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Thesis

How floods shape Kampala's urban gestalt: A case study of spatial injustice between urban form, risk exposure, adaptive capacity and sensitivity.

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One thing is sure. The earth is now more cultivated and developed than ever before. There is more farming with pure force, swamps are drying up, and cities are springing up on unprecedented scale. We've become a burden to our planet. Resources are becoming scarce, and soon nature will no longer be able to satisfy our needs

— Quintus Septimus Florens Tertullianus, 200 A.D.

Summary

Rapid urbanisation steadily increases the importance of sustainability in urban planning while it equally contributes to rising spatial injustice, mostly in sub-Saharan Africa: Access to land, services, employment opportunities and therefore the city itself varies strongly between different income and social groups. These gaps are significant and disadvantage the already most marginalised groups even more, and are increasing, specifically under the growing threat of climate change and its accompanying risks. The understanding thereof as well as realising which factors influence spatial justice is crucial for tackling these inequalities. A case study in Kampala is undertaken to examine these dynamics further. This research intends to increase the understanding of spatial justice in the field of climate change vulnerability to support better-informed policy and spatial intervention strategies with a particular focus on flood-related risks.

Starting from this broader context and in order to answer the central question how floods shape Kampala's urban gestalt and vice versa, a quantitative method is developed to measure the urban form, as well as the distinguished components of social vulnerability; namely risk exposure, adaptive capacity and sensitivity. The collected and analysed data is supported with several expert interviews from Kampala, an online survey and field observations. The objective is an improved understanding of urban dynamics, justice, and accessibility to build a better foundation for informed policy decisions and spatial interventions.

The thesis results in two principal outcomes: (1) A variety of high-resolution visualisation of the current situation of urban form and social vulnerability through 64 individual and aggregated indicators; and (2) correlations between urban form and social vulnerability, as well as its constituents, and carefully selected individual indicator pairs. Furthermore, the characteristics of urban form and social vulnerability are investigated for marginalised groups of the urban society. The applied method proves several initial presumptions from existing literature, as well as current academic theories, and results in the sound confirmation of the impact social vulnerability and urban form can have on each other, and the manifested spatial injustice. However, the findings do not just show today's complex interplay but also bring underlying developments and deeply enrooted injustices to light. Even if the results are context-specific, general conclusions apply to other urban areas and add to a more comprehensive understanding of spatial injustice in sub-Saharan African cities, while the developed and applied methodology bears a magnitude of potentials for further research in more detail and varying environments.

Keywords: *Climate change, Spatial Injustice, Urban Form, Social vulnerability, Flooding exposure.*

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Abbreviations

AC	Adaptive Capacity; Variable of Conceptual Framework
CC	Climate Change
DFID	Department for International Development, UK
EARF	East African Research Fund
EEA	European Environment Agency
GDP	Gross Domestic Product
GHSL	Global Human Settlement Layer
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Corporation for International Cooperation)
IHS	Institute for Housing and Development Studies, Rotterdam
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
KCCA	Kampala Capital City Authority
MoGLSD	Ministry of Gender, Labour and Social Development, Uganda
OSM	Open Street Map
PPI	Poverty Probability Index
RE	Flooding Risk Exposure
RoU	Republic of Uganda
SDG	Sustainable Development Goals
SE	Sensitivity Variable of Conceptual Framework
SSA	Sub-Saharan Africa
UN	United Nations
UN-Habitat	United Nations Human Settlements Programme
Urban ARK	Urban Africa: Risk Knowledge
USAID	United States Agency for International Development
USD	United States Dollar
WHO	World Health Organization

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Chapter 1: Introduction

The global population is growing at unprecedented rates and the patterns of urbanisation change rapidly and is primarily concentrated in cities of sub-Saharan Africa, which, intersected with the challenge of rising levels of climate change-related risks, mainly for the most vulnerable groups of urban societies, stress our human habitats (see amongst others Dodman et al. 2017, UN 2016, UN-Habitat 2014, Fraser et al. 2017a, Brecht et al. 2013, Bartlett 2008. This research attempts to look at a few of the resulting challenges in Kampala, Uganda. In order to introduce this study's focus, this chapter starts with the research objective, questions, and the significance of the researched topic. Finally, the scope and limitations of the anticipated research will be presented to demarcate the thematic and geographical focus.

1.1 Background

> *Our population and our use of the finite resources of planet Earth are growing exponentially, along with our technical ability to change the environment for good or ill. But our genetic code still carries the selfish and aggressive instincts that were of survival advantage in the past. It will be difficult enough to avoid disaster in the next hundred years, let alone the next thousand or million. — Stephen Hawking, 2010*

The global population continues to increase rapidly and is mostly concentrated in the urban areas of the Global South. More specifically, the African continent is experiencing the highest population rise in the present century (Fig. 1-1, p. 1). Adding to the pressure on cities of more residents and spatial expansion, climate change (CC) further stresses our urban systems. Cities became the centre of the current development and sustainability debates: Their importance is widely acknowledged and continuously highlighted by international and national institutions around the world, representing a central aspect in the Sustainable Development Goals (SDGs) of the United Nations. On the one hand, SDG 11 focuses on making "cities and human settlements inclusive, safe, resilient and sustainable" while the city itself functions as the arena for achieving nearly all the other goals (UN 2015, p. 14). This increased importance was further emphasised by the New Urban Agenda, developed at the Habitat III conference in Quito in 2016 (UN), in which the environmental and social sustainability of cities as a centre for human life are highlighted.

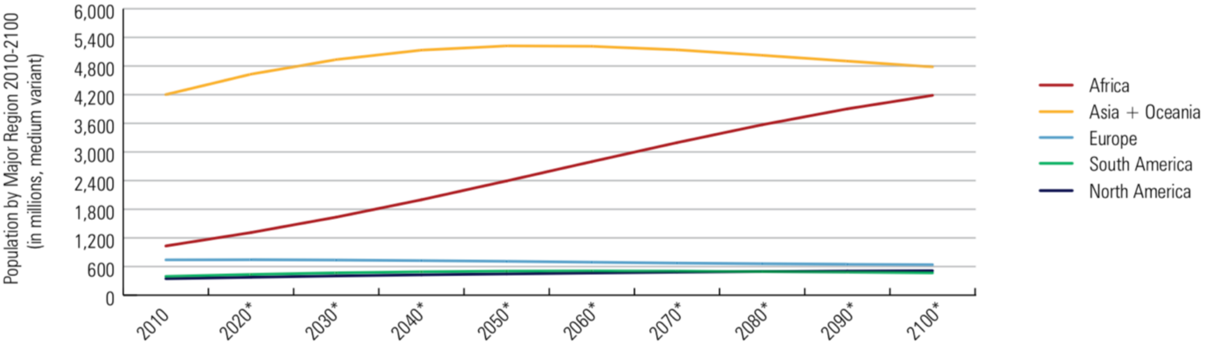

Figure 1-1: Population by region 2010-2100 (UN-Habitat 2014, p. 18)

Therefore, the questions arise what this development will mean for the population within cities and how it can be managed and steered into a sustainable direction. A commonly quoted definition at the start of countless papers, reports, and books is from the World Council for Environmental Development (WCED) report 'Our Common Future' It initiated the idea of sustainability in global debates as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987). Furthermore, the report already highlighted spatial injustice and the necessity in this context to identify the most vulnerable groups and tackle the social and environmental risks which accompany the population surge (WCED 1987). However, more than three decades went by, and even if sustainability is a primary concern nowadays, more people than ever before are living in risk-prone circumstances, and environmental depletion does not slow down either (Adger 2006; Brecht et al. 2013; UN-Habitat 2014; UN 2015 & 2016).

With urban areas as the primary habitat of the world's population, fast urbanization patterns in sub-Saharan Africa (SSA) increase the demographic pressure, while climate change stresses the cities, and its adaptation is challenging because the responsible institutions often lack the resources and capacity to tackle the rising complexity and quantity of issues (Pieterse and Parnell 2010; Myers 2016). Parnell and Pieterse emphasise in their book 'Africa's Urban Revolution' the general growth which occurs in both urban and rural areas but its strong concentration in urban agglomerations. However, this development is not only about the increase of the number of residents but comes along with "severe overcrowding, lack of sanitation, constant threat of bodily harm and abuse" and is "linked to the structural poverty and systemic exclusion experienced by a large proportion of the urban population in most African cities" (Pieterse and Parnell 2010, p. 10). These unequally over age, income and gender groups distributed pressures result in negative externalities on health, productivity and economic behaviour (Pieterse and Parnell 2010, p. 13-15; Bartlett 2008; Fainstein 2010). Furthermore, CC and the global environmental change is leading to more rural-urban or trans-national migration of climate refugees, unequal distribution of land, hazard risks for settlements in the shape of floods, landslides, droughts or heat waves, to just name a few, and highlights the "dynamic processes and the interplay" of these elements to improve the livelihood of millions of people (Parnell and Walawage, pp. 35, 53).

However, the inequality does not only exist amongst different social groups inside the cities but also on the global scale: Climate change itself is a global challenge, mainly induced by the industrialised countries while the most impoverished countries contributed the least but suffer the most from its consequences (Althor et al. 2016, Fig. 1-2, p. 2). The suffering is further intensified due to a widespread lack of adaptive capacity, referring to the "potential, capability, or ability of a system to adapt to climate change stimuli or their effects or impacts" (IPCC 2001, p. 881).

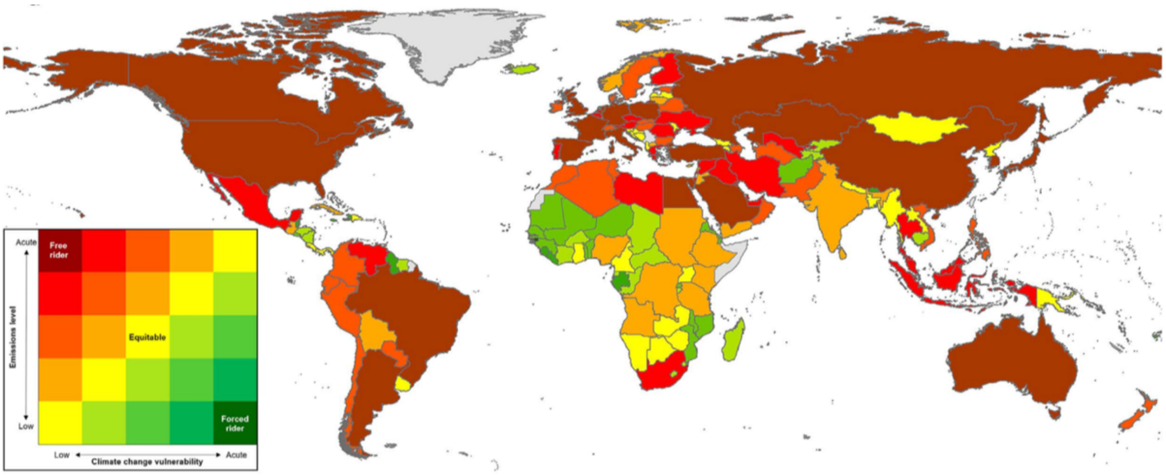

Figure 1-2: Global inequity of the responsibility for climate change and the burden of its impacts (Althor et al. 2016, p. 2) Dark red: Highest level of emissions and lowest climate change vulnerability; dark green: Lowest level of emissions and highest climate change vulnerabilty.

Parnell and Walawage further stress the importance in these complex circumstances of creating the capacity to ensure urban resilience and that each's livelihood in the city is not negatively affected by the broader global demographic and environmental processes (2010, p. 53). Another important aspect is the interplay between the social and ecological systems and its cultural understanding which varies fundamentally between the Western and most societies in sub-Saharan Africa (SSA). While the dominant Western notion sees them as separated entities, in most sub-Saharan African cultures nature and society are interwoven. This leads on the one hand to the destruction of locally much higher valued ecosystems in SSA through the consequences of the development in industrialised nations while on the other side differing perceptions result in complications in cooperation, the transfer of 'knowledge' and coping mechanisms (Myers 2016, p. 7).

All these issues emphasise the plethora of challenges which cities in SSA are facing. Its tackling will be one of the critical tasks for policy makers and planners of the coming decades. Starting with the predominant injustice and its spatiality in urban agglomeration, this research tries to contribute to the understanding thereof by looking at the interrelation between urban form and social vulnerability with a focus on risk exposure and adaptive capacity. UN-Habitat called the development in SSA cities an "urbanisation of poverty", which led to plenty unplanned and underserviced settlements with a fundamental and increasing material and opportunity-wise injustice between them and the affluent neighbourhoods (2014, pp. 31-33). The understanding of these different settlement patterns and their integration in the urban fabric will be therefore the core of the analysis of urban form, while the varying level of risk exposure, different types of risks and the interdependence of social variables and adaptive capacity will cater as comparative values.

Urban form, defined by Williams as "the physical characteristics that make up built-up areas, including the shape, size, density and configuration of settlements" (2014, p. 6) is moving towards the centre of interest in the sustainability debate, while its importance on the social and ecological risk exposure is further emphasised (amongst others, Jabareen 2006; Hillier 2009; Louf and Barthelemy 2014; Fragkias et al. 2013; Oliveira et al. 2014; Pelling and Wisner 2009). Myers adds to the definition of urban form, or in his words *cityshape*, in the context of SSA that it is once the physical environment but also the "socially and culturally produced environment" (2016, p. 19), highlighting the possibility of non-spatial characteristics. Jane Jacobs already described the strong interrelation between the built environment and social dynamics of cities in her famous book 'The death and life of great American cities' (1961), where she states that cities should be a place for people, even if that is often not the case (anymore). Building upon Jacobs' perspective, Gehl (2010) further embraces the interconnection of urban form and social life, sustainability and health through variables of density, compactness, and diversity while also highlighting its relation to risk (e.g., traffic accidents, robbery). Additionally, he argues that high-quality urban space can fuel interaction and social inclusion, and therefore a higher sense of community which again can lead to better cooperation and assistance in case of disaster regardless their type or scale. At the same time, he states the importance of shared urban space since overpopulation and rising poverty pressure the livelihood of people (Gehl 2010, p. 215). Jacobs continues to describe the impact of better interconnections on adaptive capacity, further supporting the interrelation between the spatial and social dynamics of cities.

The issue of justice in cities, in which context this research is situated, was famously put into focus by Susan Fainstein in her book 'Just cities'. Therein, she gives a broad overview of different notions of justice, how it can be conceptualised and quantified and also states that injustice rises and the poor, mostly women and children, represent the most vulnerable groups (2010). This link between poverty and vulnerability in the field of environmental risks was further studied by UN-Habitat, who name the lacking decision-making power and resources, mostly in time of disasters, as the primary reasons. Moreover, they also emphasise the unproportionate distribution of risk exposure for different age and gender groups (2014, p. 33; Bartlett 2008).

But what do risk (exposure) or vulnerability mean and what do they encompass in the urban context? Brooks (2003) divides in general in social and biophysical vulnerability. Social vulnerability includes everything related to the human and will be the focus of this research, while biophysical vulnerability focuses on the ecosystem and biophysical environment. Risk, on the other hand, is typically composed by different types of hazards but has numerous definitions which will be further examined in the next chapter (Mitchell et al. 2015; Pelling and Wisner 2009; Gu et al. 2015; Dickson et al. 2012). The last central aspect is adaptive capacity as a crucial variable about the "potential, capability, or ability of a system to adapt to climate stimuli or their effects or impacts (IPCC 2001, p. 881).

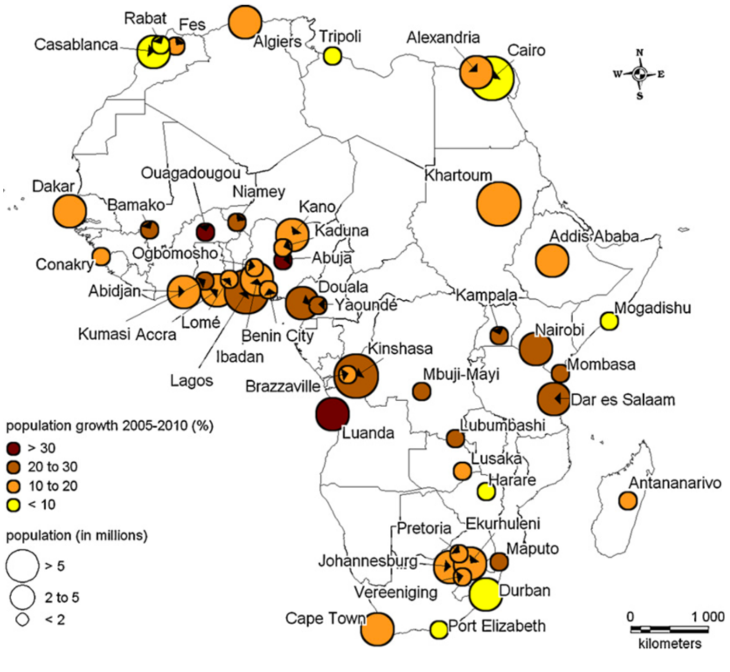

Figure 1-3: Urban population growth 2005-2010 (Karolien et al. 2012, p. 200)

These three elements – urban form, climate change related risk exposure, and adaptive capacity – and the understanding of their interplay in the context of socio-spatial justice as shaping elements of urbanisation and livelihoods will be analysed in the case study of the urban agglomeration of Kampala, the capital of Uganda. The example of Kampala provides a compelling case due to its fast urbanisation and current as well as predicted spatial expansion but early development stage in comparison to other Eastern African cities (Fig. 1-3, Karolien et al. 2012; UN-Habitat 2014, p. 5). At the same time, it experiences severe CC-related consequences, and has high levels of informality, low levels of land tenure security, building regulations and basic service provision and faces institutional challenges which further complicate the situation (Karolien et al. 2012; Nyakaana et al. 2008; Insunju 2016; Richmond et al. 2018; UN-Habitat 2014). Therefore, it caters on the one hand as an interesting case study to analyse itself while its comparability to many other cities in SSA provides the opportunity to transfer and apply the same approach in other geographical contexts.

1.2 Problem Statement

Rapid urbanisation and CC lead to increased risk exposure to environmental disasters while the higher density of urban settlers in cities increase the number of vulnerable people affected. This is already a problem by now but will become even more significant in the coming decades (Mitchell et al. 2015; Pelling and Wisner 2009; Gu et al. 2015; Dickson et al. 2012, UN-Habitat 2014). Due to the importance of urban areas for the national economies, the consequences of disasters in small spatial scales of cities can have an impact on the whole country or region. At the same time, long-term consequences like the destruction of infrastructure and agricultural land and accompanying pollution and the spread of diseases can have a much higher impact on the society as a whole (UN-Habitat 2014, p. 33).

Access to land, services, employment opportunities and therefore also the city itself varies often strongly between different income groups and social groups. Mostly in countries in SSA, these gaps are significant and disadvantage the most vulnerable groups even more, specifically under the threat of climate change and its consequences. The understanding thereof as well as realising which factors positively or negatively influence social vulnerability is crucial in tackling this injustice. While a collective agreement on unjust distribution of climate change-related risk exposure exists, together with accompanying differences of the built environment and socio-economic characteristics of the most affected population, it is difficult to quantify them in smaller spatial resolution, measure the impact of various factors and, therefore, result in more solution-oriented approaches. These challenges are not sufficiently researched yet, more particularly in urban Uganda, and become still more pressing through fast urbanising rates and rapid urban transformations.

Even if risk management or reduction and vulnerability assessment are already common tools in many organisations and governmental institutions (Dodman 2017), there is still a vast potential to improve its understanding. Mostly the interrelation between urban form and social vulnerability is not fully understood yet and can contribute to better policy recommendations and plans to improve the livelihood of urban citizens in the future. The interrelation of urban form, risk exposure, adaptive capacity and sensitivity of the residents and their built environment is, therefore, crucial for tackling the challenges of spatial injustice (Cadag and Gaillard 2011).

1.3 Research Objectives

The central objective of this research[1] is to understand and explain the interplay between the socio-spatial urban dynamics in the context of flooding exposure, adaptive capacity, and sensitivity in the case of Kampala, as well as providing a new perspective on how spatial injustice is enforced or counteracted by spatial measures and manifests itself in cities of sub-Saharan Africa.

While the relations between spatial injustices in the built environment and climate change-induced social vulnerability appear in various papers and reports, there is a lack of its scientific and spatially located quantification and of comprehensive analyses which prove the often-claimed interrelations of the constituting elements. Therefore, this research aims at improving

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[1] This research is part of the DFID (Department for International Development, UK Government) East African Research Fund (EARF) project on *Spatial Inequalities in Times of Urban Transition* which is conducted by the Institute for Housing and Urban Development Studies (IHS), the Bartlett Development Planning Unit (DPU) and IPE Triple Line.

the broader understanding of spatial injustice by looking at and measuring spatial characteristics as well as the levels of risk exposure, adaptive capacity, and sensitivity distributions in urban areas of Kampala, Uganda. The underlying motivation is to highlight and quantify the current situation of risk exposure and differences of spatial and socio-economic characteristics, as well as proving or refuting current beliefs and prepare for better addressed and located measures which counteract spatial injustice. Furthermore, unknown relationships between the natural environment, built environment, and society shall be discovered and extend the understanding of the complex dynamics of cities in sub-Saharan Africa. To achieve that, the objectives are (1) to measure the threat of climate change and more specifically of flooding on urban residents; (2) to better understand the spatial distribution of risk exposure, adaptive capacity, and sensitivity as the elements of social vulnerability; (3) quantify advantages and disadvantages for urban populations in different locations and it's assumed spatial inequality for the already most vulnerable groups; and lastly (4) to contribute to the understanding of urban form and social vulnerability as contributors for the manifestation of spatial injustice in the general urban complex.

Furthermore, the more methodical goal of the research is the application and testing of existing approaches, their combination, as well as the development of new indicators and methods. Aforementioned will be done in the urban context of Uganda to retrieve various spatial indicators from geographic data and relate them to the existing secondary data (e.g., vulnerability profile, socio-economic profiles), as well as the results of the household study, which was conducted in June and July 2018. Furthermore, during the research trip, more primary data is collected, mainly by expert interviews, a weighting survey and site observations, in order to fulfil this research objective.

1.4 Research Questions

In order to fulfil the research objectives as mentioned above, the following research questions were formulated. The central research question is:

"How are **urban form** and **flood-related social vulnerability** interrelated in urban settlements of Kampala?"

For further clarification of the different elements, four supporting research questions resulted:

1. How can **exposure to flooding risks** be quantified in small spatial resolutions in contexts of limited data availability?
2. Which characteristics of Kampala's **urban form** can be quantified and how do they influence or are affected by **social vulnerability** and its components, **risk exposure**, **adaptive capacity** and **sensitivity**?
3. What **interrelations** exist between the constituents of **social vulnerability**?
4. How is **spatial injustice** in Kampala manifested through the spatial distribution of urban form and social vulnerability?

1.5 Hypothesis

The hypothesis on which the research is based can be found in various literature and states that the residents of the most flood-prone and climate change risk affected areas are already the most marginalised and therefore suffer even more and reinforce spatial inequalities in urban agglomerations. Additionally, a two-directional correlation is anticipated, which leads to the spatial characteristics (urban form) and built quality being negatively affected by the present risks while at the same time also increasing the vulnerability of those areas. A better understanding of interrelations and quantification thereof would better show the spatial injustice and disadvantages of the marginalised urban population, and provable interrelations can help policy-makers to tackle the challenges in a more effective manner.

1.6 Significance of the Study

Many cities around the world, but mostly in SSA, face similar issues like Kampala, with more and more people experiencing higher risks. Therefore, the research of risk-related aspects and its thorough understanding became a significant element of urban academia. Various aspects have been already studied in different contexts and provide a solid foundation for this study. However, the understanding of the interrelations between risk and socio-spatial justice and in particular urban forms influence is still limited and leaves some questions unanswered.

By analysing urban form, risk exposure, adaptive capacity, and sensitivity, the research aims at partly bridging this gap by improving the academic knowledge of risk management and urban form in the particular context SSA. Simultaneously, this thesis shall provide valuable insights in some of the socio-spatial dynamics of Kampala which were not studied in depth before and support the development of improved urban management strategies to cope with CC and urbanisation induced impacts. Quantifiable interrelations can help the policy-making process to tackle these challenges more precisely and therefore also reduce prevalent inequalities. Lastly, gained insights may be valuable for urban agglomerations in similar geographical contexts and could allow another layer of classifying and comparing urban settlements in SSA.

1.7 Scope and Limitations

The geographical scope of the study will be the administrative city area of Kampala. While an analysis of the Greater Kampala Metropolitan Area (GKMA, newly introduced planning scale) could provide a more comprehensive picture by including dependent urban settlements, the data available outside of the city boundary does not allow a substantial analysis. This should however not make the research less valid, as many of the densest and most flood-prone areas are located inside the jurisdictional border. The thematic scope of research will include flood-related risks as the primary CC risks for the urban residents of Kampala. While some analyses will be done on the city level with the purpose of, e.g., distinguishing the infrastructure characteristics or city-wide accessibility, more in-depth analyses are conducted in two research-corridors which were selected by the EARF research team through a purposive sampling according to their representative characteristics as the location for the EARF household study.

However, the research will be limited by the time of the research trip and the accompanying restrictions of the amount of collectable data. Furthermore, the availability of reliable data with a high level of detail will affect the study. Even if socio-economic data with a broad coverage exists and the data collection intervals are better than in many other cities in SSA, it is not possible to reach accurate comparability of data from the same period, even if that would be essential for a high-precision study of Kampala's fast-changing urban *gestalt*. In order to reduce the impact of these limitations, the research will attempt to overcome these through a careful selection of data and measurement approaches while highlighting any possible temporal or scale-wise mismatches.

Chapter 2: Literature Review

For a general focus of the research and the investigated interactions, urban form and social vulnerability lay out the foundation and will be looked at first. Therefore, the meaning of urban form on city and settlement level will be described, and various ways of measurement examined. Furthermore, the concept of social vulnerability follows which has nearly as many notions as papers written about them. To counteract this diversity which makes the operationalisation of the concept challenging, an adapted conceptualisation thereof is developed, based on a variety of literature. Lastly and building upon this conception, the primary constituting parts of social vulnerability are described, and their possible measurement presented – risk exposure to the urban society, drivers of adaptive capacity, and determining elements of sensitivity.

2.1 Urban Form

Urban form can mainly be described as the built embodiment of the urban society, generally divided in macro, meso- and microscale (city, settlement/neighbourhood, building) and is constituted of different layers, including the street networks, build environment, and land use/division (Pont and Haupt 2009; Oliveira 2016; Hillier 2009). In order to measure the urban form, this chapter looks at two different levels of urban form. Firstly, the city level (macro scale) which includes the demarcation of the urban agglomeration and is necessary to understand larger interrelations, e.g., the accessibility to the economic centres or differences between core and peripheral areas. The second level is the settlement area (including both meso- and microscale), which looks more at the built environment and includes, amongst others, built density, space allocations, proximities, or the density of street intersection. The measurable characteristics of the latter are divided into the three layers. While there are various claims about the interrelations of urban form and sustainability in general, which for example state that smaller or denser, more interconnected cities might be more sustainable (see for example Adolphe 2001, Oliveira 2014, Jabareen 2006, Fragkias et al. 2003; Dave 2010; Louf 2014), this hypothesis would be also interesting to analyse in Kampala. However, it would require partly non-available data and, due to the overall performance of cities as systems (i.e. emission, GDP), can only result in compelling outcomes if compared to other cities.

2.1.1 City Level

As described above, the macro scale is appealing and valuable for understanding the spatial characteristics of urban areas in a more holistic manner. The first is to distinguish what the city means in the first place. While various definitions exist, which try to compensate for the fact that jurisdictional boundaries are often arbitrary and do not represent functional relations (Fig. 2-1, p. 9), a more general definition of an urban area as a continuously built-up area is used most frequently (Lamson-Hall et al. 2016). The second element is the general demarcation and classification of settlements according to their spatial and functional characteristics. This usually depends on the size of plots and houses, the type and density of roads, as well as the predominant land use.

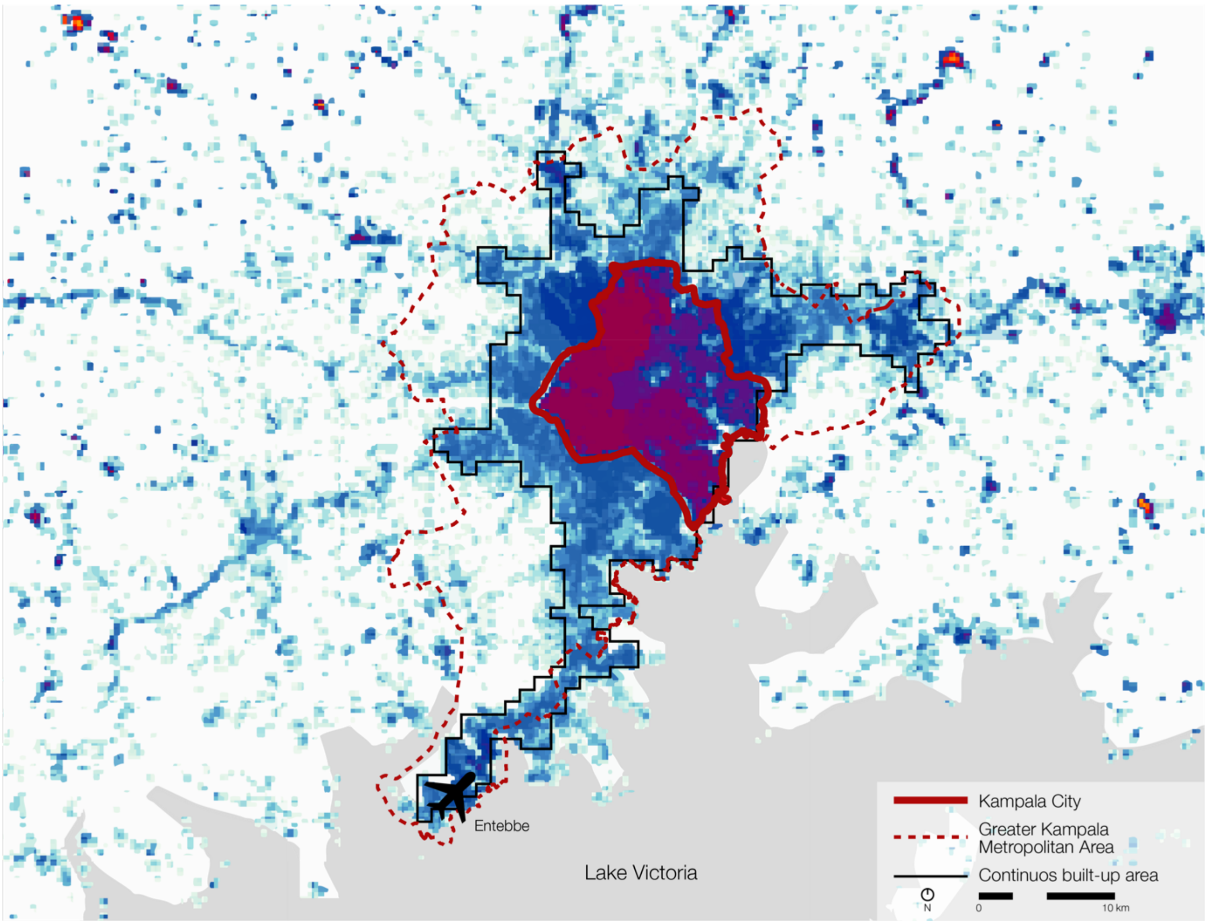

Figure 2-1: Kampala's population density & boundaries (Author 2018, Source: GHSL data and KCCA 2016)

Furthermore, accessibility to various points describes the urban form on the city scale. Different elements can, therefore, be used: 1) Basic service facilities like hospitals, schools, public transport nodes; 2) Cultural or leisure facilities like parks, sports centres, museums or theatres; 3) Central locations like economic centres or cultural hotspots. While the first two can be easily located, the latter needs a more advanced model as there is no distinct definition for, e.g., an economic centre. Linard et al. 2013 developed a method to model spatial (growth) patterns in African cities while also comparing different tools to define central locations in the city, e.g., based on the density of infrastructure or where the Bus Rapid Transit nodes are. Another approach is to look at where how many companies are located and how many jobs they provide and what revenue they make – information often accessible through national business registers (Goswami and Lall 2016).

Additionally, there are different ways to distinguish centres on the one hand but also quantify the integration of various parts of the urban fabric. UN-Habitat developed the Prosperity Index (2016) which amongst others includes several indicators like the number of street nodes or length of streets per square kilometre and indicate how well-connected areas are while building upon the assumption that the more central and accessible places have the highest infrastructure density. Another commonly applied approach is the tool Space Syntax, which measures the integration, choice and depth of road segments and is based on the theory that people's movement strongly depends on the road layouts (Pereira 2012). The integration tests the relative distance from each segment to every other, while the choice measures how likely it is that a street segment is passed when users travel from each to every street segment of the whole analysed area. Lastly, the depth measures the number of turns which need to be taken from each street segment to reach the centres of all other street segments. There exist however several critiques. For example, that not all streets can be seen as equally essential or attractive and that a certain level of the hierarchy should be included in the calculation (street weighting). Furthermore, there are several main entrance points to cities which mostly interfere with the infrastructure use and require 'boundary weighting'. Moreover, one-way streets need to be considered in case vehicle traffic is measured to avoid assumed routes which are not possible (Patterson 2016). Another critique mostly applied to regularly gridded urban fabrics which sometimes result in the same depth for the connection between two points which are both just one turn away but differ strongly in length (Ratti 2004). Therefore, the results of a Space Syntax analysis always need to be checked and verified and provide better outcomes if combined with the Euclidean distance as a weighting variable.

Lastly, the amount of green space can also give insights into the overall spatial structure. While more green space is often associated with better life quality, higher-income areas or better percolation characteristics, the effect of green space on vulnerability in the context of African cities seems to be not sufficiently researched to base assumptions on it, as for example areas which are close to rivers are mostly greener because of the natural irrigation but at the same time most vulnerable to flooding. Therefore, the percentage of green space shall be measured as part of this research, however, without any presumption about its actual impact or correlation.

2.1.2 Settlement Level

On the settlement level, the elements of urban form are primarily analysed under an independent and local perspective, and only the interrelation to the direct surrounding is taken into consideration. The most common elements are the urban tissue, the natural context, streets, plots, and buildings (Oliveira 2016). Furthermore, the spatial elements can be broken down into three layers (Fig. 2-2, p. 10) which will be briefly discussed below.

Figure 2-2: Layers of Urban Form, example for a part of Kampala, from left to right: street network, built environment, and land use (Author 2018, Source: OSM)

2.1.2.1 Street Network

The first layer is the street network and includes the size and type of streets, as well as space which is allocated to the infrastructure (e.g., sidewalks, squares) in general (Hillier 2009). Additionally, the length of the different types of streets, as well as the nodes, can be measured per square kilometre (UN-Habitat 2016).

2.1.2.2 Built Environment

The built environment can be quantified by various elements, with the density through the floor area ratio (FAR) as the most common, together with the site occupancy index (the percentage of ground covered by all buildings). Furthermore, the average plot size and building size indicate the spatial characteristics (Pont and Haupt 2009; Pont 2011). Lastly, the building proximity provides a better understanding of the spatial interrelation of the buildings on a mesoscale and measure the average distance to a specified number of closest buildings or how many individual buildings are in reachable in a certain distance and specify the interconnections and therefore add another layer to the density.

2.1.2.3 Land Use

Thirdly, the land use provides additional insights into the composition of the functions and services in an area. A high level of mixed-use is for example often associated with more sustainable urban layouts as fewer distances need to be travelled to reach places of natural interest; which can be, amongst others, supermarkets, employment opportunities, educational and health facilities (Gehl 2010). Furthermore, the percentage of public space or green space is argued to be an indication of the livelihood and (mainly social) sustainability as well (Gehl 2010). However, as the concept of public space is mainly studied in the context of the Western world and has another conceptualisation in most urban cultures of sub-Saharan Africa, these presumptions need to be handled with caution (similarly as with the green space mentioned in chapter 2.1.1). Furthermore, there are strong interlinkages between social characteristics and the land use, often rooted in the racial segregation during colonial times which often still lives on and the distinction (or discrimination) between land tenure-wise formal and informal settlements (see Munger 1951, Omolo-Okalebo 2011; Muinde 2013; Betraud 2015).

2.2 Social Vulnerability

> *Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.*
> *(IPCC 2007, p. 21)*

The second central concept is social vulnerability. As there are countless definitions of vulnerability and its constituting parts, mainly depending on the time, context and background of the academia, it is crucial to define the various parts and conceptualise them in a coherent and commonly agreed upon manner. To start with, vulnerability in a broader context is conceptualised as either "the amount of (potential) damage caused to a system by a particular climate-related event or hazard" or as the "state that exists within a system before it encounters a hazard event" (Jones and Boer 2003 and Allen 2003 in Brooks 2003). By now, the most accepted definitions follow the latter. Furthermore, a distinction between different types of vulnerability can be made, even if there is no consensus of the actual separations or terminology. The most common types which can be found in the context of urban climate change vulnerability are social (also referred to as human) and biophysical (or natural) vulnerability. However, various studies also examine, for example, the economic or institutional vulnerability (Brooks 2003). Vulnerability, in general, is defined by Adger (2006), building upon the above definition of the Intergovernmental Panel on Climate Change (IPCC) as the "state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence to adapt". In the case of social vulnerability, the system which is vulnerable encompasses all socially connected elements, while biophysical vulnerability can be defined as the vulnerability of the natural environment to climate change-related stressors. In order to describe the different elements of social vulnerability, which is the focus of this study, a quick glance on some of the most common consequences and impacts of climate change in general and more specific on urban systems is helpful (Fig. 2-3, p. 12).

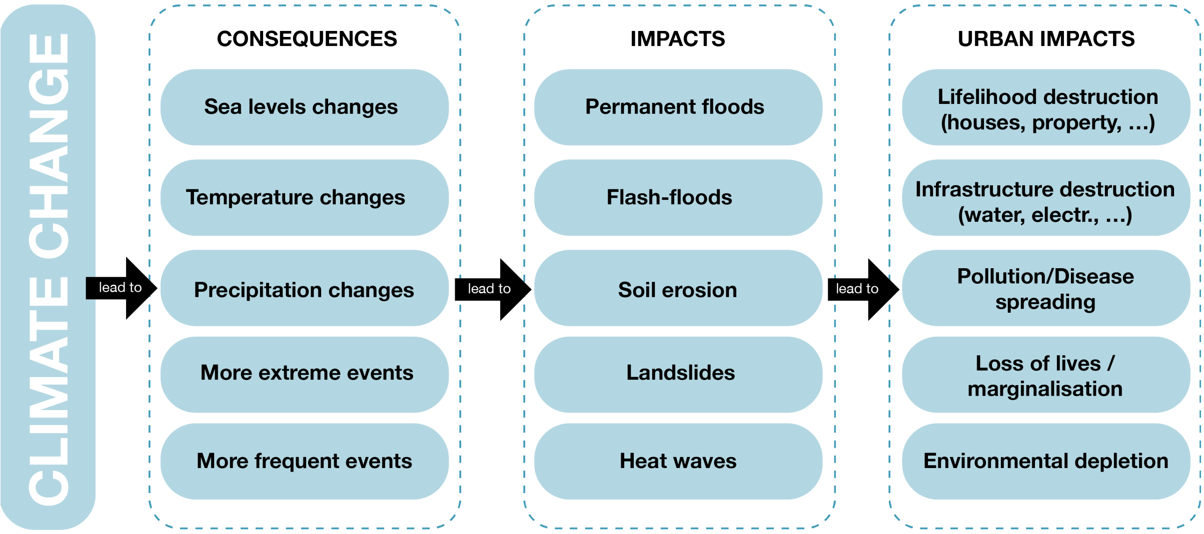

Figure 2-3: Climate Change impacts on urban systems (Author based on various CC risk literature 2018)

Climate change leads to numerous consequences, ranging from the slow change of the ecological system to the increase of frequency and severity of natural events. These lead to various general impacts, like increasing flooding, more frequent flood events or related hazards like soil erosion and landslides. Lastly, these impacts result in more tangible impacts for the cities, more in general for example increased urbanisation or specific events like the marginalisation of parts of the urban society (see amongst others IPCC 2001; Brooks 2003; Adger 2006; Lwasa 2010).

Furthermore, a variety of terminology is used to describe the elements of social vulnerability. These are amongst others risks, risk exposure, hazards, events, disaster, adaptive capacity and sensitivity. While some of them are often used interchangeably, it is crucial to distinguish between them to distinguish the nuances and conceptualise or measure them accordingly.

- **Hazard:** While there are also different types of hazards, the focus here is on natural hazards, which can be defined as "physical manifestations of climatic variability or change" (Brooks 2003, p. 3). The primary natural hazards are cyclones, floods, earthquakes and landslides (Adger 2006; Brecht 2013).
- **(Hazard) event:** A hazard describes the initial stressor / physical manifestation of climate change, while an event is the more precise occurrence of a hazard which takes the exposure of the system into account (Adger 2006; Brecht 2013).
- **Disaster:** A disaster takes the probability into account and further incorporates the consequences of events of natural hazards (Adger 2007; GIZ 2014).
- **Risk:** The combined outcome of exposure, the sensitivity of a system and its adaptive capacity. As higher the vulnerability in general or risk exposure and sensitivity, as higher the risk. As stronger the adaptive capacity, as lower the risk (Adger 2007; Cardona et al. 2012; Dickson et al. 2012; Brecht 2013; GIZ 2014; Pelling 2016).
- **Risk exposure:** "Character, magnitude, and rate of change and variation in the climate. Typical exposure factors include temperature, precipitation, evapotranspiration and

climatic water balance, as well as extreme events such as heavy rain and meteorological drought" (GIZ 2014, p. 21).

- **Adaptive capacity:** No generally applicable definition exists, as adaptive capacity depends heavily on the type of hazard, environment, and system which is looked at. However, often constituting or influencing elements are generally resources, knowledge, and institutions characteristics (Adger 2006; Adger 2007; GIZ 2014).
- **Sensitivity:** "Degree to which a system is adversely or beneficially affected by a given climate change exposure […and] shaped by natural and/or physical attributes of the system including topography, the capacity of different soil types to resist erosion, land cover type. But it also refers to human activities which affect the physical constitution of a system" (GIZ 2014, p. 21).

Based on the definitions, three central constituting components can be distinguished, which are integrating all above terms and partly stand-alone concepts while also (potentially) influencing each other. These are: 1) **Risk exposure**, which describes the physical exposure to specific hazards; 2) **Adaptive capacity** as the ability to anticipate, respond, recover and change; and 3) **Sensitivity** as the level of the severity of an impact. In combining them, a risk arises which is attenuated or reinforced by the three respective components and leads to an increased social vulnerability.

Lastly, there are three different broader types of assessing vulnerability: Once deductive analyses can be conducted, which base the assumptions on events of the past. Secondly, an inductive method can be applied which is focussing on predictions and modelling future events and probabilities. Thirdly, a combined approach joins and weighs the variables of both methods (Brecht et al. 2013).

2.2.1 Risk Exposure

The first component which affects social vulnerability is the risk exposure, which as defined above, is the physical exposure to hazards. The exposure is hazard-specific, meaning that it needs to be analysed individually for different types of hazards, and mainly depends on the type and dimension, scale and occurrence of hazards (Dickson et al. 2012; Brecht et al. 2013; Pelling 2016). Adding to the origin of hazard, they can be divided into three broader categories of hazards according to their occurrence. These are once discrete recurrent hazards (e.g., yearly floods), continuous hazards (e.g., higher temperatures or rising sea levels) and discrete singular hazards (e.g., extreme, non-recurring extreme heat waves (Brecht et al. 2013, p. 9). While these risks can occur independently, they can also weaken or strengthen each other. In the case of the latter, a risk accumulation takes place which increases the overall risk exposure (Fraser et al. 2017b; Songsore 2017). Furthermore, the direct exposure to risks and its accompanying risk factors depend on the characteristics of the affected system. For example, often specific, marginalised groups are higher exposed to risks than other (e.g., heatwaves are more threatening for the elderly) which is why the affected system needs to be considered (Sheidow et al. 2001). The different severities of risk exposure always depend on the specific location and are globally concentrated in locations of either extreme climate conditions, high population densities or often in coastal regions. Gu et al. (2014) conducted a global comparative study which does not draw a comprehensive picture as only the risk exposures of registered events (deductive analysis) could be considered, but shows the overall geographical concentration (Fig. 2-4, p. 14).

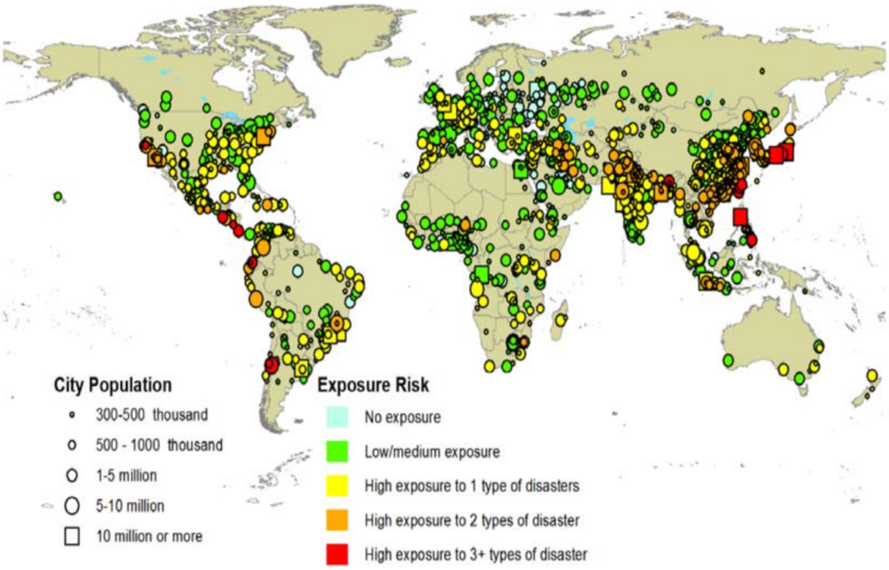

Figure 2-4: Distribution of cities by population and risk of exposure to natural disasters (Gu et al. 2014)

While there has been an increasing effort to understand and assess risk exposures globally, there is still a significant lack of data and assessments, mainly on the African continent where a strong focus of disasters is predicted to occur in the coming decades (Fraser et al. 2017a). Mainly water-related issues in Africa require more attention, as they constitute to a complex system of droughts, floods, water scarcity and accessibility and lead to overall "unjust waters" and are already nowadays one of the most fundamental resources for human existence and will be much more in the future (Douglas et al. 2018). While there is no generally applicable approach to cope with or reduce the risk exposure, Hardoy (2011) highlights seven actions which proved to be successful: 1) Risk mapping; 2) Micro-zoning[2]; 3) Updating building codes; 4) Land-use regulations; 5) Retrofitting; 6) Innovative insurance mechanisms for low-income groups; and 7) Engagement of affected groups.

2.2.2 Adaptive Capacity

The second component is adaptive capacity, which generally is defined as the "ability of a system or individual to adapt to climate change" (Cardona et al. 2012, p. 67) and can be divided in the capacity to anticipate risk, to respond, to recover and change and therefore is often compared or even equated with resilience (Cardone et al. 2012). While there are various definitions of adaptive capacity and its application is highly context-specific, a central starting point is a distinction between the subject which is studied. It can be looked at whole countries, regions or cities, neighbourhoods, individual households or spatially disconnected societal sub-groups. As a constituent of social vulnerability, adaptive capacity looks at the studied system's ability unattached to the risk exposure or sensitivity and therefore functions as an independent concept. To distinguish the most important groups of adaptive capacity, Hardoy and Pandiella (2009) propose six questions to ask for assessing adaptive capacity:

1. "Who lives or works in the locations most exposed to hazards related to the direct or indirect impacts of climate change?
2. Who lives or works in locations lacking the infrastructure that reduces risk?

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[2] Similar zones are grouped and mapped based on accurate information and determine most appropriate measures.

3. Who lacks knowledge, capacity and opportunities to take immediate short-term measures to limit impacts?
4. Whose homes and neighbourhoods face greatest risks when impacts occur?
5. Who is least able to cope with impacts?
6. Who is least able to adapt to avoid impacts?" (p. 207-213).

While the first and fourth questions include the dimension of risk exposure, they do not address the severity of CC change but instead, aim to identify particular groups and their respective resources and capacities. Generally, adaptive capacity is unevenly distributed across and within societies and affected by generic and specific factors. The generic factors include for example the education, income, and health, while the specific constituents are made up of the institutions, available and access to knowledge and technology (Adger et al. 2007). Furthermore, in many cases "social capital, social networks, values, perceptions, customs, traditions and levels of cognition affect the capability of communities" (p. 728) which differ mainly depending on the studied context and its location determines the distribution of adaptive capacity (p. 729) with some groups, e.g., women and children, being proportionally less capable of adapting due to disadvantages positions in the societies (p. 730; Bartlett 2008). Therefore, it does not make much sense to look at the adaptive capacity of a whole city, but the different communities and even households need to be analysed separately (Jones et al. 2010b; Jones 2011; Elrick-Barr et al. 2014). While adaptive capacity largely differs between locations and social groups and is difficult to assess, it has at the same time a significant potential to decrease the effect climate change has on communities and should be given a prominent role (Jones et al. 2010a; Lwasa and Kadilo 2010).

Despite its individualistic character, promising, slightly simplified approaches for its assessment have been developed. For example, Thathsarani and Gunaratne (2018) applied a method in Sri Lanka, which does not provide a comprehensive perspective but still a good starting point. They mainly suggest four sub-indexes which are made up of several indicators:

- Economic = Income + Employment + Expenditure
- Social = Education + Leadership + Culture
- Human = Demography + Dependence
- Physical = House + Land + Communication + Energy + Transport (p. 280)

However, parts of the indicators of the social and physical dimension overlap with the concept of sensitivity, which is the reason why they are often left out if sensitivity is included separately. Lastly, as mentioned before, adaptive capacity can have a significant impact on the reduction of vulnerability and interrelate strongly with exposure and sensitivity (Fig. 2-5, p. 16; Engle 2011). A stronger adaptive capacity (e.g., economic: higher income; physical: land) can reduce the exposure to hazards; e.g., in the case of flooding, better drainage systems, retention basins, rainwater storage or more permeable grounds can reduce the exposure or limit it to smaller areas, which can be induced or realised by the affected population based on their knowledge, support networks, and income, amongst others. At the same time, adaptive capacity can also affect the sensitivity of a system. For example, better housing or road quality decreases the physical sensitivity in case of a flood in comparison to temporal, low-quality buildings. Another example would be, that better leadership can lead to better early-warning mechanisms, saving the communal property from hazard impacts or through more aligned water management systems.

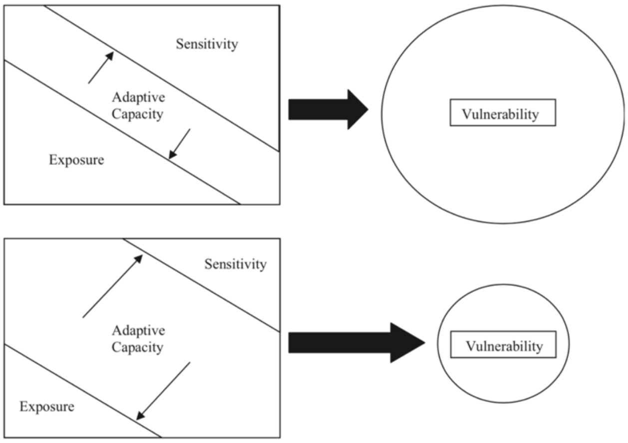

Figure 2-5: Adaptive capacity impact on vulnerability (Engle 2011, p. 650)

2.2.3 Sensitivity

As the last component, sensitivity can be described as "how affected a system is after being exposed to the stress" (Engle 2011, p. 649, compare to Adger 2006, p. 270 and IPCC 2001, p. 894) and, therefore, distinguishes the severity of the impact. Cardona et al. (2012) also mention the terms of susceptibility or fragility which are often used in disaster risk management and, based on a broad range of literature, define sensitivity as the "physical predisposition of human beings, infrastructure, and environment to be affected by a dangerous phenomenon due to lack of resistance and predisposition of society and ecosystems to suffer harm as a consequence of intrinsic and context conditions […] due to the influence of a hazard event" (p. 72). Therefore, sensitivity is influenced by demographic characteristics and the quality, quantity, location of physical structures (e.g., roads) as well as the dependence of the community on them.

2.3 Interrelation of Urban Form and Social Vulnerability

Lastly, an overview of some of the previously researched interrelations between urban form and social vulnerability attempts to give an outlook on some of the predictable findings. There are three central elements which are mainly highlighted and will be looked at: 1) Density; 2) Accessibility and mobility; and 3) Economic and societal marginalisation. As already mentioned above, another aspect does not link to urban form in detail but with the overall spatial expansion on the macro scale: Satterthwaite (2017a) points the broader interrelation of rapidly urbanising cities in the Global South, but mostly in Africa, out, which are the ones with the fastest increase of vulnerability and people living in sub-standard conditions and under the exposure of a variety of risks. Simultaneously, the sheer population sizes make vulnerability a much more critical element (van Huysteen et al. 2013).

Furthermore, urbanisation and spatial expansion often go along with an increase in density. This mainly occurs through the formal or informal encroachment of previously vacant areas (which are often necessary as natural compensation areas), self-planned settlements with high household sizes in comparatively small and dense buildings, as well as new developments with high-density, multi-level buildings. The higher density, on the one hand, does not concentrate in the areas or cities which are most suitable to live in but instead in areas which are attractive in regard to employment opportunities, while density, on the other hand, attracts even more migrants by intensifying the relative importance (van Huysteen et al. 2013). Lall and Deichmann (2009) further expand on this issue in a global perspective on density, disasters and hazard exposure and point out, that there should be a stronger focus on proper urban management to avoid densifications in vulnerable areas instead of merely trying to adapt to the consequences afterwards.

Another often-discussed interrelation is accessibility and mobility which are highly interlinked itself. The most vulnerable urban communities are often those, who live in the least accessible places and lack significant infrastructure and are therefore further marginalised and result in less spatial equity (see Yuan et al. 2017; Dadashpoor and Rostami 2017). At the same time, many cities in sub-Saharan Africa lack efficient and affordable public transport systems which result in stronger dependencies on individual modes of transport. However, as the less financially privileged population often live in peripheral or poorly connected urban areas, their dependence on public transport and individual vehicles is much higher than from the residents of formal, low-density and high-income settlements (UN-Habitat 2013; Williams 2014).

The last strong interrelation is between the spatial distribution of economic and societal marginalisation in general and the risk exposure in those areas; again, strongly linked to the elements mentioned above. As risk-prone areas are the least attractive to reside in, or forbidden by the government due to their exposure, only the poor population considers staying in the most affected areas or have simply no other option. Therefore, the interrelation between urban form and social vulnerability can be seen as a vicious circle which start off already in an unfortunate and unequal situation and continually reinforces each other – for the worse of the already marginalised (Hardoy and Pandiella 2009).

There are more city-wide relations where urban form affects the vulnerability or risk exposure like the urban form determining temperatures and enabling more extreme heat island effects, or dense buildings 'enclosing' pollution (see Cavan et al. 2014; Næss 2014; Mansfield et al. 2015). However, as these are difficult to quantify in small-scale resolutions and more challenging and data-reliant to assess in general, these aspects will not be considered further in this study; would, however, be a fruitful addition in future analyses.

2.4 The Case of Kampala

The focus of this research is on Kampala, the capital of Uganda. While it is the second least urbanised country in Eastern Africa (2011: 31.2%; UN-Habitat 2014, pp. 147-150), the urbanisation rate is significant in comparison to other countries in sub-Saharan Africa, and even more on a global level. The high urbanisation rates of over 7% per annum between 1950 and 1980 decreased since then but are still at a relatively high level at unceasingly over 4% which, combined with the increasing overall population size, leads to more urban settlers per year than ever before (UN-Habitat 2014, p. 149). These developments lead to an assumed current urban population of Kampala of somewhere between 1.6 and 2 M (1.66 M in 2011), plus an additional 1 M daytime population and predictions of about 100,000 new urban inhabitants per year, leading towards an expected population of 3.5 M in 2025 (UN-Habitat 2014, p. 150). This high urbanisation rates lead to a sprawling urban agglomeration even outside the jurisdictional boundary of the Kampala Capital City Authority (Fig. 2-6, p. 18; KCCA) and furthermore to densification and (formal as well as 'informal') infill in areas which are, either due to their soil texture and/or proximity to flooding areas, not suitable for residential areas (Karolien et al. 2012; BenBella 2012, Nyakaana et al. 2008, p. 11).

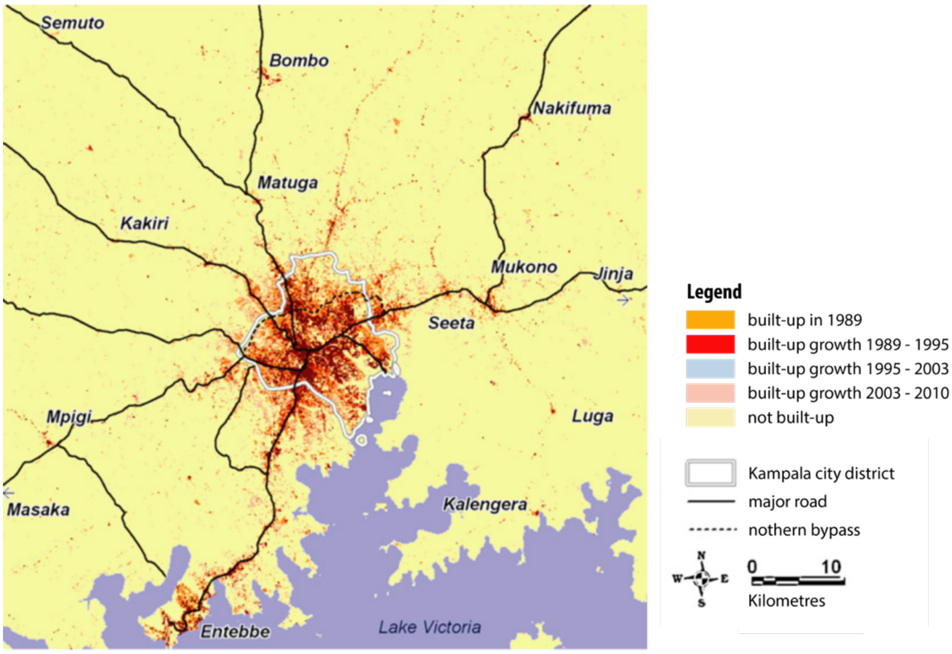

Figure 2-6: Built structure in Kampala City (adapted from Karolien et al. 2012)

At the same time, there were only 9.1 % of the national population living under the poverty line in 2009, which is one of the lowest in Eastern Africa (UN-Habitat 2014, p. 159). However, the number of people who are living in self-planned settlements[3] increased from 1.5 M in 1990 to 2.5 M in 2007 (UN-Habitat 2014, p. 165). These self-planned settlements are often experiencing the most severe livelihood challenges and are situated in inappropriate and inaccessible locations and lack access to basic services and critical infrastructure (UN-Habitat 2007). Nyakaana et al. (2008) furthermore point out that with the growth a "lack of infrastructure, social services and […] planning and environmental problems" comes along (p. ii) and emphasise the interrelationships between population, development and environmental issues (UN-Habitat 2014). While the Kampala Structure Plan was prepared in 1972 and mainly implemented, it catered mainly for the European and Asian residential and economic areas and did not consider the less privileged society. A revised plan from 1994 tried to cope with these arising challenges but was barely realised and let to the evolvement of more self-planned settlements without much institutional steering (UN-Habitat 2007, pp. 9-10).

In order to get a better understanding of the expanding poverty, the Poverty Probability Index was applied amongst others in Uganda with a globally standardised assessment method (Schreiner 2012a). The results highlight the comparatively high national poverty while pointing out the situation of missing overall access to facilities as well as basic sanitary instalments (Richmond 2018). Secondly, it shows the unequal distribution of poverty over age, with an intense concentration in the age groups under 29 (Schreiner 2012b, further detailed in Cannon et al. 2014). A more in-depth study of the most marginalised groups (street children, 'squatters', 'slum' dwellers) further stress the various lacks and challenges; namely (sorted according to significance): Flooding and infrastructure access; pollution; health issues (mainly related to the aforementioned); sanitary facilities; and social networks (Dimanin 2012). These rising

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[3] Self-planned settlements describe residential areas which are to a certain level informal, are populated mainly by the most unfortunate part of the population and which lack access to essential services and infrastructure. This type of settlement is often referred to as informal settlement or slum. However, these terms will not be used due to their negative connotation.

pressures on the urban population of Kampala are strongly linked to the increasing climate change impacts Uganda is experiencing (MoGLSD 2017; Mabasi 2009). While the climate of Uganda always led to floods and droughts in the past with accompanying negative consequences for livelihoods, infrastructure and the economy, the recent changes further intensify these pressures. The average temperature of Uganda is expected to rise by 1.5 °C until 2027 and up to 4.3 °C until the 2080s. More frequent and extreme rainfalls are projected as well, however, are more difficult to quantify. While the rising temperatures will have substantial effects on "water resources, food security, natural resource management, human health, settlement and infrastructure" and lead to more heat waves (MoGLSD 2017, p. 12), the rising rainfalls will result in even more flooding events which will be simultaneously more severe.

2.4.1 Flood-related Risks

The occurrence of a variety of disasters increased due to the changing climate patterns in Eastern Africa in the last decades (UN-Habitat 2014, pp. 160-162). Osuteye et al. (2017) attempted to compare the number and severity in countries of sub-Saharan Africa and counted 14 natural disasters in Uganda between 2010 and 2015 which led to over 700 deaths and affected more than 1 million people. While these number is higher in several other countries, Uganda has a comparatively low overall population which leads to 1 in 40 of the national population being affected in some way. This shows the significance of natural disaster and its tremendous effect it has on the lives and the country's development in general. Furthermore, they compare the different types of events and how many houses were destroyed or damaged. In the case of Uganda, floods (5,595), hailstorms (1,786) and landslides (1,663) are by far the highest numbers (Osuteye et al., p. 26). While hailstorms can barely be avoided and just adapted to through better built environments, the severity of floods and landslides is largely influenced by the infrastructure, spatial location and built environment, which will be further detailed later.

UN-Habitat prepared two expansive vulnerability assessments of Kampala (2009 and 2011) in which they further highlight floods and related risks as the primary stressors but also analyse which factors contribute to the severity of and sensitivity to disasters and point out the importance of better and more detailed vulnerability assessments increase the understanding and thereby allow for better adaptation measures. In the second assessment, more detailed measurements and spatial distributions of vulnerability were undertaken which led to a country-wide (Fig. 2-7, p. 20) and Kampala-specific scoring. While this method cannot thoroughly assess and predict the vulnerability to future disasters, it provides a good overview of how and where people are most affected. The compound vulnerability score is constituted of descriptive information like the elevation and slope of the environment, combined with climate prediction data (rainfall, sea level changes) and overlaid with the population and infrastructure (roads, hospitals, schools, health facilities) at risk (UN-Habitat 2011).

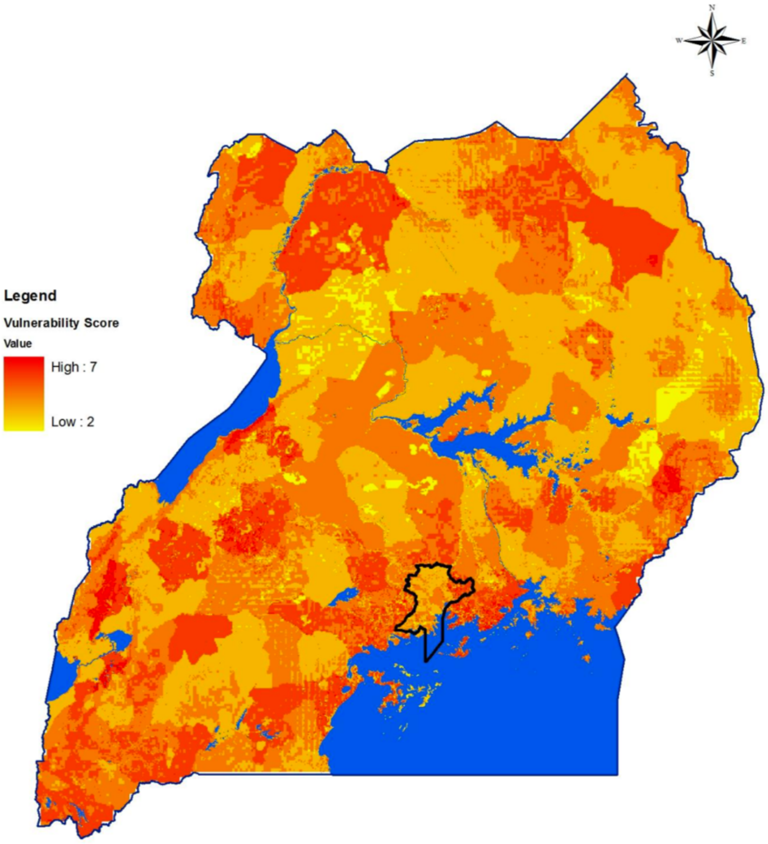

Figure 2-7: Vulnerability to Climate Change in Uganda, GKMA highlighted (UN-Habitat 2011, p. 41)

As mentioned before, from experience flood-related risks prove to be the highest challenge for Kampala and are, therefore, the focus of this study. The direct risks include the destruction of property due to flooding, as well as landslides as results of heavy rains and more spatially concentrated floods. The secondary effects are more difficult to assess but include rising water-borne diseases (Malaria, Dysentery, Cholera), pollution due to inadequate waste management (Mukama et al. 2016) and its distribution during floods (Fig. 2-8, p. 20) and resulting challenges after the destruction of critical infrastructure or the temporal inaccessibility (KCCA 2016).

Figure 2-8: Kampala flooding and pollution (© Edgar R. Batte (left) and J. Silver (right))

But why are so many people living in areas which are affected by these disasters? Isunju et al. 2015 blame the overall population growth and rural-urban migration in combination with unclear boundaries and land-ownership, as well as the "long-term failure of government regimes to enforce development control" (p. 276) which led to a large number of people encroaching on wetlands. In a study of several of these affected communities, Isunju et al. also found that over 55 % were female and over two thirds 30 years on younger, which again show the unjust exposure to disaster risks. Additionally, the majority (73.3 %) of the surveyed households were only earning between 40 and 120 USD (assumed conversion rate of 1 USD = 2,500 UGX in 2015) and nearly half without secondary education. Furthermore, the perception of vulnerability to hazards was enumerated and show that more than 50 per cent perceive themselves as very vulnerable to disease vectors and floods (Isunju et al. 2015; Isunju 2016; Fig. 2-9, p. 21). Lastly, there is a risk of floods negatively affecting the water quality of both tap water and even more well water, which combined with the rising water shortages endanger the water provision for the (mostly poor) population while contributing to the spread of diseases due to poisoned water and less preventive sanitary actions in times of clean water scarcity (Godfrey et al. 2003).

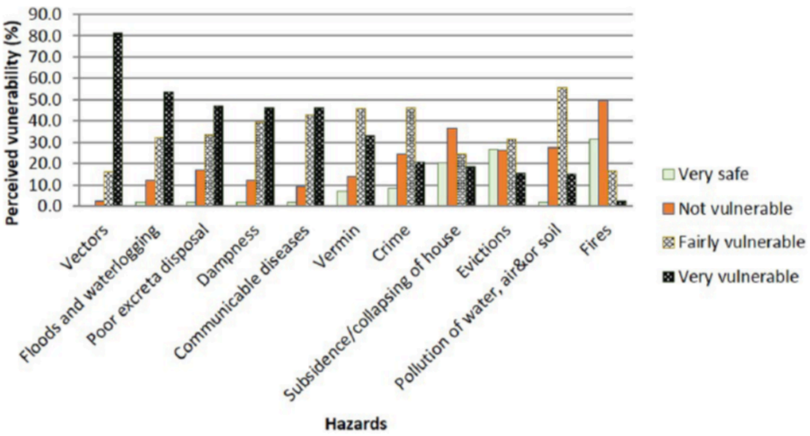

Figure 2-9: Ranked perceived vulnerability to hazards (Isunju et al. 2015, p. 286)

While a strong interrelation between the risk exposure to floods and the socio-economic characteristics of the affected population seems to exist, its verification requires an advanced model to distinguish the flood-prone areas – an endeavour which is due to its predictive character always challenging in environments of less detailed databases. Different approaches have been developed and applied to model run-off water and the effects of land use changes on the Murchison Bay Catchment area (catchment area of the Lake Victoria incorporating most of central Kampala). However, limitations of the underlying data and spatial inaccuracies make them only attractive as a basis but not sufficient to produce a more comprehensive representation (Fura 2013; Anaba et al. 2017). Therefore, the most promising approach is currently the computation of water flows and watersheds based on the topographical model, as well as the distance to the next flood-prone area as distinguished by the Municipality (Fig. 2-10, p. 22).

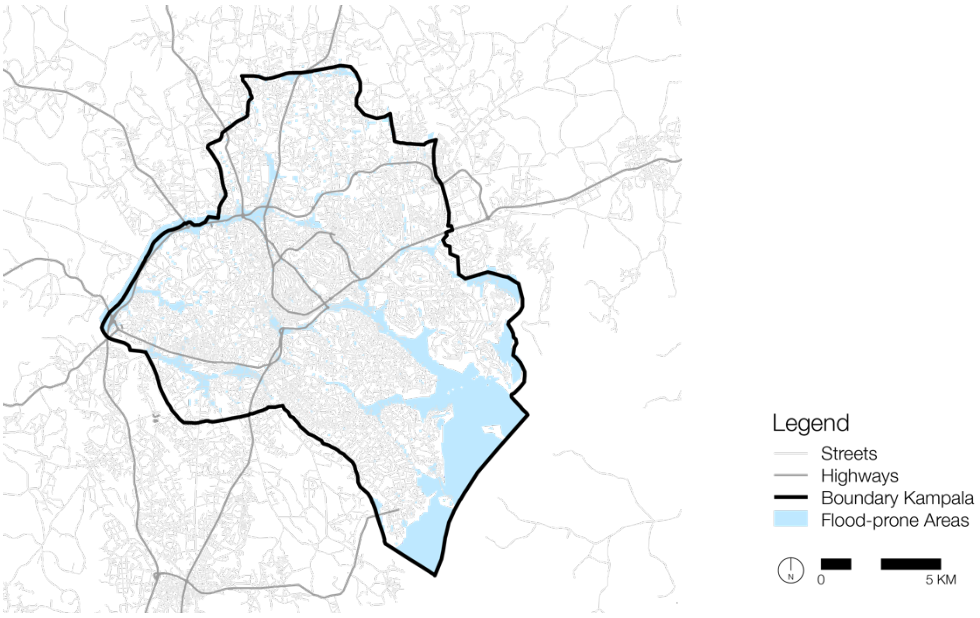

Figure 2-10: Areas most prone to flooding (Author 2018, based on data from UN-Habitat Vulnerability Profile/KCCA)

Lastly, the consequences of climate change on marginalised communities in Kampala need to be looked at to understand the contributing factors as they constitute a significant portion of the overall community and are the most affected (Dodman et al. 2015, p. 7). These contributors can be divided into physical and anthropic elements: The first are, additional to the location, the quality of infrastructure and buildings as well as the maintenance thereof. In Kampala, there is, for example, a definite difference between the quantity and quality of drainage systems between high-income, planned, and low-income, self-planned settlements. While high-income settlements are often at a higher elevation and are therefore less vulnerable by nature, they also have the best drainage systems while most self-planned settlements lack them or at least do not have them in the necessary sophistication (Dimanin 2012, p. 45). Furthermore, the garbage disposal and collection are often insufficient and therefore contributes to the pollution and spreading of poisoned water. Secondly, the anthropic elements are the underlying factors which determine the adaptive capacity and sensitivity of communities and individuals. In Kampala, these can be narrowed down to gender and age inequalities, with mostly females and young people or the elderly living in the most-risky areas (Musoke 2011, Mukwaya et al. 2012). Additionally, the resources (income, information, knowledge, institutional support), as well as the social cohesion and support structures, have a significant impact on the ability to cope with disasters (Dobson et al. 2015; Mukwaya et al. 2012; Musoke 2011). The combination and spatial overlap of many disadvantaging factors can lead to risk accumulation, meaning that the sum of risks is worse than each of them individually and reinforce each other.

2.5 Conceptual Framework

Based upon the above described theoretical concepts, a conceptual framework (Fig. 2-12, p. 24) was developed, which on the one hand shows the various aspects and their respective interlinkages, which distinctions and descriptions are the primary anticipated outcome. On the other hand, it acts as a guideline for the study, highlighting the elements which will be examined, quantified, and compared. However, before the conceptual framework is presented, a brief recap of the elements of social vulnerability attempts to combine the above-described concepts of risk exposure, adaptive capacity and sensitivity and how they interact and influence social vulnerability. In order to better visualise these elements, the overview of all common terms and elements is shown below (Fig. 2-11, p. 23; mainly based upon Brooks 2003; Adger 2006; Engle 2011).

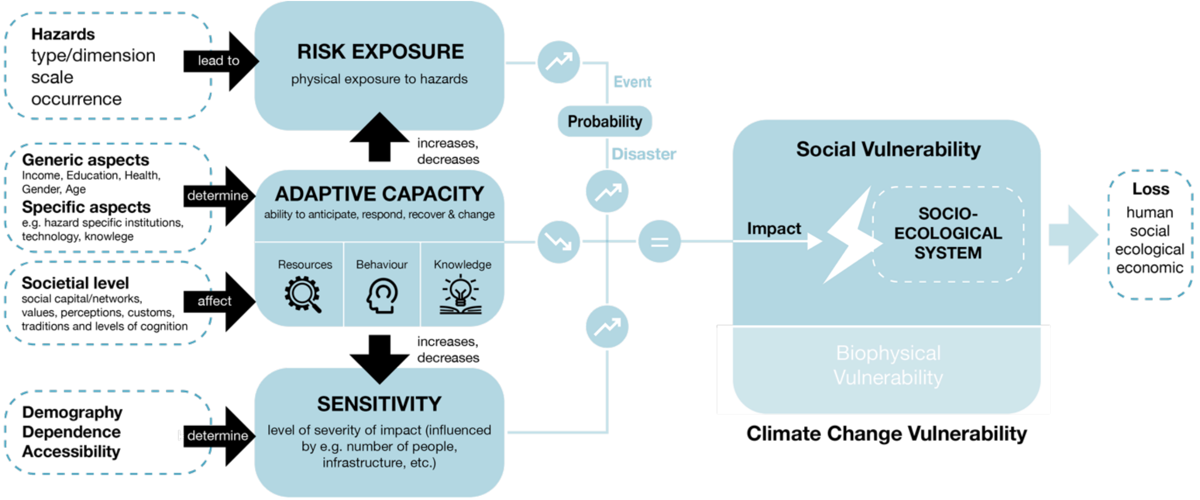

Figure 2-11: Conceptualisation of vulnerability and its elements (Author 2018)

Based upon this understanding, the conceptual framework for this research was developed to answer the research questions stated in the first chapter:

- How are **urban form** and **flood-related social vulnerability** interrelated in urban settlements of Kampala?
    - How can **exposure to flooding risks** be quantified in small spatial resolutions in contexts of limited data availability?
    - Which characteristics of Kampala's **urban form** can be quantified and how do they influence or are affected by **social vulnerability** and its components, **risk exposure**, **adaptive capacity** and **sensitivity**?
    - What **interrelations** exist between the constituents of **social vulnerability**?
    - How is **spatial injustice** in Kampala manifested through the spatial distribution of urban form and social vulnerability?

The conceptual framework consists mainly of four elements. The general context is socio-spatial justice, which is partly constituted of the analysed concepts, while it at the same time highlights the broader objective of the thesis which was stated in the background and motivation: To better understand the issue of spatial injustice and its social and environmental aspects. Second, there are a few primary stressors which have a substantial impact and increase the system's pressure. The central element of the framework is constituted of five central concepts: **(1) Urban form** of two different scales and **(2) social vulnerability**, which is further divided in **(3) risk exposure**, **(4) adaptive capacity**, and **(5) sensitivity**. Even if the three latter already have a strong interrelation by definition (see Chapter 2.3) and cannot be looked at as entirely independent concepts, they are still relevant as partly standalone elements. One principal reason is the environmental focus of risk exposure and the social context of adaptive capacity, differentiating them according to their database, while at the same time their spatial distribution is expected to be not linear distributed and understanding these inconsistencies is central for the research. Lastly, various general outcomes are likely to result from the internal dynamics, which will be relevant for the interpretations and recommendations of this paper.

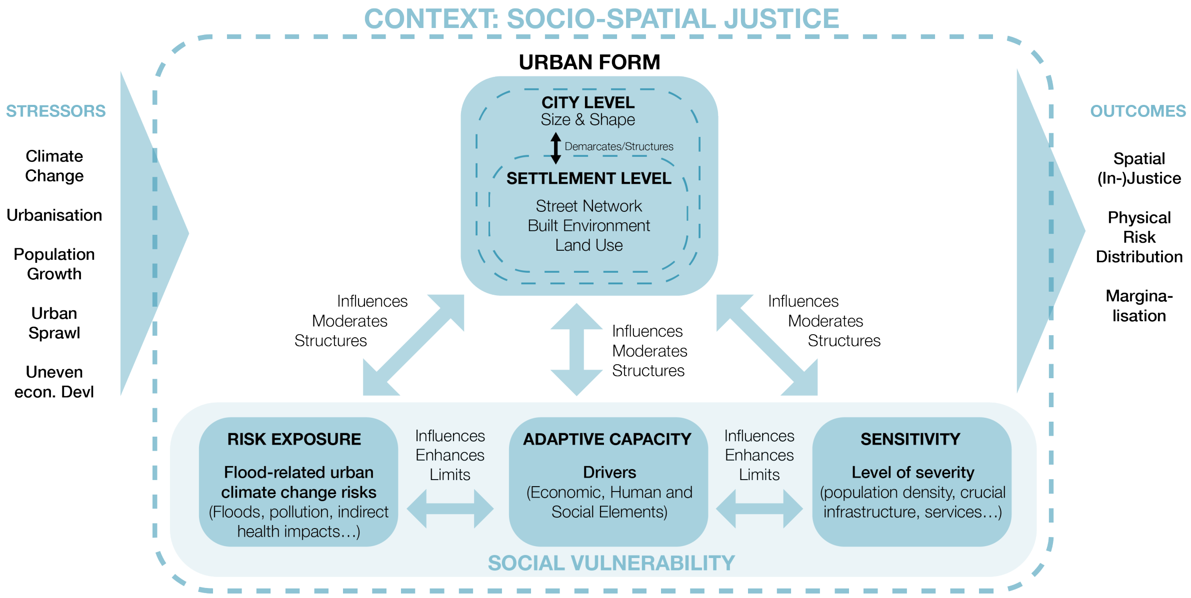

Figure 2-12 Conceptual Framework (The Author, incl. elements of EARF conceptual framework)

Chapter 3: Research Strategy and Methods

Building upon the conceptual framework presented above, this chapter discusses the research strategy and methods, as well as the data collection strategy. Furthermore, the operationalisation of the concepts and variables is presented. The chapter ends with the analysis methods, the validity and reliability as well as the limitations of the research.

3.1 Research strategy

The case study research approach is chosen which aims at exploring the various elements of the spatial distribution of flood-related urban risks as well as the characteristics of urban form in Kampala. A case study is most suitable for this research's objective as it is a holistic approach to collect an extensive and in-depth amount of data in a real-life setting (Van Thiel, pp. 86-87). The resulting conclusions shall help to understand the interrelations between the various elements more in detail and assist policy-makers to develop solutions to counteract unjust spatial risk manifestations. In order to achieve this, various research methods are applied which results can be triangulated and analysed independently as well as their interrelations and spatial distributions in Kampala. The types of planned triangulation are described in detail in the chapter about validity and reliability (Chapter 3.4). The type of case study for this purpose is a congruence, single case study.

Generally, a mix of methods is applied. On the one hand, secondary quantitative data from previous studies, surveys and reports are used, while semi-structured expert interviews and a household survey, which is conducted as part of the EARF research, extend the quantitative data by primary data. The congruence analysis is selected as the most appropriate method as it examines various factors and their interrelations and produces a comprehensive understanding by strongly basing the research design on findings of general theory. Blatter and Blume (2008) criticise, for example, the predominant co-variational case study type which often does not account for non-measurable interdependencies because of lacking data or simplified assumptions about causal relationships (p. 318). Instead, a congruence analysis is "based on the logic of retroduction" (Sinkler 2011, p. 0) and tests for varying congruences between the case study and theoretical concepts to draw a more elaborated picture without implying necessarily causal relationships (Blatter and Blume 2008; Sinkler 2011). Therefore, congruence analyses cannot lead to actual proof of theories but can support or test them in a specific context which helps the overall understanding of specific topics. In this research, the case study examines the current state of the urban form and risk allocation and investigates the situation in-depth based on previously detected interrelations or assumptions from academia. While a causal process tracing analysis could further add to the understanding of the current situation by looking at the development over time, the lack of data, both spatial and socio-economic, from before 2014 does not allow for it. However, this deficit shall be partly overcome by the expert interviews which provide a more in-depth perspective of the change over time.

A combination of the results of the methods is able to answer the research question in the most accurate way. However, a general challenge is that case studies only look at specific environments which make generalisations challenging and further stress the external validity as each neighbourhood is different and influenced by exogenous drivers which cannot be examined comprehensively. At the same time, a thorough analysis of diverse variables and the application of different methods shall be able to result in accurate results, while being detailed and differentiated enough to lead to general conclusions which can be applied to a certain degree to similar cases as well and contribute to the general theoretical understanding of spatial risk and vulnerability distribution in cities of sub-Saharan Africa.

Two factors demarcate the scope of the research: First, the geographical scope of selected areas which are part of the EARF household survey and cover various urban form characteristics and levels of vulnerability. Secondly, the depth of study requires a demarcation to guarantee a thorough analysis of the data. Therefore, the research concentrates solely on flooding risks and integrates various existing databases because its data is already processed and therefore does not require as many resources to be included in the study.

3.2 Operationalization: Variables and Indicators

In order to measure and compare the various elements of the concepts of the literature review and the conceptual framework, these elements are translated to concepts, variables and indicators (Table 3-1, pp. 27-28). The four central concepts of urban form, risk exposure, adaptive capacity and sensitivity are subdivided into several variables which definitions are included in the operationalisation table. Each of these variables is further separated into one or several measurable indicators. The definitions of the latter are briefly explained in the table while more comprehensive definitions can be found together with their visual representation in the annex (Annex 4, p. 74). Lastly, the second table (Table 3-2, pp. 29-30) presents all selected indicators and their respective level of measurement, unit, data source, and source year. The measurement level is divided into two groups: 1) The city level; and 2) the Selected Areas (SA), which are studied in resolutions of 100 * 100 m and 500 * 500 m grids, while the latter only serves as an interim step to analyse larger scale data (e.g., streets) and is afterwards transferred to the 100 * 100 m cells. The units represent the kind of the final value of each indicator which is the basis for the following normalisation. The data source and year provide additional information for the anticipated data to be used. Several indicators are not listed which are mentioned in the literature review and would be interesting to examine. However, several data limitations let to their exclusion. These are, amongst others, more elaborated spatial analyses of urban form which would, for example, require the height information of each building. Furthermore, as the level of risk exposure is calculated by a simplified model, a more advanced risk modelling method would result in more elaborated findings as well and could bring more differentiated interrelations to light as well. Also, the infrastructure sensitivity should include, e.g., the electricity and drainage network, which information are not available. Lastly, the adaptive capacity can due to its broad conceptualisations include various indicators which, for example, describe the social networks or the available resources and access to information better. However, this would require an in-depth study of households through a specialised survey which could not be conducted as part of this research. While the variety of selected and measurable indicators shall be able to draw a comprehensive picture of the actual situation, these limitations need to be considered and provide the potential for further studies when more information becomes available.

CONCEPT	VARIABLE	DEFINITION	NO	SPSS NAME	INDICATOR	DEFINTION
1 URBAN FORM	1.1. Street Network: Space Syntax	Space Syntax analysis of streets regarding road segments role in the overall road network.	1.1.1.	Integration	Integration (Space Syntax)	The number of turns which need to made from one street segment to reach all others streets through the shortest path.
			1.1.2.	Choice	Choice (Space Syntax)	The probability of each street segment to be used by users to reach another segment.
			1.1.3.	Depth	Depth Distance (Space Syntax)	Linear distance from each street segment to the total number of street segments.
			1.1.4.	Connectivity	Connectivity	Number of spaces immediately connecting a space of origin.
			1.1. AG	SpaceSyntaxAG	Aggregated indicators from 1.1.	
	1.2. Street Network: Accessibility	Network and infrastructure related aspects which define the accessibility to various physical elements of the urban area and interconnection of one area in comparison to others.	1.2.1.	EconCentre	Accessibility to economic centres	The average distance of each household to economic centres through the shortest path.
			1.2.2.	Education	Accessibility to educational facilities	The average distance of each household to educational facilities through the shortest path.
			1.2.3.	Health	Accessibility to health institutions	The average distance of each household to health facilities through the shortest path.
			1.2.4.	Busstation	Accessibility to public transport nodes	Average distance of each household to public transport nodes through the shortest path.
			1.2.5.	AccHealth	Distances to health facilities	Percentage of households with access to health facilities under 5 KM
			1.2.6.	AccSchool	Distances to educational facilities	Percentage of households with access to educational facilities under 5 KM
			1.2. AG	AccessAG	Aggregated indicators from 1.2.	
	1.3 Built Environment	Physical structures in a certain area and their individual and aggregated characteristics.	1.3.1.	NoBldgs	Building density	Buildings per sqkm
			1.3.2.	SOI	Site occupancy index	Percentage of ground covered by buildings
			1.3.3.	BldgSizeREV	Average building size	Average size of residential and commercial buildings
			1.3.4.	ProximityREV	Building proximity	Average distance to next 25 buildings
			1.3. AG	BuiltAG	Aggregated indicators from 1.3.	
	1.4 Land Use	Land use analysis incl. green percentage and the type of settlements	1.4.1.	GreenREV	Amount green space	Percentage of green space in relation to total space
			1.4.2.	SettTypeREV	Settlement type	Primary settlement type according to EARF residential settlement classification
			1.4. AG	LandAG	Aggregated indicators from 1.4.	
			1. AG	**UrbanFormAG**	**Aggregated Urban Form indicators**	
2 RISK EXPOSURE	2.1 Probability	The exposure to risk, the distance to flood-prone areas and the perception of risks of the residents living within.	2.1.1.	FloodRisk	Location in watershed area	TIN-based water runoff model
			2.1.2.	FloodDist	Distance to flood prone area	Distance to the nearest flood prone area defined by KCCA
			2.1.3.	HazardPercREV	Disaster occurrences in last 2 years	Subjective perception of number of disasters in area in the last two years
3 ADAPTIVE CAPACITY	3.1 Resources	The financial and property resources of the residents.	3.1.1.	IncRange	Range of income from household	Total income per household based on EARF household survey in selected areas
			3.1.2.	Expenses	Household expenses	Food, electricity, water, other energy, healthcare, education plus 3* transport expenses
			3.1.3.	PlotArea	Area of plot	Average plot size of residential and commercial buildings
			3.1.4.	PlotCost	Cost of purchase	
			3.1.5.	CurrentPrice	Current price	Current price of property
			3.1.6.	RelationSite	Household relation to site	Relationship of household to property/site
			3.1.7.	Ownership	Percentage ownership	Percentage of owner property instead of rented/subsidised
			3.1. AG	ResourcesAG	Aggregated indicators from 3.1	
	3.2 Access to Services	The access to basic services and the type and quality thereof.	3.2.1.	AccWater	Access to water	Availability of water
			3.2.2.	AccSewer	Connection to sewerage network	Availability of sewerage network
			3.2.3.	AccSeptic	Septic tank	Availability of septic tanks
			3.2.4.	AccSanit	Sanitation facility	Availability of sanitation facilities
			3.2.5.	AccSolarREV	Solar Panel	Availability of solar panels
			3.2.6.	WaterTypeREV	Water access	Type of water accessible
			3.2.7.	WaterQualREV	Water quality	Satisfaction with water quality
			3.2. AG	ServiceAccAG	Service access aggregated	

	3.3. Behaviour	Social characteristics which influence behaviour of residents	3.3.1.	YearsMov	Social integration	Integration in community measured by the number of years living there
			3.3.2.	InitialLoc	Initial location	Location before moving to current plot
			3.3.3.	SatisfactionREV	Satisfaction with neighbourhood	Satisfaction with living in present neighbourhood
			3.3.4.	Relocation	Plan to relocate	Existence of plan to move to another place within 2 years
			3.3.5.	ImprovREV	Prevalence of improvements on plot	Type and quantity of improvements undertaken
			3.3.6.	ImprovCosts	Cost of improvements	Amount of money invested in improvements
			3.3. AG	BehavAG		
	3.4 Knowledge and information	Access and prevalence to internet and the level of education.	3.4.1.	Twitter	Internet use	Prevalence of internet use in area measured by number of tweets
			3.4.2.	EducQual	Level of Education	Highest level of education in household based on EARF household survey in selected areas
			3.4. AG	KnowAG	Aggregated indicators from 3.4.	
			3. AG	**AdaptCapAG**	**Aggregated indicators of Adaptive Capicity**	
4 SENSITIVITY	4.1 Human sensitivity	Characteristics of the urban population which affect the sensitivity to climate change risks.	4.1.1.	PopDensity	Population density	People per hectare based on 2014 survey
			4.1.2.	HHSizeEARF	Household size 2	Household size based on EARF household survey in selected areas
			4.1.3.	FemalePopREV	Gender 1	City-wide gender distribution
			4.1.4.	FemalePopEARFREV	Gender 2	Gender distribution based on EARF household survey in selected areas
			4.1.5.	AgeGroupREV	Age groups	Age distribution in households based on EARF survey in selected areas
			4.1.6.	FemaleHHREV	Female headed households	Percentage of female-headed households based on EARF survey in selected areas
			4.1.7.	EconRes	Economic resilience	Sufficiency of current household income.
			4.1.8.	EmployerREV	Type of employer	Type of main employer
			4.1.9.	Occupation	Type of occupation	Type of main occupation
			4.1.10.	Exprop	Expropriation	Prevalence of evictions or expropriations the past five years
			4.1.11.	SafetyREV	Safety	Level of safety (regarding crimes, harassment, violence) for the women of household
			4.1.12.	AffordHH	Household affordability	Easiness for household to afford current property
			4.1.13.	PropRestr	Property restrictions	Prevalence of restrictions in process of finding a place in the area
			4.1.14.	OwnershipType	Property ownership	Type of owner of used property
			4.1. AG	HumanSensAG		
	4.2 Building sensitivity	Characteristics of the built environment which influence the severity of disasters.	4.2.1.	DwellingType	Type of dwelling	Categorical type of dwellings in area.
			4.2.2.	DwellingMat	Dwelling material	Quality and type of built material of buildings
			4.2.3.	FloorQualREV	Built floor quality	Quality of floor from 2014 survey
			4.2.4.	WallQualREV	Built wall quality	Quality of walls from 2014 survey
			4.2. AG	BuildSensAG		
	4.3 Infrastructure sensitivity	The quality and quantity of infrastructure in affected areas which are at risk.	4.3.1.	StreetDensREV	Street density	Weighted length of primary and secondary roads per sqkm
			4.3.2.	RoadProx	Nearest road	Nearest paved road
			4.3.3.	TraTime	Travel time	Average time to travel to work/school
			4.3. AG	InfraSensAG		
			4. AG	**SensAG**	**Sensitivity aggregated**	

Table 3-1: Definition of variables (Author 2018)

CONCEPT	VARIABLE	NO	INDICATOR	DATA	INDICATOR SOURCE	MEASUREMENT LEVEL	DATA SOURCE	SOURCE YEAR
1 URBAN FORM	1.1. Street Network: Space Syntax	1.1.1.	Integration (Space Syntax)	lines	Hillier 2009; Oliveira 2016; Ratti 2004	100 * 100 m grid	Open Street Map (OSM)	2018
		1.1.2.	Choice (Space Syntax)	lines	Hillier 2009; Oliveira 2016; Ratti 2004	100 * 100 m grid	Open Street Map (OSM)	2018
		1.1.3.	Depth Distance (Space Syntax)	lines	Hillier 2009; Oliveira 2016; Ratti 2004	100 * 100 m grid	Open Street Map (OSM)	2018
		1.1.4.	Connectivity	lines	Hillier 2009; Oliveira 2016; Ratti 2004	100 * 100 m grid	Open Street Map (OSM)	2018

		1.1. AG	Space Syntax aggregated	100 cells				
	1.2. Street Network: Accessibility	1.2.1.	Accessibility to economic centres	centre points	Dadashpoor and Rostami 2017; Dony et al. 2015; Goswami and Lall 2016; Kanuganti et al. 2016	100 * 100 m grid	World Bank, Uganda Business Register (Goswami 2016); Jones et al. 2016	2016-18
		1.2.2.	Accessibility to educational facilities	centre points	Dadashpoor and Rostami 2017; Dony et al. 2015; Goswami and Lall 2016; Kanuganti et al. 2016	100 * 100 m grid	Open Street Map (OSM)	2018
		1.2.3.	Accessibility to health institutions	centre points	Dadashpoor and Rostami 2017; Dony et al. 2015; Goswami and Lall 2016; Kanuganti et al. 2016	100 * 100 m grid	Open Street Map (OSM)	2018
		1.2.4.	Accessibility to public transport nodes	centre points	Dadashpoor and Rostami 2017; Dony et al. 2015; Goswami and Lall 2016; Kanuganti et al. 2016	100 * 100 m grid	Open Street Map (OSM), GoMetroApp and primary public node data collection	2018
		1.2.5.	Distances to health facilities	polygons	Dadashpoor and Rostami 2017; Dony et al. 2015; Goswami and Lall 2016; Kanuganti et al. 2016	100 * 100 m grid	National Survey 2014	2014
		1.2.6.	Distances to educational facilities	polygons	Dadashpoor and Rostami 2017; Dony et al. 2015; Goswami and Lall 2016; Kanuganti et al. 2016	100 * 100 m grid	National Survey 2014	2014
		1.2. AG	Accessibility aggregated	100 cells				
	1.3 Built Environment	1.3.1.	Building density	100 cells	Adolphe 2000; Hillier 2009; Jacobs 1961; Pont and Haupt 2009; UN-Habitat 2016	100 * 100 m grid	GeoGecko, Open Street Map (OSM), primary data extension	2018
		1.3.2.	Site occupancy index	100 cells	Adolphe 2000; Hillier 2009; Jacobs 1961; Pont and Haupt 2009	100 * 100 m grid	GeoGecko, Open Street Map (OSM), primary data extension	2018
		1.3.3.	Average building size	100 cells	Hillier 2009; Jacobs 1961; Pont and Haupt 2009	100 * 100 m grid	GeoGecko, Open Street Map (OSM), primary data extension	2018
		1.3.4.	Building proximity	bldg points	Adoplhe 2000, Dadashpoor and Rostami 2017, Dave 2010	100 * 100 m grid	GeoGecko, Open Street Map (OSM), primary data extension	2018
		1.3. AG	Built environ. aggregated	100 cells				
	1.4 Land Use	1.4.1.	Amount green space	raster	Adoplhe 2000, Dadashpoor and Rostami 2017, Jacobs 1961, Pont and Haupt 2009	100 * 100 m grid	Sentinel / Earth Explorer	2018
		1.4.2.	Settlement type	polygons	EARF research project	100 * 100 m grid	Open Street Map (OSM), EARF classification	2018
		1.4. AG	Land Use aggregated	100 cells				
		1. AG	**Urban Form aggregated**	**100 cells**				
2 RISK EXPOSURE	2.1 Probability	2.1.1.	Location in watershed area	raster	UN-Habitat 2011	100 * 100 m grid	Elevation lines / KCCA	2018
		2.1.2.	Distance to flood prone area	centre points	UN-Habitat 2011	100 * 100 m grid	Municipality's flood prone area distinction / KCCA	2014
		2.1.3.	Disaster occurrences in last 2 years	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
3 ADAPTIVE CAPACITY	3.1 Resources	3.1.1.	Income level	500 cells	Adger 2006; Adger 2007; ARCC 2013; Weis et al. 2016	SA, 100 * 100 m grid	EARF household survey	2018
		3.1.2.	Household expenses	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		3.1.3.	Area of plot	500 cells	Hillier 2009; Jacobs 1961; Pont and Haupt 2009	SA, 100 * 100 m grid	EARF household survey	2018
		3.1.4.	Cost of purchase	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		3.1.5.	Current price	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		3.1.6.	Household relation to site	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		3.1.7.	Percentage ownership	polygons	Adger 2007; ARCC 2013; Weis et al. 2016	100 * 100 m grid	National Survey 2014	2018
		3.1. AG	Resources aggregated					
	3.2 Access to Services	3.2.1.	Access to water	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		3.2.2.	Connection to sewerage network	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		3.2.3.	Septic tank	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		3.2.4.	Sanitation facility	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018

		3.2.5.	Solar Panel	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		3.2.6.	Water access	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		3.2.7.	Water quality	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		3.2. AG	Service access aggregated	100 cells				
	3.3. Behaviour	3.3.1.	Social integration	500 cells	Adger 2006; Adger 2007; ARCC 2013; Weis et al. 2016	SA, 100 * 100 m grid	EARF household survey	2018
		3.3.2.	Initial location	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		3.3.3.	Satisfaction with neighbourhood	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		3.3.4.	Plan to relocate	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		3.3.5.	First action after moving	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		3.3.6.	Cost of improvements	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		3.3. AG	Behaviour aggregated	100 cells				
	3.4 Knowledge and information	3.4.1.	Internet use	raster	Adger 2006; Adger 2007; Williams et al. 2015	100 * 100 m grid	Twitter API	2018
		3.4.2.	Level of Education	500 cells	Adger 2006; Adger 2007; ARCC 2013; Weis et al. 2016	SA, 100 * 100 m grid	EARF household survey	2018
		3.4. AG	Knowledge aggregated	100 cells				
		3. AG	**Adaptive cap. aggregated**	**100 cells**				
4 SENSITIVITY	4.1 Human sensitivity	4.1.1.	Population density	polygons	Hillier 2009; Jacobs 1961; Pont and Haupt 2009	100 * 100 m grid	national Survey 2014	2014
		4.1.2.	Household size 2	500 cells	Adger 2006; Adger 2007; Cordona et al. 2012	SA, 100 * 100 m grid	EARF household survey	2014
		4.1.3.	Gender 1	polygons	Adger 2006; Adger 2007; Cordona et al. 2012	100 * 100 m grid	national Survey 2014	2014
		4.1.4.	Gender 2	500 cells	Adger 2006; Adger 2007; Cordona et al. 2012	SA, 100 * 100 m grid	EARF household survey	2018
		4.1.5.	Age groups	500 cells	Adger 2006; Adger 2007; Cordona et al. 2012	SA, 100 * 100 m grid	EARF household survey	2018
		4.1.6.	Male headed households	500 cells	Adger 2006; Adger 2007; Cordona et al. 2012	SA, 100 * 100 m grid	EARF household survey	2018
		4.1.7.	Economic resilience	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		4.1.8.	Type of employer	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		4.1.9.	Type of occupation	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		4.1.10.	Expropriation	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		4.1.11.	Safety	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		4.1.12.	Household affordability	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		4.1.13.	Property restrictions	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		4.1.14.	Property ownership	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		4.1. AG	Human Sens. aggregated	100 cells				
	4.2 Building sensitivity	4.2.1.	Type of dwelling	500 cells		SA, 100 * 100 m grid	EARF household survey	2018
		4.2.2.	Dwelling material	polygons	Adger 2007; Dickson et al. 2012; Dodman et al. 2015; Elrich-Barr et al. 2014; Jones 2010a; Schreiner 2012	100 * 100 m grid	national Survey 2014	2014
		4.2.3.	Built floor quality	polygons	Adger 2007; Dickson et al. 2012; Dodman et al. 2015; Elrich-Barr et al. 2014; Jones 2010a; Schreiner 2012	100 * 100 m grid	national Survey 2014	2014
		4.2.4.	Built wall quality	compound	EEA 2016; Engle 2011; Isunju 2016; Weis 2016	100 * 100 m grid	OSM and score of risk exposure	2018
		4.2. AG	Building Sens. aggregated	100 cells				
	4.3 Infrastructure sensitivity	4.3.1.	Street density	lines	UN-Habitat 2016	100 * 100 m grid	Open Street Map (OSM)	2018
		4.3.2.	Nearest road	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		4.3.3.	Travel time	500 cells	EARF research project	SA, 100 * 100 m grid	EARF household survey	2018
		4.3. AG	Infrastructure Sens. aggr.	100 cells				
		4. AG	**Sensitivity aggregated**	**100 cells**				

Table 3-2: Characteristics of individual indicators (Author 2018)

3.3 Research methodology

In order to quantify the above-presented indicators, various methods are applied. While some data is already existing and geo-referenced, other indicator values need to be calculated or compromised based upon different information to compound scores. Two different grid-sizes were chosen for the study on city level and the analysis of the EARF household data inside the specified research corridors. Most values are directly calculated or converted to the 100 * 100 m grid, while some calculation (i.e. EARF survey results, street density, space syntax) are first calculated for 500 * 500 m cells. Both cell-sizes are chosen to establish a balance between large enough cells to guarantee a certain level of representativity while still being small enough to distinguish high-resolution differences in the urban fabric. Finally, all indicator values are geo-referenced and assigned to smaller size cells in ArcGIS.

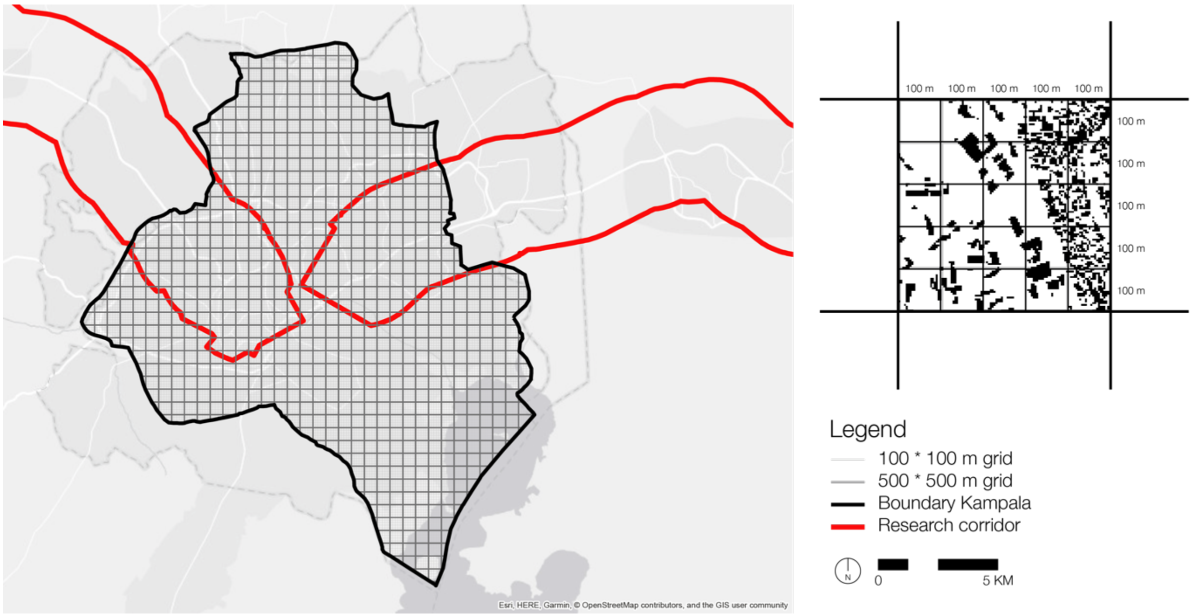

Figure 3-1: Grid division and scale reference incl. buildings (Author 2018)

3.3.1 Sample size and selection

The spatial analysis is conducted on two levels, firstly the city and secondly the EARF research corridors. The latter are selected through a purposive sample process. Two corridors were distinguished: One from the centre to the north-west, and a second one to the east. For the household survey which was carried out as part of the research compendium, 2750 households and 10109 household members were enumerated, equally distributed over eight strata (four different residential housing types and core and peripheral locations; Fig. 3-2, p. 32). Inside these, the households are selected through a random generation of coordinates. The enumerators started off from these coordinates and then approached the closest household. However, as some part of the coordinates lie outside the research demarcation, and others have no spatial reference, only about two-thirds of the data was used for the following analysis.

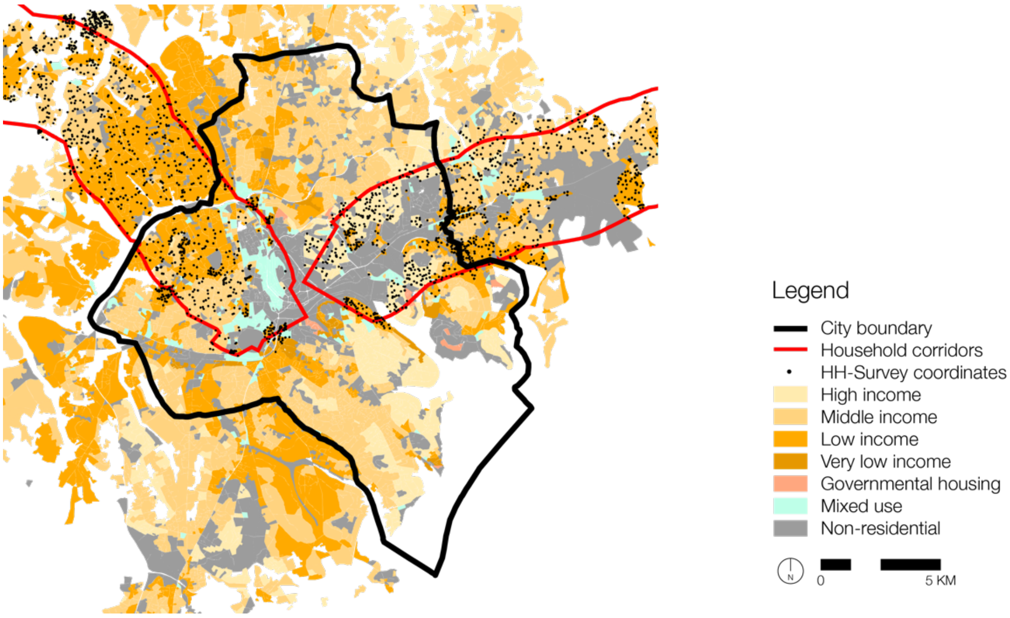

Figure 3-2: EARF settlement types, research corridors and survey coordinates (Author 2018)

3.3.2 Data collection methods

The data for the case study is both primary and secondary, which is why both methods need to be considered. Hence, the collection method is a mixed-method approach using existing quantitative secondary data and semi-structured interviews with experts, field trips for observations, as well as the household survey conducted as part of the EARF research project. The semi-structured interviews with various experts allow for collecting qualitative data about the same topics while leaving room for more open answers to take aspects into consideration which were not distinguished by the researcher beforehand. These strategies are chosen to have a broad data set of both quantitative and qualitative data to understand the distribution and prevalence of risk exposure and its interrelation to urban form.

For the selection of the qualitative data, a guideline for the semi-structured interviews is developed which aims at understanding the general elements and their interrelation. Furthermore, an online survey was used to weigh the various indicators according to their importance to allow for a representative weighting as part of the aggregation process. This weighting process will be done through a participatory multi-criteria decision analysis which lets the participants compare and assign values for each indicator in comparison to the other indicators in the same sub-group (Scott 2005, pp. 705-706). This means that the most crucial indicator gets a score of six points and other indicators are compared to the first and given scores according to the relative importance. There is the possibility to not assign a score to an indicator which, in case several interviewees rate them in the same way, would lead to the indicator to be eradicated (which did not occur). Lastly, papers and reports which focus on the climate change related risk improve the data input for the analysis of the data. The gathered qualitative data mainly assist the interpretation of the quantitative findings while also supporting the process of quantitative data collection as well as the focus and selection of the secondary data indicators.

The collected secondary quantitative data comes from various sources. Firstly, numerous information like the jurisdictional boundaries, the national household survey of 2014 as well as the flood-prone areas are from governmental institutions. Secondly, various information which was produced as part of the EARF project is integrated, mainly the different housing typologies. Additionally, numerous data sets come from a range of datasets and reports of the last years which examine one particular issue in detail. These are, amongst others, the reports on the vulnerability of Kampala (UN-Habitat 2011), Building Outlines: An Atlas of Kampala (GeoGecko 2016) or the World Bank report on economic centres (Goswami and Lall 2016). Lastly, for quantifying urban form and accessibility to various facilities, in-depth spatial data is required which is mainly collected from OpenStreetMap and extended through own mapping.

Generally, the collected spatial data or, e.g., socio-economic data, which can be associated with jurisdictional boundaries (in case of Kampala parishes), exists in four different types (Fig. 3-3, p. 32):

Points:	Bus station, facilities, survey coordinates or building centre points
(Poly-)Lines:	Streets or rivers
Polygons:	Census data, buildings or settlement types
Raster:	Digital elevation model or image analysis results

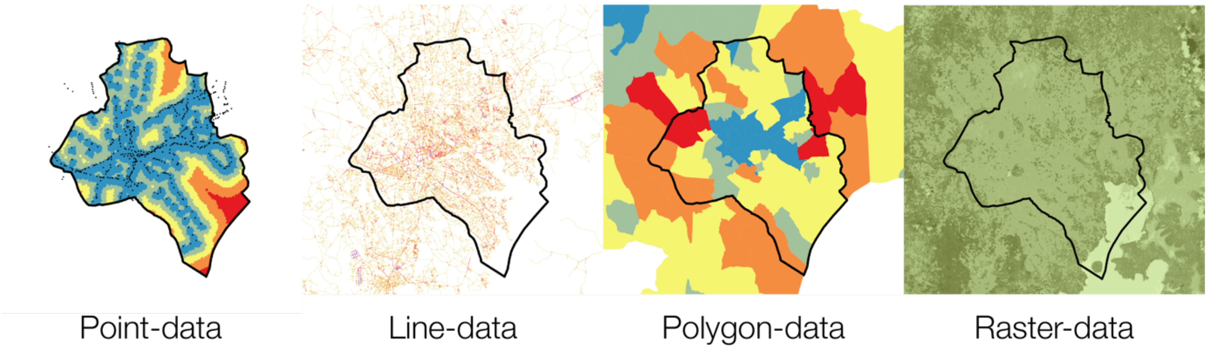

Figure 3-3: Four different underlying spatial data types (Author 2018)

3.3.3 Data assessment

The conducted data assessment of the spatial elements consists of four different parts:

1. The first is assigning existing geo-referenced data to the cells.
2. The second is comprised of various types of spatial analysis and includes basic calculations like counting the number of buildings or the length of streets per cell.
3. In order to calculate the indicators 1.1.1-1.1.4 (integration, choice, depth distance, connectivity), DepthMapX for QGIS is used, based upon the infrastructure data from OpenStreetMap (further information in Annex 1, p. 67).
4. Lastly, the accessibility to economic centres, different facilities or functions is calculated through the Variable-width Floating Catchment Area (VFCA) method which builds upon the Two-step Floating Catchment Area Method (2SFCA). The latter method was initially developed to calculate the accessibility to health facilities for the population. However, Dony et al. (2015) adapted the methodology in order to include other types of function and took varying weights or levels of attractiveness into consideration (in their case, for example, the size and number of amenities of parks). It is therefore seen as the most appropriate method to calculate accessibility to various functions and distinguish between their characteristics. To give an example, this research calculates the accessibility to educational facilities (indicator 1.2.2). However, one facility is a private university while others are public primary schools. Therefore, an adapted weighting is required to take these differences into consideration. Lastly, the VFCA, like the 2SFCA, depends on the selection of calculation method of distances. For this, different approaches exist, amongst other the

Euclidean distance, the time-distance or network distance (Kanuganti et al. 2016, p. 393). As the Euclidean distance does not consider varying infrastructure densities and time-distance is difficult to assess due to strongly varying modes of transport, the network-distance is chosen. The latter is defined by the distance in m by using the existing network in the shortest possible way. Even if this does not consider different qualities and sizes of roads (e.g., paved/unpaved) it seems to be the most accurate method. These accessibility measurements are conducted through the Network Analyst Toolbox of ArcGIS.

3.3.4 Data analysis methods

The resulting geo-referend quantitative data of the selected areas allow for various regression analyses to distinguish correlations and understand which factors are interrelated. Through the qualitative data of the interviews and previous reports and articles, the quantitative results can be further explained, interpreted and situated into the broader context of risk distribution and the resulting spatial (in-)justice. In order to be able to compare all data with varying units, the values are normalised before further analysis through which each value is represented by a number between 0 and 1. Furthermore, to reduce the number of indicators to a manageable, the statistically suitable indicators are aggregated to compound scores for each variable to simplify the comparison and regression analysis.

Afterwards, mainly three different analysis approaches are applied. In the first step, descriptive statistics are calculated, supported by their visual counterparts (Annex 4, p. 74), and the Pearson's correlation is calculated for all indicator combinations. This step helps to distinguish existing and promising correlations and can be seen as an explorative pre-step for the following analysis. Afterwards, a series of regression analyses (Fig. 3-4, p. 35) is carried out for both the city (C-models) and EARF (E-models) scale. The correlations between the main concepts (aggregated indicators) are analysed by simple linear regressions. In the first (Model C1, E1) correlations between **Social Vulnerability** (composed of Flooding Risk Exposure, Ind. 2.1.1, Adaptive Capacity, Ind. 3. AG, and Sensitivity Ind. 4. AG) and **Urban Form** (Ind. 1. AG) are tested. Secondly (Model C2, E2), the correlations between **Urban Form** (Ind. 1. AG) and the three components of social vulnerability, **Flooding Risk Exposure** (Ind. 2.1.1) **Adaptive Capacity** (Ind. 3. AG) and **Sensitivity** (Ind. 4. AG) are examined. In a third step (Model C3, E3), these three components are checked for their interrelationships.

In the fourth regression model (Model C4, E4), an Ordinary Least Squares (OLS; Hutcheson 2011) method is conducted, which looks at the main variables of social vulnerability and how they individually or combined correlate to Urban Form by distinguishing the factors in the linear regression formula. This is done through a multiple regression analysis, starting with the strongest component and extending it with the two remaining. The formula for the OLS-regression is as follows:

$$\mathbf{y^1 = \beta^1 x_i^1 + \beta^2 x_i^2 + \beta^3 x_i^3 + \varepsilon_i}$$

The variable of **Urban Form** represents the $\mathbf{y^1}$ on the left, and the aggregated variables of **Social Vulnerability** constitute the $\mathbf{x_i^p}$ values on the right with the objective to distinguish the broader $\mathbf{\beta^p}$ values.

Afterwards (Model C5, E5), the risk exposure is crosschecked with the mostly correlated individual indicators according to the Pearson's correlation to explore strong interlinkages which might get lost in the aggregated variable scores. Lastly (Model E6), a simple linear regression between the scores of the marginalised groups (youth/reversed age groups) and their strongest correlated counterparts is conducted to distinguish the prevalence of the risk accumulation phenomenon.

Concluding, the outcomes of the study are partly descriptive and partly prescriptive. Some outcomes solely represent already existing information in combined and more detailed manners and can provide a better understanding, while others, like specific interrelations between factors, help to quantify influencing factors and give an indication about expectable developments in the future and how one might affect another one and therefore also where and what kind of interventions might be more fruitful to anticipate further marginalisation and spatial injustice.

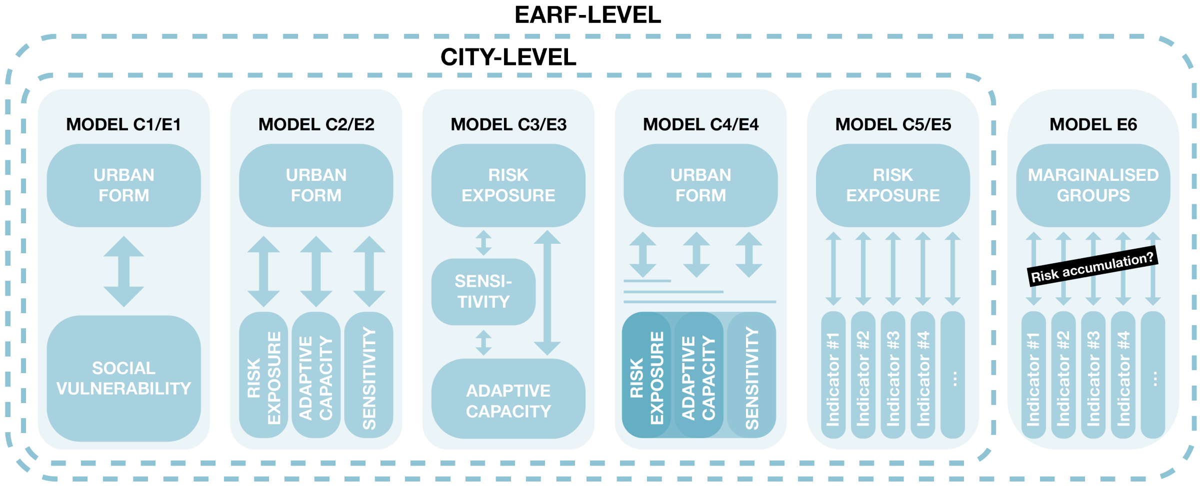

Figure 3-4: Regression models for city and EARF-level (Author 2018)

3.4 Validity and reliability

The validity of this research is constituted of two elements. The first is the internal validity which requires a consistent research design and execution and is achieved by measuring the intended variables through the selected methods (Van Thiel 2014, p. 92). This, under considerations of some limitations mentioned in the next sub-chapter, is achieved by a thorough selection of the most appropriate methods based on several scientific papers and case studies and a constant review of the firmness of the constituting elements of this research. The second element, external validity, describes how far the results of the research can be generalised and applied to other circumstances. The ability to generalise is always restricted if a case study is selected as the primary research strategy (Van Thiel 2014, p. 92). However, some more general results and findings shall be able to lead to a certain level of applicability in other contexts as well. Furthermore, a detailed description of the different steps of the methodology allows for the replication in other geographical contexts or a larger scale study in Kampala if more spatial data becomes available, and therefore try to eradicate the limitations of case studies as much as possible.

Reliability, on the other hand, is composed of accuracy and consistency and aims at producing the most accurate representation of reality and leading to valid findings (Van Thiel 2014, p. 92). The first element of accuracy is attempted to guarantee in the highest possible degree through a broad range of data, cross-checking and finally the spatial analysis in a very small scale to allow for an accurate representation of reality while still reducing the complexity to a measurable degree. The second aspect of consistency is achieved through the attempt to use data from the same and reliable sources and of the same level of detail while choosing widely-accepted analysis tools and supporting the research heavily on existing research. Moreover, the expert interviews are used as a way of validating the findings to eradicate the risk of researcher-bias and the relative unfamiliarity of the researcher with the specific circumstances of the research location. Lastly, the different data is triangulated to ensure the accuracy and consistency and avoid false findings. The primary data comes from governmental and non-governmental sources as well as various independent sources and is supplemented by primary and qualitative data which ensures a data source triangulation. Furthermore, the expert interviews also add another dimension of data input as well as cross-checking the findings and used data. Lastly, several of the indicators measure related or similar aspects which lead to a way of controlling the findings with each other and distinguish inaccuracies or methodological/data faults.

3.5 Research limitations

The limited amount of data and accessibility to data as well as the restricted available time in combination with the broad scope of variables and indicators lead to several limitations. While the selection of mainly secondary data eases the process, several data sets are not available in the required scope or level of detail. For example, the urban form analyses require the precise building outlines which only exist in a limited level of detail. Additionally, the EARF household data which constitutes a significant number of indicators, is only available for the two research corridors and limits the more accurate analysis on a smaller part of the whole city, while barely any information exists for the Greater Kampala Metropolitan Area, which is the functional area of the city. However, as research corridors are selected to be as representative as possible and parts of the analysis are conducted on city level, general conclusions can be drawn for the functional entity. Furthermore, the source year of the data varies from 2014 to 2018 which challenges the comparability. However, as the comparison is geographical instead of temporal, the inaccuracy between 2014 and 2018 is not a significant problem, as the distribution most likely did not change tremendously. Moreover, some of the research tools have methodological limitations. For example, the risk exposure to floods can generally be calculated through the digital elevation model of Kampala by flow and watershed calculations. However, these calculations can never represent the actual occurrence and must be looked at considering these limitations. Lastly, due to the necessity to analyse some elements in the 500 * 500 m grid level of detail, there are in some cases 25 100 * 100 m grid cells with the same value, which interfere with the statistical process of calculating correlations.

Chapter 4: Research Findings

In this chapter, the research findings are presented and statistically interpreted, as well as related to the literature and the results of the fieldwork in order to answer the research questions stated in Chapter 1. The chapter is structured in the same way as the previous chapter: It is divided into data assessment as the first and underlying research step, and data analysis through various correlation and regression analyses in the second part. Both are conducted independently for the study at city level (Models C1 to C5) and the zoom-in on the EARF research corridors (Models E1 to E6) as described in the previous chapter. Furthermore, a brief overview of the findings of the interviews and weighting survey follows, together with their relevance and impact on the research. Lastly, some further overall findings from the different regression analyses are discussed and lead to the following conclusions.

4.1 Findings from data assessment

In the data assessment, the values for 26 indicators on city level and a total number of 62 indicators for the EARF research corridors, were calculated and attached to the 100 * 100 m cells. The visualisation thereof allows for various subjective interpretations. For example, the monocentric structure of Kampala, the distinction of most actively used areas, green patterns and their dominance in the suburban areas as well as high-income central residential areas (Kololo) combined with low densities/proximities and higher ownership percentages, as well as a quite homogenous street grid according to the Space Syntax analysis. However, a detailed visualisation and interpretation of all maps would go beyond the scope of this chapter and are just partly important for the anticipated understanding of interrelations instead of individual thematic areas. This is the reason for its inclusion in the appendix (Annex 4, p. 74). Therein, some visual observations are described, together with the meaning behind the categories and calculation method if applicable.

4.2 Findings from data analysis

In the second step, several regression analyses are conducted. First, descriptive statistics are produced for the data of the whole city and the EARF corridors. Afterwards, the data is tested for correlations through the Pearson's r. The above-described regression models are carried out, and their simple and multiple linear regressions are conducted.

4.2.1 City-level analysis

First, the whole administrative city area is analysed. For this scale, the data exists only for 26 indicators which is the reason for some aggregated variables being incomplete and not sufficient to draw firm conclusions from them. However, mainly all of the Urban Form and Flooding Risk Exposure indicators are available and allow for general observations and findings from the regression analyses. However, to fully answer the stated research questions, the second part of the EARF research corridors is much more comprehensive and mostly better fitting to understand the concepts of Adaptive Capacity and Sensitivity and their interrelations with the existing Flooding Risk Exposure and Urban Form.

4.2.1.1 Descriptive Statistics

In the first step, descriptive statistics are conducted for all indicators of the city-level (Table 4-1, pp. 37-38). While the following analysis was conducted with the normalised scores, the descriptive statistics represent the actual values. While some indicator values have no distinct meaning (e.g., Space Syntax), distances are shown in metres and areas in square metres, while the ordinal data represents the categories and answers according to their connotation as stated in Annex 2 (p. 69).

N = 19867	***Mean***	***Std. Deviation***	***Minimum***	***Maximum***
Integration	0.05	0.05	0.00	1.00
Choice	0.02	0.05	0.00	1.00
Depth Distance	0.24	0.12	0.00	1.00
Connectivity	0.30	0.16	0.00	1.00
Dist. EconCentre	2692.80	1830.05	7.35	9352.78
Dist. Education	1052.65	569.35	73.32	3559.77
Dist. Health Facility	1063.03	630.56	12.14	3954.13
Dist. Bus Station	666.52	612.74	2.53	3717.96
Access Health	0.83	0.15	0.03	1.00
Access Schools	0.92	0.07	0.58	1.00
Street Density	0.31	0.19	0.00	1.00
No Buildings	17.36	18.333	0	132

SOI	0.38	0.47	0.00	14.83
Building Size	142.15	294.30	0.00	10682.80
Proximity	3.65	2.68	0.00	29.00
Green	8.40	2.62	0.00	15.96
Settlement Type	4.53	2.52	0.00	8.00
Flooding Risk	1025.87	402.55	0.00	1316.00
Flooding Distance	212.46	194.10	0.00	1094.74
Ownership	23.14	7.39	0.00	52.00
Internet use	1.02	0.06	0.00	1.60
Population Density	76.85	61.37	3.06	380.79
Female Population	0.53	0.04	0.28	0.77
Female-headed Households	0.31	0.0543	0.1	0.68
Floor Quality	0.56	0.10	0.13	0.70
Wall Quality	0.90	0.09	0.35	1.00

Table 4-1: Descriptive statistics for city-level (Author 2018)

After the normalisation of the scores, a Pearson's correlation test is conducted for all indicators (Table 4-2, p. 39). The blue values show positive correlations while the orange cells express negative correlations, coloured according to their strength based on the categories of Pearson's r -values. Strong correlations were mainly found in expected grouped indicators as, for example, the different accessibility scores (to economic centres, educational and health facilities, bus stations), the aggregated Space Syntax Scores or Street Density, or the Site Occupancy Index (SOI) and the number of buildings (NoBldgs). Despite that, further initial and counterintuitive observations can be drawn, e.g., that the Flooding Risk Exposure (FloodRisk) is higher if the accessibility to various facilities increases or that the percentage of owned property (Ownership) increases if the percentage of the female population (FemalePop) is higher. Furthermore, it becomes visible, that the subjective categorisation of settlement types (SetTypeREV, REV standing for a reversed score) undertaken by the EARF research project seems to be valid and represents major differences, as various correlations exist. Lastly, the newly introduced indicators of green percentage (GreenREV) and number of georeferenced tweets (InternetUse) seem to allow for several conclusion as well and therefore are promising for further use and more in-depth studies. For example, the percentage of green space decreases if the accessibility to facilities or proximity between buildings gets higher while the internet use decreases with better accessibility scores, a higher Space Syntax score and street density, while increasing in areas of a higher percentage of the female population.

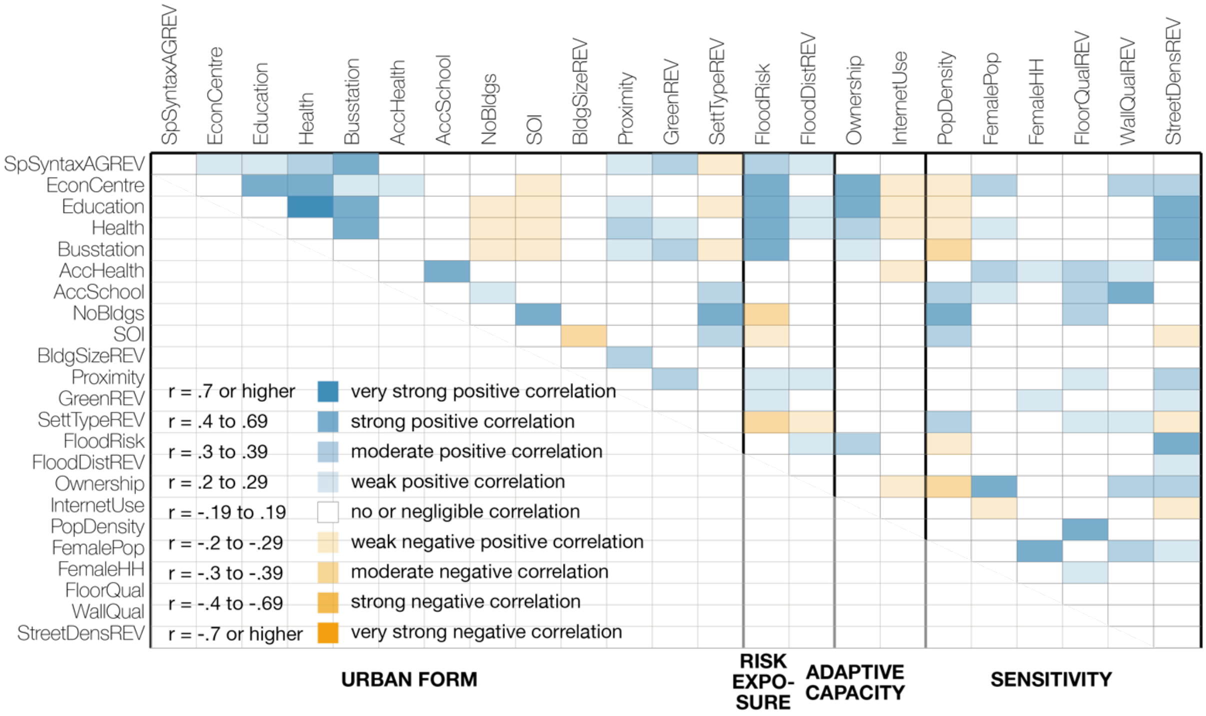

Table 4-2: Pearson's correlation at city-level (Author 2018)

4.2.1.2 Model C1: Social Vulnerability to Urban Form

In the first regression analysis, the compound score of Social Vulnerability was compared to the aggregated variable of Urban Form; testing the central hypothesis of this thesis. The findings show, that **Urban Form** (Ind. 1. AG) significantly correlates to **Social Vulnerability** (Risk Exposure (Ind. 2.1.1) + Sensitivity (Ind. 4. AG) - Adaptive Capacity (Ind. 3. AG)) (b = .088, t = 68.191, p < .001). Therefore, Urban Form explains a significant proportion of variance in Social Vulnerability ($R^2 = .19$, $F = 4650.055$, $p < .001$). In the below graphic (Fig. 4-1, p. 40), the variance of the normalised scores for both concepts can be seen. It shows the mono-centric character of Kampala combined with the aftermath of the spatial division of colonial times which will be further elaborated on in the discussion of the findings. Furthermore, larger areas with similar scores of both variables can be distinguished, which show the heterogeneous urban gestalt of Kampala's neighbourhoods.

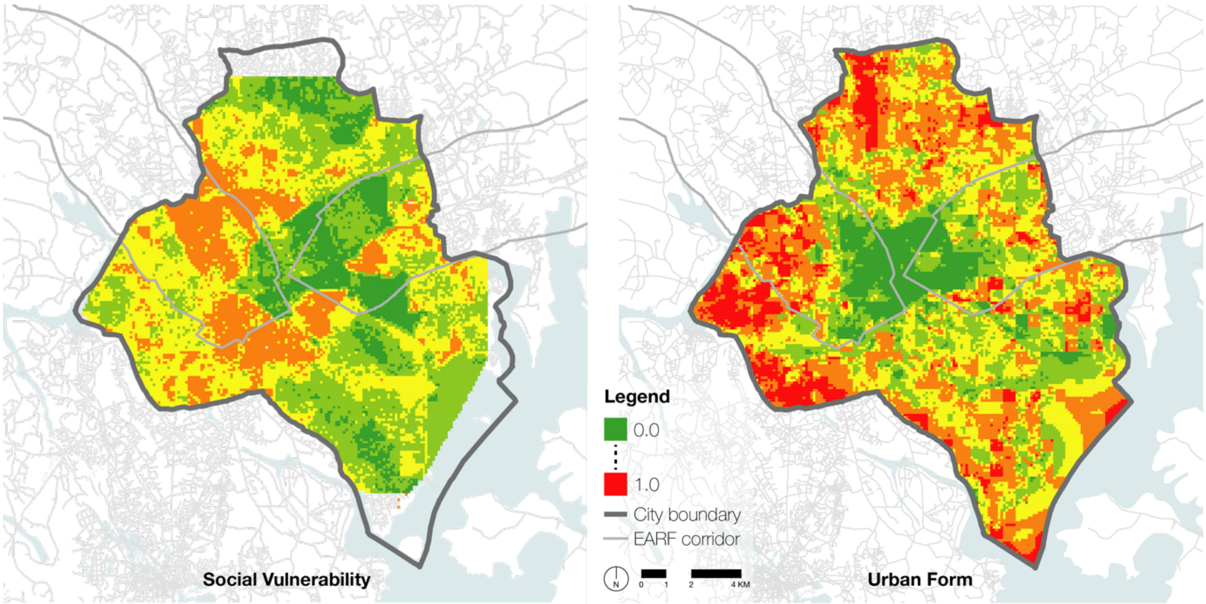

Figure 4-1: Scores Social Vulnerability (left) and Urban Form (right) (Author 2018)

4.2.1.3 Model C2: Urban Form to Risk Exposure, Adapt. Capacity & Sensitivity

In order to analyse the above-found correlation more in-depth, a simple linear regression analysis is conducted with the three constituting elements of Social Vulnerability. These are Risk Exposure (RE), Adaptive Capacity (AC) and Sensitivity (SE). Significant correlations could be found in all three cases, while the correlation for RE is the strongest, followed by AC and SE. The visual representation of their respective scores is shown in Fig. 4-2 (p. 41). It shows, that the flooding risk exposure is the highest in the catchment areas of the Lake Victoria in the southeast of the city, while the hilltops spanning the city centre are the least exposed areas and overlap with areas of higher AC and lower SE, as well as again being the old colonial prime commercial and residential area. The map of the AC shows the lowest values in the areas west of the city centre, as well as a corridor beneath the high-income residential area and location of most international organisations and embassies and some smaller enclosures in the western part. Mainly the lower values in the west around the higher-income areas can again be traced back to the initial spatial structure of the colonial times, where the inner city was for the rich and white community, surrounded by a strip of commercial buildings dominated by the Asian community and outside the black community.

	b	t	p	R^2	F	p
RE	.038	71.150	<.001	.203	5062.338	<.001
AC	.062	35.601	<.001	.06	1267.451	<.001
SE	.032	23.305	<.001	.026	543.127	<.001

Table 4-3: Correlations between Urban Form and three components of social vulnerability (Author 2018)

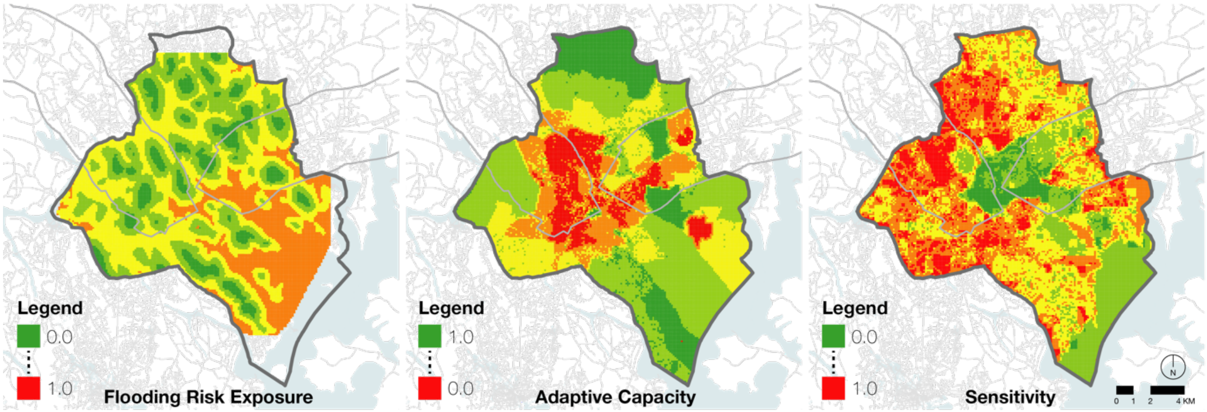

Figure 4-2: Scores Flooding Risk Exposure (left), Adaptive Capacity (middle) and Sensitivity (right) (Author 2018)

4.2.1.4 Model C3: Correlations Risk Exposure, Adapt. Capacity & Sensitivity

In the next step, a better understanding of the interrelations between the components of Social Vulnerability is anticipated. Therefore, three simple linear regressions are done between RE and AC, RE and SE, as well as AC and SE. The results showed that there are statistically significant correlations between all constituting parts. RE correlates to AC ($b = .803$, $t = 39.152$, $p < .001$) and explains a significant part of the variance ($R^2 = .072$, $F = 1532.871$, $p < .001$), while also correlating to SE ($b = -.261$, $t = -15.727$, $p < .001$) and explaining a smaller, yet significant variance ($R^2 = .012$, $F = 247.338$, $p < .001$). Lastly, AC correlates to SE, however with a very small factor and nearly no variance explained ($b = .017$, $t = 3.088$, $p < .005$, $R^2 = 0$, $F = 9.534$, $p < .005$). While this could be interpreted as an insufficient correlation despite the expected impact, it is more likely to be influenced by the small number of indicators in the variables of AC and SE on the city scale. Therefore, this part of the analysis becomes more interesting in the second part when the EARF corridors are examined.

4.2.1.5 Model C4: Urban Form to blocks

After looking at the effects of the various components in different scales, a multiple regression analysis is conducted to see how they contribute (starting from the strongest correlation) to the Urban Form variable individually and after adding the other components. This shows on the one hand, that while the correlations do not improve adding AC and SE improves the percentage of variance explained (from $R^2 = .203$ to $R^2 = .262$) and therefore still adds to the model's accuracy (see Table 4-4, pp. 41-42). If the complete model is used to apply the OLS-regression, the following formula results:

$$\textbf{Urban Form} = \mathbf{0.037*(RE) + 0.031*(AC) + 0.041*(SE) + 0.043}$$

However, as stated before, this part also becomes more interesting on the smaller scale of analysis due to more precise AC and SE scores.

	b	t	p
MODEL 1		$R^2 = .203$, $F = 5062.338$, $p < 0.001$	
RE	.038	71.150	<.001
MODEL 2		$R^2 = .220$, $F = 2796.805$, $p < 0.001$	
RE	.035	63.771	<.001
AC	.034	20.581	<.001
MODEL 3		$R^2 = .263$, $F = 2361.470$, $p < 0.001$	
RE	.037	69.261	<.001
AC	.031	19.307	<.001

SE	.041	34.110	<.001

Table 4-4: Models of multiple regression for Urban Form to three components of Social Vulnerability (Author 2018)

4.2.1.6 Model C5: Risk Exposure to individual indicators

In the last step, a more thorough analysis of the interrelations between RE and individual indicators follows. These indicators (Fig. 4-5, p. 42) were selected based upon the Pearson's correlations which were calculated in the beginning. This shows, that mainly in the infrastructure-related and accessibility indicators, strong correlations exist, which explain significant percentages of the variances. As higher the flood risk, as lower is the Space Syntax score as well as the street density, which means that there are less (primary) streets with lower a connectivity. Furthermore, the average distances to facilities are higher, while the number of buildings and the site occupancy indices are lower. Furthermore, in the case of higher flood risk exposures, the cells are greener, and the settlement types are on average lower, meaning more likely to be very low- or low-income. Additionally, the population density is lower while a higher percentage of buildings is owned than in areas of lower flood risk exposure.

	b	t	p	R^2	F	p
SpSyntaxRev	1.051	60.518	<.001	.156	3662.440	<.001
EconCentre	.769	79.660	<.001	.242	6345.695	<.001
Education	1.091	101.004	<.001	.339	10101.75	<.001
Health	.997	86.160	<.001	.272	505.666	<.001
Busstation	.836	71.121	<.001	.203	5058.226	<.001
NoBuildings	-.667	-44.756	<.001	.092	2003.140	<.001
SOI	-2.058	-30.952	<.001	.046	958.025	<.001
Proximity	.84	36.947	<.001	.064	1365.079	<.001
GreenREV	.460	35.876	<.001	.061	1287.088	<.001
SettTypeREV	-.302	-46.179	<.001	.097	2132.535	<.001
Ownership	.651	44.733	<.001	.092	2001.079	<.001
PopDensity	-.495	-38.437	<.001	.069	1477.427	<.001
StreetDensREV	.704	67.108	<.001	.185	4503.529	<.001

Table 4-5: Statistical values for correlation between Urban Form and individual indicators (Author 2018)

4.2.2 EARF-Corridor analysis

In the second section of the data analysis, only the two research corridors from the EARF research project area looked at. In this case, the data consists of all 62 indicators and can, therefore, provide a more detailed and comprehensive overview and allow to result in stronger conclusions compared to the city-level analysis above. This sub-chapter is structured in the same way as above, presenting the descriptive statistic and performing the same models, however extending them with a third model which looks in particular on marginalised groups and expected risk accumulation.

4.2.2.1 Descriptive Statistics

Firstly, descriptive statistics are calculated for the indicators of EARF corridors (Table 4-6, p. 43). Similar to the previous descriptive statistics, the data again represents the values pre-normalisation, and some values have numeric meaning (e.g., Space Syntax), but, e.g., distances are shown in metres, areas in square metres, and ordinal data according to the categories and answers possibilities (Annex 2, p. 69).

N = 4880	***Mean***	***Std. Deviation***	***Minimum***	***Maximum***
Integration	0.1	0.0	0.0	0.2
Choice	0.0	0.1	0.0	0.4
Depth	0.3	0.1	0.1	0.5
Connectivity	0.4	0.2	0.1	1.0
Dist. EconCentre	1,523.1	851.1	14.8	4,204.9
Dist. Education	766.6	333.0	73.3	1,921.5
Dist. Health	765.4	347.8	114.3	1,902.0
Dist. Bus Station	365.7	246.3	3.9	1,531.3
Access health	0.8	0.2	0.2	1.0
Access school	0.9	0.1	0.6	1.0
No buildings	23.7	19.8	1.0	132.0
SOI	0.5	0.6	0.0	14.8
Building size	167.8	202.3	0.0	4291.0
Proximity	4.3	2.3	1.5	27.0
Green	8.7	1.6	3.0	15.6
Settlement type	4.9	2.2	1.0	8.0
Flooding risk	1,191	28	1138	1316
Distance to flood- area	2,77.3	183.9	0.1	955.3
Hazard perception	1.1	0.4	1.0	3.0
Income range	4.0	1.3	1.0	8.0
Expenses	859,853	1,633,744	142,000	25,143,334
Plot area	1,385	2,364	2	18,211
Plot cost	34,505,685	67,113,638	3000	400,015,000
Current price	835,331,566	3,000,701,153	1000000	25,000,000,000
Relation to site	3.4	21.0	1.0	296.7
Ownership	20.4	7.2	0.5	38.0
Access Water	0.4	0.3	0.1	1.0
Access Sewer	0.4	0.3	0.1	1.0
Access Septic	0.7	0.3	0.2	1.0
Access Sanitation	0.7	0.3	0.1	1.0
Access Solar	0.4	0.3	0.1	1.0
Water access	1.3	0.4	1.0	4.0
Water quality	1.4	0.5	1.0	4.0
Years in location	2011	5	1982	2018
Initial location	3.0	0.9	1.0	6.0
Satisfaction	1.8	0.9	1.0	5.0
Relocation	2.9	0.9	1.0	5.0
Improvements	1.7	0.3	1.0	2.0
Improvements cost	27,637,885	71,697,746	50,000	500,000,000
Internet use	1.0	0.1	1.0	1.5
Education quality	3.0	0.7	1.4	5.8
Population density	98.5	67.7	3.8	380.8
HH-Size EARF	4.0	1.6	1.0	12.5
Female population	0.5	0.0	0.4	0.7
Female Population EARF	0.5	0.2	0.0	1.0
Age group	3.3	0.5	2.0	5.3
Female-headed households	70.2	5.8	48.7	86.1
Economic resilience	1.9	0.5	1.0	3.0
Employer	2.1	0.8	1.0	5.0
Occupation	2.8	1.6	1.0	9.0
Expropriation	2.8	0.4	1.0	3.0
Safety	2.3	1.1	1.0	5.0
Household affordability	2.1	0.8	1.0	5.0
Property restriction	0.8	0.2	0.3	1.0
Ownership type	2.1	0.5	1.0	4.0
Dwelling type	2.2	0.8	1.0	4.0
Dwelling material	1.1	0.3	1.0	3.0
Floor quality	0.9	0.1	0.4	1.0
Wall quality	0.6	0.1	0.1	0.7
Street density	0.4	0.2	0.0	0.8
Nearest road	2.5	1.0	1.0	5.0
Travel time	2.3	0.6	1.0	5.0

Table 4-6: Descriptive statistics for all indicators on EARF corridor level (Author 2018)

After these descriptive statistics, the data is again normalised, and a Pearson's correlation test is conducted (Table 4-7, p. 44). The blue values show positive correlations while the orange cells express negative correlations, coloured according to their strength based on the categories of Pearson's r -values. Various correlations were found, which can be distinguished in the table. Similar as to the city-wide analysis, the categorisation of settlement types by the EARF research team, as well as the new indicator of green space prove to be useful, while the indicator for internet use only shows slight negative correlations with the accessibility to economic centres and schools and therefore implies lower importance in further examinations.

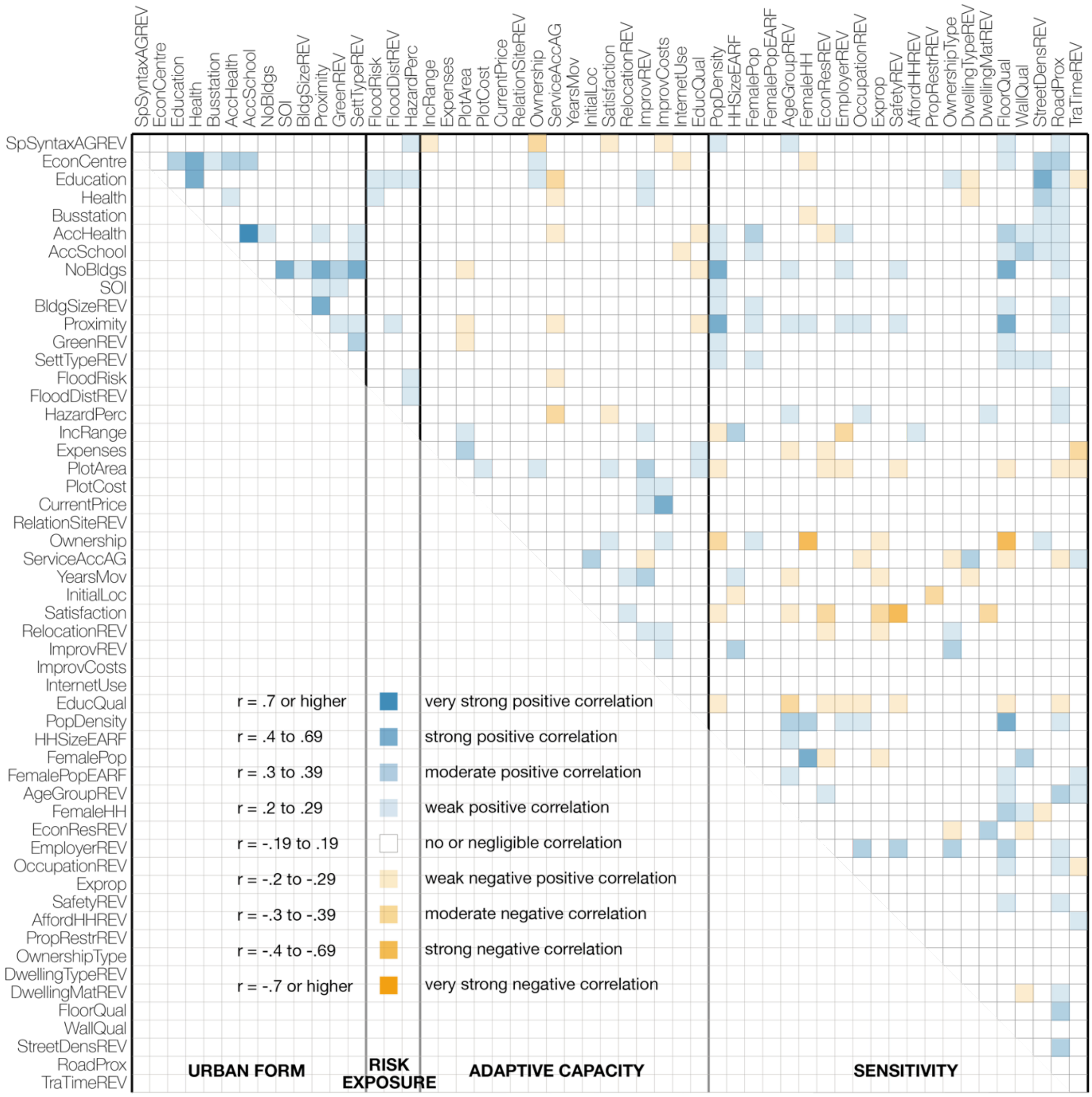

Table 4-7: Pearson's correlation inside EARF-corridors (Author 2018)

4.2.2.2 Model E1: Social Vulnerability to Urban Form

Afterwards, the first regression model on the EARF-scale is conducted, which looks at the correlation between Urban Form and Social Vulnerability. Similar to the model on the city-scale a significant correlation exists ($b = .5$, $t = 38.224$, $p < .001$), and explain a significant proportion of variance in Social Vulnerability ($R^2 = .23$, $F = 1461.048$, $p < .001$). However, this finding is, on the one hand, stronger than the finding on the city-scale while also being more representative due to the inclusion of all indicators. The maps below (Fig. 4-3, p. 45) show the values for both concepts inside the research corridors, while skipping areas which are mostly non-residential and have, therefore, not enough underlying data to be included and furthermore do not lie in the focus of this research. Similar observations can be as before, with the old, high-income area in the centre (south of eastern corridor) having the lowest Social Vulnerability and simultaneously the lowest compound score of Urban Form. The surrounding areas beneath, as well as the upper part of the western corridor, are again with lower scores in both variables. This finding itself theoretically answers the central research question, as a clear interrelation between Urban Form and Social Vulnerability is clearly visible and statistically significant correlated, however, the following regressions attempt to dismantle and quantify these relations further.

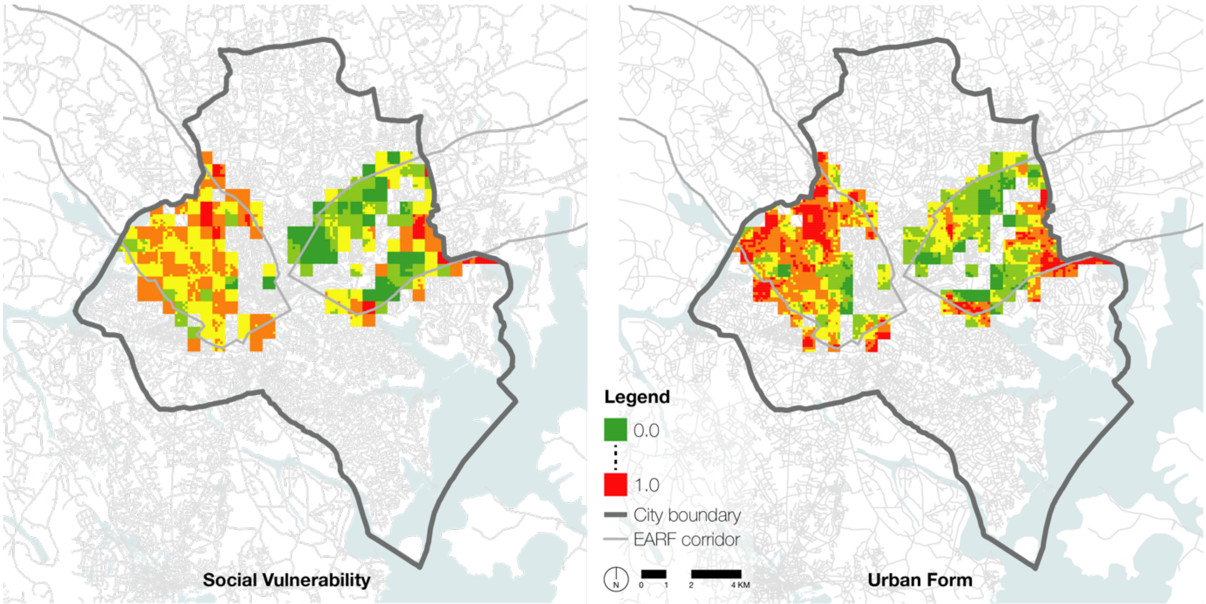

Figure 4-3: Scores Social Vulnerability (left) and Flooding Risk Exposure (right) (Author 2018)

4.2.2.3 Model E2: Urban Form to Risk Exposure, Adapt. Capacity & Sensitivity

In order to understand the above-described correlation better, a more detailed look into the correlations between Urban Form and the three components of Social Vulnerability is taken. This shows, that all three are significantly correlated (Table 4-8, p. 45), but vary in their strength and their percentage of explained variance. In this case, opposing to the study on city-level, the Sensitivity (SE) shows the strongest correlation with the highest R^2, followed by Adaptive Capacity (AC) and Flooding Risk Exposure (RE). One observation, which can be drawn, is, however, that Urban Form affects, or is affected, by all components. SE and RE increase while AC decreases in if the Urban Form value in increases, emphasising the existing correlation.

	b	t	p	R^2	F	p
RE	.212	10.107	<.001	.021	102.146	<.001
AC	-.323	-24.758	<.001	.112	612.969	<.001
SE	.374	37.828	<.001	.227	1430.974	<.001

Table 4-8: Correlations between Urban Form and components of Social Vulnerability (Author 2018)

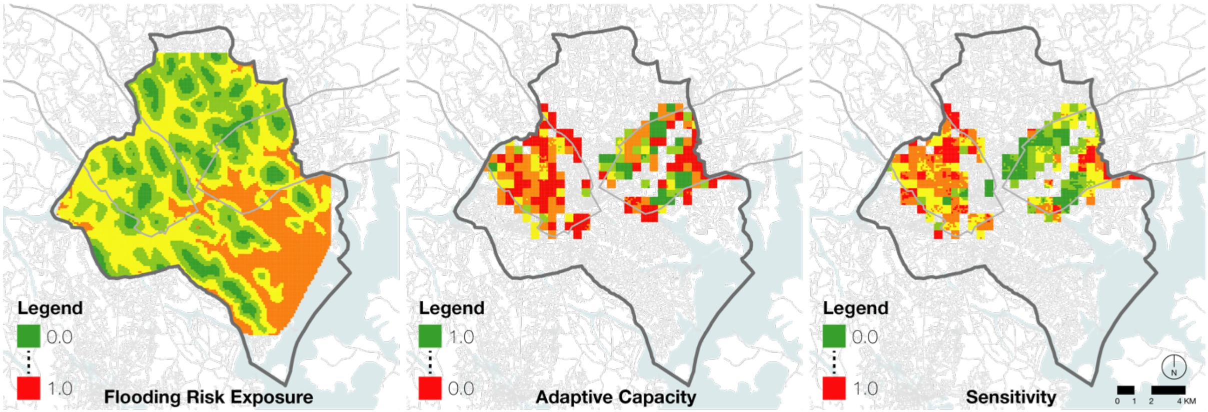

Figure 4-4: Scores Flooding Risk Exposure (left), Adaptive Capacity (middle) and Sensitivity (right) (Author 2018)

4.2.2.4 Model E3: Correlations Risk Exposure, Adapt. Capacity & Sensitivity

In the third model, the interrelations between the three components are studied again. RE to AC shows a small but significant negative correlation ($b = -.101$, $t = -11.000$, $p < .001$, $R^2 = .024$, $F = 120.995$, $p < .001$), meaning that the adaptive capacity increases if risk exposure decreases. At the same time, RE correlates positively with SE ($b = .074$, $t = 9.795$, $p < .001$, $R^2 = .019$, $F = 95.950$, $p < .001$). This means, that areas with the highest risk exposure have generally the highest sensitivity and lowest adaptive capacity. Lastly, AC correlates negatively the strongest with SE ($b = -.361$, $t = -34.518$, $p < .001$) and explains a significant percentage of the variance ($R^2 = .196$, $F = 1191.470$, $p < .001$). While does not give many additional information to the previous findings, it shows and quantifies the interrelations between the three components of Social Vulnerability.

4.2.2.5 Model E4: Urban Form and blocks

In order to test for the improvement of the model by adding each component, another multiple linear regression is carried out with the objective to result in a formula explaining Urban Form through OLS-regression analysis. In comparison to the city-level analysis, the strength of the components, and therefore also their inclusion in the three models is reversed. However, the result is the same, that the model improves if all three components are included. The resulting formula from the OLS-analysis is:

$$\textbf{Urban Form} = 0.317*(SE) - 0.141*(AC) + 0.096*(RE) + 0.359$$

	b	t	p
MODEL 1	**$R^2 = .227$, $F = 1430.974$, $p < 0.001$**		
SE	.374	37.828	<.001
MODEL 2	**$R^2 = .246$, $F = 794.178$, $p < 0.001$**		
SE	.321	29.438	<.001
AC	-.148	-11.041	<.001
MODEL 3	**$R^2 = .250$, $F = 540.973$, $p < 0.001$**		
SE	.317	29.017	<.001
AC	-.141	-10.464	<.001
RE	.096	5.130	<.001

Table 4-9: Multiple regression of correlations between Urban Form and three models (Author 2018)

4.2.2.6 Model E5: Risk Exposure to individual indicators

Furthermore, a closer look at some of the stronger (according to the Pearson's r) correlating individual indicators to RE is taken. In the case of Model E5, these are the accessibility to educational and health facilities, the perceived hazard risk, the aggregated indicator of access to basic services as well as the road proximity, meaning the perceived proximity to the next paved street by the household survey respondents (Table 4-10, p. 47. The results show that a higher risk exposure implies higher distance to educational and health facilities, as well as paved streets, while the hazard perception expectantly increases and the access to basic services decreases. Therefore, already supporting some aspects of the hypothesis of worse access to the city and its services in areas of higher risk, while introducing the last regression model which further looks at the anticipated effect of risk accumulation.

	b	t	p	R^2	F	p
Education	.291	20.859	<.001	.082	435.092	<.001
Health	.281	18.441	<.001	.065	340.076	<.001
HazardPerc	.171	14.746	<.001	.043	217.456	<.001
ServiceAccAG	-.123	-15.053	<.001	.044	226.580	<.001
RoadProx	.090	13.573	<.001	.036	184.217	<.001

Table 4-10: Correlations between Flooding Risk Exposure and individual indicators (Author 2016)

4.2.2.7 Model E6: Risk accumulation

In this regression analysis, the interrelations between the indicator of age group are tested for the strongest Pearson's correlations found at the beginning of this subchapter. The objective is to test for expected risk accumulation, meaning the overlap of several unfortunate characteristics, mainly for particular, marginalised groups like the youth which make up a vast majority in Kampala. Furthermore, the female population would have been interesting to study further. However, their disadvantage is more complex to quantify – a topic which will be further discussed below. Table 4-11 shows the various indicators which correlate with lower (!) age-groups. The findings are manifold, e.g. denser and higher populated areas, fewer expenses, years lived in the area, lower level of education, bigger household sizes, more females, less economic resilience, lower quality of floors and higher proximity to paved streets but at the same time longer travel times to reach school or work. This data can support the argument of the accumulation of risks for, in this case, the younger populations which are challenged in various ways through economic, social and spatial characteristics of their living environment and have fewer resources and (formal educational) knowledge to cope with them.

	b	t	p	R^2	F	p
SpaceSyntaxAGREV	.149	17.612	<.001	.06	310.182	<.001
NoBldgs	.152	16.743	<.001	.054	280.342	<.001
Proximity	.299	18.276	<.001	.064	334.013	<.001
HazardPerc	.2	17.021	<.001	.056	289-706	<.001

Expenses	-.324	-18.253	<.001	.064	333.165	<.001
YearsMov	-.152	-16.905	<.001	.057	285.783	<.001
Satisfaction	-.164	-21.142	<.001	.084	446.983	<.001
EducQual	-.264	-25,267	<.001	.116	638.408	<.001
PopDensity	.166	22.056	<.001	.091	486.477	<.001
HHSizeEARF	.187	16.951	<.001	.056	287.337	<.001
FemalePopEARF	.106	14.623	<.001	.042	213.846	<.001
EconResREV	.155	21.449	<.001	.086	460.044	<.001
FloorQualityREV	.210	18.608	<.001	.066	346.239	<.001
RoadProx	.178	27.922	<.001	.138	779.613	<.001
TravelTimeREV	.207	19.356	<.001	.071	374.657	<.001

Table 4-11: Correlations between reversed Age-Group and individual indicators (Author 2018)

4.3 Primary data collection

Additional to the collection of secondary data, qualitative primary data was collected during the field research. In total, 14 semi-structured expert interviews were conducted, and 13 people filled in an online weighting survey (Annex 3, p. 71). In the following, a quick overview of some of the interesting findings from the interviews is presented while the online survey for weighting is discussed afterwards.

4.3.1 Interviews

In this section, some of the outcomes of the semi-structured expert interviews are presented, which were conducted as part of the field work. The respondents were mainly urban experts from two academic institutions, the municipality KCCA, the Ministry for Land, Housing and Urban Development, intergovernmental organisations, as well as a few experts from related fields. While one of their central purposes was collecting and accessing the main data required for the quantitative research, their input could further be used for the triangulation and adaption of the methodology, understanding the roles of various involved actors, distinguishing some of the most affected areas (Bwaise, Kawempe, Maine, Kisenyi, Kalerwe, Nsoba, Ndeba, Natete, Kyanbogo, Queens Way, Namungona, Namasuba, Busega, Banda) and adapting the operationalisation accordingly. In the initial operationalisation, spreading of water-borne diseases was included, which was supposed to be measured through the number of cases in all health facilities in Kampala. However, it proved to be too spatially unprecise as the catchment areas of the clinics and hospitals are too generic or at least not understood and documented sufficiently. For example, one private clinic might be very close to an area with a high flooding risk exposure, but the affected people of that area would more likely visit a farther away public hospital due to financial reasons. Furthermore, mosquitos, as one main spreader, fly up to 5 KM and therefore can affect areas far away from flood-prone areas. Also, in some cases, interviewees questioned the impact of floods on water-borne diseases because of the short timespans of flooding which are not sufficient for breeding, however, others refuted this by stating the opposite: Floods in combination with uncollected solid waste – a common challenge in the lower-income, underserviced settlements of Kampala – can lead to water captured in small container which heats up under the sun and therefore provides even better breeding grounds. Therefore, disease-spreading was mainly seen as a secondary risk, but neither its spatial occurrence nor its possibility to measure with a sufficient level of detail does make it viable to be included in the research.

On the other hand, the above mentioned subjectively highlighted areas with frequent flooding events serve as another dimension of understanding the spatial distribution and test simultaneously the conducted research. While not all areas could be located perfectly and the below map (Fig. 4-5, p. 49) shows the administrative boundaries of the mentioned parishes instead of the actual location of floods, they support in both maps of Social Vulnerability and Urban Form the research method. In all ten parishes shown below (several are adjacent to each other), areas exist which have high values of Social Vulnerability and at the same time significantly built-up settlements.

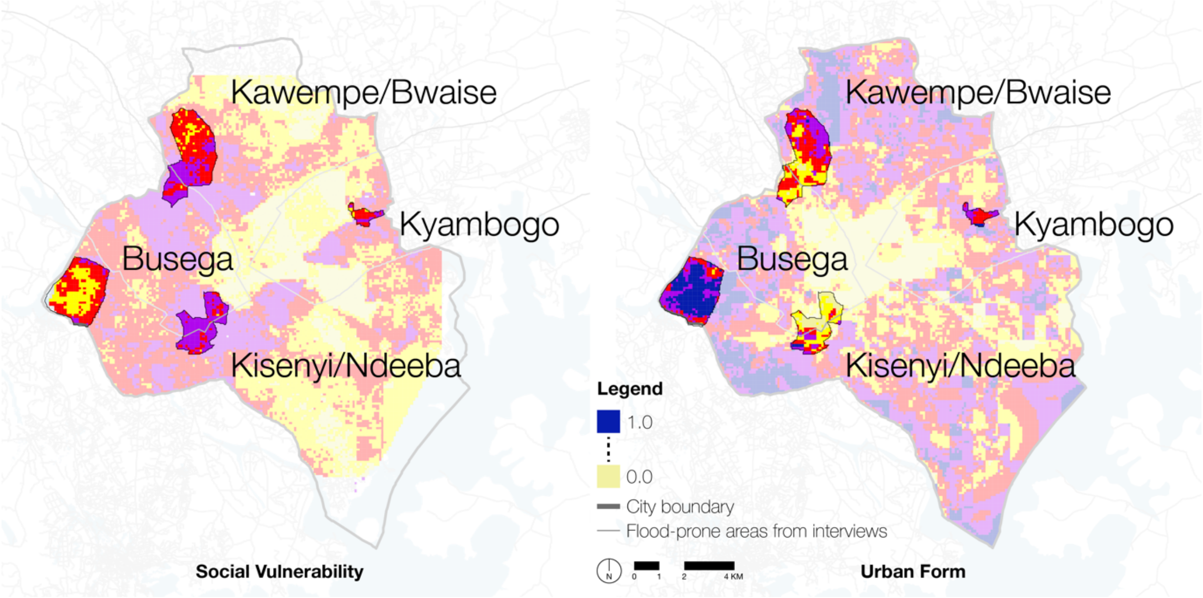

Figure 4-5: Flood-prone areas from interviews, compared to Social Vulnerability and Urban Form (Author 2018)

Lastly, several interviews went in the direction of discussing the responsibilities of various involved stakeholders, blaming back and forth between them, and the procedures which are or need to be undertaken to solve them. While this thesis does not imply to include the very complex political and institutional environment which is involved in the issue of flooding and its impact for the population, a few key takeaways still seem crucial and bear potential for further investigation. First, many areas which are repetitively affected by floods are designated flood-prone areas in which officially nobody is allowed to build, work, or live. However, on the one hand, many people live there already, and evictions or resettlements would require alternatives and would upset the population, mainly if they lived there as in many cases since a decade or longer. On the other hand, while several institutions are now involved in the approval of new projects including their encroachment on wetlands or other environmentally unsuitable plots, there is always a *financial* way to extend the active regulations according to individual's interest. Secondly, tenure rights and the complex land ownership in general in Kampala, which encompasses various types, including traditional land ownership models, make it difficult to address these issues as certain regulations would affect different groups of the populations unequally and lead to further injustice and societal discontent with the government, while it is also not sufficiently documented who owns what land, mainly outside the official city boundary which includes many areas of risk as well. This issue leads to the third aspect of insufficient data and understanding of the flooding risk, where and which people are affected in what scale and which measures would successfully counteract the flooding risks. However, the KCCA currently carries out two large-scale projects, namely the City Address Model (CAM) and Computer Aided Mass Valuation (CAMV), to improve the knowledge about ownership and land properties, at least in the administrative city. Lastly, financial restrictions hinder enhancements even in the cases of known adaptation measures like improved drainages. And if money is available, the areas where it would be most effective are often the areas which are officially designated as not suitable to live. Therefore, without being able to resettle the affected population, it is jurisdictionally contradictory to invest in those areas. These four aspects just represent a very small element of the complex environment. However, there seem to be many actions which aim to tackle the problem – both in the research and political-instrument dimension. However, even if the understanding improves and better tools become available, the constant growth and expansion outside the city and the very early stage of the larger administrative entity of the Greater Kampala Metropolitan Area, the challenges seem to still increase faster than the ambitions and opportunities to revert them.

4.3.2 Weighting Survey

While the weighting survey aimed at functioning as a basis for the aggregation process of the various indicators and concepts, it was decided to not use the results for mainly three reasons: First, the number of respondents was too low to justify a major alteration of the whole analysis. Furthermore, the variance between the respondents, even between experts of the same field and facility, was too high and therefore questions the validity of the approach as maybe either the structure and explanations of the used terminology lead to varying understandings. Or opinions are too individual to support the objective of finding a representative consensus between urban experts of Kampala. Lastly, the variance between the rating of some of the leading indicators and mostly the four central concepts was negligible and would in that cases not have had a significant impact anyway (Fig. 4-12, pp. 50-51). Thirdly, the process of working with the final data and being required to remove some indicators due to errors or insufficient reliability and adding others due to the process and grouping and aggregating them partly differently to the design of the questionnaire, finally eradicated any justification of using the collected data to tamper with the results of the research.

However, interesting results were collected by the additional comments of participants to the open-ended questions which support the interpretation and further strengthen the triangulation of the data. Furthermore, two indicators (No. of rooms in buildings and religious institutions sensitivity) received very low weights, supporting their removal which was already anticipated as a result of the interviews and the quality of the respective data.

Indicator	Weight
Elevation of location	4.7
Slope of location	4.5
Location in watershed	5.4
Disaster occurrences in last 2 years	4.1
Household income	5.3
Years lived in area	4.3
Perception of risk	4.4
Level of tenure 'formality'	4.1
Internet use (number of online posts)	1.4
Level of education	3.1
Population density	5.1
Gender distribution	2.1
Age distribution	2.9
Built floor quality	3.6
Built wall quality	3.9

No. of rooms (therefore removed)	1.9
Road sensitivity	4.1
Water provision sensitivity	3.3
Educational facility sensitivity	3.1
Health institution sensitivity	3.9
Religious institution sensitivity (therefore removed)	1.9
Centrality	4.3
Integration of road segments (Space Syntax)	3.9
Probability that road is used (Space Syntax)	4.0
Number of times road is used (Space Syntax)	3.6
Accessibility to economic centres	5.0
Accessibility to educational facilities	3.9
Accessibility to health institutions	4.1
Accessibility to public transport nodes	5.0
KM of primary road per square kilometre	3.0
KM of secondary road per square kilometre	2.9
Number of road nodes per square kilometre	3.3
Building density	5.6
Site occupancy index	5.0
Average plot size	4.4
Average building size	4.0
Building proximity to each other	4.4
Percentage of green space	3.3
Percentage of mixed-use functions	3.1
Predominant type of settlement (high-/medium-/-low income)	4.7
Risk exposure	5.4
Adaptive capacity	4.9
Sensitivity	4.4
Urban Form	5.3

Table 4-12: Weighting according to online survey

4.4 Discussion of Findings

In this last section, a short discussion of some of the findings concludes this chapter. This part is mainly constituted of the aspect of apparent remnants of the colonial urban structure and its presumably still visible consequences on spatial injustice, as well as the role of the female population and their possible disproportionate distress due to flooding.

Regarding the consequences of racial-spatial segregation during the colonial times, maps of social vulnerability today and more in-depth the flooding risk exposure, which should not have changed significantly since then, give a better perspective. On the below-shown maps (Fig. 4-6, p. 52) different residential areas of the three racial classifications from the structure plan of 1951 are visualised (Kendall 1955 in Omolo-Okalebo 2011). The green boundaries show the settlements of "African" settlers, which are mainly outside the centre and either autonomous or connected to an "Asian" settlement. The latter (pink) surrounds mainly the "European" areas and was often described as a kind of protection or buffer between the "European" and "African" residents. The blue outlines represent the "European" area and constitute the past's and today's centre of Kampala. Several observations can be made: Firstly, the "European" areas are the most central and mainly on hilltops with, according to this research's classification, very low social vulnerability scores. The "African" areas, however, are not adjacent to the "European" settlement, mainly in lower lying areas which have higher flooding risk exposures and have still today much higher social vulnerability scores, while partially overlapping with some of the subjectively defined flood-prone areas. One exception of the "African" settlements is a small area in the north of the central "European" shape, which might be related to the Luganda Kingdom which also today inhabits one of the hilltops in Kampala. The "Asian" settlements are somewhere in between, spatially as well as regarding their exposure to flooding risks and their social vulnerability scores. While this is a secondary observation and just applies to a small portion of today's city, the overlap is apparent and shows the origin of the spatial segregation and injustice in relation to flooding risks, the sensitivity as well as the ability to cope with it.

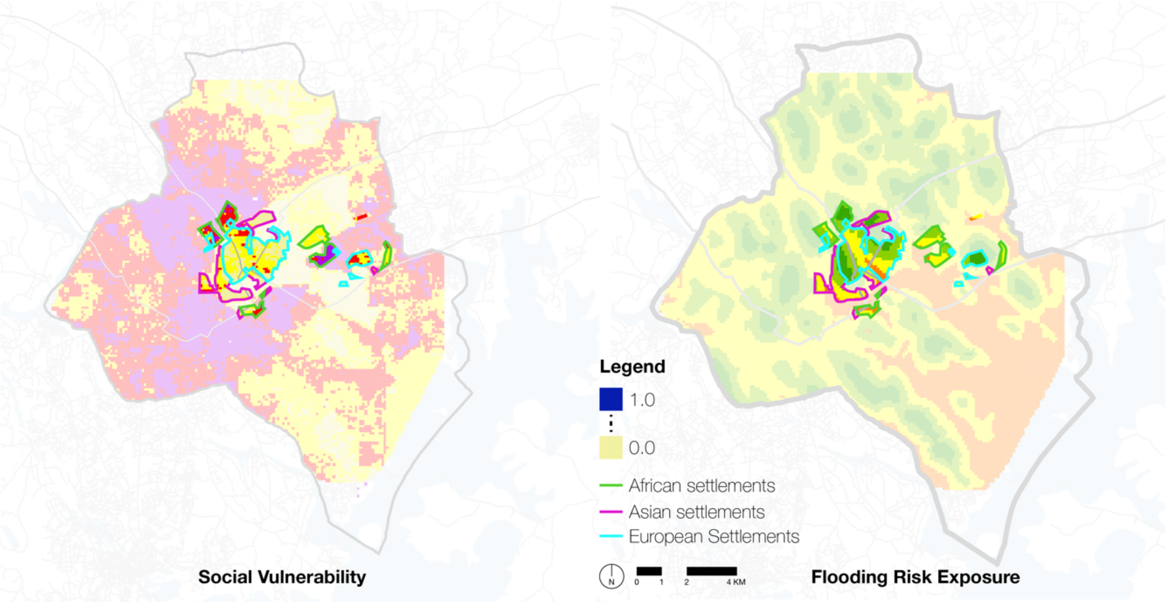

Figure 4-6: Maps of Social Vulnerability and RE overlaid with historical racial segregation of residential areas in 1951 (Author 2018, based on Kendall 1955 in Omolo-Okalebo 2011)

Lastly, a quick discussion of females as a marginalised group concludes the findings. While few statistically significant correlations could be found which also are partly correlate in the opposite direction as expected based on the theory review (e.g., better access to schools and health facilities, higher economic resilience, lower risk of expropriation, higher wall quality), some expected correlation exist as well (e.g., smaller buildings, more likely to live in very low- or low-income settlement). However, the findings are too weak and ambiguous to draw conclusions from. Furthermore, a higher female population does not imply that the female population lives by themselves or is part of larger families with a male household head. The indicator of female-headed households considers this and leads to small correlations between higher values to, amongst others, lower accessibility to economic centres and bus stations, lower street densities, much lower ownership rates, as well as higher population densities. However, the correlations and underlying data vary too much to prove the disproportional sensitivity to flooding risk exposure. However, it shows some plausible interrelations and does not conclude in no marginalisation but instead asks for more focused, qualitative and individualistic analyses of the role and effect of floods on women.

Chapter 5: Conclusions and Recommendations

The thesis tried to tackle the question if and how floods shape Kampala's urban gestalt. The central objective of this research was to quantify and understand the interplay between the socio-spatial urban dynamics and climate change-related risks better, as well as how it promotes or reduces spatial injustice. Hence, a more detailed look was taken at flood-related hazards as the most critical risks of urban Kampala. In particular, the flooding risk exposure, adaptive capacity of the population, as well as the sensitivity of the society and built environment was measured and contrasted with Urban Form, to provide new perspectives and understandings on how inequalities are enforced, counteracted or interrelated with spatial characteristics.

The primary objectives were, therefore, to measure the threat of climate change consequences and more specifically of flooding on urban residents, to improve the understanding of Kampala's urban form as well as the spatial distribution of risk exposure, adaptive capacity, and sensitivity as the elements of social vulnerability, quantify advantages and disadvantages for urban populations in different locations and it's assumed manifestation in spatial injustice for the already most vulnerable groups.

The broader hypothesis of the findings was that the residents of the most flood-prone and climate change risk affected areas are already the most marginalised and therefore suffer even more, reinforcing the spatial injustice in Kampala. Furthermore, it was expected that the spatial characteristics (urban form) are negatively affected by the existing risks while at the same time also increasing the vulnerability of those areas. Lastly, specific marginalised groups were expected to be more at risk than others. While the first two general statements are supported by the results of this study, as it will be shown below in the responses to the research questions, the last aspect of marginalisation could partly be quantified, however, requires further and more in-depth studies to conclude in a solid outcome. Lastly, very few unexpected results could be established. Mainly some smaller correlations, like a generally better quality of the buildings (floor and wall quality) in areas with higher female population, as well as higher property ownerships in areas with higher risk. While the first finding is just partly fruitful, as the applied method does not build upon sufficient data of gender aspects, and the reduction to solely numeric information for a complex topic like this seems insufficient, the second finding could have various explanations resulting from the expert interviews and underlying data: Mainly, the different and intertwined land ownership systems in Kampala were not included in the data of ownership and can therefore mean that the population in the more flood-prone areas had indeed more likely one type of ownership which, however, is more likely to be an informal and undocumented one, while these types are rarer in the officially integrated and planned areas. Furthermore, property investments and renting make up a significant percentage of the overall land markets in Kampala, which is, however, more prevalent in the higher-income and value areas with much less interest of investments of lower value and simultaneously the risk of potential property destruction due to floods. Despite these smaller findings, the central results are discussed individually below as answers to one of the following research questions. As the four supplementing research questions (RQ) are seen as steps to answer the overall question, the central RQ is answered in the end.

RQ1: How can exposure to flooding risks be quantified in small spatial resolutions in contexts of limited data availability?

The first research question concentrates mainly on the methodological part of quantifying flooding risks. The exposure itself was done for previous research through a combination of elevation, slope, and distance to flood-prone areas. However, it seemed to not sufficiently differentiate between varying levels of exposure. Hence, the hydrology tool of ArcGIS was applied to the DEM and led to a more elaborate scale of flooding risk exposure, incorporating the full topography instead. However, this model could have been improved through more detailed precipitation data, soil types and ground coverage, as well as an inclusion of the effect of existing drainage systems on the water flows – four components which either did not exist or had an inadequate spatial level of detail. However, due to the crosscheck with the flood-prone areas defined by the KCCA, the natural stream location and the input of the most affected locations through the interviews, a high validity should have been reached and showed that easily accessible or generatable information for most places, like the DEM, can account for the majority of actual flooding exposure in cities.

RQ2: Which characteristics of Kampala's Urban Form can be quantified and how do they influence or are affected by social vulnerability and its components, risk exposure, adaptive capacity and sensitivity?

The second question extends the major quest of quantification to the variable of Urban Form, and how it correlates to Social Vulnerability and its components, therefore, building upon the previous question. Several simple analyses could be conducted through basic tools of ArcGIS and QGIS, based upon openly accessible information from Open Street Maps, aerial photos or published reports and scholarly articles. However, one major limitation is often the insufficient detail of building outlines and their heights, with the latter mainly limiting the comprehensiveness of the viable indicators in Kampala. Nevertheless, this challenge could partly be overcome by the combined use of several information layers from different sources, but still bears much potential for improvement and extension over time.

The resulting compound score of Urban Form seems to be representative enough, despite the limitations, as various correlations between Urban Form and Social Vulnerability as well as its components of Flooding Risk Exposure (RE), Adaptive Capacity (AC) and Sensitivity (SE) could be established. While these correlations exist in both scales, the focus here will be on the EARF research corridor level, as the data consists of more than twice as many information and is therefore much more comprehensive, mainly in the variables of AC and SE. Between Urban Form and Social Vulnerability a quite strong and significant correlation exists, proving that there is a strong effect between them. If the Urban Form score[4] increases from, e.g., 0.2 to 0.6, the Social Vulnerability score rises from 0.2 to 0.35 and vice versa ($t = 38.224$, $R^2 = .23$, $F = 1461.048$, $p < .001$). In the case of the components of Social Vulnerability, an increase of the Urban Form score from again 0.2 to 0.6 leads to a rise of the RE from 0.2 to 0.285 and SE from 0.2 to 0.35. AC on the other would decrease from 0.2 to 0.07.

RQ3: What interrelations exist between the constituents of social vulnerability?

Furthermore, the interrelations between the elements of Social Vulnerability were examined to understand the effect they have on each other and test Engle's (2011) concept of increasing adaptive capacity leading to decreasing risk exposure and sensitivity. Again, the focus is on the analyses on EARF-level due to its better representation of reality. RE correlates significantly with AC and SE: An increase of the RE-score from 0.2 to 0.6 leads to a decrease of AC from 0.2 to 0.16 while SE would only rise from 0.2 to 0.22. The correlation between AC and SE is numerically stronger and would lead to a decrease of SE from 0.2 to 0.14 if AC increases from 0.2 to 0.6. However, the comparability of the strength of these changes of scores is restricted by the importance of the minimum and maximum scores as part of the normalisation process and by itself not representative. However, it shows that AC is lower and SE higher in areas with a higher RE – supporting the initial presumption again. The theory of Engle (2011) can just be partly proven, as SE decreases when AC increases, but while the RE is lower in areas of higher AC, it cannot support the direct influence, as this would require on the one hand a temporal study to see impacts of changing scores, while also requiring a measurement method for RE which allows for changes according to, e.g., the drainage infrastructure instead of the

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[4] Scores mean normalised values between 0.0 - 1.0

applied method of merely measuring the water flow based on the mainly unchanged topography of Kampala.

RQ4: How is spatial injustice in Kampala manifested through the spatial distribution of urban form and social vulnerability?

Finally, the last supplementing research question addresses the broader concept of spatial injustice and how it is manifested through the studied concepts. Therefore, a general comment about the approach and the numeric results is necessary: While the above-reported numbers prove the general hypothesis of a significant interrelation between the elements as mentioned earlier, they, of course, have a margin of error and do not always apply. Furthermore, no numeric conclusion can be drawn on which variable is *dependent* and which *independent*, as there is no simple *"this-leads-to-that"* situation. Instead, according to the literature review, interviews and observations, the studied interplay is highly complex, and its constituents can initiate, reinforce, attenuate or even reverse their counterparts. For example, the risk exposure is higher at one particular location, therefore the property values are lower and people with fewer economic resources and simultaneously often less formal education move there, build houses of lower quality, therefore reinforcing their sensitivity, and creating different, mainly more dense spatial environments, with less space for formal infrastructure. At the same time, their location is less fortunate, and their interests are often underrepresented, which leads to lower accessibilities to basic services and longer times to commute to work. This interplay is much more complex, however, highlights the vicious cycle which reinforces itself and is hard or even impossible to break under the current circumstances (compare to Hardoy and Pandiella 2009, as introduced in chapter 2.4). One quite constant factor, at least under the applied assessment approach, is the flooding risk exposure, which stays the same at any location and just generally increases over time due to the higher and more frequent precipitation events. Therefore, the resulting spatial injustice through lower adaptive capacity and higher sensitivity is mainly not induced due to changes of flooding risk exposure, but instead, lead to the location and spatial concentration of residents with specific characteristics in the beginning. And Urban Form, on the other hand, is also a factor which developed over a long time and works two-directional. Lower adaptive capacity comes, amongst others, from fewer resources, including smaller plots and buildings, while the high-income residential settlements are situated on hilltops, therefore are exposed to less or no flooding risks, and simultaneously have bigger plots and buildings, as well as lower densities. Also, to fully understand these dynamics, a single snapshot of the current situation just gives a very limited answer to the questions of the manifestations of spatial injustice.

As already introduced in the above chapter, many dimensions of Kampala's current spatial injustice originate from the colonial times and the accompanying spatial structure. Uganda's capital did not grow to become a spatially unjust city but has always been one and was planned as one from the beginning (see Omolo-Okalebo 2011). While the injustice in the past was originating from racial segregation, today it is mainly between different income groups, while the "European" and "Asian" part of the population, even if today constituting much smaller percentages of the overall population, is still much less affected due their predominant belonging to the higher-income class. Climate change-related risks and floods in particular, as well as the according, different measured variables of urban form and social vulnerability, are therefore not the direct reason for the unjust distribution of (appropriate) land and access to the city, but mainly reinforce spatial injustices which were initially drawn out over a century ago. To best describe the consequences for the most affected, marginalised and vulnerable urban population, it makes sense to go back to the literature and introduce the concept of the capability approach. Initially developed by Amartya Sen (1979) and further specified by Nussbaum (2003), the capability approach builds upon the idea of liberalism and attempts to define justice not as the same situations for everyone, regardless of its embodiment, but rather that everyone should have the same capabilities. As Fainstein states it in the context of just cities:

> *"Capabilities do not describe how people function (i.e., end state) but rather what they have the opportunity to do. One need not exercise one's capabilities if one chooses not to, but the opportunity must be available, including a consciousness of the value of these capabilities" (2010, p. 55).*

This way of defining or measuring justice, or in this case injustice, goes well together with the above-described situation. On the one hand, the current distribution of risk exposure and resources is unjust, while the underlying problem and injustice is less about the current moment but the temporal development and the accompanying and rising differences of capabilities which would be necessary to change the individual's situation or break the vicious cycle – mostly due to being a fundamental and historically embedded ingredient of Kampala's spatial structure. And the flooding risks – in the past as well as today – as well as the accompanying sensitivity and limited adaptive capacity, are a critical and life-endangering element of it – but still just one of many in a complex, interwoven, but clearly unjust urban environment.

Central RQ: How are urban form and flood-related social vulnerability interrelated in urban settlements of Kampala?

To come back to the central research question and also referring to this paper's title *How floods shape Kampala's urban gestalt*, a quite clear perspective should have evolved out of the previous answers: Urban form, regardless of looked at in the macro-scale of, e.g., city-wide accessibility or micro-scale of, e.g., building sizes, is strongly influenced by and reciprocally influences flood-related urban risks and social vulnerability in the whole. However, while the correlation to urban form in the macro-scale emerged mainly from historical patterns and unjust land distribution and accessibility, the meso- and micro-scale characteristics are more of a consequence of the part of urban society, who chooses to live, or better has no other option than to live in areas with already high risk-exposures and insufficient service and facility access.

To wrap it up, this research could support some of the previous assumptions of disproportional spatial distributions of lower-income groups, the youth and up to a certain degree the female population, associated with, e.g., lower accessibility to facilities, lower quality of housing or smaller houses with lower values and higher risks of expropriation, some expected correlation could not be proved. However, this does not mean that they do not exist and are part of the challenge but highlight the need to study Kampala's dynamics more in detail. The methodological approach which was developed and applied in this research, as well as the development of more indicators which are less data- and work-intensive could provide salutary findings if repeated in frequent intervals and the larger functional urban area. Also, data accessibility proved to be crucial and a major challenge for researchers working in similar contexts. On the one hand, it is difficult to find out what exists and on the other hand where and to access it.

Most of the challenges and findings as mentioned above should be able to provide a valuable and more spatially accentuated picture of the urban form of Kampala's diverse settlement as well as the distribution of exposure to flooding risk and the severity of potential disasters as well as the largely differing ability to cope or respond to it. This spatial understanding should be able to provide more empirically information on the scale of challenges as well as where and in which sectors interventions or further studies would be bear the highest potential. Furthermore, while the numeric relationships do not mean that one value can be simply calculated or assumed based on one of the others, but instead they provide a way of measuring, e.g., the development over time, or quantify the success of intervention projects. Lastly, on a larger scale, the research did not result in findings which were utterly unexpectable or differ from major academic concepts. However, they should be able to support some by proving them in the specific and profoundly affected case of Kampala, while also providing an innovative and more spatially-detailed approach to visualise, measure and compare it – while being heavily based on existing approaches.

5.1 Further Research

While this research should have been able to quantify some of the interrelations of flooding risks, urban form, adaptive capacity and sensitivity, the methodological approach could in several ways be improved, and some limitations eradicated. Generally, whenever more or more detailed data becomes available, the model could be improved. Most importantly, it would be very promising to conduct similar research including the data which the KCCA currently collects as part of the addressing and property evaluation program (CAM and CAMV). This data shall include the functions of buildings, the gross floor area, plot areas and estimated values, combined with an extended city-wide household survey. Also, the extension to the GKMA would be substantial on a long-term, as it incorporates many areas which highly depend on the city of Kampala and would spatially constitute a part of the overall urban fabric. Furthermore, a more advanced flood exposure model would increase the level of detail. Possible ways would be the incorporation of soil types and their retention potentials, as well as the ground coverage through impermeable surfaces and the quantity, quality and location of the drainage system. Lastly, after the completion of the EARF research project, a more qualitative study on the ownership and land tenure dynamics could benefit the understanding of the impact of flooding exposure on economic and legal parameters. Also, a more qualitative analysis of the most interesting found correlations, mainly the seemingly higher property ownership percentages in areas of higher risks and the likely more vulnerable role of marginalised groups like women and the youth. Furthermore, in-depth studies of highlighted locations could benefit a deeper understanding of the interrelations in the case of Kampala. Potential candidates would be the areas which were highlighted by the interviewees and survey respondents as well as the areas which were in the past defined as settlements for specific racial groups – a selection which goes well together.

Despite the extension with more data, it would be interesting to see to what findings the same method would come in cities of similar socio-economic and environmental characteristics and up to what scale generalisations or quantifiable comparisons can be made. This could possibly prove some of the found correlations, while it could test the indicators of green percentage and internet use through tweets as possible ways to assess or replace different indicators through easier ways.

5.2 Recommendations

Based on the findings and the potential fields of further research, several recommendations can be made. First and foremost, the found correlations could benefit the ambitions of the KCCA and Ministry of Lands, Housing and Urban Development to reduce floods and their impact on the population in two principal ways. On the one hand, parts of the methodology (improved and extended) could function as a monitoring system to better understand the changes over time and how different parameters of social vulnerability develop in small spatial scales.

Secondly, as some of the interviews, as well as the responses from the online questionnaire on the weighting showed, the marginalisation by age and gender is often underestimated while seemingly having a significant impact. Therefore, it would be advisable to put these challenges higher on the agenda of the discourse and develop better support and capacity building approaches, explicitly focused on the youth and female population.

Lastly, the process of this research showed how difficult the acquiring of suitable data is but at the same time, what can be done even with a limited amount. Therefore, it is highly advisable to improve the information on what data is available, where and how it can be accessed or in an optimal case even provide possibilities to access more easily, e.g., through an online platform. While this recommendation addresses mainly the governmental institutions, it applies in the same way to public and private organisations and academic facilities. Data cannot describe the complexity of the urban realities, but it can provide a foundation to a better comprehension – something urgently needed to work against the rising injustice as well as the rising climate change consequences. More openness and cooperation would allow for more progress in academia and development projects, regardless if governmental or non-governmental, and would be one step in the right direction.

Bibliography

Adger, W. N., 2006. Vulnerability. *Global Environmental Change*, 16, pp. 268-281. Available at: https://doi.org/10.1016/j.gloenvcha.2006.02.006 [Accessed 15 April 2018].

Adger, W. N. et al., 2007. Assessment of adaptation practices, options, constraints and capacity. *Climate Change 2007: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, pp. 7171-743. Available at: http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter17.pdf [Accessed 17 April 2018].

Adolphe, L., 2001. A simplified model of urban morphology: application to an analysis of the environmental performance of cities. *Environment and Planning B: Planning and Design,* 28, pp. 183-200. Available at: http://journals.sagepub.com/doi/abs/10.1068/b2631 [Accessed 11 April 2018].

Althor, G., Watson, J. E. M. and Fuller, R. A., 2016. Global mismatch between greenhouse gas emissions and the burden of climate change. *Scientific Reports*, 6. Available at: https://www.nature.com/articles/srep20281 [Accessed 10 April 2018].

Anaba, L. A. et al., 2017. Application of SWAT to Assess the Effects of Land Use Change in the Murchison Bay Catchment in Uganda. *Computational Water, Energy, and Environmental Engineering,* 6, pp. 24-40. Available at: http://dx.doi.org/10.4236/cweee.2017.61003 [Accessed 11 April 2018].

Bartlett, S., 2008. Climate change and urban children: impacts and implications for adaptation in low- and middle-income countries. *Environment and Urbanization*, 20 (2), pp. 501-519. Available at: http://journals.sagepub.com/doi/abs/10.1177/0956247808096125 [Accessed 11 April 2018].

BenBella, D. E., 2016. An Evaluation and Analysis of urban Expansion of Kampala from 1995 to 2015. Master thesis at Department of Geography and Environmental Resources, Graduate School Southern Illinois University Carbondale. Available at: http://cola.siu.edu/geography/_common/documents/papers/benbella.pdf [Accessed 11 April 2018].

Brecht, H., Deichmann, U. and Wan, H. G., 2013. A Global Urban Risk Index. World Bank: Policy Research Working Paper 6506. Available at: http://documents.worldbank.org/curated/en/804651468331205546/A-global-urban-risk-index [Accessed 11 April 2018].

Brooks, N., 2003. Vulnerability, risk and adaptation: A conceptual framework. Tyndall Centre for Climate Change Research: Working Paper 38. Available at: https://www.researchgate.net/publication/200032746_Vulnerability_Risk_and_Adaptation_A_Conceptual_Framework [Accessed 11 April 2018].

Cadag, J. R. D. and Gaillard, J.C., 2011. Integrating knowledge and actions in disaster risk reduction: the contribution of participatory mapping. *Area*, 44 (1), pp. 100-109. Available at: https://doi.org/10.1111/j.1475-4762.2011.01065.x [Accessed 10 April 2018].

Cannon, M., 2014. Uganda Vulnerability Index Assessment Results. USAID. Available at: https://www.fews.net/sites/default/files/documents/reports/UG_zonedescriptions_en.pdf [Accessed 14 April 2018].

Cardona, O.-D. et al., 2012. Determinants of Risk: Exposure and Vulnerability. In: Field, C. B., 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge: Cambridge University Press, pp. 65-108.

Cavan, G. et al., 2014. Urban morphological determinants of temperature regulating ecosystem services in two African cities. *Ecological Indicators*, 42, pp. 43-57. Available at: https://doi.org/10.1016/j.ecolind.2014.01.025 [Accessed 11 April 2018].

Dadashpoor, H. and Rostami, F., 2017. Measuring spatial proportionality between service availability, accessibility and mobility: Empirical evidence using spatial equity approach in Iran. *Journal of Transport Geography*, 65, pp. 44-55. Available at: https://doi.org/10.1016/j.jtrangeo.2017.10.002 [Accessed 11 April 2018].

Dave, S., 2010. High Urban Densities Developing Countries: A Sustainable Solution? *Built Environment*, 36 (1), pp. 9-27. Available at: http://www.jstor.org/stable/23289981 [Accessed 11 April 2018].

Dickson, E., Baker, J. L., Hoornweg, D. and Tiwari, A., 2012. Urban Risk Assessments: Understanding Disaster and Climate Risk in Cities. International Bank for Reconstruction and Development, The World Bank. Available at: http://documents.worldbank.org/curated/en/659161468182066104/pdf/709820PUB0EPI0067926B09780821389621.pdf [Accessed 15 March 2018].

Dimanin, P., 2012. Exploring livelihoods of the urban poor in Kampala, Uganda: An institutional, community, and household contextual analysis. Action Contre la Faim. Available at: http://www.actionagainsthunger.org/sites/default/files/publications/Exploring_livelihoods_of_the_urban_poor_Uganda_12.2012.pdf [Accessed 11 April 2018].

Dobson, S., Nyamweru, H. and Dodman, D., 2015. Local and participatory approaches to building resilience in informal settlements in Uganda. *Environment & Urbanization*, 27 (2), pp. 605-620. Available at: https://doi.org/10.1177/0956247815598520 [Accessed 11 April 2018].

Dodman, D., Soltesova, K., Satterthwaite, D. and Tacoli, C., 2015. Understanding the Assessment and Reduction of Vulnerability to Climate Change in African Cities: A Focus on Low-Income and Informal Settlements. International Institute for Environment and Development. Available at: https://www.afd.fr/sites/afd/files/imported-files/Serie-Grise-Understanding-Assessment-Reduction-Vulnerability.pdf [Accessed 11 April 2018].

Dodman, D., Leck, H., Rusca, M. and Colenbrander, S., 2017a. African Urbanisation and Urbanism: Implications for risk accumulation and reduction. *International Journal of Disaster Risk Reduction*, 26, pp. 7-15. Available at: http://dx.doi.org/10.1016/j.ijdrr.2017.06.029 [Accessed 10 April 2018].

Dodman, D., Leck, H. and Taylor, F., 2017b. Applying multiple methods to understand and address urban risk. Urban ARK: Briefing No. 7. Available at: http://pubs.iied.org/G04172/?c=policy [Accessed 14 April 2018].

Dony, C. C., Delmelle, E. M. and Delmelle, E. C., 2015. Re-conceptualizing accessibility to parks in multi-model cities: A Variable-width Floating Catchment Area (VFCA) method. *Landscape and Urban Planning,* 143, pp. 90-99. Available at: https://doi.org/10.1016/j.landurbplan.2015.06.011 [Accessed 14 April 2018].

Douglas, I. et al., 2018. Unjust waters: climate change, flooding and the urban poor in Africa. *Environment & Urbanization*, 20 (1), pp. 187-205. Available at: https://doi.org/10.1177/0956247808089156 [Accessed 14 April 2018].

Elrick-Barr, C. E. et al., 2014. Towards a new conceptualization of household adaptive capacity change: applying a risk governance lens. *Ecology and Society,* 19 (4), 12. Available at: http://dx.doi.org/10.5751/ES-06745-190412 [Accessed 17 April 2018].

Engle, N. L., 2011. Adaptive capacity and its assessment. *Global Environmental Change*, 21, pp. 647-656. Available at: https://doi.org/10.1016/j.gloenvcha.2011.01.019 [Accessed 14 April 2018].

EEA, 2016. European Climate Adaptation Platform. Adaptation Support Tool. European Environment Agency. Available at: https://climate-adapt.eea.europa.eu/knowledge/tools/urban-ast [Accessed 04 June 2018].

Fainstein, S. S., 2010. The Just City. Ithaca: Cornell University Press.

Fragkias, M., Lobo, J., Strumsky, D. and Seto, K. C., 2013. Does Size Matter? Scaling of CO2 Emissions and U.S. Urban Areas. *PloS One,* 8 (6), pp. 1-8. Available at: https://doi.org/10.1371/journal.pone.0064727 [Accessed 10 April 2018].

Fraser, A., Leck, H., Parnell, S. and Pelling, M., 2017a. Africa's urban risk and resilience. *International Journal of Disaster Risk Reduction*, 26, pp. 1-6. Available at: https://doi.org/10.1016/j.ijdrr.2017.09.050 [Accessed 11 April 2018].

Fraser, A. et al., 2017b. Meeting the challenge of risk-sensitive and resilient urban development in sub-Saharan Africa: Directions for future research and practice. *International Journal of Disaster Risk Reduction*, 26, pp. 106-109. Available at: https://doi.org/10.1016/j.ijdrr.2017.10.001[Accessed 11 April 2018].

Frick-Trzebitzky, F., 2018. GIS – what can and what can't it say about social relations in adaptation to urban flood risk? Urban ARK: Guest Working Paper. Available at: https://www.urbanark.org/gis-—what-can-and-what-can't-it-say-about-social-relations-adaptation-urban-flood-risk [Accessed 11 April 2018].

Fura, G. D., 2013. Analysing and Modelling Urban Land Cover Change for Run-Off Modelling in Kampala, Uganda. University of Twente, Faculty of Geo-Information Science and Earth Observation: Master thesis. Available at: https://webapps.itc.utwente.nl/librarywww/papers_2013/msc/upm/fura.pdf [Accessed 11 April 2018].

Gehl, J., 2010. Cities for People. Washington: Island Press.

GeoGecko, 2016. Building Outlines: An Atlas of Kampala. Available at: https://www.geogecko.com/blog/399388 [Accessed 19 April 2018].

GIZ, 2014. The Vulnerability Sourcebook. Concept and guidelines for standardised vulnerability assessments. Bonn: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

Godfrey, S., Niwagaba, C., Howard, G. and Tibatemwa, S., 2003. Water Safety Plans for Utilities in Developing Countries – A case study from Kampala, Uganda. Case study report. Available at: http://www.bvsde.ops-oms.org/bvsacg/red_lac_psa/casos/uganda/kampala2.pdf [Accessed 11 April 2018].

Goswami, A. G. and Lall, S. V., 2016. Jobs in the City: Explaining Urban Spatial Structure in Kampala. World Bank Group, Social, Urban Rural and Resilience Global Practice Group: Policy Research Working Paper 7655. Available at: http://documents.worldbank.org/curated/en/526171467993515746/Jobs-in-the-city-explaining-urban-spatial-structure-in-Kampala [Accessed 14 April 2018].

Hardoy, J. and Pandiella, G., 2009. Urban poverty and vulnerability to climate change in Latin America. *Environment and Urbanization,* 21 (1), pp. 203-224. Available at: https://doi.org/10.1177/0956247809103019 [Accessed 16 April 2018].

Hardoy, J., 2011. Disaster Risk Reduction in Urban Areas. ELLA Policy Brief. Available at: http://ella.practicalaction.org/wp-content/uploads/files/111209_ENV_UrbEnvGov_BRIEF4.pdf [Accessed 14 April 2018].

Hillier, B., 2009. Spatial Sustainability in Cities: Organic Patterns and Sustainable Forms. *Proceedings of the 7th International Space Syntax Symposium.* Stockholm: KTH. Available at: https://pdfs.semanticscholar.org/7853/fc9e16bf904178ae143e559d25aa6f66ec48.pdf [Accessed 10 April 2018].

Hutcheson, G. D., 2011. Ordinary Least-Squares Regression. In Moutinho, L. and Hutcheson, G. D., 2011. The SAGE Dictionary of Quantitative Management Research. London: SAGE Publishing, pp. 224-228.

IPCC, 2001. Climate Change 2001: Impacts, Adaptation, and Vulnerability. Intergovernmental Panel on Climate Change. Available at: http://www.ipcc.ch/ipccreports/tar/wg2/pdf/WGII_TAR_full_report.pdf [Accessed 15 March 2018].

IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press. Available at: https://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4_wg2_full_report.pdf [Accessed 13 April 2018].

Isunju, J.B., Orach, C. G. and Kemp, J., 2015. Hazards and vulnerabilities among informal wetland communities in Kampala, Uganda. *Environment & Urbanization*, 28 (1), pp. 275-293. Available at: https://doi.org/10.1177/0956247815613689 [Accessed 14 April 2018].

Isunju, J. B., 2016. Spatiotemporal Analysis of Encroachment on Wetlands: Hazards, Vulnerability and Adaptations in Kampala City, Uganda. PhD Dissertation, Stellenbosch University. Available at: scholar.sun.ac.za/handle/10019.1/98559 [Accessed 10 April 2018].

Jabareen, Y. R., 2006. Sustainable Urban Forms: Their Typologies, Models, and Concepts. *Journal of Planning Education and Research,* 26, pp. 38-52. Available at: http://jpe.sagepub.com/content/26/1/38 [Accessed 10 April 2018].

Jacobs, J., 1961. The Death and Life of Great American Cities. New York: Vintage Books.

JICA, 2010. The Study on Greater Kampala Road Network and Transport Improvement in the Republic of Uganda. Final Report, Executive Summary. Available at: http://open_jicareport.jica.go.jp/pdf/12013025_01.pdf [Accessed 14 April 2018].

Jones, L., 2011. Towards a holistic conceptualisation of adaptive capacity at the local level: insights from the Local Adaptive Capacity framework (LAC). Overseas Development Institute: Working and discussion paper. Available at: https://www.odi.org/publications/5854-towards-holistic-conceptualisation-adaptive-capacity-local-level-insights-local-adaptive-capacity [Accessed 17 April 2018].

Jones, L., Ludi, E. and Levine, S., 2010a. Towards a characterisation of adaptive capacity: a framework for analysing adaptive capacity at the local level. Overseas Development Institute: Background Note. Available at: https://www.odi.org/publications/5177-towards-characterisation-adaptive-capacity-framework-analysing-adaptive-capacity-local-level [Accessed 17 April 2018].

Jones, L. et al., 2010b. Responding to a changing climate: Exploring how disaster risk reduction, social protection and livelihoods approaches promote features of adaptive capacity. Overseas Development Institute: Working Paper 319. Available at: https://www.odi.org/publications/4790-responding-changing-climate-exploring-how-disaster-risk-reduction-social-protection-and-livelihoods [Accessed 17 April 2018].

Jones, P., Bird, J., Beck, C. and Haas, A., 2016. Kampala – A Policy Narrative. Building African Cities that Work: A study on the Spatial Development of African Cities. Available at: https://www.theigc.org/project/african-cities-background-kampala-policy-narrative/ [Accessed 14 April 2018].

Kanuganti, S., Sarkar, A. K. and Singh A. P., 2016. Quantifying Accessibility to Health Care Using Two-step Floating Catchment Area Method. Transport Research Procedia, 17, pp. 391-399. Available at: https://doi.org/10.1016/j.trpro.2016.11.080 [Accessed 04 June 2018].

Karolien, V. et al., 2012. Urban growth of Kampala, Uganda: Pattern analysis and scenario development. *Landscape and Urban Planning*, 106 (2), pp. 199-206. Available at: https://doi.org/10.1016/j.landurbplan.2012.03.006 [Accessed 10 April 2018].

KCCA, 2016. Kampala Climate Change Action. Available at: http://www.kcca.go.ug/uDocs/Kampala%20Climate%20Change%20Action.pdf [Accessed 14 April 2018].

Kiggundu, A. T. and Mukiibi, S., 2012. Land Use and Transport Planning in the Greater Kampala, Uganda. *Indonesian Journal of Geography*, 44 (1), pp. 1-11. Available at: https://doi.org/10.22146/ijg.2386 [Accessed 14 April 2018].

Lall, S. V. and Deichmann, U., 2009. Density and Disasters: Economics of Urban Hazard Risk. The World Bank, Finance, Economics, and Urban Development Department & Development Research Group Environment and Energy Team: Policy Research Working Paper 5161. Available at: https://openknowledge.worldbank.org/bitstream/handle/10986/15348/wbro_27_1_74.pdf?sequence=1 [Accessed 14 April 2018].

Lamson-Hall, P. et al., 2016. The Quality of Urban Layouts. Marron Institute of Urban Management, NYU: Working Paper #39. Available at: http://marroninstitute.nyu.edu/working-papers/the-quality-of-urban-layouts [Accessed 17 April 2018].

Linard, C., Tatem, A. J. and Gilbert, M., 2013. Modelling spatial patterns of growth in Africa. *Applied Geography*, 44, pp. 23-32. Available at: https://doi.org/10.1016/j.apgeog.2013.07.009 [Accessed 14 April 2018].

Louf, R. and Barthelemy, M., 2014. Scaling: Lost in Smog. *Environment and Planning B: Planning and Design*, 41, pp. 767-769. Available at: http://journals.sagepub.com/doi/abs/10.1068/b4105c [Accessed 10 April 2018].

Lwasa, S., 2010a. Adapting urban areas in Africa to climate change: the case of Kampala. *Current Opinion in Environmental Sustainability*, 2, pp. 166-171. Available at: https://doi.org/10.1016/j.cosust.2010.06.009 [Accessed 14 April 2018].

Lwasa, S. and Kadilo, G., 2010. Participatory action research, strengthening institutional capacity and governance: Confronting the urban challenge in Kampala. *Commonwealth Journal of Local Governance*, Special Issue March 2010, pp. 27-46. Available at: http://dx.doi.org/10.5130/cjlg.v0i5.1467 [Accessed 16 April 2018].

Lwasa, S., 2015. Urban Governance and Poverty Reduction in Uganda: Lessons from Foreign Aid Regime of Local Government Development Program. *Current Urban Studies,* 3, pp. 25-34. Available at: http://dx.doi.org/10.4236/cus.2015.31004 [Accessed 16 April 2018].

Mabasi, T., 2009. Assessing the Impacts, Vulnerability, Mitigation and Adaptation to Climate Change in Kampala City. *Fifth Urban Research Symposium 2009*, Kampala. Available at: http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1256566800920/6505269-1268260567624/Mabasi.pdf [Accessed 14 April 2018].

Mansfield, T. J., Rodriguez, D. A., Huegy, J. and Gibson, J. M., 2015. The Effects of Urban Form on Ambient Air Pollution and Public Health Risk: A Case Study in Raleigh, North Carolina. *Risk Analysis*, 35 (5), pp. 901-918. Available at: https://doi.org/10.1111/risa.12317 [Accessed 14 April 2018].

Mitchell, D., Enemark, S., and van der Molen, P., 2015. Climate resilient urban development: Why responsible land governance is important. *Land Use Policy*, 48, pp. 190-198. Available at: http://dx.doi.org/10.1016/j.landusepol.2015.05.026 [Accessed 10 April 2018].

MoGLSD, 2017. Uganda Management of Social Risk and Gender Based Violence Prevention and Response Project: Environmental Management Framework. Available at: http://documents.worldbank.org/curated/en/961311498788342516/Uganda-Management-of-Social-Risk-and-Gender-Based-Violence-Prevention-and-Response-Project-Chair-Summary [Accessed 14 April 2018].

Muinde, D. K., 2013. Assessing the Effects of Land Tenure on Urban Development in Kampala. University of Twente: Faculty of Geo-Information Science and Earth Observation of the University of Twente: Master thesis. Available at: https://webapps.itc.utwente.nl/librarywww/papers_2013/msc/upm/muinde.pdf [Accessed 14 April 2018].

Mukama, T. et al., 2016. Practices, Concerns, and Willingness to Participate in Solid Waste Management in Two Urban Slums in Central Uganda. *Journal of Environmental and Public Health*, pp. 1-7. Available at: https://www.hindawi.com/journals/jeph/2016/6830163/ [Accessed 14 April 2018].

Mukwaya, P. I., Sengendo, H. and Lwasa, S., 2012. Enhancing Security and Resilience of Low-Income Communities to Climate Change in Growing Cities: An Assessment of Flood Management and Planning Regimes in Kampala City, Uganda. In: Scheffran, J. et al. eds., 2012. Climate Change, Human Security and Violent Conflict. Challenges for Societal Stability. Hexagon Series on Human and Environmental Security and Peace (HSEP), 8. Heidelberg: Springer-Verlag, pp. 543-557.

Munger, E. S., 1951. Relational Patterns of Kampala Uganda. The University of Chicago, Department of Geography: Research Paper No. 21. Available at: https://doi.org/10.2307/1156926 [Accessed 14 April 2018].

Musoke, S. B., 2011. Vulnerabilities and Urban Flooding in Bwaise Parish III, Kampala, Uganda. Södertörn University, School of Life Sciences: Bachelor Thesis. Available at: http://www.diva-portal.org/smash/get/diva2:535079/FULLTEXT01.pdf [Accessed 14 April 2018].

Myers, G., 2016. Urban Environments in Africa: A critical analysis of environmental politics. Bristol: Policy Press.

Næss, P., 2014. Urban Form, Sustainability and Health: The Case of Greater Oslo. *European Planning Studies*, 22 (7), pp. 1524-1543. Available at: https://doi.org/10.1080/09654313.2013.797383 [Accessed 14 April 2018].

Nussbaum, M., 2003. Capabilities as fundamental entitlements: Sen and Social Justice. *Feminist Economic*, 9 (2-3), pp. 33-59. Available at: https://doi.org/10.1080/1354570022000077926 [Accessed 17 April 2018].

Nyakaana, J. B., Sengendo, J. and Lwasa, S., 2008. Population, Urban Development and the Environment in Kampala City and its Environs. Makerere University Kampala. Available at: http://www.cicred.org/Eng/Seminars/Details/Seminars/PDE2007/Papers/NYAKAANA_paperNairobi2007.pdf [Accessed 10 April 2018].

Oliveira, E. A., Andrade, J. S. and Makse, H. A., 2014. Large cities are less green. Scientific Reports, 4, pp. 1-12. Available at: https://www.nature.com/articles/srep04235 [Accessed 10 April 2018].

Oliveira, V., 2016. Urban Morphology: An Introduction to the Study of the Physical Form of Cities. The Urban Book Series. Basel: Springer International Publishing.

Omolo-Okalebo, F., Haas, T., Werner, I. B. and Sengendo, H., 2010. Planning of Kampala City 1903-1962: The Planning Ideas, Values, and Their Physical Expression. *Journal of Planning History*, 9 (3), pp. 151-169. Available at: https://doi.org/10.1177/1538513210373815 [Accessed 14 April 2018].

Omolo-Okalebo, F., 2011. Evolution of Town Planning Ideas, Plans and their Implementation in Kampala City 1903-2004. Makere University, Kampala and Royal Institute of Technology, Stockholm: Doctoral

Thesis in Infrastructure, Planning and Implementation. Available at: https://www.diva-portal.org/smash/get/diva2:466031/FULLTEXT02.pdf [Accessed 14 April 2018].

Osuteye, E., Johnson, C. and Brown, D., 2017. The data gap: An analysis of data availability on disaster losses in sub-Saharan African cities. *International Journal of Disaster Risk Reduction*, 26, pp. 24-33. Available at: https://doi.org/10.1016/j.ijdrr.2017.09.026 [Accessed 14 April 2018].

Parnell, S. and Walawage, R., 2010. Sub-Saharan African urbanisation and global environmental change. In: Parnell, S. and Pieterse, E. eds., 2014. Africa's Urban Revolution. London: Zed Books, pp. 35-59.

Pelling, M. and Wisner, B. eds., 2009. Disaster Risk Reduction: Cases from Urban Africa. Abingdon: Taylor & Francis.

Pelling, M., Brown, D., Lwasa, S. and Chen, F., 2016. Cities and Disaster Risk Reduction. Policy Recommendations. Available at: https://www.icsu.org/cms/2017/05/DRR-policy-brief-4-cities.pdf [Accessed 14 April 2018].

Pieterse, E. and Parnell, S., 2010. Africa's urban revolution in context. In: Parnell, S. and Pieterse, E. eds., 2014. Africa's Urban Revolution. London: Zed Books, pp. 1-17.

Pereira, R. H. M., de Holanda, F. R. B., de Medeiros, V. A. S. and Barros, A. P B. G., 2012. The Use of Space Syntax in Urban Transport Analysis: Limits and Potentials. Ipea: Discussion Paper 188. Available at: https://ideas.repec.org/p/ipe/ipetds/0188.html [Accessed 14 April 2018].

Pont, M. B. and Haupt, P., 2009. Space, Density and Urban Form. Technical University Delft: Doctoral Thesis.

Pont, M. B., 2011. Measuring urban form. Available at: https://repository.tudelft.nl/islandora/object/uuid:7dd42b3d-ca3b-4039-b8fc-cffa8586787d/datastream/OBJ [Accessed 14 April 2018].

Ratti, C., 2004. Space syntax: some inconsistencies. *Environment and Planning B: Planning and Design,* 31, pp. 487-499. Available at: http://journals.sagepub.com/doi/10.1068/b3019 [Accessed 05 June 2018].

Rawls, J., 1971. A Theory of Justice. Cambridge: Harvard University Press.

Richmond, A., Myers, I. and Namuli, H., 2018. Urban Informality and Vulnerability: A Case Study in Kampala, Uganda. *Urban Science*, 2 (22), pp. 1-13. Available at: http://dx.doi.org/10.3390/urbansci2010022 [Accessed 10 April 2018].

RoU, 2007. Local Government Development and Service Delivery Program: Resettlement Policy Framework. Final Report. Available at: http://documents.worldbank.org/curated/en/690911468310732520/Uganda-Local-Government-Management-Service-Delivery-Project-resettlement-policy-framework [Accessed 14 April 2018].

Satterthwaite, D., 2017a. The impact of urban development on risk in sub-Saharan Africa's cities with a focus on small and intermediate urban centres. *International Journal of Disaster Risk Reduction*, 26, pp. 16-23. Available at: https://doi.org/10.1016/j.ijdrr.2017.09.025 [Accessed 14 April 2018].

Satterthwaite, D., 2017b. The possibilities and limitations of community-based disaster risk reduction and climate change adaptation; findings across city studies. Urban ARK: Briefing No. 8. Available at: https://www.preventionweb.net/publications/view/56226 [Accessed 14 April 2018].

Schreiner, M., 2012a. Uganda 2012 Poverty Probability Index (PPI): Design Memo. Poverty Probability Index. Available at: https://www.povertyindex.org/country/uganda [Accessed 14 April 2018].

Schreiner, M., 2012b. PPI for Uganda 2012. Poverty Probability Index. Available at: https://www.povertyindex.org/country/uganda [Accessed 14 April 2018].

Scott, L., 2005. Participatory multi-criteria decision analysis: a new tool for integrated development planning. *Development Southern Africa*, 22 (5), pp. 695-716. Available at: https://doi.org/10.1080/03768350500364232 [Accessed 05 June 2018].

Sen, A., 1979. Equality of What? The Tanner Lecture on Human Values. Delivered at Stanford University, 22 May 1979. Transcript available at: https://tannerlectures.utah.edu/_documents/a-to-z/s/sen80.pdf [Accessed 17 April 2018].

Sheidow, A. J., Gorman-Smith, D., Tolan, P. H. and Henry, D. B., 2001. Family and Community Characteristics: Risk Factors for Violence Exposure in Inner-City Youth. *Journal of Community*

Psychology, 29 (3), pp. 345-360. Available at: https://doi.org/10.1002/jcop.1021 [Accessed 14 April 2018].

Sinkler, A., 2011. Retroduction, Congruence Analysis, and Causal Inference in Case Study Research. WPSA Conference. San Antonio, TY, 21 April 2011. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1795449 [Accessed 05 June 2018].

Songsore, J., 2017. The Complex Interplay between Everyday Risks and Disaster Risks: The Case of the 2014 Cholera Pandemic and 2015 Flood Disaster in Accra, Ghana. *International Journal of Disaster Risk Reduction*, 26, pp. 43-50. Available at: https://doi.org/10.1016/j.ijdrr.2017.09.043 [Accessed 14 April 2018].

Thathsarani, U. S. and Gunaratne, L H. P., 2018. Constructing and Index to Measure the Adaptive Capacity to Climate Change in Sri Lanka. *Procedia Engineering*, 212, pp. 278-285. Available at: https://doi.org/10.1016/j.proeng.2018.01.036 [Accessed 17 April 2018].

UN, 2015. Draft outcome document of the United Nations summit for the adoption of the post-2015 development agenda. Transforming our world: the 2030 Agenda for Sustainable Development. Available at: https://sustainabledevelopment.un.org/post2015/summit [Accessed 14 April 2018].

UN, 2016. Habitat III, New Urban Agenda. Available at: http://habitat3.org/the-new-urban-agenda/ [Accessed 14 April 2018].

UN-Habitat, 2007. Situation Analysis of Informal Settlements in Kampala. Available at: https://unhabitat.org/books/situation-analysis-of-informal-settlements-in-kampala/ [Accessed 14 April 2018].

UN-Habitat, 2009. Climate Change Assessment for Kampala, Uganda: A Summary. Available at: https://unhabitat.org/books/climate-change-assessment-for-kampala-uganda/ [Accessed 14 April 2018].

UN-Habitat, 2011. Vulnerability Assessment of Climate Change in Kampala and Uganda. Final Report. Available at: http://mirror.unhabitat.org/downloads/docs/10405_1_594150.pdf [Accessed 14 April 2018].

UN-Habitat, 2013. Mobility and Urban Form. In: UN-Habitat, 2013. Planning and Design for Sustainable Urban Mobility. Nairobi: UN-Habitat.

UN-Habitat, 2014. The State of African Cities 2014: Re-imagining sustainable urban transitions. Available at: https://unhabitat.org/books/state-of-african-cities-2014-re-imagining-sustainable-urban-transitions/ [Accessed 11 April 2018].

UN-Habitat, 2016. Measurement of City Prosperity: Methodology and Metadata. Available at: http://cpi.unhabitat.org/sites/default/files/resources/CPI%20METADATA.2016.pdf [Accessed 04 June 2018].

van Huyssteen, E., le Roux, A., van Niekerk, W., 2013. Analysing risk and vulnerability of South African settlements: Attempts, explorations and reflections. *Jàmbá: Journal of Disaster Risk Studies*, 5 (2), pp. 1-8. Available at: http://dx.doi.org/10.4102/jamba.v5i2.80 [Accessed 14 April 2018].

WCED, 1987. Report of the World Commission on Environment and Development: Our Common Future. Available at: http://www.un-documents.net/our-common-future.pdf [Accessed 14 April 2018].

Weis, S. W. M. et al., 2016. Assessing vulnerability: an integrated approach for mapping adaptive capacity, sensitivity, and exposure. *Climate Change.* Available at: https://link.springer.com/article/10.1007/s10584-016-1642-0 [Accessed 04 June 2018].

WHO, 2015?. Tool to respond to disease outbreaks. Available at: https://diseaseoutbreaks.unglobalpulse.net/uganda/pdf/2Pager-response%20to%20infectious%20disease.pdf [Accessed 05 June 2018].

Williams, K., 2014. Urban form and infrastructure: a morphological review. UK Government, Office for Science. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/324161/14-808-urban-form-and-infrastructure-1.pdf [Accessed 17 March 2018].

Williams, C., Fenton, A. and Huy, S., 2015. Knowledge and adaptive capacity. *Nature Climate Change*, 5. Available at: https://www.nature.com/articles/nclimate2476 [Accessed 04 June 2018].

Yuan, Y., Xu, J. and Wang, Z., 2017. Spatial Equity Measure on Urban Ecological Space Layout Based on Accessibility of Socially Vulnerable Groups – A Case Study of Changting, China. *Sustainability*, 9, 1552, pp. 1-20. Available at: http://www.mdpi.com/2071-1050/9/9/1552 [Accessed 14 April 2018].

Annex 1: Description of indicator assessment methods

In this annex, a few methodological elements of the spatial analysis are discussed more in detail. These include the approach for the four indicators of Space Syntax, the calculation of the flooding risk exposure through the ArcGIS hydrology toolset, the transformation of household survey coordinates to grid information and lastly, how the various types of values were assigned to the 100 * 100 m grid cells.

In the first section, the calculation of the four Space Syntax indicators (integration, depth, choice, connectivity) are explained. Starting with the data preparation, the street network of Kampala, derived from Open Street Maps, was cleaned up (removing double lines, simplifying intersections, connecting unprecise road links, and afterwards converted through a segment model in QGIS which divides the streets in straight segments according to the angle of curvature. This segment data is used in depthmapX (http://varoudis.github.io/depthmapX/) to calculate various indicators regarding each segments value of the four above mentioned indicators. As described in the methodology, Space Syntax analysis comes along with several critics. One of them, the weighting of streets, was partly done through the categorisation of roads in Open Street Map. However, as the accuracy of the crowd-sourced data is not very high, only two categories of primary and secondary streets are applied. Another related challenge is the consideration of one-way streets, which was due to missing data not viable. Furthermore, the problem of distorted results due to too regular grids is not a significant problem in Kampala. Lastly, one of the most crucial challenges of Space Syntax, boundary weighting, was tackled by conducting the analysis in a larger network scale than Kampala itself which, according to the below shown sample output, seems to be sufficiently effective.

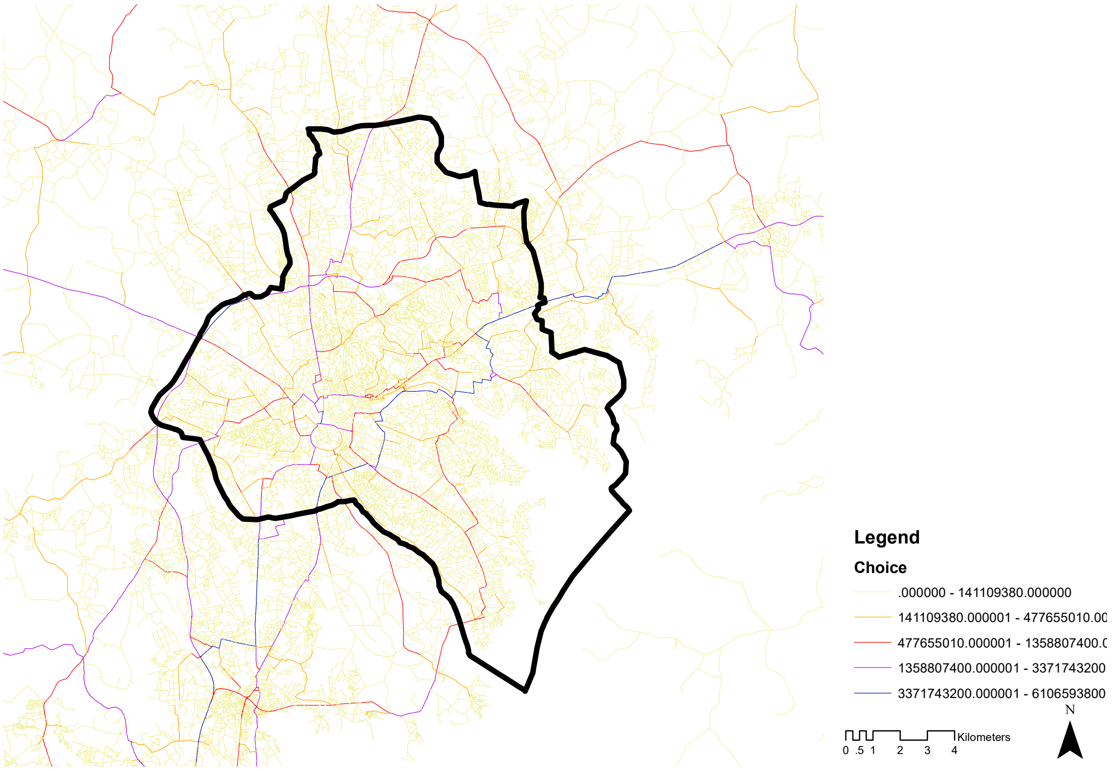


Figure 5-1: Choice values for Kampala's road segment network (Author 2018)

Another more elaborated calculation is the flooding risk exposure as the most critical part of this research. To achieve the most representative categorisation of the flooding risk, an approach is chosen which includes various factors of Kampala's digital elevation model (DEM) and calculated water flows as well as watershed areas based upon it. Therefore, a contour-line shapefile with a level of detail of 2 m is converted to a DEM. This model is prepared with ArcGIS' hydrology toolset by fixing "sinks" in the model to avoid inaccuracies. Afterwards, flow directions and continuous watersheds can be generated, which assist in the computation of potential streams and their order as well as flow length. The output of this analysis results in a raster file showing location and hierarchy of streams. This data was overlaid and compared with the actual rivers in Kampala to test the accuracy of the model, which proofed to be very precise. In a last step, a raster file of the varying amounts of water in each cell in case of rain is generated (see below), which is the underlying data of the indicator 2.1.1 Flooding risk exposure. Further information:http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/hydrologic-analysis-sample-applications.htm.

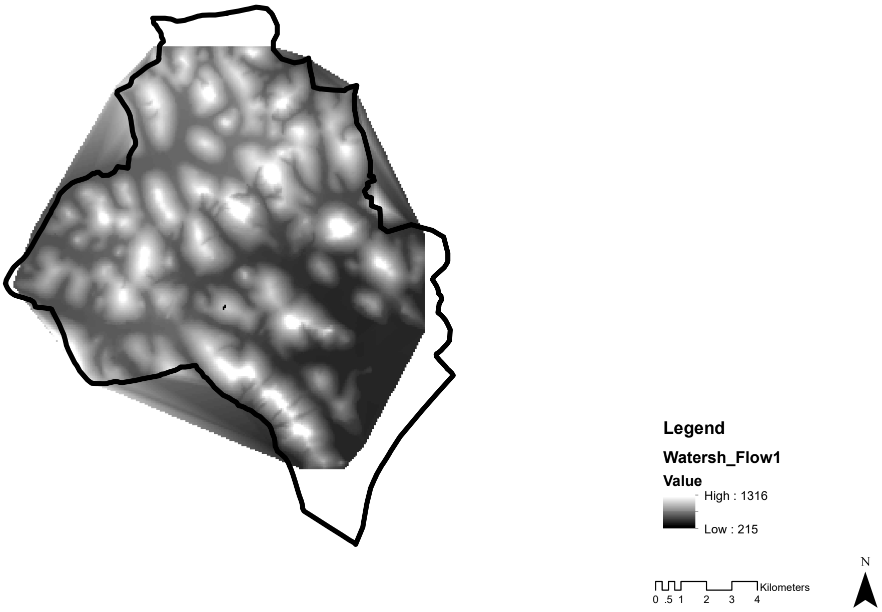


Figure 5-2: Watershed-flow model output from ArcGIS (Author 2018)

In the second part, the transformation of the different underlying database types is described. Firstly, the HH-survey results are associated with coordinates for each household and the same coordinates for each household member who responded, which allowed to geo-reference their data in ArcGIS. Afterwards, the data entries are assigned to the according 500 * 500 m cell and it is checked, if the number of respondents per cell is significantly large enough to generalise the data. If that is the case, the data entries are summarised, and their mean values associated to the respective cells.

Lastly, various data types (500 * 500 m cells, polygons, points, lines, raster data) existed and need to be transformed to the 100 * 100 m grid cells. In case of the 500 * 500 m cells, the value was simply copied to each smaller cell. Data from polygons was either only copied either if the data has no connection to the area (e.g., average gender distribution) or is proportionally assigned according to its percentage overlap with the cells (population). Point data is converted by calculating the mean of each points values, while values of line are weighted by the length of each segment divided by the total length of streets in each cell. Lastly, the mean values of the raster data inside the cell’s boundaries are assigned to their cells.

Annex 2: Choices of EARF Household Survey

Disaster occurrence	**1**	**No, certainly not**
	2	No, probably not (low risk)
	3	Yes, it might happen (medium risk)
	4	Yes, it is likely to happen (high risk)
Household income range	1	Less than UGX 100,000
	2	100,000 - 250,000
	3	250,001 - 500,000
	4	500,001 - 1,000,000
	5	1,000,001 - 2,000,000
	6	2,000,001 - 3,000,000
	7	Above 3,000,000
Household relation to site	1	Own
	2	Rent
	3	Caretaker
	4	Other occupant
Water access	1	Tapped water at premise/delivered to your premise (0 to 5 minutes)
	2	Shared water access point with neighbours (less than 10 minutes)
	3	Less than 30 minutes for a round trip
	4	Between 30 minutes and 2 hours for a round trip
	5	More than 2 hours for a roundtrip
Water quality	1-5	Likert scale from 1 (very satisfied) to 5 (very dissatisfied)
Initial location	1	I have always lived here
	2	Within this neighbourhood
	3	Another neighbourhood within this city
	4	Another city within the country
	5	Rural area within the country
	6	Urban area outside the country
	7	Rural area outside the country
Satisfaction with neighbourhood	1-5	Likert scale from 1 (very satisfied) to 5 (very dissatisfied)
Plan to relocate	1-5	Likert scale from 1 (yes, definitely) to 5 (Most definitely not)
Level of Education	1	Currently enrolled in (pre) primary school
	2	Primary school (completed)
	3	Secondary school (completed) (O or A levels)
	4	Vocational/Institute (completed)
	5	University (completed)
	6	Post-graduate (completed)
Gender	1	Female
	2	Male
Age group	1	Less than 5 years
	2	5 to 15 years
	3	16 to 25 years
	4	26 to 35 years
	5	36 to 45 years
	6	45 to 55 years
	7	Above 55 years
Economic resilience	1	Enough to build savings
	2	Only just meets expenses
	3	Not sufficient
Type of employer	1	Themselves
	2	Someone else
	3	Private Company
	4	Government
	5	Non-Governmental Entity (NGO/CBO)
Type of occupation	1	Salary/Wages
	2	Farming
	3	Buying and selling goods
	4	Making/Recycling items
	5	Transport services (e.g bodaboda, taxi)

	6	Providing irregular services for other people (e.g laundry, water vending, loading/offloading etc)
	7	Pensions
	8	Renting out property (land/housing)
Expropriation	1	Yes, many
	2	Yes, some
	3	No
Safety	1-5	Likert scale from 1 (very safe) to 5 (very unsafe)
Household affordability	1-5	Likert scale from 1(very easy) to 5 (very difficult)
Property restrictions	1	No, I did not find any restrictions
	2	Only open to family members
	3	Only open to personal connections
	4	Only through tribal relationship
	5	Restricted by religion
	6	Restricted by nationality
	7	Only open to persons with exclusive rights (e.g., club membership)
Property ownership	1	A family member / relative who lives outside this household
	2	Private individual
	3	A business, commercial entity
	4	A public entity
Dwelling type	1	Detached single family residential (standalone)
	2	Semi-Detached multi-family residential (two together)
	3	Horizontally attached multi-family unit (tenement)
	4	Apartment building
Dwelling Mat	1	Permanent
	2	Semi-Permanent
	3	Traditional/Temporary
Nearest road	1	Less than 1 km (0.5 miles)
	2	1 to 3 km (0.5 to 2 miles)
	3	4 to 8 km (2.5 to 5 miles)
	4	More than 8km (More than 5 miles)
Travel time	1	Less than 1 km (0.5 miles)
	2	1 to 3 km (0.5 to 2 miles)
	3	4 to 8 km (2.5 to 5 miles)
	4	More than 8km (More than 5 miles)

Annex 3: Online weighting questionnaire

Kampala's Flood-Risks & Social Vulnerability

(The required part of this survey takes less than minutes. However, you can give further input at the end)

I am Tjark Gall and a Master student at the Institute for Housing and Development Studies at Erasmus University, in Rotterdam. I am analysing how urban form (e.g. density, building sizes, accessibility, centrality) and flood-related urban risks are interrelated in Kampala.

This research is part of the project 'Spatial Inequality in Times of Urban Transition: Complex Land Markets in Uganda and Somaliland' (https://www.ihs.nl/en/thematic-areas/urban-strategies-and-planning/research), which is currently conducted by the Institute for Housing and Urban Development Studies (IHS), the Development Planning Unit (University College London) and IPE Tripleline and is funded by the British Government's East Africa Research Fund.

You were invited to participate in this survey due to your experience of the urban environment of Kampala and your in-depth knowledge of the spatial and environmental elements which come together. The objective of this survey is to improve the weighting process of various indicators and assist in the interpretation of collected data.

You can choose if you want to do this survey anonymously OR share your contact details below to allow for further questions and receive updates of the research. In case you want to participate anonymously but have questions or want to receive updates, please send a mail to tjark_gall@yahoo.de or contact me via WhatsApp +4917634203216.

YOUR NAME WILL BE IN NO CASE PUBLICLY DISPLAYED AND/OR RELATED TO YOUR ANSWERS.

- Your Name (voluntary)
- Your Affiliation (voluntary)
- Your Mail-Address (voluntary)

Introduction

The research consists mainly of four parts: Three elements of social vulnerability (risk exposure, adaptive capacity and sensitivity) and urban form. Definitions of each term are stated before the section. The diagram below shows the conceptual framework for a general overview.

Conceptual Diagram (see chapter 3)

Risk Exposure

The first section includes the indicators of risk exposure; defined as the "Character, magnitude, and rate of change and variation in the climate. Typical exposure factors include temperature, precipitation, evapotranspiration and climatic water balance, as well as extreme events such as heavy rain and meteorological drought" (GIZ 2014, p. 21). WEIGHTING INSTRUCTIONS: Please start with the most important indicator of this category and give it a 6 (very important). Afterwards, please rate the other indicators in comparison to the highest rated indicator (e.g., 3 = half as important as 6). Several indicators can have the same score. In case you do not consider one indicator as important at all, please rate it with 0. If there are any important, spatially quantifiable indicators missing, you can add them at the bottom.

- Elevation of location
- Slope of location
- Location in watershed
- Disaster occurrences in last 2 years
- Additional measurable indicators. Please rate again from 0-6. E.g.: Indicator xy (6)

Adaptive capacity

The second section includes the indicators of adaptive capacity; defined as the "ability of a system or individual to adapt to climate change" (Cardona et al. 2012, p. 67) WEIGHTING INSTRUCTIONS: Please start with the most important indicator of this category and give it a 6 (very important). Afterwards, please rate the other indicators in comparison to the highest rated indicator (e.g., 3 = half as important as 6). Several indicators can have the same score. In case you do not consider one indicator as important at all, please rate it with 0. If there are any important, spatially quantifiable indicators missing, you can add them at the bottom.

- Household income
- Years lived in area
- Perception of risk
- Level of tenure 'formality'
- Internet use (number of online posts)
- Level of education
- Additional measurable indicators. Please rate again from 0-6. E.g.: Indicator xy (6)

Sensitivity

The third section includes the indicators of sensitivity; defined as the "degree to which a system is adversely or beneficially affected by a given climate change exposure […and] it also refers to human activities which affect the physical constitution of a system" (GIZ 2014, p. 21). In the case of the below mentioned elements, sensitivity describes the compound scores of the importance, exposure, location, and condition. E.g., for road sensitivity, the type of road (highway, footpath), number of people using it, the exposure to floods, the locations in flood-prone areas, and conditions like paved or unpaved. The comparative scoring therefore looks at how important the sensitivity is in relation to the overall social vulnerability of the population at a certain location. WEIGHTING INSTRUCTIONS: Please start with the most important indicator of this category and give it a 6 (very important). Afterwards, please rate the other indicators in comparison to the highest rated indicator (e.g., 3 = half as important as 6). Several indicators can have the same score. In case you do not consider one indicator as important at all, please rate it with 0. If there are any important, spatially quantifiable indicators missing, you can add them at the bottom.

- Population density
- Gender distribution
- Age distribution
- Built floor quality
- Built wall quality
- No. of rooms
- Road sensitivity
- Water provision sensitivity
- Educational facility sensitivity
- Health institution sensitivity
- Religious institution sensitivity
- Additional measurable indicators. Please rate again from 0-6. E.g.: Indicator xy (6)

Urban Form

The last section includes the indicators of Urban Form; defined as the built embodiment of the urban society, generally divided in macro, meso- and microscale (city, settlement/neighbourhood, building). WEIGHTING INSTRUCTIONS: Please start with the most important indicator of this category and give it a 6 (very important). Afterwards, please rate the other indicators in comparison to the highest rated indicator (e.g., 3 = half as important as 6). Several indicators can have the same score. In case you do not consider one indicator as important at all, please rate it with 0. If there are any important, spatially quantifiable indicators missing, you can add them at the bottom.

- Centrality
- Integration of road segments (SpaceSyntax)

- Probability that road is used (SpaceSyntax)
- Number of times road is used (SpaceSyntax)
- Accessibility to economic centres
- Accessibility to educational facilities
- Accessibility to health institutions
- Accessibility to public transport nodes
- KM of primary road per square kilometre
- KM of secondary road per square kilometre
- Number of road nodes per square kilometre
- Building density
- Site occupancy index
- Average plot size
- Average building size
- Building proximity to each other
- Percentage of green space
- Percentage of mixed-use functions
- Predominant type of settlement (high-/medium-/-low income)
- Additional measurable indicators. Please rate again from 0-6. E.g.: Indicator xy (6)

Comparison of Categories

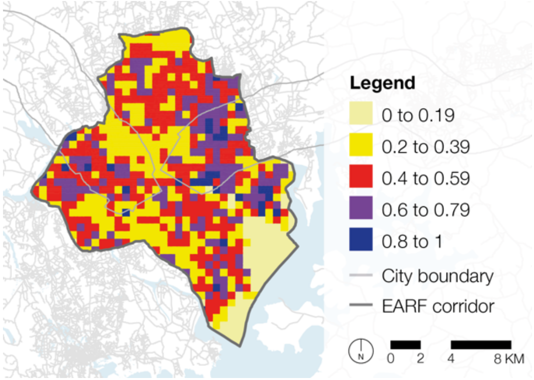
Lastly, I would like to ask you, how much the four different categories affect the social vulnerability of the urban population. WEIGHTING INSTRUCTIONS: Please start with the most important category and give it a 6 (very important). Afterwards, please rate the other categories in comparison to the highest rated indicator (e.g., 3 = half as important as 6). Several categories can have the same score. In case you do not consider one category as important at all, please rate it with 0.

- Risk exposure
- Adaptive capacity
- Sensitivity
- Urban Form

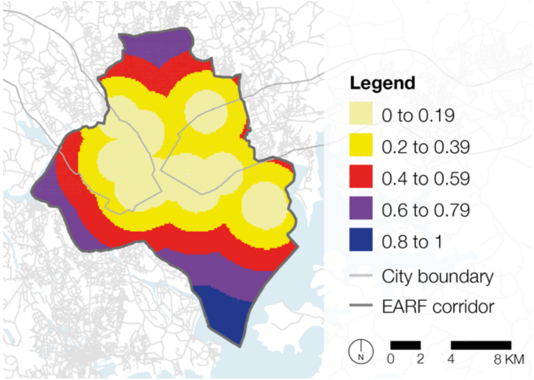
In-depth questions (voluntary)

- Can you specify which areas are most at risk?
- What main secondary risks result out of flooding?
- How does risk exposure influences social vulnerability?
- How does adaptive capacity influence social vulnerability?
- How does sensitivity influence social vulnerability?
- How does urban form influence social vulnerability?

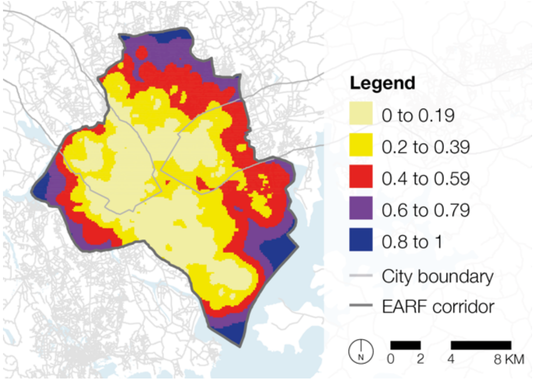
Annex 4: Maps | Meaning and underlying method



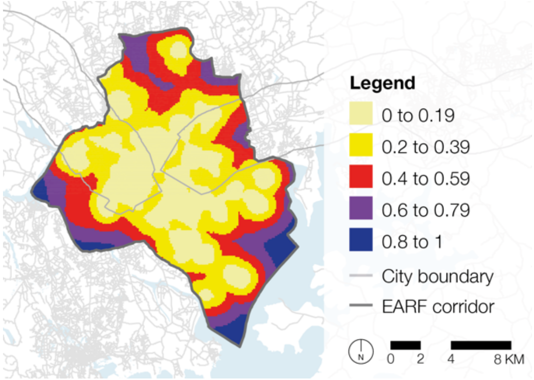
1.1 AG	**Space Syntax aggregated**
Source	Open Street Maps
Method	Calculated with DepthMapX and QGIS, aggregated through multiplying with equal weights and divided by 4
Observation/ comments	



1.2.1	**Economic centre accessibility**
Source	World Bank, Uganda Business Register (Goswami 2016, Jones et al. 2016)
Method	Locations of economic centres where digitised in ArcGIS and distances calculated by network analyst.
Observation/ comments	

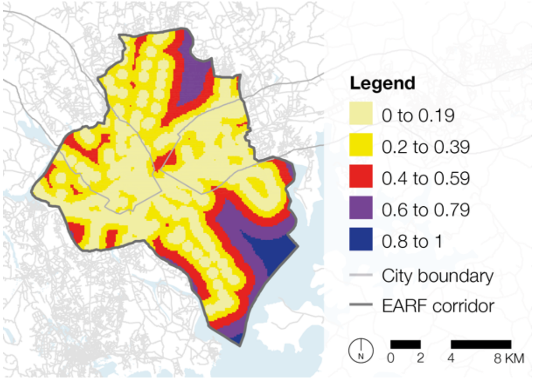


1.2.2.	**Educational facility accessibility**
Source	Open Street Maps
Method	Distances to educational facilities were calculated by ArcGIS network analyst. Resulting scores were weighted according to importance (kindergarten * 0.2, schools *0.5, college * 0.2, university * 0.1)
Observation/ comments	

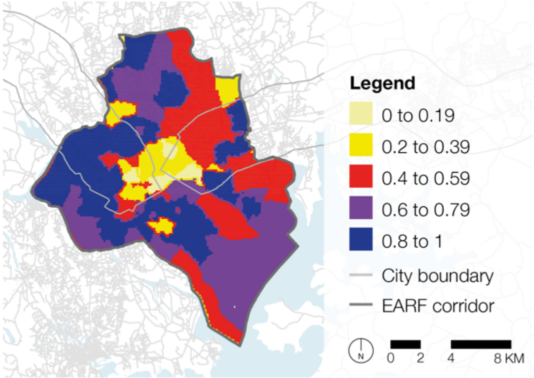


1.2.3.	**Health facility accessibility**
Source	Open Street Maps and KCCA
Method	Distances to health facilities were calculated by ArcGIS network analyst. Resulting scores were weighted according to importance (pharmacies * 0.2, clinics/doctors * 0.3, hospitals * 0.5)
Observation/ comments	

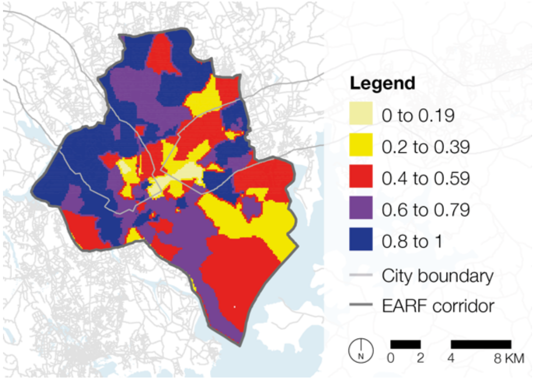
1.2.4.	**Bus station accessibility**
Source	Open Street Map and GoMetroApp



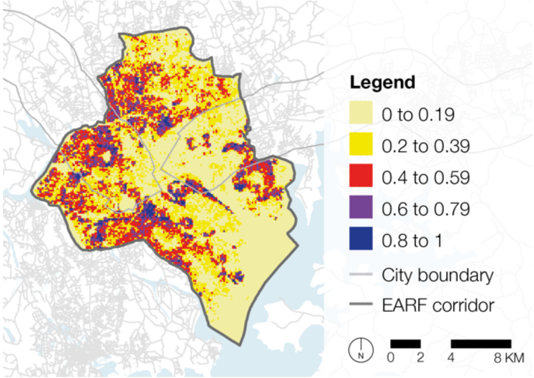
Method	Distances to bus stations were calculated by ArcGIS network analyst.
Observation/ comments	



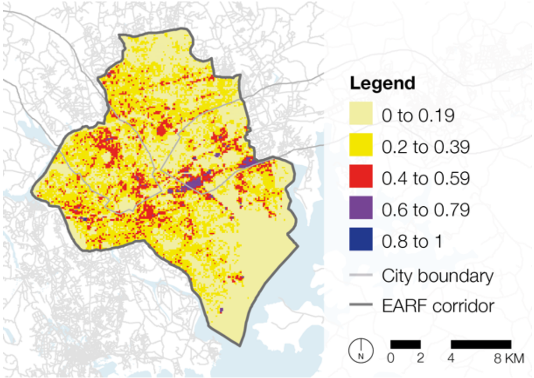
1.2.5.	**Access to health facilities**
Source	National census 2014
Method	Percentage of people in district with access to public and private health facilities in under 5 KM, weighted public * 0.7 and private * 0.3
Observation/ comments	



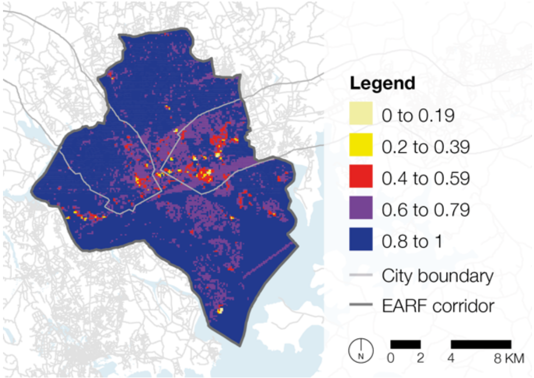
1.2.6.	**Access to educational facilities**
Source	National census 2014
Method	Percentage of people in district with access to educational facilities in under 5 KM
Observation/ comments	



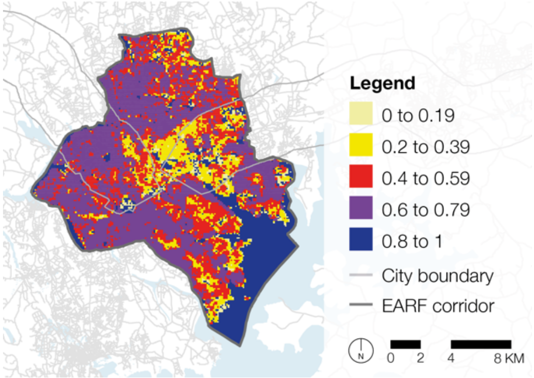
1.3.1.	**Number of buildings / building density**
Source	GeoGecko 2016, Open Street Maps
Method	Number of house centre points per 100 * 100 m grid cell was counted
Observation/ comments	



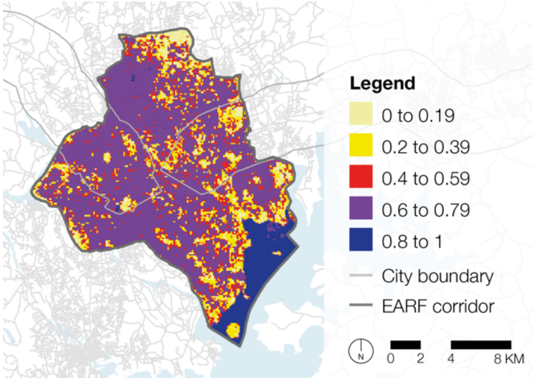
1.3.2.	**Site occupancy index**
Source	GeoGecko 2016, Open Street Maps
Method	Percentage of ground covered by buildings per 100 * 100 m grid cell
Observation/ comments	



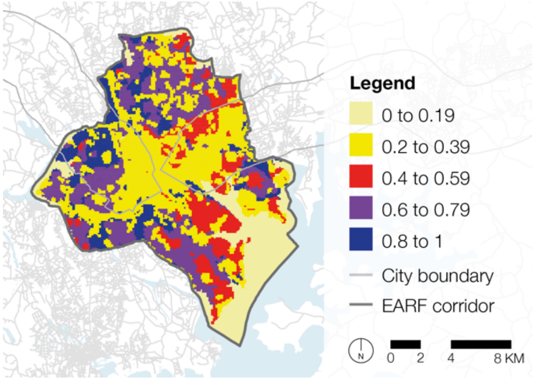
1.3.3.	**Building Size (reversed)**
Source	GeoGecko 2016, Open Street Maps
Method	Average size of buildings per 100 * 100 m grid cell
Observation/ comments	



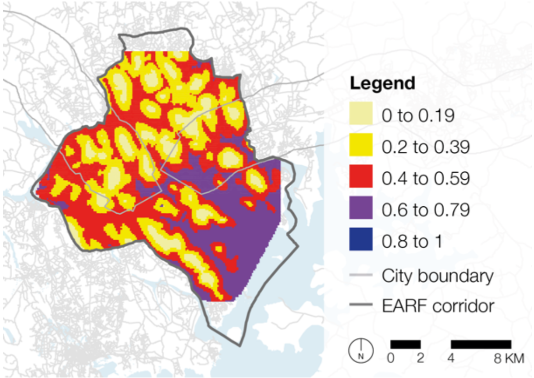
1.3.4.	**Proximity (reversed)**
Source	GeoGecko 2016, Open Street Maps
Method	Average distance to nearest 25 buildings per 100 * 100 m grid cell
Observation/ comments	



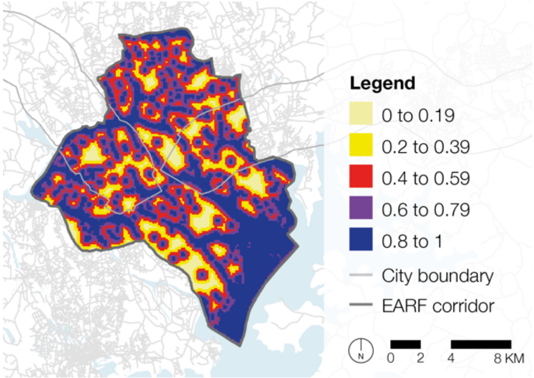
1.4.1.	**Green percentage (reversed)**
Source	Sentinel / Earth Explorer
Method	Image analysis of green band of high-resolution satellite picture
Observation/ comments	



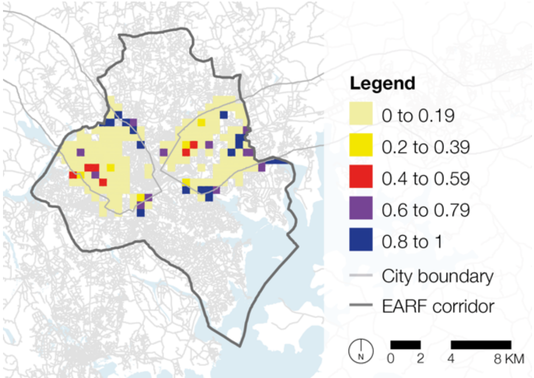
1.4.2.	**Settlement type**
Source	EARF research project, IPE Triple Line
Method	Highest classification of settlement type as defined by IPE Triple Line / EARF per 100 * 100 m grid cell
Observation/ comments	Very Low-Income = 1 Low-Income = 2 Middle-Class = 3 High-income = 4 Governmental = 5 Mixed = 6 Non-residential = 7



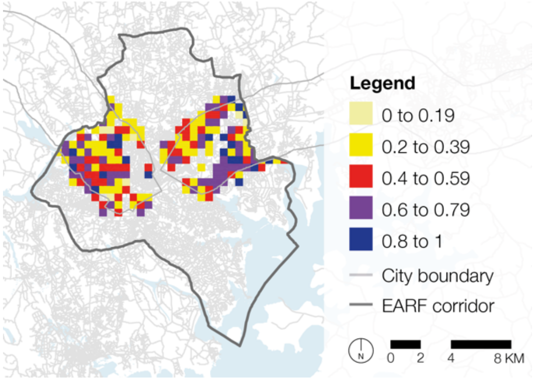
2.1.1.	**Flooding exposure risk**
Source	Contour lines from KCCA (2 m resolution)
Method	Creation of digital elevation level, calculation of watershed areas through ArcGIS hydrology toolset (modelling of direction, flow, quantity), based on assumption of homogenous precipitation. For control purposes, results were overlaid with flood prone-defined areas of KCCA and calculated expected streams with actual rivers, which led to high reliability of actual representation.
Observation/ comments	



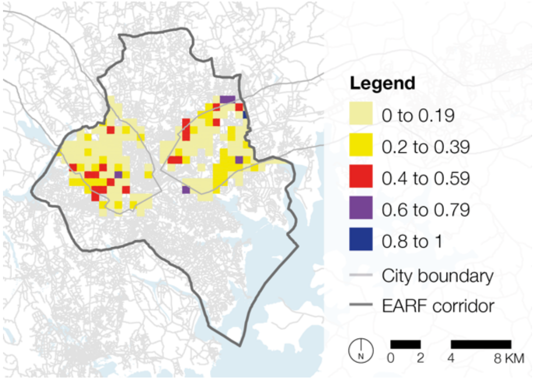
2.1.2.	**Distance to flood prone areas**
Source	KCCA
Method	Calculation of shortest distance from each 100 * 100 m grid cell centre point to flood prone area according to defintion by KCCA
Observation/ comments	



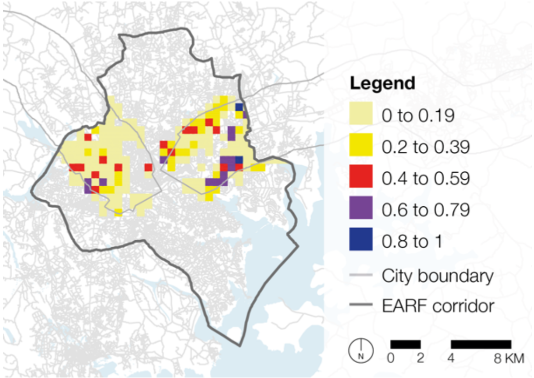
2.1.3.	**Hazard perception**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell to perceived level of hazard risk from households
Observation/ comments	1 No, certainly not 2 No, probably not (low risk) 3 Yes, it might happen (medium risk) 4 Yes, it is likely to happen (high risk)



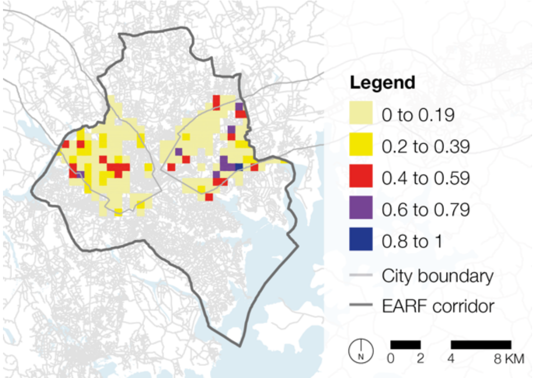
3.1.1.	**Income range**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell to household income category
Observation/ comments	1 Less than UGX 100,000 2 100,000 - 250,000 3 250,001 - 500,000 4 500,001 - 1,000,000 5 1,000,001 - 2,000,000 6 2,000,001 - 3,000,000 1,000 UGX ≈ 0.333 USD / 0.2 Euro (June 2018)



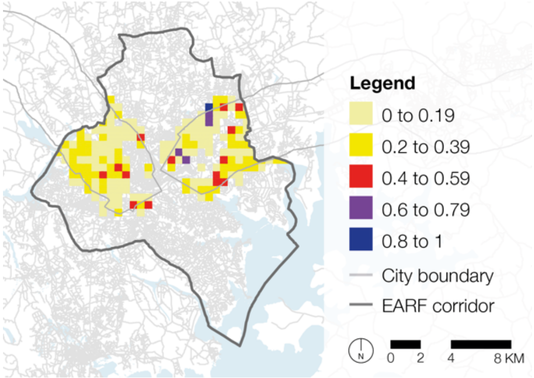
3.1.2.	**Expenses**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell to combined expenses for rent, utilities, school fees, transport from households
Observation/ comments	



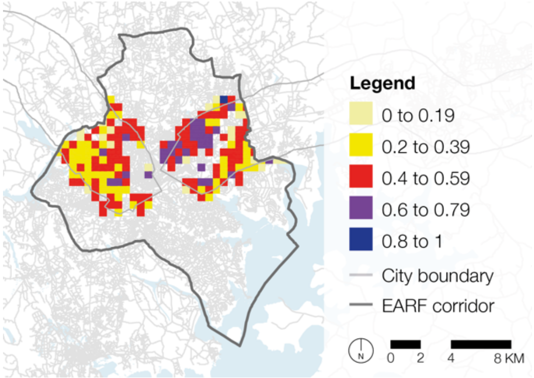
3.1.3.	**Area of plot**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell to size of plots from households
Observation/ comments	



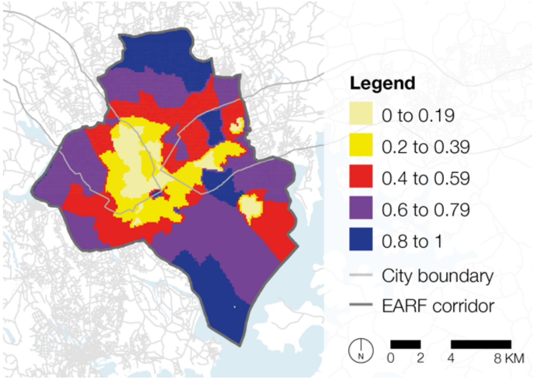
3.1.4.	**Cost of purchase**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell to cost of purchase of property from households
Observation/ comments	



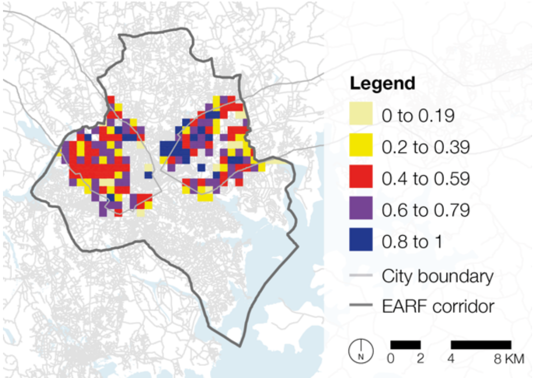
3.1.5.	**Current price**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell to current value of property from households
Observation/ comments	



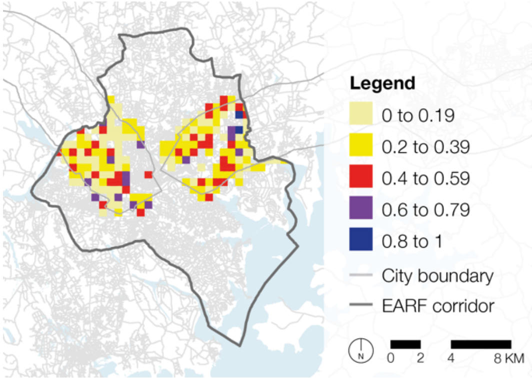
3.1.6.	**Relation to site**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell to relationship to property from households
Observation	1 Own 2 Rent 3 Caretaker 4 Other type of occupancy



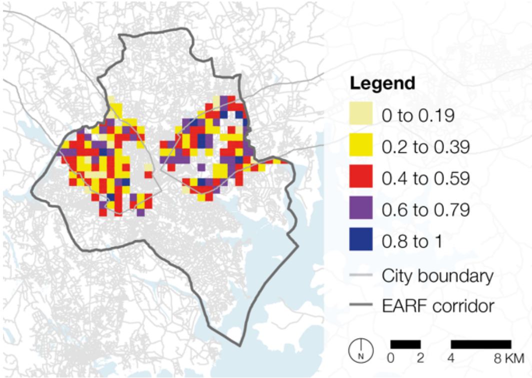
3.1.7.	**Percentage of ownership**
Source	National Census 2014
Method	Percentage of people who own property instead of renting or being subsidised
Observation/ comments	



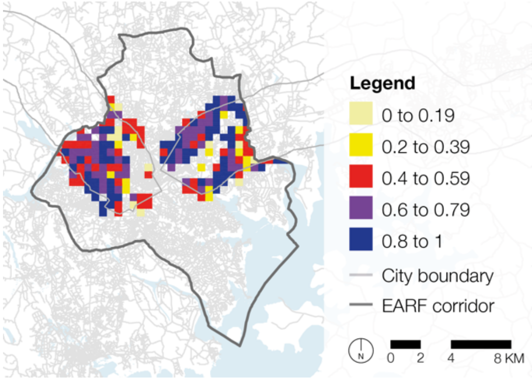
3.2. AG	**Basic service access (aggregated)**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell access to various basic services
Observation/ comments	Included services: • Water • Connection to sewerage network • Septic tank • Sanitation facility • Solar panel • Water quality (Likert scale 1-5) • Water access, accord. to: 1 Tapped water at premise/delivered to your premise (0 to 5 minutes) 2 Shared water access point with neighbours (less than 10 minutes) 3 Less than 30 minutes for a round trip 4 Between 30 minutes and 2 hours for round trip 5 More than 2 hours for a roundtrip



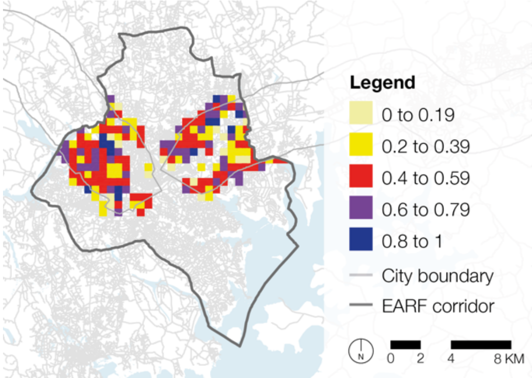
3.3.1.	**Years since moving / social integration**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell to number of years since moving to current property
Observation/ comments	



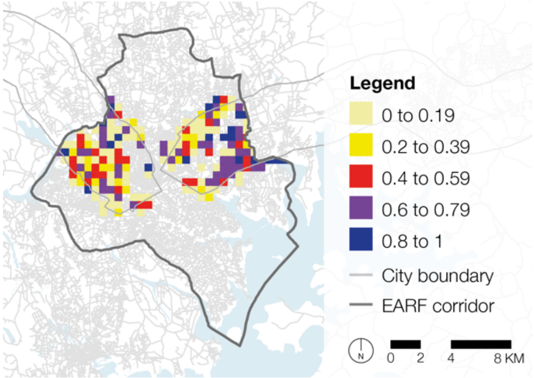
3.3.2.	**Initial location**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell to initial location before moving (sorted accord. to distance for numeric meaning)
Observation/ comments	1 I have always lived here 2 Within this neighbourhood 3 Another neighbourhood within city 4 Another city within the country 5 Rural area within the country 6 Urban area outside the country 7 Rural area outside the country



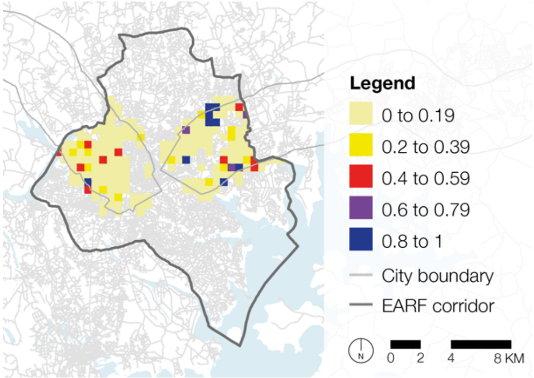
3.3.3.	**Satisfaction with neighbourhood (reversed)**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell to level of satisfaction for neighbourhood for households
Observation/ comments	Likert scale 1-5 from 1 = very dissatisfied to 5 = very satisfied



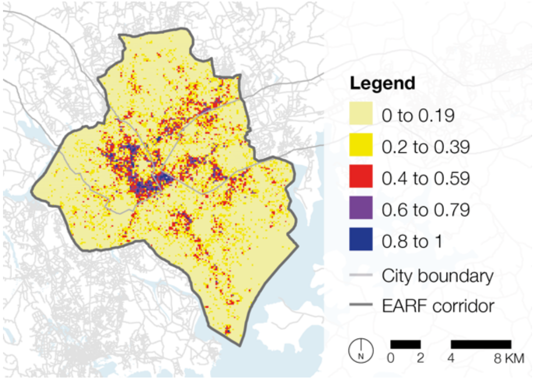
3.3.4.	**Plan to relocate**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell to likelihood to relocate for households
Observation/ comments	Likert scale 1-5 from 1 = yes, definitely to 5 = most definitely not



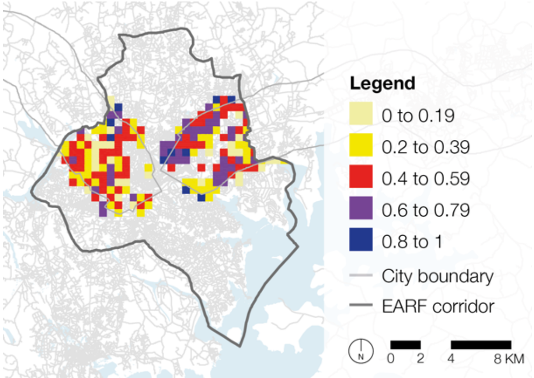
3.3.5.	**Undertaken improvements (reversed)**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell to improvements on plot undertaken for households
Observation/ comments	



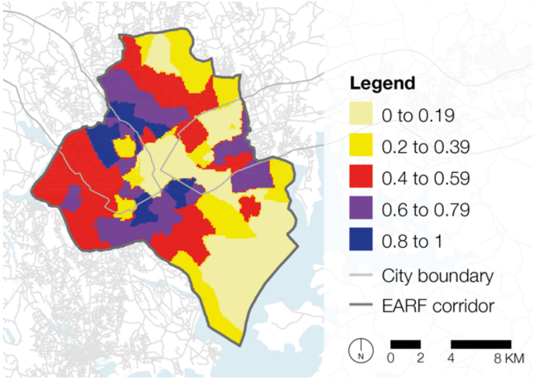
3.3.6.	**Improvement costs**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell to costs of undertaken improvements on plot
Observation/ comments	



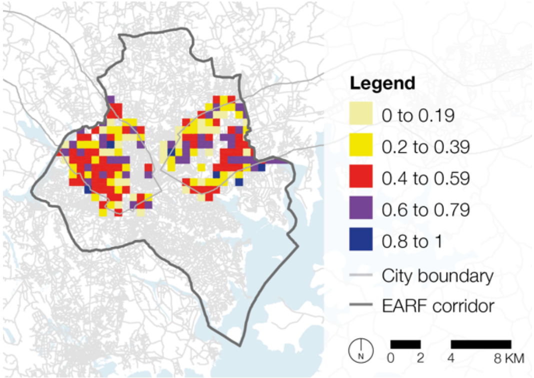
3.4.1.	**Internet use (by number of tweets)**
Source	Twitter API
Method	Geo-referenced tweets inside Kampala were extracted and their visualisation analysed with the image analysis of ArcGIS
Observation/ comments	



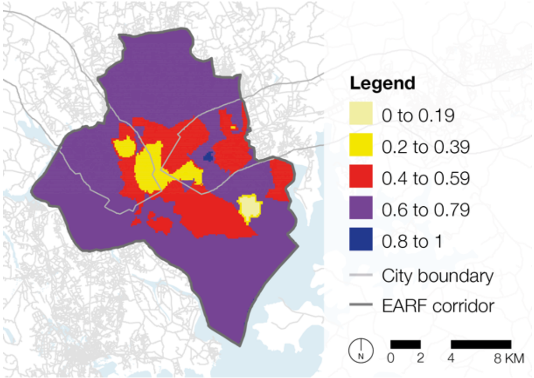
3.4.2.	**Level of education**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell to highest level of education in households
Observation/ comments	1 Currently enrolled in primary school 2 Primary school (completed) 3 Secondary school (completed; O, A) 4 Vocational/Institute (completed) 5 University (completed) 6 Post-graduate (completed)



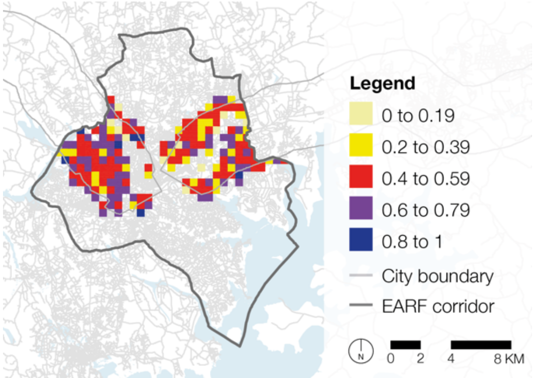
4.1.1.	**Population density**
Source	National census 2014
Method	Average number of people per hectare
Observation/ comments	



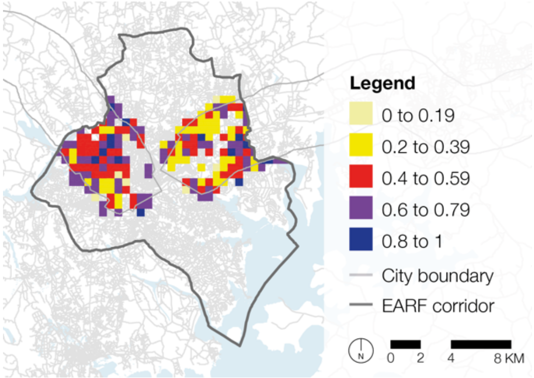
4.1.2.	**Household size**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell to household size
Observation/ comments	



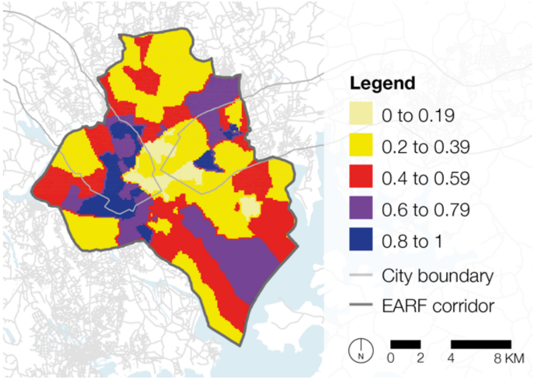
4.1.3.	**Female population (gender 1)**
Source	National census 2014
Method	Average percentage of female population of total population
Observation/ comments	



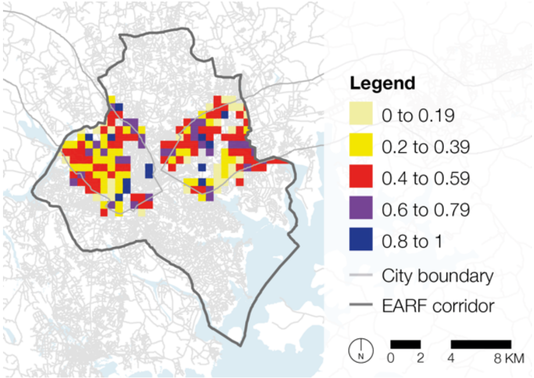
4.1.4.	**Female population (gender 2)**
Source	EARF household survey 2018
Method	Average percentage of female respondents per 500 * 500 m grid cell
Observation/ comments	



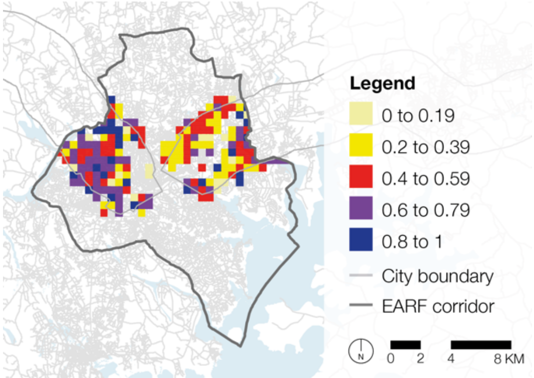
4.1.5.	**Age group (reversed)**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell to age group of household members
Observation/ comments	1 Less than 5 years 2 5 to 15 years 3 16 to 25 years 4 26 to 35 years 5 36 to 45 years 6 45 to 55 years 7 Above 55 years



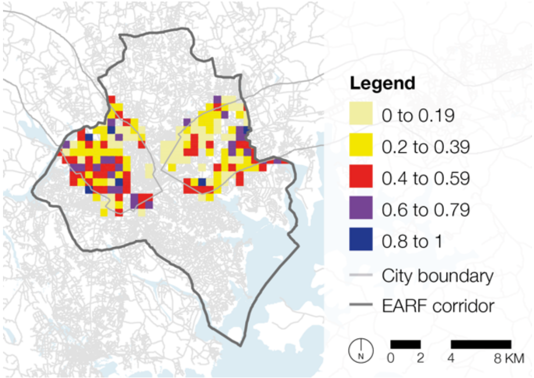
4.1.6.	**Female-headed households**
Source	National survey 2014
Method	Percentage of female-headed households per 100 * 100 m grid cell
Observation/ comments	



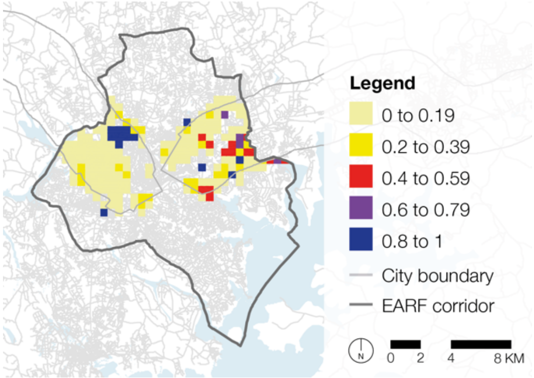
4.1.7.	**Economic resilience**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell to perception of own economic resilience as defined below for households
Observation/ comments	1 Not sufficient 2 Only just meets expenses 3 Enough to build savings



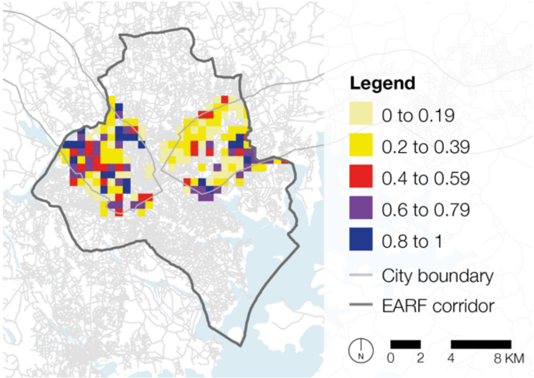
4.1.8.	**Type of employer (reversed)**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell of the type of main employer per household member
Observation/ comments	1 Themselves 2 Someone else 3 Private Company 4 Government 5 Non-Governmental Entity, NGO/CBO



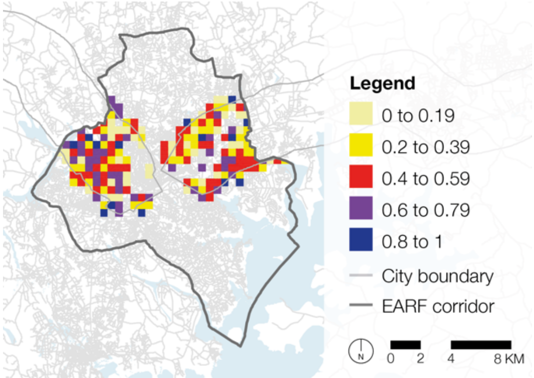
4.1.9.	**Type of Occupation**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell of the type of main occupation per household member
Observation/ comments	1 Salary/Wages 2 Farming 3 Buying and selling goods 4 Making/Recycling items 5 Transport 6 Providing irregular services for people 7 Pensions 8 Renting out property (land/housing)



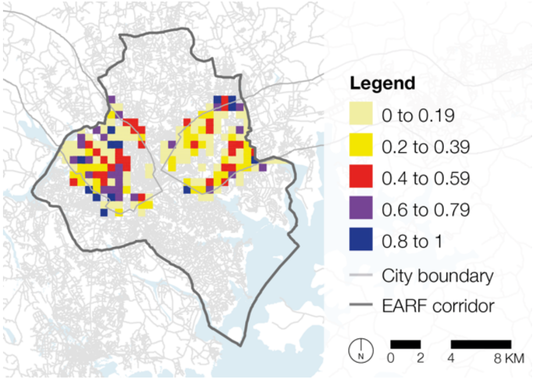
4.1.10.	**Prevalence/risk of Expropriations**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell of prevalence or risk of expropriation for households in neighbourhood
Observation/ comments	1 No 2 Yes, some 3 Yes, many



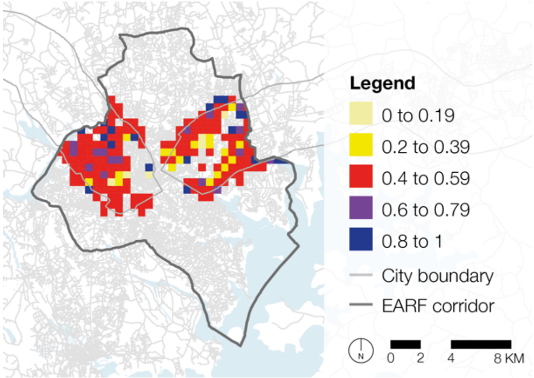
4.1.11.	**Safety (reversed)**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell of perception of safety for females in households
Observation/ comments	Likert scale from 1 = very unsafe to 5 = very safe



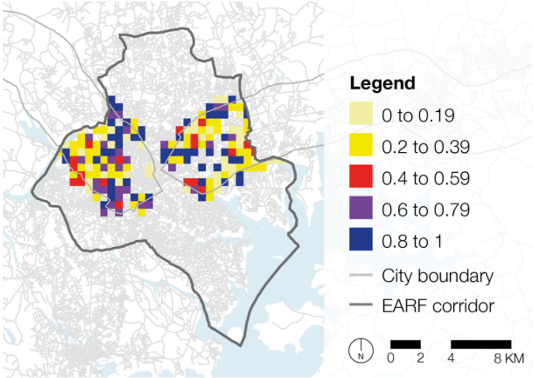
4.1.12.	**Affordability for household**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell of affordability for household in neighbourhood
Observation/ comments	Likert scale from 1 = very difficult to 5 = very easy



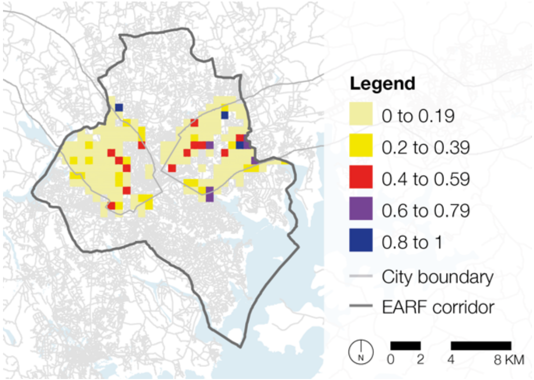
4.1.13.	**Property restriction**	
Source	EARF household survey 2018	
Method	Average response per 500 * 500 m grid cell of experienced restrictions in acquiring/renting property in neighbourhood for household	
Observation/ comments	1	No, I did not find any restrictions
	2	Only open to family members
	3	Only open to personal connections
	4	Only through tribal relationship
	5	Restricted by religion
	6	Restricted by nationality
	7	Only open to persons w/ excl. rights



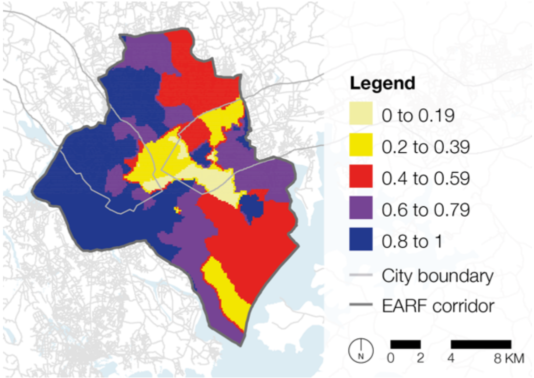
4.1.14.	**Property ownership**	
Source	EARF household survey 2018	
Method	Average response per 500 * 500 m grid cell about owner of property for household	
Observation/ comments	1	A relative not living in household
	2	Private individual
	3	A business, commercial entity
	4	A public entity



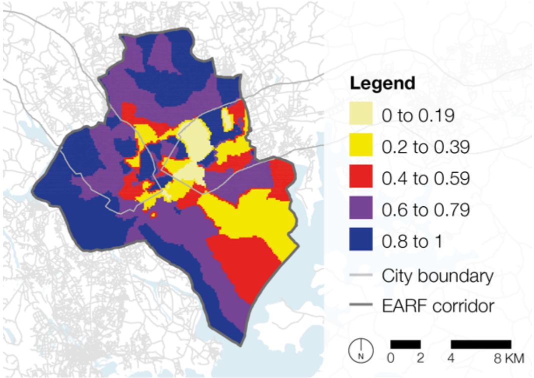
4.2.1.	**Type of dwelling**	
Source	EARF household survey 2018	
Method	Average response per 500 * 500 m grid cell about type of dwelling for household	
Observation/ comments	1	Apartment building
	2	Horizontally attached multi-family unit (tenement)
	3	Semi-Detached multi-family residential (two together)
	4	Detached single family residential (standalone)



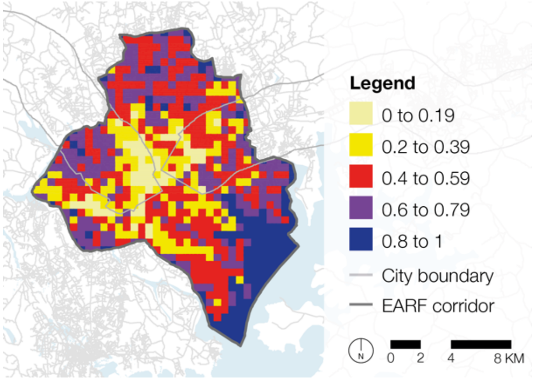
4.2.2.	**Type of dwelling material**	
Source	EARF household survey 2018	
Method	Average response per 500 * 500 m grid cell about type of dwelling material for household	
Observation/ comments	1	Traditional/Temporary
	2	Semi-permanent
	3	Permanent



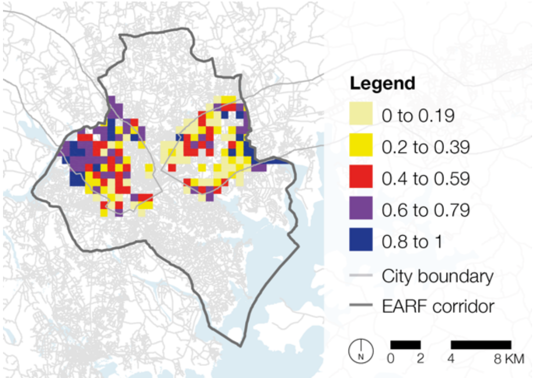
4.2.3.	**Built floor quality (reversed)**
Source	National census 2014
Method	Floor quality calculated based on 2014 census by percentage of concrete, cement screed * 0.7 + bricks, stone * 0.3
Observation/ comments	Weight 0.7: Floor: Concrete Floor: Cement Screed Weight 0.3: Floor: Bricks Floor: Stone Not counted: Floor: Earth, Rammed Earth, Wood, Tiles



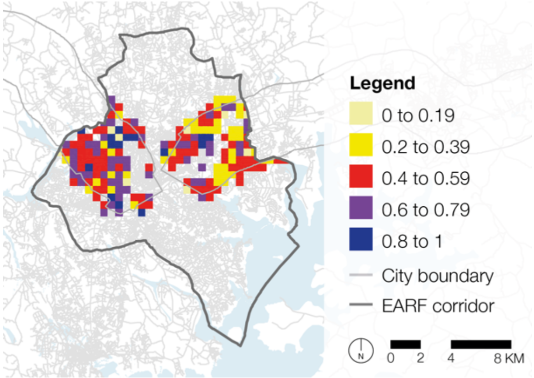
4.2.4.	**Built wall quality (reversed)**
Source	National census 2014
Method	Wall quality calculated based on 2014 census by percentage of concrete or stone, cement blocks, burned or stabilised blocks
Observation/ comments	Counted: Wall: Concrete of Stone Wall: Cement Blocks Wall: burned or Stabilised Bricks Not counted: Wall: unburned Brick or Cement Wall: unburned Brick and Mud Wall: Wood Wall: Mud or Pole Wall: Tin or Iron Sheets



4.3.1.	**Street density**
Source	Open Street Maps
Method	Metre of streets per square kilometre, weighted by 0.6 for primary, and 0.4 for secondary streets
Observation/ comments	



4.3.2.	**Nearest road**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell about distance to nearest paved road for household
Observation/ comments	1 Less than 1 km (0.5 miles) 2 1 to 3 km (0.5 to 2 miles) 3 4 to 8 km (2.5 to 5 miles) 4 More than 8km (More than 5 miles)



4.3.3.	**Travel time to work or school**
Source	EARF household survey 2018
Method	Average response per 500 * 500 m grid cell about travel time to nearest main location (work or school) per household member
Observation/ comments	1 Less than 1 km (0.5 miles) 2 1 to 3 km (0.5 to 2 miles) 3 4 to 8 km (2.5 to 5 miles) 4 More than 8km (More than 5 miles)

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