UNIVERSITY OF NAIROBI

URBAN FORM AND CLIMATE CHANGE: ENHANCING THE RESILIENCE OF MATHARE VALLEY INFORMAL SETTLEMENT IN NAIROBI CITY, KENYA

BY

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DEDICATION

This thesis is dedicated to my husband Opil, and my two children Amirah and Cera whose support and sacrifices have led up to this moment. To my mother Florence Waithera, this is for you, as you continue to rest with the angels. I know you would be very proud. To my brother Kevin, I hope this inspires you to complete your degree as well.

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ABSTRACT

Informal settlements within cities are often the most vulnerable areas to climate change due to their location in hazard prone areas, high density of population and poorly constructed structures, as well as the poor condition, or inadequacy of infrastructural facilities. Mathare Valley which is one of Nairobi's largest informal settlements, houses an estimated population of 122,115 people in an area of 1.16 square kilometres. Disasters caused by weather extremes such as flooding have been documented within Mathare Valley, yet a knowledge gap on the interaction between urban form and climate disasters in the settlement exists. This research therefore sought to assess the urban form-climate change link for the urban poor and propose solutions for incorporation of this knowledge into urban planning and infrastructure design for enhanced resilience to climate change.

This research was based on critical review of documented literature and detailed field surveys. Data collection involved administration of 100 household questionnaires, 13 commercial enterprise questionnaires, and interviews with three key informants, as well as one focus group discussion. Urban form information was collected from historical documents, field mapping and aerial images. Data analysis involved the use of the Statistical Package for Social Sciences (SPSS) to generate descriptive statistics such as frequencies and cross-tabulations, as well as geo-spatial analysis of urban form and climate risks. Data presentation within this thesis report encompasses the use of narrative writing, maps, charts, tables, graphs and diagrams.

This research found that Mathare Valley faces climate change impacts in the form of heat stress, flooding, landslides, aridity and cold stress. This is because of the settlement's location within a riparian zone with steep cliffs in some areas, high density of structures, location of most residential and commercial activities on ground-level, the non-resilient nature of building materials, and the poor condition of infrastructural services such as roads, water and electricity. Ongoing upgrading initiatives within the slum such as road and culvert construction have led to a decrease in flooding disasters, but the resultant impact of increased settlement closer to Mathare River is mal-adaption. Shifting of building materials from mud to iron sheet to create more flood-resilient structures has created uncomfortable indoor conditions increasing thermal stress for residents. Further, the dense layout of iron sheets building in the slum has created uncomfortable thermal conditions at ground level with little opportunity for air circulation. The most vulnerable sub-sets of the community to thermal stress and flooding within the settlement, are residents living within the immediate vicinity of the river, women, children, the elderly, the sick, the disabled and persons working outdoors. On the other hand, persons residing within structures constructed on top of, or at the bottom of steep cliffs are the most vulnerable to landslide risk in the event of heavy rainfall. In conclusion, this research established a clear link between the urban form of Mathare Valley and the climate change impacts it faces.

One fifth of the community proposed hard engineering solutions to flooding while the majority were in support of softer responses to climate risks. However, due to the high risks posed to both property and human life, this study proposes the relocation of structures located within the high-risk flooding and landslide zones, reinforcement of structures within the medium flooding zones and incorporation of cooler building materials such as clay bricks settlement-wide. This plan, however, can only be supported by responsive policy and further detailed research for its success.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS:

APHRC	African Population and Health Research Centre
CBO	Community-Based Organisation
CBS	Kenya National Bureau of Statistics
FBO	Faith-Based Organisation
FGD	Focused Group Discussion
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographical Information Systems
GOK	Government of Kenya
INDC	Intended Nationally Determined Contribution
KENSUP	Kenya Slum Upgrading Programme
KISIP	Kenya Informal Settlements Improvement Programme
KMD	Kenya Meteorological Department
KNBS	Kenya National Bureau of Statistics
LACPD	Los Angeles City Planning Department
LDCs	Least Developed Countries
LECRD	Low Emissions and Climate Resilient Development Project
NCCAP	National Climate Change Action Plan
NCCRS	National Climate Change Response Strategy
NEMA	National Environmental Agency
NGO	Non-Governmental Organisation
NUIPLAN	Nairobi City Integrated Urban Development Master Plan
SHOFCO	Shining Hope for Communities
SID	Society for International Development
SPSS	Statistical Package for Social Sciences
UNFCCC	United Nations Framework Convention on Climate Change
UN-HABITAT	United Nations Human Settlements Programme
WHO	World Health Organization

GLOSSARY OF KEY TERMS

Adaptation is defined as the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (UNISDR, 2009).

Climate change is defined as 'a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer' (IPCC, 2014).

Informal settlements are defined as residential areas where 'inhabitants have no security of tenure, neighbourhoods usually lack, or are cut off from, basic services and city infrastructure and the housing may not comply with current planning and building regulations, and is often situated in geographically and environmentally hazardous areas'; while slums are defined as 'the most deprived and excluded form of informal settlements' (UN Habitat, 2015: 1).

Poverty is defined as the deprivation of economic resources that are required to meet food, shelter and clothing needs necessary for physical wellbeing, as well as psychological and social wellbeing (Williamson and Reutter, 1999).

Resilience is defined by IPCC (2007) as 'the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity of self-organization, and the capacity to adapt to stress and change.' Kenya's Climate Change Act 2016 defines **climate change resilience** as the 'capability to maintain competent function and return to some normal range of function even when faced with adverse impact of climate change' (CCA, 2016).

Urban Form has been defined as 'the general pattern of building height and development intensity and the structural elements that define a city physically, such as natural features, transportation corridors, open space, public facilities, activity centres and focal elements' (LACPD, 1995).

Urbanization refers to either 'the increase in the proportion of a population living in urban areas' or the 'process by which a large number of people become permanently concentrated in relatively small areas, forming cities' (OECD, 2008: 569).

Vulnerability refers to 'the degree to which a system is susceptible to, or unable to cope with, the adverse effects of climate change, including climate variability and extremes' (IPCC 2001).

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND

Global temperatures are rising (IPCC, 2014) and as a result, the world is feeling the impact of the changing climate in the form of weather extremes. The world is also increasingly urbanizing, with 55 percent of the entire global population living in urban areas today (UN-Habitat, 2016). However, cities in the developing world are perceived as eyesores overflowing with slums that are home to an estimated one billion people worldwide (Jenks and Burgess, 2000; UN-Habitat, 2014). The interplay between the 'desire to live close to jobs and amenities', coupled with land scarcity and high rents in urban areas forces poor communities into informal settlements with lower rents, often located on 'hazard prone areas such as flood plains or steeply sloped land' (Lall and Deichmann, 2009).

Urban form is defined as the 'spaces, places and boundaries that define city life' (Warner and Wittemore, 2012), made up of elements that include density, housing or building type, spatial layout, land use and transport infrastructure within an urban space (Dempsey *et al.*, 2010). Urban form serves as a reflector of the city's socio-economic processes, with informal settlements, which absorb the poorest people within cities, often exhibiting more dense and unplanned spatial structure, which has been acknowledged to amplify the impact of climate-change induced disasters (WHO and UN-Habitat, 2010).

Climate resilience refers to 'the ability of a system to return to a pre-disturbed state without incurring any lasting fundamental change' (IPCC, 2014). Resilience is dependent not only on externalities such as the magnitude of climatic changes, but also on the ability of systems to adjust their changing climatic conditions (IPCC, 2014). The urban poor themselves are often unable to act to reduce their exposure to climate risks as they are consumed by their immediate demands of survival (UN-Habitat 2008), yet their settlements are often located on areas that are highly exposed to climate disasters, such as flooding, sea-level rise and landslides (IPCC, 2014). Addressing resilience is therefore urgent given that 32 percent of all urban residents in the developing counties live in informal settlements, with this proportion rising to 60 percent in Sub-Saharan Africa alone (UN-Habitat, 2014).

Kenya's urban population has been growing rapidly from only 19.3 percent in 1999, to 31 percent by 2013 (Central Bureau of Statistics, 2004; KNBS and SID, 2013). A quarter of Kenya's urban population lives within its capital city Nairobi, a figure estimated to be 4 million people today (KNBS and SID, 2013; UN-Habitat, 2016). Nairobi produces over half of all of Kenya's Gross Domestic Product and half of the national formal employment (NCC *et al.*, 2014; DFID, 2015). The capital city also hosts an estimated 65 percent of its residents in informal settlements (APHRC, 2014), a number expected to grow as the city population swells by 75 percent to 7 million people by the year 2030 (UN Habitat, 2016).

An increase in seasonal mean temperature as well as extreme precipitation changes has been observed in Kenya and East Africa over the last 50 years (IPCC, 2014). Nairobi city, for instance, experienced massive flooding in 2016 that caused the collapse of a building claiming tens of lives while affecting major functions such as traffic flow and electricity supply in the city (Agutu, 2016). While climate change poses a risk to all city residents, the urban poor are particularly vulnerable because of factors such as settlement on environmentally fragile sites that have higher exposure to climate risks, low incomes, dilapidated non-resilient housing and a lack of risk-reducing infrastructure (IPCC, 2014).

The selected location for this research was in Mathare Valley informal settlement, that is in Nairobi City, located between latitudes 1^{o}0'00"S and 1^{o}16'00"S and between longitudes 36^{o}50'30"E and 36^{o}52'00"S. Mathare Valley is the most derelict part of the larger Mathare, the third largest informal settlement in Nairobi City, and is home to an estimated 122,115 people (UC Berkeley *et al.*, 2012; KNBS and SID, 2013). Mathare Valley covers an area of $1.16km^2$ and is physically bounded by Juja Road, Mathare North Road, Thika Highway and Muratina Street (Figure 1.1). Mathare Valley informal settlement exhibits a variety of urban form options, with high vulnerability to climate risk due to its physical location within a river valley.

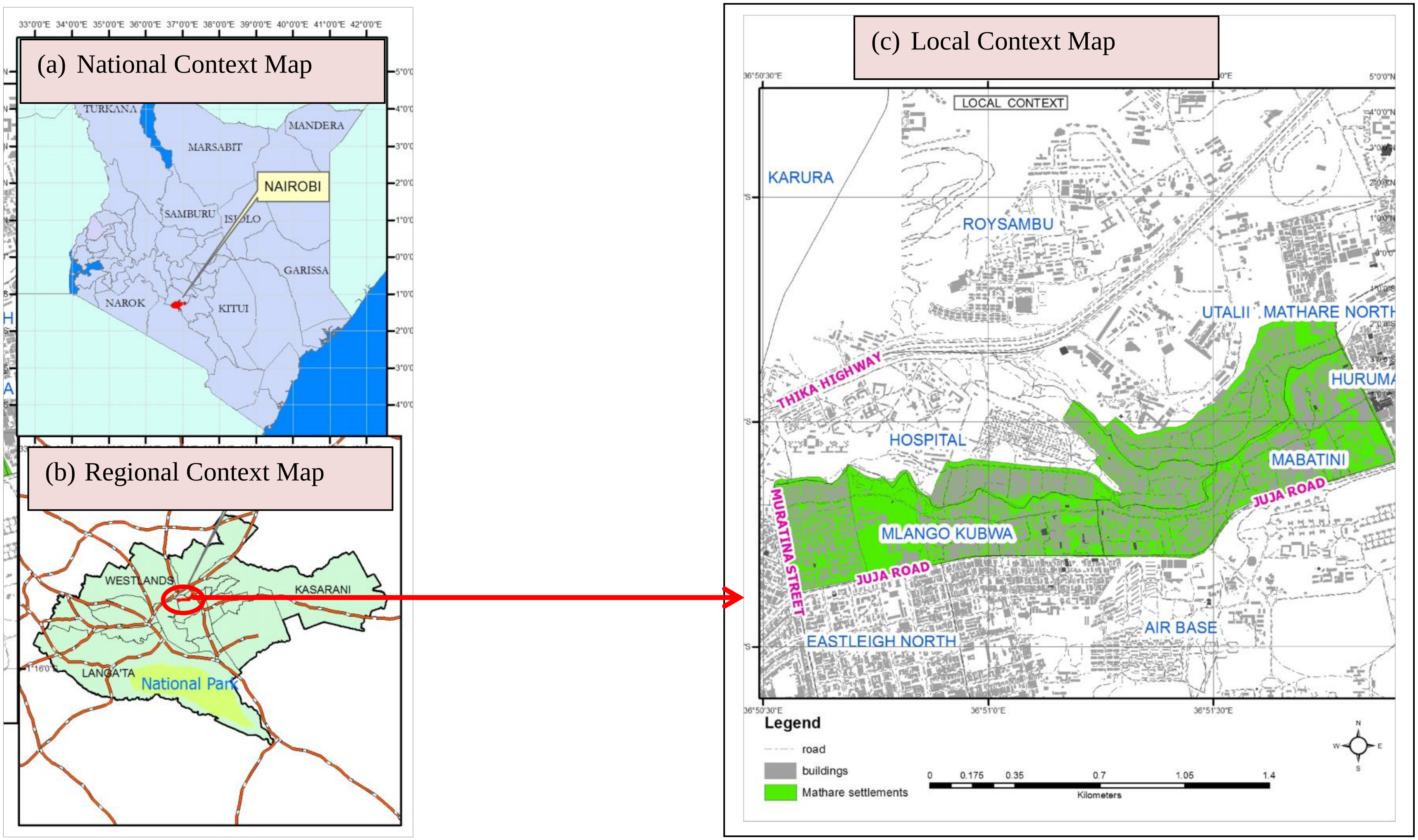

Figure 1.1: Map of the: (a) national context, (b) regional context, and (c) local context of Mathare Valley

Data Sources: Administrative boundaries based on the IEBC legal notice 12 (2012); Area features based on a vertical aerial image/ orthophoto mosaic (2013) with a resolution of 15cm.

Cities, urban poor communities and climate change are intricately linked in two ways. First, cities are to blame for the bulk of global greenhouse gas (GHG) emissions, particularly carbon dioxide, from the production and consumption patterns of urban residents (Hoomwerg *et al.*, 2011). Residents of Mathare Valley, for instance, contribute to greenhouse gas emissions through fossil-fuel burning for energy with 84.2% of residents using kerosene, for cooking (KNBS & SID, 2013), which produces an estimated 0.26KgCO_2 per kWh (Quaschning, 2015). Secondly, it is expected that climate change will amplify rural-urban migration by creating increasingly difficult conditions in the rural areas (GOK, 2013).

While there have been efforts both by government and non-governmental institutions to upgrade Mathare Valley informal settlement, little effort, however, has been specifically targeted at ensuring that climate change adaptation and mitigation are integrated into any urban form interventions. In cognisance of the eleventh Sustainable Development Goal (SDG 11) that aims to make cities inclusive, safe, resilient and sustainable, this study seeks to establish the relationship between the urban form within the city of Nairobi's Mathare Valley informal settlement, to the level of climate resilience facing residents, and propose urban form options for adaptation.

1.2 PROBLEM STATEMENT

Mathare Valley is one of the largest informal settlements within Nairobi, with an estimated population of 122,115 people (KNBS, SID, 2013) living at a high density of 105,000 people per square kilometre. Mathare Valley is experiencing the impacts of extreme climate events, mostly in the form of flooding, and a warming trend established at the adjacent Moi Airforce Base Eastleigh weather station from analysis of the mean annual maximum and minimum temperatures from 1969 to 1999 (Makokha and Shisanya, 2010). The impacts on residents have been immense, ranging from loss of property and life, water-borne diseases and damage to infrastructure such as transportation, water and electricity supply lines. In Huruma Estate that immediately borders Mathare Valley to the East, over fifty people perished when a seven-storey building collapsed on tenants as a result of heavy rainfall on the night of 29th April 2016 (Agutu, 2016).

The residents of Mathare Valley are particularly vulnerable because the settlement is located along the valleys of both Mathare and Gitathuru Rivers and around steep sloping areas (Karisa, 2010), at high risk of climatic hazards such as flooding and landslides. Mathare Valley exhibits dense urban form, either in the form of high-rise buildings or compactly stacked ground-floor shacks. At the same time, the ground layout of the informal settlement is haphazard in design, with poor access networks that would hinder any emergency evacuation or response attempts (Andvig and Barasa, 2014).

Majority of the house structures are made of iron sheets which can cause discomfort in the event of heat stress, and when coupled with poor foundations, are not resilient to strong floods (UC Berkeley, 2011). Even in the areas with stone-buildings, construction is done without formal building permits or adherence to city building codes and standards, putting the apartments at risk of collapse. Water access is limited and pipes and water points are at risk of contamination in the event of flooding, increasing the possibilities of the spread of water-borne diseases (UC Berkeley *et al.*, 2012).

While there have been many studies and attempts on upgrading urban form, infrastructural service provision and flood management of this informal settlement, such as the Mathare Valley Collaborative Upgrading Plan (UC Berkeley *et al.*, 2012), there has been little, if any, direct consideration of climate change in the planning and design processes.

1.3 RESEARCH QUESTIONS

The research questions for this study are:

1. What have been the different urban form types and trends within Mathare Valley?
2. What are the levels of climate change resilience of communities within the different urban forms within Mathare Valley?
3. What modifications can be made to the urban form to improve climate change resilience of communities within Mathare Valley?

1.4 HYPOTHESIS

This study tested the hypothesis that the prevalence of poor urban form appears to have contributed to low climate change resilience of Mathare Valley residents.

1.5 OBJECTIVES

The overall objective of this research was to assess the impact of the existing urban form of Mathare Valley informal settlement to climate change resilience of residents and propose options for adaptation to enhance climate resilience.

The specific objectives of this study were:

1. To determine the existing urban form types and trends within Mathare Valley.
2. To assess the levels of climate change resilience of communities living within the different urban forms within Mathare Valley.
3. To evaluate options in urban form for improved climate change resilience of communities within Mathare Valley.

1.6 JUSTIFICATION AND SIGNIFICANCE OF THE RESEARCH

1.6.1 JUSTIFICATION

Cities hold high populations, large portions of built assets and economic activities, but are often blighted by informal settlements. The informal settlements therein, 'most of which are located on land at high risk from extreme weather', are the nodes of concentration of most of 'the health risk and vulnerability to climate change' for the urban poor that they host (Satterthwaite, 2007; Revi *et al.*, 2008).

A key problem facing city policy-makers is that research into the interaction between urban form, climate change and resilience has been accorded little attention (Satterthwaite *et al.*, 2011; Jenks and Burgess, 2000; IIED, 2009). In addition, climate disasters impacting the physical and socio-economic well-being of the urban poor will ultimately have negative city-wide effects, while threatening to reverse any developmental progress made in the past (UN-Habitat, 2014). In this regard, this research will therefore benefit Kenya by contributing to urban climate knowledge, as it is anticipated in the National Climate Change Action Plan (NCCAP) that the nation 'will become a predominantly urban country by 2033', while noting that the urban poor living in slums are particularly vulnerable to floods (GOK, 2013).

1.6.2 SIGNIFICANCE

The importance of this topic is encompassed in the eleventh Sustainable Development Goal (SDG 11) that targets to "make cities and human settlements inclusive, safe, resilient and sustainable" and the thirteenth (SDG 13) that aims at urgent action to combat climate change and its impacts at by the year 2030. SDG 11 in particular gives focus to the poor in slums and those in vulnerable situations through target 11.5 aimed at building the resilience of these people by reducing their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters. Additionally, this study covers the salient aims of the other SDGs such as promotion of good health and well-being (SDG 3), reduced inequality (SDG 10) and the resilience for the poor (SDG 1). This topic is also significant worldwide as it responds to global frameworks such as the Paris Agreement on Climate Change that came into force in 2016, the Sendai Framework for Disaster Reduction 2015-2030 and the New Urban Agenda 2016.

One of Kenya's priority adaptation options with her Intended Nationally Determined Contribution (INDC) is to 'enhance the adaptive capacity of the population, urbanization and housing sector' (MENRRDA, 2015, p.5). As climate risk is projected to increase in the coming years, this research is significant in that it provides a case study of Mathare Valley, on climate risks facing the urban poor, who are an estimated 65% of the city population (APHRC, 2014), and proposes urban form solutions for adaptation to build resilience to climate change, that can be replicated in similar contexts. This is in line with national visions and plans outlined in the Kenya Constitution, as well as the Kenya Vision 2030, the National Spatial Plan, and the Nairobi City Integrated Urban Development Master Plan (NUIPLAN), among others.

1.7 SCOPE OF THE RESEARCH

This research limited itself to urban form interactions with climate change in informal settlements alone. The geographical scope is restricted to the region bound by Juja Road, Mathare North Road, Mathare River, Thika Road and Muratina Street (Figure 1.1).

1.8 OVERVIEW OF THE METHODOLOGICAL APPROACH

This study used both qualitative and quantitative research methods. Documentary evidence, field surveys and outputs of Geographical Information Systems (GIS) and statistical analysis were assessed in achievement of the research objectives. A detailed description of the methodological approach adopted for this research is elaborated in Chapter 3 of this thesis.

CHAPTER TWO: LITERATURE REVIEW

2.1 OVERVIEW

This chapter presents documented literature on five broad categories that form the core of this thesis: urban form and climate change; informal settlements and their vulnerability to climate change; climate resilience; urban adaptation options to build resilience; and legal and policy environment for urban resilience in Kenya. Case studies of four informal settlements have also been presented to provide possible options for urban form modification for enhanced climate resilience. This chapter concludes by highlighting the knowledge gaps that emerge from the literature reviewed, hereby making a case for the research topic selected.

2.2 URBAN FORM AND CLIMATE CHANGE

Urban form refers to the morphology of an urban area, encompassing both physical and non-physical elements (Dempsey *et al.*, 2010) that structure a city (Figure 2.1). This concept encompasses both the 'general pattern of building height and development intensity, as well as the structural elements that define a city physically, such as natural features, transportation corridors, open space, public facilities, activity centres and focal elements' (LACPD, 1995). Urban form has an impact on the identity and liveability of a place, and has impacts on transportation, social issues and environment (LACPD, 1995; Jenks and Burgess, 2000).

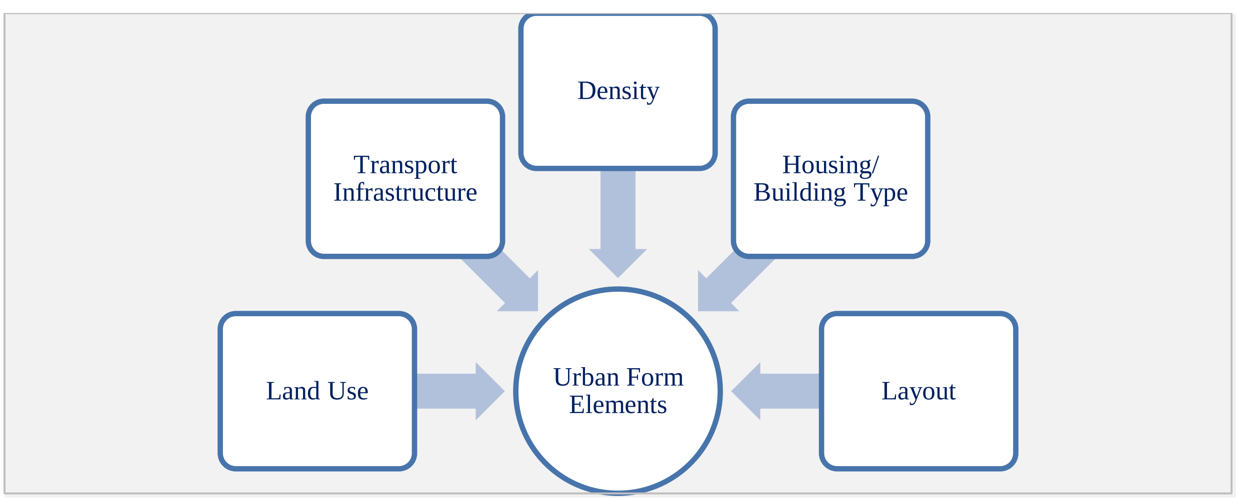

Figure 2.1: Urban Form Elements

Source: Dempsey *et al.*, 2010.

Aspects such as ‘the size, shape, density and compactness’ of an urban place determine its urban form (LACPD, 1995; Jenks and Burgess, 2000). In broad planning discourse, compact urban form that involves the densification of built-up areas and intensification of socio-economic activities has often been seen as a panacea to many urbanization problems. While urban form is a tool for achieving sustainability of urban areas, as Jenks and Burgess (2000) observe, climate varies worldwide and thus there cannot be one form of sustainable urban form, for instance in Nairobi city that falls within the tropics.

One of the relationships between urban form and climate change as noted in Revi *et al.,* (2008, p.538) is that the density and geographic scale of cities is adequate enough for them to affect their micro-climate and thus exacerbate climate risks. An example of this interaction is the Urban Heat Island (UHI) effect. The modification of the land surface in urban areas alters the thermal and radiative properties of the urban environment, as well as air movements, making them conspicuously warmer than surrounding regions (IPCC, 2007). This phenomenon’s effects on circulation and dispersal of wind and air pollution, affects human comfort, productivity and health, significantly impacting urban form (Satterthwaite, 2007; Makokha and Shisanya, 2010).

The manifestation of climate change, on the other hand, can impact on urban form, as some climate disasters have the ability to completely alter the urban landscape. For instance, sea-level rise has been observed to completely submerge or erode sections of coastal cities (such as Honiara, in the Solomon Islands), while landslides prompted by heavy and protracted precipitation can bury entire settlements (such as Medellin, in Colombia), modifying the natural and built landscape (Sassa and Canuti, 2009; IPCC, 2014). However, the modification of the urban landscape by climate disasters can serve as either an opportunity for reducing future climate risks or for increasing existing vulnerabilities (IPCC, 2012). A more resilient urban form can be built if the rebuilding process targets to strengthen settlements to future climate risks, but emphasis on quick rehabilitative measures or maladaptive responses can expose urban form to even more destruction in the future (IPCC, 2012).

2.3 INFORMAL SETTLEMENTS AND THEIR VULNERABILITY TO CLIMATE CHANGE

The IPCC (2012) highlights informal settlements as one of the most at risk elements of cities, particularly due to their geographic location on perilous zones. For instance, informal settlements along low elevation zones are at risk of losses from sea-level rise that causes coastal inundation and erosion, and extreme coastal events such as cyclones and storm surges. In inland areas, informal settlements face the risk of urban flooding, thermal stress and water scarcity; while those on steep unstable slopes, such as on hillsides or on dumpsites, are at risk of landslides from heavy and prolonged rains. Excess precipitation also poses a risk of flooding to slums along riparian zones and flood plains.

Informal settlements and slums are residential areas, characterized by deprivations of security of tenure and basic services, and hosting overcrowded and dilapidated housing in non-conformance with building codes or planning standards. Slums in particular, are the most deprived, squalid and excluded form of informal settlements (Majale, 1993; UN Habitat, 2015). A combination of poor government policies, land market distortions, the need to be close to both employment opportunities and services, and inefficient regulations have seen expansion of informal settlements, particularly into hazardous areas such as along river valleys, within low elevation coastal areas, or on steep sloping land (Lall and Deichmann, 2009; UN-Habitat, 2014).

The component of the climate vulnerability of informal settlements is not a feature of physical exposure to hazards alone. The high vulnerability of informal settlements is 'a product of intersecting social processes that result in inequalities in socioeconomic status and income, as well as in exposure' (IPCC, 2014). The factors that make informal settlement communities more vulnerable due to their lower adaptive capacity include: poverty, low education levels, marginalization by urban governments, lack of infrastructure, poor access to social services such as healthcare, gender, age and disability, and minimal relocation and insurance options (Revi *et al.*, 2008; Reid *et al.*, 2009; IPCC, 2014).

A key challenge however as noted by the IPCC (2012) is that quantification of these climate losses in economic terms is hampered by lack of recognition of impacts to the largely undocumented informal sector as well as inability to quantify non-tangible losses such as suffering or lost community networks. In addition to this, as noted by UN Habitat (2008), the preoccupation of the poor with the immediate needs of survival, such as food, leaves them with little opportunity to reduce their exposure to environmental risks. As a result therefore of their activities, location and housing characteristics, these poor communities carry an uneven burden of hazard risk as compared to the rest of the population (Lall and Deichmann, 2009; Opiyo, 2009).

The question of resilience for the dwellers of informal settlements can no longer be ignored. As the IPCC's Fifth Assessment Report 2014 observes urban climate change-related risks such as heat stress, flooding, water scarcity, landslides and air pollution are on the rise, and these risks are more pronounced for informal settlements dwellers (Revi *et al.*, 2008). In Nairobi, the nearly two million slum dwellers are housed in only 5% of the city's residential land. This density is alarming, given that Nairobi's urban population is expected to grow by 75 percent to 7 million people in the next 15 years (UN Habitat 2016).

As the World Bank and Australian Aid (2012, p.4) note, the biggest cause of deaths and losses from extreme weather is the increase of population and assets in precarious locations, a situation evident in Nairobi. An estimated 80% of informal settlement dwellers live below the national poverty line (UN Habitat, 2006) yet as Reid *et al.*, (2009) and Shepherd *et al.* (2013) observe, climate disasters entrench existing poverty by destroying multiple assets and opportunities for income-generation, and further impoverishing a population while incapacitating their ability to cope with future risks. The gap therefore lies in proper quantification of both tangible and intangible climate losses to informal communities, their recognition by state agencies and incorporation of climate adaptation into their upgrading processes.

2.4 CLIMATE RESILIENCE

Climate resilience can be defined in various ways. Carpenter *et al.* (2001) defines resilience as the magnitude of disturbance that a system (such as various ecosystems, community systems, among others) can tolerate and maintain its functions and controls. Such past definitions of resilience only limited themselves to a system's ability to maintaining the 'status-quo' but with time have evolved to also include the notions of adaptation, through both incremental and radical change (Pelling, 2010). As a result, resilience is now defined by IPCC (2007) as ‘the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity of self-organization, and the capacity to adapt to stress and change.’ A resilient system has also been defined as ‘one where disturbances are used as an opportunity to transform into one or more desired states’ (Folke *et al.*, 2005).

Urban resilience is simply defined as ‘the capacity of a city to rebound from destruction’ (Vale & Campanella, 2005), and is analysed through three key elements: systems, agents and institutions (Tyler & Moench, 2012). City systems are defined as being resilient if they are ‘flexible (can meet service needs under a wide range of climate conditions), redundant (have spare capacity to accommodate unexpected service demand or extreme climate events) and exhibit safe failure (failure in one part of the system will not lead to cascading failures of other elements or related systems)’ (Tyler & Moench, 2012).

Agents can be ‘individuals, households, businesses, community groups and private and public sector organizations’ who are at risk of asset losses due to climate risks but are ‘capable of deliberation, independent analysis, voluntary interaction and strategic choice in the face of new information’, based on their different capacities (determined by the assets at their disposal) (Tyler & Moench, 2012). Resilient agents are those with ‘capacity to organize and reorganize in an opportune fashion (responsiveness), capacity to mobilize various assets and resources in order to take action (resourcefulness) and with the ability to internalize past experiences, avoid repeated failures and innovate to improve performance; as well as to learn new skills (capacity to learn)’ (Tyler & Moench, 2012).

Institutions serve as the link between agents and systems as they are ‘formal or informal social rules or conventions that structure human behaviour, and they condition the way that agents and systems interact to respond to climate stress’ (Tyler & Moench, 2012). Institutions foster resilience if they ‘do not systematically exclude specific groups from access to critical systems or capacities (rights and entitlements), representative, inclusive and fair decision-making, make relevant information accessible to agents in order to determine effective actions and to make strategic choices for adaptation, and encourage inquiry and application of new knowledge (Tyler & Moench, 2012).

There are four factors that influence the adaptive capacity of cities and they include 'the local government capacity, proportion of residents served with risk-reducing infrastructure and services, proportion living in housing built to appropriate health and safety standards and the levels of direct or indirect climate risk' (Revi *et al.*, 2014). Informal settlements therefore are more vulnerable because they often are characterized by a 'greater exposure to hazards, lower adaptive capacity, limited access to infrastructure or insurance and small possibilities to relocate to safer accommodation' (Revi *et al.*, 2014). Even within poor communities themselves, resilience is not a 'uniformly spread characteristic but rather it is differentiated by additional vulnerability factors such as gender, age and ethnicity' (Tyler & Moench, 2012).

2.5 URBAN ADAPTATION TO BUILD RESILIENCE TO CLIMATE RISKS

As established from the previous discussions in this research, climate change impacts on the urban poor have the ability to roll back the gains of development made in the past (UN-Habitat, 2014). The IPCC's Fifth Assessment Report 2014 observes that the route to sustainable development can only be enabled through resilience-building encompassing urban climate adaptation, and possible mitigation co-benefits (IPCC, 2014). However, the IPCC (2012) stresses that one of the main challenges to attempts at reducing vulnerabilities at local levels, such as the settlement level, includes a lack of data on the risks and vulnerabilities of communities at this scale (IPCC, 2012).

Globally, there have been attempts at adaptation and resilience building for poor communities to climate change, some of which have been illuminated in sub-section 2.5 below of this research. Two major approaches to adaptation that have been used at local levels include Community-Based Adaptation (CBA) and Ecosystem Based Adaptation (EBA). CBA is an adaptation approach that is 'small-scale, place-based and often grassroots-driven', combining both local and scientific knowledge (Reid and Schipper, 2014). EBA on the other hand is an approach of resilience-building in communities, by biodiversity and ecosystem services maintenance, that brings climate vulnerability reduction as an ancillary benefit (Mavrogenis *et al.*, 2011). Overall, the IPCC (2012) emphasises on designing adaptation projects using ‘no or low regrets’ strategies, and mixing both hard infrastructural and soft options, because of the uncertainty of future climate risks.

Various forms of urban adaptation have been attempted in informal settlements around the world. For purposes of this research, four case studies have been selected in developing countries, where innovative approaches have been carried out, to deal with the impacts of climate change on the urban poor, majority of which are from African countries. These case studies have been selected to deal with three major climate risks, which are flooding, thermal stress and aridity and the accompanying food insecurity risks. The different adaptation concepts have been put in place could offer replicable solutions for the urban poor in the context of changing climate.

2.5.1 WAT KAO SLUM IN NAKHON SAWAN, THAILAND

Wat Kao is a slum located along a river, in the city of Nakhon Sawan in Thailand, and this low-income settlement faces high risk from flooding, exacerbated by climate change. In 2011, a flooding event, triggered by excess precipitation, was the most severe incident that Thailand had faced in 50 years, affecting an estimated 13 million people nation-wide (Ministry of Finance and The World Bank, 2012).

The community of Wat Kao, while highly vulnerable because of their location adjacent to the river as well as their high poverty levels, worked closely with local government and NGOs to put in place various measures to increase their resilience and reduce losses to flooding, . First, before the flood of 2011, the community had saved money over time specifically to use in the event of flooding events, through community groups. The community also stocked sandbags at settlement level for use in the event of floods.

The community was organized into teams to cover various aspects within the disaster cycle such as teams for relief and others in charge of evacuation using boats. The community ensured that systems for communication would still be operational even in the event of flood disasters, and they constructed a community centre equipped with a kitchen, that would serve as an evacuation centre (UN-Habitat, 2014; Hansen, 2015; Saiyot and Matsuyuki, 2016)

After the floods subsided, residents who were opposed to relocation were determined to raise funds to physically adjust their housing structures, to adapt to future flooding. The government developed a programme to provide community groups with loans which residents used to upgrade their building materials from wood to concrete. In addition, the structures were reconstructed on stilts to raise them above flood levels, and disaster shelters were also built on the roofs. The government also provided the local community with support to construct a wall along the river to serve as a flood barrier. Implementation of by-laws requiring that electricity plugs and water lines be built above the flood lines was also done during the recovery period (UN-Habitat, 2014).

2.5.2 JARDIM CONCEIÇÃO IN CAMPINAS, BRAZIL

The University of Campinas carried out a study of the houses built by low-income families in Jardim Conceição in Campinas, Brazil, and observed that majority of them did not provide thermal comfort among other environmental considerations (Kowaltowski *et al.*, 2005). In this low-income settlement, residents were responsible for building their own homes, yet they constructed structures whose designs were unsustainable for the sub-tropical climate in Campinas, with temperatures of up to 27-30^{o}C.

The University of Campinas decided to provide assistance to these low-income earners for sustainable house design that was responsive to the local climatic conditions. This programme encouraged residents to build the walls of their houses using ceramic which was locally available and had more comfortable indoor thermal conditions. Residents were also encouraged to use wooden or pre-fabricated concrete ceilings to reduce the heat gained through the roof.

When tested during the summer, a house that was built according to the model promoted by the University was found to be thermally comfortable. Additionally, the University noted that the use of dark colours on the external faces of structures led to low levels of reflection of solar radiation, thus increasing the heat gain within a structure (Kowaltowski *et al.*, 2005). Lessons learnt by the researchers were that due to insecurity and dusty conditions in surrounding areas, windows and other ventilation openings were rarely used or opened. This meant that efforts to design the size and orientation of these openings in an attempt to promote cross-ventilation were futile.

2.5.3 TANDALE INFORMAL SETTLEMENT IN DAR-ES-SALAAM, TANZANIA

Climate change is affecting urban poor communities in different parts of Africa, be they in coastal cities, dryland cities or even high altitude and inland cities such as Nairobi (IIED, 2009). One such case is that of the Tanzanian coastal city of Dar-es-Salaam, which is at risk of flooding from sea-level rise, drought and water scarcity. The vulnerability of its residents to climate losses is high as an estimated 70% of residents live in 'unplanned settlements' (Dodman *et al.*, 2011). Within the city's informal settlements such as Tandale, residents are transforming urban form as a coping strategy by constructing additional walls in front of their houses so as to keep flood waters out (IIED, 2009, Dodman *et al.*, 2011).

2.5.4 KIBERA INFORMAL SETTLEMENT IN NAIROBI, KENYA

Climate change is manifesting itself in the form of aridity in many parts of Africa, causing food insecurity even to urban poor communities; yet urban agriculture is largely under-developed. Urban agriculture is an element of land-use that is a key component of urban form. The introduction of urban agriculture in informal settlements has been found to contribute to 'local economic development, poverty alleviation, the social inclusion of the urban poor and women, as well as to the greening of the city through a productive reuse of urban wastes' (World Bank, 2013). Indeed FAO (2012) acknowledges that 'spatial planning should help poor and vulnerable people to realize their right to adequate food and sustainable livelihoods'.

In Kenya's Kibera slum, 11,000 households practise sack gardening that produces fresh vegetable produce, in some cases using urban organic waste as compost (FAO, 2012), with some keeping poultry as well. This has provided these households with additional sources of food, as well as income from sale of their produce in some instances, thus indirectly boosting their resilience to climate change impacts.

2.5.5 UPGRADING OF MATHARE-4A IN NAIROBI, KENYA (PHASE 2)

Mathare 4A is a village located within Mathare Valley on public land, and within an area at very high risk of flooding and landslides. Before the year 2004, houses were predominantly constructed of mud, there were no toilets or water systems, and the village was very overcrowded. The German Bank for Reconstruction (KfW) and the Government of Kenya in 2004 commenced on the second phase of upgrading of houses under the Mathare 4A Upgrading Project, an initiative that was conceived by the Catholic Church.

Upgrading of Mathare 4A was done in phases, dividing the settlement into clusters, to minimize disruption to residents. The upgrading process began with robust community meetings that aimed to come up with a participatory plan that would provide benefits to both tenants and structure owners, given that the village was located on public land, and thus no person had any legal recognized claim to it (Muthoka, 2005).

While the upgrading of house structures in the first phase had transformed former mud houses to stone structures (Muthoka, 2005), the second phase adopted a different approach. Houses were constructed using clay tiles for roofing, clay bricks for the walls and completed with concrete floors. These types of houses have been documented to be cool all year round.

2.6 LEGAL AND POLICY ENVIRONMENT IN KENYA FOR URBAN RESILIENCE

The overarching governing framework in Kenya is The Constitution 2010 that guarantees its citizens the right to life, human dignity, non-discrimination, and a clean and healthy environment. One of the pillars of Kenya Vision 2030, the country's development blueprint, is the social pillar that desires to provide a high quality of life to all its citizens in a clean and secure environment, as well as reduction of poverty levels through economic growth and job creation.

Kenya has recently enacted the Climate Change Act of 2016 that will provide the legal framework within which climate change action plans can be prepared and how climate change actions can be mainstreamed across sectors. The country is also working on the yet to be enacted National Climate Change Framework Policy. The National Climate Change Response Strategy

(NCCRS) 2010 aims to achieve a ‘prosperous and climate-resilient Kenya’ (GOK, 2010: 3, 12) through aspects such as strengthened urban planning of settlements. The National Climate Change Action Plan (NCCAP) 2013 acknowledges the role that urban areas can play in the transition to a low carbon climate resilient development pathway, and calls for expanded flood management in informal settlements to increase the urban poor’s resilience (GOK, 2013). The NCCAP also acknowledges the importance of policy and regulatory instruments such as codes and standards.

The regulatory framework for urbanization and physical development includes the National Urban Development Policy that aims at improving the living conditions in informal settlements, urban safety and protection of the rights of marginalized communities in urban areas. The Physical Planning Act 1996, Urban Areas and Cities Act 2011, County Government Act 2012, Environmental Management and Coordination Act 1999, Water Act, Land Act, and the National Land Commission Act, among others form the key legal instruments for the built environment and the land on which it rests upon.

The plans for Nairobi are currently contained in three main documents: the Nairobi Metro 2030 (2008), the Nairobi City Integrated Urban Development Master Plan (NUIPLAN) and the draft Nairobi City County Integrated Development Plan (CIDP 2018-2022). These plans envision a ‘an inclusive and fair city in which the poor have access to decent and affordable housing facilities’ (NCC, 2017). Within selected city informal settlements, the national government through the Kenya Slum Upgrading Programme (KENSUP) and the Kenya Informal Settlements Improvement Project (KISIP) have developed settlement plans and initiated various projects aimed at improving housing, regularizing land tenure and provision of basic infrastructure to enhance resilience of the urban poor.

2.7 KNOWLEDGE GAPS

While it has been acknowledged that there is a link between climate risks, disasters and urban form (Wamsler *et al.*, 2013) there is a major knowledge gap on the actual interaction of these factors in Nairobi and their resultant effect on the resilience of poor communities to climate change impacts. Indeed as Jenks and Burgess (2000, p.5) observe, the ‘relationship between climate and urban form is often a neglected issue'. IIED (2009, p.21) also notes that particularly for the Least Developed Countries (LDCs), there has been no consideration of climate changes or their resultant extreme events in urban planning or infrastructural design.

In addition to an existing gap in knowledge in this area of study, the discussions in the sub-sections above, point to a clear need for localized assessment of climate risks, contextualized adaptation design responding to the unique situations of different areas, coupled with documentation and incorporation of local adaptation knowledge for a sustainable response. In this regard, this research is targeted at vulnerability assessment and design for adaptation and resilience building at the settlement scale of Mathare Valley slum. The next chapter delves into the methodologies used to collect, analyse and synthesize data for purposes of this study.

CHAPTER THREE: METHODOLOGY

3.1 OVERVIEW

This chapter describes in detail the methodology that was used in this research, to achieve the study objectives (Section 1.5). This chapter is broadly organized into three parts: the study area; conceptual framework; and methods.

3.2 THE STUDY AREA

3.2.1 Location

Mathare Valley informal settlement is located in Kenya's capital city, Nairobi, between latitudes $1^{o}0'00''$S and $1^{o}16'00''$S and longitudes $36^{o}50'30''$E and $36^{o}52'00''$S. This settlement lies at an altitude of between 1650m and 1606m above sea level and it occupies an area of $1.16km^2$. Mathare Valley informal settlement falls within two constituencies, and covers four administrative wards, which are Mlango Kubwa, Hospital and Mabatini in Mathare constituency and Utalii ward in Ruaraka constituency (Figure 3.1). The study area is physically bound by Juja Road, Mathare North Road, Thika Highway and Muratina Street.

3.2.2 Historical Development

The history of Mathare Valley can be traced back to the pre-independence period. The settlement derived its name from the Dracena trees, called *Mathare* in the local Kikuyu language (singular *Githare*), that dominated the area (U.C. Berkeley *et al.*, 2011). Prior to the 1950's, portions of the present-day Mathare Valley were used for quarrying, with African native labourers eventually becoming the initial settlers (Weru, 2008). Certain sections of the settlement, such as the present-day Village 2 and Kiamutisya, were hiding places for the Mau Mau (a group of fighters against British colonial rule, drawn from the Kikuyu community) in the late 1950's, (Weru, 2008) After independence, land buying companies were formed after which the settlement grew rapidly (U.C. Berkeley *et al.*, 2011), within an environment of neglect and corrupt land allocations.

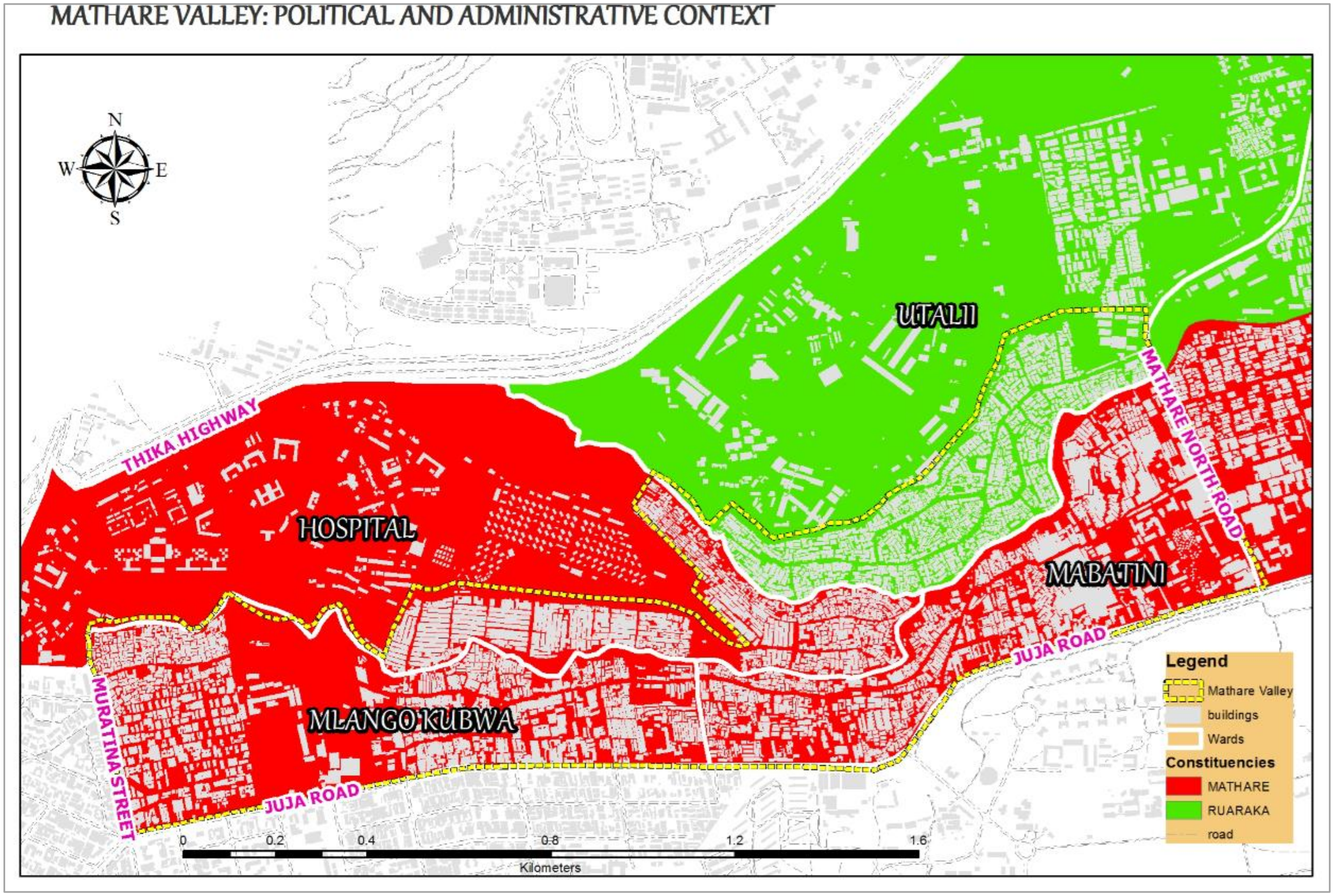

Figure 3.1: Political and Administrative Boundaries within Mathare Valley

Data Sources: Administrative boundaries based on the IEBC Legal Notice 12 (2012); area features based on a vertical aerial image/ orthophoto mosaic (2013) with a resolution of 15cm.

3.2.2 Bio-Physical Setting

3.2.2.1 Climate

Mathare Valley experiences an average of 900mm of rainfall annually, with the highest levels being in the months of April and November. The mean daily maximum temperature ranges between 22 to 28°C, with February being the hottest month of the year (NCC *et al.*, 2014).

Mean daily minimum temperatures on the other hand range between 14 to 12°C, with June being the coldest month of the year (NCC *et al.*, 2014), as illustrated in Figure 3.2 below. Relative humidity in Nairobi City ranges from over 80% to less than 40% between morning and afternoon, 'while sunshine duration varies from 4 to 9 hours per day' (Makokha and Shisanya, 2010).

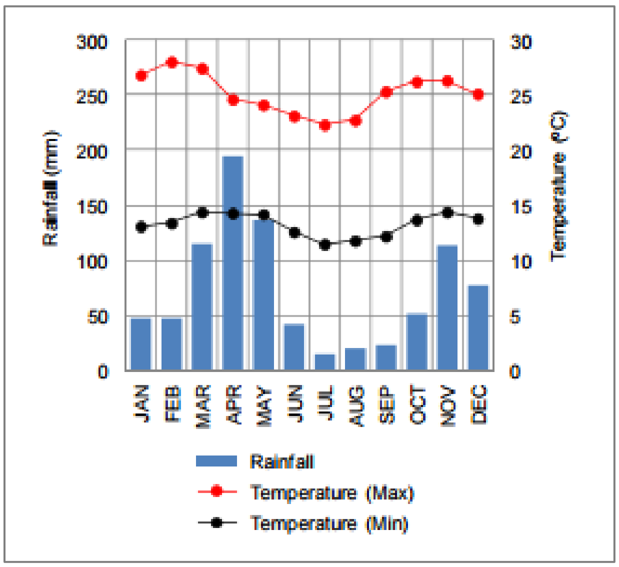

Figure 3.2: Annual rainfall and temperature patterns

Source: (NCC et al, 2014: 2-2)

Analysis of weather information from the Moi Airforce Base Eastleigh weather station (adjacent to Mathare Valley), over the period 1981 to 1999 showed a conclusive increase in mean annual minimum temperature from about 2°C to 4.5°C (Makokha and Shisanya, 2010). This warming trend, as a result of 'urban modification of minimum temperature' points to the development of an urban heat island over the research area (Makokha and Shisanya, 2010).

3.2.2.2 Physiography and Drainage

Mathare Valley lies within the river valleys of Mathare and Gitathuru Rivers, which are tributaries of Nairobi River (Karisa, 2010). The study area generally slopes eastwards, but internally also slopes towards Mathare and Gitathuru rivers (Figure 3.3). Some sections along the river banks are steep, as well as artificially steep areas created at the sites of former quarry sites (Karisa, 2010).

Mathare and Gitathuru Rivers originate from different points in the escarpments in Kikuyu and then flow through Kiambu, Karura Forest and Muthaiga (Kwena, 1999, p.7), before converging within Mathare Valley, splitting the settlement almost in half. It is estimated that a fifth of the Mathare Valley settlement lies within the riparian reserve of the two rivers (UC Berkeley *et al.*, 2011). Mathare and Gitathuru Rivers, have diminished ecological functions (water provision or bio-diversity habitat) as they are heavily polluted by the discharge of raw sewage and industrial waste into them by the residents of Mathare Valley.

3.2.2.3 Vegetation and Soils

The soils within Mathare Valley are predominantly black cotton with clay deposits, making the settlement prone to water logging (Karisa, 2010). Mathare Valley has little green vegetated area as nearly the entire settlement is built-up. The small pockets of planted crops such as maize, kales, spinach and bananas are found either at the borders of the settlement or along the riparian areas. There are no trees within the settlement, other than within the St. Teresa High School.

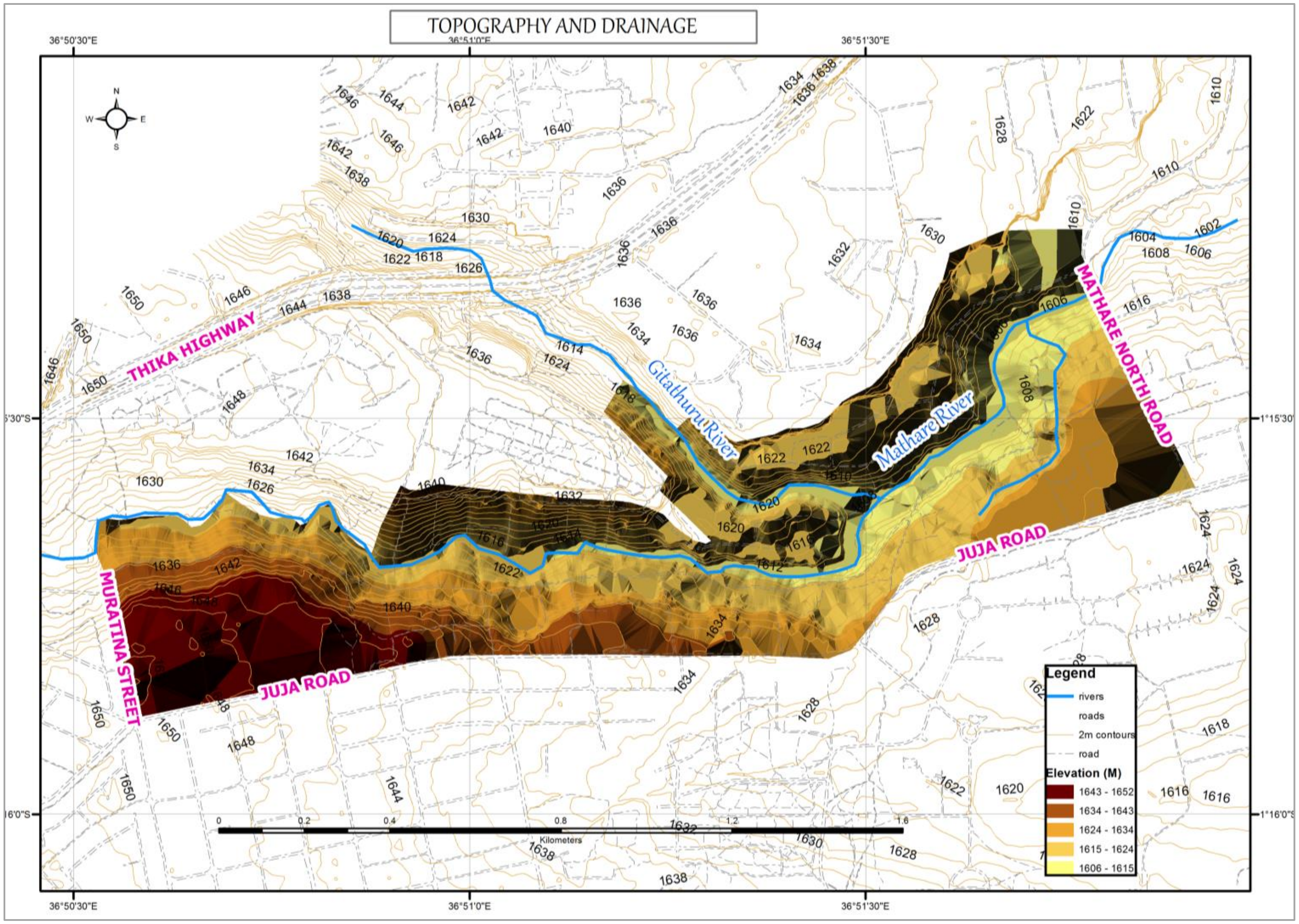

Figure 3.3: Map of Mathare Valley's topography and drainage features

Data Sources: Administrative boundaries based on the IEBC legal notice 12 (2012); Area features based on a vertical aerial image/ orthophoto mosaic (2013) with a resolution of 15cm.

3.2.3 Population and Demography

Mathare Valley informal settlement is home to an estimated 122115 people (KNBS and SID, 2013). Within the settlement, 54 percent of all the residents are male and with a female population of 46 percent (KNBS and SID, 2013). This population is predominantly youthful (Figure 3.4), with 50 percent of residents being between the ages of 15 and 34 years (KNBS and SID, 2013), unlike the national age-sex pyramid that is heaviest at the bottom.

Figure 3.4: Age-sex structure within Mathare Valley

Source: (KNBS and SID, 2013: 19-24).

Within the informal settlement itself, the communities are organized into fourteen villages (which residents refer to as '*kijiji*') which are Kiamutisya, Mlango Kubwa, Village 2, 3A, 3B, 3C, Kosovo, Gitathuru, 4A, 4B, No. 10, Mashimoni, Kwa Kariuki, and Mabatini (Figure 3.5). These villages have distinct identities and shared community sense of belonging. The main ethnic communities within Mathare Valley are the Kikuyu, the Kamba and the Luo who often live in different villages. Due to the existence of different ethnic groups, Mathare Valley is often a hotspot for ethnically-fuelled political violence and outlawed ethnic gangs (Karisa, 2010).

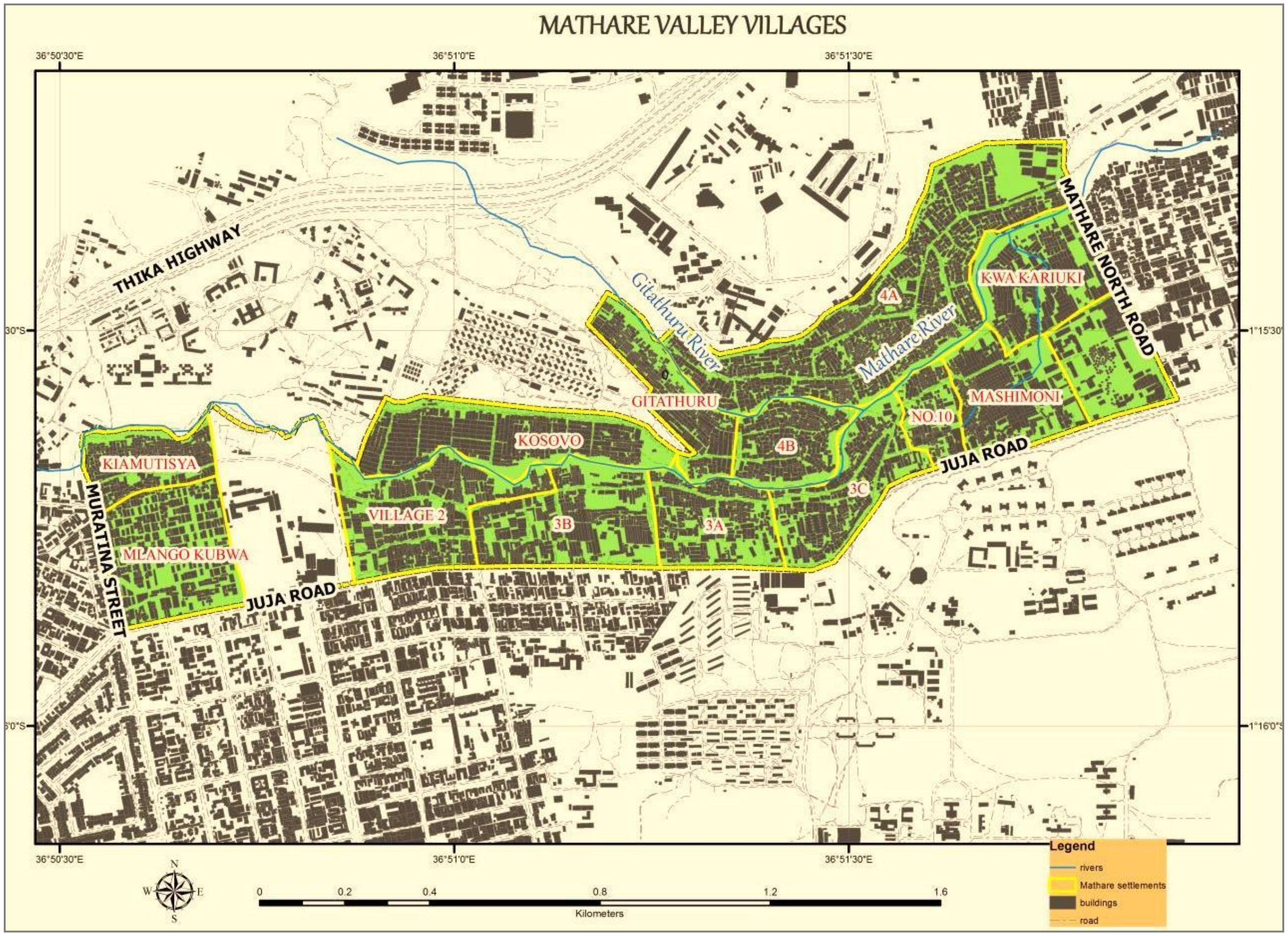

Figure 3.5: Map of the village boundaries

Data Sources: Village boundaries adapted from the Mathare Zonal Plan, 2012; Administrative boundaries based on the IEBC legal notice 12 (2012); Area features based on a vertical aerial image/ orthophoto mosaic (2013) with a resolution of 15cm.

3.2.3 Local Economy

Nearly half of the residents (48 percent) within Mathare constituency have only attained primary education (KNBS and SID, 2013) and as a result, most residents are 'employed in the informal sector, without stable incomes' (Kamau and Ngari, 2002), with 12.6% being unemployed (KNBS and SID, 2013; Andvig and Barasa, 2014).

Majority of the economic activities carried are informal, or in some instances illegal (Karisa 2010; Andvig and Barasa, 2014). The ethnic angle comes to play in the economics of Mathare Valley. The dominance of economic activities that range from small trading, crop and livestock farming, and small industry, changes per village due to ethnic preferences. Informal or casual labour employment (UC Berkeley *et al.*, 2011) often is characterized by low wages and unreliable income supply, which in turn restricts the amount they can spend on expenses such as rent and food.

3.2.4 Land Use and Housing

The predominant land use within Mathare Valley is residential land use. The educational land use is also significant within the study area, mainly because of the St. Teresa High School which occupies a large area. There are however other small informal schools within Mathare Valley, as well as religious institutions, housed in small structures. Commercial land use is indistinct as most commercial activities are conducted in informal kiosks, in the open-air along roads and along the river banks.

Mathare Valley largely exhibits what can be defined as 'shack architecture' (Andvig and Barasa (2014), with the building material of the houses mainly being iron sheets for both walls and roofs (UC Berkeley *et al.*, 2011)

3.2 CONCEPTUAL FRAMEWORK

As detailed in sections 2.3, the poorest people in urban areas are absorbed by informal settlements. These settlements are often densely populated, located on hazardous sites, with dilapidated housing and unavailable infrastructure and community spaces (Lall and Deichmann, 2009; UN-Habitat, 2014), elements that denote non-resilient urban form. In addition, the density within these settlements increases the numbers of people and assets at risk (World Bank and Australian Aid, 2012).

Climate hazards are on the rise globally (IPCC, 2012), and these hazards are 'shaped and configured' by factors such as urbanization (World Bank and Australian Aid, 2012). Non-resilient urban form that is unable to withstand climate stresses often configures these hazards to be disastrous (Revi *et al.*, 2008) to the informal settlement dwellers. Additionally, impacts of the same climate hazard may reshape the urban landscape of the informal settlements, potentially weakening it in the event of future climate risks (IPCC, 2012).

One of the solutions for such urban poor communities therefore lies in the building of resilient urban form, through efforts of both city institutions and local communities themselves. Such resilient urban form should be able to accommodate climate disturbances, and use these climate turbulences as opportunities for reducing future climate risks as shown in Figure 3.6 below (Folke *et al.*, 2005; Hamin and Gurran, 2008; Tyler & Moench, 2012; IPCC, 2012).

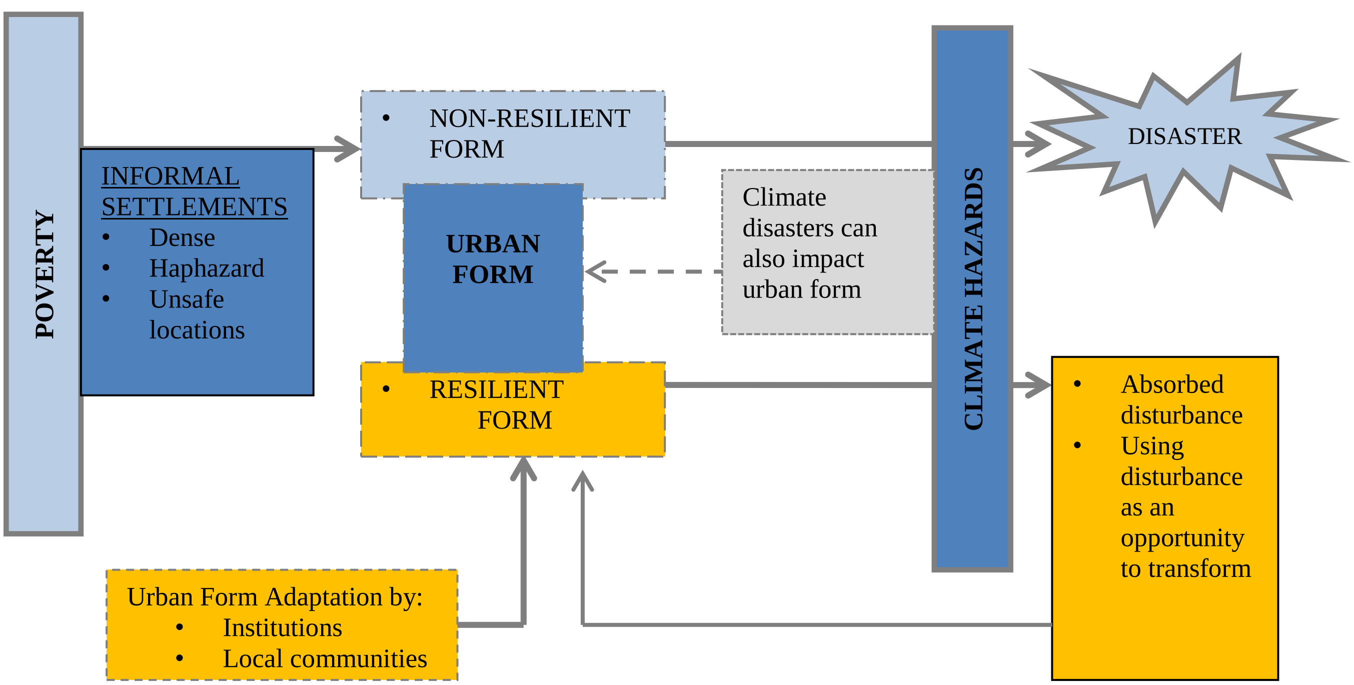

Figure 3.6: Conceptual framework

Source: Adapted from Folke et al., 2005; Lall and Deichmann, 2009; Tyler & Moench, 2012

3.3 METHODS

3.3.1 OBJECTIVE ONE: URBAN FORM TYPES AND TRENDS

3.3.1.1 Desktop Studies

Documentary sources such as published literature in the form of peer-reviewed journals, reports from respected global agencies as well as previous plan reports prepared for Mathare Valley provided guiding secondary data sources for this research. For a global synopsis of issues, reports from authoritative sources such as the International Panel on Climate Change (IPCC), the United Nations and the World Bank provided information on climate change, the state of cities, informal settlements and adaptation planning. Peer reviewed journals, published books, conference proceeding papers and online articles provided scholarly literature on key study variables such as urban form, informal settlements, climate vulnerability, adaptation and resilience building.

At the national level, government policy and legal framework documents were sources of data that provided clarity on the institutional framework within which this study revolves. Local information about Mathare Valley was sourced from the Mathare Zonal Plan 2012, proposed physical advisory plans for different villages in Mathare Valley submitted for approval to the City Council of Nairobi under the Kenya Informal Settlements Improvement Programme (KISIP) and academic papers about the settlement.

Digital data for base-map preparation came from shapefiles prepared using ArcGIS (Geographical Information Systems) software, from a vertical aerial image/ orthophoto mosaic captured in 2013 with a resolution of 15cm. Key settlement features of the built and natural environment were digitized in ArcGIS software and the GIS shapefiles created provided data on the spatial development intensity within Mathare Valley, and the structural elements that define the study area such as roads, rivers, open spaces, public facilities, activity centres and focal elements. The output maps used in this thesis are at a scale of 1:2500.

The historical change in urban form was established through analysis of data from two sources. First, aerial and satellite images acquired for the years 2002, 2004, 2007, 2013 and 2016 provided visible spatial-temporal trends. An aerial image taken over Mathare Valley in 2004 that was sourced from the team that prepared the Mathare Zonal Plan 2010, while Landsat satellite imagery for the years 2002, 2007, 2013 and 2016 were downloaded from Google Earth Pro with a resolution of 15 meters. These images were visually compared to identify visible geographic spots of change within the settlement. The general pattern of building heights was visible from clear aerial and satellite images, as the settlement is predominantly at shack-level and thus high-rise structures produced a visible shadow on images when observed at eye altitudes of approximately 5800 feet. Secondly, additional historical changes in urban form were established through review of secondary information from the Mathare Zonal Plan (2012) and the Inventory of Nairobi Slums (USAID, 1993).

3.3.1.2 Field Studies

To enable the study directly capture the local community's perceptions, concerns and aspirations, primary data was obtained from extensive field surveys that included use of household questionnaires, interviews with key informants and operators of commercial enterprises, and from one Focus Group Discussion (FGD) with members of the local community on 21st, 27th-28th January and 7th of April 2017.

A reconnaissance visit to the site was carried out on 21st January 2017 in order to familiarize with the local conditions and mobilize the community. The entry point used was a former Muungano Support Trust Team (MUST) member (Baraka Mwau) who provided a link to settlement leader (Jason Waweru), also residing in Mathare Valley. Jason Waweru assisted in the identification of two additional local guides for provision of security for this researcher. At the same time, this reconnaissance visit was used to recruit twelve local data collectors to minimize possible community hostilities to external data collectors.

From literature review, it was established that the population of 122,115 people formed 42,558 households within the study area, as there are an estimated 2.8 persons per household on average (KIBS and SID, 2013; Mathare Zonal Plan, 2012), all of whom have attributes of interest.

Calculation of an appropriate sample size was done using the formula and values below, identifying that 100 households needed to be sampled:

Equation 3.1: Sample size calculation

$$n = N \div [1 + N(e)^2]$$

$$n = 42558 \div [1 + 42558(0.1)^2] = 100$$

Where: N (estimated population with attributes of interest)	=	42558
e (level of precision)	=	0.1

Training for household questionnaire administration was conducted on 27th January 2017 by the researcher (Figure 3.7). After the training, piloting of the questionnaires was done in households in Kosovo village adjacent to the training hall. The team converged to discuss difficult questions and seek clarifications after each enumerator had filled one pilot questionnaire.

Figure 3.7: Training of local enumerators at the Mathare community hall

Source: Field Survey, 2017

The team carried out a household data survey exercise on 28th January 2017. As the team of enumerators was large, all 100 questionnaires were filled in one day, with each enumerator filling between eight and nine questionnaires. To ensure a representative coverage of households in the study area, the 100 household questionnaires were proportionately distributed among the fourteen villages (Table 3.1 below) in Mathare Valley based on the respective village population.

Table 3.1: Proportionate distribution of household questionnaires

	Village Name:	Population:	Number of Questionnaires Administered:
1.	Mlango Kubwa	41,806	34
2.	Kiamutisya	5825	5
3.	Village 2	7875	6
4.	3A	4059	3
5.	3B	7433	6
6.	3C	5316	4
7.	Kosovo	8085	7
8.	Gitathuru	3737	3
9.	4A	18776	15
10.	4B	5681	5
11.	No. 10	2594	2
12.	Mashimoni	4478	4
13.	Kwa Kariuki	5290	4
14.	Mabatini	1160	1
	TOTAL	122,115	100

Source: Author, 2017 (Population Data: Mathare Zonal plan, 2012; KNBS and SID, 2013)

These questionnaires (Annex 1) were then randomly distributed within each village, with the nearest landmark to the sampled structure being indicated, to capture a broad geographic location of sampling points (Figure 3.8). In each village, enumerators conducted household surveys from the farthest point, moving inwards to ensure a wide spatial coverage of the villages.

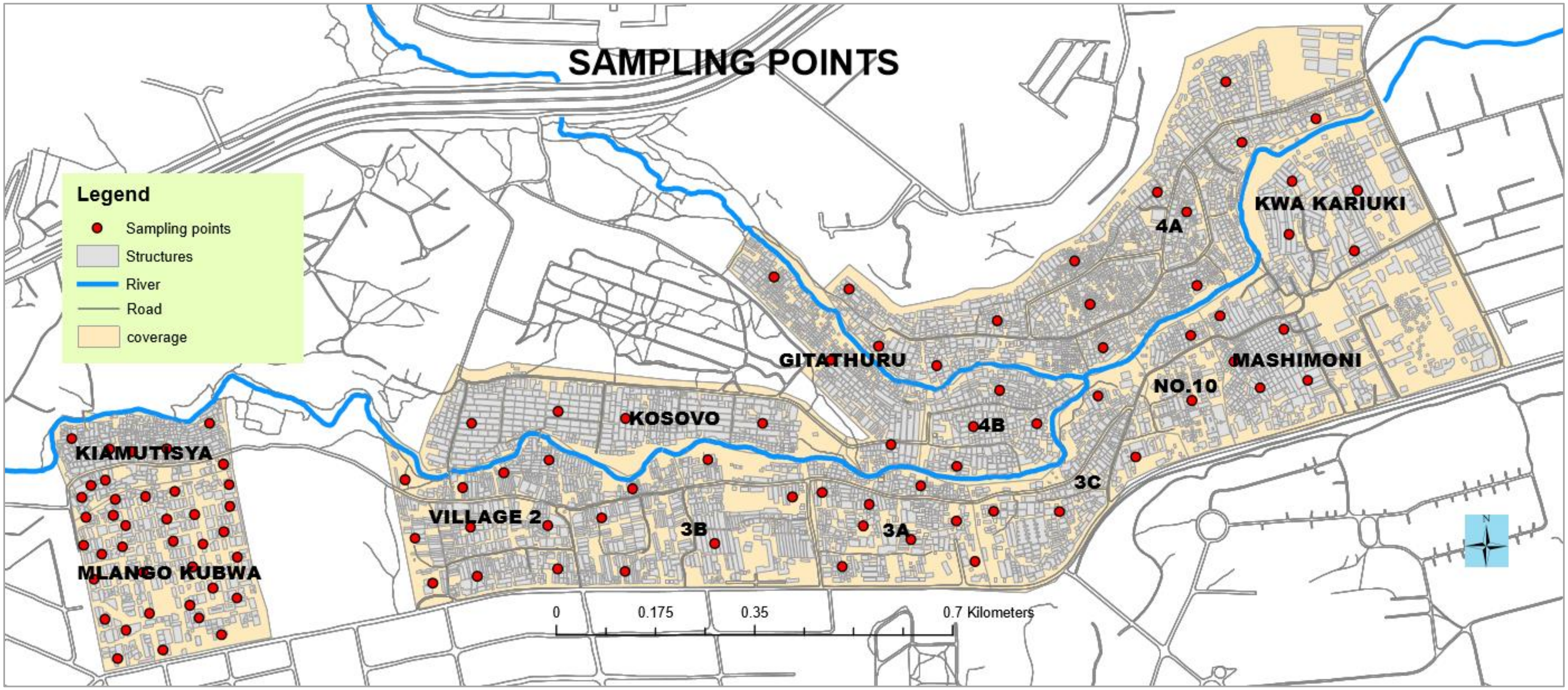

Figure 3.8: Map of sampling points for household questionnaires administered

Data Sources: Village Boundaries (Adapted from Mathare Zonal Plan, 2012; Administrative Boundaries (Based on the IEBC Legal Notice 12, 2012); Area Features (Based on a Vertical Aerial Image/ Orthophoto Mosaic with a Resolution of 15cm, 2013.

The household questionnaire captured information on households' demographics, housing profiles, available infrastructure services, type of climate hazards, community perceptions of climate change and proposed adaptation options.

Due to the largely informal and undocumented nature of commercial enterprises in Mathare Valley, random but purposeful selection of these businesses was done. 13 commercial enterprise questionnaires (Annex 2) were administered, with the respondents including small retailers and service providers (such as an outdoor food kiosk and a salon), farmers (a crop farmer and a livestock keeper) and operators of small industry (such as a manufacturer of illegal liquor and another of furniture). Each enumerator was given one commercial questionnaire to administer, with clear instructions on which type of business to survey. This allowed for a spatial spread of respondents, yet capturing a multiplicity of enterprises (Figure 3.9).

Figure 3.9: Different types of businesses sampled (livestock farming and an illegal changaa brewery)
Source: Field Survey, 2017

Key informants with first-hand information about the community living in Mathare Valley, as well as those involved in plan formulation of Nairobi's slums were selected. The key informants included the Chairman of Muungano wa Wanavijiji, two resident opinion leaders active in politics, the ward administrator (former assistant chief) for Mathare ward and one enforcement officer from Nairobi City County. Muungano wa Wanavijiji, in particular, served as the researcher's entry point for this research to the local community because through their work within Mathare Valley, they have rich grassroots networks. The interview guides for interactions with the key informants have been attached as Annex 3 of this thesis.

One focus group discussion was held on the morning of 7th of April 2017 (Figure 3.10). A pool of eight participants was mobilized through Muungano wa Wanaviji. The selection of participants targeted one local administrator, two residents living within the immediate vicinity of the river, two people who had lived in Mathare for more than fifteen years, one person from the upgraded Village 4A and two residents of high-rise buildings.

Figure 3.10: FGD with selected local residents at Mathare community hall

Source: Field Survey, 2017

The participants were selected to ensure representation of the different genders and age cohorts (that is men, women, youth, and the elderly). The opinion leaders assisted in the selection of a community hall located in Kosovo village that serves as a children's library as an appropriate venue for holding the FGD. Mobilization of the targeted participants was conducted through telephone calls. A list of the participants of this FGD is attached as Annex 4 of this thesis.

3.3.1.2 Data Analysis

Quantitative data analysis of household and commercial surveys was done using the Statistical Package for Social Sciences (SPSS 16.0) and MS Excel. Each individual questionnaire, responses per question was reviewed and the data collected was used to generate a codebook. Within the codebook, each response per question was allocated a numerical code that was then typed into the SPSS data-frame.

Descriptive statistics such as frequencies and cross-tabulations were generated. Where one question in the questionnaire had attracted multiple responses, variable sets were defined and frequencies of the combined responses were generated. All the statistics generated on SPSS were then transferred to Ms Excel to generate the tables, charts and graphs used in this thesis. The percentages presented in this thesis are for the valid responses obtained per question in the questionnaire only.

Qualitative analysis of data collected from interviews with commercial enterprise operators, and key informants was done. Data was organized broadly into the pre-independence period, post-independence period (1963-1999) and the New Millennium (2000-2016), and descriptive writing of findings done. Aerial images acquired were compared to identify urban form changes in the years 2004, 2007, 2013 and 2016. The focus of analysis was to establish changes in ground development density, building heights and other structuring elements, such as the rivers and roads.

3.3.2 OBJECTIVE TWO: ASSESSMENT OF CLIMATE RESILIENCE LEVELS OF COMMUNITIES

3.3.2.1 Desktop Studies

Published literature on key study concepts such as climate resilience, urban poverty, urban form and informal settlements, climate risk and associated costs, social differentiation of impacts and attribution of all this to urban form was assessed.

3.3.2.2 Field Studies

Household surveys, commercial enterprise surveys and FGDs (described in section 3.3.1.2 above) captured data on the climate change related risks and losses communities have faced over time, the risks residents attribute/ can be attributed to the existing urban form, their perceptions of climate risks, and the differentiation of impacts on the different sub-sets within the population (women, youth, children, and the elderly).

The participants of the Focus Group Discussion (described in section 3.3.1.2 above) conducted community mapping of risk zones. This was done by first asking the participants to list the climate change impacts they experienced, after which they were provided with maps of the settlement on which they sketched the zones within the settlement that were most prone flooding and landslide hazards. These sketches were then used in the development of GIS maps of climate risk.

3.3.2.3 Data Analysis

Quantitative analysis of data collected from field surveys has been described in detail in section 3.3.1.3 above. Qualitative analysis involved the organization of data collected into broad themes such as: the climate change observations made, climate risks identified, urban form changes identified and the implications on climate resilience of Mathare Valley. This information was presented in the form of descriptive writing highlighting the local community's experiences, insights and feelings.

GIS merged both quantitative and qualitative analysis results by spatially depicting critical emerging issues thus highlighting hotspot areas that require prioritized intervention. GIS analysis was used to overlay climate risks onto the current urban form layout to establish any linkages. Information generated has been presented in the form of GIS thematic maps within this thesis.

3.3.3 OBJECTIVE THREE: URBAN FORM OPTIONS FOR IMPROVED CLIMATE RESILIENCE OF COMMUNITIES

3.3.3.1 Desktop Studies

Literature review on successful urban form design options for building climate resilience of poor communities in developing countries was done to establish best practices. Previous and proposed spatial planning interventions on the study area were also analysed to identify their successes and failures to guide in proposal designs. Advisory plans prepared for various villages within Mathare Valley (Kosovo, Mashimoni and Mathare 4A) under the Kenya Informal Settlements Upgrading Programme (KISIP) were sourced from the City County of Nairobi's Planning Department.

3.3.3.2 Field Studies

Household heads and commercial enterprise operators were queried on any current adaptation options they undertake as well as changes they would desire for urban form improvements for climate change adaptation through administration of the household and commercial questionnaires. Key informants and the participants of the FGD also provided insights into possible adaptive proposals as well as highlighting any institutional challenges that can be experienced in the implementation of the desired proposals, as well as possible means to circumvent these challenges.

3.3.3.3 Data Analysis

Qualitative and quantitative analysis of data collected was done using methodology similar to that detailed in section 3.3.1.3 above).

3.4 DATA SYNTHESIS

Data on the different urban form types and trends in Mathare Valley was compared with the climate resilience levels over the years so as to establish if a link between the two variables exists, with emerging patterns being identified. Aspects of this research that were synthesized using this narrative approach have been presented in this thesis in the form of report-writing. Quantitative synthesis of numerical data was done by cross-tabulating frequencies of various inter-related issues to illuminate any emerging patterns. The identified linkages between aspects from the different objectives shaped the development of the final proposals. This involved combination of both qualitative and quantitative synthesis for the emergence of sustainable and holistic proposals.

CHAPTER FOUR: RESULTS ON URBAN FORM TYPES AND TRENDS IN MATHARE VALLEY

4.1 OVERVIEW

This chapter presents the results of the first objective of this research, which was to determine the existing urban form types and trends within Mathare Valley. The trends in urban form are described within three key periods: the pre-independence period (pre-1963), post-independence (1963-2000), and the new millennium (2001- 2016).

4.2 PRE-INDEPENDENCE PERIOD

The history of Mathare Valley can be traced back to the pre-independence period. Key informant accounts corroborated literature review findings that prior to 1963 Mathare Valley settlement was a zone covered by Dracena trees (*Mathare* in the local Kikuyu language) from which the settlement derived its name, interspaced by pockets of quarries run by the Indian community.

Kenyan labourers set up makeshift structures surrounding the quarries for ease of access to their places of work. Early villages within the settlement were named local supervisors that had been appointed to oversee the labourers (such as *Kia-mutisya*, *Kwa-ndururu* and *Kwa-kiboro*). In addition, women drawn from rural Kenya were attracted to the quarries by the opportunities for income generation through sale of food to labourers. The women began putting up make-shift structures, made of building materials such as nylon and carton boxes, gradually permanently settling there. With time, villages such as Kiamutisya and Village 2 developed. During this period, the African settlers had no documentation to prove ownership of the parcels of land that they had begun to build structures on.

Before the year 1963, the urban form of Mathare Valley was characterized by small clusters of settlements around the quarries. Structures were not constructed adjacent to Mathare River, retaining the green nature of the riparian reserve. Residents grew some crops for subsistence, relying on rainfall for water as climate was predictable, allowing residents to plan themselves.

4.3 POST-INDEPENDENCE PERIOD (1963-1999)

At the beginning of the post-independence period, while informal settlements continued to develop in Mathare Valley, Mathare and Gitathuru Rivers still held ecological value. They were a source of water and were lined with indigenous trees such as fig and *croton-megalocarpus* trees called *mugumo* and *mukindori* in the local Kikuyu dialect. While the structures were developed in a clustered manner, much of Mathare valley was still undeveloped, and the riparian reserve still intact, as corroborated by literature reviewed (Figure 4.1).

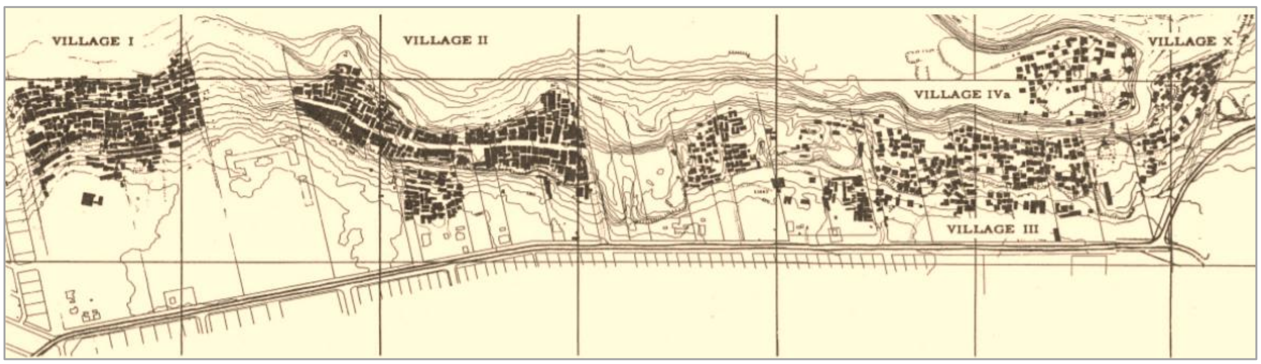

Figure 4.1: Urban form in 1969

Source: (U.C. Berkeley et al., 2011; p.9)

According to key informants interviewed, as the population of Mathare Valley grew in the 1970's, local land buying and house building companies were formed, and settlements began to develop on sites that had previously been deemed as inhabitable, a finding corroborated by literature within the Mathare Zonal Plan (U.C. Berkeley *et al.*, 2011). A settlement such as Village 3A was developed on what was previously a deserted quarry. In what was previously part of Village 1 Kiamutisya, a few well-connected individuals organized themselves into groups, and without the knowledge of locals, purchased land on what is today Mlango Kubwa (the name literally means 'the gateway' into Mathare).

In the 1980s, Mathare Valley continued to grow unabated, according to key informant accounts. Villages such as 3B, 3C and Mashimoni developed in this decade. Structures constructed were made out of mud with recycled tar drums used for roofing. Chiefs facilitated this growth by accepting bribes to allow people to build additional structures on empty parcels of land.

The growth of Mathare Valley continued into the 1990's with villages such as 4A and 4B coming up. The nineties saw Mathare becoming increasingly congested, as corroborated by literature reviewed that found that structures housed an average of 4 to 5 people per room at a density of 200 dwelling units per hectare (USAID, 1993). The predominant building materials used during this period mud, timber and cardboard that was highly flammable and completely non-resilient to flooding.

During the post-independence period, the land tenure system was complex, comprising of a mix of public, private and communal land ownership systems. During this entire post-independence era, the City Council's way of dealing with slums was by demolition and forceful eviction. An example was on 22nd November 1999 when residents were forcefully evicted from a parcel of land sold to a Mosque. This approach to slums by government authorities discouraged most residents from putting up structures constructed with permanent materials.

According to key informants, as people built more structures closer to the river through the 1980's and 1990's, floods would inflict great damage. According to residents, the river would rise over three meters in level and storm water would flow dangerously through the settlement, carrying everything in its path while leaving deep trenches, lost property and lives, especially of children. In 1997 for instance, the El Niño rains caused great damage to the settlement, carrying away complete houses, cars, trees, people and livestock.

4.4 THE NEW MILLENIUM (2000-2016)

From the residents' accounts, following the forceful eviction of settlers on a parcel of land set aside for a mosque in 1999, President Moi issued a directive to resettle the displaced residents. A parcel of public land belonging to the Kenya Police was identified, on which the present-day Kosovo and Gitathuru villages exist, where the resettlement was done. The new millennium has brought other marked differences in the urban form of Mathare Valley. Three key aspects have been greatly transformed, as discussed in the sections below include: spatial development density, general pattern of building height and change in structuring elements.

4.4.1 INCREASED SPATIAL DEVELOPMENT DENSITY

With increasing population pressure, the years 2000 to 2017 have seen intense densification of Mathare Valley. From aerial maps of the years 2004 and 2013 (Figure 4.2) it is observed that areas that were previously undeveloped between existing structures have now been built up further congesting the settlement.

Figure 4.2: Spatial-temporal change in ground development density in (a) 2004 and (b) 2013

Source: Aerial Image 2004; Google Earth Pro, 2017

On average, plots are 20 by 13 feet in size today and are currently allocated for about 200,000 Kenya shillings each. The predominant land-use today is residential use (Figure 4.3). Household survey results established that a majority of the residents were tenants (87%), with only 13% being the structure owners themselves.

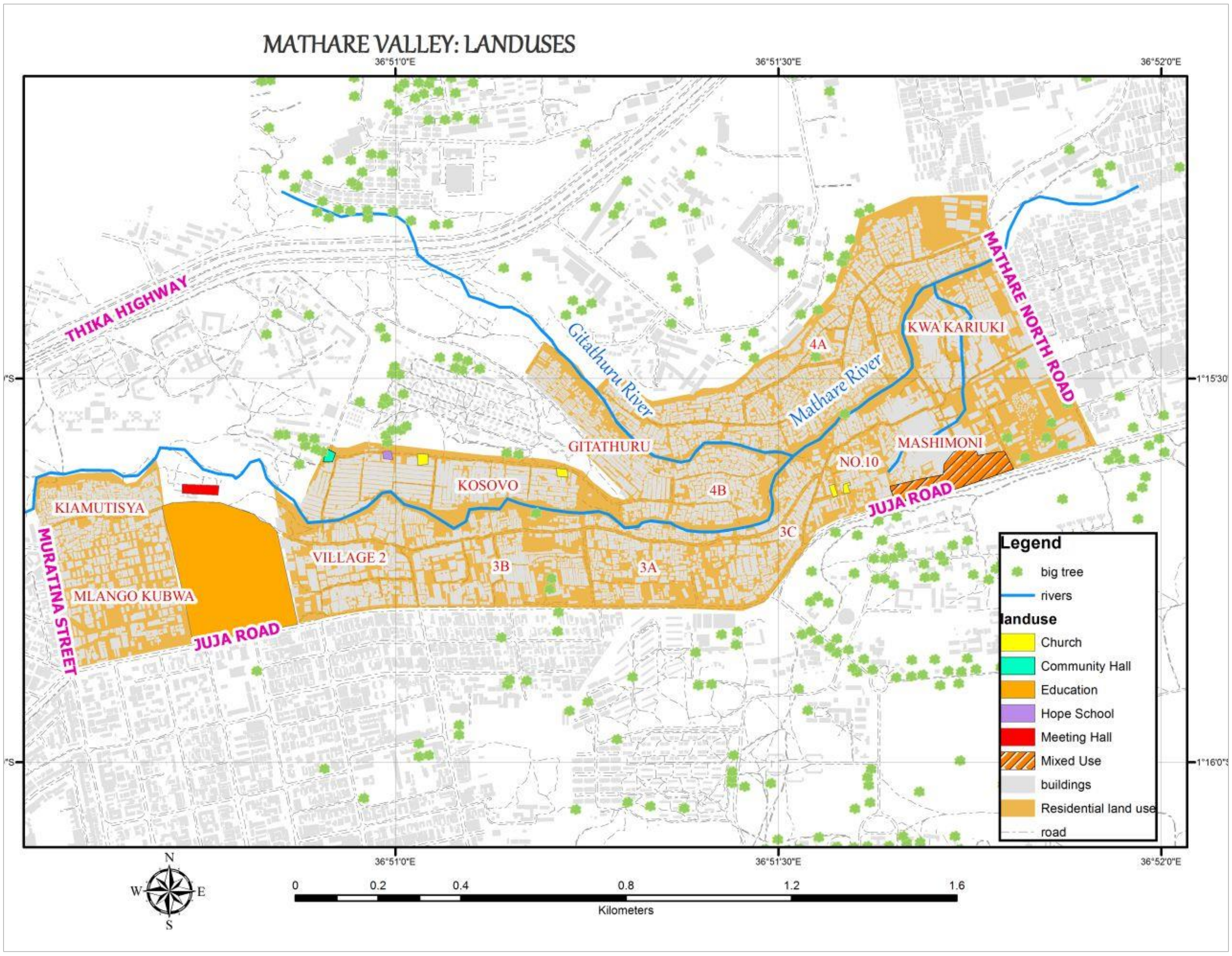

Figure 4.3: Map of land uses in Mathare Valley

Data Sources: Administrative boundaries based on the IEBC Legal Notice 12 (2012); Area features based on a vertical aerial image/ orthophoto mosaic (2013) with a resolution of 15cm.

4.4.2 CHANGES IN BUILDING HEIGHT PATTERNS

While Mlango Kubwa developed largely as a high-rise settlement, the remaining villages in the previous periods had existed predominantly at shack-level. However, in the new millennium, an increase in the number of high-rise buildings was observable. For instance, Village 2, Village 3A and Kosovo experienced the transformation of some shacks into high-rise stone houses. On average, the high-rise apartments were found to have between four to six storeys (approximately 14m in height), with staircases that are less than a meter wide. Iron sheet structures in the past were only constructed at ground-level. The new millennium has seen an increase in the number of double-storey iron sheet structures, which in some cases are partially built of stone as well. As a result of all of these building heights transformations, Mathare Valley's fabric has a non-uniform texture of ground-level shanties interspersed by double-level shanties and high-rise apartments. (Figure 4.4)

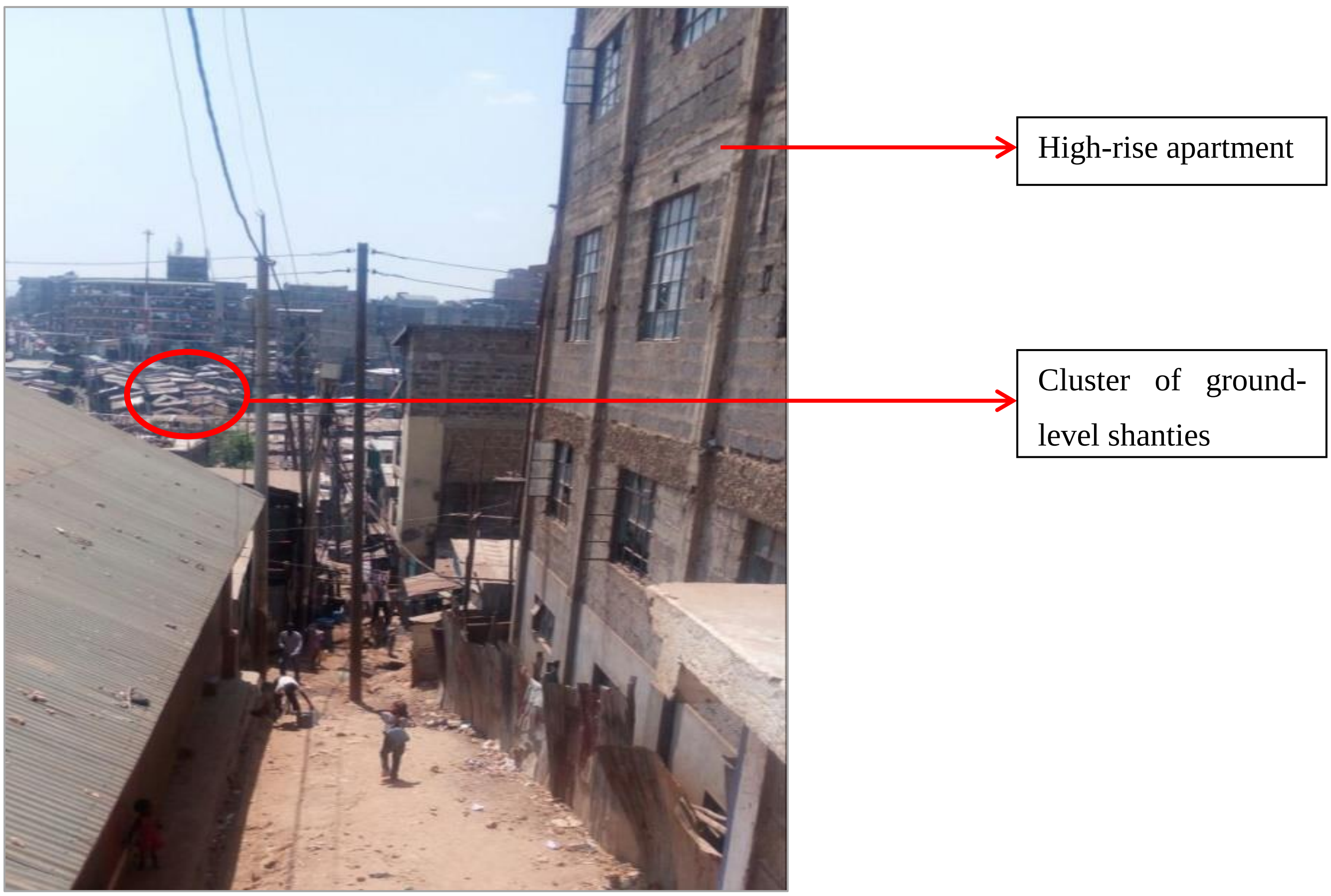

Figure 4.4: Mix of building typologies in Mathare Valley

Source: Field Survey, 2017

Settlement-wide however, the ground level shanty is still the predominant building typology as established by field survey (Figure 4.5). While high-rise apartments provided an increased number of tenants for landlords, tenants themselves preferred to rent houses at ground level. This was because one could use the ground level house for various purposes, such as mixed commercial and residential use, making these houses more expensive. The rents for these houses ranged from 2000 to 4000 Kenya shillings depending on their distance from the road and infrastructure facilities they offered.

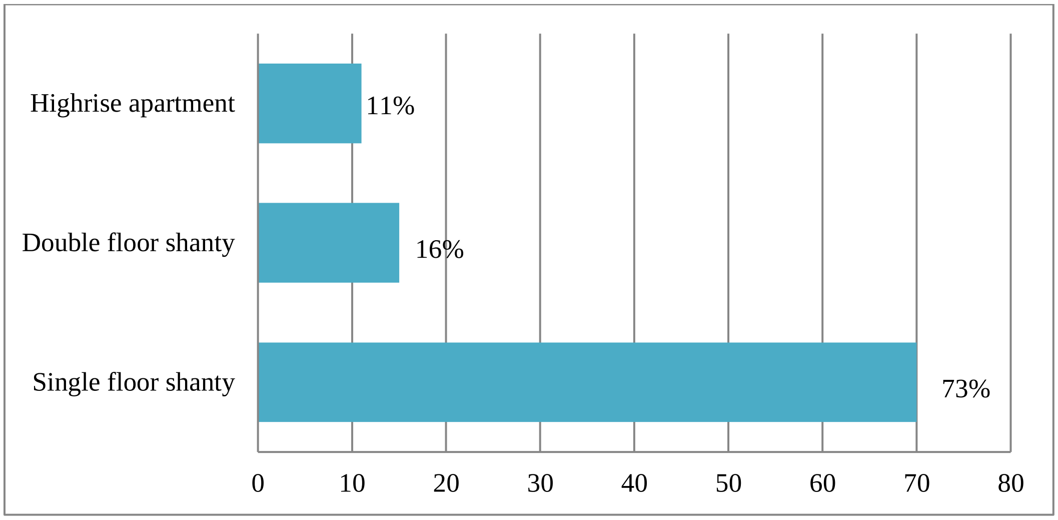

Figure 4.5: Building typologies in Mathare Valley

Source: Field Survey, 2017

4.4.3 TRANSFORMING STRUCTURAL ELEMENTS

4.4.3.1 Emergence of New Transport Corridors

The elements determining the boundaries of Mathare Valley in the past were mainly the Mathare and Gitathuru Rivers, as well as Juja Road and Mathare North Road. However, in the new millennium, government and donors adopted slum upgrading as one of the ways of dealing with informal settlements, as opposed to forceful evictions or ignoring them totally. According to key informants, in 1993 for instance, the German Bank for Reconstruction (KfW) and the Government of Kenya began the upgrading of Mathare 4A, thereby improving the quality of housing and basic services, while structuring the village along planned roads, a finding corroborated by literature in Muthoka (2005).

Through upgrading and widening of various roads that necessitated the demolition of structures, the Government of Kenya and donor partners have defined new structuring elements (Figure 4.6).

Figure 4.6: Various upgrading efforts across Mathare Valley: (a) road construction, (b) bridge construction, (c) and (d) road widening and tarmacking

Source: Field Survey, 2017

4.4.3.2 Encroachment on the Riparian Reserve

From the FGD proceedings it was noted that before the year 2000, a large portion of the riparian reserve (up to 10 meters on sections that were high flood risk zones) had minimal development. However, during the past five years, structures have increasingly been constructed within the riparian reserve driven by a mix of increased land grabbing, corruption and the community's perception that flooding is on the decline. These findings were corroborated by analysis of aerial images acquired from the years 2013 and 2017 (Figure 4.7).

Figure 4.7: Spatial-temporal depiction of encroachment on the riparian zone in 2013 (a) and 2017 (b)

Source: Aerial Image 2004; Google Earth Pro, 2017

This research estimates that 20% of all households lie within the riparian reserve itself, a figure similar to that established by the Mathare Zonal Plan, covering an estimated 8500 households today (Figure 4.8). The riparian reserve is considered to be 30 meters from the edge of the river according to the Physical Planning Handbook.

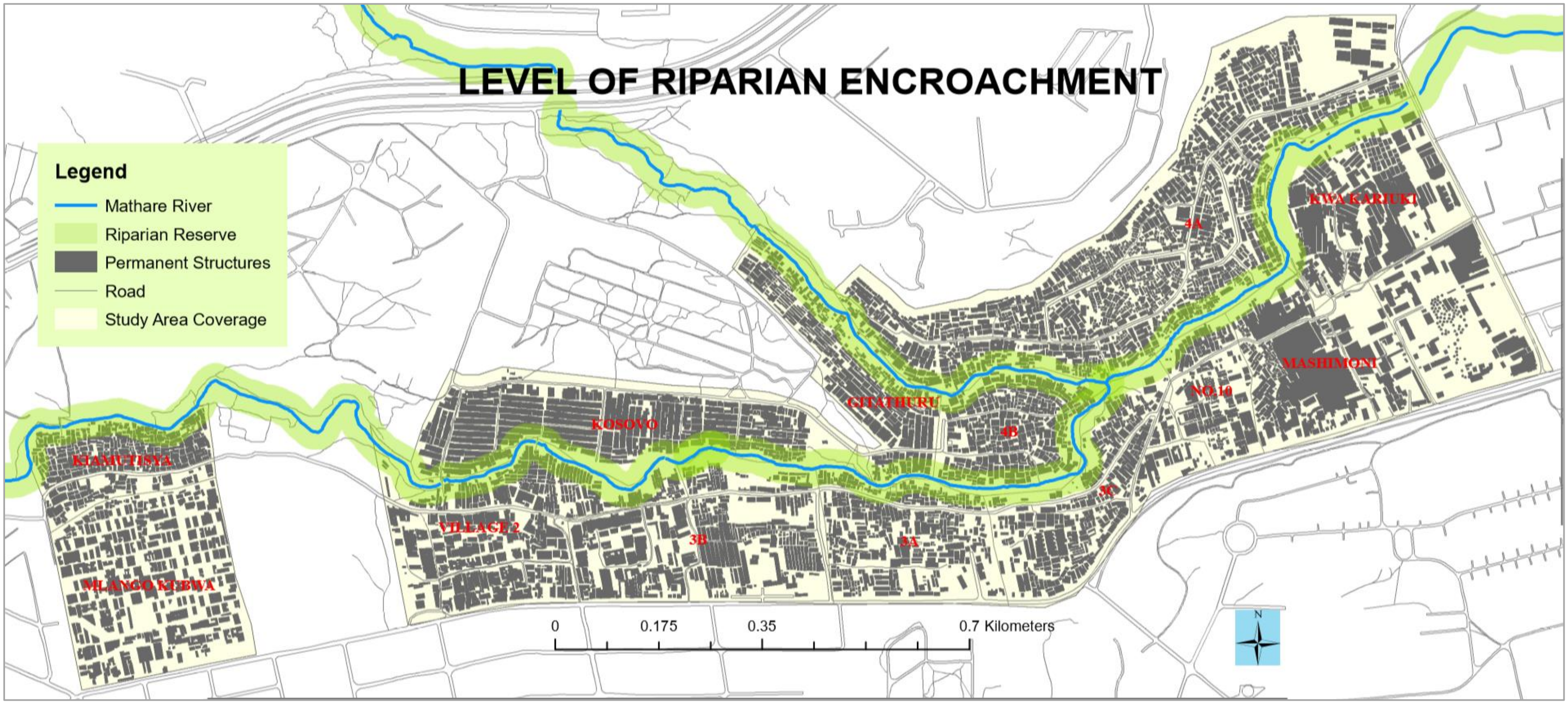

Figure 4.8: Structures encroaching on the thirty (30) meter riparian zone

Data Sources: Area features based on a vertical aerial image/ orthophoto mosaic (2013) with a resolution of 15cm; Administrative boundaries based on the IEBC legal notice 12 (2012).

Areas that were covered with riparian vegetation are now either built-up or dotted with farmlands of sugarcane, bananas, kales and livestock-keeping. The gardens for urban agriculture are not allocated by any authority, but rather are a result of either individual or group initiative. Residential structures are in some instances within one meter from the river bank and thus are completely within the high water-point zones (Figure 4.9).

Figure 4.9: Encroachment on the riparian reserve
Source: Field survey, 2017

Various institutional land boundaries have prevented further sprawl of Mathare Valley and they include Mathare Mental Hospital, the Kenya Police Depot, Muslim Mosque and St. Teresa Secondary School. These largely open spaces lie in stark contrast with the congested settlement. Within Mathare itself, there are no green open spaces left. The only recreational area is a green open space adjacent to Gitathuru settlement and the adjoining land belonging to Mathare Mental Hospital. This park that was a result of the Nairobi River clean-up (2004 to 2008) initiated under the former Minister of Environment John Michuki is lined with grass and trees that provide shade, along the banks of Gitathuru River. At the junction of Gitathuru and Kosovo villages, there is also a small space that is only undeveloped as it lies on government land that had been set aside for a shooting range for police reservists. The location of previous quarry site walls are however undeveloped as they are too steep for any construction to be done.

4.5 SUMMARY OF URBAN FORM TRANSFORMATION

From this entire review of findings under objective one, a picture emerges of a settlement whose urban form has evolved, from a low density in the pre-independence period, to a densely populated area today. The densification of Mathare Valley has come at an ecological cost, of lost biodiversity, depletion of open spaces, as well as encroachment on environmentally fragile zones. However, adoption of slum upgrading approaches by the Government of Kenya has seen a transformation of the urban form of Mathare Valley from one entirely dense settlement, to blocks of density separated by wide main road corridors.

It is also clear from the findings that the building typologies in Mathare Valley have transformed from purely ground-level shacks to double or multi-storey structures. Building materials have changed from temporary materials such as carton boxes and mud to iron sheet and stone today, transforming the urban fabric of Mathare Valley (Table 4.1)

Table 4.1: Summary of urban form element transformations

Period:	Spatial Layout/ Density:	Housing/ Building Typologies	Transport Infrastructure
Pre-Independence Period	- Small clusters surrounding the quarry sites. - Existence of an abundance of green spaces.	- Shacks/ ground-level structures. - Temporary building materials such as nylon and carton boxes.	- Consisted of unplanned footpaths.
Post-Independence Period (1963-1999)	- Growth of pre-independence clusters eventually merging across villages. - Dwindling amount of green spaces.	- Shacks/ ground-level structures. - Temporary building materials such as mud, timber and cardboard.	- The main spine within the settlement (Mau Mau Road was known but highly encroached. - Settlement internal roads and footpaths were all unpaved. - Bridges were makeshift in nature, constructed of temporary materials.
The New Millennium (2000-2017)	- Intense densification of the settlement. - Village boundaries no	- Emergence of high-rise apartments and	- New road corridors were created forming new structuring elements.

	longer easily identifiable. - Construction of structures within previously unbuildable sites such as on top of steep and unstable slopes. - One-fifth of the settlement constructed within the riparian reserve. - Existing green/ open spaces almost completely infilled with structures.	double-storied shacks. - Emergence of structures constructed by stone and bricks. - Predominance of iron-sheet structures.	- The main settlement road have been paved/ tarmacked. - Bridges have been constructed of permanent material such as steel and concrete.

Source: Field survey, 2017

The next chapter assesses the impact of this transformed urban form with the climate resilience of the communities within Mathare Valley, to establish if a link between these two aspects exists.

CHAPTER FIVE: URBAN FORM AND CLIMATE RESILIENCE OF COMMUNITIES

5.1 OVERVIEW

The second objective of this research was to assess the levels of climate change resilience of communities living within the different urban forms within Mathare Valley. This chapter is presented through four categories: climate change risks, climate vulnerabilities and impacts, differentiation of vulnerabilities and impacts on population sub-sets, community adaptation mechanisms and the link between urban form and climate risks and impacts faced.

5.2 CLIMATE CHANGE RISKS

Field studies conducted for purposes of this research established that majority of the respondents (88% of households and 85% of businesses) felt that climate within Mathare Valley had changed. This finding was corroborated by scientific evidence in Makokha and Shisanya (2010) that established development of an urban heat island from the adjacent Moi Airforce Base Eastleigh weather station. Cross-tabulation of the responses against the number of years that respondents had lived in Mathare Valley showed that over half of the respondents (57%) who had lived in the settlement for over 30 years felt the most noticeable climatic changes were in the new millennium from the year 2000 (Figure 5.1).

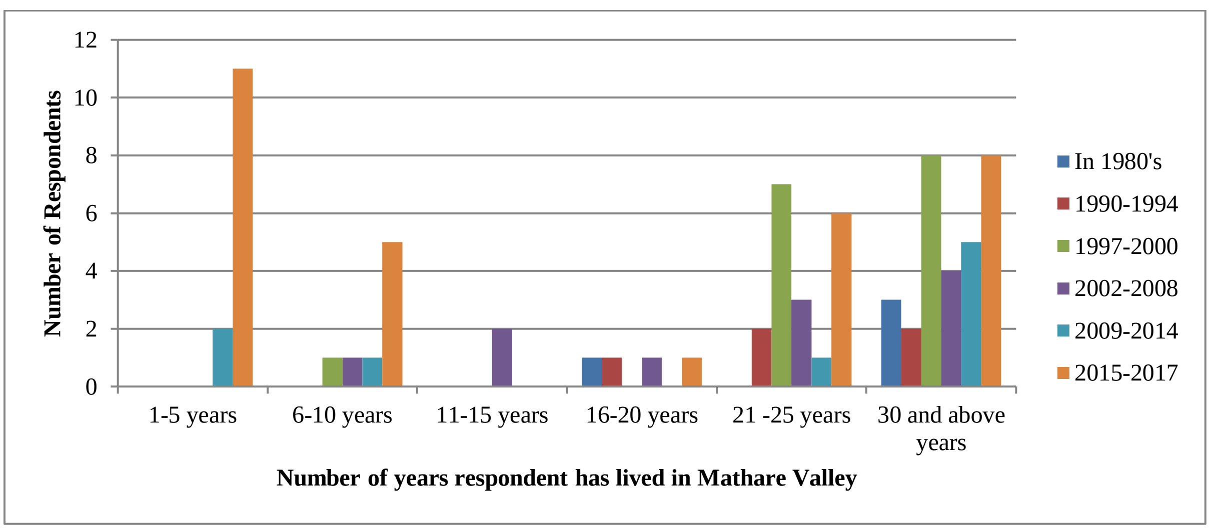

Figure 5.1: Year of noticeable climatic change versus the number of years lived in settlement

Source: Field Survey, 2017

Majority of respondents (41%) highlighted dry weather conditions (such as extreme drought, dust, high temperatures and water scarcity) as the climatic change that they currently experienced the most (Figure 5.2). 25% felt that changes in climate in Mathare Valley were mostly in the form of variations in precipitation (such as heavy rainfall and extreme storms followed by decreased rainfall during other periods). 26% of respondents cited unpredictable weather patterns as the climatic change that they currently experienced the most, while the rest highlighted extreme wind conditions (4%), water and air-borne diseases (3%) and extreme cold (1%). Overall however, the community felt that the climate risk that held the most risk for loss of life and property was extreme precipitation/ rainfall.

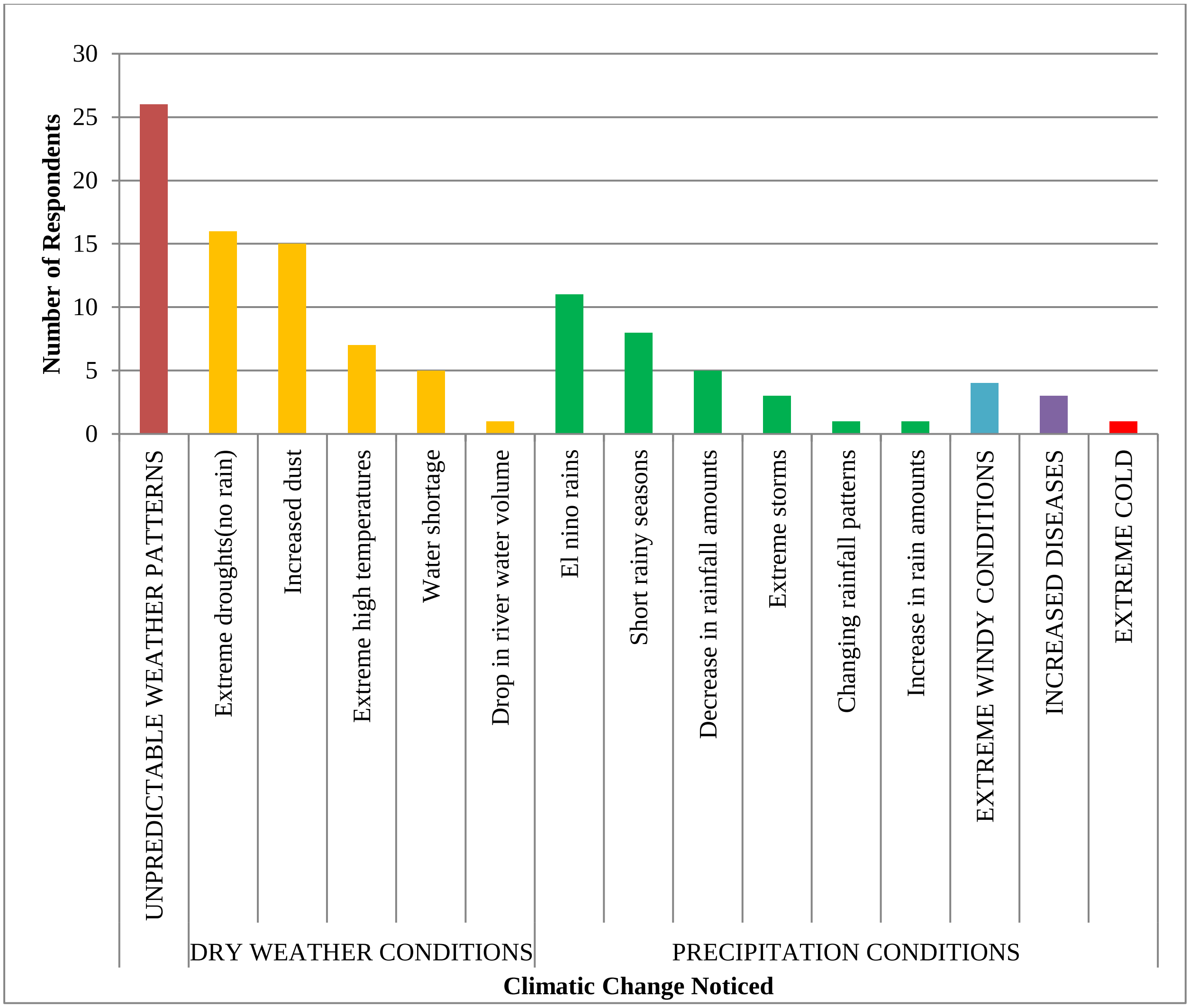

Figure 5.2: Climatic change noticed

Source: Field Survey, 2017

5.3 VULNERABILITY AND IMPACTS OF CLIMATE RISKS IDENTIFIED

5.3.1 EXTREME PRECIPITATION (FLOODING AND LANDSLIDES)

5.3.1.1 Flooding

Mathare Valley settlement lies within a geographic zone with high exposure to flooding disasters. This is because the settlement which lies within the river valley of Mathare and Gitathuru rivers (which are both tributaries of Nairobi River), at an altitude of between 1650m and 1606m above sea level. An estimated 8500 households who make up 20% of all households lie within the 30 meter riparian reserve itself (Figure 5.3)

While the settlement exhibits characteristics of an area highly at risk of flood disasters, the community perceives the risk of flooding to have reduced, with a drop in river flood levels evidenced by the expansion of the settlement into areas that were previously undevelopable in the past two decades (Section 4.4.3.2). However, no literature was found corroborating this communal perception of a drop in river volumes.

The increased encroachment into the riparian reserve has come at a great price. As a majority of activities within the settlement are at both ground and shack-level, the proportion of people, assets and infrastructure at risk from destruction from flooding is high. The El Niño rains between November 1997 and January 1998 caused great damage to the settlement, carrying away complete houses, cars, trees, people and livestock along the riparian zone. In May 2002 heavy rainfall caused Mathare River to swell and it flooded up to the sixth row of houses in Kosovo village (approximately 1620m in altitude), sweeping both people and property in its path.

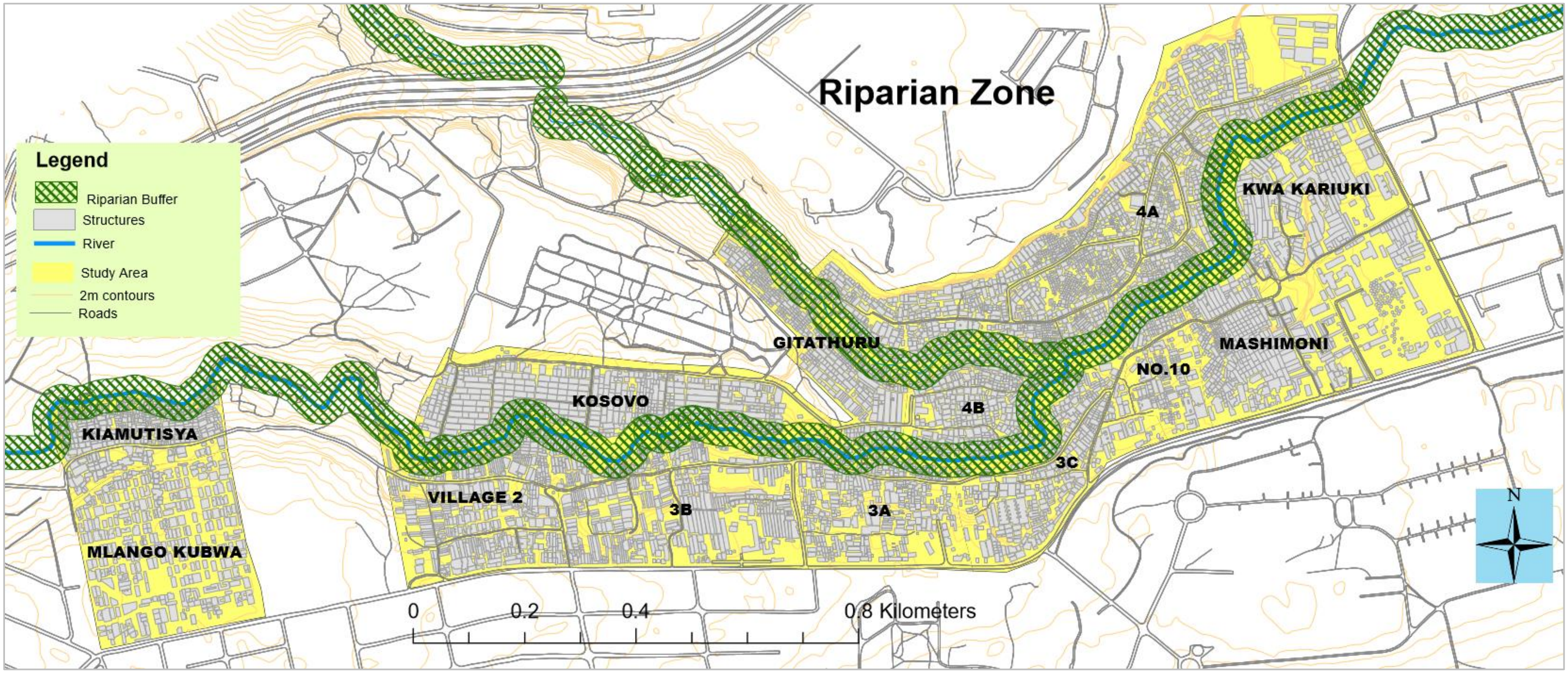

Figure 5.3: Thirty (30) meter riparian zone

Data Sources: Area features based on a vertical aerial image/ orthophoto mosaic (2013) with a resolution of 15cm; Administrative boundaries based on the IEBC legal notice 12 (2012).

One of the most high-risk areas is the riparian reserve of Gitathuru River, which also has a high level of riparian encroachment. While Mathare River floods gradually, allowing residents of villages such as Kiamutisya and Kosovo to evacuate to higher ground, Gitathuru River floods fast, with no warning causing great damage to villages such as Gitathuru and 4B. According to key informants, this river flows through the Muthaiga Golf Course Dam that overflows over periods of heavy rains, draining excess water into Gitathuru River causing a rapid increase in river discharge (Figure 5.4). For instance, in 2014, heavy rains at night triggered an overflow of water from the dam into Gitathuru River, which rose suddenly causing losses to both life and property.

Figure 5.4: Aerial image of Muthaiga Golf Course Dam and its link to Gitathuru River in Mathare Valley
Source: Google Earth, 2017

The building materials have also changed over time from temporary materials such as carton boxes and mud to more durable materials such as iron sheets and stone that are more resilient to floods. Iron sheet is used by 86% of respondents for roofing and 54% for walls. Stone and concrete is used by 31% of households for walls and in 13% of houses as roofing, mostly in high-rise apartments. Other wall materials are clay bricks (7%), mud (5%) and mixed stone and iron sheets (3%). Only 1% of all respondents live in structures where timber has been used for roofing (Figure 5.5).

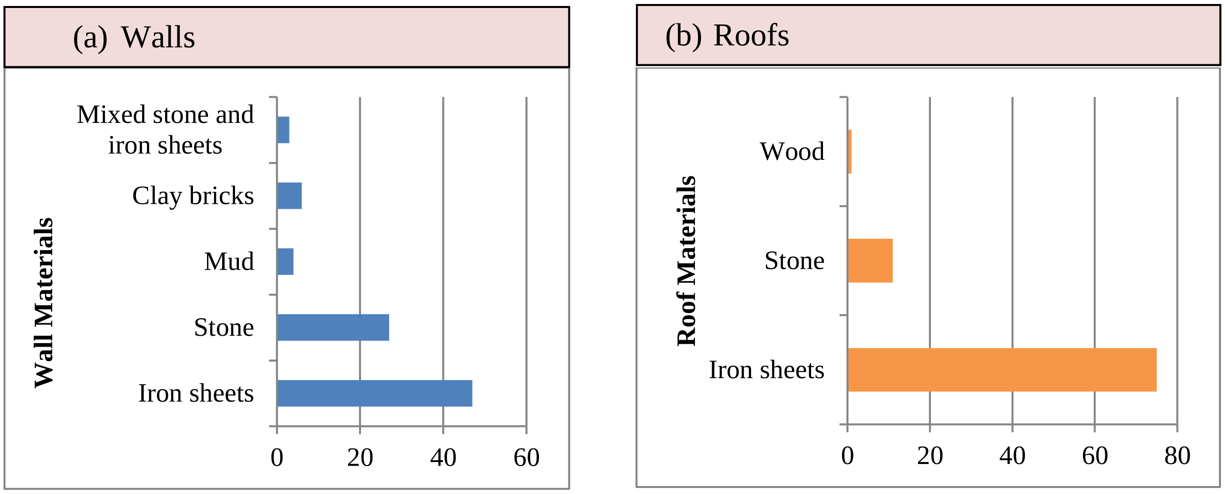

Figure 5.5: Materials used for construction of (a) wall and (b) roofs

Source: Field Survey, 2017

Iron sheet, the predominant building material in the settlement is fairly resilient to flooding. However, where iron sheets are old and in poor condition, they make households vulnerable to impacts of floods. Walls made of such degraded iron sheet or mud allows storm water to seep into houses causing damage (Figure 5.6).

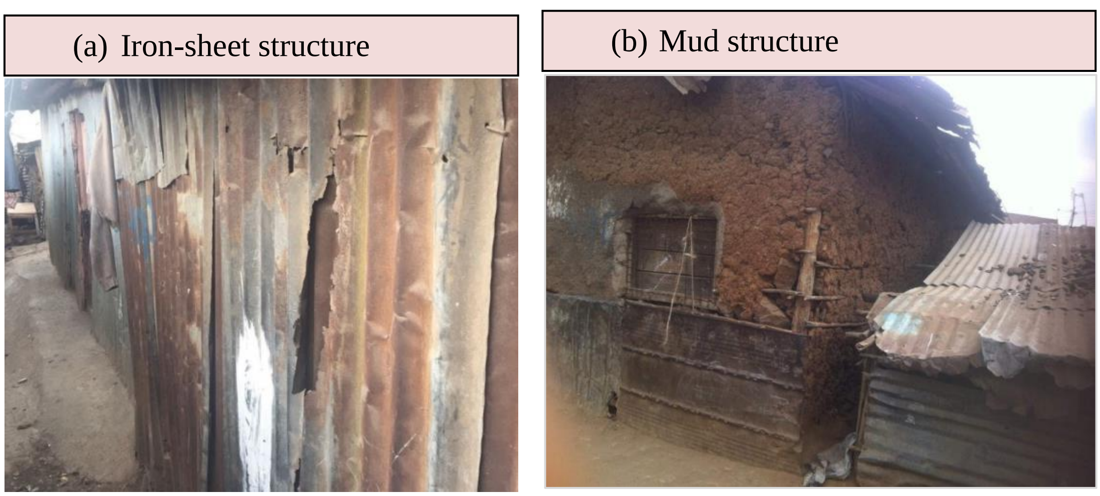

Figure 5.6: Poor condition of walls constructed out of (a) iron sheets and (b) mud

Source: Field Survey, 2017

While majority of houses (64%) have cemented floors, and 2% have ceramic tiles, one third (34%) of houses have earth floors. In the event of flooding, earth floors become muddy, making attempts to drain water out even more challenging.

The steep nature of the land on which the settlement is built has led to the construction of houses with a downward dip at their entrances, which in some instances are upto one foot deep. This feature increases the risk of flood waters flowing into homes, and accumulating as rains continue. In addition, this design constrains efforts to drain houses of the flood waters once the rains subside.

Flooding has a variety of impacts on both households and commercial enterprises. 44% of respondents identified the sweeping away of residential and business structures near the riverbank as the main impact of heavy floods, accompanied by the loss of lives through drowning (16% of respondents). The floods also spread garbage over the settlement (10%), making the environment even more untidy and unhygienic. Flood waters that flow into houses result in damage to property such as furniture and electronics (10%) and displace people that live on the ground-floor (6%). Flooding also puts the buildings at risk of collapse (4%) because they are often poorly constructed, and thus are unable to withstand the floods.

During the flood season, there is an increase in water-borne diseases such as cholera (5%) as there is increased risk of contamination from flowing sewage. This happens when flood waters cause the sewage water to overflow from exposed drains or toilets. As the water pipes in the settlement have been laid at ground level and some water points lie within the immediate vicinity of the river, the overflow of sewage water increases the risk of contamination of water (Figure 5.7). Water shortages caused by reduced availability of uncontaminated water results in hikes in water prices (3%) negatively impacting the economy of both households and majority of businesses.

Though upgrading of the slum’s infrastructure has significantly reduced the impacts of flooding (see Section 4.4.3). The tarmacking of major roads with installed culverts means that residents using these routes can access their workplaces all year round. Unfortunately, in some instances, storm water drains get clogged by solid waste dumped in them, hampering their ability to drain water effectively over the rainy season (Figure 5.7).

Figure 5.7: Storm water drain clogged by solid waste; water pipe nearby is at risk of contamination in the event of flooding

Source: Field Survey, 2017

5.3.1.2 Landslides

A portion of Village 4A lies directly underneath a steep cliff which becomes unstable during heavy rainfall and has caused landslides in the past. The cliff drops from 1628 meters in altitude to 1620 meters sharply at this point, at a slope of nearly 90 degrees, triggering a rapid falls of water in rainy seasons. In 2012, according to local key informants, excess precipitation caused heavy run-off of water from higher elevation regions north-east of Mathare Valley, causing a landslide that killed about 7 people while leaving many people homeless. There is also a steep cliff (with a slope of nearly 75 degrees) within Mashimoni Village where structures rest precariously and soil and rocks are gradually eroding away thus putting residents at risk of landslides (Figure 5.8 below).

Figure 5.8: Houses on top of cliff at risk of landslides, with gradually eroding slopes

Source: Field Survey, 2017

The location of a large part of the settlement (all villages within the settlement other than Mlango Kubwa) on this flood plain increases its susceptibility to massive losses from flooding; a condition further enhanced by the prevalence of soils such as black cotton and clay deposits, which are susceptible to water logging. Mathare Valley is pre-dominantly built-up and thus has little green or vegetated area that would reduce the speed of flowing rain water. Flood and landslide risk hotspot areas within Mathare Valley based on community mapping are shown in Figure 5.9 below.

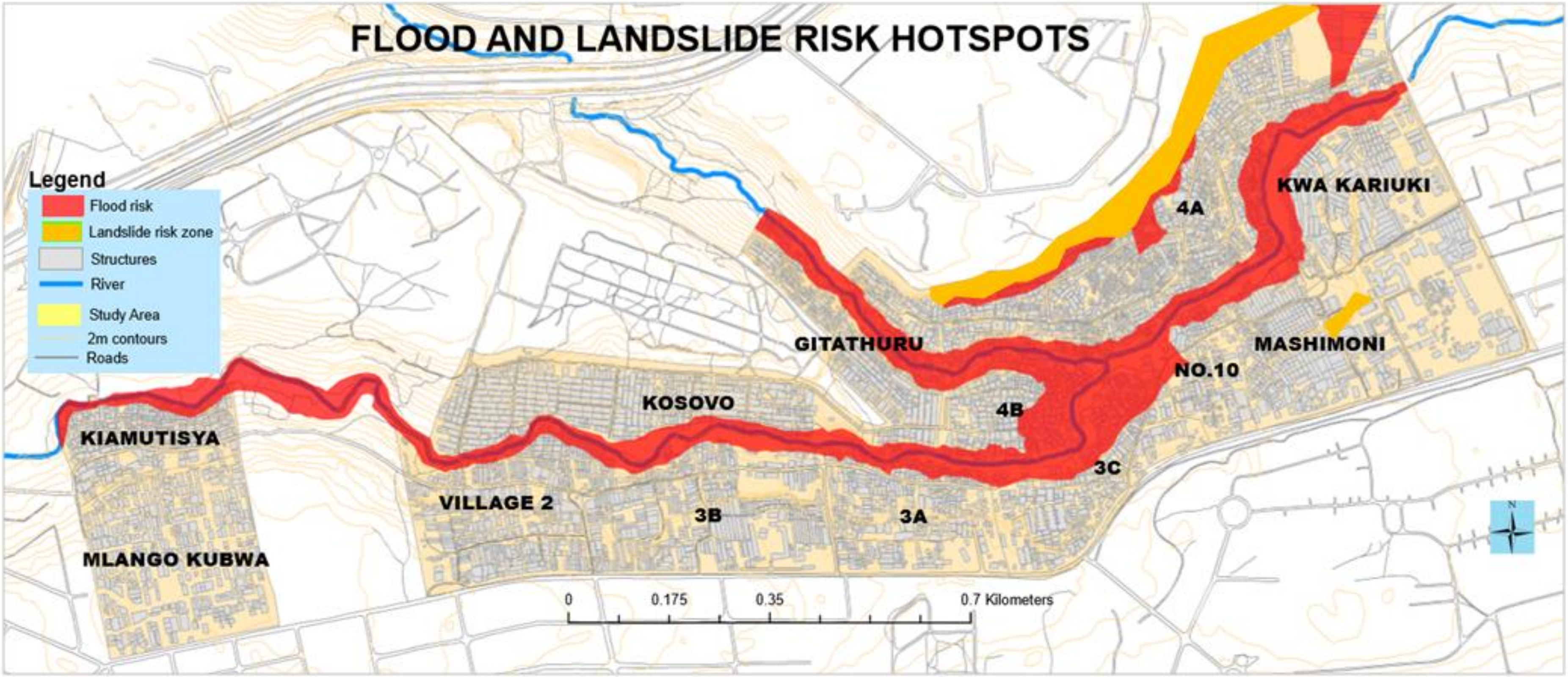

Figure 5.9: High flood and landslide risk hotspots

Data Sources: Flood and landslide zones based on community mapping at the focus group discussion held on 7th of April 2017; Administrative boundaries based on the IEBC legal notice 12 (2012); Area features based on a vertical aerial image/ orthophoto mosaic (2013) with a resolution of 15cm.

5.3.2 EXTREMELY HIGH TEMPERATURES

The predominant building material used for construction within Mathare Valley is iron sheets. It is used by 54% of households for walls and by 86% of people for roofing. These iron sheets absorb heat during high temperatures, making the houses very hot, particularly during the day, and in some cases, even into the night. The thermal discomfort is highest during the months of January through to March and September up to November.

This situation is exacerbated by the congestion of people with 74% of all respondents interviewed living in one-room houses, 21% in two-roomed houses and 5% in three-roomed homes (Figure 5.10). Among the respondents living in one room houses, half of them (51%) have an average of 5 household members. This points to overcrowding as rooms are on average 3.5meters by 4 meters in size.

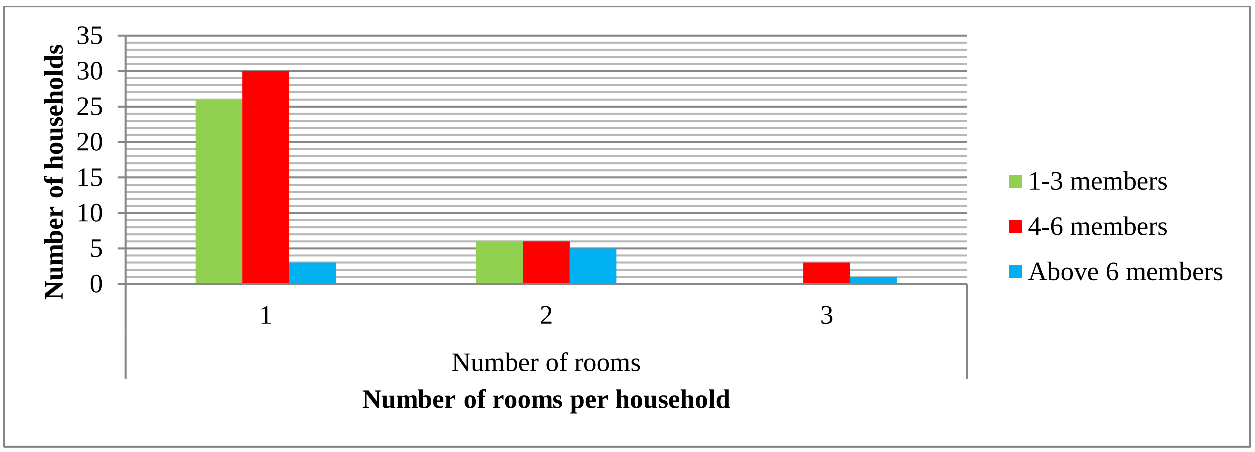

Figure 5.10: Number of household members

Source: Field Survey, 2017.

Majority of the respondents (94%) live in houses with either one window per room, or none at all (Figure 5.11). This is because the insecurity within the informal settlement means that windows are viewed as spaces through which thieves can access homes. At the same time, as most houses are at ground level, windows also decrease the privacy of homes as people pass directly in front of them. Finally, the houses are small in size (with an area of about 14m^2 in average) and thus the residents feel that windows are an unnecessary use of space as they would rather use that location for placement of furniture. This means that there are minimal opportunities for ventilation during hot seasons increasing thermal discomfort.

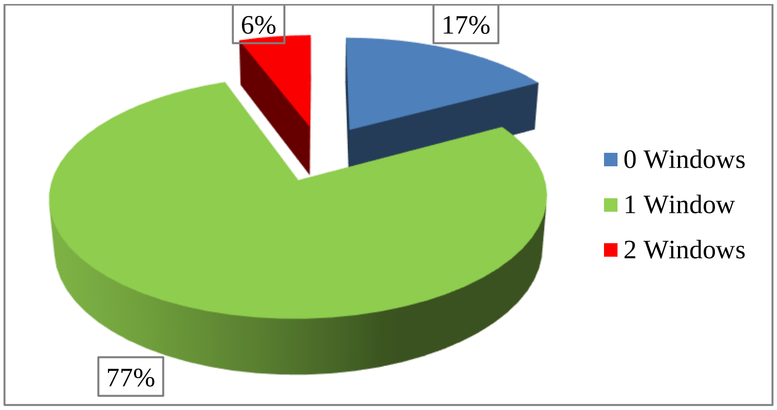

Figure 5.11: Number of windows per room

Source: Field Survey, 2017

The space between rows of houses are very narrow, in some cases less than one meter in width, to allow for adequate passage of wind for ventilation, and completely covered by iron sheet roofing which creates warm conditions along the paths as well.

83% of respondents identified thermal discomfort within structures, in the entire settlement, especially during the day as an impact of uncomfortably warm temperatures. The lack of windows and ventilation gaps creates uncomfortably hot indoor conditions, often causing heavy sweating. People that work night shifts such as watchmen are unable to sleep in their houses during the day due to this thermal discomfort. Even at night, the warm temperatures force residents to sleep without beddings to keep cool during the hot season (months of January through to March and September up to November). 17% of respondents identified headaches as another major impact of the high temperatures and dehydration. People that work outdoors such as hawkers, welders and carpenters complained of headaches particularly in the afternoon when temperatures are at their highest, impacting on their labour productivity and health as well.

5.3.3 DECREASED PRECIPITATION

Decreased precipitation has been on the rise within Mathare Valley and it has diverse negative impacts on the quality of life, health and economy of its residents. First, 15% of respondents identified that lower rainfall has resulted in drying up of crops and deaths of livestock both in farms within the boundaries of Mathare Valley or in peri-urban areas that supply Nairobi with food. Within Mathare Valley, there are people that keep livestock such as chicken, pigs and goats, while others do small-scale farming of maize and bananas along the riparian zone. Farmers within Mathare Valley would plant at the beginning of the year in the past, relying purely on rainfall, and harvest their crops in April and May, but today, the season is entirely dry.

56% of respondents identified the resultant food shortages and hikes in food prices within the settlement as additional impacts of lower rainfall. In the month of March 2017 when Kenya was experiencing drought, for example, the prices of basic food prices went up (Table 5.1). As a result, certain food items become unavailable on household menus, impacting the ability of people accessing balanced diets.

Table 5.1: Change in prices of basic food items from December 2016 to April 2017

Food Item:	Price (December 2016):	Price (April 2017):
Collard greens (*Sukuma Wiki*) (1 hand bunch)	Ksh. 20	Ksh. 50 (for smaller bunch)
Maize meal flour (2 kilogram)	Ksh. 80	Ksh. 150
Milk (1 packet)	Ksh. 40	Ksh. 60
Beef meat (1 kilogram)	300	Ksh. 360

Source: Field Survey, 2017

A fifth of commercial enterprise respondents identified water scarcity, rationing, and subsequent hikes in water prices as additional impacts of decreased precipitation. This shortage in water supply coupled with reduced agricultural yields has negatively impacted businesses by pushing quality produce out of their reach, while increasing their costs of operation. Decreased precipitation also results in an increase in dusty conditions within Mathare Valley. When coupled with wind, dust decreases the quality of air within the settlement, resulting in respiratory illnesses such as colds.

5.3.4 EXTREME LOW TEMPERATURES

Iron sheet, the predominant building material within the settlement, is poor at insulating households from low temperatures as well. This means that during cold seasons (June through to August when temperatures are as low as 12^{o}C), which are now harsher, and in some years more prolonged, residents are greatly affected. Residents feel that the month of June in particular is much colder than in the past.

According to respondents, extremely cold temperatures cause respiratory diseases such as colds and flu among residents, particularly children. The vulnerability of residents is increased by the reliance on charcoal jikos for warming, which increases household costs while exposing people to unhealthy pollutants such as carbon monoxide, although there were no reported deaths from such poisoning in the slum during the survey.

5.4 DIFFERENTIATION OF VULNERABILITIES ACROSS MATHARE VALLEY

5.4.1 CHILDREN

It is estimated that there are 19,729 children under five years of age and 18,479 children aged between six and fourteen years (KNBS and SID, 2013). This means that children under 14 years of age comprise 31% of the total population of Mathare Valley. Of the households surveyed, 56% had families of between one and three children, while 19% has between four and five children.

The impacts of climate change on the health of children are immense. The prominent climate-induced diseases affecting children identified by 53% of respondents are either water-borne such as cholera, pre-dominant during flooding, or respiratory diseases such as colds and flu that are predominant either during extreme cold spells or as a result of dusty conditions. Malnutrition of children in particular was identified by 11% of respondents as an impact of decreased rainfall, which pushed the prices of high-nutrient foods such as fruits and milk out of reach for this cohort. As children sweat a lot, thermal discomfort (identified by 13% of respondents) during periods of high temperature accompanied by dehydration due to reduced access to clean drinking water negatively impacted children during dry seasons. Climate change-induced impacts therefore cause pain, suffering and in some instances death to children.

Climate change also causes loss of access to services to children. First, access to education services is affected either when children are physically unable to access schools during flooding (7%), or when weather extremes reduces income generation opportunities for their parents thus impacting their ability to pay school fees (1%). This puts stress on children who either have their academic performance dip, or drop out of school altogether. Secondly, access to housing, which is a basic right, is also disrupted by climate change when children are displaced from their homes during flooding (identified by 4% of respondents).

5.4.2 WOMEN

Nearly half of the population (46%) in Mathare Valley is female (KNBS and SID, 2013: 19-24; Mathare Zonal Plan, 2011: 16) with 25% of all households interviewed being single-parent families, headed by mothers. Various factors were identified during field surveys as contributing to the vulnerability of women to climate change. It is the role of women to provide water for their families and as a result, water scarcity causes them to travel long distances in search of water, as identified by 43% of respondents. This means that women lose time that would otherwise be spent in other economic activities or with their families, in addition to the increased physical burden of carrying water over longer distances. Sixteen percent of respondents felt that women have a lower purchasing power and thus are more unable to access food when food prices go up, putting their households at higher risk of malnutrition. Pregnant and lactating women are even more affected as they have special eating needs that these lower incomes cannot meet.

Eleven percent of respondents felt that difficult economic conditions created by climate change led to an increase in engagement in prostitution by women. Ten percent felt that women experienced reduced incomes due to their inability to go to work during flood periods. There was also an increased possibility of women getting pregnant during the cold seasons (identified by 7% of respondents), which further increases their dependants. Diseases such as colds and flu (6%) and thermal discomfort that reduced their productivity (5%) were also identified as impacts on women. However, 2% of respondents felt that prolonged and harsher cold periods provided an opportunity for some women as they made higher incomes during this time from sale of sweaters.

5.4.3 THE ELDERLY

There are an estimated 933 persons above 65 years of age in Mathare Valley (KNBS and SID, 2013: 19-24), and 3% of all households interviewed had an elderly person in their home. From field surveys, it was established that the main climate-induced impact on the elderly was respiratory diseases such as colds, the flu and pneumonia (as identified by 32% of respondents). Flooding greatly impacts the mobility of the old people (21%), reducing their ability to evacuate to safer ground and even get around to access basic services. This causes them to be increasingly dependent on their kin (23%), and in cases of neglect, can result in death (13%). Finally, in seasons of decreased precipitation, the elderly face malnutrition (11%) as healthy food options become more costly, and priority is given to children. While literature reviewed highlighted the severe impacts of heat on the elderly (IPCC 2014), this component did not emerge from the field results collected.

5.4.4 THE SICK

As corroborated by literature reviewed, the sick are a highly vulnerable cohort in Mathare Valley. As identified from field surveys conducted, the already poor health of the sick is worsened by additional illness acquired during cold seasons (as identified by 57% of respondents) and the diminished access to balanced diets during their illness, resulting in malnutrition (7%) and increased possibility of death (17%). Climatic events such as flooding also negatively impact their access to health facilities (17%) because shorter routes may be rendered impassable and the use of a longer route may either cause greater discomfort and pain or come at a higher cost. With decreased precipitation, water scarcity increases costs to the sick as they are forced to purchase this commodity since they are unable to travel long distances to fetch water.

5.4.5 THE DISABLED

The physically disabled are among the most vulnerable persons within Mathare Valley to the impacts of climate change (Figure 5.16). Based on the proportion of disabled persons in Nairobi as established by the Kenya National Survey for Persons with Disabilities versus the total city population, the disabled in Mathare Valley are estimated to be 225 in number (NCAPD and KNBS, 2008; KNBS 2012). The main direct impacts of climate changes to the disabled are increased risk of neglect by caregivers (32%), challenged mobility during flooding (27%), inability to plan their schedules due to unpredictable weather (27%), inability to access more distant water sources during times of scarcity (8%) and discomfort from extreme sun for disabled persons that beg on city streets (3%).

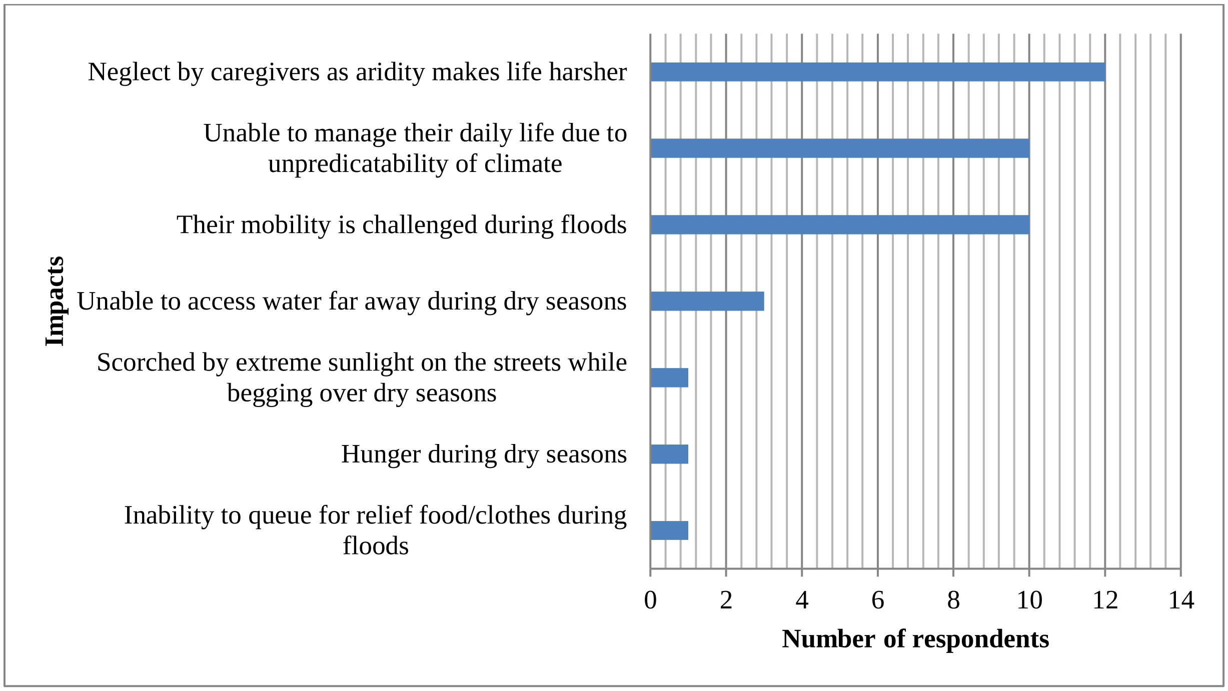

Figure 5.12: Impacts of climate change to the disabled

Source: Field Survey, 2017

5.4.6 THE YOUTH

Half of the population of Mathare Valley is between the ages of 15 to 34 years. As temperature conditions become warmer, there is increased idling among the youth (as identified by 71% of respondents), as the heat makes working or even the search for jobs even more tedious, exacerbated by reduced availability of food over dry seasons. As a result, there is a rise in insecurity (9%), early marriages of girls (7%), increased abuse of drugs (5%) and starvation (4%). For the youth interested in engaging in extra-curricular activities such as sports, the extremely dusty conditions of the playgrounds make this difficult.

5.4.7 HOUSEHOLDS AND BUSINESSES LOCATED IN IMMEDIATE VICINITY OF MATHARE AND GITATHURU RIVERS

This research estimates that approximately 42,500 people are living on, or operating within the 30 meters riparian reserve of the Mathare and Gitathuru Rivers. Field surveys showed that both houses and business premises lined the rivers throughout the settlement, in some cases less than a meter to the river itself (Figure 5.13).

Figure 5.13: (a) structures within the immediate vicinity of a heavily polluted Mathare River; (b) a child plays unaware of the health risks posed

Source: Field Survey, 2017

These households and businesses are at a very high risk of loss of life and assets in the event of an unforeseen flood event. The main factor that attracts people to this high-risk area is the cheaper rents offered within this zone. These houses adjacent to the river attract monthly rents of between Ksh. 800 to Ksh. 1500, compared to rents above Ksh. 2000 elsewhere, which drives the poorest households here.

5.5 COMMUNITY-BASED ADAPATATION MEASURES

The residents of Mathare Valley have over the years adjusted their lives to adapt to the changing climate at individual, household and communal levels. At individual level, residents change of dressing code to suit the different temperature conditions and drink a lot of water to prevent dehydration over hot seasons.

During flood seasons, household heads caution their children against playing near the river and clear storm water drains outside their houses to avoid overflow of flood waters. Additionally, o to reduce the risk of flood waters flowing into the houses, some households put up sacks of sand at their doorsteps to serve as mini-gabions reducing the flow of water directly into the structures (Figure 5.14).

Figure 5.14: Sacks of sand laid at doorsteps to keep floodwaters out

Source: Field Survey, 2017

Households have also adopted several physical adaptation measures that adjust the physical design of structures within Mathare Valley. First, there has been a shift to iron sheet and stone houses from the previous mud structures which were not resilient to flooding. Owners of some structures abutting the river have attempted to raise their structures by one foot to a nearly a meter high, by either putting stone layers underneath while others have constructed their structures on wooden stilts to reduce the impacts during floods (Figure 5.15).

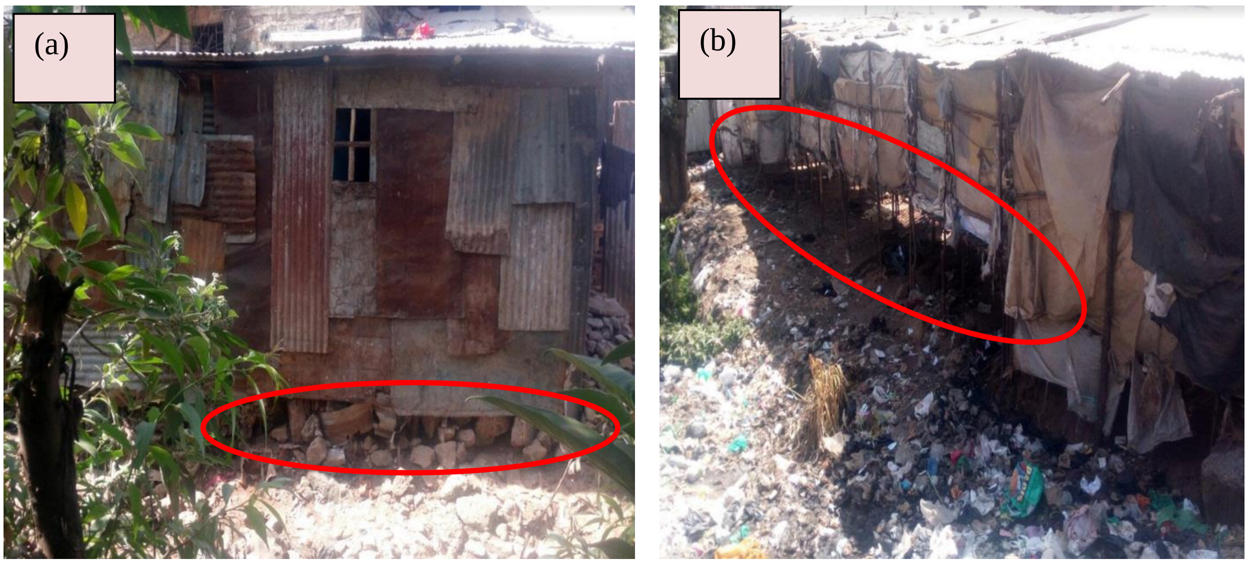

Figure 5.15: Structures raised to minimize flooding using (a) stones and (b) wooden stilts

Source: Field Survey, 2017

During the hot season, households attempt to reduce the heat from the iron sheet structures, by lining the ceiling with sack material (*gunia*) so as to cool the houses. Additionally, households make efforts to reuse water and reduce household consumption of food as much as possible during the dry seasons. Some households also try to allow for air circulation by keeping their doors open, although this is often constrained by security concerns. During cold season, some households prefer to use charcoal to cook, as opposed to kerosene, so as to warm the house as well in the process.

At the community level, NGOs have played an important role in jump-starting various communal adaptation measures such as tree planting near the river, settlement clean-ups and community sensitization on climate-related matters. These NGOs operating in Mathare Valley include Red Cross, the National Youth Service (NYS), Father Grols Organization, and three NGOs (Pamoja Trust, Muungano Support Trust (MUST) and Humankind First). Some of the activities by these organizations include tree planting and urban agriculture such as Muungano wa Wanavijiji for instance, operating a communal farm for irrigated agriculture due to the unreliability of rainfall. Urban agriculture creates green spaces that can absorb rain water minimizing flooding while boosting food security. Additional activities by NGOs include offering of training on disaster management during floods, rain water harvesting, water conservation, all of which are elements of adaptation to climate change.

5.6 URBAN FORM AND CLIMATE CHANGE IMPACTS LINK

From the review of objective two above, it is clear that a link between urban form and the climate change impacts facing the community of Mathare Valley exists. Respondents largely attributed impacts of climate change to five elements: lack of green cover/ trees (41%), improper solid waste disposal/ sanitation (25%), over-population and congestion (12%), encroachment and construction on the riparian reserve (11%), and limited sources of water (5%). Among these components identified, three in particular had an urban form implication as discussed further below:

- Congestion that has led to **overcrowding of structures resulting in dense urban form** is directly linked by residents to the thermal stress they experience during the hot seasons.
- **Reliance on iron sheet for building** has created thermally uncomfortable indoor conditions, which are either too warm or too cold depending on the season.
- The **transformation of spatial use of the riparian reserves** to that of a built-up environment has increased the number of people and assets exposed to flooding. Additionally, expansion of built-up use into precarious sites such as adjacent to steep cliffs increases the exposure of community members to landslides.
- The **lack of green spaces with trees** that can serve as the lungs of the settlement is a deficiency in Mathare Valley's urban form that could reduce the heat stress residents are experiencing. Green spaces can also reduce the absorb some of the runoff (infiltration) and reduce the amount of storm water getting into the river channel, both in the paved areas upstream and within the settlement itself.

While residents perceive flooding as having reduced, the impacts may have diminished largely in part from **risk-reducing infrastructure** that has been put up (see Section 4.4.3) such as wider all-weather roads, bridges and culverts, coupled with improved building materials. Changes in urban form have however brought about the challenge of heat stress. The shift from cooler mud structures to iron sheet ones, clearing of previously green spaces and the increasing densification of structures has created very hot conditions with little opportunity for ventilation, making heat stress an increasing climate risk over time.

The next chapter presents possible climate adaptation options for Mathare Valley, which make use of urban form for improved resilience.

CHAPTER SIX: URBAN FORM OPTIONS FOR CLIMATE RESILIENCE

6.1 OVERVIEW

The third objective of this research was to evaluate options in urban form for improved climate change resilience of communities within Mathare Valley. This has been presented in this chapter through two sub-sections: community proposals and finally, options for climate-resilient urban form.

6.2 COMMUNITY PROPOSALS

In-order to suggest options for urban form adjustments or transformation, it is important to understand the needs and priorities of the local community. From the field surveys conducted, the local community proposed options to reduce flooding (Figure 6.1).

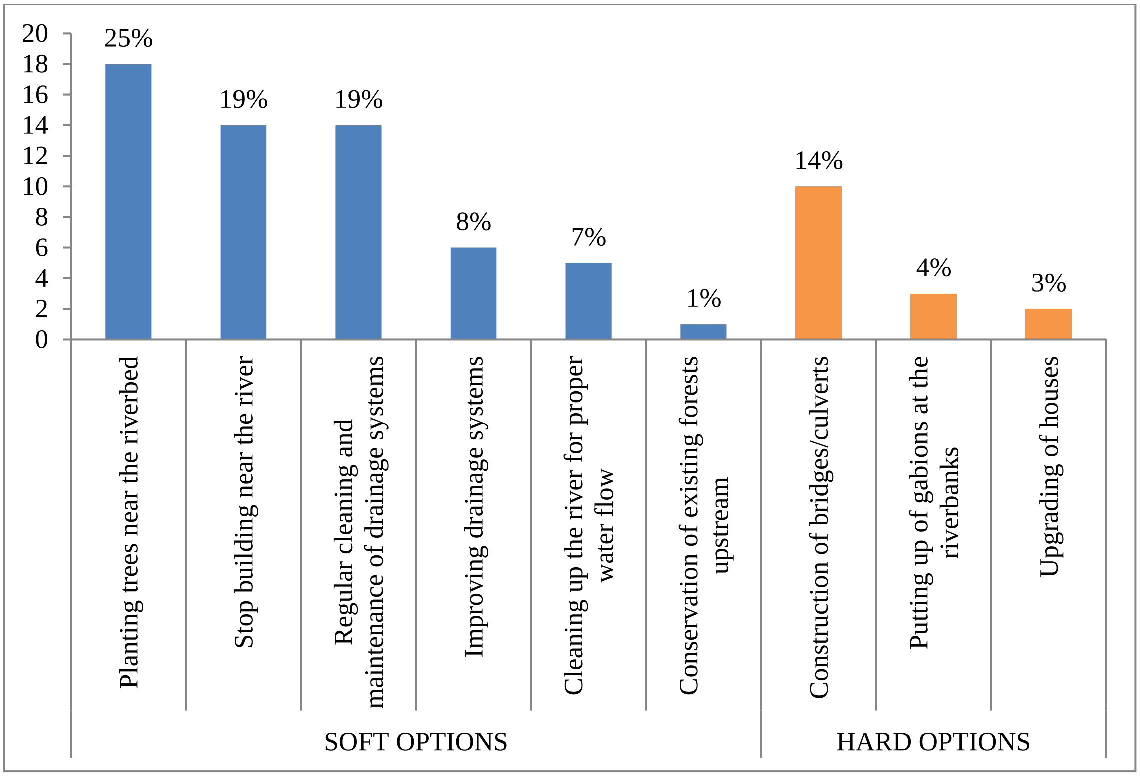

Figure 6.1: Community's proposals to reduce flooding

Source: Field Survey, 2017

The community also suggested options to reduce their exposure to heat stress, with planting of trees being suggested by nearly half of the respondents (Figure 6.2), as well as improved ventilation of houses (25%).

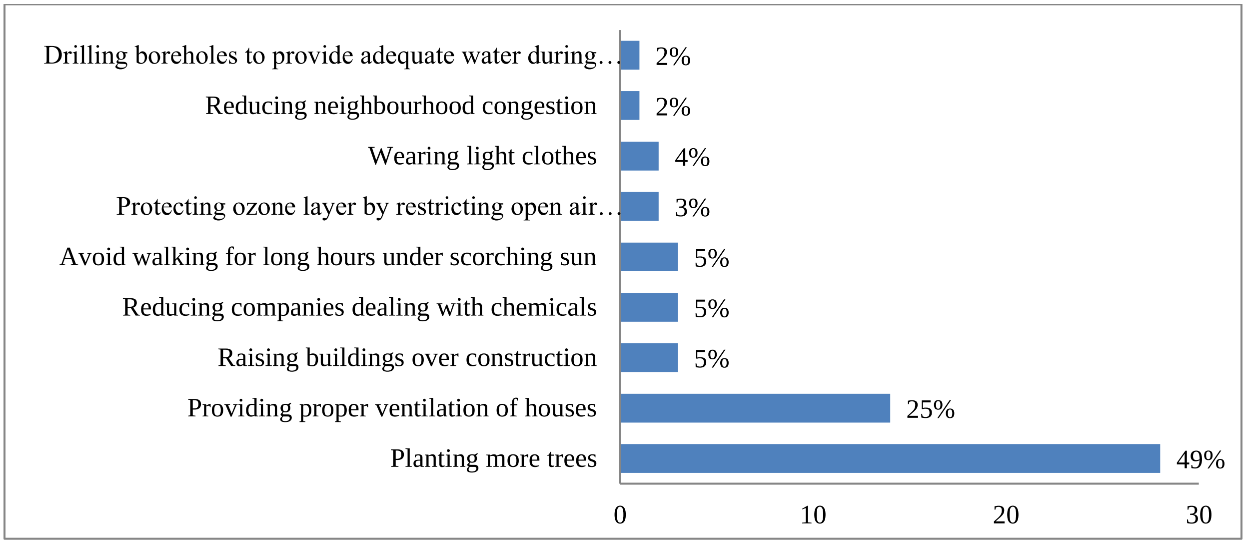

Figure 6.2: Community's proposals to reduce heat stress

Source: Field Survey, 2017

The community also suggested options to reduce cold stress (Figure 6.3), with a majority citing wearing of warm clothes (70%), construction of better housing (15%), provision of spaces for recreation (7%) and reduction of charcoal prices (3%).

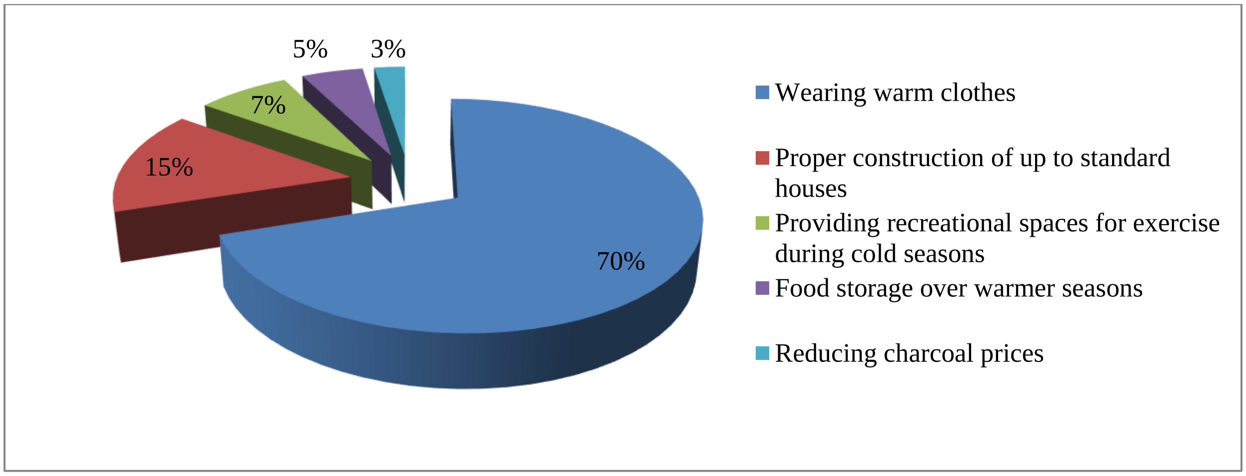

Figure 6.3: Community's proposals to reduce cold stress

Source: Field Survey, 2017

From the results in figures 6.1, 6.2 and 6.3 above, while some of the proposals by the community were behavioural (such as dressing warmer during periods of cold stress), majority of the proposals involved direct transformation or adjustment in urban form as listed below:

- Construction of gabions at the riverbank
- Construction of bridges and culverts
- Restriction of construction near the river
- Tree planting within the settlement and along the river bank
- Decongestion of structures
- Raised buildings
- Provision of spaces for recreation
- Upgrading houses through improved building materials and designs

6.3 OPTIONS FOR CLIMATE RESILIENT URBAN FORM

From the analysis of the link between urban form and climate change, it is clear that adjustments in urban form can have the greatest impact to three climate change impacts; flooding, thermal stress and landslides. This research proposes to address these three climate risks through zoning of the settlement (Figure 6.4) as elaborated in the sections below:

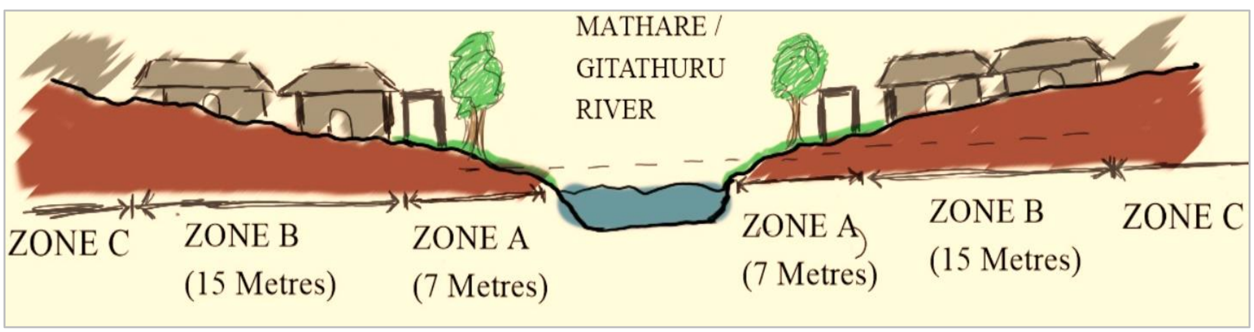

Figure 6.4: Flooding adaptation proposals (not to scale) for the riparian reserve

Source: Author, 2017

Zone A is the region that is most at risk from flooding from increased water volumes, due to its immediate proximity to the river, as discussed in Sections 5.3.1 and 5.4.7. From community engagements, it was established that this area holds an estimated one row of housing parallel to the river, at a distance of about 7 meters from the river bank and at an elevation ranging from between 1606 meters and 1616 meters above sea-level depending on the location of the area within the settlement. Due to the magnitude of risk faced, it is proposed that all structures within this reserve be demolished, and no construction of structures should be permitted within this zone.

Because of the displacement that the relocation will cause, it is proposed that a Resettlement Action Plan be prepared first, to identify possible relocation sites outside of the hazard zone, but where possible within the settlement itself, and measures to mitigate the impacts of displacement. Structure owners should be adequately consulted and compensated for their structures and revenue lost. A plan must be put in place for relocation of tenants, in a way that cushions them from increased rents elsewhere. As there is the risk of creating a large open area attracting new settlers, it is proposed that the relocation be done in phases. Phasing will allow for a gradual creation of actively used spaces, as well as making enforcement easier.

It is proposed that trees be planted along this reserve creating a green buffer which would act as lungs of the settlement, and create cooler temperatures within Mathare Valley. It is also proposed that this green buffer be designed with zones for purely trees, separated by zones where urban agriculture is practised by marginalized groups, such as women and the disabled (Figure 6.5).

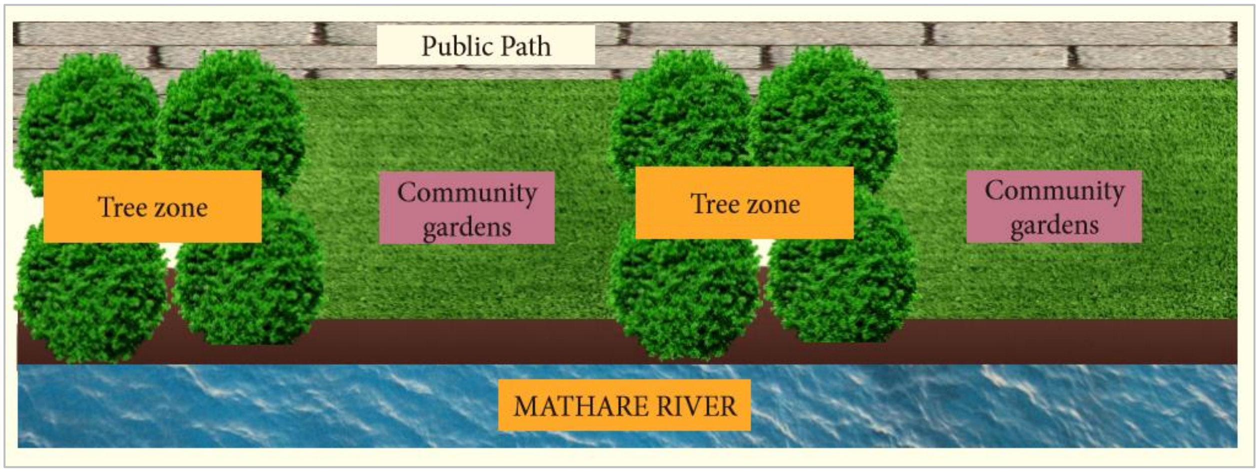

Figure 6.5: Different functions within the green riparian buffer in Zone A (not to scale)
Source: Author, 2017

The presence of these communally-held farms could serve as both a food security measure, as well as income generation for this marginalized groups. In addition, these groups should be responsible for the clean-up of the tree areas adjacent to their gardens, and will prevent the transformation of the riparian buffer into a dumping ground for waste. In addition, these farmers should be encouraged to use organic waste from households and livestock farmers as manure for these farms. At the same time, the active use of the green space will discourage any encroachment of the reserve by unscrupulous people, as the land will not be perceived as undeveloped land.

These green spaces would also serve as places for community interaction, building deeper community ties that are crucial for resilient societies. In addition to this buffer serving an adaptation purpose, this green space will also bring about mitigation co-benefits, as it will promote carbon sequestration. The tree species selected for this zone should be fast growing to withstand flooding, have fibrous root systems to absorb the water as fast as possible and their foliage should be above flood height.

The green buffer zone should be separated from the rest of the settlement by a wall and a raised path that will boost inter-village connectivity. These walls will climate-proof the path from destruction during flood seasons, and limit opportunities for encroachment into the riparian area. The road will also provide an additional route of non-motorized transport (pedestrian, bicycle and motorcycle) to people of the low-lying areas of the settlement that are poorly served by roads.

Zone B, delineated for purposes of this research as holding approximately two lines of structures and measuring about 15 meters in width, has a moderate risk of flooding from swelling river volumes. While all structures within this Zone as well as Zone A (22 meters in total) fall within the 30 meters riparian reserve as required by the Physical Planning Handbook and thus would ordinarily be proposed for relocation, this research proposes alternative measures bearing the significant portion of the population that would be adversely affected if relocation was selected.

This study proposes *in-situ* upgrading within this zone, involving some structural adjustment. However, all critical facilities such as clinics and schools lying within this zone should be relocated to a site to be identified through a Resettlement Action Plan, and no critical infrastructure such as water pipes, bridges should be laid at ground level within this zone. Options such as aerial water pipe construction that has been done in Kibera slum in Nairobi, by Safaricom Kenya (a private telecommunications company) and an NGO called Shining Hope for Communities (SHOFCO).

This research proposes that structures within this zone be reinforced by introducing an exterior protective layer of concrete, and ensuring that all floors are concrete (Figure 6.6). This will prevent the destruction of structures from the ground upwards by flood waters. The concrete floors will also make it easier to drain any flood waters that may seep into the structures through simple scooping. However, it is proposed that detailed architectural studies be done to establish actual construction options and dimensions. This research hopes that the circulating air from the adjacent green buffer in Zone A will also create a cooling effect for structures within Zone B.

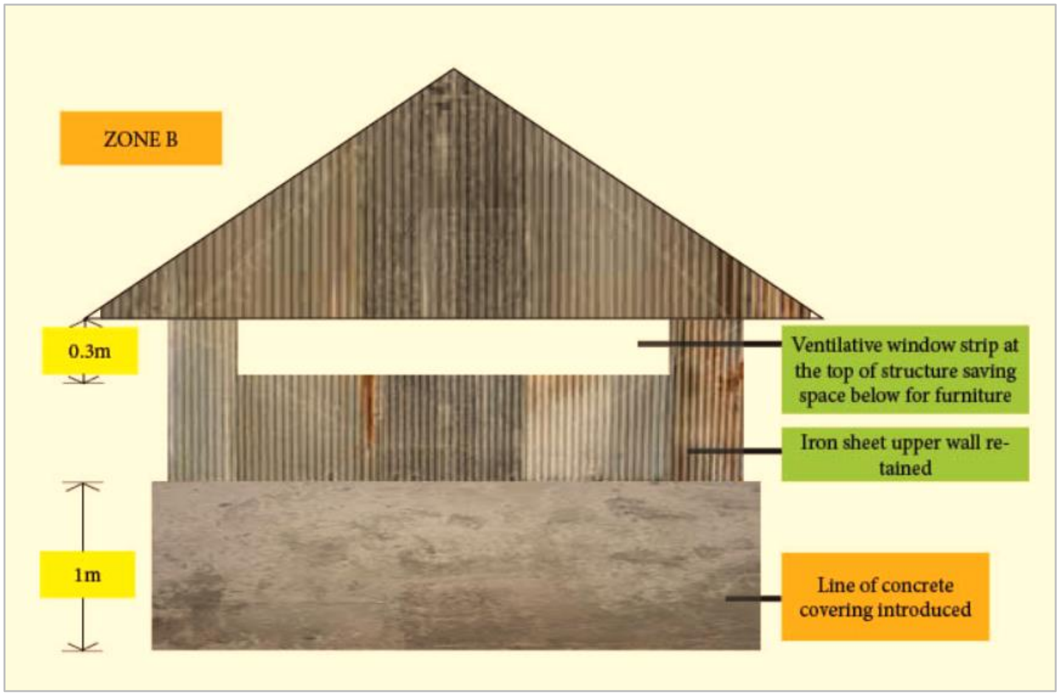

Figure 6.6: Artistic impression (not to scale) of reinforced structure design for Zone B

Source: Author, 2017

Zone C region is mostly affected by thermal stress as it a highly congested area, dominated by purely iron sheet structures. This research proposes that that the construction of structures using iron sheet only should be discouraged. Contextual research into appropriate building technologies and materials to achieve thermal comfort should be fast-tracked. Gradually, residents should be encouraged to adjust their structures to incorporate a mix of iron sheet and cooler materials such as stone or clay bricks for walls.

In the short-term, structure owners should be encouraged to put up ceilings (made of for instance ceiling board) to reduce the heat gained through the roof. Additionally, the iron sheet roofing material can be painted white on the exterior to increase solar radiation and thus minimize roof heat gain. As security concerns have made windows unattractive to community members, small ventilation openings should be made on the upper part of walls to allow in air. For structures under commercial use, often located along streets that are in some cases oriented towards the sun, it is proposed that permanent sun-shades and rain shelters can be constructed for the local community at subsidized costs. All these thermal stress adaptation measures should also be implemented in Zone B as well as thermal stress is a settlement-wide climate risk.

While there is a great need for green spaces within this zone, this research proposes to advocate for the relocation of the least number of households. For this reason, this research proposes only further greening of existing open spaces such as St. Teresa Girls. However, a proper road circulation system can create paths for cool air flow, and this would be work in progress with the ongoing construction of major roads within the settlement.

This zone faces the risk of flooding from storm water flowing downslope into the river. This research proposes promotion of the use of sand bags at the entrances of all houses to prevent storm water flowing in, as an immediate measure. Gradual introduction of concrete mini-walls at the entrances of plots should be done as well, whose actual designs should be established by detailed architectural studies. Additionally, a proper storm water and sewerage system needs to be laid to address flooding and the resultant health challenges. A clear system for solid waste disposal needs to be established to prevent dumping of waste in the storm water drains thus clogging them up.

The Landslide-Prone Zone occupies the width of approximately one-line of structures along the outer boundary of Village 4A as well as all structures on top of the cliff at Mashimoni. This research proposes that due to the destructive nature of landslides, all these structures should be demolished. A Resettlement Action Plan should be developed to determine relocation points for the displaced or establish commensurate compensation in cases where no such site is available nearby.

Settlement-wide, this research proposes that all the footpaths within the settlement should be made all-weather so as to allow for uninhibited movement all year round. All roads should have well maintained culverts and bridges where needed, and all footpaths should have small storm water drains through their entire length. As there is little ground cover for greening, this research proposes that residents can be encouraged to grow creepers along the outer walls to reduce heat gain along the walls.

From the review of the findings of objective three above, it is clear that the community of Mathare Valley recognizes climatic changes as challenges they face and therefore have developed their own local adaptation measures. In addition, the community suggested options for adapting to thermal stress and flooding, which mixed both hard engineering and soft options. The case of Mathare 4A provided localized lessons into how building materials such as clay bricks can be used to create comfortable indoor thermal conditions compared to iron sheet.

This research borrowed ideas from community proposals and innovative ideas from the global and local case studies analysed. The proposals suggested complete relocation of structures within high risk flood and landslide zones. To minimize the social cost of high levels of displacement, this research proposes the engineering option of a flood wall that serves as a transportation corridor to protect residents of the medium-flooding zone. Housing improvements have been proposed to improve the resilience of remaining structures to flooding while enhancing thermal comfort. A green corridor along the river has been proposed to make active use of the cleared high risk flood zone, while contributing to food security and income generation for the most vulnerable in the slum.

CHAPTER SEVEN: SYNTHESIS AND DISCUSSION

7.1 URBAN FORM TYPES AND TRENDS

The urban form of Mathare Valley experienced gradual growth during the pre-independence era (before 1963) due to the pre-dominant use of the area for quarrying as well as the restrictions imposed on local Kenyans travelling to the city by the colonialists. The riparian zones were intact, covered by trees and other vegetation while structures were few and scattered within Mathare Valley.

After Kenya gained independence, the search for urban opportunities saw Mathare Valley growing as the city was ill-prepared to meeting the housing demand for the poor. The period from 1963 to 1999 saw the largest urban transformation of the settlement. Residential use became the predominant land use and structures increased both in number and density. Development happened haphazardly, consuming spaces that previously served as roads, green areas and the riparian reserve.

In the new millennium, densification of Mathare Valley has continued unabated, with nearly all remaining empty spaces being infilled with structures, and new villages established. In addition, the urban fabric of Mathare Valley has transformed with the sprouting up of high-rise stone apartments in various areas. Construction along the riparian reserve has become more daring, with some structures being less than a meter away from the flowing river water. This period has also seen the emergence of government policy supportive of physical upgrading of informal settlements. As a result, structures have been cleared to pave way for wide main access roads as well as bridges. Additionally, portions of Village 4A were demolished and new improved housing structures within a planned framework.

7.2 URBAN FORM AND CLIMATE RESILIENCE OF COMMUNITIES

Today, the community of Mathare Valley is vulnerable to climatic changes because of a mix of external and internal vulnerability factors. External vulnerability factors which are beyond the community's control include climate change that causes increased precipitation, more frequent extreme events, higher temperatures, lower temperatures, and aridity. Internal factors are those that community members or government authorities have the opportunity to change. These include constructing structures within a riparian reserve, use of non-resilient and building materials appropriate for the tropical climate, and low levels of provision of risk-reducing infrastructure by government.

In the past, flooding was the major climatic challenge facing residents. However, with climate change and changes in building materials, thermal stress is an emerging hazard. While the shift to iron structures increased resilience to flooding, it has increased the community's vulnerability to thermal discomfort, particularly when coupled with the overcrowding in the settlement. Structures made of mud in the past were cooler all year round while today, the iron sheet structures are too hot during both the day and the night, almost all year round. From the months of early June until the end of August, the structures then become too cold. There is need for a detailed research on innovative and climate friendly building materials that are locally available in Nairobi.

It is also clear that within Mathare Valley, there are differing levels of vulnerability among the residents. Children, women, the elderly, sick and disabled persons are disproportionately vulnerable to climate change within the settlement. This is because they have constraints in mobility, lower levels of immunity, higher levels of dependency, special dietary needs and have limited options for income generation. The people and commercial enterprises located within the immediate proximity of Mathare and Gitathuru Rivers are also among the most vulnerable group of people within the settlement as they are highly exposed to river flood risk.

There is a growing expansion of the settlement towards the river; fuelled by the community's perception that flooding is on the decrease within Mathare Valley. There is therefore a need for scientific research in Mathare Valley to validate or invalidate this belief as there was no literature reviewed that supported this assumption. However, it is the opinion of this research that promoting structural adjustment to structures under either residential or commercial use that have cropped up extremely close to the river would be maladaptation, given the unpredictable nature of climate change. In addition, literature reviewed projects that there will be an increase in the frequency of climate disasters into the future (IPCC, 2014)

7.3 URBAN FORM OPTIONS FOR IMPROVED CLIMATE RESILIENCE

In the past two decades, there has been a momentous shift in Kenyan government policy towards informal settlements, from demolition approaches to those of upgrading. Indeed, the overarching governing framework in Kenya is the Constitution that guarantees its citizens the right to life, human dignity, non-discrimination, and a clean and healthy environment. The social pillar of Kenya Vision 2030 is to provide a high quality of life to all its citizens in a clean and secure environment. The National Climate Change Response Strategy (NCCRS) 2010 also aims to achieve a 'prosperous and climate-resilient Kenya' (GOK, 2010: 3, 12). The National Urban Development Policy recently launched aims at improving the living conditions in informal settlements, urban safety and protection of the rights of marginalized communities in urban areas. This policy shift provides a legal basis and points to political will for informal settlement upgrading and infrastructure improvement.

Kenya is among the global nations that have committed to the Sustainable Development Goals, as well as global commitments on disaster preparedness and climate action. SDG 11 in particular is focused on building inclusive, safe, resilient and sustainable cities, giving particular attention to the residents of slums. Kenya through programmes such as the Kenya Slum Upgrading Programme (KENSUP) and the Kenya Informal Settlements Improvement Programme (KISIP) has since 2001 being upgrading housing and infrastructure in slums in various towns in Kenya.

While there have been major strides in mainstreaming climate change at national level, there is a gap in inclusive policy at city level, to incorporate slums into city-wide planning. For instance, informal settlements are not given the weight they deserve in current plans such as the Nairobi City Integrated Urban Development Master Plan (NUIPLAN). At the Nairobi City County's Planning Department, there is no section specifically dealing with slums. Integration of slums into city-level planning will facilitate local communities to partner with both Nairobi City County and the national government, a component identified by the IPCC (2014) as a key driver of building urban adaptation.

Among the proposals made by this research as discussed in the previous chapter, the creation of a green buffer zone may in itself be problematic because there is the risk of cropping up of new structures even after clearing of the previous ones, fuelled by corruption and greed. In areas that structures have been cleared to pave way for wayleaves of underground structures such as culverts, residents have still gone back and re-constructed houses on such zones. However, where structures have been cleared for construction of actively used infrastructure such as roads, there has been no reconstruction. The solution therefore is to create an extremely active space, held by groups, on which encroachment of structures would be improbable, as the land is not perceived as open and undeveloped.

The field survey conducted found that 87% of respondents do not own the houses in which they live in, and this makes the desire to upgrade structures very low among the owners as they are not residents themselves. The challenge of upgrading therefore would lie in showing the structure owners the benefits of adjusting their structures, without increasing the rent burden on their tenants. While they can be incentivized to make adjustments by educating them on the reduced damage to their structures by flood waters, there is little physical damage to their property from thermal stress. Therefore, this research anticipates difficulty in convincing structure owners to adjust their structures for thermal comfort.

Muungano wa Wanavijiji was interested in making their own interlocking bricks using clay mixtures, convinced that brick would be a cheaper building material and that the business would generate income for members. The group approached the then Planning Department at the City Council of Nairobi with the idea, seeking the authority's approval. Unfortunately, the department refused to allow this project because the building regulations enforced in the city do not recognize clay bricks as allowable construction materials (Building Code, 1968, Part III).

This is evidence that city by-laws (The Local Government Adoptive By-Laws: Building Order 1968) are unresponsive to local situations particularly for low income settlements. Additionally, these laws appear to be enforced selectively because the use of clay bricks was allowed in the upgrading of Mathare 4A as well as construction of various National Youth Service (NYS) projects in the slum. While stone may therefore be the next alternative building material, there exists a genuine fear among residents that such upgrading would result in increased rents settlement-wide. This fear is justifiable as houses constructed of stone attract rents of over Ksh.

4500 monthly compared to a maximum of 2500 shillings for iron sheet structures of the same size, which is economically out of reach of many residents.

IPCC (2014) identifies that capacity building the population to make them 'aware, educated and trained' is an adaptive action with mitigation co-benefits. Sensitization of the local community on climate change, its impacts, vulnerabilities and possible adaption options therefore becomes crucial for the building of a resilient society. The ethnic divide that exists in Mathare Valley, however, threatens the creation of community structures for resilience building. The villages are split among ethnic groups, polarized particularly during electoral cycles. Even the riparian activities differ across ethnic communities living in different villages. This poses a challenge to climate resilience building as the climate risks transcend village boundaries and thus require cross-village interventions. Climate resilience programmes must therefore be tailor-made with this sensitive issue in mind.

Finally, there is a need to ensure that all the ongoing initiatives to upgrade the infrastructure within Mathare Valley are climate-proofed and maintained for their sustainability.

CHAPTER EIGHT: CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

Mathare Valley is experiencing the impacts climate change all year round in the form of thermal discomfort and seasonally in the form of flooding and landslides, and the urban form of the settlement is linked to the magnitude of impacts that the residents of this settlement face. First, the location of this settlement within a hazardous river valley physically exposes Mathare Valley to the risk of flooding. The physical location of a portion of Village 4A beneath a steep cliff also exposes residents to landslides. The dense spatial layout of the slum is responsible for the creation of uncomfortably warm temperatures at ground level. The building materials such as iron sheet are responsible for high levels of vulnerability to climate change, as they contribute to the thermal discomfort residents face all year, and in some instances allow flood waters to flow into structures or destroy them all-together. The housing typologies on the other hand have resulted in a concentration of people, assets and urban functions at ground level, increasing the exposure to flood risk significantly.

While climate change is a global phenomenon, there exist possibilities for adaptation to its effects, albeit at different degrees of intensity per area within the slum. The zone immediately bordering Mathare and Gitathuru Rivers must be devoid of construction to reduce the levels of exposure to flood risk. High risk landslide zones must also be cleared of all forms of construction. Zones with medium risk of flooding from the rivers should have structures reinforced with stone to make them able to withstand the impacts of flooding. The zones with low risk of river flooding, but high risk of storm water flooding require construction of climate-proofed infrastructure, such as culverts, storm water drains, reinforced water pipes and all-weather roads.

8.2 RECOMMENDATIONS

8.2.1 POLICY RECOMMENDATIONS

Policy and regulatory instruments such as codes and standards have been acknowledged in the National Climate Change Action Plan (NCCAP) 2013 as key in addressing climate change at local level. Planning in Kenya relies on various acts such as the Physical Planning Act 1996, and other subsidiary legislation and related guidelines such as the Building Code, the Building and Development Control Rules 1998, and the Physical Planning Handbook. In its Zoning Ordinances, Nairobi City recognizes the informality of Mathare Valley, which for instance falls in Zone 7 that allows minimum plot area of 0.05 Ha, ground coverage of 50, plot ratio of 75, and the development of high-density residential (flats) or informal settlements (slums) (NCC, 2004: 5). Unfortunately, the building standards themselves have not been tailored to reflect local contexts and incorporating climate change concerns through components such as thermally comfortable yet flood resilient building materials. There is therefore a need for regulatory instruments that foster climate resilience in informal settlements to be developed. This can be done by revising the Building Code to incorporate locally available or innovative building technologies.

The danger of reconstruction of structures on a cleared riparian buffer cannot be understated. There is a need for strong will to enforce the plan from both politicians and local administrators as these have been the two parties responsible for the allocation of riparian plots in the past. This research therefore recommends a strong local policy approach that emboldens enforcement of planning rules while building on a culture of transparency and accountability for actions. The Physical Planning Act has strong guidelines on development control, but its enforcement by government is weak. This Act therefore should be implemented, even within informal settlements, to prevent additional uncontrolled development in these areas.

8.2.2 FURTHER RESEARCH RECOMMENDATIONS

There is a need for detailed scientific research on the actual rise in river levels with the current climate as a result of excess precipitation to accurately delineate the areas of high flood risk. This research also recommends that this scientific evidence should also include projections of the river volume changes under different climate scenarios in the future to ensure that maladaptation is avoided. Mapping of the accurate climate risk hotspots and vulnerability areas will also help in targeted solution development.

This research has not exhaustively examined the appropriate building materials and techniques that are applicable in Mathare Valley. In particular, detailed research in the area of thermal comfort within informal settlements such as Mathare Valley will be crucial in shaping slums in the future as temperatures rise. Further researches of affordable building technologies, particularly for *in-situ* upgrading are also proposed. Research into engineering options for building of the flood wall and a climate-proofed path is required to determine the feasibility of this proposal.

Finally, this study proposes that a detailed study of appropriate tree and crop species for the riparian buffer of Zone A be carried out. This will ensure that the plant species selected will be resilient to heavy flooding and bring only positive benefits to Mathare and Gitathuru Rivers.

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ANNEXES

ANNEXES 1: HOUSEHOLD QUESTIONNAIRE

Questionnaire Number: ……………………..

Name of Interviewer: ……………………….. Date: ………………

Location (Village Name): ………………………………

Nearest landmark/ feature/ GPS point……….

Bio-Data of Respondent:

1. Name of Respondent (Optional) …………………………………
2. Gender: …………………………………
3. Age: ……………………………………
4. Household Composition (actual family members that live in house)

TOTAL NUMBER:	……………….
Father (tick)	
Mother (tick)	
Number of children	…………………
	(Under 5) ………..
	Primary-school going age………..
	Secondary-school going age………..
Grandmother	
Grandfather	
Other (specify)	

5. Were you born in Mathare Valley?

Yes			No	

6. If no, where were you previously living before moving to Mathare Valley? (Specify if settlement was urban/ rural, informal/ formal, its name and County) …………………………
7. How many years have you lived in Mathare Valley? …………..……………
8. What was your reason for moving to Mathare Valley from your previous residence? ………………………………………………………………………………………

Economic Profile:

9. What is your main source of income? …………………………………………………….

10. On average, how much is your total monthly household income? …………..……………

11. How much do you estimate your total monthly expenditure to be on:

a) Rent	
b) Food	
c) School fees	
d) Health services	
e) Water	
f) Electricity	
g) Other (specify)	

Housing Profile:

12. Do you own this house in which you live in?

Yes			No	

13. What housing typology does this house fall under?

	(Tick)
Single-floor shanty	
Double-floor shanty	
High-rise apartment	(Indicate number of storeys………..)

14. List the building materials of this house:

a) Wall material	
b) Roof material	
c) Floor material	

15. What is the estimated distance between:

a) Ground level and the raising at the entrance of the house?	
b) Ground level and dip downwards into the house	

16. Indicate the number of rooms in the house ……………………………………………….

17. What is the average number of windows per room? ………………………………………

Infrastructure & Service Utilities Profile:

18. Describe the type of road/ street directly outside the structure ……………………………

	(Tick)
Tarmac	
Earth	

19. What form of waste disposal do you mainly use for:

a) Solid waste	
b) Liquid waste	
c) Human waste	

20. What are your sources of the following services?

a. **Water supply**? (tick)	Water point	
	Water vendor	
	Council water network	
	Other (specify)	
b. Cooking energy (tick)	Charcoal jiko	Old ☐ Improved ☐
	Firewood	
	Kerosene stove	
	Other (specify)	
c. Lighting energy (tick)	Paraffin lamp	
	Electricity	Legal ☐ Illegal ☐
	Solar	
	Other (specify)	

Climate Change and Hazards:

21. Have you noticed any climatic changes since you first moved to Mathare Valley?

Yes		No	

22. Describe these changes……………………………………………………………………….

23. From which year have you felt that these changes have been most severe? ………………

24. What have been the impacts you have experienced as a result of these climatic changes?

	Describe:
a) Flooding	

b) Drought/ Extreme Heat Periods	
c) Extreme Cold Periods	
d) Others (specify)	

25. What impacts have affected the following groups of people the most?

	Describe Impact:
a) Children	
b) Women	
c) The elderly	
d) The disabled	
e) The sick	
f) Youth	
g) Men	

26. What aspects of the physical form of Mathare Valley do you think are most responsible for the climate change impacts that you have described above? ………………………….

27. Have you received any training individually or in a group on climate change, when extreme events may occur, its impacts and what you can do to cope with its challenges?

Organization:	Describe Training Received:

28. Has there been any upgrading to Mathare Valley that in your opinion has reduced/ increased the impacts to climatic changes? ………………………………………………..

29. What have you done in an attempt to adapt to the changing climate and its impacts?

a) Individually	
b) As a Household	
c) Communally	

30. What proposals would you give to reduce the climate change related impacts described above?

a). Flooding	
b). Heat Stress	
c). Cold	
d). Other (specify)	

Thank You!

ANNEX 2: COMMERCIAL ENTREPRISE INTERVIEW SCHEDULE

Questionnaire Number: ……………………..

Name of Interviewer: ……………………… Date: ………………

Type of Business/ Institution………………

Location (Village Name): ………………………………

GPS point…………….

General Respondent Data:

1. Name of Respondent: ………………………………….
2. Gender: ……………………………….
3. Age: ……………………………………….
4. How long have you operated within Mathare Valley? ………………………
5. Describe commercial enterprise housing:

a) Housing typology (high-rise apartment, shanty, row housing, outdoor facility)	
b) Wall material	
c) Roof material	
d) Floor material	
e) Number of rooms/ structures	

Climate Change:

6. Have you noticed any climatic changes since you first started operating in Mathare?

Yes		No	

7. Describe these changes

   ……………………………………………………………………………………..

8. From which year have you felt that these changes have been most severe? ………….
9. What impacts you have experienced as a result of these climatic changes on your business/ institution? …...……………………………………………………………………
10. What aspect within Mathare Valley do you think is most responsible for the impacts mentioned above? ……………………………………………………………………

11. What have you done individually or with others in an attempt to adapt your business/ institution to the changing climate and its impacts? ……………………………………….

12. What proposals would you give to reduce the climate change related impacts described above?

a). Flooding	
b). Heat Stress	
c). Cold	
d). Other (specify)	

Thank You!

ANNEX 3: KEY INFORMANT INTERVIEW SCHEDULE GUIDES

	Key Informant:	Issues:
	Opinion leaders representing the various villages (such as village elders and area chiefs).	• How has the urban form of Mathare Valley changed over time? • What have been the climate change related risks communities have faced over time? • What have been the estimated amounts of loss residents have faced (loss to life, assets, infrastructure, or community/ eco-system functions) due to the identified climate risks, highlighting the most affected asset category? • Which of the identified risks do you attribute/ can be attributed to the existing urban form and have levels increased over time as form changed? • Describe the differentiation of impacts on the different sub-sets within the population (women, youth, and children, elderly).
	Local community-based organisations (CBOs), faith-based organisations (FBOs) and non-governmental organisations (NGOs) operating in the area.	• What are your perceptions on the role of urban form on climate risks facing residents of Mathare Valley and how this has changed over time? • What role has your organisation/ group played in climate change adaptation, particularly in relation to urban form? • What opportunities and challenges have you encountered in playing the role described above?
	Nairobi County Government (The Physical Planning and Environment Departments)	• What building standards and land use/ zoning regulations are in place for the study area? • Are there any special plans for study area, proposed or ongoing? • Is climate change a consideration in plan-making for informal settlements? • Does the County have capacity to implement these plans and enforce regulations?

ANNEX 4: FOCUS GROUP DISCUSSION LIST OF PARTICIPANTS

NAME:	PHONE NO.	LOCATION:
1. Michael Joel	0715980801	Githurai
2. Michael Otieno	0798605245	4A Ruaraka
3. Nancy Njeri Wangari	0724240397	KOSOVO
4 Naftaly Njoroge	0722-354117	Asst. chief office Mathare
5 ELIZABETH NJERI	0721502237	KOSSOVO
6 LIVINGSTONE MBAABU	0710527701	Kosovo
7 JASON Waweru	0725631286	Kosovo
8 ANTONY Waweru	0710170878	Kosovo