the following related issues:

- Investigating how to incorporate variables like road networks and shadows to classification of development stages of slum
- Investigating if socio-economic characteristics can be used to differentiate SDS
- Investigating how a 3D approach to physical development stages of slum might work
- Identifying types of interventions for each slum development stages that require minimum effort and easy to apply and yield maximum benefit, and
- Revealing the driving forces for change of slum from one stage to another in a more structured approach

This could be enabled by systematic empirical investigation methods; extracting rich, detailed spatial information, careful selection of indicators, and the inclusion of case studies where significant numbers of slum dwellers continue to exacerbate the growth and expansion of slum settlements.

Overall, this study has a more context understanding of the physical development process of Manyatta slum settlement. Specifically, the study attempted to categorise slum settlements of Manyatta into infancy, consolidated and saturated stages using spatial data in its effort to improving the analytical capabilities in similar context of SSA where detailed census data pertaining to slums at local level are typically not available. This could potentially enhance better understanding toward the direction and speed of slum growth and help urban planner and decision maker for informed prospective interventions which would eventually improve the well-being of slum dwellers and better yet reduce slum formation.

The study has also discussed that any effort to improve services, utilities and infrastructure in slum settlements could focus on stages of slum development which would require relatively less effort and yields maximum benefits. Given the actual trend of population growth and the proportion of slum dwellers without access to improved social and physical services in Manyatta settlements, the basic amenities and infrastructures should be rehabilitated and expanded. Ultimately, in any context, it is political will that is essential for implementing interventions aimed at improving the living and the economic conditions of urban slum dwellers. The inevitability of urbanisation as a positive force, vital to on-going national and global development, must be realised. Of course, the rapid growth of urban population and their vulnerability raises and escalating of slum formation is unprecedented challenges. Fortunately, however, if urbanisation is managed and guided well by the local government particularly if systematic interventions through shared responsibility with the community are developed and made to contain SDS, continued slum formation is not inevitable.

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