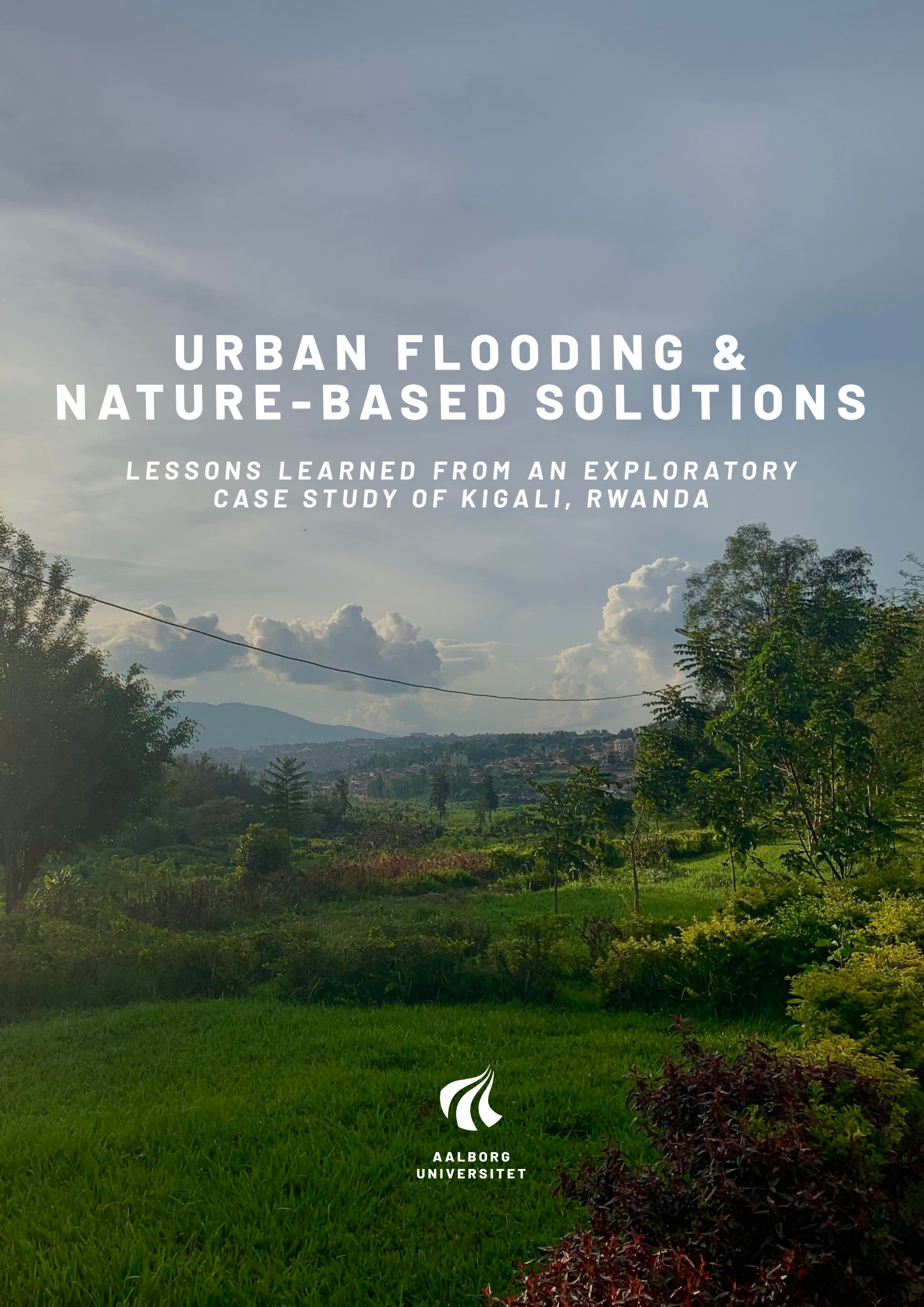
URBAN FLOODING & NATURE-BASED SOLUTIONS

LESSONS LEARNED FROM AN EXPLORATORY CASE STUDY OF KIGALI, RWANDA



AALBORG
UNIVERSITET

I. TITLE PAGE

PROJECT TITLE
URBAN FLOODING AND NATURE-BASED SOLUTIONS
LESSONS LEARNED FROM AN EXPLORATORY CASE STUDY OF KIGALI, RWANDA

COURSE
F22 - SUSCI4 - MASTER'S THESIS

SEMESTER
SPRING 2022

MASTER'S DEGREE
SUSTAINBLE CITIES

UNIVERSITY
AALBORG UNIVERSITY, COPENHAGEN
C. MEYERS VÆNGE 15, 2450 KØBENHAVN

FACULTY AND DEPARTMENT
THE TECHNICAL FACULTY OF IT AND DESIGN
DEPARTMENT OF PLANNING

SUPERVISOR
JAMAL JOKAR ARSANJANI

SUBMISSION DATE AND TIME
03-06-2022, 10:00 (CET)

CHARACTERS WITHOUT SPACES
308,330 EQUALLING 128 STANDARD PAGES

REFERENCE STYLE
APA 7TH EDITION

FRONT PAGE
KIMICHANGA WETLAND RESTORATION IN KIGALI

END PAGE
THE CENTRAL BUSINESS DISTRICT OF KIGALI

FOTOS
RIKKE KRISTIANSEN & THALE JACOBSEN RYE

BY

RIKKE KRISTIANSEN
20200899

THALE JACOBSEN RYE
20200903

AALBORG UNIVERSITET
STUDENTERRAPPORT

II. ACKNOWLEDGEMENTS

FIRST AND FOREMOST, WE WOULD LIKE TO ACKNOWLEDGE AND GIVE OUR DEEPEST THANKS TO OUR SUPERVISOR JAMAL JOKAR ARSANJANI. YOUR GUIDANCE AND TECHNICAL ADVICE HAVE GUIDED US THROUGH THE ENTIRE RESEARCH PROCESS AND HAVE HELPED US IN ALL STAGES OF OUR WRITING.

WE OWE A DEPTH OF GRATITUDE TO ALL INTERVIEWEES WHO LINED UP FOR OUR ENDLESS RANGE OF QUESTIONS DESPITE TIME ZONES AND LANGUAGE BARRIERS. YOUR EXPERTISE, ARGUMENTS, AND INSIGHT IN THE CASE OF KIGALI, URBAN FLOODING, NATURE-BASED SOLUTIONS, AND CLIMATE CHANGE ADAPTATION IN EAST AFRICA AND BEYOND ARE VALUED INPUTS AND HAVE HELPED SHAPE THE SCOPE OF THE PRESENT STUDY.

A SPECIAL THANKS TO JUDITH, SHANNON, AND INNOCENT FOR BEING THE UTMOST WELCOMING HOSTS DURING OUR FIELD STUDY IN KIGALI, RWANDA, IN APRIL. THANK YOU FOR INTRODUCING US TO YOUR BEAUTIFUL COUNTRY AND GIVING US LOCAL INSIGHTS INTO THE COMPLEX CITY. WITH YOUR GENUINE HOSPITALITY, WE WERE ABLE TO GET THE MOST OUT OF OUR STAY AND COLLECT THE NEEDED DATA FOR OUR RESEARCH.

FINALLY, WE WOULD LIKE TO THANK OUR RESPECTIVE FAMILIES AND FRIENDS FOR THEIR CONTINUOUS SUPPORT AND ENCOURAGEMENT THROUGHOUT THE ENTIRE PROCESS OF WRITING THIS MASTER'S THESIS.

III. ABSTRACT

THE PRESENT EXPLORATORY STUDY INVESTIGATES HOW THE CITY OF KIGALI, THE CAPITAL OF RWANDA IN EAST AFRICA, ADDRESSES CURRENT CHALLENGES OF URBAN FLOODING EXACERBATED BY ANTHROPOGENIC CLIMATE CHANGE AND RELATED URBAN DEVELOPMENT CHALLENGES. IT FURTHER SEEKS TO UNDERSTAND TO WHAT EXTENT NATURE-BASED SOLUTIONS (NBS) HAVE EMERGED AS A NOVEL INNOVATION TO ENHANCE THE URBAN CLIMATE RESILIENCE AND STORMWATER MANAGEMENT PRACTICES IN THE METROPOLIS.

TO GRASP THE COMPLEXITY OF THESE CHALLENGES, THE STUDY APPLIES A THEORETICAL FOUNDATION BUILDING ON GROUNDED THEORY (STEINBERG & STEINBERG, 2006) AND THE MULTI-LEVEL PERSPECTIVE ON SOCIO-TECHNICAL TRANSITIONS (GEELS, 2005). THESE CONSIDERATIONS GUIDE THE DATA COLLECTION PROCESSES FRAMED BY A RANGE OF QUALITATIVE METHODS, SUCH AS EXPERT INTERVIEWS AND IN-SITU OBSERVATIONS, SUPPLEMENTED WITH A QUANTITATIVE BLUE SPOT MAPPING (BALSTRØM, 2022).

FINDINGS INDICATE THAT THE RAPIDLY GROWING CITY OF KIGALI IS FACING A NEXUS OF URBAN DEVELOPMENT CHALLENGES FROM THE INCREASING IMPACTS OF ANTHROPOGENIC CLIMATE CHANGE AND ASSOCIATED URBAN FLOODING. WHICH ARE FURTHER COMPOUNDED BY RAPID URBANISATION AND URBAN SPRAWL OCCURRING AT THE EXPENSE OF BIODIVERSITY AND ECOSYSTEMS.

THE STUDY EXPLORES THE STRUCTURE OF THE CURRENT URBAN PLANNING REGIME IN THE CITY OF KIGALI AND HOW THE COMPLEXITY OF URBAN DEVELOPMENT CHALLENGES PLACES PRESSURE ON THE EXISTING URBAN PLANNING REGIME AND STORMWATER MANAGEMENT. ULTIMATELY, THE STUDY FINDS THAT THE REGIME FAILS TO ADDRESS THE NEXUS OF URBAN DEVELOPMENT CHALLENGES, YET A WINDOW OF OPPORTUNITY HAS SURFACED FOR NBS TO EMERGE AS A NOVEL INNOVATION IN KIGALI. HOWEVER, THE STUDY IDENTIFIES SEVERAL BARRIERS AND CHALLENGES HINDERING THE FURTHER SUSTAINABILITY TRANSITION OF NBS FROM NICHE TO NORM.

TO STRENGTHEN URBAN PLANNING PRACTICES AND STORMWATER MANAGEMENT IN KIGALI, A RANGE OF RECOMMENDATIONS TO BRIDGE THE IDENTIFIED GAPS AND ULTIMATELY ACCELERATE THE TRANSITION ARE PRESENTED. CONSEQUENTLY, THE STUDY ARTICULATES THE URGENT NEED TO ADVANCE THE IMPLEMENTATION OF CLIMATE CHANGE ADAPTATION INITIATIVES IN THE FORM OF NBS IN KIGALI AND HIGHLIGHTS THE IMPORTANCE OF CREATING HOLISTIC AND SYNERGETIC PLANNING PRACTICES WITH NATURE AT THEIR HEART TO ENHANCE URBAN RESILIENCE AND STORMWATER MANAGEMENT.

IV. TABLE OF CONTENTS

V. ABBREVIATIONS

ASEAN	Association of Southeast Asian Nations
ASWAP	Agricultural Sector Wide Approach
BI	Blue Infrastructure
CBD	Central Business District of Kigali
CCA	Climate Change Adaptation
CSO	Civil Society Organisation
CoK	The Council of the City of Kigali
CSO	Civil Society Organisations
DEM	Digial Elevation Model
Dutch MFA	Dutch Ministry of Foreign Affairs
EbA	Ecosystem-based Adaptation
EE	Ecological Engineering
EIRR	Economic Internal Rate of Return
ES	Ecosystem Service
EU	European Union
GBI	Green-Blue Infrastructure
GDP	Gross Domestic Product
GFDRR	The Global Facility of Disaster Risk Reduction
GGGI	The Global Green Growth Institute
GHG	Greenhouse Gas
GI	Green Infrastructure
GIS	Geographical Information System
ICCCAD	International Centre for Climate Change & Development
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
LDC	Least Developed Country
LiDAR	Light Detection & Ranging
LLA	Locally Led Adaptation
MIDIMAR	The Ministry of Disaster Management & Refugee Affairs, Rwanda.
MINEMA	Ministry in Charge of Emergency Management, Rwanda
MODIS	Moderate Resolutions Imaging Spectroradiometer
NAPA	National Adaptation Programmes of Action to Climate Change
NatuRes	Natural Resources Stewardship Programme
NbA	Nature-based Action
NbS	Nature-based Solutions
NCS	Natural Climate Solutions
NDC	Nationally Determined Contribution
NDVI	Normalised Difference Vegetation Index
NGO	Non-Governmental Organisation
NST	National Strategy for Transformation
OECD	Organisation for Economic Co-operation & Development
PES	Payment for Ecosystem Services
RCP	Representative Concentration Pathways
RECOR	Rwanda Environmental Conservation Organisation
REMA	Rwanda Environment Management Authority
RoR	Republic of Rwanda
RWB	Rwanda Water Resources Board
SEI	Stockholm Environment Institute
SJ	Surbana Jurong
SRTM	Shuttle Radar Topography Mission
SSP	Shared Socioeconomic Pathways
UHI	Urban Heath Island
UN	United Nations
UN FAO	United Nations Food & Agriculture Organization
UNEP	United Nations Environment Programme
USD	United States Dollar
VSLAS	Village Savings & Loans Associations
WAC	Water Adaptation Community
WBG	The World Bank Group
WWF	World Wildlife Fund for Nature

VI. READING GUIDE

THE STUDY EMBODIES FOURTEEN CHAPTERS WHICH ARE OUTLINED BELOW.

CHAPTER 1. INTRODUCTION
THE FIRST CHAPTER OF THE STUDY SERVES AS A BRIEF INTRODUCTION TO THE PROBLEM AREAS OF INVESTIGATION, URBAN FLOODING IN KIGALI, AND PRESENTS THE RESEARCH AIM, OBJECTIVES, THE PROBLEM STATEMENT, RESEARCH QUESTIONS, THE RESEARCH DESIGN AND THE STRUCTURE OF THE STUDY.

CHAPTER 2. BACKGROUND TO THE STUDY
THE SECOND CHAPTER GIVES A SHORT BACKGROUND TO THE STUDY BY BRIEFLY TOUCHING UPON FOUNDATIONAL DETAILS OF RWANDA AND KIGALI, INCLUDING THE GEOGRAPHICAL LOCATION, SOCIO-ECONOMIC FACTS, CLIMATE, AND RECENT DEVELOPMENTS, WHICH ARE SIGNIFICANT FOR THE FOLLOWING ANALYSES AND DISCUSSION AND SET THE SCENE FOR THE PRESENT STUDY.

CHAPTER 3. THE THEORETICAL FOUNDATION
THE THIRD CHAPTER ESTABLISHES THE THEORETICAL FOUNDATIONS OF THE PRESENT STUDY, WHICH IS BASED ON THE GROUNDED THEORY (STEINBERG AND STEINBERG, 2006) AND THE MULTI-LEVEL PERSPECTIVE ON SOCIO-TECHNICAL TRANSITIONS (GEELS, 2002, 2005, 2011, 2019), AND HOW IT GUIDES THE DATA COLLECTION AND THE FOLLOWING ANALYSES.

CHAPTER 4. METHODOLOGY
CHAPTER FOUR ELABORATES UPON THE EMPLOYED METHODOLOGY CONSISTING OF AN EXPLORATORY CASE STUDY, AN EXTENSIVE LITERATURE REVIEW, SEMI-STRUCTURED INTERVIEWS, A FIELD STUDY, SITE VISITS, IN-SITU OBSERVATIONS AND PHOTO DOCUMENTATION. THE CHAPTER DESCRIBES THE INTERLINKAGES OF THE QUALITATIVE METHODS AND THE SUPPORTING QUANTITATIVE METHOD BEHIND THE GEOGRAPHICAL INFORMATION SYSTEMS (GIS) BLUE SPOT MAPPING.

CHAPTER 5. PRELIMIMINARY ANALYSIS 1
CHAPTER FIVE EXPLORES THE DEVELOPMENT CHALLENGES OF KIGALI CENTRING ON CHANGES IN PRECIPITATION PATTERNS, CLIMATE-INDUCED AND WATER-RELATED HAZARDS INCLUDING URBAN FLOODING AND SOIL EROSION, ALONGSIDE URBANISATION, URBAN SPRAWL, AND THE DEGRADATION OF BIODIVERSITY AND ECOSYSTEMS.

CHAPTER 6. PRELIMIMINARY ANALYSIS 2
CHAPTER SIX TAKES A DEEP DIVE INTO THE ROLE OF NATURE-BASED SOLUTIONS (NBS) IN URBAN PLANNING AND THEIR POSSIBILITIES FOR ADDRESSING THE IMPACTS OF CLIMATE CHANGE INCLUDING URBAN FLOODING. THE CHAPTER REVIEWS FIVE CASES OF NBS IN NEIGHBOURING CAPITALS TO KIGALI TO EXPLORE THE CURRENTATUS QUO OF NBS FROM AN EAST AFRICAN PERSPECTIVE.

CHAPTER 7. ANALYSIS 1
THE SEVENTH CHAPTER CONTAINS THE FIRST ANALYSIS OF THE STUDY. THE RATIONALE OF THE ANALYSIS IS TO EXPLORE THE INPUTS, METHODOLOGIES, AND OUTCOMES OF CURRENTLY AVAILABLE RESEARCH ON FLOOD HAZARDS AND RISKS WITHIN THE CITY OF KIGALI. ADDING TO THIS OBJECTIVE, THE ANALYSIS AIMS TO PRESENT A NOVEL GIS BLUE SPOT MAPPING APPROACH THAT CAN GUIDE FUTURE RESEARCH AND URBAN DEVELOPMENT IN KIGALI

CHAPTER 8. ANALYSIS 2
CHAPTER EIGHT BUILDS UPON THE PRECEDING ANALYSIS IN CHAPTER 7, AS IT INVESTIGATES THE STRUCTURES OF THE CURRENT URBAN PLANNING REGIME AND HOW WELL IT IS COPING WITH THE URGENT LANDSCAPE PRESSURES REGARDING CLIMATE CHANGE AND URBAN FLOODING.

CHAPTER 9. ANALYSIS 3
CHAPTER NINE HOLDS THE THIRD AND FINAL ANALYSIS WHICH IS BUILDING ON THE OUTCOMES OF THE TWO PREVIOUS ANALYSES. THE ANALYSIS EXPLORES THE ROLE OF NBS AS A NOVEL INNOVATION IN TERMS OF URBAN PLANNING, STORMWATER MANAGEMENT, AND REHABILITATION OF DEGRADED BIODIVERSITY AND ECOSYSTEMS IN KIGALI. THE ANALYSIS SEEKS TO DETERMINE THE CURRENT PHASE OF THE SUSTAINABILITY TRANSITION OF NBS FROM NICHE TO NORM IN KIGALI.

CHAPTER 10. DISCUSSION
CHAPTER 10 CONTAINS A DISCUSSION ON SEVERAL OUTCOMES FROM THE PRECEDING ANALYSES THAT NECESSITATE CLOSER ELABORATION, EVALUATION, AND DISCUSSION. THE DISCUSSION REVERTS TO THE QUESTION CONCERNING THE BARRIERS AND CHALLENGES OF THE SUSTAINABILITY TRANSITION OF NBS FROM NICHE TO NORM. THUS, THE DISCUSSION SEEKS TO CREATE AN UNDERSTANDING OF THE OBSTACLES THE NOVEL INNOVATION OF NBS HAVE TO OVERCOME TO FURTHER TRANSITION.

CHAPTER 11. RECOMMENDATIONS & FURTHER RESEARCH
CHAPTER 11 PRESENTS A RANGE OF DIFFERENT RECOMMENDATIONS AND POINTS FOR FURTHER RESEARCH AIMING AT EASING AND ACCELERATING THE SUSTAINABILITY TRANSITION OF NBS IN KIGALI.

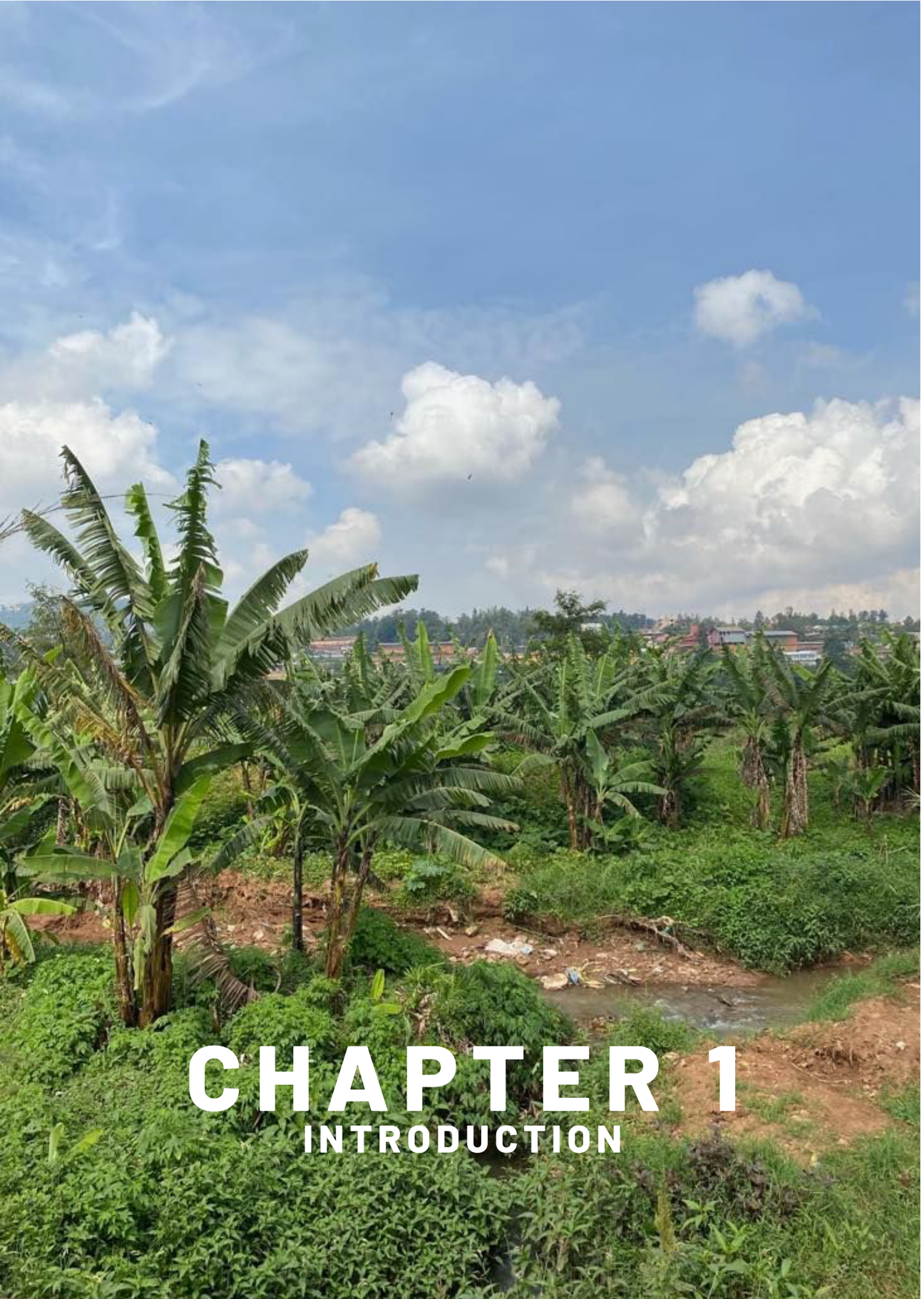
CHAPTER 12. EVALUATION & REFLECTIONS
CHAPTER 12 EVALUATES THE FINDINGS FROM THE PRECEDING ANALYSES AND DISCUSSION CENTRING ON HOW CREDIBILITY, VALIDITY, AND RELIABILITY MAY BE AFFECTED BY SUBJECTIVITY AND BIAS. THE CHAPTER LIKEWISE COVERS A REFLECTION UPON THE TERM FLY-IN FLY-OUT EXPERTS AND ITS RELEVANCE FOR THE PRESENT STUDY.

CHAPTER 13. CONCLUSION
THE THIRTEENTH CHAPTER ROUNDS OFF THE STUDY BY PROVIDING THE CONCLUSION OF THE INVESTIGATED RESEARCH QUESTIONS.

CHAPTER 14. BIBLIOGRAPHY
CHAPTER 14 IS THE FINAL CHAPTER OF THE STUDY. IT HOLDS A COMPLETE LIST OF THE USED REFERENCES.

APPENDICES
APPENDICES 1- 9 HOLD THE INTERVIEW TRANSCRIPTIONS OF INTERNATIONAL EXPERTS AND LOCAL PRACTITIONERS WHILE APPENDIX 9 CONTAINS THE CASE JOURNAL OF THE FIELD STUDY AND APPENDIX 10 THE GIS TOOLBOX. APPENDIX 11 CONTAINS A GLOSSARY OF DEFINITIONS OF VITAL TERMS AS THEY ARE INTERPRETED AND UNDERSTOOD WITHIN THE DOMAIN OF THE PRESENT STUDY.

VII. ENUMERATION



CHAPTER 1
INTRODUCTION

THE CHALLENGES OF URBAN RESILIENCE

In the forthcoming century, life on earth will change fundamentally. A triple planetary crisis of climate change, biodiversity loss, and pollution, aggravated by the impacts of anthropogenic activities, poses an unprecedented threat to the world as we know it. The crisis materialises in an array of cascade effects that negatively influence all life on earth, as the current trajectory is imposing significant challenges for sustainable and resilient development. Accordingly, the need for widespread climate change adaptation and mitigation actions is of the utmost priority and should be the immediate task at hand for the global society (IPCC, 2022; UNEP, 2022).

In a progressively urbanising world, the planetary crisis will be won or lost in cities and urban centres. In the scientific community, there is a broad consensus that African cities are disproportionately affected by the adverse impacts of climate change. They are highly exposed and vulnerable to these manifestations, due to their multifaceted fragility originating from poor environmental, social, and financial capacities. The challenges of urban resilience are further complexified when cities are urbanising rapidly. A prominent concern in African cities, as the urban population is growing at an average annual rate of 3.4%, and projections indicate that a staggering 60% of its citizens will reside in urban areas by 2050 (WBG, 2016).

Such rapid urbanisation raises questions regarding how to enhance urban resilience and adaptive capacities. During the past decades, East African cities have been subject to great changes in the dynamics of the hydrological cycle, where balancing too much water and too little water is a matter of life and death (Kalantari et al., 2018). An overarching consequence is the environmental hazard of urban flooding, which has increased in both intensity and frequency in recent years. Other concerns relate to the degradation of natural ecosystems, which is further exacerbated by rapid urbanisation (IPCC, 2022)

For far too long, urbanisation and urban development have occurred at the expense of nature. As so, there is a pressing need to incorporate initiatives that can address the need to restore the original capacity of natural ecosystems to cope with environmental hazards. In response, there is a growing focus on the potential for incorporating Nature-based Solutions (NbS) to enhance climate resilience in urban areas. NbS have widely been suggested as a novel innovation that can address the nexus of urban development challenges (OECD, 2020).

One of the urban areas in Africa, where the impacts of climate change and urbanisation are already evident, is the City of Kigali in the Republic of Rwanda. While existing and future levels of precipitation pose a significant threat to urban life, surface areas are becoming increasingly impervious aggravating the risk of urban floods and adding pressure on the urban planning practices in the capital city. This raises concerns regarding the need to alter planning practices in order to increase urban resilience and adaptive capacity in the face of climate change.

PROBLEM AREA

Kigali, the capital city of the land of a thousand hills, is home to nearly half of the Rwandan urban population and has experienced rapid development and urbanisation in the recent decade. The city faces a nexus of intertwined urban development challenges aggravated by anthropogenic climate change. Culminating in the recurrence of a range of environmental hazards, where urban flooding is a major concern. In critical events, urban floods have destroyed critical infrastructures and on several occasions culminated in the loss of lives. As such, urban flooding poses a significant threat to the life, health, and safety of the urban dwellers of Kigali (Alemayehu & Benitez, 2020). Previous research on the local causes and possible responses to urban flooding has been conducted based on poor data and has focussed on structural, engineered measures. There have been few studies incorporating qualitative methodologies that explore the issue of urban flooding and to what extent NbS are emerging as a novel innovation to address the nexus urban development challenges.

The complex structures of the existing planning regime and urban stormwater management must be explored to uncover possible gaps in current planning practices as well as barriers and challenges to incorporating NbS as a flood-protective measure in Kigali.

Addressing the problem of urban flooding and current planning practices could potentially inform policy objectives, local urban practitioners, and those aiming at enhancing urban resilience through the use of nature.

Building on the above problem statement, the study presents the following research question:

RESEARCH QUESTION

How are urban flooding and the related nexus of development challenges placing pressure on the current urban planning regime in the City of Kigali, Rwanda, and to what extent have Nature-based Solutions (NbS) emerged as a novel innovation to enhance urban resilience?

Sub-questions
To narrow the scope of the research and navigate the complexity of the problem area, the study explores the research question through the lens of four sub-questions.

#1. *What is the state of available geospatial flood hazard models and visualisations, and what are the potentials of using the Blue Spot Mapping methodology as a tool for local urban practitioners to identify potential flood hazards in the City of Kigali?*

#2. *How is the current urban planning regime governed and stormwater management practices, and how does the regime address the urban development challenges of flooding, urbanisation, and urban sprawl?*

#3. *How are NbS emerging as a novel innovation in response to the challenges of urban flooding and the degradation of biodiversity and ecosystems?*

#4. *How are barriers and challenges hindering the transition of NbS from niche to norm, and how can the transition be accelerated?*

Research Objectives
The overall aim of the present exploratory study is to investigate how the City of Kigali is dealing with the current urban flooding problems arising from climate change and related urban development challenges aggravating the impacts of the hazard, and further understand to what extent Nature-based Solutions (NbS) have emerged as a novel innovation to enhance urban resilience of the metropolis.

To fulfil this complex aim, the research objectives of the study are multifold. First, it compares available geospatial flood hazard models and visualisations in order to explore the current state of urban flood hazard mapping in Kigali. Likewise, the potential of employing a Blue Spot Mapping methodology as a tool for identifying flood hazards in the future.

Secondly, building upon qualitative methodologies, the study explores the current urban planning regime and how it addresses the urban development challenges of urban flooding, urbanisation, and urban sprawl.

Thirdly, the study investigates how NbS are emerging as a novel innovation in regard to the urban development challenges of urban flooding and degradation of biodiversity and ecosystems.

Lastly, it discusses barriers and challenges obstructing the transition of NbS from niche to norm and how sustainability transition can be accelerated to inform local urban practitioners on how to strengthen urban planning practices through the use of NbS.

To successfully meet the objectives and conclude upon the research question of the present study, a case-specific research design has been defined. Figure 1 illustrates the research design.

RESEARCH DESIGN

RESEARCH QUESTION

How are urban flooding and the related nexus of development challenges placing pressure on the current urban planning regime in the city of Kigali, Rwanda, and to what extent have Nature-based Solutions (NbS) emerged as a novel innovation to enhance urban resilience?

PRELIMINARY ANALYSIS

Exploring the urban development challenges of the City of Kigali, including climate change impacts today and in the future, urban flooding and other climate-induced, water-related hazards, urbanisation and urban sprawl, and degradation of biodiversity and ecosystems

SUB-QUESTIONS

#1. What is the state of available geospatial flood hazard models and visualisations, and what are the potentials of using the Blue Spot Mapping methodology as a tool for local urban practitioners to identify potential flood hazards in the City of Kigali?

#2. How is the current urban planning regime governed and stormwater management practices, and how does the regime address the urban development challenges of flooding, urbanisation, and urban sprawl?

#3. How are NbS emerging as a novel innovation in response to the challenges of urban flooding and the degradation of biodiversity and ecosystems?

#4. How are barriers and challenges hindering the transition of NbS from niche to norm, and how can the transition be accelerated?

ANALYSES

Chapter 7.
Urban Flood Hazards in Kigali

Chapter 8.
The Current Urban Planning Regime

Chapter 9.
A Slow Paradigm Shift – Turning Back to Nature

Chapter 10.
Barriers and Challenges to the Sustainability Transition

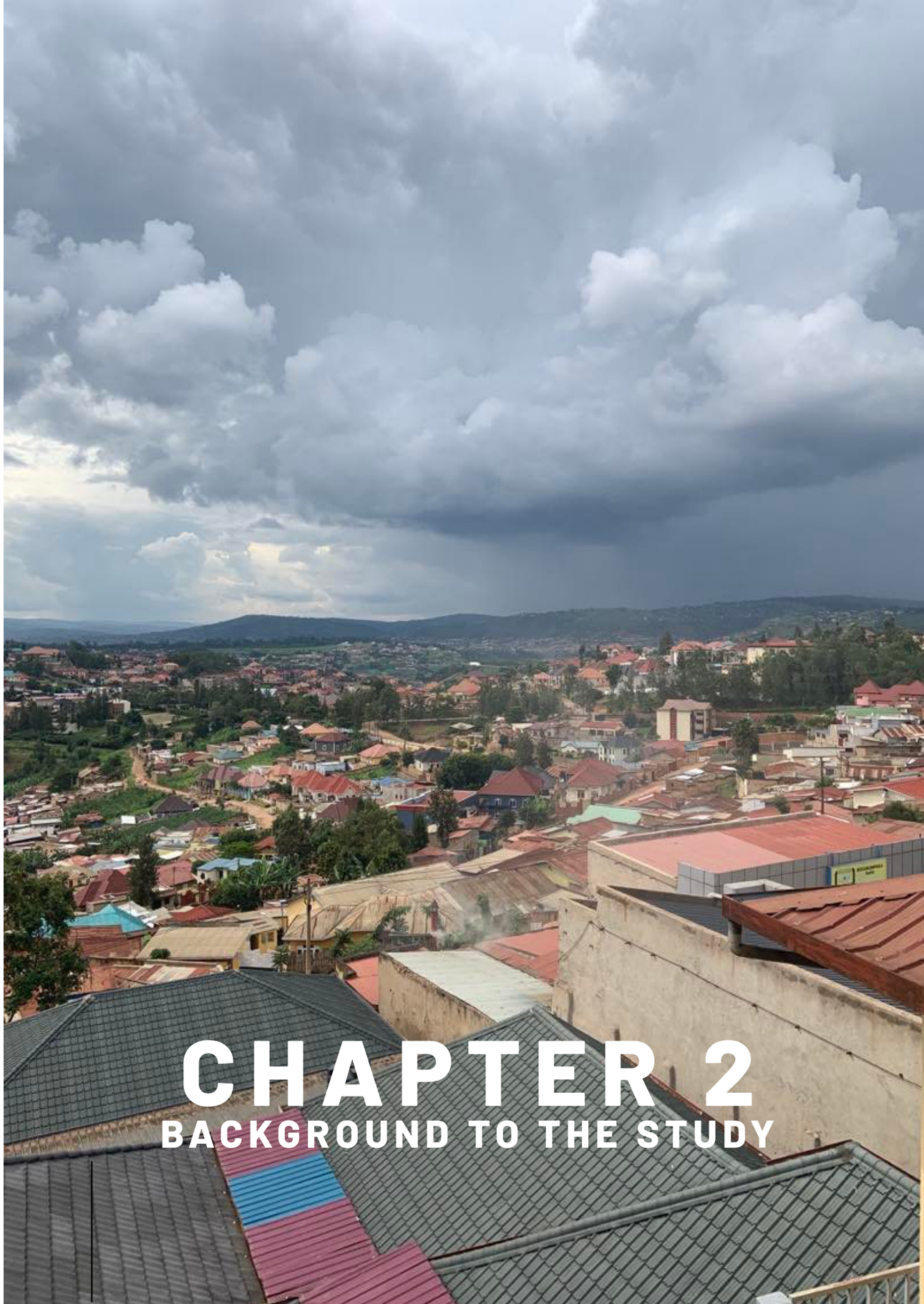
THEORETICAL FOUNDATION

Grounded Theory (Steinberg and Steinberg, 2006) and Multi-Level Perspective (Geels, 2005)

METHODOLOGICAL APPROACH

Case study, literature review, semi-structured interviews, field study, site visits
in-situ observations, and photo documentation, Geographical Information Systems (GIS)

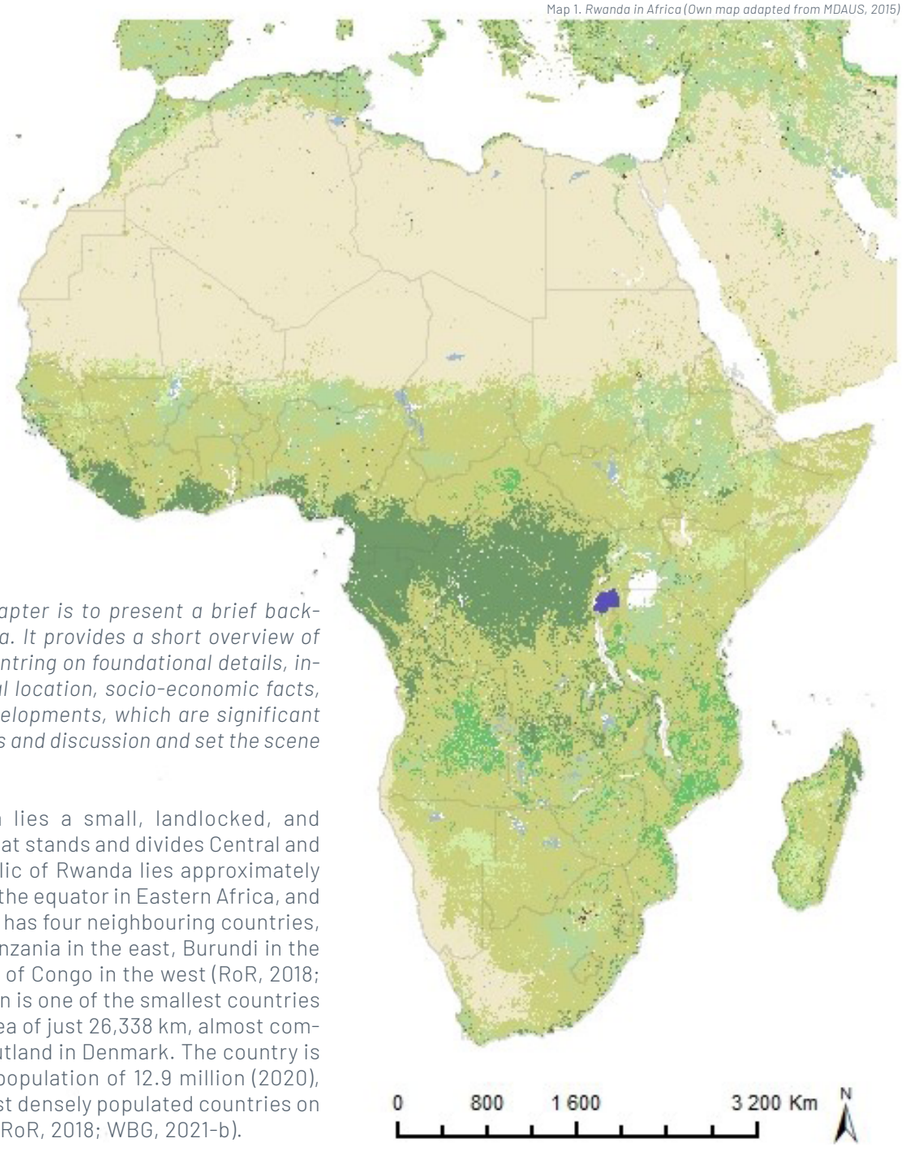
Figure 1. *Research Design*



CHAPTER 2
BACKGROUND TO THE STUDY

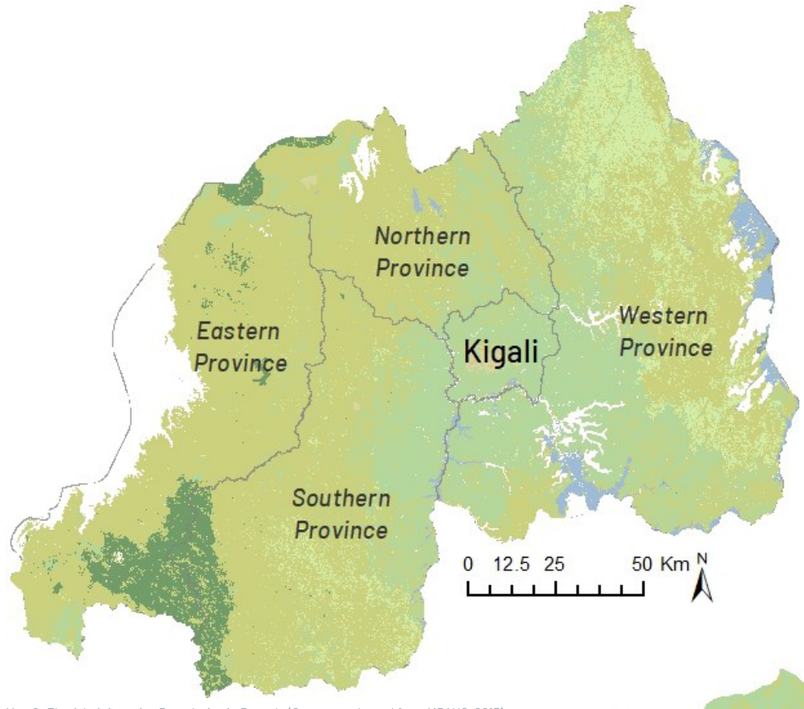
RWANDA AT A GLANCE

Map 1. *Rwanda in Africa (Own map adapted from MDAUS, 2015)*



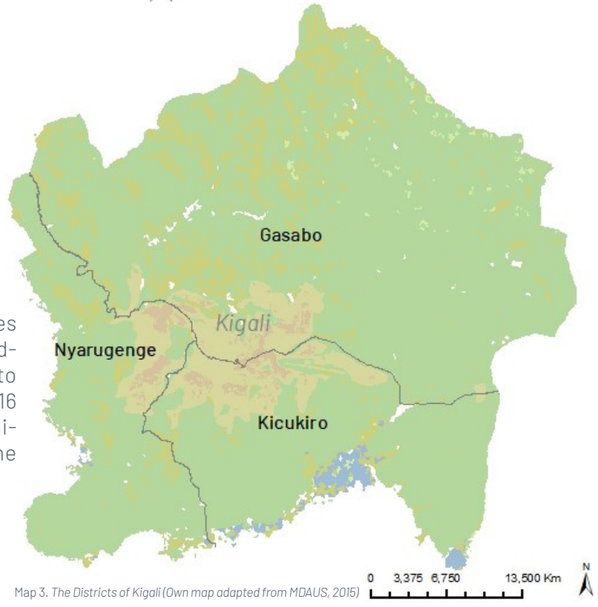
The purpose of this Chapter is to present a brief background of the study area. It provides a short overview of Rwanda and Kigali by centring on foundational details, including the geographical location, socio-economic facts, climate, and recent developments, which are significant for the following analyses and discussion and set the scene of the present study.

In the heart of Africa lies a small, landlocked, and mountainous country that stands and divides Central and East Africa. The Republic of Rwanda lies approximately 120 kilometres south of the equator in Eastern Africa, and as visualised in Map 1, it has four neighbouring countries, Uganda in the north, Tanzania in the east, Burundi in the south, and the Republic of Congo in the west (RoR, 2018; WBG, 2021-a). The nation is one of the smallest countries in Africa, with a total area of just 26,338 km, almost comparable to the size of Jutland in Denmark. The country is home to an estimated population of 12.9 million (2020), making it one of the most densely populated countries on the continent of Africa (RoR, 2018; WBG, 2021-b).



Map 2. *The Administrative Boundaries in Rwanda (Own map adapted from MDAUS, 2015)*

The Eastern, Western, Northern and Southern Provinces and the City of Kigali are the five administrative boundaries of Rwanda. The provinces are further divided into 30 districts comprising 416 sectors, 2.148 cells and 14.816 villages (RoR, 2020-a). Map 2 and 3 visualises the administrative boundaries of the provinces in Rwanda and the districts of Kigali.

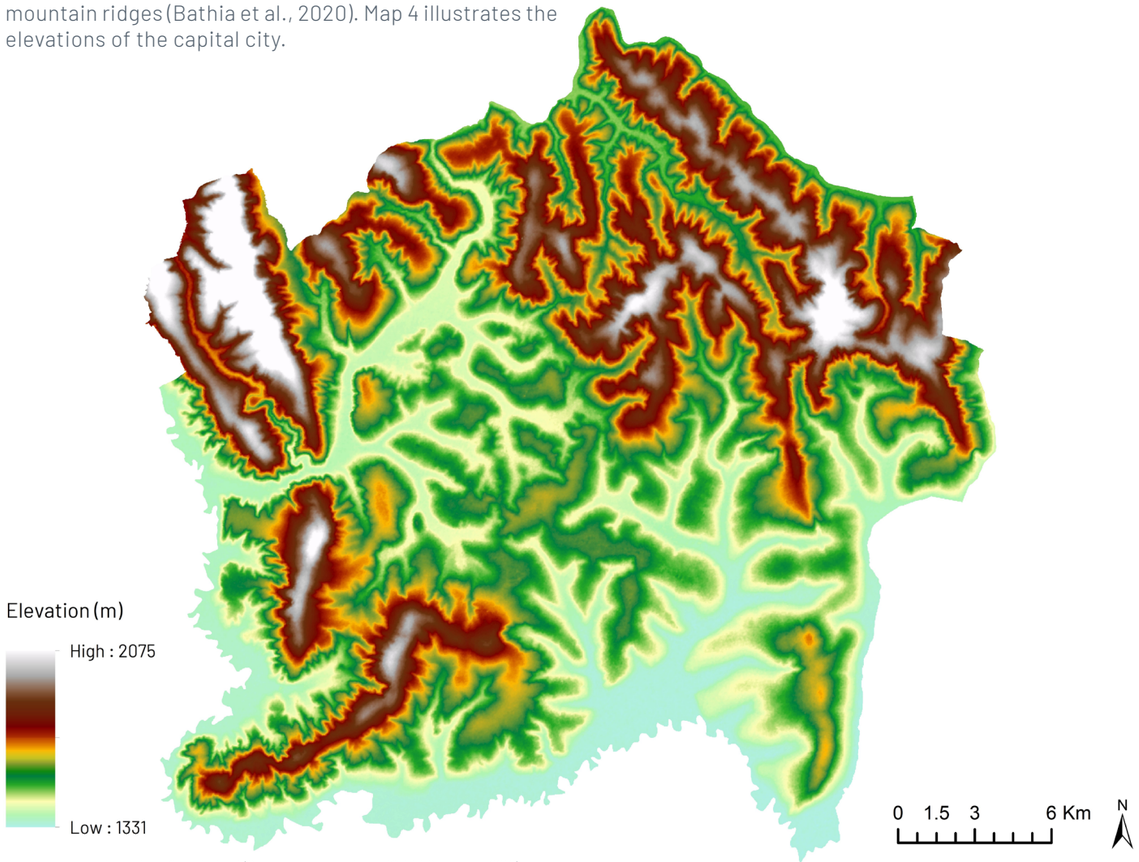


Map 3. *The Districts of Kigali (Own map adapted from MDAUS, 2015)*

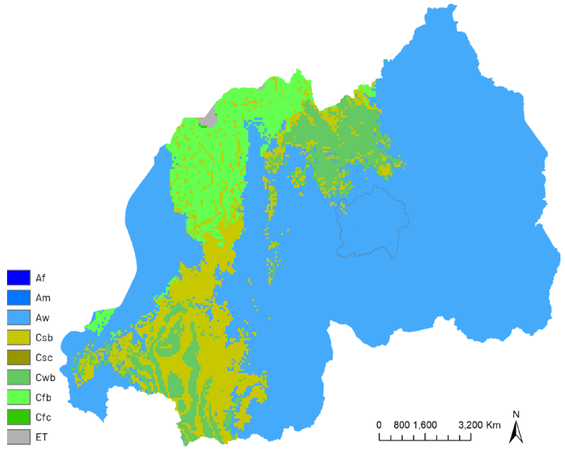
Rwanda is a high laying country, topographically defined by tall mountain chains in the east with a maximum elevation of 4,507 metres at the top of the Kalisimbi Volcano, while the lower-lying savannah grassland in the interior highlands lies on 1,000 m to 1,500 m. The lowest point above sea level is measured at 900 metres at the Lake Kivu and Bugarama plains in the west (RoR, 2020-a).

In the City of Kigali, the elevation ranges between 1,300m to 2,100 m across an intricate landscape of valleys and mountain ridges (Bathia et al., 2020). Map 4 illustrates the elevations of the capital city.

The weather in Rwanda, and the capital city of Kigali, falls under a temperate highland climate where the high elevations highly affect the temperatures. Therefore, the average temperatures are lower, contrasting other equatorial countries and cities. The average daily temperature ranges from 15 to 27 °C, with minor variations throughout the year. Using the Köppen climate classification, the City of Kigali falls under the tropical savanna climate (Aw), as visualised in Map 5 (Beck et al., 2018; Weather and Climate, 2022).



Map 4. *The Elevations of the City of Kigali (Own map adapted from RCMRD Geoportal, 2018)*



Map 5. *Climate Classifications of Rwanda and Kigali (Own map adapted from Beck et al., 2018)*

The climatic seasons of Rwanda are clustered into four phases throughout the year, namely the long (March-April-May, MAM) and short (September-October-November) wet seasons interspersed with the long (June-July-August) and short (Mid-December-January-February) dry seasons (RoR, 2018). Figure 2 visualises these four seasons and the bimodal rainfall pattern of the country.

The western parts of the country experience the highest average precipitation of above 1500 mm, while the eastern areas receive approximately 700 mm yearly (Ministry of Foreign Affairs of the Netherlands, 2018). In Kigali, April is the wettest month, with an average precipitation of 154 mm. July is the driest, with average rainfall corresponding to a mere 11 mm. In 2020, Kigali received an annual average rainfall of 1345 mm (WBG, 2021-a; WMO, 2022). Figure 3 exhibits the general monthly climatology of the minimum and maximum temperature and precipitation based on data from 1991 to 2020 (WBG, n.d.).

Figure 2. *The Seasons of Rwanda*

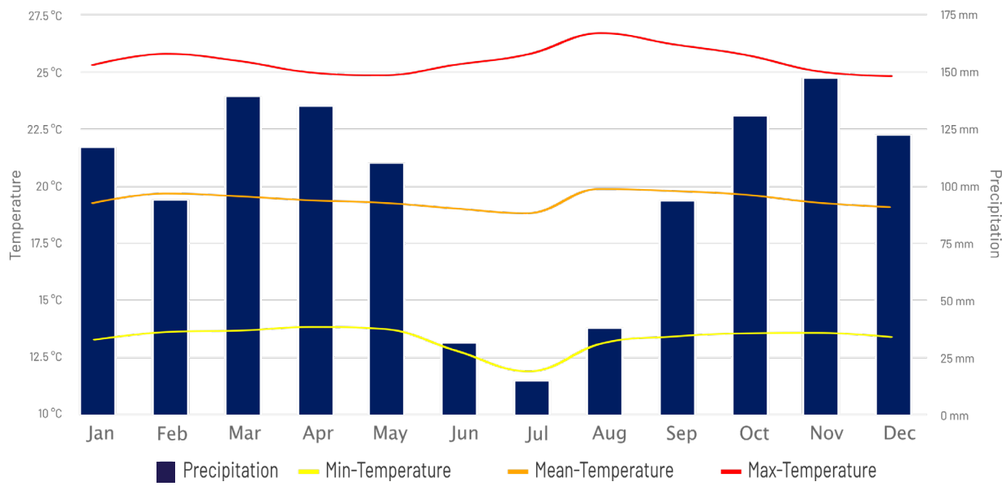


Figure 3. *Monthly Temperature and Precipitation Patterns of Kigali (1991-2020) (Own figure adapted from WBG (n.d.)).*

Image 1. *The Katabaro Area in Kigali*

FAST FACTS
RWANDA & THE CITY OF KIGALI

Table 1. *Fast Facts, Rwanda and the City of Kigali*

RWNADA	
Population Rwanda (2020)[1]	12.9 million
Population Growth (2020)[1]	2.5%[2]
Population Density (2020)[1]	498.7 pers. per km^2
Predicted Population (2050)[2]	21.9 million
GDP (2020)[3]	$10.33 billion USD
Geographical Size[4]	26,338 km
Corruption Perceptions Index (2020)[5]	52 of 180 countries
Gender Inequality Index (2019)[6]	151 of 189 countries
Gini-Index (2016)[7]	0.437
Human Development Index (2020)[8]	160 of 189 countries
Literacy (2018)[9]	73% total population male 78%, female 70%
Life expectancy at birth (2020)[10]	69 years
Official Languages[1]	Kinyiarwanda, French, English, and Swahili
Religion[11]	Christianity (94%) Islam (4.6%), Other (1.4%)

THE CITY OF KIGALI	
Population (2022)[12]	1.21 million
Predicted Population (2030)[1]	1.9 million
Predicted Population (2050)[1]	3.8 million
Geographical Size[4]	730 km^2

[1] (Uwera et al., 2020). [2] (RoR, 2020-a). [3] (DataCommons (2020). [4] (RoR, 2020-a). [5] (Transparency International, 2021). [6] (UNDP, 2019). [7] (WBG, 2021-c). [8] (UNDP, 2020). [9] (UIS, n.d.). [10] (ARN & GLWC, 2020) [11] (Clay, 2021). [12] (MacroTrends, 2022)

AN EMERGING RWANDA

The Republic of Rwanda has a turbulent history, marked by European colonialism, civil disputes, and the horrific genocide in 1994, which almost ruined the social and economic fabric of the nation. It is currently categorised as a low-income country and as one of the 20 poorest countries in the world based on the Gross Domestic Product (GDP) per capita as of 2020, corresponding to $2,213 in international dollars (PPP) (ARN & GLWC, 2020; WBG, 2021-a). However, Rwanda has come a long way in developing and recovering from the devastating aftermaths of its history. Records show that national poverty declined from 77% to 38% from 2001 to 2020, and in 2017 Rwanda was ranked as the 11th safest country in the world (ARN & GLWC, 2020).

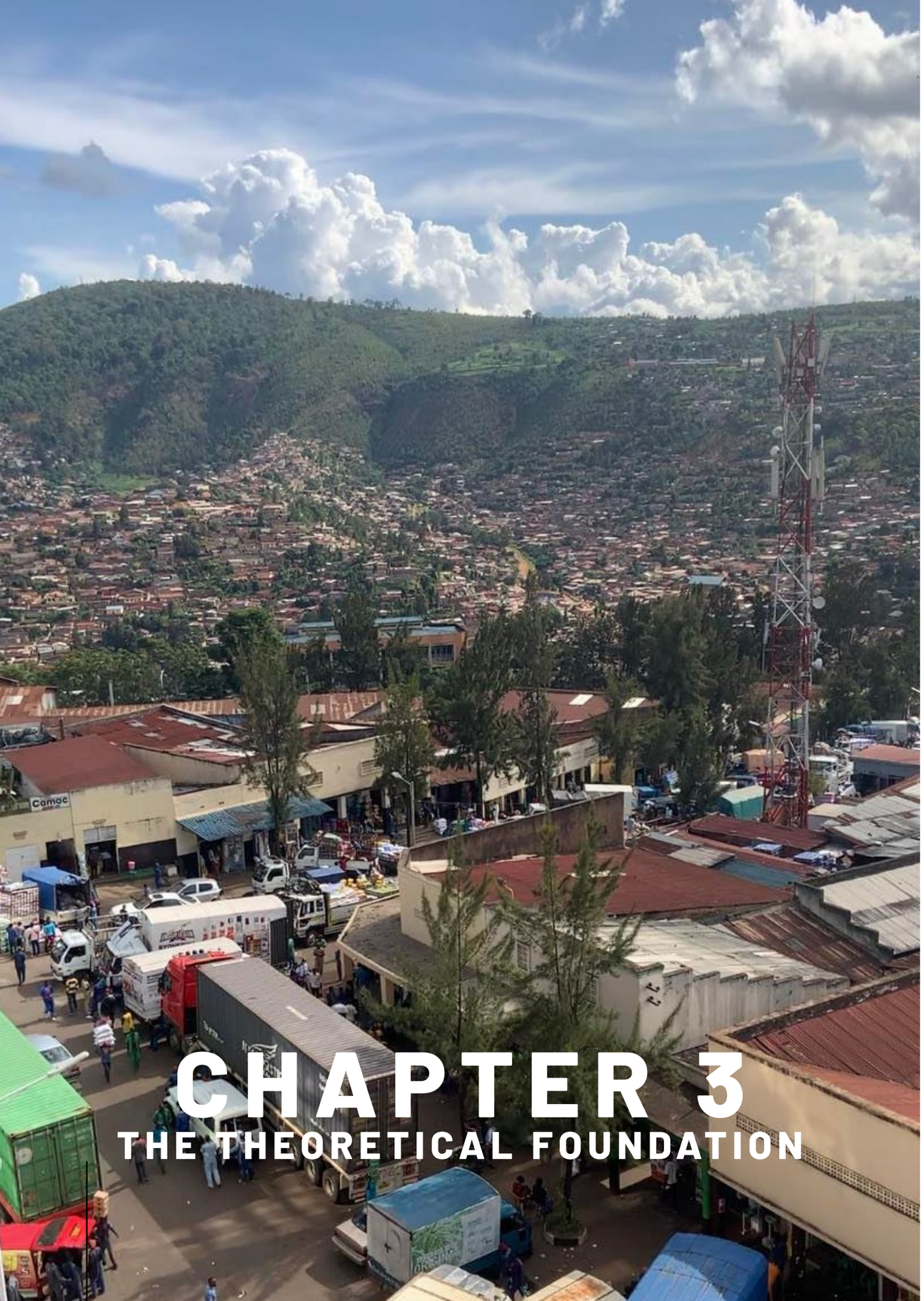
Furthermore, life expectancy has increased from 29 years in the mid-1990s to 69 years in 2019, and the country has experienced rapid population growth from 2.2 million in 1950 to an estimated 12.9 in 2020 (ARN & GLWC, 2020, WBG, 2021-b; WPR, 2022). Consequently, Rwanda has a young population, with approximately 40% of the population aged 14 and younger. Therefore, the government has made great efforts to improve the education system and literacy rate. As a result, the country has become one of the top-performing countries in sub-Saharan Africa. Almost all children, 98%, are enrolled in primary school education, although 71% complete primary school. On the other hand, the quality of the education system in Rwanda is still criticised. One aspect is that there are not enough qualified teachers for the number of students. In the adult population, 68% of women and 79% of men are considered literate, with a mere 6.2% enrolled in higher education (UNICEF, n.d.; UIS, n.d.).

Rwanda held its first democratic election in 2003, and the most recent election was organised in 2018, resulting in another dominating win for President Kagame, with 99% of the votes in his favour. He was re-elected for another seven-year term after a constitutional amendment allowed the president to serve a third term. The same election saw women receive 61% of the parliamentary seats, which is the highest parliamentary representation of women in the world (Lemarchand & Clay, 2021; WBG, 2021-b).

Annually, the national economy (GDP) has steadily grown at a 7% rate from 2009 to 2019, heavily due to long-term development strategies focusing on the private sector and the national objective to obtain middle-income country status by 2020 (ARN & GLWC, 2020). Despite its classification as a low-income country, its economic growth rate makes it one of the fastest-growing economies in Africa (Nzohabonimana, 2019; WBG, 2021-a).

Today, Rwanda aspires to gain middle-Income status by 2035 and, ultimately, become a high-Income country by 2050, as described in Vision 2050 (WBG, 2021-a). The National Strategies for Transformation (NST) and sector-focused strategies for reaching the Sustainable Development Goals form the blueprints for achieving these ambitious development goals. Unfortunately, the COVID-19 pandemic sharply curtailed the economic growth of Rwanda, as many economic activities were held at a standstill due to the lockdown and social distancing. Consequently, the national GDP dropped by 3.4% in 2020 and was the first recorded recession since 1994 (WBG, 2021-a; WBG, 2021-b).

Despite experiencing steady growth on paper, Rwanda and Kigali still face many profound challenges of climate change, urban flooding, urbanisation, urban sprawl, and degradation of biodiversity and ecosystems. These challenges are all hindering the sustainable development of the country and capital. Accordingly, they are a central part of the present study, and the following two Chapters, Theoretical Considerations and the Case Study as a Methodological Approach in Exploratory Research, present how the study aims at exploring these challenges in the City of Kigali.



CHAPTER 3
THE THEORETICAL FOUNDATION

THE THEORETICAL FOUNDATION

The present study is founded on two theoretical concepts, The Grounded Theory, as described by Steven J. Steinberg and Sheila L. Steinberg (2006) and the Multi-Level Perspective on socio-technical transitions, as defined by Frank W. Geels (2002, 2005, 2011, and 2019). The theoretical conceptualisations guide the research with regard to the chosen iterative research approach and the structure of the following analyses (Geels, 2002; Geels, 2005; Geels, 2011; Geels, 2019; Steinberg & Steinberg, 2006).

Applying Grounded Theory as the General Theoretical Research Approach

The Grounded Theory operates as an overarching approach that embodies both the methodological and theoretical features of the present study. It complements the exploratory nature of the study, as it does not seek to verify or prove an existing theory. Alternatively, it is an inductive process that views research as an iterative action. Grounded Theory aims at exploring and gathering information about a topic where the goal is to generate novel knowledge objects through research and observations (Steinberg & Steinberg, 2006).

The core concept of Grounded Theory is that theory, or in the case of the present study, novel knowledge objects evolve through analyses of systematically gathered empirical data. Consequently, the collected data determine what is relevant for the researcher to further investigate. As a result, Grounded Theory considers research methodologies to be an integral component of the knowledge-generation processes. Therefore, the theoretical framework is closely related to the general methodological approach of the present study, the explorative case study.

The iterative aspects of employing Grounded Theory are visible in the workflow, as the researchers explore data and analyses regularly, inspect themes and links, and then conduct further inspections. Consequently, Grounded Theory is a highly hands-on approach to organising sampled and collected data (Steinberg & Steinberg, 2006).

In general, grounded knowledge objects unfold through a series of research steps ranging from the initiation research - to identifying themes - leading to the establishment of categories and links between these - to constructing knowledge objects - and finally - to the presentation of these objects (Steinberg & Steinberg, 2006) Figure 4 exhibits what each of these six steps entails in the present study.

Conjunctions to the Employed Research Methodology - The Explorative Case Study

According to Steinberg & Steinberg (2006), the Grounded Theory approach complements the use of case studies as a research method. A case study is an excellent option when the researcher has an idea or assumption that a specific place or event can serve as a (role)model or best practice for other similar cases, as in the case of Kigali in terms of sustainable urban planning and urban water management. The Grounded Theory guide the present research, field study and data collection methods, as it is highly structured upon the mentality that "*researchers do not go into the field with a traditional hypothesis or idea about what they are going to find. Instead, they allow the concepts or ideas to arise from the fieldwork itself*" (Steinberg & Steinberg, 2006, p. 94). Chapter 4 further elaborates upon the methodological choices of the present study.

Figure 4. *Steps in Knowledge Production Through the use of Grounded Theory (Own figure adapted from Steinberg & Steinberg, 2006)*

While the Grounded Theory functions as the overall research approach, the present study employed the Multi-Level Perspective on sustainability transitions to theoretically ground the analyses of the current urban planning regime and the transition of Nature-based Solutions (NbS) from niche to norm.

The Multi-Level Perspective on Sustainability Transitions

It is vital to explore the system dynamics on multiple levels to follow how, when, and why sustainability transitions take place, including NbS in urban planning and water management in Kigali. By employing theoretical concepts of the Multi-Level Perspective on transitions to sustainability, the study explores the current socio-technical landscape, the urban planning regime, and the emergence of NbS as radical niche innovations in the case of Kigali through a multifaceted lens. Geels (2002) divides this lens into three spectres, the macro-, meso-, and micro-level, which the following sections go into detail with (Geels, 2002). Figure 5 illustrates the Multi Level Perspective as defined by Geels (2005).

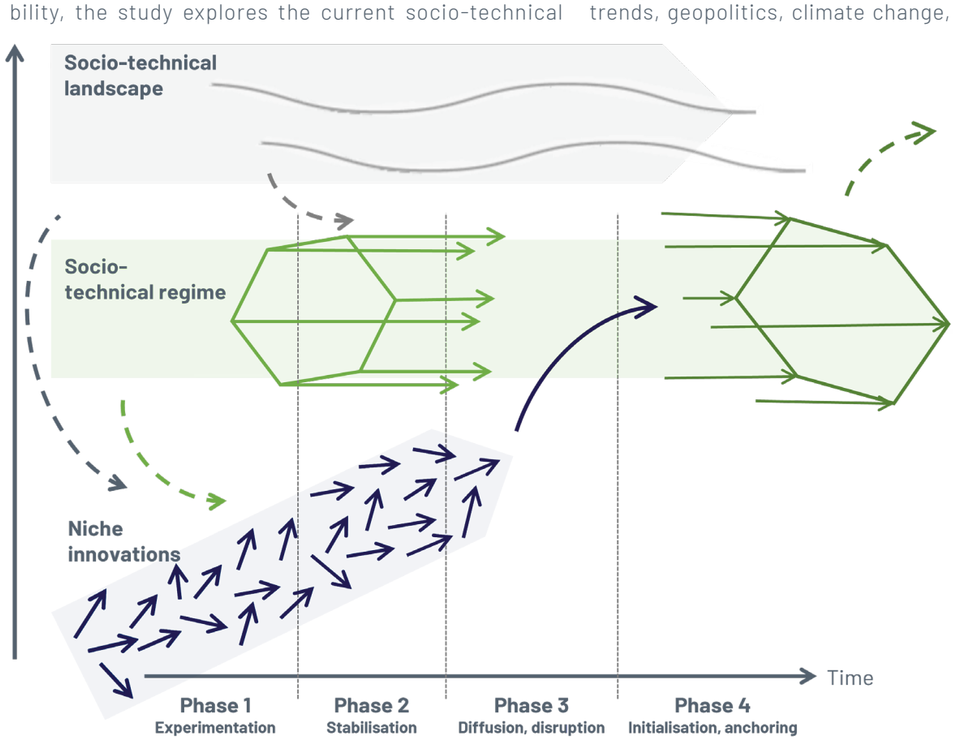


Figure 5. *The Multi-Level Perspective (Own figure adapted from Geels, 2005)*

Macro-level - The Socio-Technical Landscape

The socio-technical landscape consists of external factors that influence and pressures the Meso-level (the regime). The external context is stable yet likely to change over longer timeframes. External factors include slow-changing trends such as demography, macroeconomic trends, geopolitics, climate change, societal concerns, and ideologies. External shocks, such as regression, inflation, war, accidents, and pandemics, are likewise parts of the landscape. The broader landscape creates different gradients of force fields that sustainability transitions have to navigate within (Geels, 2002; Geels, 2019). In other words, the socio-technical landscape affects the development and interrelations between radical system innovations, niche innovations, and socio-technical systems within the existing regime (Geels, 2019).

In the present study, the major external factor influencing the existing urban planning regime is climatic changes, including water-related hazards such as urban flooding, landslides, soil erosion, and droughts. additionally, land degradation, loss of biodiversity and ecosystems are likewise external forces at the landscape level which might influence the existing socio-technical regime and foster niche innovations.

The Meso-Level - The Socio-Technical Regime

Socio-technical regimes are found at the meso-level and are known as the existing paradigms, perceptions, behaviours, and actions of social groups (incumbent actors) moulded by ingrained, shared rules and institutions. An alignment between technologies, policies, user habits, infrastructures, and cultural discourses established through time, creates stabilising and sustaining socio-technical systems (Geels, 2019). Thus, the "*'regime' is an interpretive analytical concept that invites the analyst to investigate what lies underneath the activities of actors who reproduce system elements*" (Geels, 2011, p 31). In other words, the socio-technical regime provides a collective orientation and coordination of the actions of the incumbent actors, the corporations, engineers, users, policymakers, decision-makers, and regulators, in a state where they replicate, sustain, and progressively enhance the current system features (Geels, 2005; Geels, 2019). For this reason, "*existing systems are locked in at multiple dimensions*", often in path-dependent manners rendering changes or transitions within regimes challenging (Geels, 2005, p. 683). The stability of socio-technical systems is dynamic as innovations are able to transpire within the system. However, these are often of accumulative and incremental nature, resulting in path dependencies and locked-in trajectories (Geels, 2005; Geels, 2019).

SOCIO-TECHNICAL SYSTEMS VS. SOCIO-TECHNICAL REGIMES

SOCIO-TECHNICAL SYSTEMS "*REFERS TO TANGIBLE AND MEASURABLE ELEMENTS (SUCH AS ARTEFACTS, MARKET SHARES, INFRASTRUCTURE, REGULATIONS, CONSUMPTION PATTERNS, PUBLIC OPINION)*" (GEELS, 2011, P. 31).

SOCIO-TECHNICAL REGIMES "*REFER TO INTANGIBLE AND UNDERLYING DEEP STRUCTURES (SUCH AS ENGINEERING BELIEFS, HEURISTICS, RULES OF THUMB, ROUTINES, STANDARDIZED WAYS OF DOING THINGS, POLICY PARADIGMS, VISIONS, PROMISES, SOCIAL EXPECTATIONS AND NORMS)*" (GEELS, 2011, P. 31).

These path dependencies, fixed trajectories, and locked-in regimes are subject to changes through co-evolutionary processes. These processes may occur when pressures from the socio-technical landscape take place, which in turn creates a window of opportunity for radical niche innovations to infiltrate the existing regime (Geels, 2002; Geels, 2005; Geels, 2019).

The Micro-Level - Radical Niche Innovations

At the micro-level, the emergence of radical innovation originates in small niches on the fringe of existing socio-technical systems. They typically develop through pioneering, first-mover efforts of actors operating outside of the existing regime, such as entrepreneurs, activists, and start-ups. The degree to which niche innovations diverge from the existing regime in terms of technological, social, business model, or infrastructure aspects, determines their radicality and impact (Geels, 2019).

In many cases, green or sustainable niche innovations are subject to numerous challenges threatening their development and adoption. Geels (2019) describes that green niche innovation "*tend to be more expensive than existing technologies ... radical innovations often suffer from the 'liability of newness' ... which reduces their cultural legitim-*

acy, social acceptance, and access to financial resources" (Geels, 2019, p. 190). Another challenge is the perception of the diffusion of green and sustainable niches as they "*may lead to the decline of established systems and industries*" resulting in negative societal regression in terms of job loss or economic loss for industries operating within the established regime (Geels, 2019, p. 195). These conditions stabilise and preserve the existing system by creating a foundation for resistance to the development of niche innovations and sustainability transitions (Geels, 2019).

The present study explores NbS as radical niche innovations in urban planning and water management within the City of Kigali and the larger perspective of urban climate adaptation from a global perspective.

Socio-Technical Transitions

According to Geels (2005), "*transitions are conceptualised as system innovations, i.e., a change from one socio-technical system to another*" (Geels, 2005, p. 1). System innovation is a co-evolutionary process resulting from the interaction of activities at the micro, meso, and macro levels (Geels, 2005). While the specifics of transition differ by domain, the overall multi-level dynamic follows three steps, as pictured in Figure 6.

The Multi-Level Perspective quarters sustainability transitions into the phases of *experimentation, stabilisation, diffusion, and anchoring* described on the following page (Geels, 2019).

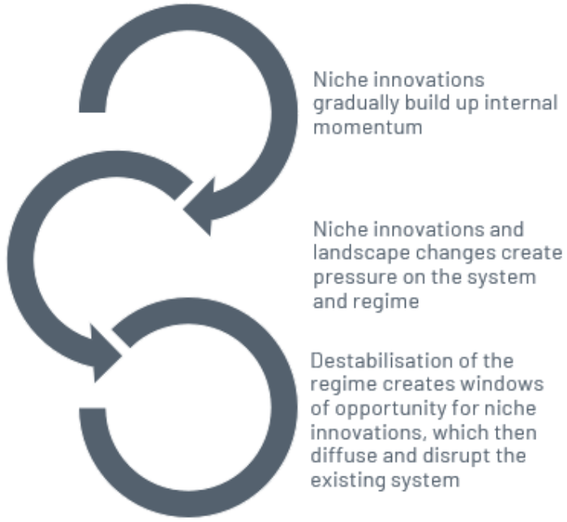


Figure 6. *The Dynamics of Transitions (Own figure adapted from Geels, 2019, p. 190)*

1 EXPERIMENTATION

During the experimentation phase, novelties evolve in smaller niches with respect to the existing regime and landscape changes. In this first phase, there is no dominating design yet, and different technical forms may compete with one another. To determine the optimal design on the novelty and learn what the end-users and the market wish for, actors of the innovations improvise and do experiments (Geels, 2005).

2 STABILISATION

In the stabilisation phase, radical innovations are employed in smaller market niches that enable technological specialisation. Steadily, a committed community of manufacturers and engineers focuses their efforts on improving the new technology. Following a progressive approach, engineers design new rules, and novel innovation generates its technological trajectory. Step by step, the technology matures as an outcome of the learning process. In the meantime, the market and end-users slowly begin to discover new functions when they interrelate with radical innovation. The second transition phase leads to the stabilisation of rules regarding the dominant design of the novelty (Geels, 2005).

3 DIFFUSION & DISRUPTION

The breakthrough of the novelty, widespread diffusion and rivalry with the existing regime are characteristic traits of the third phase. On one side, internal forces are substantiating a breakthrough, and important actors have a vested interest in the distribution of the technology. On the other side, a successful breakthrough is dependent on external conditions and a so-called window of opportunity (Geels, 2005, p. 685). Changes in the landscape might stress the regime, or there may be internal technological issues that the regime cannot address with current technology. Negative externalities in the regime, such as shifting consumer preferences or tighter rules and restrictions, may also cause issues for existing technology. The premise of MLP is that system innovations emerge as a result of interactions across various levels of development. As new technology becomes more widely used, it launches into competitive relations with the existing regime (Geels, 2005).

4 INSTITUTIONALISATION

In the anchoring phase, the new technology reinstates the old technological system causing changes in the broader breadth of the socio-technical regime. As forming a new socio-technical regime takes time, it usually happens gradually. Moreover, due to entrenched interests and sunk investments, incumbents tend to adhere to outmoded technology. When established, the new regime may have a long-term impact on the landscape. The MLP emphasises the elimination of simple causation in system innovations, as there exists no single cause or factor for such transitions. Instead, operations occur at numerous dimensions and levels at the same time. If and when these processes are linked and reinforced, system innovations can emerge (circular causality) (Geels, 2005).

CHAPTER 4
METHODOLOGY

THE CASE STUDY AS A METHODOLOGICAL APPROACH IN EXPLORATORY RESEARCH

Given the exploratory nature of the present study, the methodological approach is structured to pave the way for the research and data collection process through a grounded theory approach. Collectively, the study is rooted in a case study as its overarching methodological research approach, based on Flyvbjerg's (1988) definition and description (Flyvbjerg, 1988). The study further builds on the principles of exploratory and comparative case studies described by Streb (2010).

The decision to employ an exploratory research method influences the data collection processes that primarily rely on qualitative methods, including an extensive literature review of empirical research, interviews with international and local professionals, a field study, site visits, in-situ observations, and photo documentation following the snowball sampling method. A Geographical Information Systems (GIS) Blue Spot Mapping is employed to supplement and further explore the case in question in detail through quantitative means.

The Case Study as a Research Method

The case study is a qualitative research method explained and narrated by numerous scholars. According to Flyvbjerg (1988), the case study as a research method is a specific way to collect, organise, and analyse empirical data (Flyvbjerg, 1988). The purpose of employing this approach is to assemble in-depth information and data on the specific case of interest (Flyvbjerg, 1988).

As a qualitative research method, the case study predominantly deals with the processes of either adding, integrating or replacing existing knowledge objects through the inductive development of new information. The scientific, theoretical standing point has a leg in both hermeneutics and phenomenology, as case studies commonly centre on research through holistic, inductive, and actor-oriented elements (Flyvbjerg, 1988).

In the present study, the geographical boundary of the case study is the City of Kigali in Rwanda. While the academic scope is broader, the case study predominantly focuses on sustainable urban development in terms of urban flooding and Nature-based Solutions (NbS) as a measure to enhance urban resilience. The case study takes a holistic approach by drawing on diverse data sources. The nature of the study is, through this approach, inherently actor-oriented, as great emphasis lies on the individual viewpoints, experiences, thoughts, and reflections of the interviewed stakeholders, in addition to state-of-the-art scientific research.

The case study of Kigali is inductive in that it seeks to both add to and integrate with existing knowledge objects. Specifically to the field of NbS and its potential ability and capacity to provide protective and adaptive measures for urban flooding in Kigali and the eastern part of Africa. Thus, the aim is not to develop a new theory but to explore a field of research that is currently limited in terms of best practice examples and to create new knowledge objects and new learnings which can pave the way for the transition of NbS from niche to norm.

Employing Principles From the Exploratory Case Study

The explorative case study is a vital research method when investigating previously unknown academic fields and the current scientific status quo. In other words, when a phenomenon lacks detailed preliminary research, exploratory case studies can be executed as an eminent research method. The broad concepts of exploratory case studies equip the researcher with a high degree of flexibility and independence in terms of the research design, data collection, sampling, and analysis. This approach complements the theoretical foundations of the present study, which accommodates an iterative research process of a complex phenomenon. Likewise, the research approach is favourable when data is scarce (Streb, 2010).

The present study embodies exploratory characteristics as it examines a research question which has not been studied in detail previously, see Chapter 1. The study functions as preliminary research undertaken to understand the challenges and barriers of working with NbS in urban planning and water management. It specifically aims to lay the foundation for the acceleration of the implementation of NbS as standard practice in urban stormwater manage-

ment by identifying and discussing barriers to change and recommending possible solutions to local practitioners. It further aims to create a narrowed scope for further research, rather than presenting concrete solutions or conclusions, that can ultimately contribute to the current state of the art of scientific knowledge on the role of NbS as a tool in climate adaptation and urban development.

The degree of flexibility linking to exploratory case studies has been critiqued, especially regarding the data collection methods and their lack of theory-based expectations. To address these weaknesses, the present study employs a solid theoretical foundation based on Grounded Theory and the Multi-level Perspective on socio-technical transitions to guide the data collection and analysis and ensure the reliability and viability of the findings (Geels, 2005; Steinberg & Steinberg, 2006). The previous Chapter 3 describes the theoretical foundations of the study.

Carrying out the Case Study

The process of carrying out the case study is, as mentioned, both iterative and exploratory in nature. Using the terminology set out by Flyvbjerg (1988), the workflow of the present study follows three overarching steps visualised in Figure 7 Insights gathered at each step feedback to the previous step to deepen the obtained knowledge, thus strengthening the knowledge base for the next step (Flyvbjerg, 1988). The following subsections elaborate upon each of the three steps.

DATA COLLECTION & SNOWBALL SAMPLING

The present study employs an assortment of data collection methods to ensure that the gathered information is diverse and provides a solid foundation on which to base the case analyses. The present study emphasises qualitative data collection methods, such as literature review, semi-structured interviews, and field notes, which is one of the general strongholds of the case study approach. Supporting the qualitative methods is the quantitative method of GIS modelling. The following sections elaborate upon the overall sampling method, the data collection methods, and sources of empirical data.

The first step of conducting a case study focuses on the collection of data and empirical knowledge. It is a necessity to draw on existing knowledge within the scope of interest to ensure that the research builds on the current state-of-the-art. During the data collection, the researcher must be aware of potential preconceived biases to ensure that data is collected openly, meaning data should not be placed in standardised or predetermined categories (Flyvbjerg, 1988).

The overall data collection process has its basis in snowball sampling, a helpful approach when pursuing data in cases where obvious or predetermined resources are not available (Morgan, 2008). In the present study, snowball sampling is evident in various ways, such as the initial data collection that takes its point of departure in an extensive review of existing research. Following the review are interviews with experts in NbS, flooding and urban development in Kigali. The selection of experts is determined based on the preliminary research, as well as through recommendations from interviewees. The experts serve as vital informants by providing detailed, local and international knowledge and narrowing the scope of the study.

Figure 7. *Case Study Workflow (Own figure adapted from Flyvbjerg, 1988)*

Literature Review

Literature reviews are vital components of data collection in most case studies. It facilitates deep insights into the history and context of the given case through the review of relevant journals, reports, policies and other literature sources to generate and synthesise data vital for conducting the case analysis (Flyvbjerg, 1998). The general objective of a literature study is to enhance the understanding of the research area and ensure the viability and reliability of the findings (Race, 2008). Additionally, it is a crucial tool for identifying and exploring knowledge gaps and guiding the formulation of questions for interviews and objectives for field observations (Flyvbjerg, 1988).

As all research adds to the ongoing debate and current state of the art of a given topic, it is vital to position the study in relation to peer-reviewed literature, alongside governmental policies, strategies, and reports from acknowledged institutions to grasp the complexity of the case at hand. The review and preliminary research of the present study are executed with the purpose of both setting the scene of the case study of Kigali in terms of current and future climate-induced challenges; exploring the current status quo of NbS in East Africa; and creating a theoretical sound framework and methodology for data collection and analyses. Relevant literature is continuously reviewed iteratively throughout the research and analysis processes.

Semi-structured I nterviews

The semi-structured interview is a primary method of collecting qualitative data, where the researcher (the interviewer) asks the informant (the interviewees) prearranged open-ended questions. Compared to unstructured or fully structured interviews, the semi-structured interview puts the researcher in a position with a higher degree of control over the topics and the direction of the interview. The potential downfall of this approach is that the quality and degree of usefulness of responses may vary in quality and relevancy, particularly in comparison to a structured approach (Ayres, 2008).

In the present study, all interviews take the form of semi-structured. They follow an interview guide where questions relate to the general research question but are also specifically angeled for the individual informant based on their expertise and professional line of work. Through active listening, the flow and scope of the interview might change during the session as the researcher allows the interviewee to influence the interview. However, the interview guides form the frame for the overall objectives and desired outcomes. The interviews are recorded and transcribed to ensure that information and statements can be revisited. The transcriptions are subject to corrections in terms of grammatical errors and punctuation. Appendices 1 - 10 hold the transcriptions of the interviews.

The interviewees are selected based on their profession and area of expertise. Informants include practitioners from international institutions, such as the International Centre for Climate Change and Development (ICCCAD), Deltares, Defacto Urbanism, and Surbana Jurong (SJ), in addition to local authorities and organisations, such as the Rwanda Water Resource Board (RWB), the City of Kigali, and Rwanda Environmental Conservation Organisation (RECOR). Table 2 contains an overview of interviewees with a summary of relevant expertise and professional background. The interviews aim to obtain a multitude of perspectives on current urban planning and water management, NbS, urban flooding, and sustainable urban development in Kigali to enable a thorough understanding of the research problem in question. The interviews shed light on research gaps within the scope of the study and provide first-hand experiences and recommendations of new data sources. Most interviews were conducted online, primarily due to geographical constraints, whereas physical interviews were conducted when possible during the field trip to Kigali.

Table 2. *Interviewees*

INTERVIEWEE	POSISTION	EXPERTISE	DATE
Dr. Saleemul Huq	Director of the International Centre for Climate Change & Development (ICCCAD) (Dhaka, BD)	Climate adaptation, with a particular focus on least developed countries. Lead and co-author on chapters in the Assessment Reports of the International Panel on Climate Change (IPCC)	02.03.2022 (Online)
Mona zum Felde	Urban Designer at Defacto Urbanism (Rotterdam, NL)	Flooding and climate adaptation with the use of Nature-based solutions. Landscape analysis and pre-feasibility study for NbS in Kigali.	02.03.2022 (Online)
Bobby Russell	Senior Advisor, Water Resources Management Specialist at Deltares (Delft, NL)	Storm Water and Wetland Management Modelling of flood-prone areas in Kigali, Rwanda.	07.03.2022 (Online)
Anonymous	Senior Urban Planner and Project Manager at Surbana Jurong (SJ) (Kigali, RW/SG)	Urban planning, The City of Kigali Master Plan	09.03.2022 (Online)
Imleda Dada Bacudo	Expert on Climate Policy and Finance and Land-Use at the Association of Southeast Asian Nations (ASEAN) (Jakarta, ID)	Sustainable development in developing countries, working with large international institutions such as the EU, UNEP, UN FAO, and SEI	09.03.2022 (Online)
Hussein Bizimana	Hydraulic Flood Modelling Specialist at the Rwanda Water Resources Board (RWB) (Kigali, RW)	PhD in hydraulic and water resources engineering and expert knowledge of water management within the City of Kigali and Rwanda.	11.03.2022 (Online) 22.04.2022 (In person)
Bernard Musana	Head of Knowledge and Forecasting Hub Department at the RWB (Kigali, RW)	Watershed modelling, management, and soil science	22.04.2022 (In person)
Davis Bugingo	Flood Management and Water Storage Division Manager at the RWB (Kigali, RW)	Water research engineering, hydrological, and hydraulic modelling	22.04.2022 (In person)
Abias P. Mumuhire	Architect at the Council of the City of Kigali (Kigali, RW)	Urban development in Kigali, the implementation process of the Kigali Master Plan, affordable housing and upgrading of informal settlements	22.04.2022 (In person)
John R. Gakwavu	Environmental Specialist at Rwanda Environmental Conservation Organisation (RECOR) (Kigali, RW)	Climate change concerns and conversation projects in Kigali and Rwanda.	25.04.2022 (In person)

Fieldnotes

According to Flybjerg (1988), field notes and general notes from interviews, conversations and observations are of utmost importance for a successful case study as they form the empirical basis for the study in its entirety. For this reason, it is vital to record detailed notes, preferable during or just after observations or interviews are conducted. While it is important to report what is happening, it is equally important to note what is not happening, the so-called no-actions or no-decisions (Flyvbjerg, 1988).

In the present study, field notes comprise notes of in-situ observations, interviews, site descriptions and conversations, as well as photo documentation, citations, personal reflections, experiences, and feelings. Likewise, ideas, inspiration, interpretation, and preliminary analyses are included in the notes to guide the actual case analyses. Site visits for in-situ observations are pinpointed based on the reviewed literature, expert interviews and GIS modelling. The field notes comprise a considerable part of the case journal of the present study. Please refer to Appendix 10 for the whole case journal.

Remotely Sensed Data & GIS

Considering the complexity of the research area in question, the methodological approach of this study relies on remotely sensed data and Geographical Information Systems (GIS) to gain spatio-temporal insight and quality findings from other sources. The GIS software used in this project is ArcMap version 10.5 from ESRI. Data primarily stems from the RCMRD GeoPortal (n.d.), which is the central regional geographical portal, both for hydrological analysis and the creation of maps. A variety of maps are created and used throughout the study to visualise spatial characteristics and aid the research process as it deepens the understanding and knowledge of the field through new insights. For example, the construction of a map with contour lines indicates the steepness of slopes and the varied typography. The lines are representations of fixed intervals, as such, the density of the lines specifies terrain features. Insights such as these are particularly relevant in exploratory case studies where the geographical area is previously unknown or poorly defined (Bolstad, 2016; Steinberg & Steinberg, 2006).

The hydrological analysis conducted in GIS uses a 30m Digital Elevation Model (DEM) captured by the Shuttle Radar Topography Mission (SRTM), as this is the open-source topography dataset with the highest spatial resolution of the area. Preferably, data from a Light Detection & Ranging (LiDAR) survey should be used, because of the high spatial accuracy such data provides. However, such data does not exist in the City of Kigali. The study employs a Blue Spot Mapping methodology to conduct a hydrological analysis of the spatial flow and accumulation of water within the City of Kigali to complement the analysis of current stormwater management practices in the city. Hence GIS Blue Spot Mapping uses various spatial functions.

A Blue Spot Mapping essentially highlights potential hotspots where water is likely to accumulate based on an assessment of hydrological dynamics at a given location (Balstrøm, 2022). The acquired DEM raster layer is acquired, for which reason the layer is orthorectified and projected to the GCS ITRF 2005 coordinate system, which is the most frequently used coordinate system in Rwanda. Raster datasets easily interpret and understand the relationship between the various cells in the layer and are therefore favoured in spatio-temporal hydrologic modelling (Bolstad, 2016). Figure 8 illustrates the workflow of spatial functions applied to the DEM. The Toolbox can be found in Appendix 11.

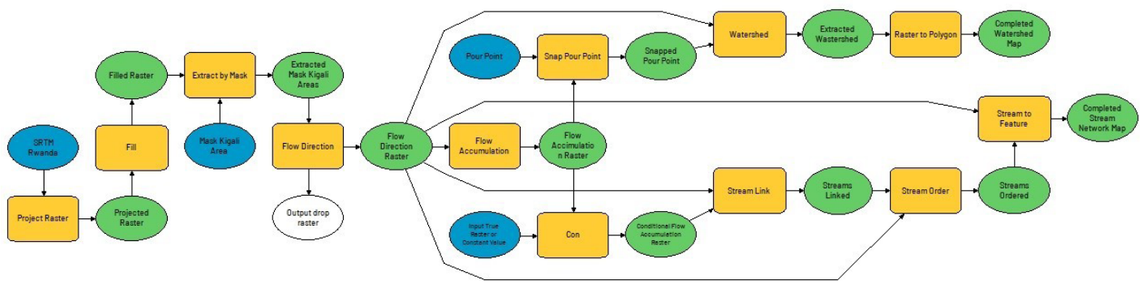


Figure 8. *Workflow and Spatial Functions, created in ArcMap ModelBuilder*

2

DEVELOPING THE CASE JOURNAL

A case journal is a unique form of a journal which sorts out the raw data in a comprehensive yet manageable journal. The journal comprises all edited raw data, excludes unnecessary data, and merges different forms of data (Flyvbjerg, 1988). It is often structured chronologically and thematically to create an organised and accessible overview of the collected data for later analyses. The collected data, information, and knowledge rapidly accumulate, adding to the challenge of organising and navigating journal entries and highlighting the importance of adopting a solid structure and format.

The case journal of the present study follows a chronological and thematic order to ease and guide the analyses. Please refer to Appendix 10 for the complete case journal. The chronology of the document follows the days of the field trip in subcategories of each day. The further division mind the following themes, Nature-based Solutions, The City, Site Visits, and lastly, Vegetation. Upon finalising the case journal, the case analyses can begin.

3

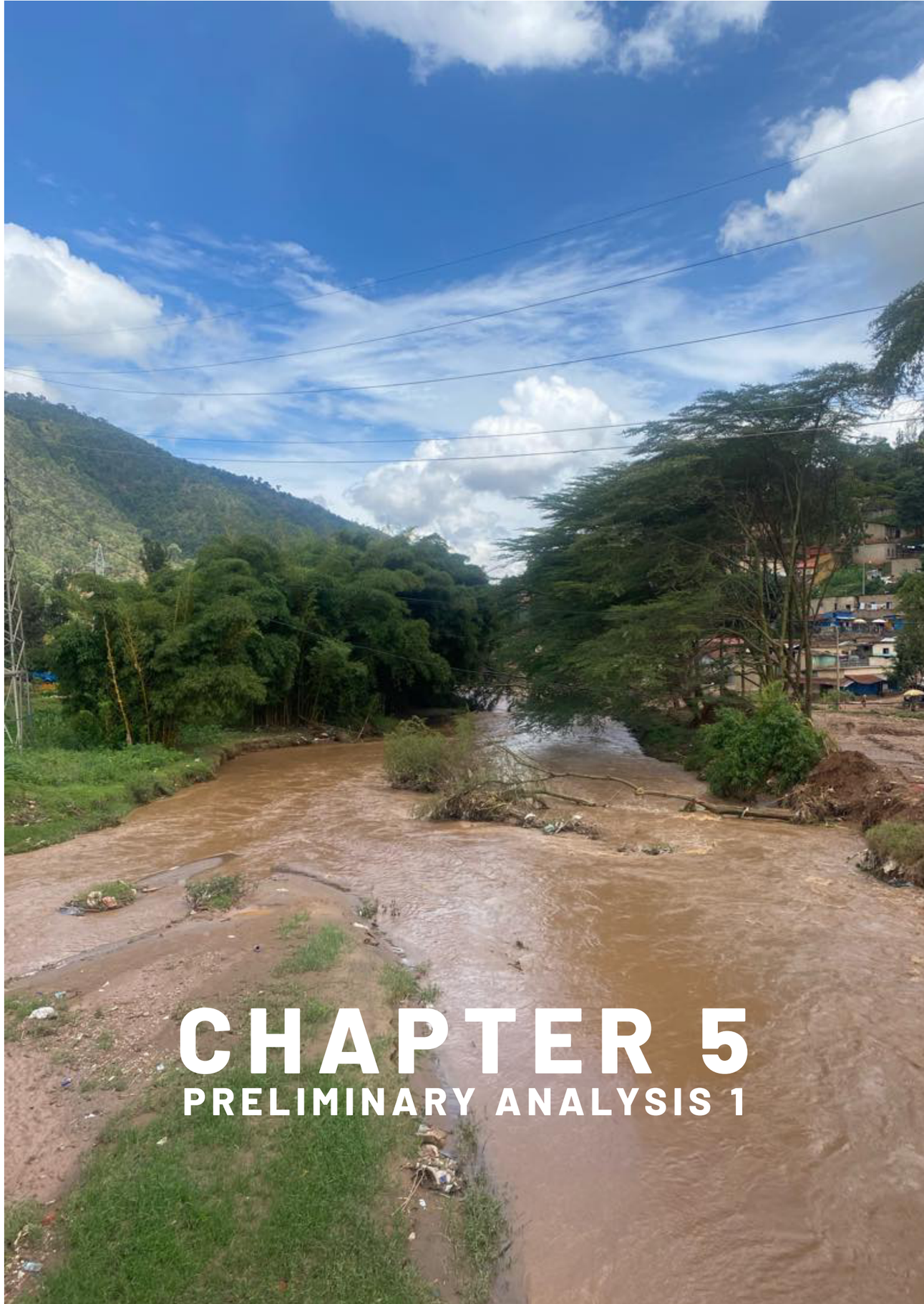
THE CASE ANAYSES

As stated previously, the theoretical and methodological frames of the study guide the case analyses. The analyses in question utilise central concepts and principles from the theoretical basis and data from the literature review, interviews, and the case journal.

The first analysis explores currently available flood hazard models and visualisations and investigates the portential of the Blue Spot Mapping methodology based on available opensource data sets.

The theoretical concepts of the Multi-Level Perspective frame the second analysis that examines how the current urban planning regime and stormwater mangement is structured and how well it is coping with the urgent landscape pressures regarding climate change and urban flooding, as explored in the first analysis.

The third analysis investigates the role of NbS as a novel innovation in terms of urban planning, stormwater management, and rehabilitation of degraded biodiversity and ecosystems in Kigali.



CHAPTER 5
PRELIMINARY ANALYSIS 1

URBAN DEVELOPMENT CHALLENGES

Like most other East African countries and cities, Rwanda and Kigali face pronounced seasonal climatic fluctuations and long-term climate change impacts. The present Chapter explores how climate change is putting external pressure on Rwanda and Kigali in terms of changing precipitation patterns and appertaining climate-induced, water-related hazards. Furthermore, the Chapter probes how urbanisation and urban sprawl further aggravate the impacts of urban flooding before digging deeper into how rapid urban development has degraded biodiversity and ecosystems in the city. In this way, the Chapter seeks to create a deeper understanding of three fundamental urban planning and development challenges of Kigali, climate change and urban flooding, urbanisation and urban sprawl, and lastly, degraded biodiversity and ecosystems.

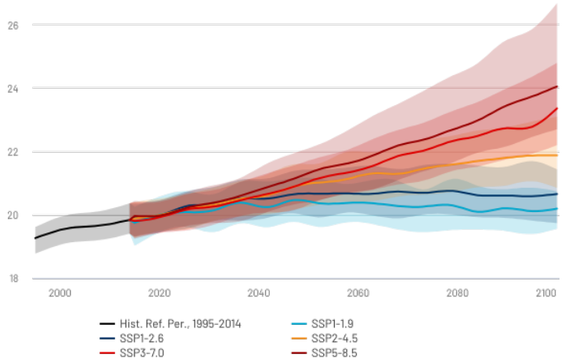


Figure 9. *Projected Mean-Temperature [°C] (y-axis) Changes in Kigali in Various Climate Change Pathways (ref period 1995-2014) (WBG, n.d.)*

CLIMATE CHANGE

Findings indicate that Rwanda and the City of Kigali are being affected by climate change in several interconnected ways. Examples of great concerns include fluctuations in precipitation patterns and projected increases in temperature, which directly influence the level and amount of evapotranspiration, humidity, water availability, urban heat island (UHI) effect and wildfires. Projections indicate that temperatures can increase as much as 3.9°C by the end of the century based on the worst-case scenario, Representative Concentration Pathway (RCP) 8.5. Figure 9 illustrate the various scenarios for the projected mean temperature in the City of Kigali (WBG, n.d.; WBG, 2021-a). Alongside the increase in temperatures, forecasts predict a subsequent increase in the number and duration of heat waves in Rwanda. These projections are likely to cause significant downdrafts in socio-economic and technical systems in Rwanda as it impacts the rain-fed agricultural productivity, the already poor water management infrastructures, and the hydro-powered energy production. Consequently, climatic fluctuations may affect food, water, and job security (WBG, 2021-a).

As urban flooding is one of the focal points of the present study, climatic conditions leading to this environmental hazard are vital to explore and understand. Accordingly, Table 3 holds a review of **past and predicted** rainfall and precipitation patterns in Rwanda and Kigali.

The review indicates that poor, incomplete, and inadequate data sets and historical records of high fluctuations and viability cause findings in the observed precipitation trends to deviate. While data provided by the WBG (2021-b) indicates a steady increase in annual precipitation in Rwanda from 1901 to 2020, Haggag et al. (2016) find an overall decrease in rainfall using records from 1980 to 2000 (Haggag et al., 2016; WBG, 2021-a). Other findings suggest a decline in annual mean-precipitation in the period from 1961 to 2016 (RoR, 2018), while McSweeney (2011) is unable to conclude on historically observed trends in percipitation due to the aforementioned poor quality and quantity of data from the **past** two decades (McSweeney, 2011; RoR, 2018). In the reviewed studies, there is a slight predominance of scholars and data arguing for a general decrease in rainfall in Rwanda and Kigali in past records. Additionally, there seems to be a broader consensus among scholars that Rwanda and Kigali have experienced high fluctuations and variability of rainfall which have caused changes in the length, duration, and intensity of the historical dry and wet seasons (McSweeney, 2011; RoR, 2018).

In terms of **predicted** changes in precipitation, the review uncovers several uncertainties and discrepancies in the studies. Some findings indicate projected increases in the short dry season, while projections expect a decrease in precipitation during the long dry period (RoR, 2018).

According to the Republic of Rwanda (RoR) (2018), projections show a decline in rainfall in the period 2015 to 2050, which is likewise supported by the Updated Nationally Determined Contribution (RoR, 2018; RoR, 2020). On the other hand, Haagag et al. (2016) present projections which indicate a tendency for a wetter and warmer climate. The study states that Rwanda and Kigali can expect an increase in rainfall up to 29% in the periods of 2010 to 2039 and 2070 to 2099 (Haagag et al., 2016). Alongside this, Ntikubitubugingo (2018) expects that Kigali and Rwanda will receive an increased amount of annual rainfall in the period from 2021 to 2050 (Ntikubitubugingo, 2018). Also, projections by the WBG (2021-a) show a steady increase in rainfall in the period 2015 to 2100 (WBG, 2021-a).

Despite some discrepancies and high fluctuations in the projected climate of Rwanda and Kigali, there is an overweight of findings indicating that climatic conditions of precipitation are expected to change both from a long- and short-term perspective. The common consensus among the reviewed literature is that the City of Kigali has to prepare for more precipitation in the future.

THE EAST AFRICAN CLIMATE PARADOX

THE GENERAL OBSERVED DECREASING TREND OF PRECIPITATION RECORDED IN RWANDA AND KIGALI AND THE PROJECTIONS OF A WETTER CLIMATE CORRESPOND WELL TO THE GENERAL RECORDINGS AND PREDICTIONS OF THE EASTERN PART OF AFRICA, WHICH GIVES RISE TO THE SO-CALLED EAST AFRICAN CLIMATE PARADOX.

THE OBSERVED DECLINE OF THE EASTERN AFRICAN LONG RAINS FROM THE 1980S TO THE LATE 2000S CONTRADICTS THE FUTURE CLIMATE CHANGE PROJECTIONS, WHICH INDICATE AN INCREASE IN PRECIPITATION ACROSS THE EAST AFRICAN REGION (WAINWRIGHT ET AL., 2019).

THE EAST AFRICAN CLIMATE PARADOX AND ITS CAUSES HAVE BEEN INVESTIGATED, AMONGST OTHERS, BY WAINWRIGHT ET AL. (2019), STATING THAT THERE HAS BEEN A "*DECLINE IN EASTERN AFRICA MAM [MARCH-APRIL-MAY] RAINFALL DURING 1998-2008 RELATIVE TO 1986-1997, AND RECENT RECOVERY FROM 2010 ONWARDS, ALTHOUGH WITH HIGH YEAR TO YEAR VARIABILITY*" (WAINWRIGHT ET AL., 2019, PP. 1).

THE FINDINGS FURTHER HIGHLIGHT THAT DESPITE PROJECTIONS INDICATING AN OVERALL INCREASE IN THE LONG RAINS IN EAST AFRICA, THERE HAS BEEN "*LITTLE CHANGE IN OVERALL SEASON LENGTH AND AN INCREASE IN THE INTENSITY OF RAINFALL ON INDIVIDUAL DAYS*" (WAINWRIGHT ET AL., 2019, P. 6). ALTHOUGH OBSERVATIONS OF DRY PERIODS INDICATE THAT THESE ARE EXTENDING, THE OBSERVED AMOUNT OF YEARLY PRECIPITATION HAS NOT DECLINED. INSTEAD, THE SEASONAL PATTERNS OF PRECIPITATION HAVE SHIFTED, AND THE INTENSITY OF PRECIPITATION EVENTS HAS INCREASED. SUCH FINDINGS UNDERLINE THE COMPLEXITY OF INVESTIGATING AND UNDERSTANDING PAST AND PREDICTED CLIMATIC CHARACTERISTICS (WAINWRIGHT ET AL., 2019).

Image 2. *Drainage Channel*

LITERATURE REVIEW
CHANGES IN PERCIPITATION

Table 3. *Review of Climatological Studies*

The following review expands on past and predicted precipitation patterns in Rwanda and Kigali.

PAST. During the period 1961 to 2016, the annual rainfall in Rwanda gave away high fluctuations. Indicated by observed decreases in mean precipitation in January, February, May, and June, while preceding increases are exhibited in the remaining months of the year throughout the entire nation (RoR, 2018).

In the Northern Region of Rwanda, observations indicate a general increase in rainfall from 1960 until an apex in 1982. From 2000 to 2009, observations indicate the driest recorded period, while more frequent fluctuations in mean precipitation were observed from 2009 to 2016. As so, data show a general decline in mean precipitation in the northern region of Rwanda during the investigated period (RoR, 2018).

In the Western and Volcanic Regions in the North, a dry period was been recorded from 1998 to 2005, while the area experienced its wettest period from 2008 to 2014 (RoR, 2018). On the contrary, recordings from the Eastern Region exhibited a dry period from 1992 to 2008 and a wet period from 1978 to 1990. The observed trends indicate that the Eastern Region has frequently experienced dry episodes (RoR, 2018). The region of the Central Plateau experienced its wettest period from 1978 to 1992, while the driest was recorded from 1998 to 2010 (RoR, 2018). On a national level, the period from 1961 to 1991 has reportedly been wetter than the period running from 1991 to 2016, indicating a decrease in annual mean rainfall across the country in this period (RoR, 2018).

Analyses of rainfall trends in Rwanda conducted by The Dutch Ministry of Foreign Affairs (MFA) (2018) indicate an increase in the occurrences of extremes over time and in different parts of the country. On a general level, the analyses state that the two wet seasons are becoming shorter yet more intense, particularly in the northern and western provinces. Contrary, the eastern regions of the country have experienced a significant decline in average precipitation in several years during the past decades alternating with extremes in rainfall in other years (Dutch MFA, 2018).

On the other hand, a study by Haggag et al. (2016) did not find a significant trend in precipitation patterns in Rwanda based on research done on records from six different sites based on data from 1964 to 2010. However, the study found a decrease in precipitation from the 1980s to 2000 (Haggag et al., 2016).

Data and findings provided by WBG (n.d.-b) indicate that extreme rainfall events have occurred more frequently since the 1960s and that observed annual rainfall observations in Rwanda in the period from 1961 to 2016 have shown high fluctuations. However, the study revealed a mean decrease in January, February, May, and June and an increase in the months from September to December on a national scale (WBG, n.d.-b).

These observations deviate from the findings presented by RoR (2018), as the data provided by WBG (n.d.-b) indicates a fluctuating but steady increase in average annual precipitation (RoR, 2018; WBG, n.d.-b). As evident from the recorded observations, annual mean precipitation increased from 1141 mm observed in 1901 to 1345mm in 2020. According to the dataset, the apex of average annual precipitation took place in 1963 (1476 mm), while the lowest annual average occurred in 2004 with 850 mm (WBG, n.d.-b).

Other scholars, such as McSweeney (2011), are more hesitant to conclude on historical trends. Accordingly, the quality and quantity of historical data recordings of precipitation in the region have been criticised to be inadequate to provide a foundation upon which qualified conclusions about the 20th-century climatological conditions of Rwanda can be drawn. McSweeney (2011) states that for "*precipitation, no significant trends have been found for the period 1961-90; there are insufficient records to assess the most recent two decades of rainfall with these stations*" (McSweeney, 2011, p. 17). However, McSweeney (2011) does agree with findings regarding observed high interannual fluctuations in precipitation for all regions of Rwanda (McSweeney, 2011).

Kigali. Data provided by WBG (n.d.-b) indicate a steady increase in annual average precipitation for the City of Kigali in the period from 1901 to 2020, with 929 mm recorded in 1901 and 1117 mm in 2020. The lowest and highest records are registered for the years 1911 (695 mm) and 1963 (1299 mm), as visualised in Figure 10 (WBG, n.d.-b).

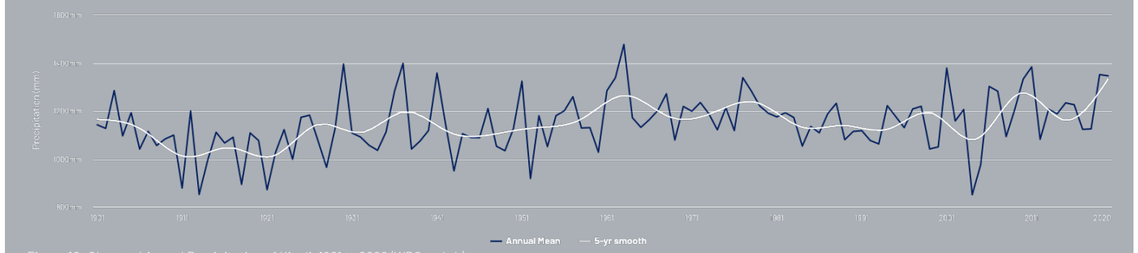


Figure 10. *Observed Annual Precipitation of Kigali, 1901 to 2020 (WBG, n.d.-b)*

PREDICTED. Local governmental reports, such as the Third National Contribution (2018), highlight the substantial uncertainties and discrepancies in studies of projected climate changes in terms of precipitation over East Africa and Rwanda (RoR, 2018). Some findings suggest that local climate circulation effects are going to lead to a general, long-term decrease in rainfall, while other predictions indicate an increase in rainfall "*by 5%-20% from December to February, and decreased rainfall by 5%-10% from June to August by 2050*" (RoR, 2018, p. 11).

Investigations of the period from 2015 to 2050 show a general declining trend in the observed average rainfall throughout the country, with the expedition of the northwestern highlands. The study predicts that a decrease in precipitation will take place in the periods of 2015 to 2038 and 2043 to 2047, especially in the Eastern region of Rwanda, while the alternating periods (2039 to 2042 and 2048 to 2050) indicate an increasing trend in the amount of precipitation. Likewise, findings from the study show a high level of variability in the average mean rainfall with a declining tendency in the years 2015 to 2023 and 2033 to 2042 (RoR, 2018).

According to the Updated Nationally Determined Contribution (2020) by the Republic of Rwanda, "*Rainfall has become increasingly intense, and the variability is predicted to increase by 5% to 10%*" (RoR, 2020-a, p. 1.). Likewise, the paper presents rainfall projections and the number of days with precipitation with a declining trend. These indications correspond to projections of an increase in the frequency of future dry spells throughout the country, particularly in the eastern regions. On the other hand, findings presented in the Updated Nationally Determined Contributions anticipate that the southwestern districts and the northwestern highlands are to experience future increases in rainfall intensities (RoR, 2020-a).

The Dutch MFA documents projections indicating that average annual precipitation in Rwanda will fluctuate, ranging between -100mm and +400 mm for the period from 2000 to 2050. However, the models suggest differences in terms of seasons and geographical regions. Parts of the eastern and southern regions are predicted to experience frequent periods of below-average precipitation levels, while increases in precipitation are predicted in parts of the northern, southern, and western provinces. Changes in the precipitation patterns are expected to bring heavier periods of rainfall during the wet seasons, while dry seasons are predicted to become dryer and longer (Dutch MFA, 2018).

Other studies indicate an increasing trend of precipitation ranging from 1% up to 29% correlating to the periods of 2010 to 2039 and 2070 and 2099. The analyses of different climate projections and scenarios of the climate of Rwanda in the 21st century predominantly indicate a tendency toward projections of a wetter and warmer climate. On a general level, the forecasts suggest that the increases in precipitation are relatively small compared to the observed interannual variabilities in precipitation patterns and the current climatological conditions in Rwanda (Haggag et al., 2016).

Climate projections from the IPCC provide global in their assessment and do not provide the necessary precision and accuracy to be used at a regional or city scale. Although, using methods of statistical downscaling can improve the spatial accuracy for local use. Downscaling is done based on the relationship between local climate observation and global climate models and does come with a certain marginal error. According to a statistical downscaling study by Ntikubitubugingo (2018), projections based on historical CORDEX output data and local station data from Meteo Rwanda, the City of Kigali is expected to receive an increased amount of annual rainfall in the period from 2021 to 2050 (Ntikubitubugingo, 2018). These findings are based on scenarios of RCP 4.5 and 8.5 (Ntikubitubugingo, 2018).

Kigali. Likewise, data and projections provided by the WBG (n.d.-a) on future precipitation patterns of Kigali indicate a steady increasing trend in the period from 2015 to 2100. The projections are based on five scenarios, as listed below and documented in Figure 11. The increase in projected change in precipitation depends on the different pathways ranging between + 80 mm to + 334 mm (WBG, n.d.-a).

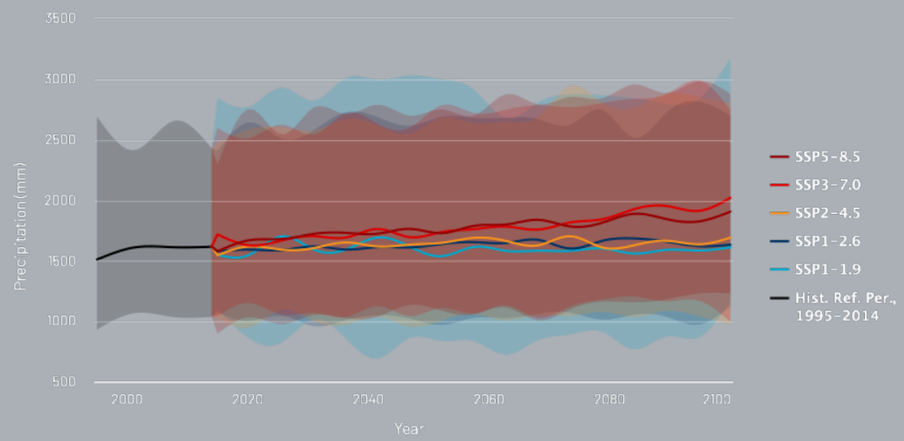


Figure 11. *Projected Average Rainfall in Kigali (ref. period 1995-2014) (WBG, n.d.-a)).*

Path	2015	2100	Change
SSP1-1.9	1574 mm	654 mm	+ 80 mm
SSP1-2.6	1596 mm	1654 mm	+ 58 mm
SSP2-4.5	1572 mm	1728 mm	+ 158 mm
SSP3-7.0	1734 mm	2043 mm	+ 309 mm
SSP5-8.5	1588 mm	922 mm	+334 mm

CLIMATE-INDUCED HAZARDS

In Rwanda and Kigali, the fluctuating climatic conditions and projected climate trends add great pressure on the hydrological cycle and overall (urban) stormwater management practices. Projections and scientific findings indicate that the future intensified precipitation will aggravate the frequency and intensity of natural hazards such as flooding, droughts, landslides, and soil erosion. According to the WBG (n.d.-b), floods account for approximately half of the reported hazards recorded between 1980 and 2020 (WBG, n.d.-b). Figure 12 visualises how Rwanda otherwise is exposed to various environmental hazards.

Ministry in Charge of Emergency Management, Rwanda (MINEMA) states that "*Over the last decade, the frequency and intensity of natural hazard-induced disasters have significantly increased, raising the toll of human casualties as well as economic and environmental losses*" (MINEMA, n.d.). Furthermore, the recordings reflect a lack of consistency in reporting and recording hazardous events, recognised by MINEMA as a priority area of potential improvement at a national level (MINEMA, n.d.).

Flooding

Due to the geographical landscape and climatic conditions, Rwanda and the City of Kigali have experienced several devastating flooding events in the past decades. Although floods are environmental and recurrent hazards, their frequency and intensity have increased concurrently with an increase in events of heavy precipitation.

On a national level, Rwanda regularly experiences fluvial floods, mainly due to its dense network of rivers and wetland areas. Fluvial flooding, or riverine flooding, is a common type of flooding occurring when rivers overflow and exceed their banks. Pluvial flooding, or flash floods, is likewise an immense challenge in Rwanda. Particularly, urban and mountainous areas, including Kigali, are exposed to this flood type due to excessive amounts of high-velocity runoff and poor stormwater management. Pluvial flooding usually occurs as a localised flood triggered by excessive surface runoffs. Generally, both flood types originate from cloud bursts or heavy precipitation leading to a high-velocity flow of water, ultimately culminating in downstream floods. Especially the North-Western Province of Rwanda is exposed to fluvial flooding, while pluvial flooding is predominantly recorded in the City of Kigali (MIDIMAR, 2015, Muhire, 2015).

A range of conditions contributes to the high-velocity runoffs and subsequent flash floods within the City of Kigali. These conditions include rapid urbanisation compounded with extreme climatic conditions, a lack of well-planned drainage systems, and progressively reduced permeability and infiltration from development. Consequently, the urban population of Kigali are increasingly at risk of flooding and associated hazards such as landslides and soil erosion. These hazards may cause severe damage to critical infrastructure, injuries, fatalities, loss of agricultural areas and crops, and environmental and ecosystem degradation (MIDIMAR, 2015; Uwera et al., 2020). The characteristic mountainous topography further accelerates the velocity and impact of floods within the cityscape, exacerbating the severity and hazardousness of the events (MIDIMAR, 2015). The urbanised steep hills of Kigali create high-velocity runoffs, flowing downstream into the valley bottoms (Opperman et al., 2021).

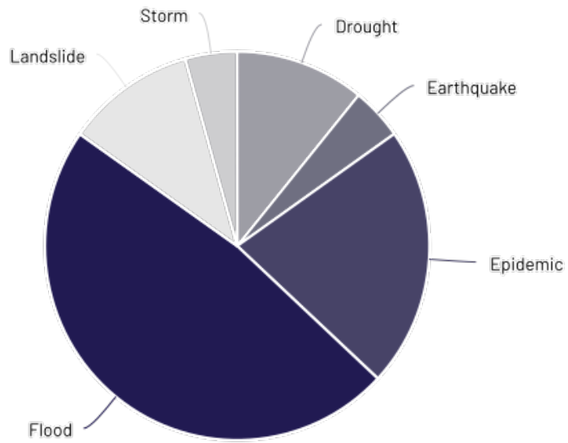


Figure 12. *Average Annual Hazard Occurrence, 1980-2020 (Own figure adapted from WBG, n.d.-b)*

Events of flooding have substantial impacts on lives, livelihoods and infrastructure in the city. Unfortunately, flooding resulting in human casualties has become a recurrent event with recent, devastating records from 2019, 2020 and 2022, see Table 4 (Alemayehu & Benitez, 2020; Niyokwiringirwa, 2021). Further, flooding has been documented to damage homes and agricultural areas, and they interfere with the road network of the city, often isolating the city areas between hillsides (Opperman et al., 2021).

During the short and long wet seasons, precipitation typically falls with high intensity over short periods and with high spatial variability. Records from the past decades document that flooding events occur on an irregular basis but with a significant increase in the frequency of incidents in recent years, underlining the importance and need for floodproofing the cityscape (Uwera et al., 2020).

Using a so-called Water Risk Filter analysis, Opperman et al. (2021) state that "*Kigali is projected to go from a flooding risk of high to very high by 2050 with the current trend scenario*" (Opperman et al., 2021, p. 63). The impacts of climate change and urban flooding are further aggravated by the expansion of impervious surfaces due to urban development, densification and population growth.

In a recent study by Uwera et al. (2020), findings indicate "*that land use and land cover, rainfall, elevation, slope and ... soil texture were the major parameters conditioning the occurrence of flood in Kigali city*" (Uwera et al., 2020, p. 122). The study further describes that all three districts, Gasabo, Kicukiro and Nyarugenge (Map 3, p. 08) are exposed to flooding. According to the Uwera et al. (2020), the Gasabo District holds the highest risk of experiencing high and very high categories of flood hazards, as the study reveals that "*the residents of Gasabo district are, at a large extent, exposed to flood at 55.4% compared to residents of Nyarugenge and Kicukiro Districts, which are exposed to flood at 25.4% and 19.2%, respectively*" (Uwera et al., 2020, p. 122).

Uwera et al. (2020) state that the Gasabo District in the City of Kigali holds the majority of green infrastructure (44.32%) compared to the two remaining districts. The existing green infrastructures within the city boundaries are mainly wetlands placed downstream, while areas identified as being highly exposed to flooding are located upstream. Thus the study stresses the need for storing, retaining, and slowing upstream runoff to protect and flood-proof the city (Uwera et al., 2020).

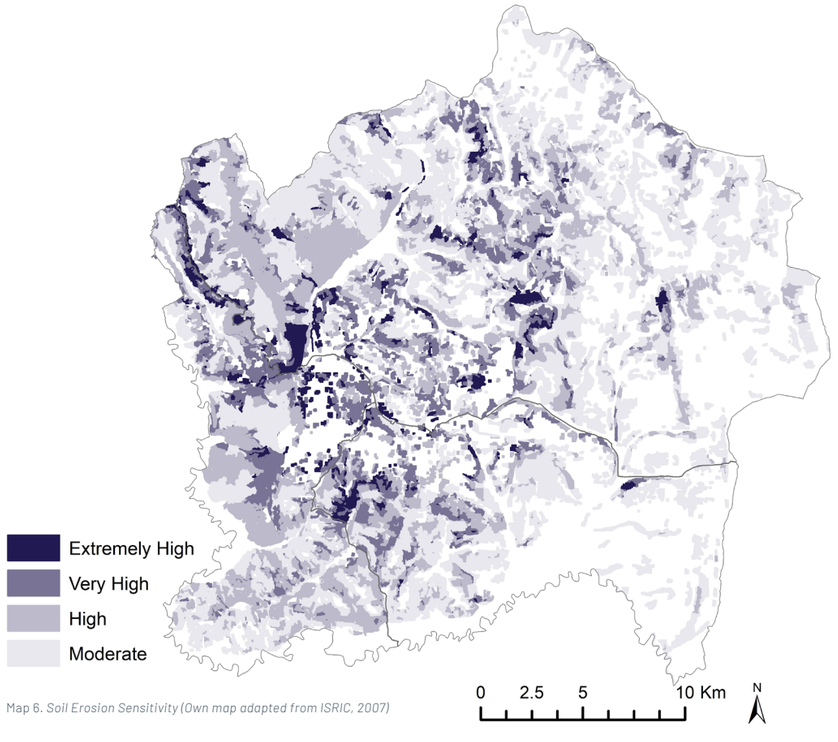
Soil erosion, landslides, and droughts are likewise common phenomena in Rwanda and in the City of Kigali, largely attributable to the varied topography combined with their lithographic and climatological characteristics. These hazardous events are complex and intrinsically interrelated, simultaneously influencing each other in a complex nexus. For example, prolonged drought may reduce agricultural yield and increase the intensity of flooding, soil erosion and landslides in a heavy precipitation event (WBG, 2021-a).

Table 4. *Recent floodings in Kigali (*Niyokwiringirwa, 2021; ** Crisi24, 2022)*

Year	Rainfall [mm]	Duration [hrs]	Fatalitites
December 2019*	140	24	12
May 2020**	140	4 - 5	65
April 2022**	Unk	Unk	11

Soil Erosion

Because of the topographically varied landscape and steep slopes, the City of Kigali has collectively been categorised as being, on average, of 'medium to high risk' of soil erosion (Krishnasamy et al., 2020). Records show that soil erosion in Rwanda directly damages lives, livelihoods, and infrastructure. Additionally, soil erosion reduces the availability of nutrients and the fertility of soils for agriculture, which reduces agricultural yield and productivity (REMA, 2019). Another cascade effect regards the fact that excess precipitation and stormwater runoffs are known to cause significant sediment transport and movement of pollutants downstream. Sediment transport may also result in clogged or blocked rivers or stormwater channels, leading to overflow of stormwater onto roads creating high-velocity surface runoffs (Krishnasamy et al., 2020). Conversely, periods with low levels of precipitation further exacerbate the likelihood of soil erosion as it increases the aridity and stability of the soils (WBG, 2021-a). The soil composition in Kigali has a high percentage of clay content, which inherently entails that the area has a high water-holding capacity and drains slowly. These soils are generally more structurally stable and less susceptible to erosion caused by water. However, in areas with steep slopes, the structural integrity of the soils is unpredictable (Holden, 2017). Map 6 visualises the soil erosion sensitivity of Kigali.



Map 6. *Soil Erosion Sensitivity (Own map adapted from ISRIC, 2007)*

Landslides
Landslides occur when slopes lose their natural stability, commonly occurring in the aftermath of earthquakes, droughts or heavy precipitation. Landslides are a recurring hazard in Rwanda and in the City of Kigali, attributable to a range of factors, two of them being Rwanda's distinct topographic characteristics and fluctuating climatological patterns. In the past, heavy precipitation and subsequent flooding have triggered landslides and mudslides in Rwanda and Kigali, with immense damage to livelihoods and infrastructure. These hazardous events are exacerbated by changing climatic conditions, land-use changes and urban sprawl into steep areas. In Rwanda, over 90% of crops are cultivated on steep slopes. As such, severe landslide events threaten food production and the degree of self-sufficiency for both rural and urban populations. Today, estimates show a total of 40% of the population resides in areas at high risk of landslides in Rwanda(WBG, 2021-a).

Droughts
Droughts are another natural and recurring environmental phenomenon affecting the City of Kigali. Due to changing climatological patterns, the frequency and intensity of droughts have been predicted to change. Specifically, seasonal droughts are projected to prolong in the future. Extended periods of drought may also result in the degradation of land areas, ecosystems, and biodiversity. Furthermore, droughts put pressure on the availability of water, alongside the water supply infrastructure and the quality of the available water. They have a wide range of effects, such as leading to scarcity of freshwater, increasing the spread of diseases, and hampering the productivity of agricultural land areas. In 2016 a total of 44,000 households lost crops and livestock due to a prolonged dry period. Furthermore, extended periods of drought directly affect the production of hydroelectric power, an electricity source that Rwanda is heavily reliant upon (WBG, 2021-a).

URBANISATION & URBAN SPRAWL

The impact of climate change is fundamentally complex and interlinked with a range of challenges and concerns, and whilst urban flooding continues to be a substantial challenge for the City of Kigali, other worries exacerbate this issue. Urbanisation and urban sprawl are two phenomena that contribute to the growing need for increased emphasis on climate adaptation and mitigation measures in the capital city.

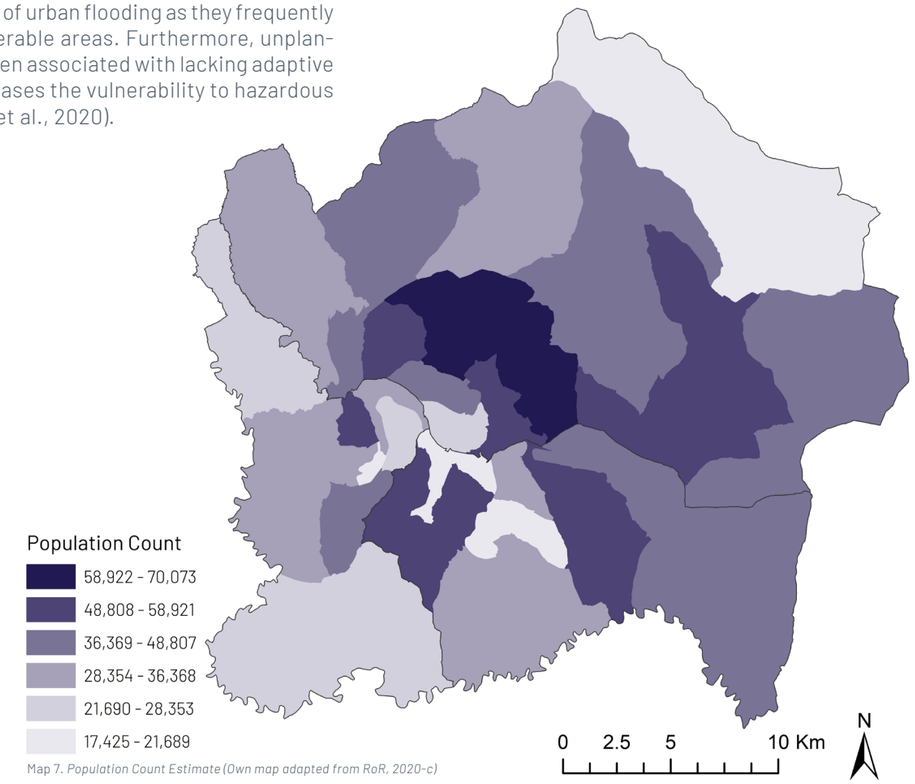
Forecasts show that two-thirds of the global population will reside in cities by 2030, and an estimated 80% of this urban growth will occur within the regions of Africa and Asia (Kalantari et al., 2018). As the African continent is continuously urbanising and population growth is accelerating, the continent is becoming increasingly vulnerable to climate-induced hazards, such as flooding, landslides, and soil erosion (Welborn, 2018). The WBG (2021-d) explicitly states that "*In rapidly urbanising areas, a significant proportion of urban growth risks to materialise in dense, lower-quality unplanned settlements. In these vulnerable areas, climate impacts are exacerbated - now and into the future - as these settlements are often located in high-risk areas, such as on floodplains or steep slopes*" (WBG, 2021-d, p. 9).

Kigali has faced enormous development and urbanisation in the past 25 years. While records indicate that urbanised land has tripled since the mid-90s, the city is still facing continuous population growth alongside urban densification today and in the future (City of Kigali, 2020). The most recent population count states that 1.21 million people (2022) find their home within the city boundaries of 730km2 of Kigali. Projections indicate that the urban population will increase to 1.9 million in 2035 and 3.8 million in 2050 (WPR, 2022; UN, n.d.). Map 7 visualises the most recent population count estimate from 2020.

Due to the rapidly increasing population, the City of Kigali is in demand of 310,000 housing units to accommodate the estimated future population. In other words, the city has to construct approximately 20,700 units annually, whereas the current rate of construction culminates at less than 1,000 units annually. Additionally, there is a specific need for affordable housing, and with the impact of the COVID-19 crisis, the country has seen substantial price inflation of building materials alongside a decrease in the supply and availability of such materials (Nkurunziza, 2022-a).

As described earlier, urbanisation contributes to the risk of flooding as developments change the composition of land cover and land use by introducing hard, impermeable surfaces which hinder precipitation from penetrating the ground, ultimately causing runoffs to accumulate. The sprawl of uncontrolled and unplanned urbanisation further aggravates the impacts of urban flooding as they frequently move into already vulnerable areas. Furthermore, unplanned settlements are often associated with lacking adaptive capacities, which increases the vulnerability to hazardous urban flooding (Uwera et al., 2020).

A considerable problem within the City of Kigali is that an estimated 70% of the urban population resides in informal and unplanned settlements. Residents in these settlements are often listed as 'urban poor', and as Kigali is hastily urbanising and economic activity is increasing, the income gap is widening correspondingly. Records show that the urban sprawl and increase of unplanned settlements often encroach on undeveloped lands such as wetlands or steep slopes and flood-prone areas in the city, thereby degrading land areas and ecosystems (City of Kigali, 2020; Uwera et al., 2020).



Map 7. *Population Count Estimate (Own map adapted from RoR, 2020-c)*

DEGRADATION OF ECOSYSTEMS & BIODIVERSITY

Records indicate that the development in the City of Kigali has occurred at the expense of nature. Consequently, the city has been subject to significant environmental degradation, damaged water resources, and degradation of ecosystems and biodiversity (WBG, 2021-a). Within the City of Kigali, the native biota has been significantly reduced in the past decades, and foreign non-native species have been widely introduced, especially for agricultural cultivation. Measures have been taken in recent years to improve previously damaged areas, for example, through reforestation or ecosystem restoration. Yet, several implemented plans and strategies have, in retrospect, been criticised for bringing about cascade effects. Examples include cases of reforesting areas with the introduction of non-native species. Although these were introduced with good intentions based on their capabilities and strengths, findings suggest that cascade effects often follow such implementations. For example, species of Eucalyptus have been introduced within the city for their capabilities of slope stabilisation and erosion control. Unfortunately, this has a cascade effect of depleting surrounding biodiversity. Eucalyptus plants are used as crops but have proven to impact local biodiversity when introduced for slope stability on roadsides and parks (Krishnasamy et al., 2020).

Wetlands are vital ecosystems in Kigali and Rwanda, as they provide a wide range of ecosystem services such as stormwater management, carbon sequestration, and water purification. Despite their climate-adaptive capacities, the geographical extent of wetlands in Kigali has declined from 14% in 2013 to 10.6% as of 2020. The wetlands in the city identify as Central Plateau Swamps based on the low-lying topography compared to the national average. Image 3 shows one of the wetlands in Kigali, the Gikondo Wetland The decline of wetland land cover is primarily attributed to urban development, agriculture, and material extraction of clay and sand for building materials (Krishnasamy et al., 2020). The updated Master Plan for the City of Kigali states that "*Over half of the wetlands in Kigali are degraded and have lost ecological functions, and over 2078 establishments are identified as encroaching on the city's wetlands*" (Krishnasamy et al., 2020, p. 109).

Rwanda and Kigali have made efforts to address these issues through policy-making and conservation. Today, wetlands have been protected under the National Organic Law since 2005, and the Rwanda Environmental Management Authority holds the institutional responsibility for management, conservation, and restoration (Krishnasamy et al., 2020).

Image 3. *Gikondo Wetland*

SUMMARY

The majority of reviewed climatological research and studies indicate that local authorities, urban planners, and stormwater management specialists must prepare for higher annual precipitation rates in Kigali and Rwanda. Additionally, findings suggest that the dry periods are becoming dryer and wet seasons are becoming wetter, essentially indicating that both sides of the spectrum are becoming more extreme. Despite this, there are major discrepancies and high fluctuations in observed and projected precipitation patterns from the reviewed sources.

The city of Kigali is facing a nexus of urban development challenges, where urban flooding classifies as one of the most severe climate-induced, water-related hazards. Other challenges aggravated by the complex dynamics of climate change and urban development include landslides, droughts and soil erosion. The findings from the preliminary analysis highlight that as patterns of precipitation are projected to change, floods are expected to become more hazardous in the future. Therefore, the present study centres upon the challenges directly related to urban flooding in the city of Kigali.

During the past 25 years, the city of Kigali has experienced rapid urbanisation and urban development, simultaneously, the urban population has vastly grown. The preliminary analysis indicates that the trend of increased urbanisation and urban sprawl aggravates the challenges of urban flooding in the city. Urban sprawl is particularly contributing to the problem of informal and unplanned settlements, which is, furthermore, closely linked to problems associated with poor urban planning practices. Estimates suggest that 70% of the urban population resides in informal and unplanned settlements and that these communities encroach on wetlands, steep slopes, and flood-prone areas in the city. Consequently, urbanisation and appertaining development have taken place at the expense of nature for many years in Kigali. Today, over half the wetlands in the city are degraded and deprived of their natural ecosystem functioning, which entails that their capacity to buffer floods and retain stormwater has been drastically reduced.

Rounding off, findings from the above Chapter suggest that the city of Kigali faces a multitude of complex and interconnected challenges in the face of anthropogenic climate change. As such, there is a need for solutions that can balance the nexus of climate change, urbanisation, urban sprawl, and the degradation of ecosystems and biodiversity. The following Chapter explores how Nature-based Solutions (NbS) can address urban challenges when used in climate change adaptation practices.

CHAPTER 6
PRELIMINARY ANALYSIS 2

THE ROLE OF NATURE IN URBAN PLANNING

The present Chapter takes a deep dive into the role of Nature-based Solutions (NbS) in urban planning and their abilities to address the impacts of climate change, including urban flooding. First, it explores the prospects and limitations of NbS through an international lens before zooming in on the potential of the approach in an African setting. Hereafter, five cases of readily implemented NbS initiatives in neighbouring capitals to Kigali will be reviewed to shed light on the status quo of NbS in East Africa and familiar settings to Kigali. Thereby, the Chapter aims to provide a thorough understanding of the strengths and weaknesses of NbS.

The Prospects of Nature-based Solutions

NbS have been widely recognised for their ability to address both the causes and the consequences of climate change (Seddon et al., 2019). They are furthermore a vital component of ensuring a sustainable transition towards resilient and adaptive cities in terms of urban flooding and droughts. NbS have been found to provide cost-effective solutions that build on natural ecosystem processes to address both the need for climate mitigation and adaptation measures (Seddon et al., 2020-a). There is a wide range of definitions for what NbS entails, for example, the Organisation for Economic Co-operation & Development (OECD) defines NbS as "*measures that protect, sustainably manage or restore nature, with a goal to maintain or enhance ecosystem services to address a variety of social, environmental and economic challenges*" (OECD, 2020, p. 5). As such, the definition builds on the three pillars of social, environmental and economic sustainability through the use of nature to provide both climate mitigation and adaptation. The uses a similar definition, stating that NbS are measures that "*aim to help societies address a variety of environmental, social and economic challenges in sustainable ways. They are actions inspired by, supported by or copied from nature; both using and enhancing existing solutions to challenges, as well as exploring more novel solutions, for example, mimicking how non-human organisms and communities cope with environmental extremes*"(Seddon et al., 2021, p. 1520). This definition highlights that NbS are novel innovations that mimic natural ecosystems. Alternatively, the International Union for Conservation of Nature (IUCN), takes on a broader definition, of NbS being "*actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits*" (Seddon et al., 2019, p. 7). Collectively, these definitions highlight that NbS can take many forms, yet they fundamentally build on the ability of nature and ecosystems to provide a range of services through their natural processes and functioning. Figure 13 visualises a selection of different NbS that can be implemented in urban environments (WBG, 2021-d).

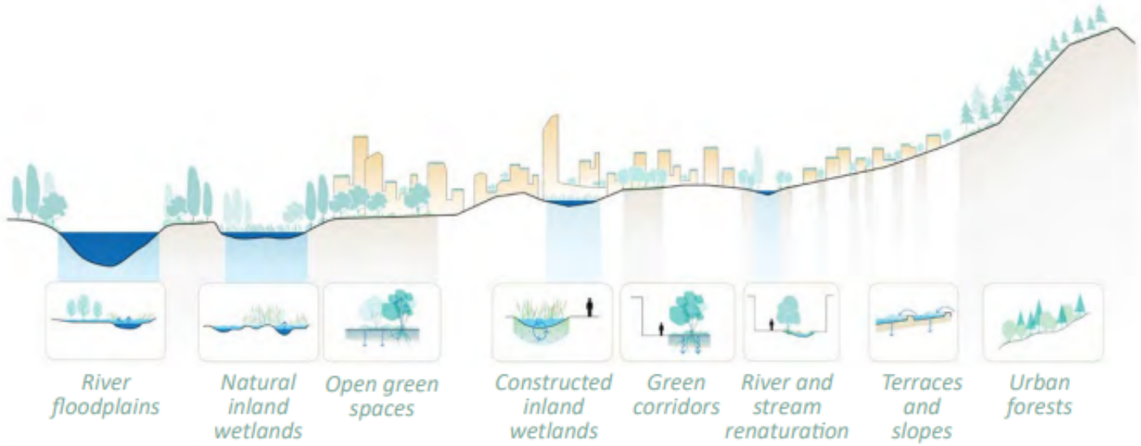


Figure 13. *Examples of Different Types of NbS (WBG, 2021-d)*

NbS rely on natural processes and ecosystems' inherent ability to perform provisioning, regulating, cultural, and supporting ecosystem services. Ecosystem services can be defined as "*The benefits provided by ecosystems that contribute to human wellbeing*" (Seddon et al., 2021, p. 1521). There is a range of available definitions and categorisations for ES, in the past, they were commonly structured into three categories; Provisioning, Regulating and Cultural. In recent years the fourth category of Supporting Ecosystem Services has been commonly adopted. Four examples of ES that relate to hydrology and water management are listed below (Kalantari et al., 2018; OECD, 2020; Seddon et al., 2020-a).

PROVISIONING. Drinking water, and water for non-drinking purposes, agriculture, sanitation, fishery, hydropower production

REGULATING. Carbon storage and sequestration, flood management, drought management, temperature regulation, water purification, erosion prevention, maintaining populations and habitats

CULTURAL. Recreational, tourism, cultural heritage, spiritual and symbolic meaning

SUPPORTING. Primary production, production of atmospheric oxygen, photosynthesis, nutrient cycling water cycle

(Kalantari et al., 2018; OECD, 2020; Seddon et al., 2019; Seddon et al., 2020-a)

Creating synergies

The overarching benefit of NbS is the fact that they can tackle the several problems at once through the generation of synergies and co-benefits. For example, the reintroduction of native species in deforested upstream catchment areas has been found to reduce the risk and impact of flooding downstream. A result of the ability of the surrounding vegetation, soils and sediments to absorb and hold larger amounts of water, and as such reduce flow velocity and accumulation downstream. Alongside the tangible solution of protecting local communities and infrastructures from flooding, NbS, such as upstream reforestation, provides the added benefits, or co-benefit, of promoting biodiversity and sequestering carbon.

The alternative engineered solution could, in this example, culminate in the construction of a dam to barricade water from flowing into flood-prone areas. The cascade effects of this solution could result in negative effects on biodiversity, further degradation of local ecosystems, and greenhouse gas emissions, both embodied and operational. Not only does NbS enable protection against environmental hazards such as flooding, but it also promotes the ability of green and blue infrastructure to promote human well-being. For example, reducing noise and air pollution, and can create public areas that promote social and physical well-being, community spirit and physical activity. Wider effects include that NbS have been found to regulate temperature and avoid incidents of urban heat island effect (Seddon et al., 2020-a). One of the strengths of NbS is that they have the natural ability to balance the need to for example handle flooding events and ensure water availability for communities (Acreman et al., 2021; Chausson et al., 2020).

Although the term NbS is relatively novel, there is a range of older concepts and terminologies that fall within the same scope. Common approaches include concepts of Green-and Blue Infrastructure (GI and BI), Ecological Engineering (EE), and Ecosystem-based Adaptation (EbA, as defined in Table 5. The different concepts and definitions are used by different actors, and especially different governments and countries have been known to interpret and define these concepts differently (OECD, 2020; Seddon et al., 2021).

On an international scale, NbS are gaining traction and are increasingly recognised for their climate adaptation and mitigation potential both in urban and rural settings. Further, increasingly recognised for their ability to foster sustainable and resilient urban development, while protecting communities and infrastructure from the impacts of climatic variations and environmental hazards. As such, they are increasingly highlighted in international agreements and forums such as those of the Intergovernmental Panel on Climate Change (IPCC) and the sixth assessment report and NDCs to the Paris Agreement, in addition to influential organisations such as the OECD, the World Bank and the World Wildlife Fund for Nature (WWF)(OECD, 2020; Seddon et al., 2019; WWF, 2021).

Table 5. *Concepts That Fall Within the Umbrella of NbS*

Concept	**Definitation**
Ecological Engineering (EE)	"*The design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both*" (Seddon et al., 2021, p. 1520).
Ecosystem-based Adaptation (EbA)	*"The use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change"* (Seddon et al., 2021, p. 1520).
Green-, Blue-, and Green-Blue Infrastructure (GI, BI, and GBI)	"*A strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services such as water purification, air quality, space for recreation and climate mitigation and adaptation*" (Seddon et al., 2021, p. 1520).
Hybrid adaptation actions	*"A direct action that includes elements of different adaptation approaches including NbS, engineered approaches and/or indirect actions or enabling conditions"* (Seddon et al., 2019, p. 47)
Natural Climate Solutions (NCS)	*"Conservation and management actions that reduce greenhouse gas (GHG) emissions from ecosystems and harness their potential to store carbon"* (Seddon et al., 2021, p. 1520).
Nature-based Action (NbA)	*"An intervention involving the restoration, management or protection of ecosystems or nature-based agricultural practices"* (Seddon et al., 2019, p. 47)

Examples of Nature-based Solutions
NbS can be implemented at a variety of scales, from micro-scale solutions such as green walls and vertical forests on buildings to macro sale catchments wide interventions such as river restoration or rehabilitation (WBG, 2021-d; WWF, 2021). The WBG (2021-d) categorises and defines NbS within 14 different typologies, as visualised in Figure 14 (WBG, 2021-d). Within these typologies, there are vast a number of different initiatives, that all build on natural processes to provide ecosystem services.

NbS offers a wide range of benefits when properly implemented. Additional benefits from NbS for flood management include

- Increasing biodiversity
- Regulating temperature
- Improving food availability
- Social benefits
- Community engagement
- Improving biodiversity
- Filtering of pollutants
- Carbon sequestration
- Improving water quality
- Recreational benefits
- Cultural heritage
- Health and wellness
- Creating habitat

Figure 14. *The 14 Different NbS Typologies (WBG, 2021-d)*

Limitations of Using NbS
Although the value of NbS has increasingly been accepted on the international agenda, there remains a lack of evidence on its effectiveness. For example, Chausson et al. (2020) present findings that point to a lack of research and sound, comparable, methodologies investigating the benefits of NbS, drawing the conclusion that there are "*significant gaps in the evidence base*" (Chausson et al., 2020, p. 6134). It is further highlighted in the academic literature that there is a lack of compatibility of findings, and as such, an urgent need to develop measurable, evidence-based targets that account for spatiotemporal variability (Chausson et al., 2020; Frantzeskaki et al., 2019).

Furthermore, it has been highlighted in the scientific literature that there is a lack of accessibility for policymakers and decision-makers towards using NbS, as evidence and best practice examples are scattered across academic and scientific disciplines. Specifically, there is a lack of economic data underpinning whether or not NbS provide a cost-effective alternative to traditional grey interventions (Chausson et al., 2020). Furthermore, there is a lack of economic data that evaluates the effect of NbS in terms of both the potential for return on investment and the avoided cost of mitigating hazards (Frantzeskaki et al., 2019). The benefits of NbS spread across a variety of spatiotemporal scales, with the potential to affect a variety of stakeholders, and there is a need for methods that can assess their effects across these scales (Chausson et al., 2020).

Challenges arise in comparison to NbS and traditionally grey interventions for a range of reasons, primarily because they function on different spatiotemporal scales. First and foremost, the effects of grey interventions generally involve larger-scale interventions that drastically alter the location and natural environment in question. NbS on the other hand can be applied across all scales and aim to maintain and enhance the natural environment. In terms of the temporal scale, grey interventions tend to rapidly provide the intended results or purpose, whereas the introduction of NbS usually does not provide an instant effect. Rather, the impact and effect of NbS are low upon initial introduction and through its dynamic nature evolve to its full potential and capacity over longer timeframes (Chausson et al., 2020; WBG, 2021-d).

Evidence of negative trade-offs from the introduction of NbS to improve flood resilience has been found in some cases. For example, measures to enhance resilience result in increased ability to handle stormwater, whilst simultaneously decreasing the availability of freshwater for drinking and sanitation downstream. Finding like these have particularly been found in cases where non-native species and interventions are introduced (Acreman et al., 2021; Chausson et al., 2020).

NATURE-BASED SOLUTIONS VS. GREY INFRASTRUCTURES

NBS ARE ALTERNATIVES TO WHAT IS OFTEN REFERRED TO AS 'GREY' OR ENGINEERED INTERVENTIONS, THESE LARGELY RELY ON THE INTRODUCTION OF STATIC INFRASTRUCTURE THAT IS BOTH EXPENSIVE AND ASSOCIATED WITH LARGE CARBON FOOTPRINTS (KALANTARI ET AL., 2018; SEDDON ET AL., 2020-A).

THE WBG (2021) DEFINED GREY INFRASTRUCTURE AS "*BUILT STRUCTURES AND MECHANICAL EQUIPMENT, SUCH AS RESERVOIRS, EMBANKMENTS, PIPES, PUMPS, WATER TREATMENT PLANTS, AND CANALS. THESE ENGINEERED SOLUTIONS ARE EMBEDDED WITHIN WATERSHEDS OR COASTAL ECOSYSTEMS WHOSE HYDROLOGICAL AND ENVIRONMENTAL ATTRIBUTES PROFOUNDLY AFFECT THE PERFORMANCE OF THE GREY INFRASTRUCTURE*" (WBG, 2021-D; P.9).

IN TERMS OF WATER- AND STORMWATER MANAGEMENT APPROACHES AND STRATEGIES, THESE SOLUTIONS HAVE BEEN THE PROMINENT PARADIGM, COMMONLY IMPLEMENTED IN THE FORM OF CHANNELLING, DIKES AND DAMS. THESE INTERVENTIONS ARE INFLEXIBLE, AND LARGELY DESIGNED TO HANDLE STATIC HYDRO-CLIMATIC CONDITIONS, LACKING THE FLEXIBILITY TO ACCOMMODATE FLUCTUATIONS IN CLIMATIC CONDITIONS. WHILST THESE APPROACHES PROVIDE BOTH PROTECTION AND POTENTIAL FOR ADDITIONAL BENEFITS SUCH AS REGULATING THE SUPPLY AND AVAILABILITY OF WATER, AND THE GENERATION OF HYDROPOWER THERE IS A WIDE RANGE OF ASSOCIATED NEGATIVE EFFECTS.

FIRST OF ALL, THE IMPLEMENTATION OF GREY INFRASTRUCTURES COMMONLY HAS A SIGNIFICANT UPFRONT COST. FURTHERMORE, THE INTERVENTIONS ARE LARGELY STATIC AND CANNOT COPE WITH LARGE FLUCTUATIONS IN HYDRO-CLIMATIC VARIABILITY. FURTHERMORE, THEY ARE LARGELY ASSOCIATED WITH SIGNIFICANT CARBON FOOTPRINTS, BOTH UPFRONT AND EMBEDDED, AS THE MAIN MATERIAL USED IS LARGELY CONCRETE (OECD, 2020).

Evidence and Potential for NbS in Africa
It is crucial to obtain an understanding of local biophysical dynamics within the specific landscape and catchment before selecting and implementing NbS. It is, furthermore, essential to draw on local knowledge and engage with local stakeholders in the decision-making and implementation process of introducing NbS (Acreman et al., 2021). Chassuson et al. (2020) highlight the need for NbS to "*be tailored to the socio-ecological context*" in order to have a long-standing positive impact (Chausson et al., 2020, p. 6150).

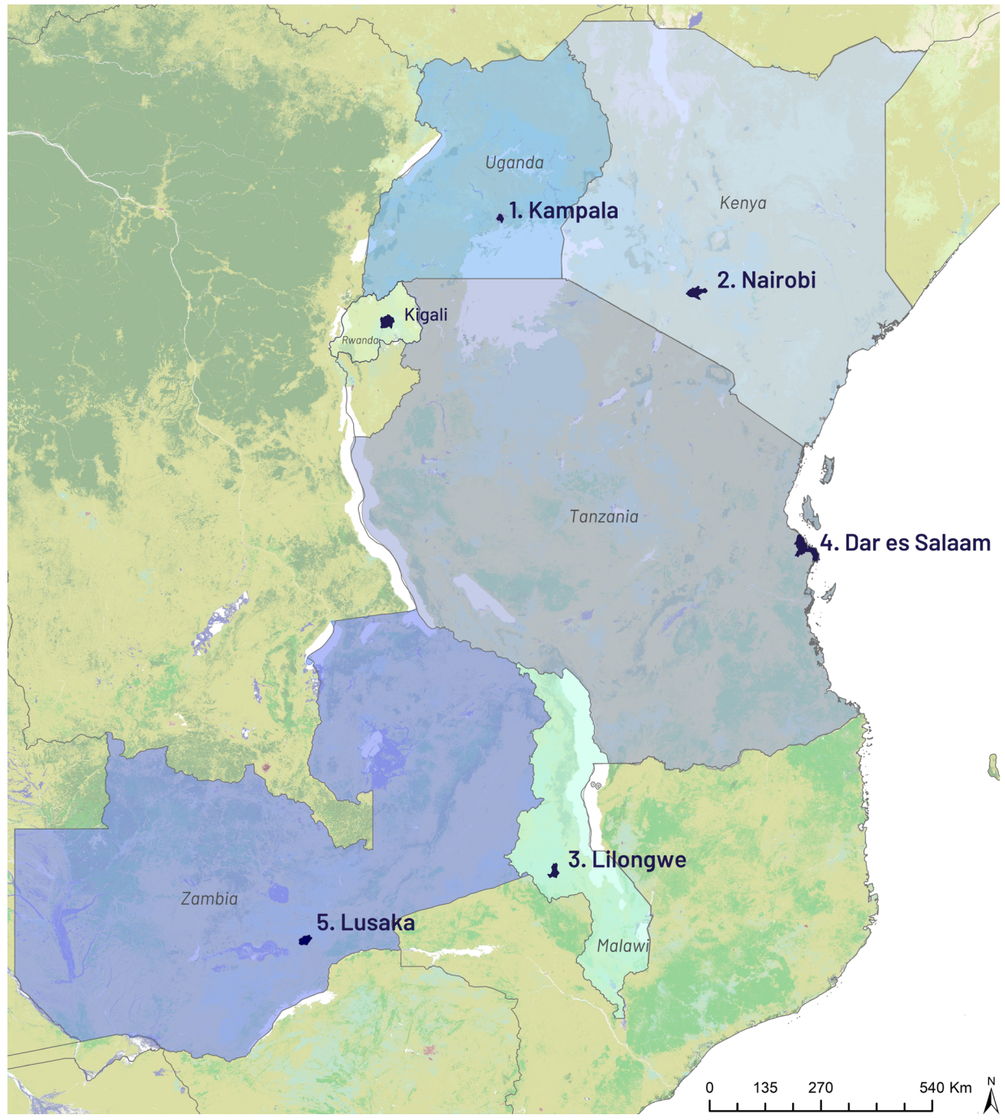
The most common form of NbS that has been implemented in Africa as climate adaptation has focused on agroforestry (Seddon et al., 2019). There is a range of examples of how NbS have been implemented in water management, cases include reforestation and aforestation with both native and non-native vegetation, river and floodplain restoration, natural ecosystem conservation, creation of artificial wetlands and introduction of urban green infrastructure, such as green roofs (Acreman et al., 2021). There is although, a lack of scientific evidence documenting their effectiveness. Chausson et al. (2020) highlight a general lack of scientific evidence on the effectiveness of NbS, and identifies a bias within the existing evidence base and research toward the Global North (Chausson et al., 2020). This is further supported by Acreman et al. (2020) whose findings conclude that the lack of scientific evidence on the effectiveness of NbS is particularly apparent in Africa. As a result, funding of projects has traditionally focused on countries and sites in the Global North (Acreman et al., 2021).

Findings from studies on implementing NbS in Africa to manage stormwater highlight cases that identify potential trade-offs and unintended negative effects of introducing novel upstream wetlands and forests, as evidence identifies the unintended consequence of decreasing downstream water availability. The studies further identify that the introduction of non-native upstream afforestation has a greater effect on water availability downstream, compared to studies of native species (Acreman et al., 2021). The need for efficient water management practices in African countries balances a fine line between accommodating spatiotemporal differences, alongside periods of 'too much' or 'too little' water. This is particularly a concern in the rapidly developing and urbanising regions of East Africa where the physical environment is increasingly altered and modified (Kalantari et al., 2018).

One of the cascade effects of flooding in many African countries is the fact that heavy precipitation and rapid river currents can move great amounts of sediments and cause landslides downstream. The introduction of vegetation through forests and wetlands has the potential to have a stabilising effect and limit sediment transport (Acreman et al., 2021).

Beyond improving resilience to flooding, the implementation of NbS has been identified as an approach for making East African cities safer and more inclusive, in addition to improving and promoting resilience towards the impact of climate change on a general level (Kalantari et al., 2018).

Best Practice Cases in Neighbouring East African Capitals
Kigali is by far not the only city in Africa under pressure from urbanisation and climate change. The urban population in Sub-Saharan Africa is projected to exceed the rural population by 2040, and by 2050 a trebling of the urban population in African cities has been predicted. Projections indicate that almost half of the urban development up to 2030 will occur in flood-prone areas (Opperman et al., 2021). As so, there is a pressing need to address urban flooding challenges in Africa and the rest of the world. To shed light on the current status quo of the implementation of NbS as a flood preventive measure in East Africa, the following section explores five cases of implemented NbS in the neighbouring capitals of Kigali, that is Kampala, Nairobi, Lilongwe, Dar es Salaam, and Lusaka. Map 8 illustrates the location of the five cases of NbS in East Africa, while pages 47 to 49 hold the descriptions of each case.



Map 8. *The Location of the Five Cases of NbS in East Africa*

CASE COMPARISON

NBS IN EAST AFRICA

THE FIVE INDIVIDUAL CASES ARE SELECTED BASED ON THE FOLLOWING CRITERIA.

LOCATION. LOCATED WITHIN THE CAPITAL OF A NEIGHBOURING COUNTRY TO RWANDA.

HAZARD. ADDRESSING URBAN, INLAND FLOODING.

NBS. DIFFERENT TYPES OF NBS WITHIN THE URBAN FAMILY.

STATUS. AN IMPLEMENTED PROJECT, PREFERABLY WITH A MONITORING OR EVALUATION REPORT.

1 DAR ES SALAAM, TANZANIA

Dar es Salaam Metropolitan Development Project. The general objective of the development project is to strengthen institutional capacity and improve urban services for citizens in the metropolitan area of Dar es Salaam. The project likewise addresses issues of poor emergency responses and aims at facilitating such a response system. To do so, the project has improved the construction of primary and secondary drainage systems through measures such as bank stabilisation, detention ponds and establishing stormwater drainage and flood control (WBG, n.d.-f). These improved urban infrastructures have resulted in a reduced impact of flooding in vulnerable neighbourhoods, reduced erosion, land value appreciation and improved living conditions for communities located along with the drainage systems (Morton, 2021).

Urban NbS family	Bioretention
Duration	2015 - 2022
Cost	$330.3 million USD
Partners	The World Bank
Implemented NbS	Detention ponds, riverbank stabilisation, connection to river basins (WBG, n.d.-f)

2 KAMPALA, UGANDA

The Greening of Kampala. The Greening of Kampala is related to the agenda of the Ugandan capital to become more climate-resilient and reduce its carbon footprint through the planting of 500,000 trees and secure the proper management of the general assets of nature and within the cityscape. 10,000 trees are planted every month to increase from 13 trees per acre to 50 trees per acre in the coming 20 years (Nyaga, 2021). Initial findings show the environmental impacts of the implementation include a recorded lowered local temperature, enhanced carbon sequestration and increased areas of green spaces. Furthermore, part of the local biodiversity has been recovered and species have increased. Social and cultural impacts include increased local knowledge of local nature and capacity building of locals in terms of increased awareness of NbS and their benefits for the environment, social structures, health and the local economy (Naturvation, 2022).

Urban NbS family	Urban Forest, Green Corridors
Duration	2016 -
Cost	Unknown
Partners	Public local authorities and EU
Implemented NbS	The local municipality Agroforestry, urban forests pocket parks and neighbourhood green spaces. Equip allies and streets with vegetation combined with grey infrastructures (Ibid)

3 LILONGWE, MALAWI

Agricultural Sector Wide Approach (ASWAP). The project is highly focused on developing new schemes and rehabilitation of existing schemes in order to articulate and attend to the, at that time, current gaps in the irrigation systems and tackle the overreliance on the rain-fed food production and agricultural sector (WBG, 2017). In the cityscape of Lilongwe, 700,000 urban citizens practise urban home gardening by cultivating cash crops, especially fruit trees and vegetables, to both meet their individual food needs and to sell to earn an extra income. Thus, urban agriculture and farming is a major contribution in terms of creating additional income for some of the most vulnerable and disadvantaged population groups. The medium-sized urban farms are now an integrated part of the agricultural sector as they count for almost a quarter of cultivated land in Malawi (WGB, 2021-d).

Urban NbS family	Urban Farming
Duration	2011 - 2015
Cost	$95 million USD
Partners	The World Bank
Implemented NbS	Medium-scaled urban farms, home gardens, home gardening of cash crops (WBG, 2017, WBG, 2021-d)

LUSAKA, ZAMBIA

Zambia Wetland Restoration Efforts, the Natural Valley Wetland. In Lusaka, areas of natural inland wetlands have been drained for the benefit of urban development. Severe flash floods are recorded in urbanised areas placed in former wetlands (WWF, 2018). The Natural Valley Wetland is one of the last remaining urban wetlands in the capital city, integral to the water management of the metropole. However, the provision of important ecosystem services is threatened by the degradation of the wetland in terms of human activity, such as chemical and plastic pollution. The restoration efforts aim at restoring the capacity of the wetland to reduce urban flood risk, including conserving the local biodiversity, promoting micro-climate regulations and protecting the general groundwater recharge (NatuRES, 2022).

Urban NbS family	Natural Inland Wetlands
Duration	2011 - 2033
Cost	Unknown
Partners	Natural Resources Stewardship Programme (NatuRes) and WWF
Implemented NbS	Restoration of wetlands, floodplain and grasslands. Urban wetland protection, biodiversity conservation

NAIROBI, KENYA

Kibera Public Space Project. Kibera is an area of Nairobi located close to a busy river crossing and has a history of periodic destructive floods. The public space project contains numerous sub-projects and programmes aimed at anything from developing locally-led businesses to strengthen the economic conditions of residents, improving sanitation services, ensuring safe, clean drinking water and improving social and climate change resilience (WBG, 2021-d). The project has established productive urban gardens of many sizes in the neighbourhood and a well-functioning farm, the Kibera Park, alongside a greenhouse irrigated by recycled water. The flooding issue of the area is addressed through a range of different initiatives including rainwater harvesting, gabion walls, drainage channels, and bioswales (Madete, 2021).

Urban NbS family	Open Green Spaces, Green Corridors
Duration	2006 -
Cost	Unknown
Partners	Arup, Eningeers without Borders UK, New Nairobi, Dam Community
Implemented NbS	Pocket gardens, home gardens, green playgrounds (Ibid)

COMPARING THE CASES

The five selected cases showcase how NbS can be implemented at different scales and settings to address similar overall challenges, in this case, urban flooding. The different takes on NbS in terms of climate mitigating and adapting, underline that NbS are flexible and multifunctional measures which can be formed to suit a wide variety of conditions. The cases furthermore underline the importance of understanding the individual settings and characteristics of a location, to select an intervention that will have the best effect.

Besides addressing the challenges of urban flooding, the cases showcase the ability of NbS to simultaneously provide a range of ecosystem services and co-benefits. As such, the cases provide a variety of added value that benefit the individual capitals beyond the concern of flooding. Evidence of this can be found in several of the projects, in Zambia by including sustainable and local job creation in the wetland restoration project, generating additional income for vulnerable households through urban gardening in Lilongwe, and increasing knowledge and raising awareness of the benefits of NbS for residents to create a local anchor, as ownership and empowerment in Kampala, Uganda.

Similar to all of the five cases is the involvement of international organisations in terms of funding, planning, and implementing the NbS. Especially the World Bank has a prominent role in driving this agenda. Only the Kibera Public Space Project in Nairobi, Kenya, reports having local organisations as partners. In general, the funding structures of the five case studies rely on international involvement, with minimal funding from local governments. Only the Greening of Kampala project explicitly states that it is co-funded by the public local authority.

As touched upon earlier, the case studies are selected on the basis of a range of parameters indicating similarities to the challenges seen in the City of Kigali, Rwanda. The purpose is to draw lines between the outcomes and lessons learned from capital cities in Africa. However, case examples of NbS in the eastern part of Africa are scarce, as such, it is challenging to find best practice examples. Most adaptational programmes centre on the agricultural sectors in rural areas, as this is an area extremely vulnerable to climate change in many African countries where the economy and livelihoods are reliant on rain-fed crops. The difficulties in researching and identifying implemented NbS programs in East Africa underline how ecosystem-based, biodiversity-focused and green-infrastructure projects are still not common or standard practice.

There is no complete database for collecting experiences or learning from climate adaptation and mitigation projects, although there are a few initiatives that have compiled projects, such as the *Urban Nature Atlas* developed by Naturvation, the *NbS Initiative Database* developed by the University of Oxford, and the *Catalogue of Nature-Based Solutions for Urban Resilience* by the WBG (Naturvation, n.d.; NBSI, n.d.; WBG, 2021-d). In those cases and projects where it is possible to find information and literature, the sources are often lacking the element of monitoring or evaluation, and without such reports, it is impossible to determine their actual impact. This issue colours the present review as well, for example, as the project in Kampala is the sole project to explicitly reports on its environmental and socio-cultural impacts. For the other projects, regardless of whether they have been fully completed or are in their final stages, the authors have not been successful in providing evaluations or conclusions regarding the impact of the given NbS on urban flooding or additional impacts. If such factors are addressed it is in vague phrases, commonly formulated as a desire, goal, objective or aspiration rather than an actual achievement.

So even though, the five cases showcase available best practice examples of NbS tackling urban flooding, the actual data on the impact of the solutions is poor, highlighting an area for future research and improvement. In other words, there is still a need for more projects to establish scientific justifications and conclusions on their effectiveness and impact. However, drawing on the outcomes from the selected five cases in the present study, NbS are evidently measures that can reduce flood risk while also improving living conditions and the natural environment for the people living in the areas of the implemented NbS.

SUMMARY

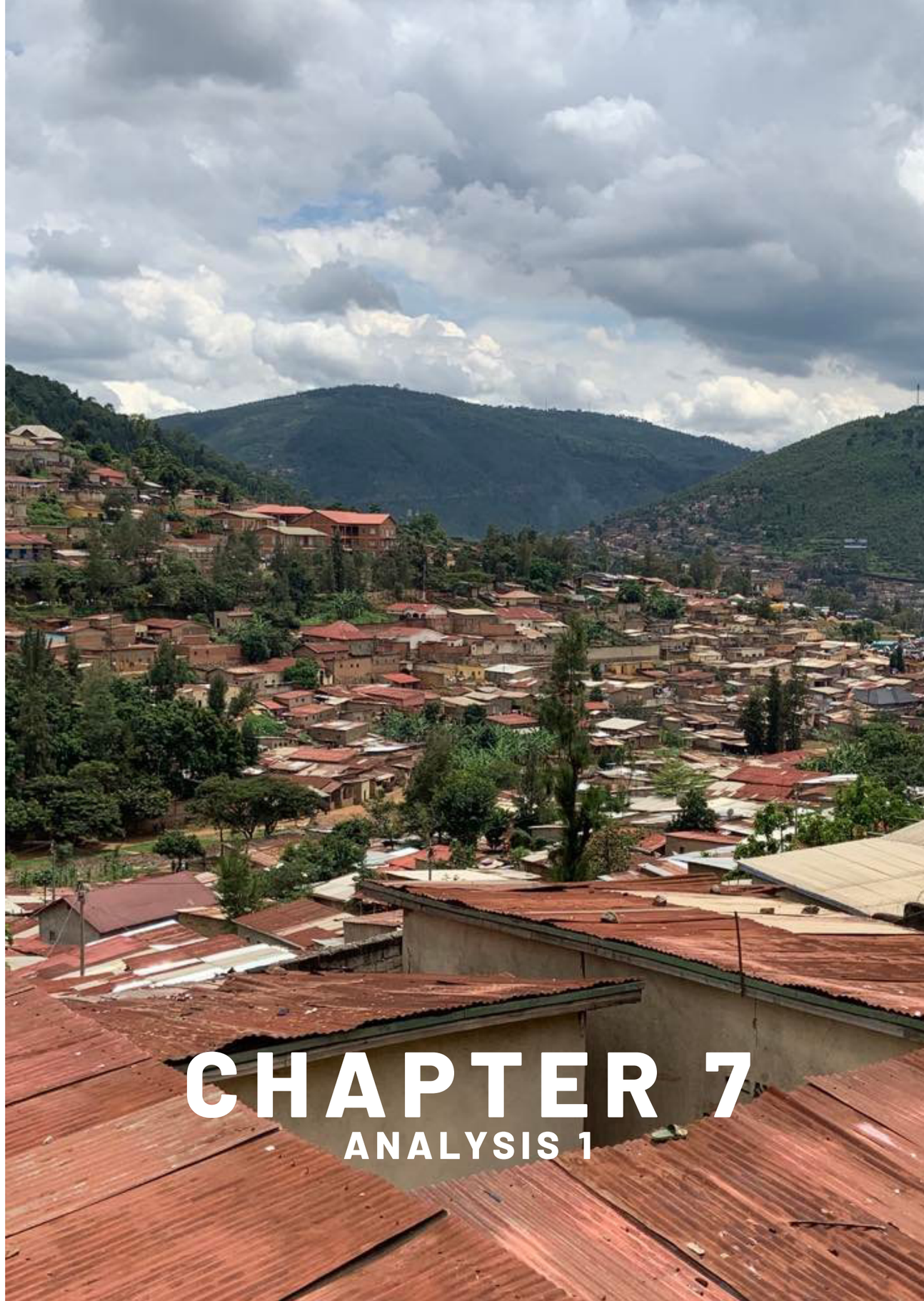
The role of NbS to address climate adaptation and mitigation needs has been widely acknowledged on the international agenda. In terms of the urban development challenges flooding in the city of Kigali, there is great potential in the use of NbS to achieve this transition. The preliminary analysis highlights the importance of NbS as a central component in the transition towards sustainable and resilient cities regardless of environmental concerns. This is largely attributable to their capacity to create synergies and co-benefits through the provision of a range of ecosystem services, such as promoting biodiversity and ensuring water availability. Thereby, they can, beyond serving as protective measures against environmental hazards, also address societal concerns and promote human well-being.

The widespread use of NbS faces several challenges, as such, they can be categorised as novel innovations. These challenges are largely rooted in limitations stemming from a lack of scientific evidence documenting their effectiveness, missing best practice examples, and poor economic data for use in cost-benefit analyses and to understand and communicate potential returns on investments.

The preliminary analysis indicates that NbS for climate adaptation has great potential in Africa as an alternative to traditional grey infrastructure. There are a wide variety of NbS typologies that can improve stormwater management practices, such as agroforestry, reforestation and aforestation with native and non-native vegetation, river and floodplain restoration, natural ecosystem conservation, artificial wetlands, and green roofs.

By exploring five cases of implemented NbS to urban flooding in the neighbouring capitals of Kigali, findings suggest that NbS measures may help reduce floods while improving local biodiversity and living conditions. However, findings also indicate a scarce scientific data foundation evaluating the effect of the implemented measures.

Dealing with a scarcity of open-source data sets and methodologies alongside a shortage of knowledge on existing flood hazards, the following analysis explores how urban flood hazards are identified in Kigali, aiming to contribute to a novel approach to guide further research within this field.



CHAPTER 7
ANALYSIS 1

URBAN FLOOD HAZARDS IN KIGALI

As highlighted previously, anthropogenic climate change is a major concern in the City of Kigali, which ultimately threatens the city, its population, infrastructure, ecosystems, and biodiversity through a range of challenges. One of the major concerns for the City of Kigali is urban flooding, a phenomenon that brings about a range of negative cascading effects. Navigating the complex dynamic of the flood concerns facing Kigali is challenging. There is a prominent need for quantitative and qualitative data, models, and visualisations to understand and communicate current and future potential hazards.

The City of Kigali has a long history of devastating floods, and with changing climatic conditions there is an increasing need to understand the changing dynamics of the hydrological cycle. Despite this, there are few in-depth studies on flood hazards in Kigali, and from those that do exist, there is an apparent lack of open-source data sets and methodologies. As such, there is also a shortage of knowledge as to whether the existing models and predictions are accurate and updated (Appendix 3; Grossi & Dinku, 2022; RBG, 2021-a).

The rationale of the present analysis is to investigate the inputs, methodologies, and outcomes of currently available research on flood hazards and risks within the City of Kigali. Through compiling and investigating existing research and its findings, the analysis seeks to investigate available data sources and methodologies in terms of their validity, availability and comparability. Building on this outcome, the analysis seeks to present a novel Geographic Information System (GIS) Blue Spot Mapping approach to guide future research and urban development in Kigali. The analysis is supplemented by empirical data from interviews to paint an in-depth and multilayered picture of flood hazards in the capital.

Existing Flood Hazard Mappings

To understand the current state of research and scientific knowledge of flood hazards in the City of Kigali the analysis contains a compilation of available maps, models and visualisations. The sources stem from scientific journals, government publications, accredited online platforms, and expert interviews. The analysis investigates the original data set sources and parameters that have been used and the methodologies used and followed, in addition to their findings and conclusions. On this foundation, the analysis investigates the quality and accuracy of the available research and seeks to use this to pave the way for future methodologies.

Flood modelling analyses and visualisations are great tools for urban practitioners because they can guide urban development and promote resilience towards environmental hazards. They can be applied to understand the complexity of the urban water cycle and directly be used to determine where, and potentially also what, intervention is needed. In order for such tools to be useful, they need to build upon data and research that is spatially and temporally accurate.

The following sections contain a compilation of four existing GIS data models and visualisations of urban flooding available for the City of Kigali followed by a Blue Spot Mapping conducted by the authors.

MIDIMAR, 2012

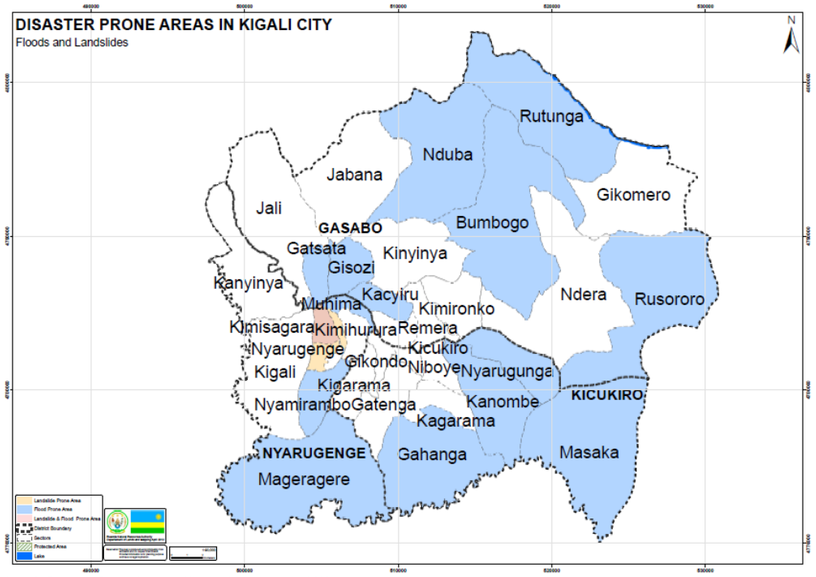
Mapping of disaster high-risk zones on floods and landslides by The Ministry of Disaster Management and Refugees Affairs (MIDIMAR, 2012). The map visualised in Map 9 was created in 2012 by The Ministry of Disaster Management and Refugee Affairs (MIDIMAR) with the purpose of identifying areas within the city of Kigali particularly prone to landslides and floods. The analysis was, as stated by the Ministry "*carried out using mainly perceptions of hazards by local authorities/local population and local authorities, intensity and frequency of floods/landslides coupled with caused damages and triggering effect*"(Nsengiyumva, 2012, p. 13). The study provides no further information on data sources, other than that the "*methodology combined: literature review, field observations, interviews, questionnaire and spatial techniques (GPS/GIS tools) to collect data*" (Nsengiyumva, 2012, p. 13). In addition, the analysis builds on empirical data from field visits alongside historical records of the occurrences of flooding and landslides in Kigali (Nsengiyumva, 2012).

The study reports identify areas at high risk of landslides based on a GIS analysis using thematic layers containing information on the slope, soil type and land use (Nsengiyumva, 2012). However, there is no information available on whether a quantitative GIS analysis was conducted to identify the areas at high risk, or if the thematic layers were merely used visually.

Nsengiyumva (2012) states that "*The best predictor of future floods and landslides is past floods and landslides because they tend to occur in the same places*" (Nsengiyumva, 2012, p. 19). Although this argument undermines the influence that anthropogenically induced climatic changes have on climatic conditions, it highlights how local knowledge and history of hazardous events are valuable indicators.

The findings from the analysis do not identify particular areas at risk or quantify the risk, alternatively, the analysis presents an "*identification of high-risk zones*", which is bound by the geographical extent of administrative boundaries (Nsengiyumva, 2012, p. 30). Defining hazardous risk within the frames of administrative boundaries does not reflect the true spatial and temporal differences within catchments. However, by highlighting high-risk zones, the study showcases areas that are particularly in need of intervention and acts as a visual tool to guide future research.

The downfalls of the employed approach of MIDIMAR (2012) are that it is subjective and lacks a scientific basis and justification, which limits the outcome and useability of the study. Nevertheless, it should be noted that the purpose of this analysis was to highlight areas that are 'disaster prone', rather than identifying a particular degree of potential hazardousness of flooding and landslides in Kigali. By relying on knowledge about past hazardous events from local actors, the findings successfully present the perceived areas of flood hazards within the different sectors in Kigali, as visualised in Map 9.



Map 9. *Disaster Prone Areas in Kigali (Nsengiyumva, 2012)*

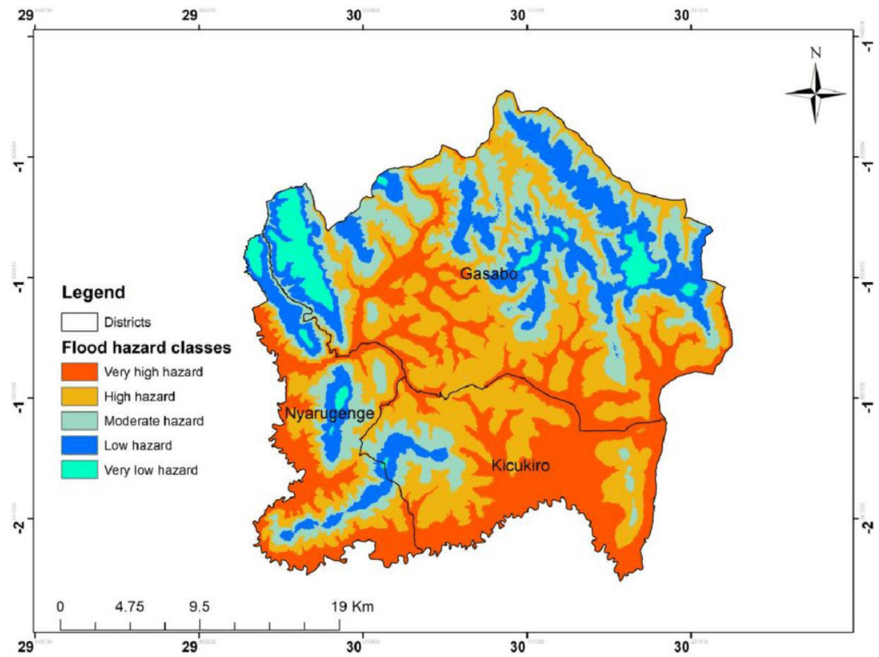
UMWERA ET AL., 2020

Flood hazard Mapping by Uwera et al. (2020). Uwera et al. (2020) investigates the contribution of green infrastructures to reduce flood risk within the City of Kigali. To understand flood risk in Kigali, the study analyzed and visualised areas at risk of flooding within the city boundary. The methodological approach of this study is reportedly grounded in the use of GIS and Microsoft Excel, where it builds on secondary data on recent hazardous events, a review of existing literature, and expert opinions to investigate flood risk in the City of Kigali (Uwera et al., 2020). Specifically, the analysis is carried out based on a selection of factors that can contribute to flooding, that being; "*elevation, slope, rainfall, land use and land cover, distance from rivers, lithology and soil texture, and Normalized Difference Vegetation Index*" The study combined this with flood losses from recent years (January 2017 to April 2020) to develop five flood hazard classifications of flood-prone areas in Kigali, as visualised in Map 10 (Uwera et al., 2020, p. 117).

In terms of data sources, the study used a wide range of datasets identified as having a flood inducing factor. The study presents that data is derived from the United States Geological Survey and Rwanda Environment Management Authority (REMA). However, the study does not present the original acquisition date of the datasets, or the spatial resolution of the various layers, except one. The one layer that is described is a preconstructed map of the Normalised Difference Vegetation Index (NDVI) at a 250 m resolution, which was derived from the online Moderate Resolutions Imaging Spectroradiometer (MODIS) database (Uwera et al., 2020).

Although lithology and soil texture are temporally stable, it does present a limitation as the spatial accuracy and resolution remain unknown as the original source is not disclosed (Appendix 3). In turn, this hinders the comparability of results, which is further aggravated by the lack of open-source data sets, methodologies or workflow used in the analysis. There is no reference or justification as to how the 'classes' of flood hazard were concluded upon, nor how the parameters were weighed against each other.

Nevertheless, this analysis is the most extensive analysis to date, as it builds on a variety of relevant parameters. Although a question remains, around the aspatial accuracy of the various layers, as the journal does not present how or when the original data sets were produced. The journal concludes that "*based on the spatial distribution of flood hazard in Kigali city, the analysis revealed that Gasabo District is at large extent, exposed to flood compared to other districts*" (Uwera et al., 2020, p. 122).



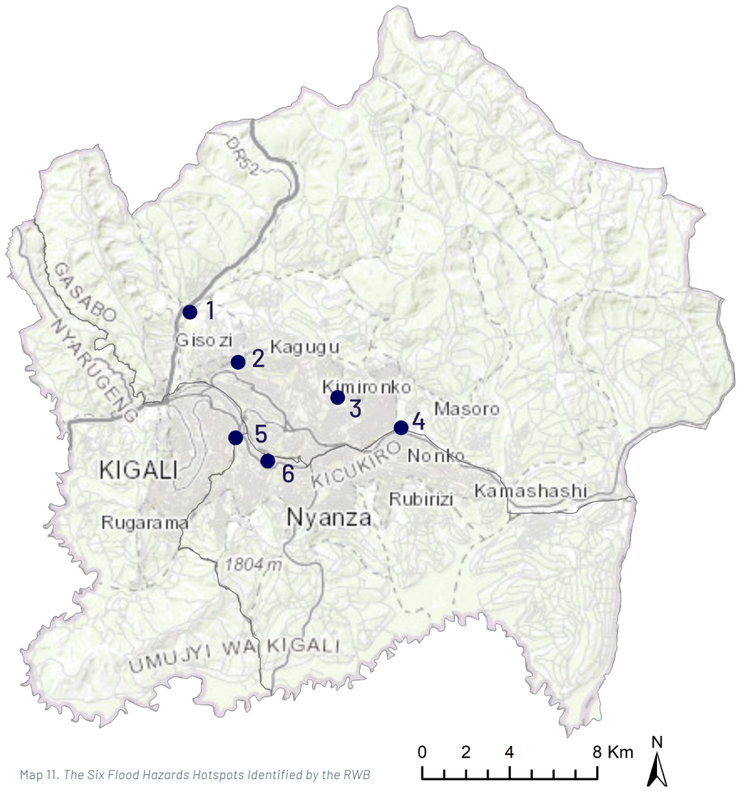
Map 10. *Flood Hazard Distribution in Kigali (Uwera et al., 2021)*

RWANDA WATER RESEOURCES BOARD, 2022

Flood Hazard Hotspots identified by the Rwanda Water Resources Board (RWB) (2022). The Rwanda Water Resources Board (RWB) has identified six flood hazard hotspots, which have been defined in collaboration with a project funded by the World Bank and executed by Deltares. The project was initiated in 2020 and a report has been finalised by Deltares, which is awaiting approval and publication by the World Bank (Appendix 3). While this study is yet to be published, the RWB have willingly disclosed the six hotspot sites, which as presented in the list to the right, as Rugunga, Rwandex-Magerwa, Nyabugogo, Gisozi, Gastata, and Kinunga (Appendix 7). As visualised in Map 11, the six hotspots are all located in valley bottoms, near rivers and wetlands.

The parameters and methods used to delineate the locations have not been disclosed. Nor are the datasets, visualisations, and models accessible or open-source. However, based on insights from interviews, it is understood that the hotspots were derived based on qualitative assessments, where historic flooding and proximity to road infrastructure crossing the valley bottoms were considered important factors. Based on interviews, it is clear that the report written by Deltares seeks to investigate the flood hazard at the six locations, and ultimately guide future urban development and stormwater management measures in Kigali to improve urban flood resilience (Appendix 3, 6 and 8). The analysis of flood hazards was conducted in the programme wFlow, which is a Deltares-developed hydrological modelling software.The results derived from the programme are presented in a series of hydrographs that can be used to interpret potential flood hazards. Bobby Russell, a Senior Advisor at Deltares, criticised the datasets used in the analysis, stating that "*there is a lack of river flow and water level data within the city*" (Appendix 3). Russell criticises these data sets both in terms of quantity and quality, and further elaborates on other challenges, such as the fact that the topographic map they use had an "*enormous error range*" (Appendix 3).

Hotspots	Discription
1. Karuruma	Upstream (North) of Nyabygogo wetland, near dense development
2. Gisozi-Mukindo	Upstream (East) of Nyabugogo wetland, near dense development
3. Nyabisindu	Wetland near new developments upstream of Nyabugogo
4. Kigali Parents	In wetland north of Kigali International Airport, near dense development
5. Rugunga	Channelised river near-critical road infrastructure, adjacent to the outlet of the Gikondo Wetland
6. Rwandex	Wetland area near-critical road infrastructure, upstream of the Gikndo Wetland



Map 11. *The Six Flood Hazards Hotspots Identified by the RWB*

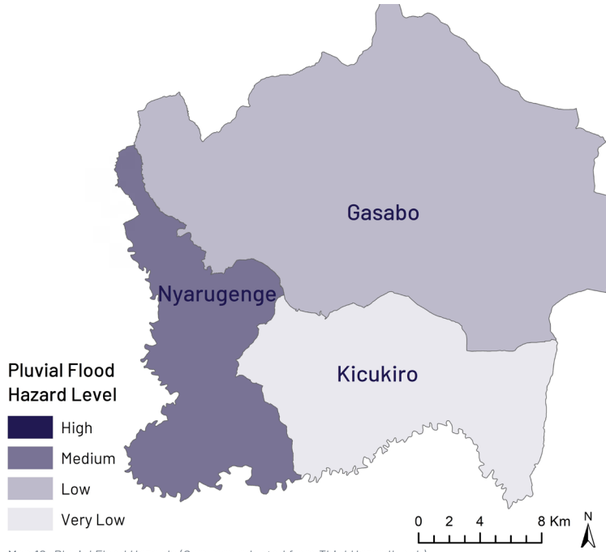
THINKHAZARD!

Flood hazard mapping by ThinkHazard! (n.d.). ThinkHazard! is an online risk tool developed by the Global Faculty of Disaster Risk Reduction (GFDRR) in collaboration with several international institutions such as Deltares and the World Bank. The tool is particularly useful for developing countries as it is simple and enables a quick assessment of various environmental hazards. The platform presents an assessment of 11 types of hazards, that being, urban flooding, river flooding, coastal flooding, tsunami, volcano, cyclones, water scarcity, extreme heat, wildfire, earthquakes, and landslides (Petley, 2016; ThinkHazard, n.d.).

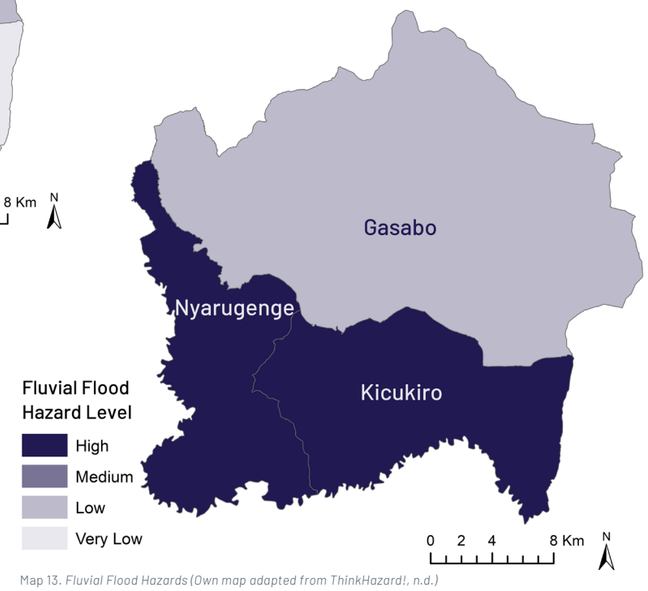
In the case of Kigali, the output from ThinkHazards! is defined based on administrative boundaries and differentiates between two flood types, namely river flooding (fluvial) and urban floods (pluvial). The tool provides a broad generalisation of flood hazard levels in the City of Kigali and its three administrative districts (Gasabo, Kicukiro and Nyarugenge). As such, the maps and categorisations are of very low spatial resolution and are inherently generalising in nature. The three administrative districts are given a classification of hazard levels, on a scale ranging from 'Very low' to 'High', as presented in the liste to the right. Maps 12 and 13 visualise the pluvial and fluvial flood hazards of Kigali based on the categorisations by ThinkHazard! (ThinkHazard!, n.d.).

The tool does not disclose its sources of information or the methods used in the classification or generation of the maps. The database states that "*The data set used to classify the hazard in this area is not publicly available to view or download due to licensing restrictions*" (ThinkHazard, n.d., p. 1). For that reason, it is not possible to determine the origin of the data or methodology used for this hazard mapping.

Area	Pluvial	Fluvial
Gasabo	Low	Low
Kicukiro	Very Low	High
Nyarungenge	Medium	High
The City of Kigali (General)	Medium	High



Map 12. *Pluvial Flood Hazards (Own map adapted from ThinkHazard!, n.d.)*



Map 13. *Fluvial Flood Hazards (Own map adapted from ThinkHazard!, n.d.)*

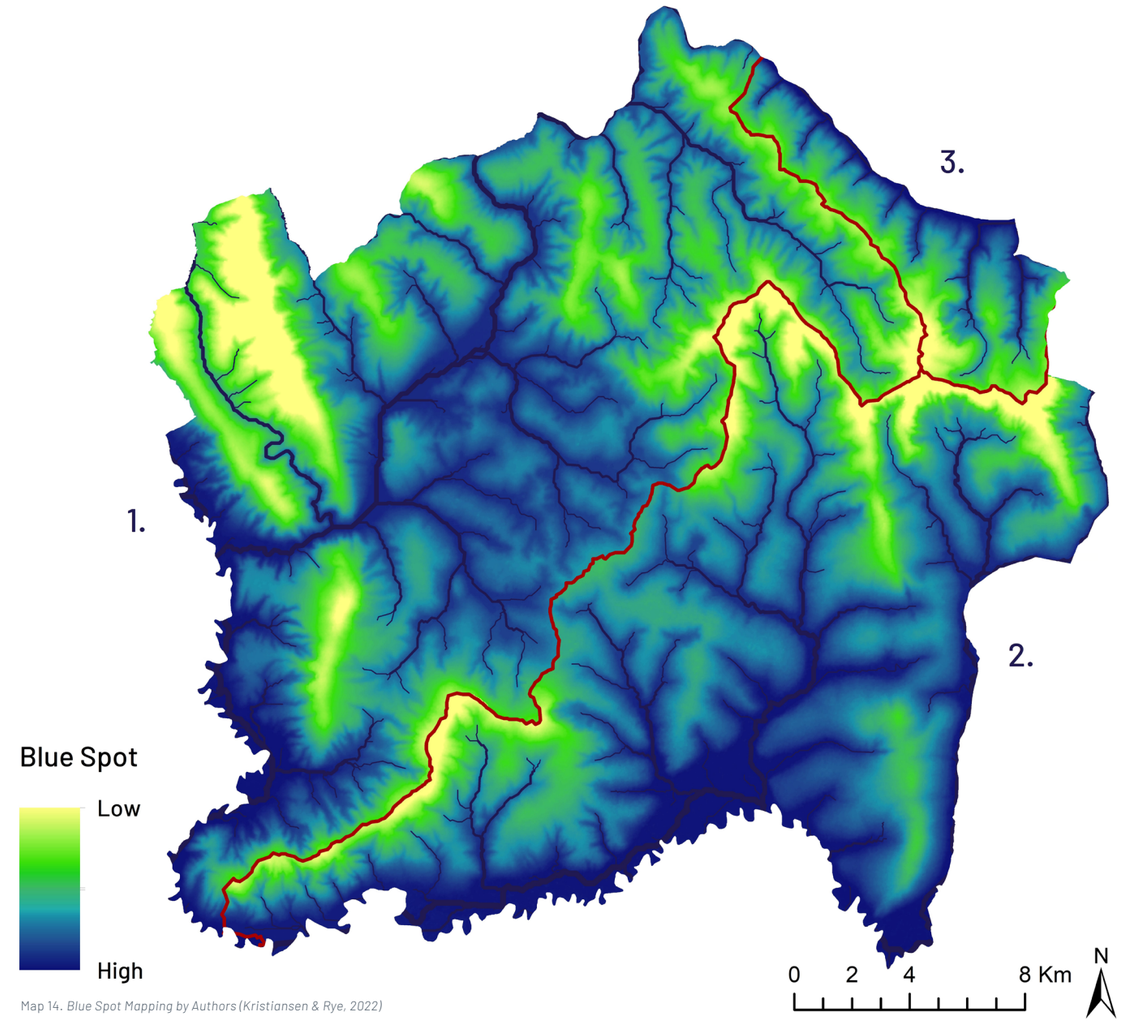
BLUE SPOT MAPPING

Blue Spot Mapping (Kristiansen & Rye, 2022). The Blue Spot Mapping visualised in Map 14, aims to showcase where stormwater is likely to accumulate within the City of Kigali. The mapping builds on existing available geospatial data and visualises the vast differences in topography within the city and the dense network of deep valley bottoms. As the map visualises, there are areas with significantly steep slopes around the mountain ranges in the western and northeastern boundaries of the city.

In terms of the hydrological dynamics within the city, the map visualises that there are two major catchment systems, which entails that precipitation respectively accumulates in the valley bottom of the two. The third catchment is significantly smaller in size, as visualised in the northeastern region. All of the catchments hold areas of very steep slopes, which inevitably lead to high-velocity runoffs in events of heavy precipitation. It is apparent that the geographical span of catchment number one is slightly wider than catchment number two, which suggests that catchment one receives more precipitation compared to the latter. Additionally, this catchment holds the area with the steepest slopes near the west of the city boundary. The steepness falls from 1860 m to 1370 m down towards the Nyabugogo wetlands. The hillside in this area is heavily developed by a combination of planned and unplanned settlements, predominantly the latter (Appendix 10). As such, this suggests that the developed area along the slope is likely to experience high-velocity stormwater runoffs in combination with downstream flooding near the wetland. Catchment number two comprises the largest low-lying, floodplain area, in the southern Kicukiro region. This valley bottom holds the Kitaguzirwa wetland, and the area in its immediate proximity is less developed than that of catchment number one. The wide floodplain can, as the name suggests, act as a buffer during flooding events and as a retention basin to hold stormwater runoffs. Despite this, the dense development surrounding the wetland may potentially become flooded, particularly in the event of consecutive days of heavy precipitation, where the amount of rainfall exceeds the water-holding and flood-buffering capacity of the wetland. Similarly to catchment number one, the area is also topographically defined by steep slopes which indicate that runoffs may gain high velocities as it flows down the valley sides (Holden, 2017; Appendix 3).

The model does not predict potential flood hazards, rather, it showcases areas where water is likely to accumulate and the paths it will follow as it moves towards the valley bottoms. The model further highlights the unique topographic characteristics of the city of Kigali, which underlines the fact that the city is reliant on successful urban stormwater management practices, given the wide array of climatic and development challenges the city is facing. Furthermore, the model underlines the fact that the city has a dense network of streams that flow downstream into the valley bottoms. This highlights the need for both efficient upstream stormwater management that can divert and guide the flow of water, and for effective downstream interventions that can hold and store stormwater runoffs.

The methodological approach applied to conduct this Blue Spot Mapping builds on a few data inputs, primarily because data has been identified as scarce and of poor spatial accuracy. The model builds upon a simplified version of the Blue Spot Mapping methodology (Balstrøm, 2022). There is a wide range of parameters that could be incorporated into the model to enhance its accuracy and potential for predicting and modelling future flood hazards within the city. For example, a digital elevation model with higher resolution would provide spatial accuracy to assess hydrological dynamics at a neighbourhood scale. In turn, this could aid planning practitioners in understanding and pinpointing blue spots with a much larger degree of precision.



Map 14. *Blue Spot Mapping by Authors (Kristiansen & Rye, 2022)*

COMPARING STUDIES & UNDERSTANDING DISCREPANCIES

Previous assessments of flood hazards in Kigali are scarce. As evident from the compilation of previous research, there are both similarities and differences in the findings and methodological approaches of the available studies. Flood models and visualisations are great analytical tools that can aid planning processes by informing and guiding practitioners. They can successfully add value and insight when created on the basis of good-quality datasets and methodologies. Assuming that these criteria are met, the tools can accurately visualise hydrological dynamics within a geographical area, and as such predict areas prone to flooding, estimating how water will flow, where it will accumulate and how much there will be. Simultaneously, they can indicate areas at risk of exposure and where intervention is recommended.

The different approaches taken by the reviewed studies generate different results. For example, MIDIMAR (2012) and ThinkHazard! (n.d.) assesses flood risk as being confined by administrative boundaries, taking a spatially generalising approach. Whereas the study by Uwera et al. (2020) and the blue spot model assess based on catchment boundaries. As the phenomenon of urban flooding is bound by natural processes and dynamics it is beneficial to delineate impact areas based on natural boundaries, such as individual catchments or subcatchments. The rationale and objectives behind these studies are also different, For example, Uwera et al. (2020) aim to identify potential flood hazards, the RWB (2022) seek to understand the dynamics of flooding and its local impact, and the assessment by ThinkHazard! is alternatively made with the purpose of "*providing a general view of hazards*" (ThinkHazard!, n.d.). The reasoning of the blue spot model is to understand the hydrological dynamics at play in Kigali and to identify where stormwater is likely to accumulate within the city.

The conclusions drawn from the various studies give rise to another point of comparison. The sites identified by the RWB (2022) provide site-specific identification of flood-prone areas, the study by Uwera et al. (2020) gives broader and more generalised identification of areas at risk. Both are useful as they highlight specific areas that are vulnerable (RWB, 2022; Uwera et al., 2020). This is in contrast to the findings from ThinkHazard! (n.d.) that provide very broad spatial generalisations, as they identify and categorise flood risk classification based on a district scale within the city (ThinkHazard!, n.d.).

There are wide differences between areas categorised as flood-prone by Uwera et al. (2020) and the RWB (2022). The latter identifies six sites in downstream, low-lying areas (RWB, 2022), whereas Uwera et al. (2020) state that "*the areas mapped as highly exposed to floods, were located in the upstream*" (Uwera et al., 2020, p. 123). The conflicting points of view indicate that there is a discrepancy in findings, which is likely attributable to the different methodological approaches. The blue spot model agrees with the findings from the two studies, as it suggests that the downstream areas of the valley bottom are particularly vulnerable, yet recognises that the extensive network of streams will result in upstream challenges during heavy precipitation events.

There are similarities in the study by MIDIMAR (2012) and Uwera et al. (2021) as both assessments identify flood-prone areas within the Kicukiro district. The former study gives a general geographic identification of the district as being 'flood prone' and later categorises the area as ranging between the 'very high hazard' and 'high hazard' categorisation (MIDIMAR, 2012; Uwera et al., 2021).

A discrepancy in findings is evident upon comparing the results of MIDIMAR (2012) and ThinkHazards! (n.d.), where the former identifies a significant number of flood-prone areas to be located within the northern Gasabo district (MIDIMAR, 2012; ThinkHazard!, n.d.). Uwera et al. (2021), on the other hand, categorise this area as predominantly in the category of 'low hazard' and 'moderate hazard' (Uwera et al., 2012). ThinkHazard! takes a similar stance as Uwera et al. (2021) by categorising the whole Gasabo district as a 'Low' hazard (ThinkHazard!, n.d.; Uwera et al., 2021).

Another aspect that affects the outcome of analyses is the definition of floods. This is evident in the approach taken by ThinkHazard! as it differentiates between urban and river flooding. The different approaches provide divergent conclusions, specifically categorising the district of Kicukiro as 'very low risk' for urban flooding and 'high risk' for river flooding (ThinkHazard!, n.d.). The other studies do not differentiate the two flood typologies, despite it being a useful differentiation considering the fundamental variations in hydrological dynamics between the two.

Upon exploring available models and assessments to evaluate the potential impact of flooding in Kigali, it is evident that there are vast discrepancies in the data sources, methodologies and conclusions derived from the different approaches. However, they also hold a degree of similarity. The overarching conclusion that can be drawn from the reviewed studies and the Blue Spot Mapping underlines the already known fact that the City of Kigali is vulnerable to flooding. The complexity of mapping potential environmental hazards and risks is strongly visualised on the maps from the various explored studies. Using different parameters leads to significantly different results. When the intention of conducting these assessments is to inform urban planning processes it is a significant downfall that models are not accurate and transparent in their methodological approaches. The use of qualitative understandings can supplement quantitative methodologies, especially in cases where available data is insufficient. The study by MIDIMAR (2012) is an example of such an approach, as it relies on relevant actors 'perceptions' of risk (MIDIMAR, 2012). This finding underlines the importance of considering local knowledge as valuable input in flood hazard modelling.

There are two fundamental problems that arise from the present analysis, the first being that there is a lack of available data to use in flood models, and the second problem is that there is little transparency as to what methods and datasets have been used in previous studies. The following section further explores these issues.

Data Availability and Transparency of Methods

The distinct topographic and climatological characteristics found in Kigali entail that the city is at particular risk of environmental hazards. The lack of good-quality hydrological models, predictions, and assessments is a substantial limitation for urban planning practitioners as they cannot accurately predict the potential environmental hazards they have to plan for. This is reflected in the approach taken by the government, where the Master Plan for Kigali states that "*The City plays a reactive role by identifying flood-prone areas*" (Krishnasamy et al., 2020, p. 155). Hinting at the fact that current climate adaptation and mitigation efforts intended to manage urban flooding are directed towards areas that have previously experienced flooding. The city is lacking urban planning practices founded on solid scientific understanding and assessments that engage in a 'proactive' response to the major challenges posed by climate change and future environmental hazards. Instead of focusing on areas that are predicted to flood in the future, they look backwards to areas previously exposed. Without models that account for the great variability of earth system dynamics, it is fundamentally challenging to predict future challenges. Particularly a concern for the City of Kigali, as climatic changes directly influence the dynamics leading to urban flooding, and the dynamics that govern flood patterns.

Furthermore, a lack of knowledge of how models have been developed, including the employed data and parameters, is a significant limitation to both the end-users of the conducted research and the development of future research. Combined, these are factors that limit the comparability of results and hinder the development of successful mitigation and adaptation solutions. Studies conducted by MIDIMAR (2015) underline the need for detailed, local level assessments of flood risks to guide policy- and decision-makers in planning and implementing sustainable urban flood risk systems. However, to do so "*High temporal rainfall and river discharge datasets are highly needed*" which is an issue in the setting of Kigali and Rwanda (MIDIMAR, 2015, p. 68). One of the reasons why data availability is scarce is because of patchy historical records. Although climatological recordings were initiated in the early 1990s, as visualised in Figure 15, the number of stations and recordings were heavily affected by the critical national circumstances brought on by the civil war and political instability in Rwanda. As visualised in Figure 15, the collection of climatological data significantly decreased from the mid-1990 to the early 2000s, and remained low up until 2010, resulting in a gap in records spanning 15 years (Grossi & Dinku, 2022).

According to Hussein Bizimana, a Hydraulic Flood Modelling Specialist at the Rwanda Water Resources Board (RWB), one of the biggest challenges in flood risk management in Kigali is the lack of available data in terms of down-scaled climate projections and scenarios. Accurate data is of utmost importance when dealing with solutions for implementation. Otherwise, there is a risk of underestimating (or overestimating) the effects of the hazard which essentially determines whether a given solution is robust enough to withstand the climate-induced shock (Appendix 7). Bizimana further elaborates on this challenge by explaining that there is a lack of streamlining between different actors and organisations in Rwanda in terms of which climate scenarios they make use of. He states that "*Sometimes organisations use the [Representative Concentration Pathways (RCP)] 8.5, but there is another project within which they use [RCP] 6. This is frustrating, especially when the results are going to inform an implementation study*" (Appendix 7). Failure to disclose which projections and pathways have been used in assessment further limits comparability and accuracy of results.

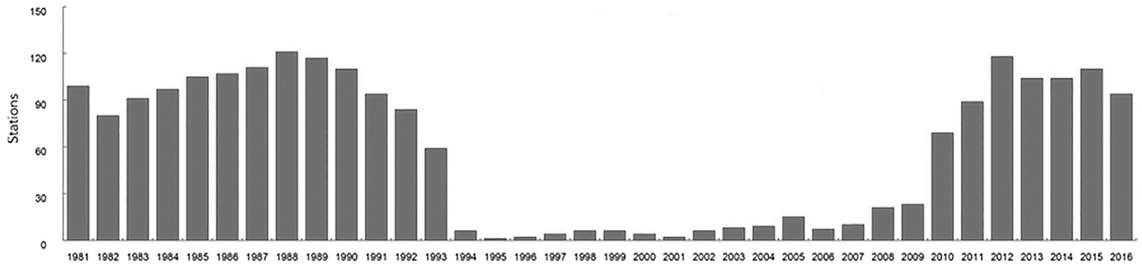


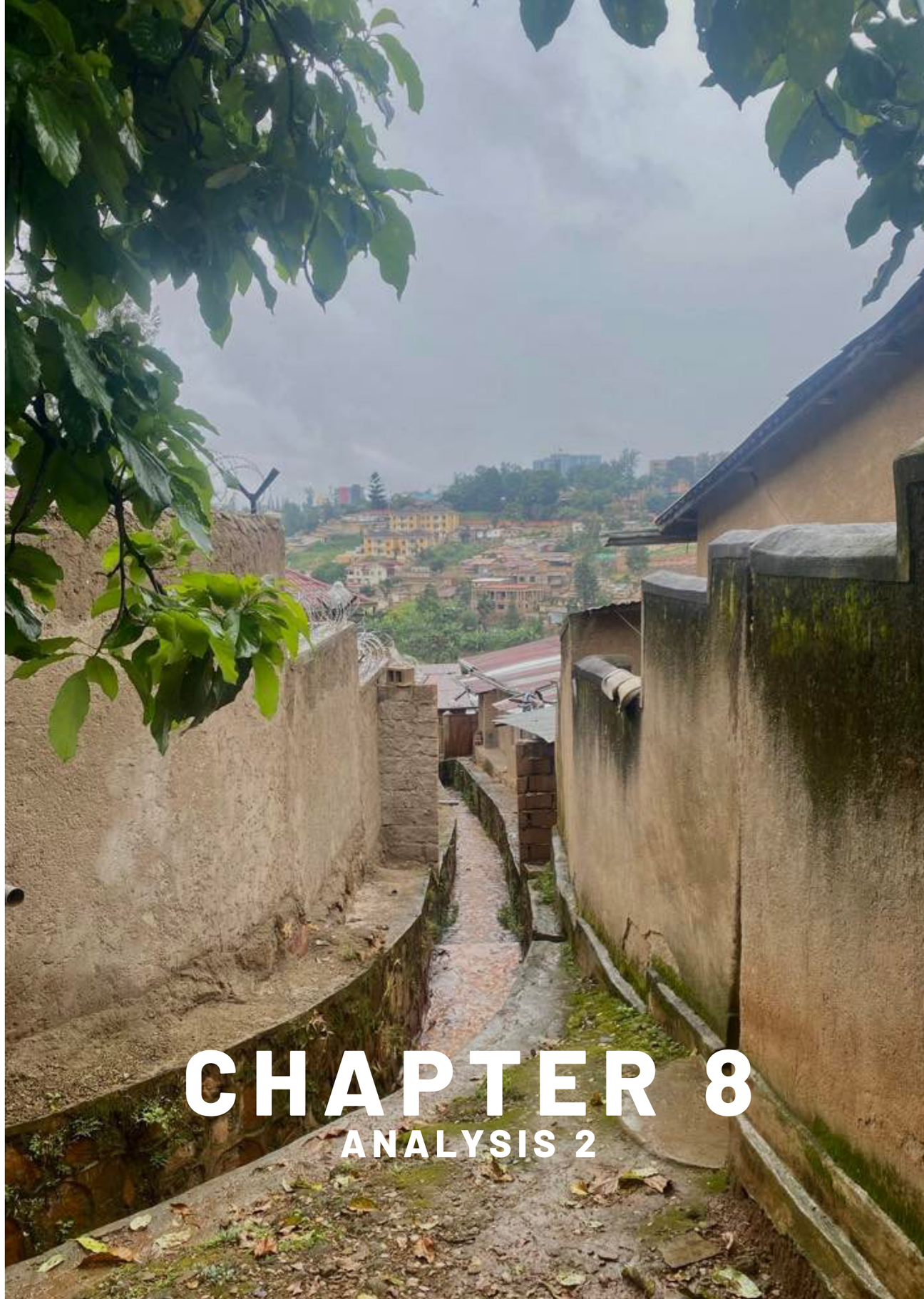
Figure 15. *Visualisation of Climatological Data Records Available from Stations in Rwanda (Grossi & Dinku, 2022)*

The lack of complete and reliable data sets result in a large margin of error in all of the previous mappings of urban flood hazards in Kigali, including the Blue Spot Mapping conducted in the present study. As highlighted previously, all of the available data in Kigali is either old or of poor quality, Russell attributes this partially to the lack of sound methods for capturing and generating data sets. He specifically points towards the historical precipitation data, elaborating on how errors emerge when the daily precipitation data is recorded manually. This may lead to discrepancies in data coverage if, for example, the rain gauge overflows in a heavy precipitation event without personnel to record and empty the gauge. This is a problem in Kigali and is the direct cause of errors within existing datasets (Appendix 3). Information such as this stipulates that the results from the reviewed mappings and the blue spot model should be viewed from a general angle where care should be taken before drawing conclusive statements.

SUMMARY

The analysis explores and compares previous studies investigating flood hazards and risks in the city of Kigali. The overarching findings indicate that there is a prominent lack of both spatial and temporal data. Despite the lack of available data sets, the reviewed flood hazard mappings and the blue spot model indicate that flooding is a severe problem in the City of Kigali. Without an accurate understanding of how the hydrological system in Kigali functions and the various dynamics at play, it is fundamentally challenging for urban planners to adequately propose solutions. As such, there is a need to develop sound methodologies that can aid future research and assessment of flood hazards in Kigali. While historical data is limited, this should not limit the onset of new studies and climatological observations. It is necessary to generate time series from in-situ measurements on river discharge, precipitation, and infiltration rates to ensure adequate stormwater management in Kigali.

Urban flooding is already posing as a major concern in the city of Kigali, leading to recurring damages to infrastructure and in the worst cases, fatal incidents. As urban flooding is predicted to have an increasing impact on the city of Kigali in the future, the environmental hazard will continue to place pressure on existing urban planning practices. With this in mind, it is essential to ensure that the city is able to cope with these future challenges and their cascading effects. The following analysis investigates how the current urban planning regime in the city of Kigali is structured, how it addresses the development challenges of urban flooding, and how the predicament of urbanisation and urban sprawl aggravate flooding.



CHAPTER 8
ANALYSIS 2

THE CURRENT URBAN PLANNING REGIME

The following analysis explores how the current urban planning regime is structured and how well it is coping with the urgent landscape pressures regarding climate change and urban flooding, as explored in the previous analysis. The analysis draws on observations from the field study and site visits, including notes, photo documentation, interviews, and local development policies and strategies. The analysis kicks off by examining the governance structures of the urban planning regime in Kigali to shed light on the different stakeholders in play leading to a detailed analysis of the present socio-technical trajectory of urban stormwater management and contrasting paradigms within the regime.

THE GOVERNANCE STRUCTURES

The Organisational and Governance Structures of the Current Planning Regime. In the City of Kigali, the urban planning regime is under the responsibility of various ministries and authorities. Supporting these agencies are a wide range of local Civil Society Organisations (CSOs), Non-Governmental Organisations (NGOs), and international institutions. The governance structure is somewhat hierarchical and is structured under different thematic umbrellas (Appendix 9).

A multiplex institutional framework of policy and administrative institutions, regulatory agencies, and implementing institutions governs urban planning and water management in Kigali (CSE, 2019). The Rwanda Water Resources Board (RWB) is primarily responsible for the thematic umbrella under which water is governed. The RWB is an implementation institution which informs policymakers in all respects about water-related issues, and it is in charge of monitoring and analysing the flooding problems of Kigali. The Rwanda Environmental Management Authority (REMA) manages wetlands and protected areas, while the Council of the City of Kigali (CoK) is responsible for the drainage systems and other infrastructures. Besides this, the CoK manages the overall urban planning and development of Kigali, the implementation of the Master Plan of Kigali, and the general management of urbanisation and urban sprawl. Additionally, there are meteorological organisations, such as Meteo Rwanda, which are in charge of weather forecasts and warnings. NGOs such as Rwanda Environmental Conservation Organisation (RECOR) work with urban resilience through their network of programmes and initiatives established with the government or external stakeholders, such as the World Bank. Lastly, international consultancies and organisations, such as Deltares, Defacto Urbanism, and Surbana Jorung (SJ), are hired as external experts and consultants on projects on all levels (Appendix 3, 6, and 10). Figure 16 depicts the complexity of the governance structures and the various stakeholders alongside their respective workflows.

The complexity of the urban governance system makes it a multifaceted discipline of addressing, preparing for, and implementing adaptational measures to urban flooding in Kigali. Accordingly, Bobby Russell states that "*It is often a very multi-departmental challenge*" that requires solid collaboration and clear communication (Appendix 3). Abias P. Mumuhire, an Architect at the City of Kigali (CoK), further elaborates upon the governmental structures. He describes how the most challenging aspect is the information sharing and coordination between stakeholders, highlighting that the way administrative boundaries divide Rwanda "*can be very limiting*" (Appendix 8).

A general point of critique on the current urban planning practices revolves around how the Rwandan and Kigali authorities deal with integrating climate change adaptation in urban planning and development. Mwenje (2019) indicates that a regulatory mainstreaming of flood risk adaptation is currently missing, articulating issues stemming from the highly top-down approaches of national strategies and policies. As such, highlights the lack of stakeholder engagement and participatory practices, particularly in the lower levels of planning jurisdictions, such as the City of Kigali (Mwenje, 2019). Additionally, the study states that strategies concerning climate change adaptation are not coherent in Kigali, as they have been designed by (too) many different institutions based on individual technical capacities, tools, and budgets. The study gives rise to concerns regarding conflicts of interest and lack of responsibility and accountability (Mwenje, 2019).

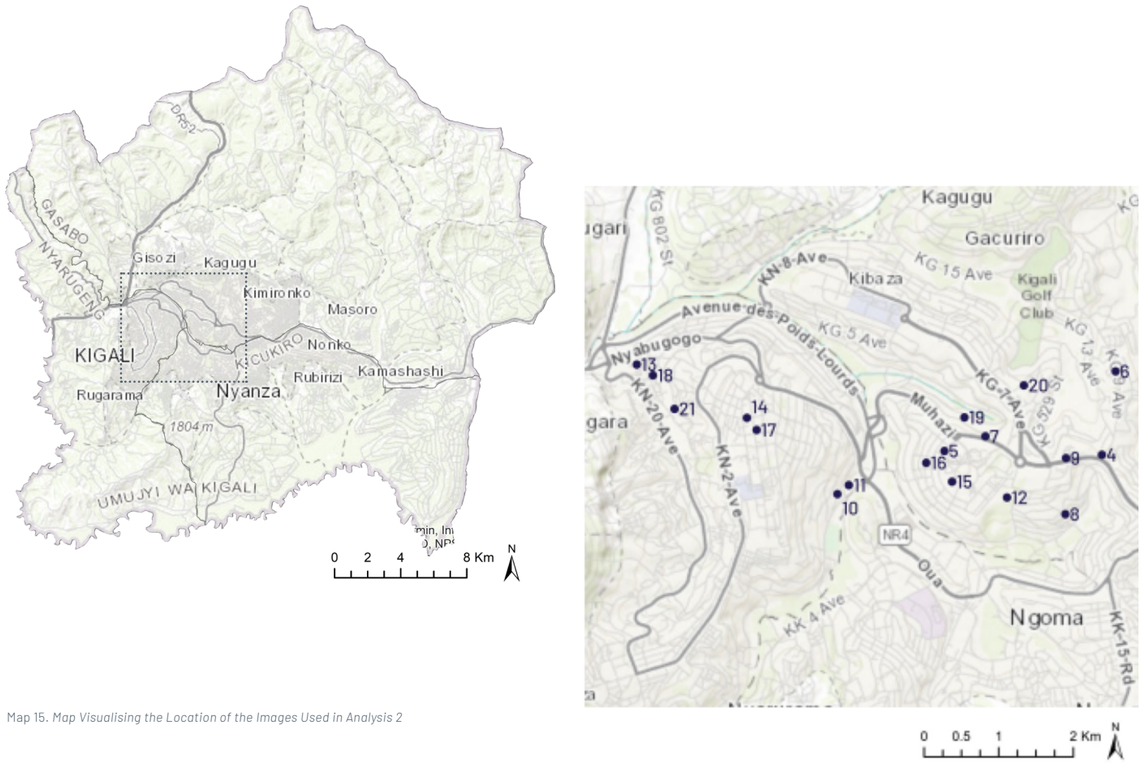
The following sections explore how planning trajectories concerning urban flooding, urbanisation, and urban sprawl structure the existing urban planning regime in Kigali.

Actors	Mandates and Responsibilities	
Ministry of Environment, Ministry of Agriculture and Animal Resources Ministry of Infrastructure, Ministry of Trade and Industry, Institute of Policy Analysis and Research, Ministry of Disaster Management and Refugee Affairs	Policies, oversight, and administration	**The Government**
Rwanda Environmental Management Authority Rwanda Utilities Regulatory Authority Rwanda Standards Board	Wetlands and protected areas Water and sanitation services Code of Practice on stormwater control	**Regulatory Agencies**
Local governments, districts and lower structures Rwanda Water Resources Board Council of the City of Kigali Rwanda Environmental Conservation Organisation	Planning, designing, implementing, education and outreach Informs policymakers, flood modelling Urban planning, drainage systems, urbanisation Conservation, restoration	**Implementing Institutions**
Meteo The University of Rwanda	Weather predictions, weather warnings Research, assessments, modelling	**Research Actors**
Surbana Jurong (SG) Deltares Defacto	The Kigali Master Plans Flood hazard modelling, climate resilience NbS Feasibility study	**International Consultancies**
The United Nations European Union The World Bank	Doners, partners, project creators and The project owners	**International Doners**

Figure 16. *Findings from Interviews on Stakeholders in Urban Planning and Stormwater Management in Kigali (Own figure adapted from CSE, 2019)*

URBAN FLOOD MANGEMENT

A Grey-Dominant Trajectory. The urban flood management of Kigali is somehow both complex and straightforward at the same time. By simply walking on the streets of the city, flood control measures are visible even to the untrained or unprofessional eye. The urban stormwater management measures currently in place substantially rely on drainage channels to divert runoffs towards the valley bottoms and prevent flooding. Throughout the city, there is an immense network of intertwined drainage channels both underground and at the surface of roads and sidewalks. These drainage channels are small-scale and commonly have low drainage capacities because of their relative sizes. It has been highlighted that the common trend within the Rwandan water sector has been largely "*focused on infrastructure development for water supply, hydropower production and agriculture. Consequently, little resources were allocated to stormwater management*" (CSE, 2019, p. 28). This is reflected in the lack of large scale solutions to handle runoffs and heavy precipitation events efficiently (Appendix 10, CSE, 2019). Map 15 visualises the location of the introduced images in the present analysis. Images 4, 5, 6, and 7 illustrate different types of open drainage systems.



Map 15. *Map Visualising the Location of the Images Used in Analysis 2*

Image 4. *Open Drainage System, Example 1*

Image 5. *Open Drainage System, Example 2*

Image 6. *Open Drainage System, Example 3*

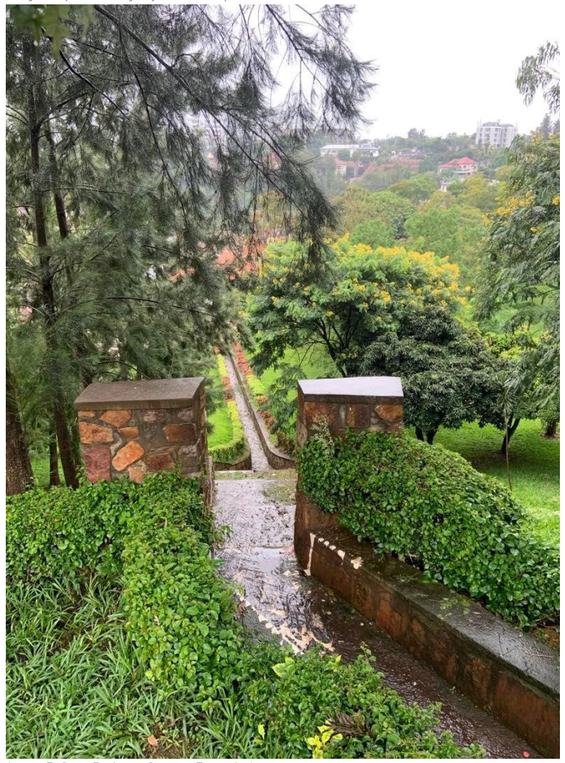


Image 7. *Open Drainage System, Example 4*

Current efforts to improvise stormwater management in Kigali include the ongoing expansion of the existing stormwater drainage infrastructures; laying cobblestone instead of asphalt on designated roads; establishing retention walls; building gabion walls and water stairs, closed underground drainage systems, channelisation of rivers, and using stone pitching to prevent landslides caused by heavy rainfall (Appendix 10), see Images 8, 9, 10, 11, 12, and 13. REMA indicates that the immediate task to curb flooding in Kigali should focus on the rehabilitation of drainage channels and that these efforts should aim to increase their drainage capacity (Nkurunziza, 2022-a). Based on these findings, it is evident that urban flood management practices have centred on establishing and building structural and engineered systems and the appertaining upgrading of the existing infrastructures (Appendix 9).

Image 8. *Cobblestone*

Image 9. *Retention Wall*

Image 10. *Water Stairs*

Image 11. *Closed Underground Drainage System*

Image 12. *Channelisation of River, Example 1*

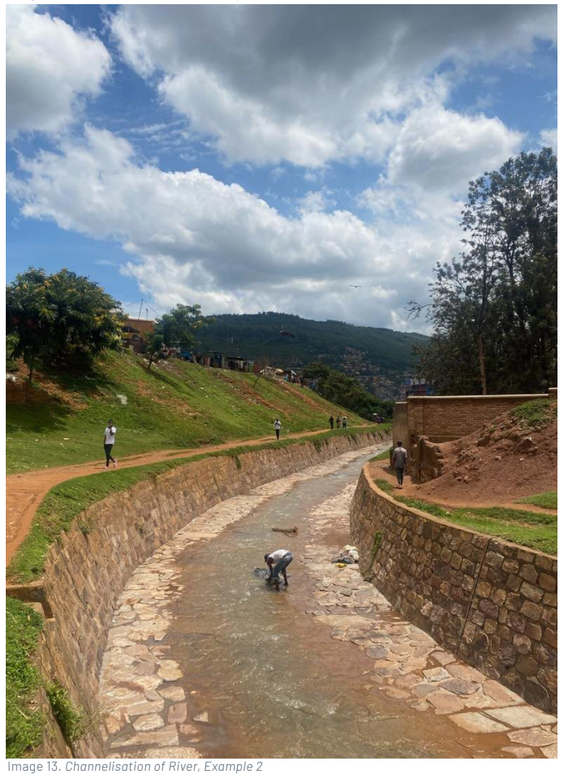


Image 13. *Channelisation of River, Example 2*

As Kigali has developed in the past decade, structural solutions have been the predominant and preferred measure when dealing with urban flooding (Appendix 7). The Senior Urban Planner from Surbana Jurong (SJ) supports this disclosure in the interview and highlights that the best way to deal with heavy precipitation in Kigali is "*to have these retaining walls in place wherever it is unsafe. For such a huge amount of water, you need concrete infrastructures to be in place ..., and we have all these huge channels ... which direct the stormwater to the wetlands*" (Appendix 4). Quite expectedly, she continues the conversation by underlining that stormwater drains and management are the current and future premises of urban flood management in Kigali (Appendix 4).

Hussein Bizimana adds to this perspective by stating that "*Ten years ago, the city of Kigali was not like this. So we invested a lot of time and money to make ... it a more sponge city and try to reduce runoff as much as we can in the drainage system*" (Appendix 7).

Bizimana and the Rwanda Water Resources Board (RWB) work with water activities in three different sectors, "*flood control, erosion control and development of artificial storage like dams and reservoir ponds*" (Appendix 6). The overarching objective of the organisation is to further develop their existing engineered flood hazard models, "*Within this year, we have to extend the flood models we have. So, the flood and hotspot models developed by Deltares are being extended to a couple of other hotspots, as we need high-quality flood modelling to manage the hazard in the best way possible*" (Appendix 6). Bisimana highlights that efforts are intensifying to cope with urban stormwater. An example of such efforts is the upgrading of currently implemented engineered solutions, such as the elevation of canals and channels to enable them to accommodate more water (Appendix 9).

The RWB states that controlling and managing stormwater is a multifaceted challenge that carries the potential to address other water-related issues of Kigali, such as water scarcity during dry periods. This includes efforts to cultivate co-benefits, for example, the RWB emphasises that "*If we can channel that runoff without causing the flood, then we can think about how we can store that [water] ... So we are working on how to capture water to use in the dry seasons*" (Appendix 7). Considering the projected climatic changes the City of Kigali will have to face in the future, periods of droughts and water scarcity pose challenges they will have to accommodate. Consequently, it is vital to establish synergistic solutions which address both issues that arise from too little and too much water in the cityscape of Kigali.

In general, it seems as if the government and its underlying institutions are heavily investing in localising flood-prone areas in the City of Kigali (Appendix 9). Evident in the way the city has designed an intertwined system of drainage structures and other structural solutions to address urban flooding. Therefore, it is justifiable and plausible to describe the general urban flood management trajectory as relying thoroughly on engineered and so-called grey solutions.

According to Russell, the current urban stormwater management trajectory of managing urban flooding in Kigali is manifested in the overarching engineering belief that grey solutions are the most effective measures for urban flooding. He adds to this viewpoint by addressing the urgency of the hazard by stating that "*They [the city] want and need quick fixes. And so we can talk about smart, integrated solutions, but a big concrete wall will work quickly. And yes, that is perhaps sad to hear, but sometimes you have to reflect on the democratic needs ..., and these people need those things [flood protective measures], and they need them now!*" (Appendix 2).

Although it may appear as if the City of Kigali is well-prepared for urban flooding, the fact is that "*A series of flash floods always occur in every heavy rainfall season in Kigali ..., causing damages along the channels, roads, bridges, culverts, properties as well as humans*" (CSE, 2019, p. 29). Statements like this prove that urban flooding is a recurring challenge that Kigali is yet to overcome. John R. Gakwavu, an Environmental Specialist at RECOR, adds to this concern by expressing that the city "*still has problems with settlements both upstream and downstream*" as they are regularly exposed to flooding (Appendix 9).

While flooding might be the most pressing climate-related issue stressing urban planners and practitioners in Kigali, the city simultaneously faces other aggravating challenges, such as rapid urbanisation and urban sprawl. These are undoubtedly intertwined with the issues of urban flooding and are equally important to address. The common theme is that there is a prominent need "*to look into how we can enhance the capacity*" of stormwater infrastructure in the city in vulnerable and exposed areas, as stated by Gakwavu (Appendix 9). The following section digs deeper into how present planning paradigms are addressing the problems of urbanisation and urban sprawl in the cityscape of Kigali.

A CITY OF CONTRASTING PARADIGMS

Caught Between Modernity and Poverty. Proponents of the current urban planning regime often landmark Kigali as a symbol of development and progression in Eastern Africa, especially in comparison to its neighbouring capital cities. Skyscrapers for commercial usage emerge around the skyline. Streets are asphalted, maintained, and regularly cleaned by a herd of street cleaners. Urban parks, green spaces, trees, bushes, and other vegetation are around every corner and are as well maintained as the streets of the city (Appendix 10). Even the market for electric cars has begun to emerge with the introduction of charging stations in several places around the city.Furthermore, fibre optic networks and free WiFi is widely accessible in most parts of the city (Le Touzé, 2014). Rwanda was also the first country in Africa to issue a nationwide ban on plastic bags in 2008, and 11 years later, in 2019, a national ban was implemented that prohibits all "*manufacturing, importation, use, and sale of single-use plastic items*" (Nkurunziza, 2022-b). Images 14, 15, 16, and 17 illustrate newly developed buildings and showcase the increasing modernity of the City of Kigali.

The Senior Urban Planner from SJ joins this positive narrative of Kigali stating that "*Kigali City has been growing at a massive rate, we started with just 100 plus hectares, and now the city is looking at 2000 hectares ... major issues in such cases are industrial pollution and they [the CoK] are handling it absolutely fine*" (Appendix 4).

Image 14. *Kigali City Hall*


Image 15. *Department of Justice*


Image 16. *Residential Apartments*


Image 17. *I&M Bank*

It is easy to believe this plaster saint when only scratching the surface of the complexity of the socio-economic status of Kigali and Rwanda. While this picturesque painting, to a certain degree, is true for Kigali, it also hides another reality. This is the significant gap in living standards, socioeconomic status, and the state of natural ecosystems in the city. Despite the fact that a million Rwandans have desisted from poverty since 2001, 38% of the population still lives in poverty. Furthermore, findings indicate that the urban development which took place in Kigali from 1984 to 2016 has resulted in a loss of ecosystem services corresponding to "*69 million US dollars as a result of cropland degradation in favour of urban areas*" (Mugiraneza, 2019, p. 234).

Additionally, Rwanda has the absolute highest economic disparity between affluent and impoverished in East Africa (Le Touzé, 2014). The Senior Urban Planner from SJ further highlights this issue when stating "*every city has a dark side. I am pretty sure you are aware that money keeps getting pumped into just the CBD [The Central Business District of Kigali], whereas affordable housing gets ignored*" (Appendix 4). This statement corresponds with the field study observations of the city centre, which is currently emerging as a bustling and modern inner city with skyscrapers. Whilst areas nearby are inhabited by informal settlements that are lacking basic infrastructures, such as sanitation and electricity. As highlighted by the representative from SJ, there is a discrepancy in where funding is directed in Kigali.

Image 18. *Collapsed River Channel in an Informal Settlement in Katabaro*

Image 19. *Backyard in an Informal Settlement in Gikondo*

Images 18, 19, and 20 exhibit some of the visited informal areas around the City of Kigali and showcase the other reality of the city.

Image 20. *Path in an Informal Settlement in Kavure*

As the income gap grows and the urban core becomes increasingly modernised, the urban poor population is increasingly sprawling and gathering in informal and unplanned settlements. In many cases, these settlements are located in areas which are not suitable for built structures, due to their particular vulnerability to floods, landslides and soil erosion. Most often, the areas lie in dangerous flood-prone zones making the residents highly vulnerable and exposed to a range of environmental hazards. It has been estimated that 70% of the population in Kigali lives in these unplanned settlements, which is a significant challenge for the future development of the city. (Appendix 10, Appendix 8). It is unfortunately a common phenomenon in developing cities in Africa that urban areas are not officially planned, and as such reside in inadequate housing lacking basic infrastructure and services (Niang et al. 2014).

The informal settlements stand in contrast to the formal parts of Kigali in several ways. What catches the eye at first sight when visiting these types of settlements is the characteristic earth-toned pallet of colours. With every step taken from the hilltops down towards the valley bottoms the lush, green areas disappear with incremental steps. Small, brown and poorly constructed housing units of climate-sensitive, clay-like materials replace lavish mansions and big compounds of concrete and expensive facade materials. Big stones anchor the fragile zink roofs of the housing units to stabilise them during windstorms. From above, the density of building units is striking and it is clear that only a little sunlight reaches the ground in the cores of the settlements, see Image 21.

Residents have restricted access to fundamental services such as electricity, safe water, and sanitation The informal settlements lack stormwater management measures and coupled with the lack of vegetation it ultimately leads to severe soil erosion problems. Landslides are likewise a threat to the informal settlements as uncontrolled development takes place on the slopes of the hillsides towards the valley bottoms (Appendix 10).

A barrier for residents of informal settlements to relocate is the fact that few residents have the economic privilege to take out a loan as they lack official papers on their owning their houses or plots Additionally, most of the residents have no access to health care or health insurance. Mumuhire adds to the central issues of the informal settlements in Kigali, by addressing the immense task of upgrading informal settlements and securing safe and healthy living standards for all, regardless of the social-economic status of the individual, community or area (Appendix 8). He states that "*They lack facilities, basic infrastructure, roads, green spaces, waste collection, and stormwater management. So we work with upgrading and establishing these services. In my experience, it is a huge and difficult task*" (Appendix 8).

The nexus of poor adaptive capacity, a lack of access to primary services, poorly managed stormwater, and low economic status separate the population and highly influence the urban planning regime and paradigms in Kigali. Eventually, the nexus adds to the complexity of upgrading and consolidating the informal settlements.

Image 21. *Informal Settelment in Katabaro From Above*

According to Gakwavu and Mumuhire, the striking contrasts between the two paradigms of poor and rich, or informal and formal settlements, are an exceptional headache for the government and decision-makers, as the settings are complex, and the level of vulnerability is disproportionately allocated (Appendix 8 and 10). Gakwavu adds to this narrative, stating that "*We have many giant mansions on the hilltops. But other places if you go down and down and down. We see the unplanned settlements, which are not really great*" (Appendix 9). Not only does this statement highlight the discrepancy between the two population groups and paradigms, but it also calls attention to the fact that unplanned settlements are commonly located at the valley bottoms in Kigali. As stated in the previous analysis, stormwater accumulates in these downstream areas, where the potential occurrence of floods is significantly high. Consistently, the dominating planned and formal urban paradigm, coupled with the present housing crisis, is actively pushing the urban poor to increasingly settle in unsuitable and exposed areas, as this population group has limited options for residing elsewhere (Appendix 10). Image 22 how the two paradigms live side by side in Kigali.

In an attempt to address these challenges, the government has issued a range of policies and plans, such as the Rwanda National Urbanisation Policy (2015) and the Kigali Master Plan (2020)(Krishnasamy et al., 2020). Please refer to Table 6, for a review of relevant policies, strategies and plans. Gakwavu also elaborates upon the efforts of the government to try to close the gap between the two paradigms by looking at the social economy of the informal areas. He states that "*We need to consider infrastructure and increase access to finance for people living in these areas. The government is trying to empower poor communities through financial systems*" (Appendix 9).

In countries such as Rwanda, it is typical that urban development does not occur based on a predetermined plan, as these national and urban areas lack official guidelines and development plans. Therefore, development occurs incrementally and organically based on localised needs and initiatives.

For this reason, settlements often lack formal infrastructures and facilities such as water, wastewater and electricity (Appendix 4; Niang et al., 2014). To deal with these challenges, the government and the City of Kigali have issued policies that now require developers and individuals to obtain a building permit before settling down. Gakwavu elaborates upon this, stating that "*In Kigali, you cannot build your house without getting standards and public permits ... to make sure that they are not building in, for example, wetlands or floodplains*" (Appendix 9). These permits come in addition to the requirement to comply with development and land use plans from the Master Plan for Kigali, which incorporates zoning regulations, see Table 6 (Krishnasamy et al., 2020).

To a certain degree, the policies and initiatives have facilitated an upgrade of some former unplanned settlements as intended. However, this has not come without a prize. The top-down dominated implementation approach taken by the government and other decision-makers has not unconditionally been greeted by the local residents. In some cases, the issue of relocation has led to public discontent (Nikuze et al., 2022).

Furthermore, the Kigali Master Plan is criticised by scholars for its lack of implementation plans, including requirements for monitoring and evaluations. Especially, an area of concern in the case of informal settlements, which paradoxically was the main driver for the Master Plan (Neuwirth, 2022). Currently, the existing planning practices hold little knowledge and give poor attention to the nexus of challenges in informal settlements, and as the settlements grow rapidly, the issues of poor long-term plans and implementations are further aggravated (Appendix 10).

Image 22. *Informal (Left) and Formal Housing (Right) Side by Side in Gikondo*

The interviews and review of policies reveal a significant gap between urban strategies and the actual implementation of measures in Kigali. Gakwavu adds to this argument in the interview when expressing "*Vision 2050 is a vision and some goals, but not an implementation plan*" (Appendix 9). A study on the impact of the Kigali Master Plan on living standards by Nyiransabimana et al. (2019) shows that while the implementation of the Master Plan has partially improved the living conditions of urban dwellers, the overall execution of the plans is low as the zoning categories and new building standards "*are not affordable for low-income citizens*" (Nyiransabimana et al., 2019, p. 1). Thus the study criticises the plan for showing little or no consideration for the economic perspectives of the presented initiatives, as such undermining the stakeholders in low-income communities (Nyiransabimana et al., 2019). This critique highlights that although the government has formulated a wide variety of plans and strategies they do not necessarily grasp the need and the challenges facing the majority of the urban population.

As stated several times, the challenges of urban flooding and informal settlements are highly interconnected. As is the identified grey-dominant trajectory of urban planning practices and the contrasting urban paradigms, as they constitute important parts of the urban planning regime in Kigali. As such, the following section briefly explores how these elements interrelate.

INTERDEPENDENCIES

The interdependencies of the grey-dominant trajectory and the contrasting paradigms of the urban planning regime. In Kigali, multifaceted fragility characterises informal settlements, and most have no or inadequate urban stormwater management. As a result, they are subject to frequent floods hampering potential development (Appendix 10). Grey, engineered solutions are not widely adopted in these unplanned areas. Consequently, the current urban planning trajectory fails to address and overcome the flooding issues in these parts of the city.

Furthermore, the Kigali Master Plan (2020) states that upgrading the informal settlements to a high degree relies on grey and engineered solutions regarding urban flooding, and little emphasis is given to alternative, novel innovations (Krishnasamy et al., 2020). In other words, the path dependency of the traditional, grey-dominant trajectory reinforces the circumstances of the informal settlements. In essence, the path dependency of the current trajectory entails that the existing urban planning regime is merely equipped for dealing with urban flooding in the formal and planned areas of Kigali. Figure 17 illustrates the structure and interdependencies of the urban planning regime in Kigali. The green-outlined hexagon illustrates the current planning regime, while the blue dots visualises the different stakeholders, as analysed previously, and the grey squares symbolise the two contrasting paradigms of informal and formal settlements, while the orange triangle marks the current trajectory of urban stormwater management in Kigali.

As illustrated in the Figure, every element in the regime is interconnected, therefore, actions within each element have an impact on the entire regime and the overall trajectory. If actions are aligned, stabilising innovations within the frames of the regime may occur.

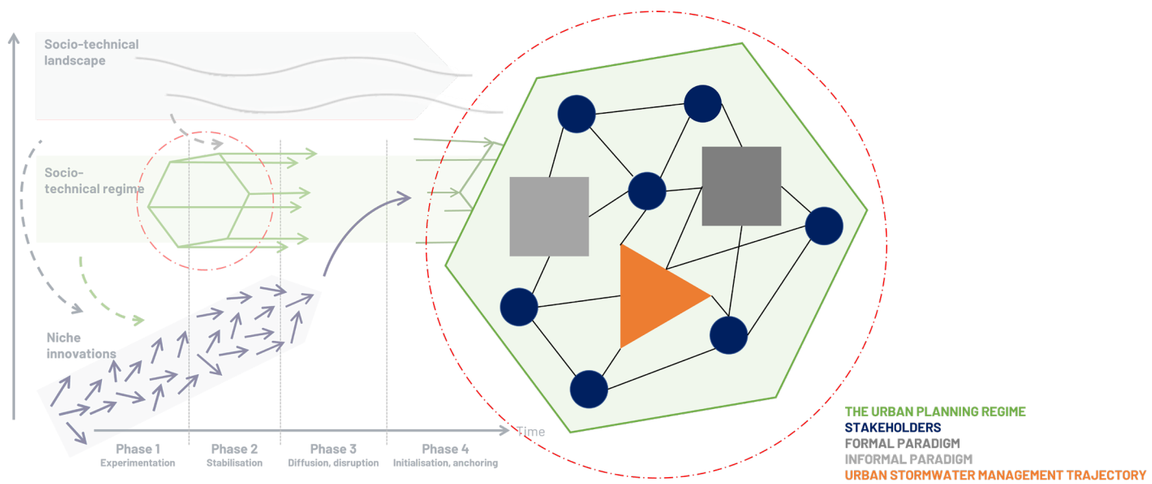


Figure 17. *The Structure and Interdependencies of the Urban Planning Regime (Own figure adapted from Geels, 2005)*

Image 23. *Informal Settelment in Katabaro*

POLICY & STRATEGY
POLITICAL INCENTIVES

Table 6. *Review of Significant Political Incentives for Urban Flooding, Urbanisation, and Climate Change Adaptation*

Rwanda and Kigali have a range of different visions, strategies, and policies dealing with the development issues of the country and city. The present Table comprises a review of a handful of the most significant and determining political incentives in Kigali, with a specific focus on climate change adaptation, NbS and urbanisation.

Vision 2050 (2020). The 2050 Vision of Rwanda is a long-term strategic trajectory building upon Vision 2020 and it sets the scene for many important frameworks, policies and strategies such as the Green Growth and Climate Resilience National Strategy for Climate Change and Low Carbon Development and National Strategy for Transformation (NST) (2017). Vision 2050 visualises Rwanda as a fully developed country with a strong service sector, little unemployment and low levels of poverty. It puts forward directions enabling these objectives, where the overall aim is to modernise and strengthen living conditions for all Rwandans (RoR, 2020-b). Lastly, the vision focuses on how Rwanda by 2050 will be able to accommodate and adapt to challenges posed by climate change (RoR, 2020-b).

The Vision is intended as a critical policy blueprint for planning for the future by guiding all stakeholders involved in the development including the private and public sectors, political parties, citizens, civil society, academia and research institutions (RoR, 2020-b).

Updated Nationally Determined Contribution (2020). The Nationally Determined Contributions (NDCs) are climate action plans dealing with targets of how to cut emissions and adapt to climate change established by the United Nations (UN) as a part of the Paris Agreement. The NDCs explain how each party to the Agreement are to reach the targets and describe monitoring systems ensuring development stays on track (UN, n.d.).

The updated NDC of Rwanda describes how the nation is to carry out urgent climate actions to both mitigate and adapt to current and future climate changes. Contributions to Rwanda's adaptive capacity include creating baselines and developing performance targets and indicators based on eight different sectors (Water, Agriculture, Land and Forestry, Human Settlement, Health, Transport, Mining, and Cross-Sectional). The NDC puts forward 25 adaption interventions as well as 38 indicators within these sectors (RoR, 2020-a).

National Adaptation Programmes of Action to Climate Change (NAPA) (2006). NAPAs are work programmes supporting Least Developed Countries (LDCs) in responding to their challenges and immediate needs to adapt to climate change given their particular vulnerability. Community-level input is emphasised as a crucial source of information in the NAPA processes, acknowledging that civil society and grassroots communities are the primary stakeholders. NAPAs rely on existing data and do not necessitate new research. The programmes are country-driven, action-oriented, adjustable, and tailored to the needs of the given country. NAPA materials are visualised in a simple style that is easily comprehended by policy-level decision-makers as well as the general public to successfully attend to urgent and immediate adaptation needs (UNFCCC, 2022).

In the case of Rwanda, the NAPA report identifies a range of different action points guiding political figures and national planners to prioritising "*vulnerable economic sectors as well as strategies and priority actions of adaptation to climate change which were identified according to retained criteria during workshops and seminars of stakeholders organized for this purpose*" (RoR, 2006, p. 5).

Generally seen, the identified activities, projects and initiatives in the report are aimed at 1) preventing deforestation, floods, and erosion by advancing land conservation as well as flood and erosion protection at the district level, and 2) improving and strengthening rapid intervention and early warning structures using a multi-hazard centred approach in the light of socio-economic impacts of climate change as well (RoR, 2006).

To address the high vulnerabilities of the above-mentioned effects of climate change and its cumulative effects on the population, livelihoods and infrastructures, the report lists a six-step adaptational response that includes "*1) An Integrated Water Resource Management – IWRM; 2) Setting up information systems to early warning of the hydro-agro meteorological system and rapid intervention mechanisms; 3) Promotion of non-agricultural income-generating activities; 4) Promotion of intensive agro-pastoral activities; 5) Introduction of species resisting to environmental conditions; 6) Development of firewood alternative sources of energy*" (RoR, 2006, p. 7).

Green Growth and Climate Resilience National Strategy for Climate Change and Low Carbon Development (2011). This strategy takes form as a guide in the process toward climate resilience and low carbon development in the central part of the economic sector of Rwanda. It incorporates a long-term, strategic vision for 2050 including programmes of action, strategic objectives and a roadmap for the implementation stages. In terms of climate resilience and climate change adaptation, the national strategy brings forward four central focus areas specifically 1) irrigation infrastructures, 2) robust road networks, 3) a Centre for Climate Knowledge for Development, and 4) agroforestry. For each of these areas, the strategy elaborates upon individual Programmes of Action to implement the given visions and objectives. However, the programmes are solely based on stakeholder engagement and best practices (RoR, 2011).

Rwanda National Urbanization Policy (2015). In 2015, the National Urbanization Policy was established to address the aforementioned challenges in line with rapid urbanisation and population growth. The policy promotes the coordinated, spacially integrated, sustainable, and orderly development of urban areas in Rwanda whilst having a strong focus on ensuring adequate social and economic services, effective organisations and institutions, safe lining and working conditions for all citizens. Thus the general aim of the policy is to nurture high-quality urban development that strengthens national and local economies and guarantees a good living standard for the Rwandanese people. The policy has a strong focus on cross-sectorial actions and aims at enhancing collaboration and partnerships between all involved stakeholders and civil society as well. (RoR, 2015).

National Strategy for Transformation (NST) (2017). The NST is a seven-year government programme for the period 2018 to 2024. It builds on the former vision 2020 for Rwanda and is well guided and aligned with the 2050 Vision of the nation. The overall aim of the strategy is to ensure a secure foundation for continuous growth and transformation in the coming decades as well as to accelerate the transition towards reaching high living standards for all Rwandans.

The strategy has little focus on climate change adaptation, however, it does touch upon the importance of improving "*cross-sectoral coordination to ensure smooth implementation of environmental policies and regulations*" (RoR, 2017, p. 43). The sectors identified to have a critical role in pursuing this agenda are agriculture, infrastructure, land use management, and urbanisation. Additionally, the strategy proposes a stronger emphasis on monitoring and evaluation practices, especially regarding environmental and social impact assessments, pollution and waste management, and biodiversity and ecosystem management (RoR, 2017).

Kigali City Master Plan (2013). To tackle the challenges associated with urbanisation and urban sprawl of informal settlements, authorities in Kigali approved the Kigali City Master Plan in 2008 developed by the Singaporean government-owned consultancy company SJ. The Kigali Master Plan 2013 builds upon the Kigali Conceptual Master Plan from 2008 and the Detailed Master Plans for the Nyarugenge District conducted in 2010 also developed by SJ. The 2013 Master Plan aims at developing Detailed Physical Plans for the remaining districts in the city of Kigali, that is, Gasabo and Kickukio to create a unified plan for the entire city. The Master Plan especially considers climate mitigation, while climate adaptation, on the other hand, is addressed implicitly under the 5th goal (Krishnasamy et al., 2020).

Kigali Updated Master Plan (2020). As the 2013 Kigali Master Plan Implementation Report states, the blueprint has to be updated five years after it's approved to monitor the implementation and apply new measures and updates based on real-time information. As such an updated Master Plan was developed in 2020, to guide development towards 2050. The central aim of the update is to strengthen the existing plan and make it more inclusive through stakeholder involvement (Krishnasamy et al., 2020).

The 2020 updated version centres on two focal points

1. Incorporating intense participatory processes to involve important stakeholders and gain new valuable inputs and viewpoints in the updating processes
2. Support the updating processes with new and detailed research and studies e.g. in terms of social-economic assessments, mar ket surveys, and transport modelling (Krishnasamy et al., 2020).

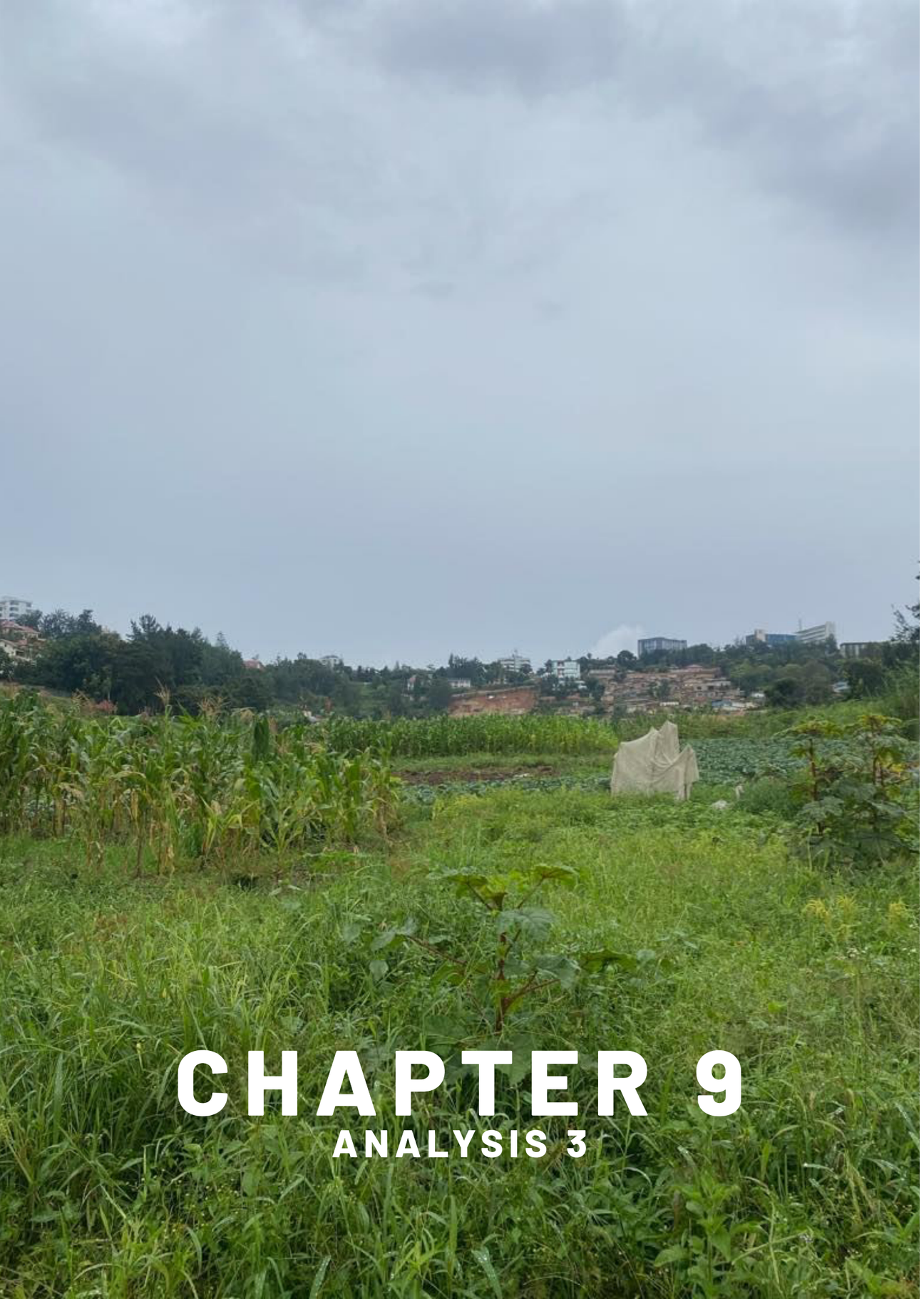
The updated Master Plan integrates previous plans and reports on development in Rwanda and Kigali to ensure new measures and recommendations for the city's development are aligned with national strategies when proposing a new, updated direction for growth. In terms of climate change adaptation and ature-based solutions, the 2020 version of the Master Plan acknowledges the role of environmental protection as a key player in the economic development of the nation. The fourth development theme Green City deals with Topography, Geology and Soil, Water bodies, Watershed & Drainage Wetlands, Biodiversity and Green Cover, Agriculture, Forestry, Land Availability for Development and Land Exploration, Green Growth and Climate Change, Disaster Risk and Resiliency, and Green Initiatives (Krishnasamy et al., 2020).

SUMMARY

The analysis investigates the current urban planning regime within the city of Kigali and highlights the wide range of different institutions that govern urban stormwater management in the city. It further explores the complexity of the matter and the importance of coordination between silos, departments, and layers in the general governance structure.

The vast majority of involved institutions contribute to the general path dependency of the current urban stormwater management and urban planning trajectory in the city of Kigali. Where, the current regime is grounded in engineering beliefs of grey infrastructures, structural solutions, and policy paradigms favouring climate mitigation rather than climate adaptation initiatives. Examples of current solutions and infrastructure to manage urban flooding include engineered drainage channels, retention walls, gabion walls, and stone pitching along river banks. However, urban flooding continues to be a severe challenge for the city of Kigali, as devastating floods occur every rainy season, underlining that current measures lack the capacity to manage the challenges at hand.

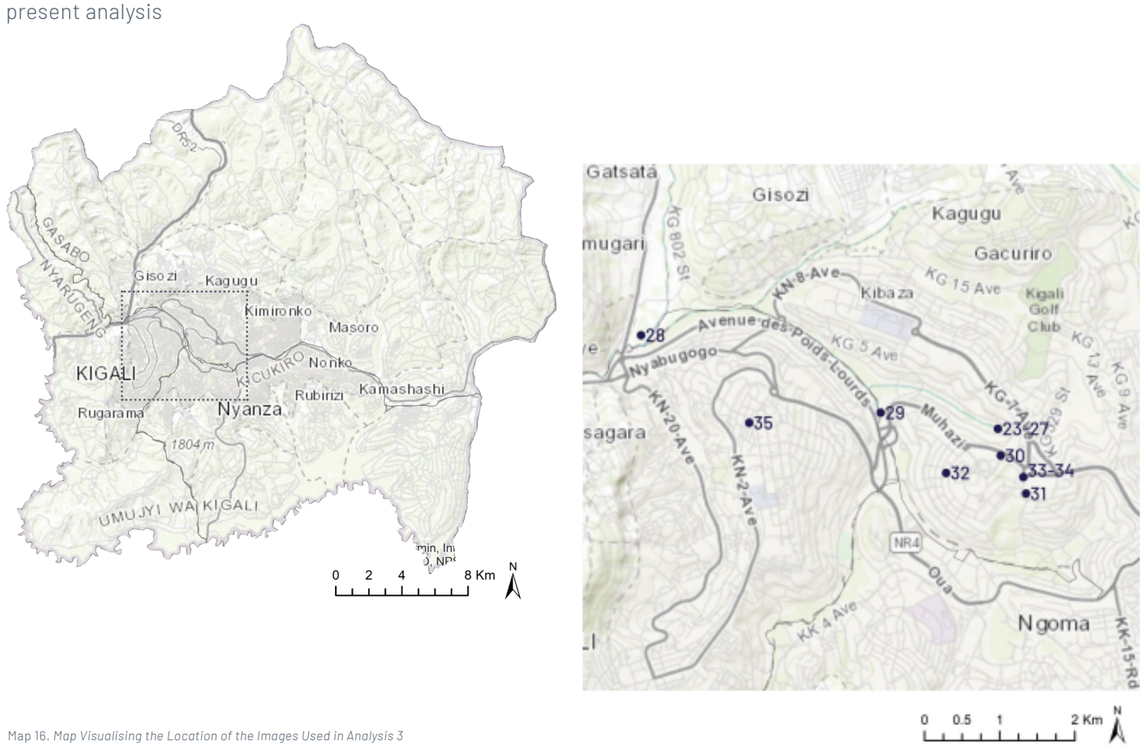
The analysis reveals a pronounced gap between the two paradigms of unplanned and planned settlements and how the current regime fails to ensure affordable housing and adequate access to basal services for all Kigalians. Ultimately, this aggravates the gap and the appertaining urban development challenges of Kigali. Thus, the analysis finds that the existing urban planning regime unsuccessfully addresses the climate adaptational needs of Kigali in terms of urban flooding and urban sprawl. As such, it is evident that the external landscape pressures of climate change and urban flooding have destabilised the current urban planning regime, thus creating a window of opportunity for NbS to emerge as novel innovations. The succeeding Chapter explores how Kigali has implemented NbS in attempts to enhance urban resilience. Further, it explores where the novel innovations are in the sustainability transition from niche to norm.



CHAPTER 9
ANALYSIS 3

A SLOW PARADIGM SHIFT TURNING BACK TO NATURE

As evident in the previous analysis of the existing urban planning practices in Kigali, the current planning regime highly centres upon engineered beliefs and structures. The following analysis explores the role of Nature-based Solutions (NbS) as a novel innovation in terms of urban planning, stormwater management, and rehabilitation of degraded biodiversity and ecosystems in Kigali. It aims to illustrate the current phase of the sustainability transition in order to facilitate a later discussion on how to accelerate the changeover. To do so, the analysis explores current restoration and rehabilitation initiatives before diving into other smaller-scale NbS in the city. The analysis draws on observations done through the field study, including photographs and notes, alongside interviews and relevant literature. Map 16 visualises the location of the introduced images in the present analysis



Map 16. *Map Visualising the Location of the Images Used in Analysis 3*

Wetland Restoration and Rehabilitation

The general character traits of the current urban planning regime in Kigali favour and centre upon strong engineering practices. This is especially evident in terms of dealing with urban flooding and goes well in hand with the overall lack of focus on restoration and conservation of biodiversity and ecosystems within the urban environment as explored in the previous Chapter.

While the current urban planning regime in Kigali favours and centres upon fundamental engineering practices, to a trivial degree, NbS are present in the cityscape. There are natural features within the city boundaries which function as unintended NbS, such as the forest cover and vegetation on the steep slopes of Mount Kigali and Mount Jali, which decreases the velocity and amount of water flowing into developed areas downstream (Appendix 10). According to Abias Mumuhire a growing trend is emerging, focusing on integrating green zones and green infrastructure in the city. He indicates that there is evidence that the traditional paradigm of engineered solutions to address climate change and urban flooding is slowly shifting and that the City of Kigali is "*trying to bring in green into the city*" (Appendix 8).

In recent years, extensive restoration and rehabilitation initiatives of several natural wetlands of the city have been put in motion. The Rwandan government have been preparing rehabilitation plans for the remaining urban wetlands within the city. Collaboration partners on the initiative include international stakeholders such as the World Bank (Appendix 10). The rehabilitation plan aims to reinstate the capacities of the wetlands to retain stormwater runoff, thus reducing the risk of flooding, restoring the abilities of the wetlands to improve water quality, and rehabilitating wetland habitats for recreational purposes as green urban spaces. In other words, urban wetlands are identified as one of the central solutions to the growing problem of urban flooding in Kigali. In recent years, an increasing focus on investing in rehabilitation initiatives has increased both from the national and international sides. With continuous urban growth in Kigali, the interest also centres on expanding the wetland areas across the city (Oppermann et al. 2021; GCA, 2021).

In the interview with theThe Senior Urban Planner from Surbana Jurong (SJ), she mentions several times the management of wetlands as the prime focus of Kigali in terms of NbS, stating that "*we have to ensure that these wetlands are managed*" (Appendix 4). Her impression of the current planning practices addressing urban flooding and restoration of wetlands is that they add to the urban resilience to climate change (Appendix 4).

NBS IN A GLOBAL PERSPECTIVE

DR. SALEEMUL HUQ, THE DIRECTOR OF THE INTERNATIONAL CENTRE FOR CLIMATE CHANGE AND DEVELOPMENT (ICCCAD), CHARACTERISES THE CURRENT SHIFT TOWARDS NBS IN URBAN RESILIENCE AND CLIMATE CHANGE ADAPTATION AS A VITAL MOVEMENT IN THE RIGHT DIRECTION. AFTER DECADES OF DEVELOPMENT AT THE COST OF NATURE, CHANGES IN PLANNING CULTURES AND PARADIGMS ARE SLOWLY GAINING A FOOTHOLD ALL ACROSS THE WORLD.

"*WE NEED TO BE BETTER AT DEVELOPING WITH NATURE WITHOUT DESTROYING NATURE. THE GOOD NEWS IS THAT PEOPLE REALISE THAT THIS NEEDS TO BE DONE. THE BAD NEWS IS NOBODY IS DOING IT VERY WELL YET*" (APPENDIX 1).

HE ARGUES THAT IT IS POSSIBLE TO DEVELOP WITHOUT DESTROYING NATURE BUT THAT BEST-PRACTICE EXAMPLES ARE STILL MISSING IN THIS EMERGING PROFESSIONAL FIELD, AND SEVERAL UNCERTAINTIES ARE RELATED TO WORKING WITH NBS IN CLIMATE CHANGE ADAPTATION,

"*PREVIOUSLY, WE HAD TO DESTROY NATURE OR ELSE WE WOULD NOT BE ABLE TO DEVELOP. NOW, WE START TO ARGUE THAT YOU CAN DO BOTH, BUT WE HAVE TO HAVE GOOD EXAMPLES, AND THEY ARE STILL MISSING. SO NOW, LET US DO THE RIGHT THING. BUT WHAT IS THE RIGHT THING? WE DO NOT KNOW*" (APPENDIX 1).

THE GIKONDO WETLAND RESTORATION INITIATIVE

An example of a wetland restoration project in the cityscape of Kigali is the Gikondo wetland. In 2019 and 2020, the government moved an industrial area out of the flood-prone area to protect the wetland, restore its retention capacity and rehabilitate the area to its natural and original habitat for flood buffering (Appendix 10; Oppermann et al., 2021). Gikondo wetland is surrounded by hills on three sides and lies in a valley bottom centrally within the City of Kigali (Appendix 10). Before the industrial development of Gikondo, the wetland comprised an intertwined system of swamps which were of great environmental importance as they supplied the downstream rivers with water during the dry seasons and functioned as a flood buffer zone during the rainy season (Nemus, n.d.; GCA, 2021). In addition to the environmental benefits of the wetland, it also had economic and social attributes, as it accommodated agricultural activities and livestock production (Appendix 10; Nemus, n.d.)

In the 1970s, the wetland was drained to make room for a large industrial area that could accommodate emerging industrial activity in Kigali. Findings indicate that these industries discharged toxic pollutants that severely degraded soil, vegetation, and water resources in the area and ultimately put human health at high risk. As a result of urban development due to an increasingly urban population, the now industrialised area of Gikondo repeatedly flooded, resulting in infrastructure damage, soil erosion and loss of ecosystems and biodiversity (Nemus, n.d.).

As a result of these challenges, the restoration of Gikondo was initiated in 2013. Today, the industrial activities have been relocated elsewhere, and all prior developments are completely cleared, leaving the area bare, allowing nature to take its rightful place and return to its original state through natural, ecological succession. According to John R. Gakwavu, the restoration of Gikondo really was a landmark action in the City of Kigali. He states "*So flooding impacted all that area heavily, and now this area is completely cleared from the previous industry. Back then, we could not imagine that one day you would see that. Seriously, no one could believe that!*" (Appendix 9). Aside from providing flood protection, the restored wetland also increases biodiversity and provides social benefits to the surrounding communities (Appendix 10; GCA, 2021).

The demolishing of the previously industrial area has caused the Gikondo area to identify more like a wetland again rather than an industrial area. It is green and lush, and several smaller streams run through the wetland. To this day, the valley bottom welcomes ecological succession, where wild flora and fauna naturally reemerge. However, several parts of the area are cultivated for agricultural purposes, and plants such as corn, kale and other native crops. The activities provide a means of subsistence for urban dwellers located in neighbouring communities. In particular, inhabitants of the unplanned settlements surrounding the Gikondo wetland participate in urban farming (Appendix 10). It is unknown whether these small-scale agricultural activities will be allowed to continue indefinitely or if the original plan of restoring the area into fully functional wetlands will be commenced in the future. Images 24, 25, 26, and 27 showcase the current state of the wetland.

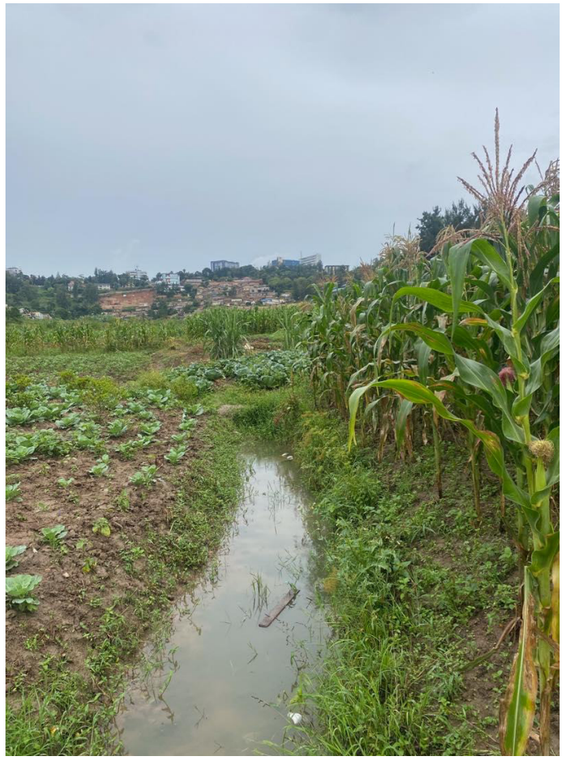


Image 24. *Gikondo Wetland, Example 1*

Image 25. *Gikondo Wetland, Example 2*

Image 26. *Gikondo Wetland, Example 3*

Image 27. *Gikondo Wetland, Example 4*

OTHER WETLAND RESTORATION PROJECTS

Other wetland restoration projects include the Nyabugogo wetland rehabilitation in the western part of the city, the Nyandungu Urban Wetland Eco-tourism Park in the eastern part of urban Kigali, and the Kimicanga expropriation project located in the centre of the city.

The Nyabugogo Wetland Restoration

Nyabugogo wetland was one of the first wetlands to be restored in the City of Kigali. It faced similar challenges as described for Gikondo as the area before rehabilitation suffered from consequential "*degradation of land, vegetation and water resources due to the increasing occupation by various industries, intrusive agriculture and housing areas*" (Nemus, 2017, p. 1). Please refer to Image 28 for a visualisation of the wetland today.

The Nyandungu Urban Wetland Eco-Park

The rehabilitation of the Nyandungu wetland has resulted in an urban eco-park in the City of Kigali. The project involved a complete ecosystem restoration and subsequent conservation focused on socio-economic development. The area comprises green infrastructures, while strategies for sustainable, green energy and water efficiency, storage, and recycling form the design of the visitor centre of the park (GGGI, 2022-a).

The Kimicanga Expropriation Project

Kimicanga used to be a slum area in the Kimihurura Sector in the Gasabo District in Kigali. The expropriation of Kimicnga began in late 2011 as a part of the Kigali City Master Plan (2008). Besides focussing on the upgrading of the informal settlement and relocating dwellers, the project centred on improving "*the ecological functioning, aesthetics and recreational potential of the wetland areas of ... Kimicanga in Kigali City*" (GGGI, 2015). Please refer to Image 29 for a visualisation of the wetland today.

Image 28. *Nyandungu Wetland*

Image 29. *The Kimichanga Wetland*

SMALLER-SCALE NBS

As evident in the above sections, most NbS initiatives revolve around wetland restoration or conservation. However, some smaller-scale NbS are appearing in the cityscape of Kigali too.

URBAN GREENING. There has been an increase in efforts aimed at urban greening, such as planting trees and other vegetation, which protect and stabilise soil from erosion and landslides (Nkurunziza, 2022-a). Gakwavu adds to this agenda by describing a new planting programme aiming at "*planting 100,000 trees to improve road conditions in terms of flooding, also flowers and other greens are being planted*" (Appendix 9). This initiative is one of many Kigali focused on planting more trees. According to findings from the updated Master Plan (2020), the urban "*Forest cover has increased by 2.2% in 2018 relative to the forest cover at the time of Master Plan 2013, which is reflective of progress in forest conservation, reforestation and afforestation efforts in Kigali*" (Krishnasamy et al., 2020, p. 111).

The increase in urban greening in the city landscape provides a wide range of benefits and contributes to managing some of the urban challenges the City of Kigali is facing. When successfully introduced, trees can stabilise soils and, as such, lower the potential risk of soil erosion and landslides. Furthermore, forest cover and its canopy have a positive effect in heavy precipitation events as it contributes to the absorption of rainwater, slowing and retaining the water before it becomes runoff flowing downstream (Appendix 3; WBG, 2021-d). Images 30, 31, and 32 visualises some of the greenery of Kigali.

Image 30. *Urban Greening, Example 1*

Image 31. *Urban Greening, Example 3*

Image 32. *Urban Greening, Example 3*

THE INTERSECTION OF GREY AND GREEN INTERVERNTIONS. In terms of small scale interventions Mona Zum Felde, an Urban Design from Defacto Urbanism working on a feasibility study on NbS in Kigali, highlights their work on green infrastructures and states that many of their solutions are in the cross field of green and grey infrastructures (Appendix 2). Examples include drainage channels with vegetation to slow and retain rainwater runoff and small urban gardens or farming areas in industrial areas, see Images 33 and 34. Also, Bobby Russell highlights the benefits of integrating grey and green solutions, "*I am a firm believer that you need blue, green and grey structures and you need to integrate them*" (Appendix 3). Zum Felde further elaborates upon innovative solutions for water storage tanks made of local materials that can be adapted to the steep slopes of Kigali. These forms of solutions are beneficial for a range of reasons. First of all, they are relatively affordable and low maintenance. Furthermore, they can accommodate the specific context and geographical location (Appendix 2).

Image 33. *Green Drainage Channel, Example 1*

Image 34. *Green Drainage Channel, Example 2*

CAR-FREE ZONES. Other initiatives aimed at integrating greenery into the city have resulted in the introduction of Car-Free Zones in busy urban areas. These initiatives centre on transforming previously heavy trafficked streets into pedestrian-friendly and walkable open streets. Further, it focuses on new forms of public space for the city of Kigali by creating "*sustainable public space, integrating environmental, social and economic aspects*" (Boniburini et al., 2018, p. 1). The planning phase of the first project was initiated in 2017, the building began in 2021, and it was completed in early 2022. Locations of other places with similar characteristics have been proposed for future transformation (Boniburini et al., 2018; GGGI, 2022-b). The first street has been titled 'Imbuga City Walk' and has created an entirely new cityscape to the hectic Central Business District (CBD) of Kigali. The project has involved removing the previously asphalted road and introducing a mix of permeable and semi-permeable surfaces, as visualised on Image 35.

Likewise, the transformation focuses on implementing native Rwandan flora throughout the areas by introducing green roofs and walls on newly built stalls for cafes and shops along the street. Through the implementation of bioswales and rain gardens, the project aims at laying out so-called "*key technical solutions*" to safeguard against heavy precipitation events (Boniburini et al., 2018, p. 1). In addition to these measures, the project provides some added biodiversity as the number of green infrastructures increases. Therefore, the initiative adds a climate-regulating benefit to air purification and temperature regulation. However, as there is no evidence of any evaluation or maintenance plans of the actual climate adaptation or mitigation measures, their effects remain unknown (Boniburini et al., 2018; GGGI, 2022-b).

The previous examples showcase that NbS to a certain degree is emerging into urban flood management in Kigali. The following part of the analysis examines the transition of NbS as a novel innovation within the urban planning regime of Kigali.

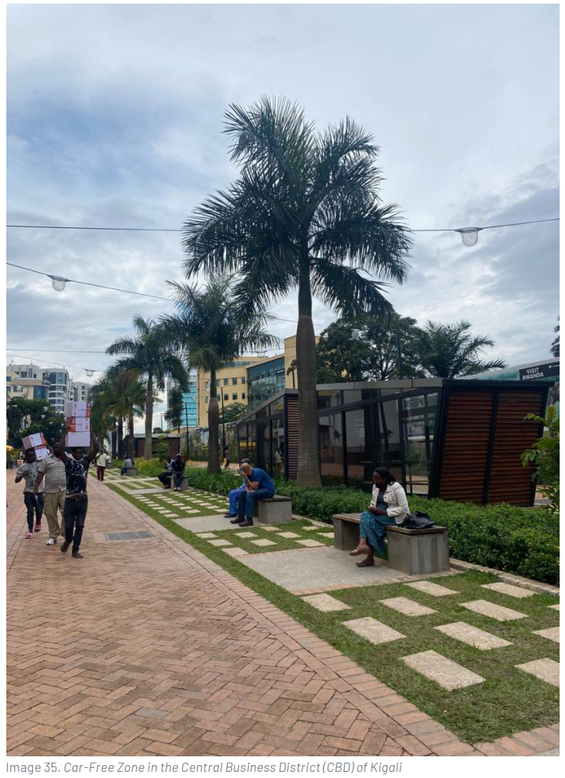


Image 35. *Car-Free Zone in the Central Business District (CBD) of Kigali*

THE PHASE OF THE TRANSISTION

NbS as a Stabilised Novel Innovation in Kigali. As NbS are employed sporadically in Kigali, they are yet to diffuse and disrupt the existing regime, which to this day, is still reasonably dominated by engineered and grey solutions as explored in Chapter 8. Using the preceding analyses of the existing urban planning regime, its underlying trajectory and paradigms, as well as the current NbS practices in the City of Kigali as justification, it is readily apparent that NbS as a novel innovation has entered the stabilisation phase in terms of transition phases as described by Geels (2005). Landing at this understanding entails that NbS already has transitioned from the first phase of experimentation into the second phase, where it is slowly steadying, as visualised in a modification of the Multi-Level Perspective illustration by Geels (2005) in Figure 18.

Although NbS is not a widespread practice in Kigali, there is growing evidence that they are increasingly becoming more recognised amongst stakeholders within the predominant planning regime. Such an example is the stronger emphasis on nature and the benefits of green infrastructure in government plans and strategies. For example, the city of Kigali Master Plan highlights the need for "*Integration of natural drainage channels into the urban landscape and citywide green network*" and the "*Use native vegetation along the riparian corridor to control the flow of water, reduce erosion and trap pollutants from the catchment*" (Krishnasamy et al., 2020, p. 108). This statement highlights that the use of NbS is stabilising in terms of the current planning regime of relying on engineered solutions to manage stormwater.

It is possible to explore why NbS ends up at the second phase of the transition from niche to norm using different, contrasting angles.

On one hand, it demonstrates that NbS are beginning to gain a foothold in sustainable urban water management in Kigali, including stakeholders taking ownership of the new innovation and its change of course of the existing regime. In other words, NbS are gradually maturing as an alternative urban water management planning practice complementing and contrasting the current engineered trajectory at one and the same time. Concurrently, with NbS emerging into the existing regime, more examples, pilot projects, and learnings are established, which aid the further transition of the novel innovation.

International urban experts and local practitioners expect NbS initiatives in Kigali will increase in strength in the near future (Appendix 10). According to zum Felde, NbS have great potential in Kigali. Together with Deltares, the World Bank, and local authorities, zum Felde and Defacto Urbanism have been working on a yet-to-be-published feasibility study in recent years. She highlights the ability of NbS to function on a range of spatial scales and highlights the benefits of smaller-scale initiatives to complement the use of large-scale interventions such as wetland rehabilitation in Kigali (Appendix 2). Zum Felde was able to share some insights on their proposed solutions, although the feasibility study is confidential at the time of this writing (May 2022). However, the information was sparse, "*We did not get to the point that we would advise on specific plans, but we did workshops and discussed which Nature-based solutions are feasible or would make sense and which are really not suitable for the location because they do not have the building technique or they have different materials, so we also did a lot of adjustments to the Nature-based solutions to fit the local conditions*" (Appendix 2). In the wake of the detailed feasibility study, the involved stakeholders hope to raise awareness and build local capacity to take on NbS as a possible urban flood protective measure. If the feasibility study succeeds in meeting this objective, it might just be the last push to move the novel innovation of NbS to the next phase of the sustainability transition.

On the other hand, it likewise depicts a cease in the transition. There are different causes of NbS not being further in the sustainability transition than the second phase. For instance, as NbS are investments that slowly provide a climate adaptation or mitigation effect, and because their impact is often seen on a variety of spatial scales, it is challenging to report on their effect on a concern or an area. In terms of the adaptive capacity provided by NbS, there are a few best practice examples to draw learnings from in regards to understanding their trajectory from niche to norm in a context such as the City of Kigali. According to Gakwavu, the lack of knowledge on the long term effects of implementing NbS and their need for monitoring and maintenance continues to be a big issue in Kigali (Appendix 9). Accordingly, there is an overarching lack of experience and capacity in the city to push the transition of NbS further in Kigali, which hinders the emergence of NbS from niche to the norm and entering the later stages of the sustainability transition.

Other than that, the current urban water management practices view preserving and restoring nature as secondary to engineered stormwater management, which further aggravates the barriers to transition. As an example, the Kigali Master Plan (2020) states "*Preservation and restoration of the natural drainage channels across the catchments in Kigali is an important strategy for managing to flood, especially in the absence of developed stormwater drainage infrastructure in much of the City*" (Krishnasamy et al., 2020, p. 106). Mumuhire reflects upon the limited use of nature to adapt to changing climatic conditions while stating, *"I'm not sure we are doing 100%, but we are trying to do something"* (Appendix 8).

Another hindering cause of NbS becoming standard practice in Kigali might be attributed to the low-income status of Rwanda (WPR, 2022-g). Generally, there is a widespread understanding in academia that developing countries face challenges of breaking their locked-in regimes, path dependencies and fixed trajectories, as they have to address profound issues of "*enduring poverty and social inequalities, past and current practices of injustice … poor knowledge accumulation, flexible institutional embedding, discourse and propaganda*" (Wieczorek, 2018, p. 208).

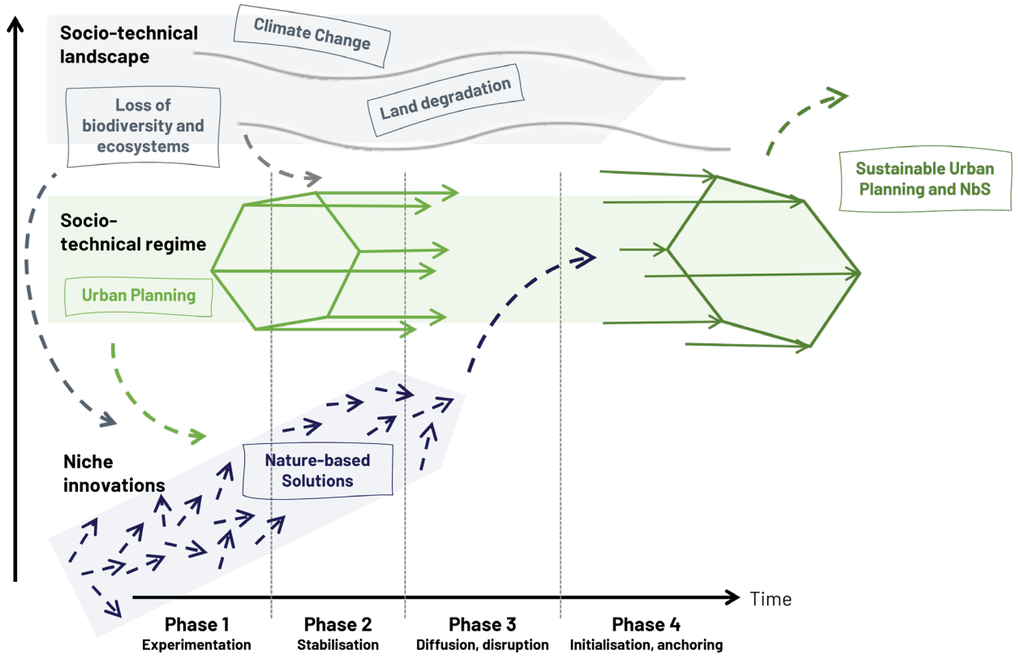


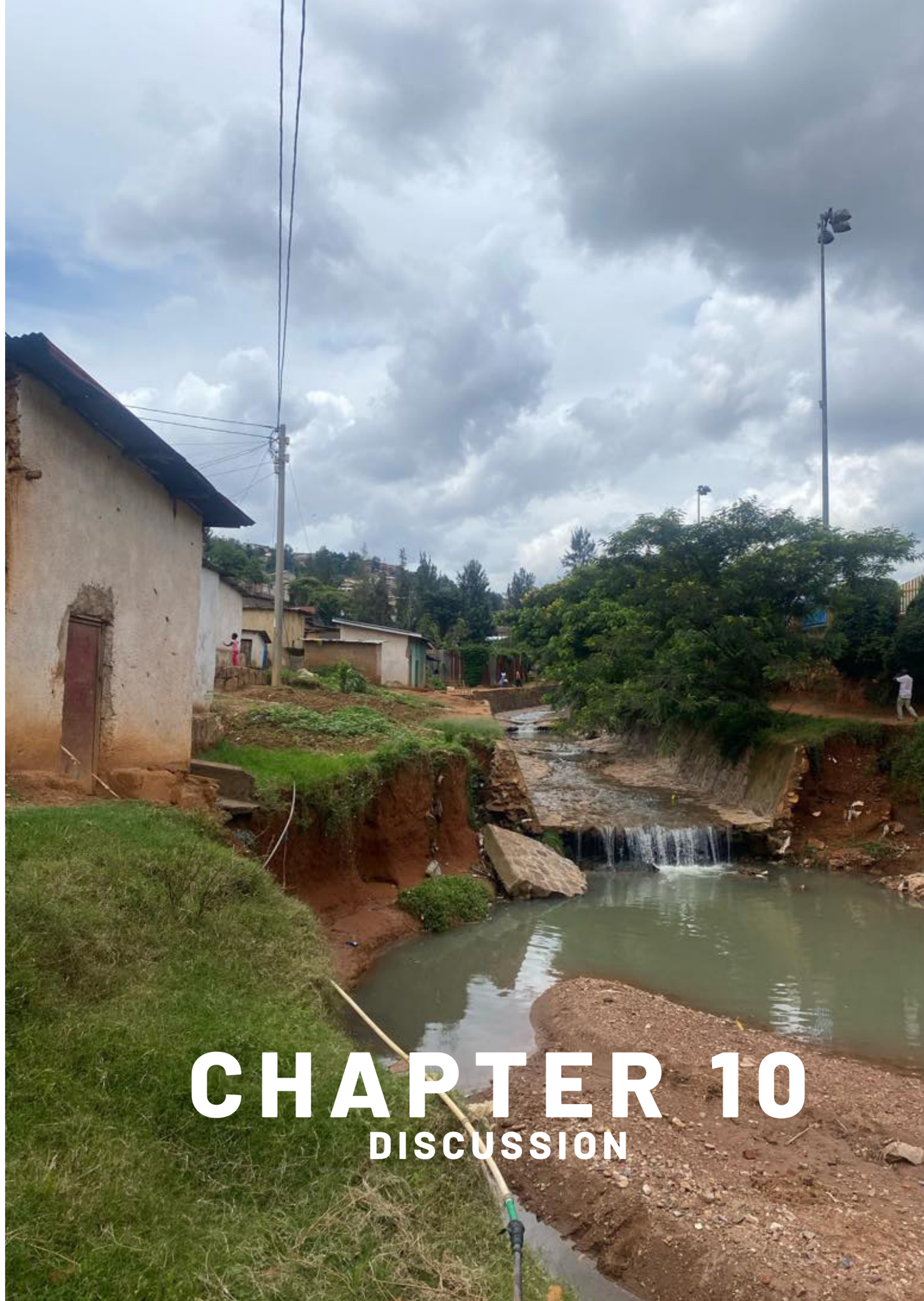
Figure 18. *Findings from the Analyses indicating NbS Stabilising as a Novel Innovation (Own figure adapted from Geels, 2005)*

SUMMARY

The analysis investigates the use of NbS in the city of Kigali as climate adaptation measures, and how far along the novel innovation is in the sustainability transition from niche to norm. The findings from the analysis indicate that NbS are sporadically used in the City of Kigali, and propose that they have entered the second phase of the sustainability transition, which is the stabilisation phase. The hitherto introduced NbS in the city predominantly focuses on various wetland restoration initiatives and smaller-scale greening in urban areas. Interventions aimed at rehabilitating degraded ecosystems, increasing biodiversity, and general beautification of the cityscape.

In other words, the novel innovation has gained a foothold in the urban planning and stormwater management practices in the Rwandan capital but is yet to fully diffuse and disrupt the existing regime. As such, the transition of NbS from being a niche innovation towards becoming standard practice is a slow moving paradigm shift towards turning back to nature.

The further transition of NbS depends on how and if the novel innovation is able to overcome a range of different obstacles including financial and institutional barriers, path-dependent policy structures, design-related challenges, and locked-in mindsets of important stakeholders. The following Chapter 10 discusses these barriers to the further transition of NbS from niche to the norm, while Chapter 11 elaborates upon how these barriers can be broken in order to inform local urban practitioners on how to approach NbS as a socio-technical novel innovation to enhance urban resilience and adaptive capacity.



CHAPTER 10
DISCUSSION

BARRIERS AND CHALLENGES TO THE SUSTAINABILITY TRANSITION OF NBS FROM NICHE TO NORM

The previous exploratory analyses show that the urban planning regime in Kigali focuses on engineered solutions while failing to address the continuous challenges of urban flooding and aggravated urban sprawl. Likewise, the analyses suggest that Nature-based Solutions (NbS) have emerged into the socio-technical system of urban planning and stormwater management of the city as a novel alternative. Certain aspects of the analyses necessitate closer elaboration, evaluation, and discussion, this Chapter seeks to do so, by reverting back to the questions concerning barriers and challenges of the sustainability transition of NbS from niche to norm. The findings from the analyses and wider literature success that barriers to incorporating NbS are traditionally seen as financial, institutional, and policy-related, in addition to practical challenges with design, implementation, and maintenance. The overarching theme throughout these barriers is the limitations set out by path-dependent mindsets and processes. The barriers differ depending on stakeholders and scales and this discussion seeks to detangle the complexity of the sustainability transition by centring on these challenges.

1 FINANCIAL BARRIERS

Inequitable Funding Systems. The previous analysis, which explores the slow paradigm shift toward NbS, suggests that the sustainability transition is stagnant in the second phase, stabilisation. When discussing barriers to sustainability transitions and systemic changes in general, there is no getting around the economic perspectives and the role of funding structures. In the world of development work, aid, and climate change capitalism, conservative and traditional systems can block factors that prohibit novel innovations from emerging.

In Rwanda, foreign development aid constitutes around 16.7% of the National GDP and more than 40% of the national budget, corresponding to $1 million USD a year. Hereby, the country receives the highest amount of donor aid in East Africa measured per capita, at $85 USD in comparison to $60 USD in Kenya and $43 USD in Uganda (Bertelsmann Stiftung, 2022). In other words, international economic donations have a considerable macroeconomic say in the country. Some scholars believe that the Rwandan economy could collapse if international aid is substantially curtailed (Bertelsmann Stiftung, 2022).

John R. Gakwavu shares the concern that the nation has become too reliant on international aid, further stating that "*Rwanda is improving but is still so, so reliant on international funding, and it is an issue for this kind of initiatives [NbS] as well*" (Appendix 9). He continues to elaborate upon how the issue is visible in all layers of governance, highlighting that especially Non-Governmental Organisations (NGOs), such as RECOR, depend on international funds to be able to carry out projects, "*The majority, more than maybe 70%, of funds, come from international funding and donors such as the EU, UN, and foreign governments*" (Appendix 9).

As implementing organisations have contractually-bound obligations to their donors, they might lack creative freedom to shape projects. In the best cases, RECOR collaborates with the donor part when preparing project proposals, but in other cases, they are not involved throughout the planning phase. As such, problems may arise if there is a discrepancy between the expectations of the international partner and what is possible to execute in reality. This is a common problem, where the financial system, dominated by foreign stakeholders and funding, situates organisations, and the general urban planning regime, in a vulnerable and locked-in position.

Uncovering this barrier underlines the importance of creating a local anchor and foundation, incorporating local knowledge, and including experiences of the local implementing part in development and aid initiatives, as further discussed in the following section. Gakwavu and his organisation are well aware of the existing unsustainable financial systems but articulate how challenging it is to change the discourse. While the Rwandan government has some funds accessible for NGOs, such as RECOR, banks are only allowing private companies to take out loans, wherefore "*capital is always a problem*" for non-profit organisations (Appendix 9). It is furthermore challenging for NGOs to make use of these services as their activities are inherently difficult to monetise. The path dependency seen here reinforces the current financial system, as organisations have few alternatives to international funding when it comes down to finance their activities.

Imelda Dada Bacudo, a Senior Consultant and Expert in Climate-Smart Agriculture, Land Use Policy, and Climate Finance, further elaborates on the challenges of foreign donors. In her experience, most financially aiding entities tend to believe that "*donor money has to return to the donating country in the end*" (Appendix 5). This highlights the fact that foreign aid organisations have their own overarching agenda, which may not always align with the interests of the receiver. For this reason, bias and trained incapacity might be building up in these institutions, overlooking local knowledge in principal decision-making processes for the benefit of employees from the donating country (Appendix 5). She further states that "*On paper, they would say that they would have policies that deal with equal opportunities, but the reality is something else*" (Appendix 5).

Other stakeholders are hesitant to label capital as a problem in urban planning and stormwater management in Kigali. The Rwanda Water Resources Board (RWB) states that the government is investing a lot in flood protection and that development partners are always aligning "*with the vision of the government*" (Appendix 7). In addition, the close collaborations with international donors, such as the World Bank, have positioned Rwanda as "*a sustainable and successful development partner*" (Bertelsmann Stiftung, 2022, p. 33). Which highlights how foreign and local collaboration can collaborate successfully. The fact that organisations such as the World Bank continuously take on development projects and engage in project work in Rwanda, and that they are repeatedly invited back to partake in these projects indicate that there are mutual benefits from both sides of the collaboration.

It is also important to emphasise that financing and capital do not have to obstruct sustainability transitions, as financial restrictions and pressures can foster new economic systems. Unlike traditional infrastructure initiatives, studies indicate that NbS necessitates novel funding solutions and structures that include a thorough assessment of costs and benefits. Therefore, proponents of NbS, such as the Water Adaptation Community (WAC) dedicate time and resources to developing such funding solutions centring on the profitability of potential investments in NbS. Focussing on Kigali and the cases of wetland protection in the city, an analysis of a "*market-based repayable financing model*" shows "*a potential Economic Internal Rate of Return (EIRR) of about 22%*" (WAC, 2021, p. 3). Findings like these can facilitate the acceleration of the NbS agenda in Kigali, as evidence of their revenue-generating abilities are justified (WAC, 2021).

Likewise, Dr. Saleemul Huq addresses financing issues not as a restraining factor but as an enabling element that can foster new thinking, "*obviously the biggest barrier is always financing and resource, but that does not mean within whatever resources are available, we cannot do something. We have some capability. We can do something within these frames*" (Appendix 1). Instead, Dr. Huq highlights issues concerning having large-scale international involvement in urban planning and development initiatives, including the implementation of NbS in Kigali. During the interview, he expresses concern about lacking local institutional capacity aggravated by the work approach of international entities, disregarding the importance of local capacity building and empowerment.

INSTITUTIONAL BARRIERS

The Role of International Experts and Organisations. According to Dr. Huq, a consequential barrier limiting the transition of NbS from niche to norm is the institutional challenges and problems of locked-in planning trajectories, "*There is a lack of incentives to do things. There is a traditional way of doing things, which is difficult to challenge and innovate and do things differently*" (Appendix 1). He elaborates and underlines the possibilities of breaking established path dependencies and trained incapacities by building local capacity when stating, "*We have to make progress by developing this [institutional] capacity to generate and use the knowledge at the national level*" (Appendix 1).

In the interview, Dr. Huq expresses how capacity building is one of the most central tasks of international organisations working with and in developing countries. Organisations like his own, ICCCAD, must help "*build the capacity of the country itself so they can carry out the research that they need themselves*" (Appendix 1). While this argument builds upon the need to foster synergies and collaboration across borders, it also articulates that building local capacity is necessary to ensure the long-term impacts of development initiatives.

External organisations that fail to build local capacity are often referred to as fly-in fly-out or parachute experts. The terms are almost self-explanatory and originate from a type of employment method commonly used in remote areas where workers are flown in on-site for a short period and then flown home again. Today, the term also covers a negatively charged description "*whereby foreign consultants or "experts" provide short-term, project-based technical assistance*" through means that may both be ineffective and damaging to local capacities (Westoby et al., 2021, p. 1).

In the eyes of Dr. Huq, the so-called fly-in fly-out experts "*are useful ... but that is not good enough. That does not help. It does not leave much behind*" (Appendix 1). Westoby et al. (2021) add to this perspective and highlight that there is a general tendency "*for adaptation [projects] to be driven by, and over-reliant on, external 'experts' and resources, which can diminish local self-efficacy, agency and overall adaptive capacity*" (Westoby et al., 2021, p. 1).

The Senior Urban Planner from Surban Jurong (SJ) highlights how capacity building became a central part of the updated Kigali Master Plan (2020),

"*Although we did one year of hand-holding everything, the people we trained unfortunately left the country they went to other places - now the government was handicapped again. So, in 2018, when we did the new Master Plan, the entire methodology was focused on capacity building of the authorities and a larger awareness of the local people. So, we were just on the field in each and every village and every sector trying to explain how the Master Plan would impact them*" (Appendix 4).

This storyline likewise addresses a vital aspect of awareness-raising in the framework of capacity building. First of all, it recognises that SJ had an initial awareness of the government lacking capacity at the beginning of the project. Secondly, the fact that SJ was invited back by the Rwandan Government to update the plan shows that they were also aware that they did not have the capacity to undertake such a project without external resources. The Senior Urban Planner from SJ currently resides in Kigali to work with the local authorities on the execution and implementation of the most recent Master Plan. This highlights the efforts put forward by the SJ and by the Rwandan Government to ensure that the project succeeds long-term. Furthermore, it diminished the risk of SJ acting as a fly-in fly-out expert. However, it should be mentioned that the Senior Urban Planner from SJ does not have a long-term history with the project or the City of Kigali. She has been involved in the Master Plan project over the past two years, which is a short time considering the first Master Plan of Kigali was initiated in 2008. Another point to highlight is the fact that there is little evidence as to how much influence SJ have on the local processes, and how involved they are on a daily basis with urban development and decision-making processes.

Whereas SJ and the World Bank have a long history of working on projects in Kigali and Rwanda, companies such as Defacto Urbanism and Deltares are only hired on short-term, project-based, contracts. This gives rise to questions regarding how these organisations have roles and influence urban development in Kigali. In some ways, Defacto Urbanism serves as a fly-in fly-out expert, as they were hired on a short-term project to provide technical assistance in the form of a pre-feasibility study on the potential for NbS in Kigali. Defacto Urbanism is in this case hired as a client to Rwandan authorities and the World Bank, where the "*project provides insight ...)and supports the government of Rwanda*" (Appendix 2; Defacto Urbanism, n.d.). Zum Felde disclosed how employees from the design office were unable to visit Rwanda and experience the local conditions due to COVID-19 travel restrictions. This is a fundamentally challenging problem as none of them had insight into the local environmental and socio-economic context. Instead of visiting, the Dutch team used online workshops and meetings to form the basis of the project. Zum Felde reveals that it was a challenging process as no one was used to collaborating in such an environment (Appendix 2). The lack of local insight and knowledge is a disadvantage, especially since NbS are inherently site-and context-specific, it is as such challenging to design and plan for their implementation without this prerequisite (Seddon et al., 2020-b). The lack of local knowledge gives rise to the concern of Defacto Urbanism serving as fly-in fly-out experts, this is further evident in the lack of collaboration post finalising the project. There is no evidence of follow-up evaluation or monitoring or mentioning of any capacity building initiatives. Therefore, it is questionable whether the project has had a positive or lasting impact. This is although not solely a critique of Defacto Urbanism, as they are providing what the original tender requested, and if there was no mention there of a need or desire to incorporate capacity building activities, it is only fair that Defacto Urbanism does not go out of their way to incorporate it. This is rather a critique of the procurement process and project framework than of the employed consultants.

The analyses and conclusion of Defacto Urbanism have culminated in a pre-feasibility study assessing the potential implementation of NbS in Kigali. Zum Felde expresses how she is unsure if the study will lead to the actual implementation of any NbS. It is likewise unknown if they will use the findings or look further into the suggested areas presented in the study. The project officially ended in August 2020, yet the report has not been published, nor is it possible to obtain access. Whether or not the report will be made available is also uncertain (Appendix 2; Defacto Urbanism, n.d.).

The tendency in developing countries to rely on external institutions and resources in their climate adaptation and mitigation efforts has been found to "*diminish local self-efficacy, agency and overall adaptive capacity*" (Westoby et al., 2021, p. 1). As international entities continue to play a vital role in such projects, the external actors should explore the possibilities to partner with local institutions and organisations and "*act as 'enablers' that develop the capabilities of local actors to be self-sufficient and achieve diverse local objectives themselves, equitably and effectively*" (Westoby et al., 2021, p. 5). If international experts and organisations fail to do so by continuing to follow the parachute work model, most development and aid initiatives, including climate change adaptation and NbS in Kigali, are destined to be unsuccessful. Capacity building is one of many elements to consider to break this trajectory. Other related approaches include ensuring local empowerment, raising awareness, and creating a strong local anchor through locally-led adaptational initiatives.

LOCALLY LED ADAPTATION (LLA). Climate change adaptation requires an understanding of various expressions of climate change impacts through learning and records from individuals who have first-hand experience and are rooted in the local socio-ecological context (Chausson et al., 2020; Westoby et al., 2021). Thus, Locally-Led Adaptation is grounded on making use of local knowledge and builds on the understanding that initiatives should be "*led by those who best understand the problem and socio-political context*" (Westoby et al., 2021, p. 4). Furthermore, it builds on the notion that external experts should focus their efforts on avoiding the fly-in fly-out phenomena and instead take measures to fundamentally reduce the need and dependency for external aid, through means that "*support local autonomy*" (Westoby et al., 2021, p. 1).

In many cases, this is easier said than done. To ensure that projects leave behind a meaningful impact, local communities have to be involved, and according to Gakwavu, there are significant challenges in including local communities in urban planning in Kigali. One of the reasons is that development is taking place extremely rapidly, and it is therefore challenging to account for and understand changing demographic characteristics. During the interview, he elaborates on this concern, "*For me, the biggest challenge is simply, how to represent the community dimensions. So much is changing so fast and developing rapidly in Kigali and Rwanda*" (Appendix 9).

Bacuda also highlights the need for intermediaries to bridge the divide between the local communities and the technical and scientific community. She states that climate change adaptation projects and initiatives "*should be used in ways to teach themselves [local communities] self-reliance*" (Appendix 5). Technical expertise and knowledge are not always enough if the proposed recommendations and solutions are not fit for the local context. This is evident in terms of addressing the actual local challenges, in terms of the local abilities to actually implement solutions, and lastly, in terms of their capacity to maintain implementations to ensure long-term impact. For example, in the case of Defacto Urbanism, it is uncertain whether their suggested typologies of NbS are fit for the local context. The lack of incorporating local knowledge is unfavourable as local communities inherently know the extent of the challenges they are facing and the local context-specific attributes. Welborn (2018) highlights the need for external organisations and experts to include local actors in developing countries, stating that "*Local communities and their knowledge of the climate will be indispensable resources as Africa confronts harsher and more increasingly erratic climates*" (Welborn, 2018, p. 9). As such, the role of local citizens can not be disregarded and should be ensured through participatory approaches and projects grounded in locally-led initiatives.

Whilst the focus on LLA is important, it is not a stand-alone solution. It is relevant to emphasise the fact that LLA should be viewed as an approach to complement all efforts made by development organisations. It should not be seen as a reason to diminish the value and importance of external development organisations. Rather it should be seen as an opportunity to maximise the impact of implemented climate adaptation measures, by combining expert local knowledge from local communities, alongside local private-, public- and civil society organisations, with the expert knowledge of external development organisations. LLA should be used as a means to bridge the gap between local and international actors. Ultimately this ensures that projects are anchored locally, which fosters their long-term success and circumvents the fly-in fly-out phenomena (Westoby, 2021).

Linked to the need for climate adaptation measures to be locally led, is the need to focus on how existing policy structures contribute to effective measures to facilitate urban development, which is resilient to the impacts of anthropogenic climate change.

Image 36. *Plants for Urban Greening*

REGULATORY BARRIERS

Existing Policies Favour Climate Change Mitigation in Preference to Adaptation. Compared to other nations in East Africa, Rwanda is seen as a frontrunner in terms of climate mitigation strategies and goals, "*On paper, Rwanda ranks high regarding its commitments to environmental protection, sustainability and climate change mitigation. However, the practical implementation remains wanting and inconsistent. Economic needs are perceived as more important than environmental concerns*" (Bertelsmann Stiftung, 2022, p. 24). Furthermore, there is a clear gap in the prioritisation, development, and implementation between climate change mitigation and adaptation efforts. This issue is evident in the lack of adaptation policies and focuses on mitigation initiatives in Rwanda, as explored in Chapter 8 (Table 6, p. 98).

The focus on climate change mitigation strategies is unfavourable in a city such as Kigali, where the impacts of climate change are already creating problems, particularly the challenge of urban flooding, as explored in Chapter 7. Therefore, it is problematic to emphasise the reduction of greenhouse gas emissions (GHGs), rather than increasing resilience to the recurring environmental hazards the city is experiencing. The City of Kigali should concentrate their political and policy efforts on dealing with the urgent need of adapting to these changing climatic conditions as they are projected to have an increasing impact in the near future.

Currently, the intention behind many adaptational projects and implementation of NbS originates from plans and goals which deal with mitigation practices rather than enhancing urban resilience and adaptive capacity. Several of the smaller-scale NbS cases explored in Chapter 9 are facilitated by a set of goals aimed at reducing GHGs and greening the city for the purpose of beautification. Examples include the urban greening of the Central Business District (CBD) of Kigali, particularly the Car-free Zone project centring on reducing CO2 emissions of the city centre. Although the project involves urban greening and measures to manage urban stormwater, these implementations come secondary to the primary objective of emission reduction and creating a space that fosters recreation and tourism. This notion is further evident in projects involving greening alongside roads and urban parks, as these are largely implemented for the sole purpose of improving the visual identity of the cityscape. Here, it is once again evident that the solutions are not implemented for their environmental benefits. In these cases, adaptational capacity is secondary to other planning goals and is often perceived as a side-effect rather than a focus of efforts. By the means of this, residents and local urban practitioners often do not regard or interpret these interventions as actually falling within the category of NbS - with good reason.

According to Welborn (2018), both paths of climate action, mitigation and adaptation, are rudimentary in urban planning, and are most successful when integrated (Welborn, 2018). She attributes this to the fact that no single strategy will be entirely sufficient in covering all environmental, social, and economic issues at once. Furthermore, findings suggest that efforts to reduce the impacts of climate change and enhance climate change adaptation, and financing thereof, must be addressed simultaneously in transformative initiatives (Welborn, 2018). Slightly contradicting this argumentation, the Intergovernmental Panel on Climate (IPCC) states that local responses to climate change in terms of adaptation are urgently needed, and must centre on creating or enhancing resilience and adaptive capacity at the community level (Niang et al., 2014).

No matter the argumentation, there is a wide disparity in the prioritisation of the two climate action pathways when assessed through the lens of policies and finance. Recent assessments state that only 10% of global climate finance was allocated to climate adaptation and creating adaptive capacity around the world (Westoby, 2021). This is a significant issue as climate change will continue to worsen and the impact will become increasingly more hazardous. Climate change adaptation should be the immediate task at hand for Kigali and the rest of the African continent (Welborn, 2018).

As local policies fail to address the need for climate adaptation, examples of NbS implemented to enhance urban resilience are scarce in Kigali. The following section discusses how missing best practice examples of NbS to urban stormwater management in the Rwandan capital, and the rest of the world, curb the further transition of the novel innovation.

Image 37. *Kigali City Hall*

DESIGN & DATA BARRIERS

Poor Best Practices and a Lack of Scientific Evidence. One of the vital barriers to the transition towards integrating NbS in urban planning in Kigali, and many other places around the world, is the lack of best practice examples to draw learning from. Moving beyond just the case of Kigali, Rwanda, there is a range of particular challenges of working with NbS in climate change adaptation that have to be addressed. As articulated in the present study, an overarching theme is the lack of knowledge on best practices in terms of implementation. In hand with this challenge is the missing scientific evidence documenting the actual impacts of implemented NbS.

While NbS can be used strategically and equitably to assist societies in addressing a wide range of climatic and non-climatic concerns, there is still little scientific evidence on their actual impacts on flooding and other climate-related issues. Going back to the case of Kigali, Uwera et al. (2020) find no evidence of reduced flood risk in Kigali when analysing the currently implemented green infrastructures of restored wetlands, as explored in Chapter 9. Contrarily, the study concludes its analyses by stating, "*the initiated Green Infrastructures (mainly wetland) did not contribute to reducing flood risk in Kigali city*" (Uwera et al., 2020, p. 123). There is a range of factors that contribute to this conclusion, first and foremost, the lack of sound methodologies for assessing the impact of implemented solutions. In the study by Uwera et al. (2020) there is no baseline to evaluate impact against, nor is it certain that the parameters they have used represent the actual adaptive capacity provided by the restored wetlands. Situations such as these add to the challenge of transitioning NbS from niche to norm as it contributes to the overarching problems of understanding and communicating the impact and influence of their site-specific introduction. Hence, local practitioners are often met with mistrust and uncertainties when advocating for NbS in climate adaptation and they hinder further design and implementation of the solutions. This is further exacerbated by the challenges of measuring, assessing or quantifying the indirect impact and potential co-benefits, as the spatio-temporal boundaries are blurred and challenging to define.

Zooming in on the Gikondo wetland in Kigali, as explored in Chapter 9, the missing monitoring and evaluation efforts make it questionable whether the restored area has fully returned to its original natural state, with the same natural ecosystem and capacity as a flood buffer. Nor is there a baseline to compare against. The missing assessment of the actual effects of wetland restoration projects is a general issue in the City of Kigali, and there is a prominent need to improve such efforts. Gakwavu elaborates upon the challenge of implementing evaluation and monitoring plans, stating that "*You can have good documents and strategies and visions, but there will still be a gap in the implementation. So that is currently a challenge*" (Appendix 9).

Due to the lack of focus on implementation, evaluation, and monitoring of the action points and projects, it is almost impossible to conclude the outcome of restoring the Gikondo Wetland. This amplifies the gap between plans and implementation in practice. The missing benchmarking aspects add to the continued uncertainty of the effect of NbS on urban flooding in terms of quantifiable data and stand as one of the main barriers to the acceleration of NbS transitioning from niche to norm in urban planning practices in Kigali.

The lack of official documentation on the restoration project could be attributable to the project not having entered its final stage, and as such not being officially completed. The interviews, site visits, and the literature do not agree on how far the restoration process is. Gakwavu, Abias Mumuhire from the City of Kigali, and the The Senior Urban Planner from SJ all agree that the restoration process has been completed (Appendix, 4, 9, 10). Where he later specifically states that the wetland "*is restored back to its original functioning level*" (Appendix 4). This contradicts existing literature, which states that rehabilitation "*is not complete due to lack of funding*" (Krishnasamy et al., 2020, p. 155). Once again, the financial barriers seem to have an influential vote in the implementation of NbS, as discussed previously in this Chapter. Upon visiting the wetland, it is evident that the area has not been completely restored to its original wetland state, although it is evident that some of the areas are currently left for ecological succession. The wetland is now completely abandoned by industrial activity, but once the industrial activity left, and the area was cleared of built structures, local communities started using the area. Components of the wetland habitat are now used by local communities for small-scale subsistence farming. It is uncertain whether these activities will be allowed to commence, and if the area will become increasingly used for crop production by local communities in the future.

As discussed above, one of the primary challenges of implementing NbS emerges from a lack of best practice examples to lean against, both in terms of the blueprints of projects and initiatives and in sound, qualified argumentation of investments in NbS. The missing evaluation and monitoring practices deepen the challenge and limit the creation of incentives and scientific knowledge backing up the argumentations. These circumstances make it difficult for NbS-advocating practitioners seeking to change the locked-in urban planning regimes. Their job is further complicated by a path-dependent perception of how to carry out urban planning and stormwater management. The following section takes up the discussion of shifting perceptions of existing planning practices.

MORE THAN A PARADIGM SHIFT

Shifting the Mindset of Stakeholders. Advocating for the use of NbS in urban climate adaptation projects can be difficult as it challenges traditional planning practices. Being an Urban Designer and practitioner advocating for the use of NbS in urban planning, zum Felde introduces what she believes is the most considerable barrier when stating, "*The limiting factor is always that they [clients] want new solutions, but with the same old approach and that does not work. So they expect to have the same accurate model for NbS as for technical interventions. They want to have the same exact budgeting and the same detailed maintenance scheme, but you cannot control nature. That is also the power of it*" (Appendix 2). In this way, she articulates how a path-dependent mindset of accustomed practices highly influences urban planning and stormwater management and limits the creativity and possibilities of NbS.

Likewise, working at the intersection of grey and green solutions comes with challenges. According to zum Felde, as soon as you integrate green and grey infrastructures, the development of maintenance plans turns into a compound task where local conditions have to have a central role. There is a wide range of new parameters that have to be considered when introducing NbS in planning practices, zum Felde elaborates on this, stating , "Y*ou do not know how often you might have to maintain or maybe even replace the plans. You have to find that out yourself - from scratch - because that is very specific to the site, to the weather conditions in different seasons in different years*" (Appendix 2). This highlights the need for novel practices for monitoring and maintaining the implemented solutions that account for the dynamic nature of NbS because they are inherently different from traditional engineered solutions for climate adaptation.

She adds to the issue by explaining how she believes future challenges of NbS are going to build upon the current trajectories of planning practices revolving around the mindset that clients want to keep the "*same approach, but for different solutions and for us to be innovative, and that is impossible*" (Appendix 2).

Adding to the complexity of climate change adaptation and urban stormwater management is the fact that it is troublesome to propose NbS as an alternative to engineered solutions because they function on different spatiotemporal scales. In many cases, it might not even be possible to compare the two approaches. The incomparability hampers the transition of NbS as the argument for using these solutions naturally worsens, making it more difficult for advocating practitioners and decision-makers to replace the known and measurable engineered solutions with the novel and more unpredictable NbS. This highlights the need to not view NbS and grey solutions as two individual pathways or conflicting pathways, but as solutions that can be integrated symbiotically (Chausson et al., 2020; Seddon et al., 2020-b).

During the interview with zum Felde, it becomes apparent that some stakeholders are ready to use and implement NbS in urban planning and as a climate-adaptive measure. However, the path dependencies and locked-in thought processes from the existing planning regime are difficult to break down and hinder their emergence. In other words, there are many vital stakeholders with good intentions regarding NbS, but as long as clients and other stakeholders expect to get the identical outcomes as from engineered solutions, the transition will end at a standstill at the stabilisation phase of the current trajectory (Appendix 2).

The above sections discuss and explore the current barriers to implementing NbS in urban planning and stormwater management in Kigali. Antagonists of NbS might highlight these discussion points as weaknesses and fuel a discussion questioning whether NbS is the rightful novel innovation to transition the current planning regime to accommodate the development challenges of the city. Therefore, it is equally important to consider whether NbS is the right trajectory to be pursued in Kigali, considering the urgent issues of recurrent flooding events. The following section elaborates upon the urgency and how NbS might struggle to accommodate the acute need for enhancing urban resilience.

Image 38. *Soil Erosion in Katabaro*

TURNING BACK TO NATURE

Is Turning Back to Nature the Best Trajectory for the Future Planning Paradigm of Urban Stormwater Management in Kigali?. Recently, Kigali has experienced devastating events of flooding in several parts of the city and country (Appendix 6 and 11). Both Hussein Bizimana and the The Senior Urban Planner from SU articulate the urgency of recent and recurrent floods. Further elaborating that "*It is evident that because of steep slopes, there is a lot of flooding happening here [Kigali] …)we need to manage the water and ensure that no lives are lost and that people are not living in the ways of these floods*" (Appendix 4). Bizimana adds to this haste by articulating the hindering impacts of urban flooding on the sustainable development of Kigali and Rwanda, "F*loods are the biggest barrier to us reaching our vision of 2050. The country will not be a high-income country by 2050 if floods keep coming and destroying everything*" (Appendix 7).

Likewise, time is a significant matter when it comes to urban flooding in Kigali. Bobby Russell sheds light on the contrast between preparing for future impacts and planning for current urban floods, "*Time is probably the hardest thing as these problems [urban flooding] are occurring now. We tend to talk about climate change and planning for the future, but in Kigali, climate change is occurring right now …)The city has problems right now. They are not interested in talking about what is going to happen in the future. They need things fixed right now. They are not so interested in these extensive studies of the future*" (Appendix 3).

This argument undermines the rationale of previous flood hazard mappings, including the Blue Spot Mapping in the present study (Chapter 7). As suggested in Analysis 1, previous analyses and mappings of flood hazards in the City of Kigali are of different quality and spatial accuracy which unnecessarily reduces their usability and confuses and sometimes prolong the process of addressing this pressing issue. In the eyes of Russell, Kigali, Rwanda, and other countries in Africa do not need very technical analyses to map out where floods occur. Locals know where flooding happens and do not need either international organisations or national authorities to define hotspots as "*They are up to their waist in water every rainstorm*" (Appendix 3).
While urban flooding remains an urgent challenge for Kigali, recognised scholars, alongside the present study, recommend turning back to nature to enhance urban resilience through the implementation of NbS. Several scholars and literature attribute and concentrate on NbS as a perfect solution to a range of different urban challenges, including urban flooding, densification, and combating the degradation of biodiversity and ecosystems (Acreman et al., 2021; Chausson et al., 2020; Frantzeskaki et al., 2019; Seddon et al., 2021). Whereas nature has a strong ability to provide ecosystem services, there are potential negative aspects of advocating for nature as a proposed dominating solution to climate change and its cascading effects. In the case of Kigali, where most implemented NbS centres upon wetland restoration and rehabilitation, Russell enters this point of discussion when stating that urban planners of Kigali "*thought if they restore the wetlands, it will soak up the floodwaters and by regreening them, and removing the river channels and turning them into true valley bottom wetlands, flood risk would decrease. However, today there are no drainage channels through the new designs, and actually, the flood depths got bigger*" (Appendix 3). This underlines the fact that it is challenging to predict how natural environments and ecosystems will respond to interventions, such as NbS.

This argumentation ties fittingly into the restoration and rehabilitation case of Gikondo, as explored in Chapter 9. While the Gikondo wetland, to some extent, has been restored, the communities located at the lower elevations of the valley bottom are still at risk of floods and other environmental hazards such as soil erosion. Building on Russell's concern about increasing flood depths in restoration projects, it is an area of concern whether the Gikondo wetland will provide sufficient adaptive capacity. Although the area may provide a great buffer in the event of heavy precipitation, there will be a point where the area breaches its water holding capacity. This, in turn, may lead to flooding of nearby areas, which in this case are predominantly inhabited by informal settlements. The area receives significant amounts of precipitation during the rainy season as rainwater runoff from the hilltops is directed to the wetland through the previously analysed network of drainage channels and water stairs intertwining with the communities. As the hillsides are densely developed by informal and formal settlements, the water flows directly through the communities. The stormwater channels have proved to be insufficient in events of heavy precipitation, as they do not accommodate the high velocity and great masses of water during the rainy season. Thus, the rainwater runoff regularly causes upstream floods with subsequent damage to the buildings on the slopes, where the informal settlements are disproportionately affected due to poor infrastructures and building materials, as explored in Chapter 8 (Appendix 10). Indicating that in the proximity of the Gikondo wetland, there is both an issue of upstream and downstream flood hazards, and downstream wetland restoration alone is likely not enough.

Russell enters this subject of conversation during the interview and addresses wetland and flood management of Kigali in a bit more critical way, "*I firmly believe that they [Kigali] should restore the wetlands, but upstream. … if you are going to do these valley bottom wetlands, do them way upstream. Do not do them right at the very bottom where the flood problem is*" (Appendix 3). Instead, he argues that NbS likewise should be implemented "*strategically from upstream to downstream*" (Appendix 3). He adds by saying that rainfall should instead be captured at the hilltops, slowed down on the slopes of the hills and quickly be diverted at the valley bottom towards river outlets (Appendix 3). This highlights the need to understand the complexities of the urban hydrological cycle and how NbS can be implemented at different scales in a vast variety of typologies.

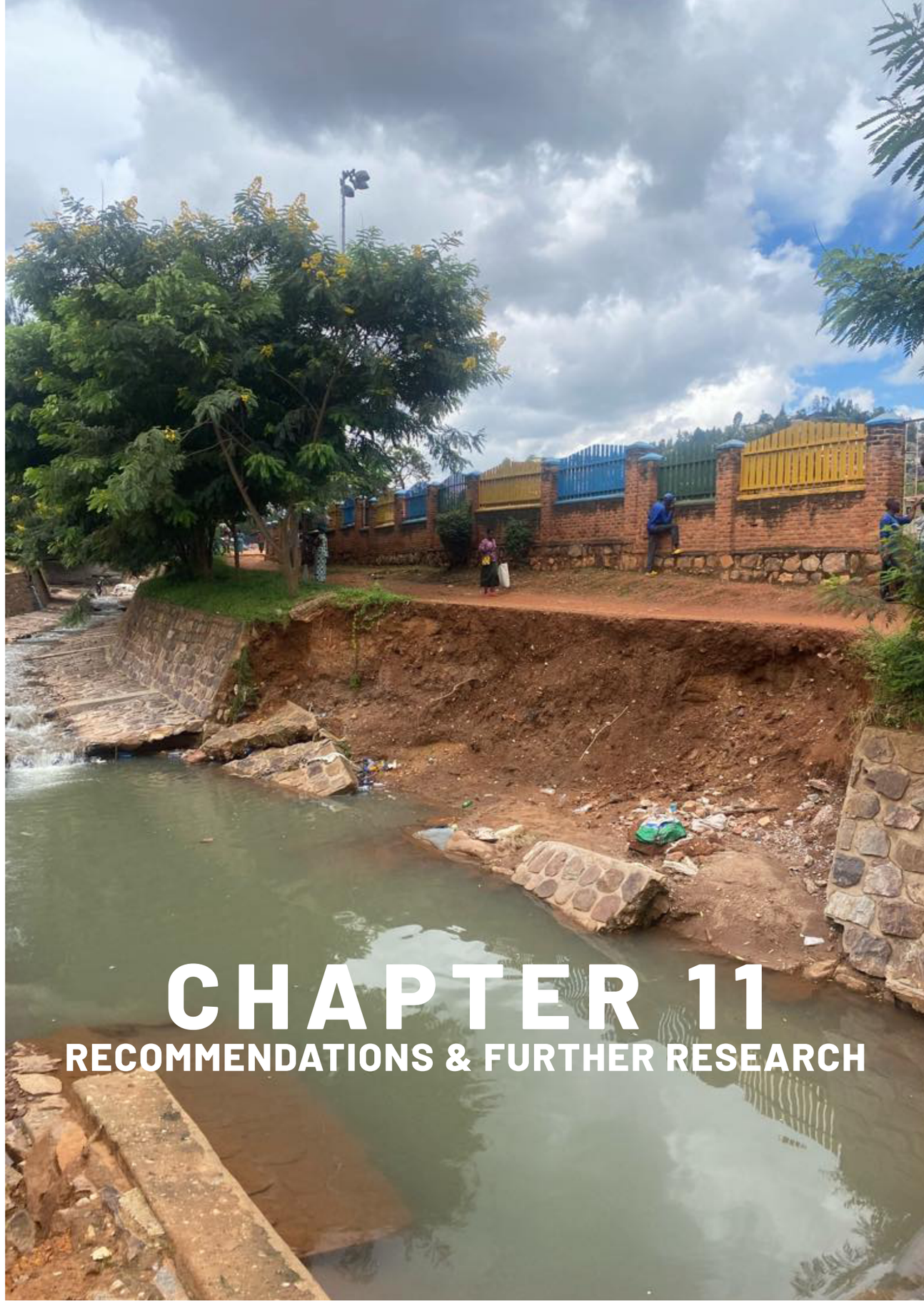
To fully harness the potential to increasingly integrate NbS in climate adaptation and urban planning practices, there is a need to foster synergetic thinking between green and grey solutions. Seddon et al. (2020) highlight the need for "*Moving beyond pitching green solutions against grey*", and instead focus on how solutions can be combined to increase adaptive capacity (Seddon et al., 2020, p. 7). NbS and grey interventions should not be framed as equal counterparts, they should be framed as components of the same solutions. As such, planning practices in Kigali should focus on ways to integrate these solutions, in order to create co-benefits and synergies to promote resilience to urban flooding. Such an integrated approach towards increasing adaptive capacity across scales, with the ability to "*address diverging stakeholder needs*" (Seddon et al., 2020, p. 8). This notion is further emphasised by Russell, stating that "*I am a firm believer that you need blue, green and grey structures, and you need to integrate them*"(Appendix 3). Highlighting the need to break down silos of traditional planning practices, that moves beyond the 'default approach' favouring engineered solutions (Seddon et al., p. 9).
In a concluding manner, the above-mentioned recurrent flooding events indicate that the existing planning regime and the novel innovation of NbS fail to address the issues of urban flooding in Kigali. Accordingly, justifications are suggesting and pointing in the direction of NbS being insufficient in dealing with urban flooding, at least in the way the solutions are implemented, at the moment, which is mostly wetland restoration.

SUMMARY

As evident in this Chapter, there is a large selection of barriers and challenges that hinders the further transition of NbS from niche to norm in urban planning and stormwater management practices in Kigali. These include a widespread dependence on an internationally funded financial system, low institutional capacity and knowledge of NbS, local policies neglecting the importance of adaptation efforts, and poor monitoring and evaluation processes for implemented initiatives.

Additionally, the Chapter discusses the path-dependent mindset of involved stakeholders and urban planning practitioners, which adds to the list of challenges hindering NbS from transitioning from the second phase of the trajectory, stabilisation, to further sustainability phases. These are all challenges that have to be overcome in order for NbS to reach their full potential as a sustainable, cost-effective and resilient means of adapting to climate change in the city of Kigali. The present study acknowledges that urban flooding continues to be an extensive challenge in the City of Kigali. It is evident from the preceding analyses and discussions that the present-day planning regime, paradigms, and trajectory of urban stormwater management in Kigali fails to address the environmental and climatic challenges the city is facing.

Concurrently, the present discussion indicates that the currently implemented initiatives of NbS in Kigali, most of which are wetland restorations, also fail to ensure resilience towards urban floods. This discovery gives rise to a conclusive remark centring around the need to incorporate other typologies of NbS, both upstream and downstream. Furthermore, that their use as stormwater management measures should be upscaled, and with time they will hopefully gain the foothold to become common practice in urban planning practices in Kigali and beyond. Based on the findings from the analyses and discussion of the present study, Chapter 11 recommends possible solutions and areas for further research to enhance urban resilience in the city and thereby accelerate the transition of NbS.



CHAPTER 11
RECOMMENDATIONS & FURTHER RESEARCH

ACCELERATING THE SUSTAINABILITY TRANSITION

To ease and accelerate the transition of Nature-based Solutions (NbS) from niche to norm in urban planning and stormwater management in Kigali and other parts of the world, the present Chapter presents central points of interest and recommendations for future urban planning practices and research.

1 FINANCIAL GAP

Microfinance and Local Funding. As evident in the preceding discussion, the current financial structures and funding systems based on international aid and donations pose a significant threat to the sustainability transition of NbS. Consequently, future research should look into how climate adaptation and the implementation of NbS can become more self-reliant and self-funded.

Research could look into how to establish sustainable microfinance services and how to promote funding initiatives like Village Savings and Loans Associations (VSLAS) in areas exposed to urban flooding to secure funding for Locally Led Adaptation (LLA) and owned (smaller-scale) NbS. In this way, NbS initiatives would rely less on international monetary aid and simultaneously create ownership and empowerment of the locals affected by the solutions.

As a means of accelerating the use of NbS, further research could also investigate the potential for implementing systems that incorporate Payment for Ecosystem Services (PES). This method is essentially an innovative approach that through financial incentives facilitates the conservation and maintenance of nature and the ecosystem services that natural habitats provide. PES is recognised as a strategic method to increase resilience towards climate change whilst simultaneously creating local ownership, a source of income and employment in local communities (WWF, n.d.).

2 INSTITUTIONAL GAP

Stakeholder Involvement, Raising Awareness, Capacity Building, Creating Empowerment and Local Ownership. As discussed in the previous Chapter, the long-term sustainability of NbS is closely related to raising awareness of the local problem and the benefits of the solutions and capacity building of local communities. In terms of efforts to manage urban flooding, building local capacity can be achieved through a range of methods. These include local stakeholder involvement and inclusion, knowledge-sharing, training local people, creating local empowerment and ownership, and ensuring that there is a willingness in the local community to take on maintenance tasks. Accordingly, this study recommends including these measures in NbS project objectives and local policymaking. These measures are especially essential in initiatives operating with external experts as they can ensure that the design, implementation, and maintenance processes of the NbS are locally-led, thus avoiding the fly-in fly-out phenomenon, as discussed previously.

3 REGULATORY GAP

Synergistic Policies and Projects. Politicians and decision-makers have the political power to change the status quo through legally-binding policies and ambitious strategies. Thus, the governmental bodies of both Rwanda and Kigali have a great responsibility to include climate change adaptation and NbS in future regulations to enhance urban resilience. Updating and even creating new policies should focus on identifying synergies (and potential trade-offs) across sectors and disciplines, including adaptation, mitigation, biodiversity restoration and conservation, energy, waste management, transportation, water supply and wastewater management. In addition, synergistic policies and project approaches, which do not focus efforts solely on NbS, are likely to lower the risk of creating a new silo and path-dependent planning regime.

The trajectories of grey and green solutions to climate change adaptation and urban flooding have deliberately been handled as two separate paths to highlight their differences in the present study. However, the reality is that the two portfolios of solutions often work well together. Future research should explore how to improve the existing structural infrastructures in Kigali by implementing elements of nature and NbS.

Furthermore, new policies regarding urban development should prioritise flood risk analyses, flood-prone zoning and climate change mitigation in the early development phases of any project. In such a manner, some urban flood challenges may be avoided as this insight will limit new development in flood-prone areas.

As outlined in the preceding analyses and discussion, upstream flooding continues to be a menace in Kigali. Therefore, adaptation policies must consider upstream flooding and adaptation to enhance urban resilience, which is not the case today. Uwera et al. (2020) recommend looking into the possibilities of upstream agroforestry, afforestation, and reforestation to reduce rainwater runoff and to conduct in-depth analyses of the feasibility and suitability of green infrastructure locations within the city to ensure their contribution to reducing flood risks (Uwera et al., 2020).

Consequently, further research could look into how upstream implementation of NbS can help slow down the velocity of rainwater runoff and ultimately shift peak flows. When looking into upstream adaptation, it is of high importance to ensure that the changes in the flow and river discharge do not result in two rivers within a catchment reaching peak flow simultaneously that previously did not. If this is the case, it can have the cascade effect of causing water to accumulate downstream with a higher volume and velocity. As the present study finds that upstream climate change adaptation is needed to enhance the urban resilience of Kigali, future research is recommended to look into site-specific locations for NbS in such places.

Finally, adaptation policies and regulations should include evidence-based targets and feedback systems to monitor the progress and whether initiatives reach these goals or not. This strengthens the data foundation for implemented NbS initiatives, which helps policymakers and local practitioners argue for their validity.

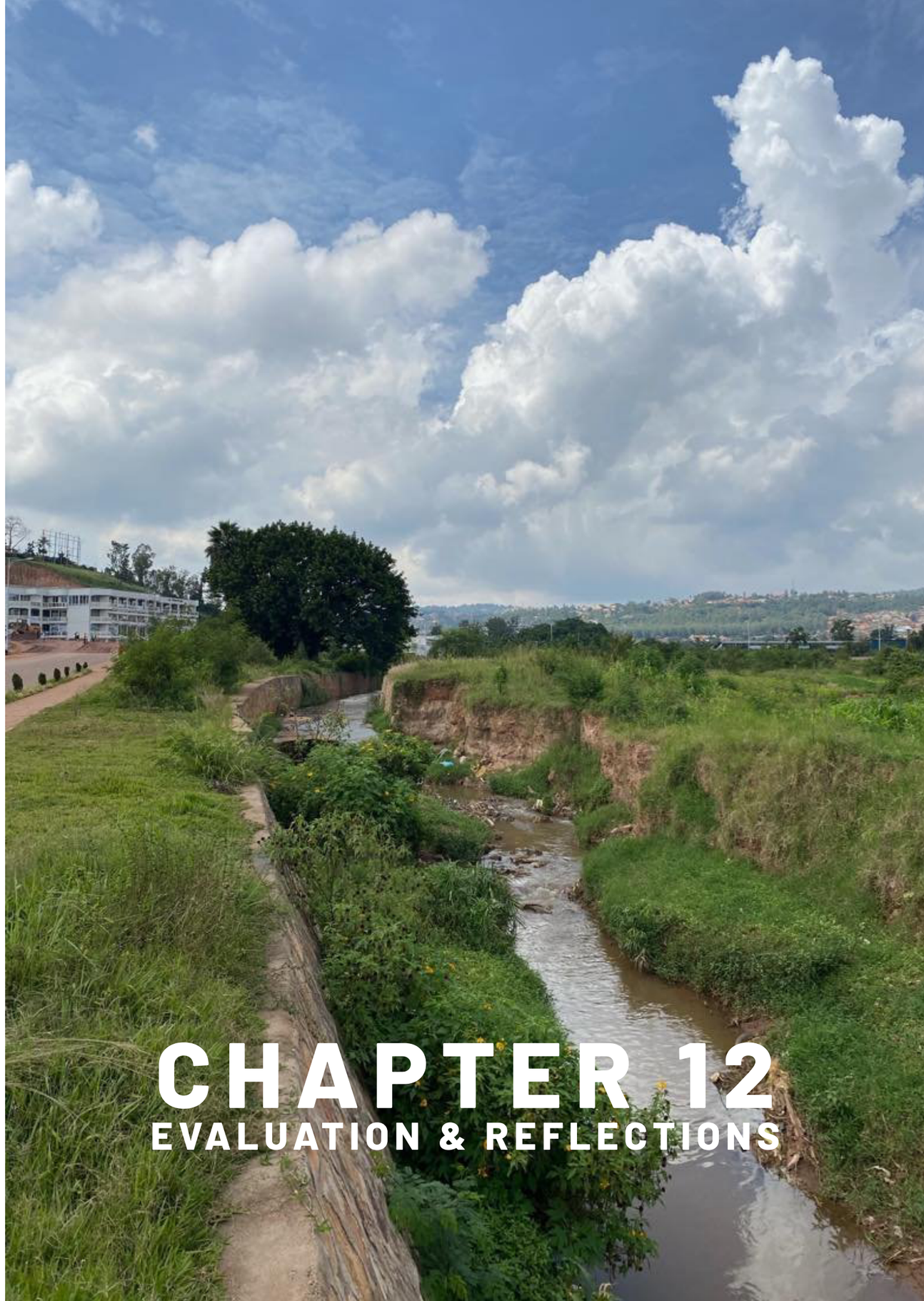
DESIGN &DATA GAPS

Monitor Implementation and Create Feedback Systems. As stated throughout this study, there is still a lack of best practice examples of NbS initiatives in climate change adaptation in East Africa, including Rwanda, and Kigali. To accelerate the transition of NbS from niche to norm, it is necessary to incorporate effective evaluation, ongoing monitoring processes, and feedback systems to assess the given solutions. These features will likewise ensure the quality of the given initiative, as reporting will be able to show gaps in the project or implementation. Additionally, such measures will enhance the data foundation for future projects and models. The learnings collected from the feedback systems must be communicated and made publicly available to encourage and inspire others to undertake NbS in climate adaptation and mitigation projects.

Make Data Accessible and Applicable. On several occasions, the present study has highlighted the pressing need to improve the existing geospatial data foundation for Geographic Information System (GIS) flood hazard modelling in Kigali. The quality and availability of spatial data needed for GIS modelling are poor, and even fundamental datasets on temperature and Digital Elevation Models (DEM) are both scarce and of low quality and accuracy. Therefore, there is a need to develop high-resolution data and accelerate the recording efforts of climatological data in Kigali, which should be of high concern for institutions responsible for flood hazard modelling, including the Rwanda Resource Water Board (RWB).

One way to obtain topographic data with high spatial resolution is to conduct a Light Detection & Ranging LiDAR survey of Kigali. The best available topographic model for Kigali is at a 30 m resolution. Although this is common in the area, European countries commonly have datasets with a resolution of 0.5 m open-source.

As the present study has found - and suffered from - a lack of open-source data sets for flood hazards and hydrological modelling, it is highly recommended to publish such data sets through open-source channels. It is a great misfortune to keep such data under bureaucratic barriers. The current Rwanda GeoPortal should be significantly improved and updated with all available datasets.



CHAPTER 12
EVALUATION & REFLECTIONS

EVALUATION OF FINDINGS & REFLECTIONS OF RESEARCH APPROACH

A variety of circumstances are likely to influence the findings of the preceding analyses and discussion. This Chapter aims to evaluate these findings alongside the employed methodology by elucidating how their credibility, validity, and reliability may be affected by subjectivity and bias. The Chapter rounds off by presenting reflections on the fly-in fly-out phenomenon in the present study, followed by thoughts on the importance of knowledge creation and sharing.

SUBJECTIVITY AND BIAS IN QUALITATIVE RESEARCH

Generally, subjectivity can be defined as the way a researcher's viewpoints, values, social experiences, and perspectives influence the research processes and, ultimately, the outcomes of the given study. According to the empirical-focused path of traditional scientific discourses, subjectivity is equated with personal biases due to the direct or indirect effect of the researchers in terms of data collection, sampling, handling, analysis, and presentation (Davis, 2017). All aspects are considered to have an invalidating influence on the findings of the given research. However, Davis (2017) argues that it is nearly impossible to undertake qualitative research without being affected by some degree of bias or subjectivity, for which reason, both discourses have an influence on the present study (Davis, 2017).

Another point to consider is that the insights and arguments received from the expert interviews are a central part of the empirical data collection of the study and form a strong qualitative basis for conducting the previous exploratory analyses and discussions. While external interviewees are selected based on their field of expertise and relations to Rwanda and Kigali, the selection of the local interview persons reflects a wish to represent different viewpoints from various layers of the governmental structures (Figure 16, p. 70). Representatives from the planning and implementing governance layer include the Rwanda Water Resources Board (RWB), the Council of the City of Kigali (CoK), and the Rwanda Environmental Conservation Organisation (RECOR). Due to specific research regulations in Rwanda, government institutions (ministries) and regulatory agencies (authorities) were not allowed to partake in interviews or share any information that could be used in the present study.

Each of the interviews bears marks of bias, some more than others. Depending on the individual relationship and investments in Kigali, each interviewee has an agenda that they want to put forth in the interviews. Sometimes this was pronounced, such as in the case of the The Senior Urban Planner from Surbana Jurong (SJ). Her personal bias is evident in her statements on the urban challenges and the effectiveness of the Kigali Master Plan developed by her company. Compared to interviews with local experts and practitioners (RWB and RECOR) as well as other international stakeholders (Defacto Urbanism and Deltares), she tends to belittle urban problems and instead bring up the qualities of the Master Plan, such as when she states that urbanisation and industrial pollution is not a problem in Kigali, that "*they are handling it absolutely fine*" (Appendix 4). On the contrary, Bobby Russell explicitly highlights the weaknesses of their analyses on flood hazards and makes an effort to underline problems and challenges. These instances exemplify the importance of being aware of individual agendas and biases and how they may affect findings.

Local interviewees likewise show signs of bias and subjectivity. Especially when asked to reflect upon central challenges within their field of expertise, they tend to highlight their strong sides rather than their shortcomings. This was, for example, apparent in the interview with John R. Gakwavu, when questioned about the extensive unplanned and informal settlements, and poverty levels in the city. The atmosphere in the room changed instantly. After a long break of silence, he answered in a subdued voice, it was apparent that he was uncomfortable talking about this issue. However, as he understood that the questions were not asked in a confrontational manner, neither towards his organisation nor the city of Kigali, he slowly elaborates on the challenges (Appendix 10).

The case journal comprising field notes of in-situ observations and photo documentation is another backbone of empirical data utilised in the preceding analyses and discussion of the present study. In this way, the researchers have taken an active role in the formulation of the argumentation and viewpoints presented in the analyses and discussion, as the field notes highly reflect subjective and personal takes on situations and observations. The field study has, however, been of critical importance to establish a deep understanding of the local conditions and challenges beyond what was possible to gather from literature, regulations, and projects. Therefore, the data derived from the case journal bridges gaps in the existing literature and helps paint a more detailed picture of the local circumstances of Kigali.

Even though subjectivity and bias are evident in the conducted research, several steps are employed to address this potential point of critique. Examples include inviting a broad spectrum of different interviewees to elaborate upon the same issues. This choice adds to the validity and reliability of the findings as information obtained from each interview is cross-checked with statements from other interviews. When viewpoints are deviating, they are held against each other in the discussion to bring forward the different perceptions of, for instance, barriers to the transition of Nature-based Solutions (NbS) from niche to norm. Reviews of relevant literature support the statements and viewpoints of the individual interviewees when possible to enhance the credibility and underline similarities and differences vital to understanding the complexity of urban planning and stormwater management in Kigali.

Conclusively, the qualitative empirical data collection methods employed in the present study are necessary to construct a valuable and detailed understanding of the challenges of urban flooding and the current planning process beyond what is described and reflected by relevant literature. In this regard, it is vital to emphasise that subjectivity and bias do not automatically invalidate findings, and as highlighted by Davis (2017) some degree of subjectivity is requisite to make sense of human behaviour and the social world (Davis, 2017). Consequently, the present study embraces the employed methodology and views and acknowledges the qualitative approaches as strengths rather than weaknesses.

TAKING THE ROLE OF FLY-IN FLY-OUT EXPERTS

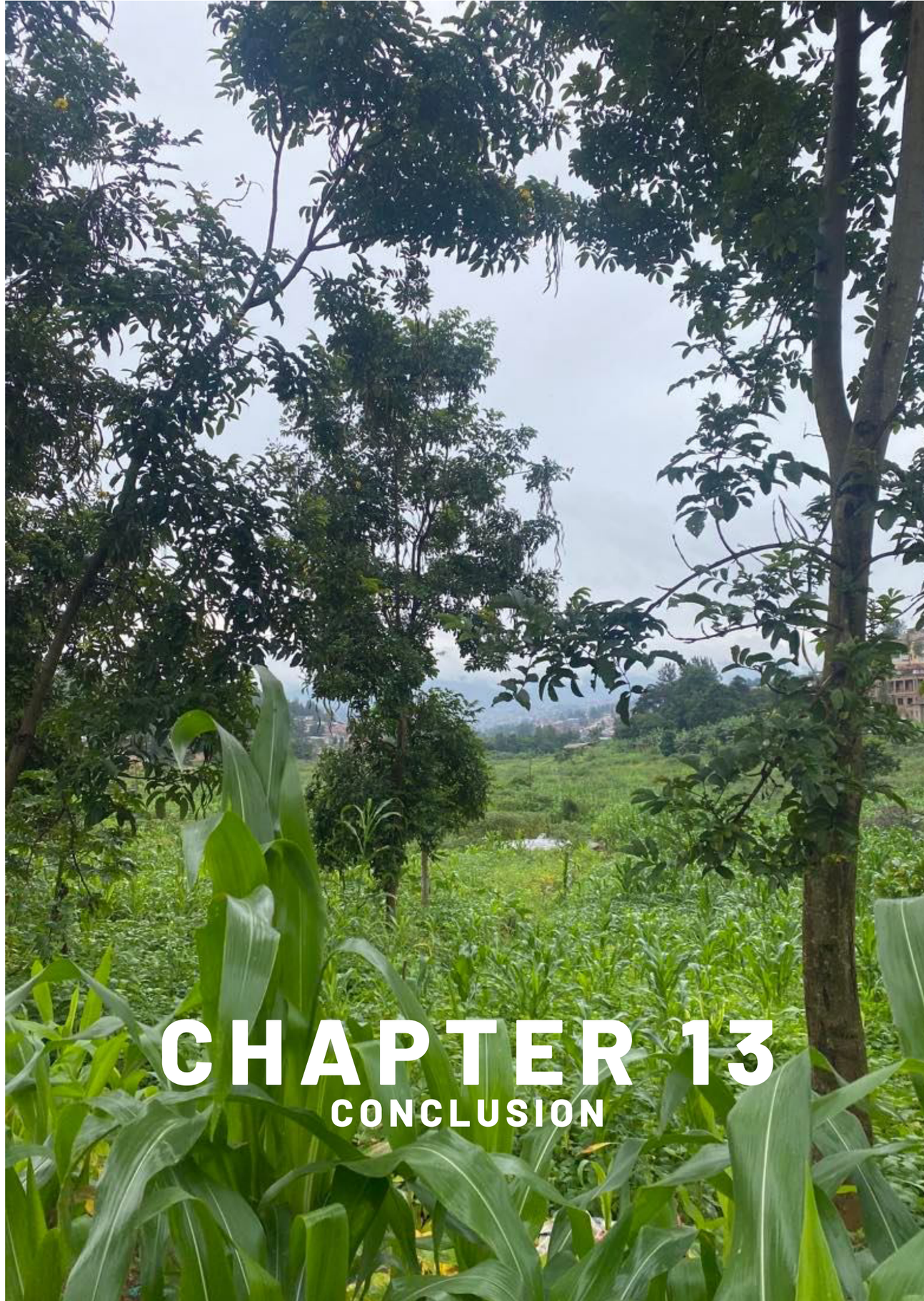
As explored in the discussion, Rwanda and Kigali are highly reliant on foreign aid, both in terms of funding and expertise in complex areas such as urban flooding, climate adaptation, and NbS. Among other things, the discussion centres upon the effects of the so-called fly-in fly-out structures. As the present study is conducted by external researchers in urban planning and stormwater management, it seems relevant to reflect upon how the study may fall under the fly-in fly-out phenomenon.

The most obvious and literal reason is the fact that the field study was conducted by the authors in the literal sense of flying in and then flying out of Kigali. While the study does not have a direct objective to contribute to local empowerment, capacity building, or local ownership, it hopes to inform local practitioners and other central stakeholders on the subjects of urban planning and climate adaptation in Kigali. It seeks to advise these actors on the challenges identified in their field of work, ultimately improving the current planning practices and paving the way for future research, specifically targeting the accelerated use of NbS.

When reflecting upon the phenomena of fly-in fly-out experts, it is apparent that external experts are, to a certain degree, needed in Kigali and the Global South, where current capacities are not able to address the severe challenges of climate change. Consequently, local governments and stakeholders often look upon the knowledge sharing and creation, capacity building, resources, and expertise from aiding countries in the Global North as valuable inputs in enhancing local urban resilience.

Reflecting upon the role of the authors, if there is anything the Sustainable Cities masters programme has emphasised, it is the importance of knowledge creation and knowledge-sharing. Accordingly, these are central components of the present study as it seeks to create new knowledge objects of urban flooding and Nbs in Kigali. The rationale of the present study is to conduct research which can aid local practitioners in implementing NbS as a measure to deal with urban flooding. However, the broader scopes of the findings are applicable in many other developing countries and cities as well. Therefore, the study also serves as a reminder for external experts, local laypersons, and all layers of local governmental bodies to consider and attempt to break down the identified transition barriers in terms of climate adaptation and the use of NbS.

On a final note, the present study has prepared the authors to argue for the importance of local empowerment and ownership within the framework of climate change adaptation, and how to bring these learnings to the table in future roles as Sustainable City Engineers.



CHAPTER 13
CONCLUSION

CONCLUSION

Today, cities face several environmental concerns and urban development challenges arising from climate change, rapid urbanisation, unplanned development, poor urban planning practices, and the degradation of biodiversity and ecosystems. Consequently, the likelihood of urban floods and urban sprawl is increasing in metropolitan areas around the world.

Cities located in East African are especially vulnerable to urban flooding due to the prospects of increasing precipitation, high climatic fluctuations and viability leading to the intensification of climatic hazards such as flooding. Poor adaptive capacities and economic incentives to address these challenges further deepen the vulnerability adding to the multifaceted fragility of the cities.

By using Kigali, the capital of Rwanda, as an explorative case study, the present study investigates how urban flooding and development challenges are placing pressure on the existing urban planning regime and to what extent Nature-based Solutions (NbS) are emerging as a novel innovation to enhance urban resilience in the metropolis.

The present study identifies and explores a complex nexus of urban development challenges in Kigali. These include exacerbating anthropogenic climate change and changes in precipitation patterns leading to recurrent urban floods, which are further aggravated by rapid urbanisation and unplanned urban sprawl. Urbanisation and urban development are identified as the main contributors to the degradation of biodiversity and ecosystems in Kigali, as development has for a long time occurred at the expense of nature. On a national and city level, the identified nexus of urban development challenges have cascading effects on social, economic, and environmental systems. As climatic conditions continue to change in response to human activity and development, projections indicate that Kigali will experience altered precipitations patterns. Which will materialise in periods of heavy precipitation, and ultimately to the intensification and higher frequency of urban floods.

The reviewed studies and blue spot model agree that urban flooding is a dominating concern in the city. The degree to which different areas of the city are vulnerable varies, although there is a common consensus that low-lying wetland areas are particularly prone to flooding. A reason for this is that episodes of heavy precipitation generate high-velocity runoffs which flow downstream towards the valley bottoms. Hence, it is crucial to also recognise that upstream areas play a central role in urban stormwater management. The findings from comparing findings from previous studies highlight that significant discrepancies emerge depending on the employed methodological approaches, particularly on the use of different data sources. In addition, the comparison shows that there is a significant challenge to data availability and quality in Kigali. The available data is of poor spatial resolution and lack temporal continuity. Interview statements further underline these findings and reflect a need to incorporate qualitative information in the process of managing urban stormwater. Simultaneously, there is a prominent need to improve the existing datasets to be used in future blue spot models to enable urban practitioners to make informed decisions as to how to improve stormwater management practices in Kigali.

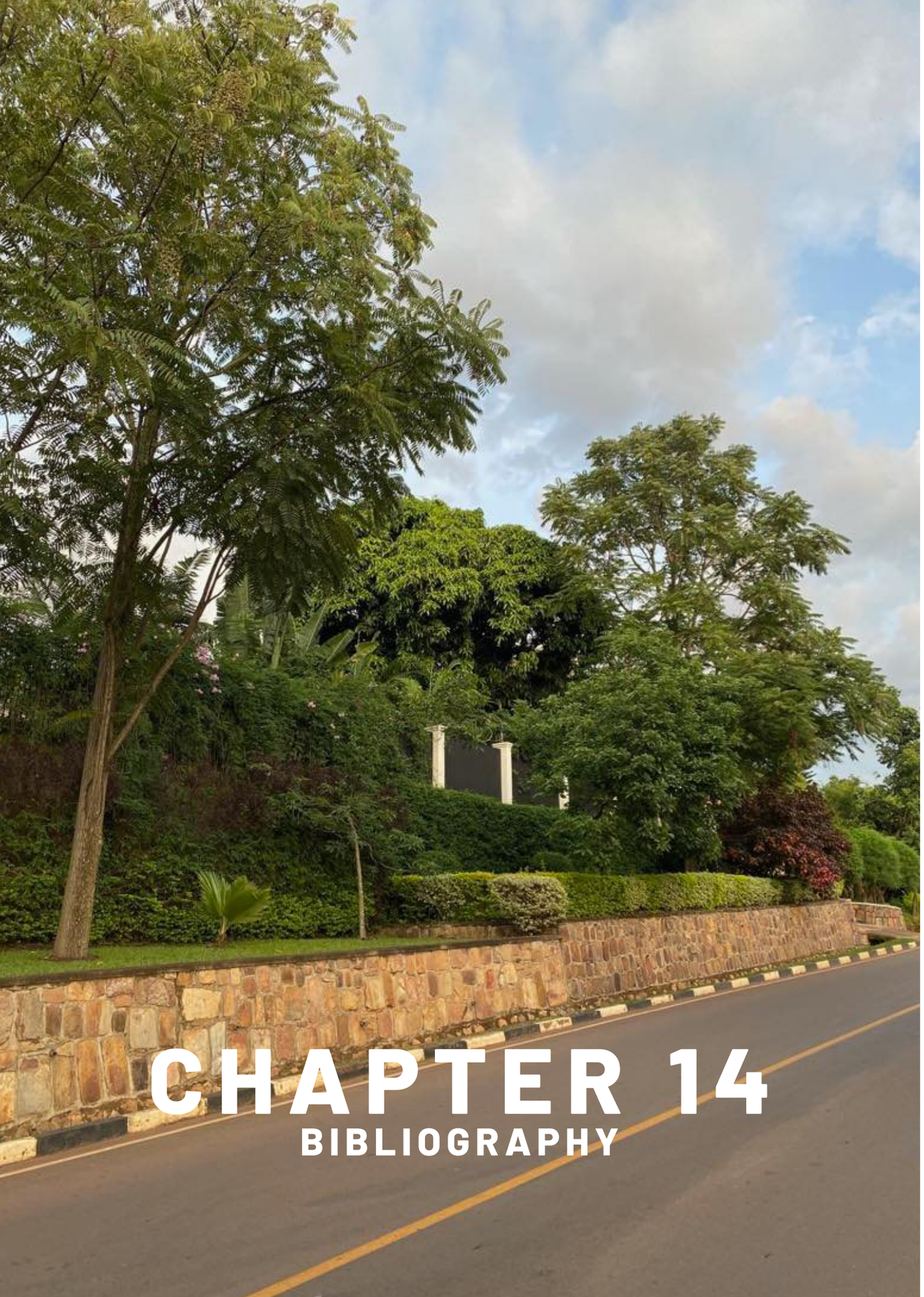
A multilayered structure comprising different stakeholders from the government (ministries), regulatory agencies (authorities), and implementing institutions (City Council and Non-Governmental Organisations), supported by international consultancies and donors, characterise the current urban planning regime and stormwater management in Kigali. This overlapping and complex governance structure underlines the importance of good coordination and clear communication across sectors and silos to successfully execute plans and strategies. The existing urban planning regime is highly path-dependent, following a traditional trajectory of engineered beliefs, grey infrastructures, structural solutions, and policy paradigms that ultimately prioritise climate change mitigation rather than adaptation. An impressive intertwined network of built drainage channels largely manages the urban stormwater in Kigali, supported by retention walls, riverbank stone pitching, and gabion walls. Despite these structural measures, urban floods are a recurrent event every rainy season with devastating impacts in the City of Kigali. Likewise, urbanisation and urban sprawl continue to be a menace in Kigali. The study uncovers a pronounced gap between the two planning paradigms of informal and formal settlements, which ultimately aggravates the urban development challenges of the capital city. Hence, the present study finds that the existing traditional urban planning regime and stormwater management fail to address the urban development challenges of urban flooding, urbanisation, urban sprawl, and the appertaining climate adaptational need of Kigali. Ultimately, the external landscape pressure of climate change and urban flooding have destabilised the current urban planning regime. Thus a window of opportunity has surfaced for NbS to emerge as novel innovations.

As NbS are sporadically employed in the City of Kigali, findings indicate that the novel innovation has entered the second phase of the sustainability transition, stabilisation. NbS marks the cityscape of Kigali in several ways, although predominantly through larger-scale wetland restoration initiatives. Accordingly, the novel innovation has started to gain a foothold in urban planning practices, stormwater management, and rehabilitation of degraded ecosystems and biodiversity in Kigali. Despite this, NbS are yet to wholly disrupt the existing traditional urban planning regime and transition from niche to norm. To further accelerate the trajectory of the transition, the study finds that the novel innovations of NbS must overcome a range of different challenges and barriers.

The present study clusters the transitional barriers and challenges into gaps in local financial and institutional capacities, path-dependent policy structures; design and data-related challenges; and locked-in mindsets of central stakeholders. The study proposes to bridge these gaps, and thereby enhance the urban resilience of Kigali, by respectively recommending that future strengthening of urban planning practices and research should centre upon microfinance and local funding schemes; stakeholder involvement, raising awareness, capacity building, creating empowerment and local ownership; monitoring implementation and creating feedback systems; and making data accessible and applicable.

In many ways, the urban flooding problem of Kigali underlines the need for integrated, sustainable urban planning, which considers the environmental and urban development concerns of climate change, urbanisation, urban sprawl, and the degradation of ecosystems and biodiversity. Simultaneously, future planning practices should centre upon creating synergies across the challenges and barriers brought on by the high reliance on international funding and aid, low institutional capacity, inadequate political regulations, poor monitoring, and the lack of data availability and best practice examples.

It is evident from this study that there is significant aspiration and willingness among the interviewed stakeholders to ensure that Kigali and Rwanda develop sustainably in the future through local capacity building and knowledge sharing. In the words of Dr. Saleemul Huq, climate change adaptation and NbS is "*a paradigm shift away from the old way of doing things to the new way of doing things. ... Climate change is a truly global problem. It's happening everywhere. It's happening in your country. It's happening in my country, and we have to learn from each other. We must share knowledge with each other and the unfortunate*" (Appendix 1).



CHAPTER 14
BIBLIOGRAPHY

BIBLIOGRAPHY

Acreman, M., Smith, A., Charters, L., Tickner, D., Opperman, J., Acreman, S., Edwards, F., Sayers, P. & Chivava, F., (2021). Evidence for the effectiveness of nature-based solutions to water issues in Africa. *Environmental Research Letters, 16*(6), 063007

Alemayehu, A., & Benitez, A. P. (2020). Making room for stormwater: How floods in Kigali shed light on the need for integrated urban planning and upgrading. *World Bank Blogs*. https://blogs.worldbank.org/nasikiliza/making-room-storm-water-how-floods-kigali-shed-light-need-integrated-urban-planning-and

ARN & GLWC. (2020). *Rural Rwanda 2020*. Anker Research Network & Global Living Wage Coalition. Universidad Privada Boliviana.

Ayres, L. (2008). The SAGE Encyclopedia of Qualitative Research Methods. In L. M. Given (Ed.). *Semi-structured Interview* (pp. 811-812). Thousand Oaks, SAGE Publications, Inc.

Balstrøm, T. (2022). *Model blue spots to map flood risk*. Learn ArcGIS. https://learn.arcgis.com/en/projects/model-bluespots-to-map-flood-risk/

Beck, H.E., Zimmermann, N. E., McVicar, T.R., Vergopolan, N., Berg, A. & Wood E. F. (2018). Present and future Köppen-Geiger climate classification maps at 1-km resolution. *Scientific Data, 5*, 180214

Bertelsmann Stiftung. (2022). BTI 2022 Rwanda Country Report. *Bertelsmann Stiftung*, Gütersloh, Germany

Bolstad, P. (2016). *GIS Fundamentals: A first text on geographic information systems*. Eider Press, Minnesota, USA

Boniburini, I., Breda, A. A., Gasana, S., Mutabazi, E. K., Izere, I., Renzaho, Y. Nkurunziza, A., Mugisha, F. & Habiyambere, E. (2018). *Imbuga City Walk, Kigali, Rwanda*. City of Kigali, Rwanda

CARO. (n.d.). *Fluvial Flooding*. The Climate Action Regional Offices. https://www.caro.ie/knowledge-hub/climate-action-adaptation/flooding/fluvial flooding#:~:text=Fluvial%20flooding%20occurs%20when%20rivers,areas%20(the%20natural%20floodplains)

Chausson, A., Turner, B., Seddon, D., Chabaneix, N., Girardin, C.A., Kapos, V., Key, I., Roe, D., Smith, A., Woroniecki, S. & Seddon, N., (2020). Mapping the effectiveness of nature-based solutions for climate change adaptation. *Global Change Biology, 26*(11). 6134-6155

Clay, D. (2021). Rwanda. *Britannica Encyclopedia*. https://www.britannica.com/place/Rwanda

Climate Data.org. (n.d.-c). *Climate Lilongwe, Malawi*. Climate-Data. https://en.climate-data.org/africa/malawi/central/lilongwe-925117/

Climate Data.org. (n.d.-a). *Climate Kampala, Uganda*. Climate-Data. https://en.climate data.org/africa/uganda/central-region/kampala-5578/

Climate Data.org. (n.d.-b). *Climate Nairobi, Kenya*. Climate-Data. https://en.climate-data.org/africa/kenya-124/

Climate Data.org. (n.d.-d). *Climate Tanzania*. Climate-Data. https://en.climate-data.org/africa/tanzania-132/

Climate Data.org. (n.d.-e). *Zambia*. Climate-Data. https://en.climate-data.org/africa/zambia-192/

Crisi24. (2022). *Rwanda: Disruptions ongoing in multiple regions due to flooding as of April 26; further adverse weather forecast*. Crisis24. https://crisis24 garda.com/alerts/2022/04/rwanda-disruptions-ongoing-in-multiple-regions-due-to-flooding-as-of-april-26-further-adverse-weather-forecast

CSE. (2019). *Potential for Rainwater Harvesting in Rwanda*. Centre for Science And Education Publishing, New Delhi, India

DataCommons. (2020). *Rwanda*. DataCommons Place Explorer. https://datacommons.org/place/country/RWA?utm_medium=explore&mprop=amount&popt=EconomicActivity&cpv=activitySource%2CGrossDomesticProduction&hl=en

Davis, S. M. (2017). Research Reports, Subjective. In M. Allen (Ed.). *The SAGE Encyclopedia of Communication Research Methods* (pp. 1461-1462). Thousand Oaks, SAGE Publications, Inc.

Defacto Urbanism. (n.d.). *Nature Based Solutions Kigali*. Defacto Urbanism. https://www.defactourbanism.com/portfolio-item/nature-based-solutions-kigali/

Dutch MFA. (2018). *Climate Change Profile: Rwanda*. Dutch Ministry of Foreign Affairs, the Netherlands

Flyvbjerg, B. (1988). *Case studiet som forskningsmetode*. Aalborg University, Danmark

Frantzeskaki, N., McPhearson, T., Collier, M.J., Kendal, D., Bulkeley, H., Dumitru, A., Walsh, C., Noble, K., Van Wyk, E., Ordóñez, C. & Oke, C. (2019). Nature-based solutions for urban climate change adaptation: linking science, policy, and practice communities for evidence-based decision-making. *BioScience, 69*(6).455-466

GCA. (2021). *Accelerating adaptation through large scale Nature-Based Solutions: A report on the WAC webinar on 7th October 2021*. Global Center on Adaptation. https://communities.adaptationexchange.org/sites/weadapt.org/files/20211123_nbs_upscaling.pdf

Geels, F. W. (2002). Technological Transitions as Evolutionary Reconfiguration Processes: A Multi-Level Perspective and Case-Study. *Research Policy, 31*, 1257-1274. https://doi.org/10.1016/S0048-7333(02)00062-8

Geels, F. W. (2005). Processes and patterns in transitions and system innovations: Refining the co-evolutionary multi-level perspective. *Technological Forecasting & Social Change, 72*(6), 681–696. https://doi.org/10.1016/j.techfore.2004.08.014

Geels, F. W. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions, 1*(1), 24-40. https://doi.org/10.1016/j.eist.2011.02.002

Geels, F. W. (2019). Socio-technical transitions to sustainability: A review of criticisms and elaborations of the Multi-Level Perspective. *Current Opinion in Environmental Sustainability, 39*, 187-201. https://doi.org/10.1016/j.cosust.2019.06.009
GGGI. (2015). *Sustainable Urban Wetlands Development within Kigali City*. The Global Green Growth Institute. https://gggi.org/project/sustainable-urban-wetlands-development-within-kigali-city/
GGGI. (2022-a). *Sustainable Urban Wetlands Development within Kigali City- Nyandungu Wetland Eco-Park*. The Global Green Growth Institute. https://gggi.org/sustainable-urban-wetlands-development-within-kigali-city-nyandungu-wetland-eco-park/
GGGI. (2022-b). *GGGI, the Government of Rwanda and UNEP proposed area for Car Free Zone in Huye Secondary City*. The Global Green Growth Initiative. https://gggi.org/gggi-government-of-rwanda-and-unep-proposed-area-for-car-free-zone-in-huye/
Government of the Republic of Kenya. (2018). *National Climate Change Action Plan 2018-2022*. Ministry of Environment and Forestry, Nairobi
Grossi, A., & Dinku, T. (2022). Enhancing national climate services: How systems thinking can accelerate locally led adaptation. *One Earth, 5*(1), 74-83
Haggag, M., Kalisa, J.C, &, Abdeldayem, A.W. (2016). Projections of precipitation, air temperature and potential evapotranspiration in Rwanda under changing climate conditions. *African Journal of Environmental Science and Technology, 10*(1), 18-33
Holden, J. (2017) Catchment Hydrology. In J. Holden (4th ed.), *An Introduction to Physical Geography and the Environment* (pp. 465-492). Pearson Education Publishing, UK
ISRIC (2007). *SOTER-based soil parameter estimates (SOTWIS) for Central Africa*. ISRIC Data Hub. https://data.isric.org/geonetwork/srv/eng/catalog.search#/metadata/348a9bcc-ca7d-4fe9-ad34-42fed0d0bf52
Kalantari, Z., Ferreira, C. S. S., Keesstra, S., & Destouni, G. (2018). Nature-based solutions for flood-drought risk mitigation in vulnerable urbanizing parts of East-Africa. *Current Opinion in Environmental Science & Health, 5*, 73-78
KCCA. (2016). *Kampala Climate Change Action Strategy*. Kampala Capital City Authroity, Uganda
Krishnasamy, S., Chhetri, L., Thosani, D. G., Mchugh, A., van Jaarsveld, G., Da Silca, B., Westwood, M., Malunda, D., Robba, G., Plessis, D. D., Mullen, M. V., Morriello, E. & Karanukaran, A. (2020). *Kigali Master Plan 2050 – Master Plan Report*. Surbana Jurong, Singapore
Le Touzé, A. (2014). *Rwanda - caught between modernity and poverty*. Deutsche Welle. https://www.dw.com/en/rwanda-caught-between-modernity-and-poverty/g-17669049
Lemarchand, R. & Clay, D. (2021). Rwanda. *Encyclopedia Britannica*. https://www.britannica.com/place/Rwanda
MacroTrends. (2022). *Kigali, Rwanda Metro Area Population 1950-2022*. MacroTrends. https://www.macrotrends.net/cities/22404/kigali/population#:~:text=The%20current%20metro%20area%20population,a%203.38%25%20increase%20from%202019
Madete, E. (2021). Gardens of Kibera: The Kibera Public Space Project by Kounkuey Design Initiative. *The Architectural Review*. https://www.architectural-review.com/buildings/gardens-of-kibera-the-kibera-public-space-project-by-kounkey-design-initiative#:~:text=The%20Kibera%20Public%20Space%20Projects,first%20settled%20there%20in%201912
McSweeney, R. (2011). *Rwanda s Climate: Observations and Projections - Appendix E*. Smith School of Enterprise and the Environment, University of Oxford. Oxford, United Kingdom
MDAUS (2015). *World Land Cover 20m BaseVue 2013*. ArcGIS Image Service. https://www.arcgis.com/sharing/oauth2/authorize?client_id=arcgisonline&response_type=token&state=%7B%22portalUrl%22%3A%22https%3A%2F%2Fwww.arcgis.com%22%7D&redirect_uri=https%3A%2F%2Flandscape6.arcgis.com%2Farcgis%2Flogin%2F%3FreturnUrl%3Dhttps%3A%2F%2Flandscape6.arcgis.com%2Farcgis%2Frest%2Fservices%2FWorld_Land_Cover_30m_BaseVue_2013%2FImageServer%3Ffbclid%3DIwAR2sirjnmUzSXNByoy-Irb_v0IK0FjAq478ro0rOdN5tNj2gAX7s_KyXCy0&hideCancel=true
MIDIMAR (2015). *The National Risk Atlas of Rwanda*. The Ministry of Disaster Management and Refugee Affairs, Rwanda
MIDIMAR. (2012).*Mapping of disaster high-risk zones on floods and landslides*. The Ministry of Disaster Management and Refugees Affairs, Rwanda
MINEMA. (n.d.). *Disaster Management*. Ministry in Charge of Emergency Management. https://www.minema.gov.rw/disaster-management
Morgan, D.l. (2008). Snowball Sampling. In L. M. Given (Ed.), *The SAGE Encyclopedia of Qualitative Research Methods* (pp. 818). Thousand Oaks: SAGE Publications, Inc.
Morton, J. (2021). *Dar es Salaam Metropolitan Development Project - P123134*. The World Bank Group. http://documents.worldbank.org/curated/en/099240012232128769/Disclosable0Ve0134000Sequence0No014
Mugiraneza, T., Ban, Y., and Haas, J. (2019). Urban land cover dynamics and their impact on ecosystem services in Kigali, Rwanda using multi-temporal Landsat data. *Remote Sensing Applications: Society and Environment, 13*, 234-246. https://doi.org/10.1016/j.rsase.2018.11.001
Muhire, E. (2015). *Identification of flood-prone areas in Kigali City – Case Study: Mulindi watershed, a tributary of Nyabarongo River*. University of Rwanda.
Mwenje, E. (2019). *Regulatory mainstreaming climate change adaptation into urban planning in the global south a case of Kigali City*. University of Twente.
NatuRES. (2022). *Urban Wetland Protection in Lusaka, Zambia*. Natural Resources Stewardship Programme. https://nature-stewardship.org/countries/zambia/urban-wetland-protection/
Naturvation. (2022). *Greening Kampala - Urban Nature Atlas*. Narturvation. https://una.city/nbs/kampala/greening-kampala
Naturvation. (n.d.). *Urban Nature Atlas*. Naturvation. https://una.city/
NBSI. (n.d.). *Nature-based Solutions Evidence Tool*. Nature Based Solutions Initiative University of Oxford. https://www.naturebasedsolutionsevidence.info/evidence-tool/
Nemus. (2017). *New project in Rwanda: Restoration of Wetlands in the Kigali City – Sub-catchment of Gikondo and Nyabugogo*.Nemus. https://www.nemus.pt/en/new-project-in-rwanda-restoration-of-wetlands-in-the-kigali-city-sub-catchment-of-gikondo-and-nyabugogo/
Nemus. (n.d.). *Sub-catchment management plans for Gikondo and Nyabugogo wetland systems, Rwanda*. Nemus. https://www.nemus.pt/en/projects/reabilitacao-ambiental/development-of-detailed-sub-catchment-management-plans-for-gikondo-and-nyabugogo-wetland-systems/
Neuwirth, R. (2022). *A Singaporean firm has become the go-to master planner for African cities*. City Monitor. https://citymonitor.ai/government/infrastructure/a-singaporean-firm-has-become-the-go-to-master-planner-for-african-cities
Niang, I., O.C. Ruppel, M.A. Abdrabo, A. Essel, C. Lennard, J. Padgham, & P. Urquhart (2014). Africa. In Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (Eds.). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1199-1265). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA
Nikuze, A., Flacke, J., Sliuzas, R. & van Maarseveen, M. (2022).Urban induced-displacement of informal settlement dwellers: A comparison of affected households' and planning officials' preferences for resettlement site attributes in Kigali, Rwanda. *Habitat International, 119*. https://doi.org/10.1016/j.habitatint.2021.102489
Niyokwiringirwa, P. (2021). *Extreme flood events in Rwanda, the Case of Kigali city*. ArcGIS Storymaps. https://storymaps.arcgis.com/stories/1f814d6184a141e2a03a7bd7707c14c5
Nkurunziza, M. (2022-a). Are affordable housing projects viable in Rwanda?. *The New Times Rwanda*. https://www.newtimes.co.rw/business/are-affordable-housing-projects-viable-rwanda
Nkurunziza, M. (2022-b). No extension of grace period for single-use plastics. *The New Times Rwanda*. https://www.newtimes.co.rw/news/no-extension-grace-period-single-use-plastics-rema#:~:text=In%202019%2C%20Rwanda%20passed%20a,which%20they%20would%20phase%20out.Accessed
Nsengiyumva, J. B. (2012). *Disaster High-Risk Zones on Floods and Landslides*. The Ministry of Disaster Management and Refugees Affairs, Rwanda.
Ntikubitubugingo, E. (2018). *Future Rainfall Projection for Rwanda Using Statistical Downscaling*. University of Rwanda
Nyaga, J. (2021). *Astounding Progress: Kampala's Plan for Trees*. SWARA. https://swara.co.ke/astounding-progress-kampalas-plan-for-trees/#:~:text=The%20plan%20identified%20%E2%80%9Cproper%20management,for%20improved%20health%20and%20income%E2%80%9D
Nzohabonimana, D. (2019). *What makes Rwanda one of Africa's fastest-growing economies*? TRT World. www.trtworld.com/magazine/what-makes-rwanda-one-of-africa-s-fastest-growing-economies-23410
OECD. (2020). *Nature based solutions for adapting to water-related climate risks - policy perspectives*. OECD, Environmental Policy Papers, Report No. 21. OECD Publishing, Paris, France. https://doi.org/10.1787/2257873d-en
Opperman, J., E. Oyare, H. Baleta, S. Fahrbach, & R. Camargo. (2021). *Waterways to Resilience: Nature-based Solutions for Adaptation in Africa*. World Wildlife Fund for Nature International, Gland, Switzerland
Petley, D. (2016). The GFDRR ThinkHazard! tool. *The Landslide Blog*. https://blogs.agu.org/landslideblog/2016/05/20/thinkhazard-tool/
Race, R. (2008). Literature Review in L. M. Given (Ed.), *The SAGE Encyclopedia of Qualitative Research Methods* (pp. 488-489). Thousand Oaks, SAGE Publications, Inc
RCMRD Geoportal. (n.d.). *Data and Documents*. RCMRD GMES & Africa Geoportal. http://geoportal.rcmrd.org/
RCMRD Geoportal. (2018). *Rwanda SRTM DEM 30 meters*. RCMRD GMES & Africa Geoportal. https://gmesgeoportal.rcmrd.org/datasets/rcmrd::rwanda-srtm-dem-30-meters/about?fbclid=IwAR2hp6r2yOf_0Ax_LbvX7xvPEPMkhuS7D8KKeCfqCLZzRNhu1KNnuWejrew
RoR. (2006). *National Adaptation Programmes of Action to Climate Change. NAPA - Rwanda*. The Republic of Rwanda, Kigali
RoR. (2011). *Green Growth and Climate Resilience National Strategy for Climate Change and Low Carbon Development*. The Republic of Rwanda, Kigali
RoR. (2017). *7 Years Government Programme: National Strategy for Transformation (NST1) 2017–2024*. The Republic of Rwanda, Kigali
RoR. (2018). *Third National Communication: Report to the United Nations Framework Convention on Climate Change*. The Republic of Rwanda, Kigali
RoR. (2020-a). *Updated National Contribution*. The Republic of Rwanda, Kigali
RoR. (2020-b). *Vision 2050, Abridged Version*. The Republic of Rwanda, Kigali
RoR. (2020-c). *Population Kigali*. https://services2.arcgis.com/y20RuA5nmE8htWdM/arcgis/rest/services/Population_Kigali/FeatureServer
Seddon, N., Chausson, A., Berry, P., Girardin, C. A., Smith, A., & Turner, B. (2020-b). Understanding the value and limits of nature-based solutions to climate change and other global challenges. *Philosophical Transactions of the Royal Society B, 375*(1794), 20190120
Seddon, N., Daniels, E., Davis, R., Chausson, A., Harris, R., Hou-Jones, X., Huq, S., Kapos, V., Mace, G.M., Rizvi, A.R. & Reid, H. (2020-a). Global recognition of the importance of nature-based solutions to the impacts of climate change. *Global Sustainability, 3*
Seddon, N., Sengupta, S., Garcia-Espiosa, M., Hauler, I., Herr, D. & Rizvi, A. R. (2019). *Nature-based Solutions in Nationally Determined Contributions - Synthesis and recommendations for enhancing climate ambition and action by 2020*. IUCN and Oxford University, Gland, Switzerland and Oxford
Seddon, N., Smith, A., Smith, P., Key, I., Chausson, A., Girardin, C., House, J., Srivastava, S. & Turner, B., (2021). Getting the message right on nature-based solutions to climate change. *Global Change Biology, 27*(8), 1518-1546
SRC. (2021). *How to reduce risks of flooding in and around urban areas*. Stockholm Resillience Centre. https://www.stockholmresilience.org/research/research-news/2021-08-23-how-to-reduce-risks-of-flooding-in-and-around-urban-areas.html
Steinberg, S. J. & Steinberg, S. L. (2006). Qualitative Research methods and GIS in S. J. Steinberg & S. L Steinberg (Eds.), *Geographical Information Systems for the Social Sciences: Investigating Space and Place* (pp.77-98). Sage Publications
Streb, C. K. (2010). Exploratory Case Study in A. J. Mills, G. Durepos, & E. Wiebe (Eds.), *Encyclopedia of Case Study Research* (pp. 373-374). Thousand Oaks, SAGE Publications, Inc.
ThinkHazard!. (n.d.). *Kigali City*. ThinkHazard! GFDRR. https://thinkhazard.org/en/report/21970-rwanda-kigali-city-umujyi-wa-kigali/UF

Transparency International. (2021). *Corruption Percentage Index*. Transparency International. https://www.transparency.org/en/cpi/2021/index/rwa
UIS. (n.d.). *Rwanda*. UNESCO Institute for Statistics. http://uis.unesco.org/en/country/rw
UN. (n.d.).*Kigali City Master Plan 2050*. UN Department of Social and Economic Affairs. https://sdgs.un.org/partnerships/kigali-city-masterplan-2050
UNDP. (2019). *Gender Inequality Index*. United Nations Development Programme. http://data.un.org/DocumentData.aspx?id=415
UNDP. (2020). *Latest Human Development Index Rating*. United Nations Development Programme. https://hdr.undp.org/en/content/latest-human-development-index-ranking?utm_source=EN&utm_medium=GSR&utm_content=US_UNDP_PaidSearch_Brand_English&utm_campaign=CENTRAL&c_src=CENTRAL&c_src2=GSR&gclid=CjwKCAjwve2TBhByEiwAaktM1GfI0efsP9h-0T0hVePbcrp0ZO-uII2k70YcLsiGj8euHxYEcUGDNBoC3K4QAvD_BwE
UNDP. (n.d.). *Zambia*. UNDP Climate Change Adaptation. https://www.adaptation-undp.org/explore/africa/zambia#:~:text=Zambia%20has%20been%20experiencing%20adverse,changes%20in%20the%20growing%20season
UNFCCC. (2022). *National Adaptation Programmes of Action*. United Nations Framework Convention on Climate Change. https://unfccc.int/topics/resilience/workstreams/national-adaptation-programmes-of-action/introduction
UNICEF. (n.d.). *Education Rwanda*. Unicef Education. https://www.unicef.org/rwanda/education
Uwera, M., Nsanzumukiza, M. V., Maniragaba, A., Mukasekuru, F., Mucyo J. C., Ntabugi, M. C., & Niwenshuti, E, (2020). Contribution of Green Infrastructures on Flood Risk Reduction in Kigali City of Rwanda. *International Journal of Environmental Planning and Management, 6*(4). 115-124.
W&C. (2022). *City Of Kigali, Rwanda Climate*. Weather & Climate - The Global Historical Weather and Climate Data. https://tcktcktck.org/rwanda/city-of-kigali
Wainwright, C. M., Marsham, J. H., Keane, R. J., Rowell, D. P., Finney, D. L., Black, E., & Allan, R. P. (2019). Eastern African Paradox'rainfall decline due to shorter not less intense Long Rains. *npj Climate and Atmospheric Science, 2*(1), 1-9
WBG. (n.d.-a). *Rwanda: Climate Data Projections*. Climate Change Knowledge Portal. https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-projections
WBG. (n.d.-b). *Rwanda - Climatology*. Climate Change Knowledge Portal. https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-historical
WBG. (n.d.-c). *Uganda*.The World Bank Databank. https://data.worldbank.org/country/uganda?view=chart
WBG. (n.d.-d). *Kenya*. The World Bank Databank. https://data.worldbank.org/country/kenya?view=chart
WBG. (n.d.-e). *Malawi*. The World Bank Databank. https://data.worldbank.org/country/malawi?view=chart
WBG. (n.d.-f). *Tanzania*. The World Bank Databank. https://data.worldbank.org/country/tanzania?view=chart
WBG. (n.d.-g). *Dar es Salaam Metropolitan Development Project*. The World Bank Group. https://projects.worldbank.org/en/projects-operations/project-detail/P123134
WBG. (2016). Urban Resilience: Challenges and Opportunities for African Cities. The World Bank Group.https://www.worldbank.org/en/news/feature/2016/01/21/urban-resilience-challenges-and-opportunities-for-african-cities
WBG. (2017). *Combined project Information Document/Integrated Safeguards Data Sheet (PID/ISDS)*. The World Bank Group. https://documents1.worldbank.org/curated/ar/627721490623342886/ITM00184-P158434-03-27-2017-1490623340300.docx
WBG. (2021-a). *Climate Risk Country Profile: Rwanda*. The World Bank Group, Washington DC, USA
WBG. (2021-b). *The World Bank in Rwanda*. The World Bank Group. https://www.worldbank.org/en/country/rwanda/overview#1
WBG. (2021-c). *Gini index*. The World Bank Group. https://data.worldbank.org/indicator/SI.POV.GINI
WBG. (2021-d). *A catalogue of Nature Based Solutions for Urban Resilience*. The World Bank Group, Washington DC, USA
Welborn, L. (2018). *Africa and climate change - Projecting vulnerability and adaptive capacity*. Institute for Security Studies (ISS) Africa Report, 14, 1-24
Westoby, R., Clissold, R., McNamara, K. E., Ahmed, I., Resurrección, B. P., Fernando, N., & Huq, S. (2021). Locally led adaptation: drivers for appropriate grass roots initiatives. *Local Environment*, *26*(2), 313-319
Wieczorek, A. J. (2018). Sustainability transitions in developing countries: Major insights and their implications for research and policy. *Environmental Science & Policy, 84*, 204-216. https://doi.org/10.1016/j.envsci.2017.08.008
WMO. (2022). *World Weather Information Service - Kigali*. World Meteorological Organisation. https://worldweather.wmo.int/en/city.html?cityId=254
WPR. (2022-a). *Kigali Population 2022 - Demographics, maps and graphs*. World Population Review. https://worldpopulationreview.com/world-cities/kigali-population
WPR. (2022-b). *Kampala Population 2022*. World Population Review. https://worldpopulationreview.com/world-cities/kampala-population
WPR. (2022-c). *Nairobi Population 2022*. World Population Review. https://worldpopulationreview.com/world-cities/nairobi-population
WPR. (2022-d). *Lilongwe population 2022*. World Population Review. https://worldpopulationreview.com/world-cities/lilongwe-population
WPR. (2022-e). *Dar es Salaam Population 2022*. World Population Review. https://worldpopulationreview.com/world-cities/dar-es-salaam-population
WPR. (2022-f). *Lusaka Population 2022*. World Population Review. https://worldpopulationreview.com/world-cities/lusaka-population
WPR. (2022-g). *Low income countries 2022*. World Population Review. https://worldpopulationreview.com/country-rankings/low-income-countries
WWF. (2018). *Wetlands for Sustainable Cities*. World Wildlife Fund for Nature. https://www.wwfzm.panda.org/climate___energy_footer/?27825/%20Wetlands-for-Sustainable-Cities
WWF. (2021). *Urban Nature Based Solutions*: Cities Leading the Way. World Wildlife Fund for Nature International, Gland, Switzerland.
WWF. (n.d.). *Payments for Ecosystem Services*. World Wildlife Fund for Nature. https://wwf.panda.org/discover/knowledge_hub/where_we_work/black_sea_basin/danube_carpathian/our_solutions/green_economy/pes/