LIVING RIVERS

Regenerative river planning for Nakuru

Bouke de Jong
Nico Tillie, Kristel Aalbers

Delft University of Technology
Urban Ecology, Landscape Architecture

COLOPHON

Living Rivers

A framework for regenerative river planning in Nakuru

Author

B. J. J. (Bouke) de Jong

Supervisors

First mentor: Dr. ir. N. M. J. D. (Nico) Tillie

Second mentor: Ir. K. P. M. (Kristel) Aalbers

Examination committee: Dr. ir. M. (Marjolein) Spaans

Delft University of Technology

Faculty of Architecture

With support of:

STICHTING N·H·BOS
ter bevordering van de landschapsarchitectuur

TU Delft | Global Initiative

Science for the benefit of people. All people. Worldwide.

PHILIP-SPANGENBERG-TRAVEL-GRANT

Acknowledgements

First, I would like to express my gratitude to Nico and Kristel. Thank you for giving me freedom and trusting me with this project.

This report would not have been possible without the support of my parents and grandmother, who have always been there for me during my entire education. Also, I am grateful for all my dear friends I have made during my education in both Wageningen and Delft. In particular Nanook, for all her support throughout the years and especially this last graduation year. And also Thamar, with whom I have shared this adventure in Nakuru, and Bram who helped us find our flow in Kenya.

Finally, many thanks go out to all my Kenyan friends who have supported me in my research. Especially Joy, Jamal, our host Loise and my friend Enock. Asante sana.

1 *Construction work on the road to our accommodation in Nakuru (Image by author, 2025).*

Abstract

Living Rivers

A framework for regenerative river planning in Nakuru

The Njoro River, the primary tributary of Lake Nakuru in Kenya's Rift Valley, is facing severe ecological degradation due to deforestation, agricultural intensification, and rapid urban expansion. This thesis explores how regenerative landscape design can be used to restore the ecological integrity of the river while supporting the livelihoods of communities within its catchment. Building on the methodology of Research Through Design (RTD), this work integrates hydrological analysis, socio-spatial mapping, and co-design workshops conducted in collaboration with local actors. The study develops a spatial framework based on nature-based solutions that can be implemented through decentralized, community-led action. Rather than proposing a singular fixed intervention, the thesis offers a contextual strategy that acknowledges the complexity of socio-ecological systems and the limitations of top-down planning models. The outcome is a layered, adaptable vision that aims to rebalance ecological and human needs in the Njoro watershed.

KEYWORDS: regenerative design, river catchment planning, Njoro River, watershed degradation, nature-based solutions, hydrological restoration, urban ecology, climate resilience, Nakuru.

Content

1. Introduction

1. Introduction

1.1. Global Urbanization Challenges

Globally, more and more people live in an urban environment. Large groups of people move away from agricultural communities to settle and find work in cities. As per November 2022, 55% of the world population lives in a city (UN, 2022). Cities often offer unique cultural values, creating communities that produce their own form of art, music, food culture, and languages. They are lively communities with their own values, beliefs and identity that connects the people that live in them.

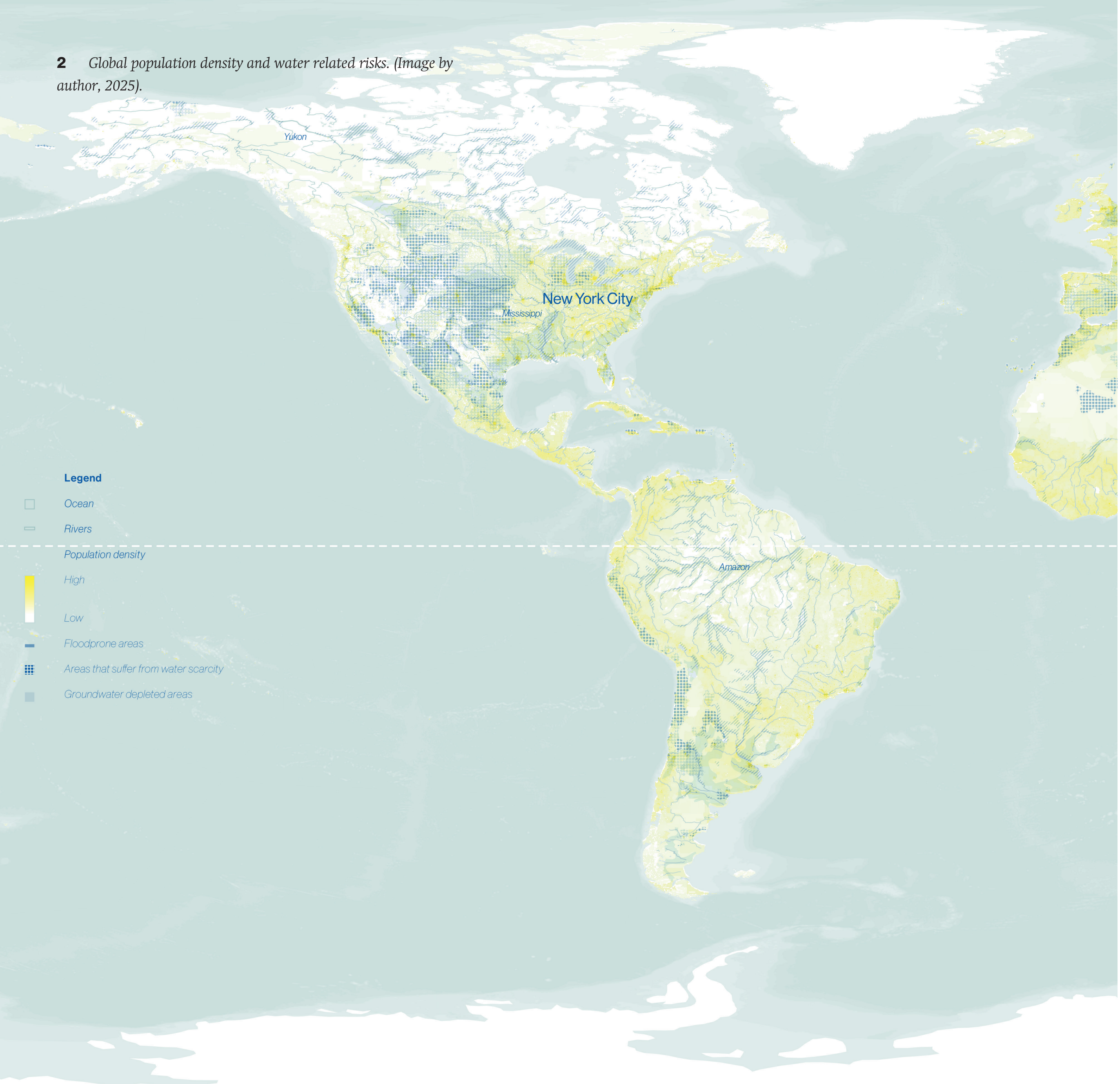
However, cities are prone to lose the connection to the natural systems that they are built upon and surround them. This disconnect brings a imbalance in the system in and around the city. The effects of climate change put increasing pressure on our way of living, even more so in cities. Climate change will increase weather extremes, causing more droughts, floods, heatwaves and other natural disasters. Models also predict that an increasing percentage of people will move to cities. Can we design our growing cities to be more in touch with the natural system? What are the benefits of this synergy between nature and culture? These questions are becoming ever more relevant and urgent.

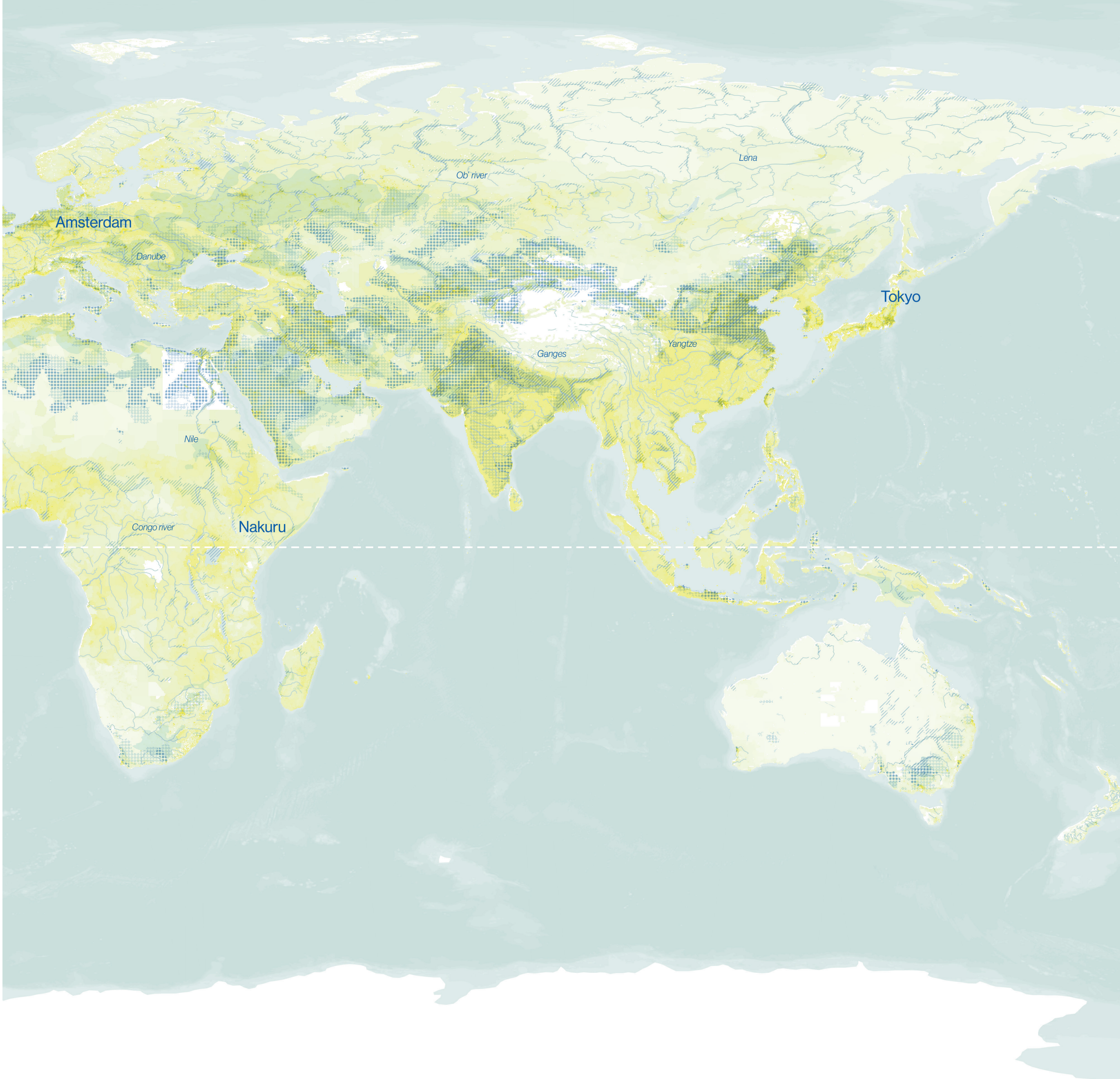
The Intergovernmental Panel on Climate Change (IPCC) is part of the United Nations and a leading voice in climate change science. In their previous assessment report, they stated that 'Considering climate change impacts and risks (…) in the design and planning of urban and rural settlements and infrastructure is critical for resilience and enhancing human well-being.' (IPCC, 2021). The report also highlights the importance of green and blue infrastructure in mitigating the effects of climate change. Mell and Scott (2023) define blue-green infrastructure (BGI) as '(…) the managed network of terrestrial and water spaces found across our urban and rural landscapes that help deliver socio-economic and ecological benefits supporting ecosystem functions and societal wellbeing.'.

According to Mell and Scott BGI should be elevated to primary importance and considered as critical infrastructure in city planning (Mell & Scott, 2023). The new issue and seventh IPCC assessment report (which is currently in the works) is exclusively dedicated to cities. The outline of the report includes a part that underlines the importance of 'context specific urban adaptation' and 'urban nature-based solutions and ecosystem-based adaptation' (IPCC, 2024). As an example of BGI in an urban environment, the IPCC report names i.a. urban forestry and river restoration as effective measures in reducing risks from extreme weather events such as droughts and heavy rainfall.

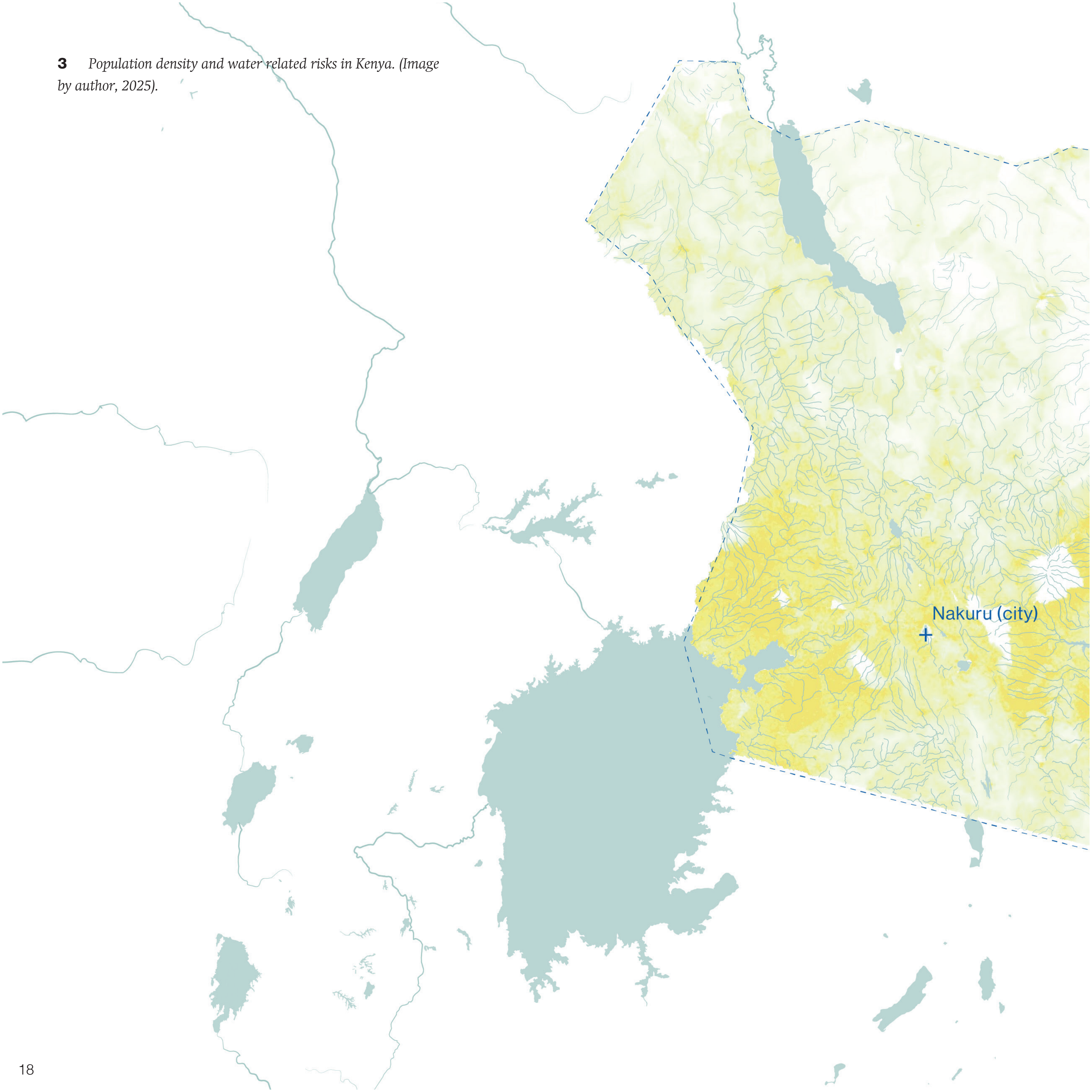
With half of the world's population living in cities, the importance of planning for healthy, climate resilient cities cannot be overstated.

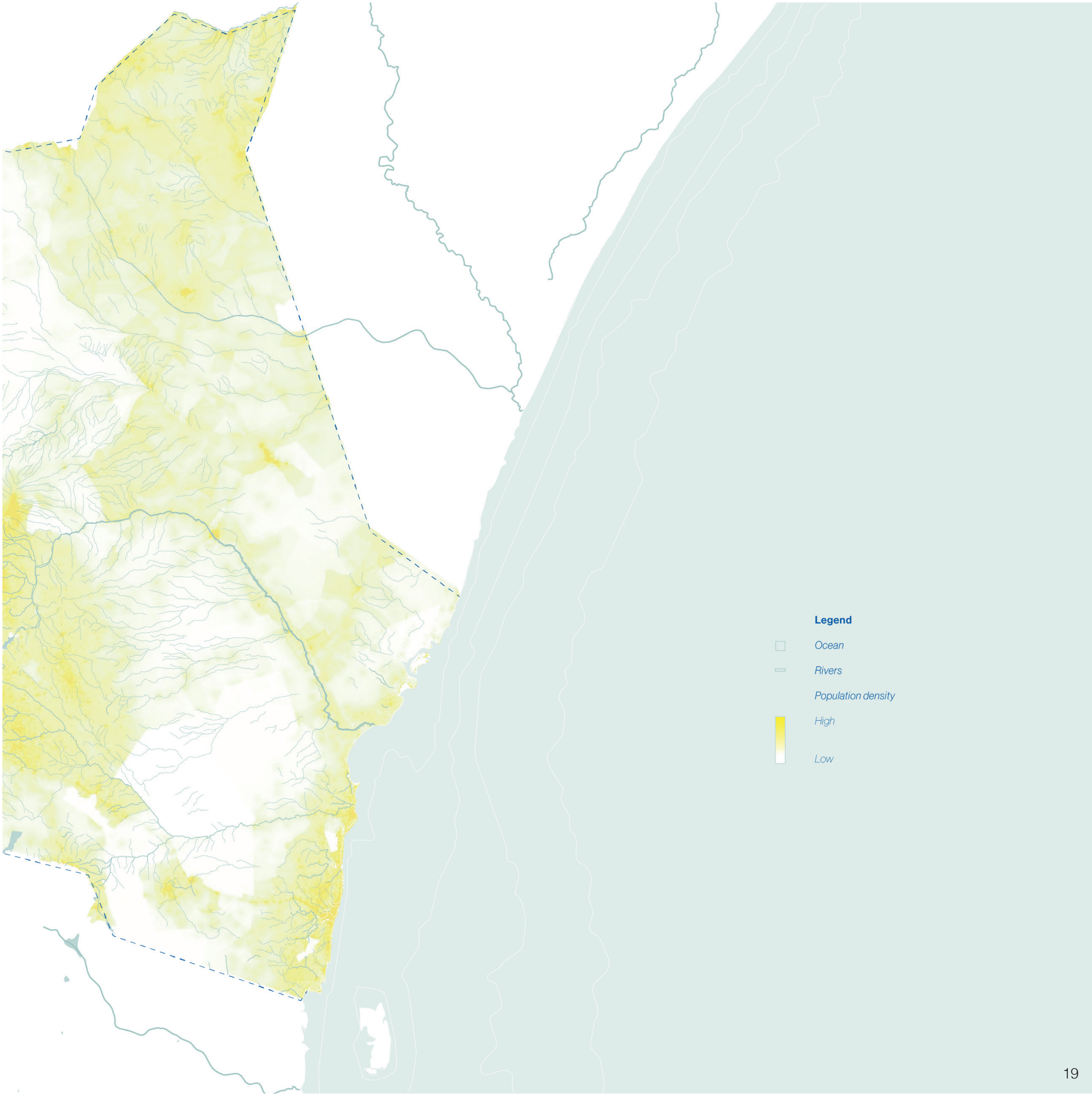
2 *Global population density and water related risks. (Image by author, 2025).*




Amsterdam
Danube
Ob' river
Lena
Tokyo
Yangtze
Ganges
Nile
Congo river
Nakuru

3 *Population density and water related risks in Kenya. (Image by author, 2025).*




Legend
Ocean
Rivers
Population density
High
Low

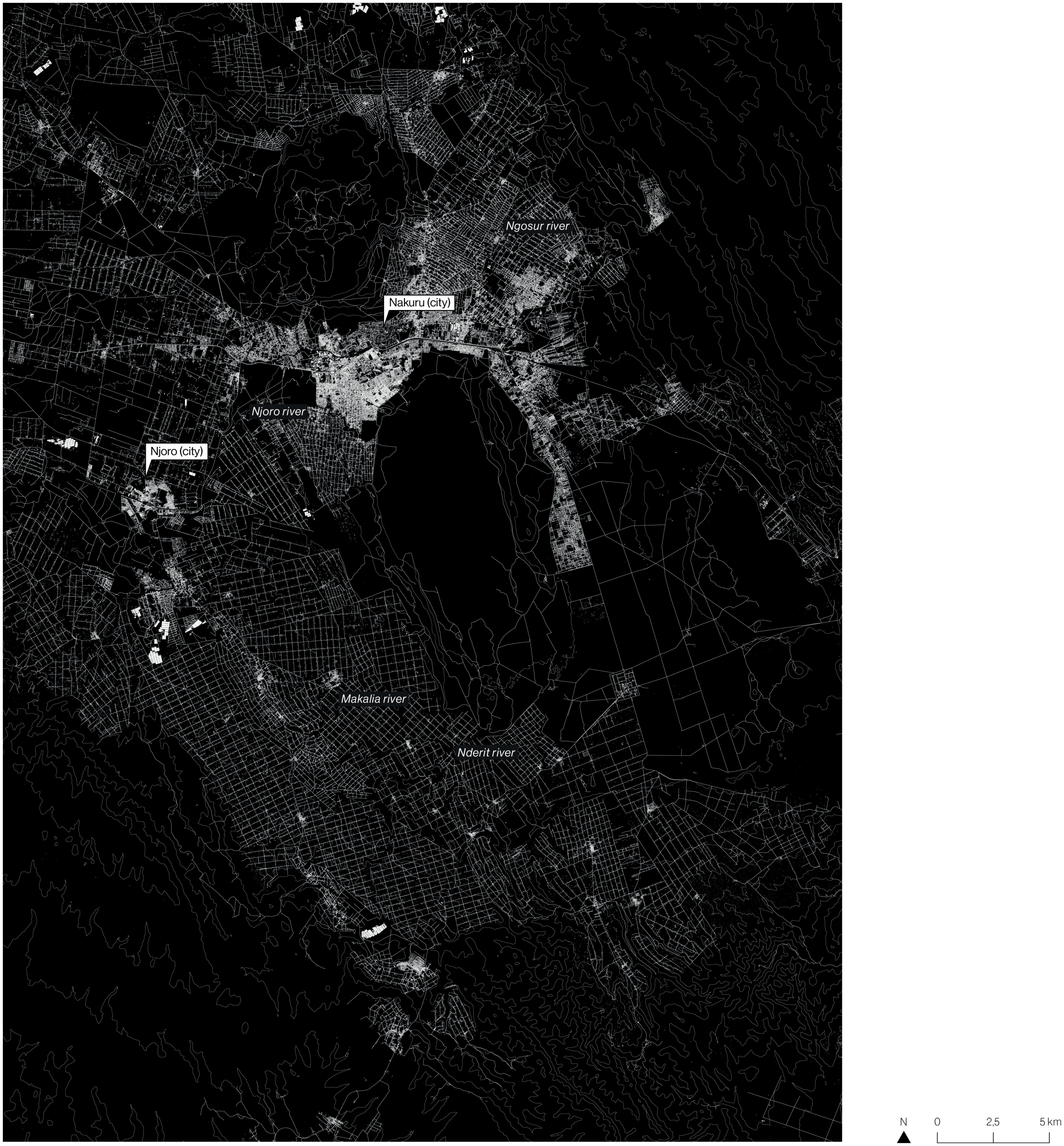
1.2. Site context

NAKURU Nakuru was founded by the British colonizers as a small railway post during the construction of the Ugandan railway in 1904, because of its strategic location between Nairobi and Uganda (Naikumi, Njogu & Ngugi, 2024). In that era, Nakuru was the capital of the White Highlands., a toponym that lend its name to the colonial policy that specific agricultural grounds in Kenya should be reserved for European settlers (Morgan, 1963). Nakuru grew into a service center for the fertile agricultural hinterland in the Rift Valley (Ehrensperger et al. 2004). The relatively wet climate of the region enabled the production of i.a. maize, which was then exported by rail through Nakuru (Morgan, 1963). During the struggle for independence, the city was a stronghold of white settlers resisting giving back control to the black African majority.

After Kenyan independence in 1963, Nakuru remained an important town. It was the semi-official residence of Kenya's first two post-independence presidents, Jomo Kenyatta and Daniel Arap Moi. Nakuru retained its agricultural character post-colonialism (Ehrensperger et al. 2004). The region houses many farms producing a variety of crops including "coffee, wheat, barley, maize, beans, fruits and vegetables." (Mwakikagile, 2010). Dairy farming is also an important activity in the province. The presence of Egerton University, Kabarak University, the Rift Valley Institute of Technology, the Kenya institute of Management and the Kenya Industrial Training Institute make Nakuru "one of the most important learning centers of the country" (Mwakikagile, 2010).

URBAN GROWTH RATE The population growth in Nakuru city is unprecedented. Between 1969 and 2009, the population has increased with a factor of six from 47.151 to 309.424 in 2009 (Muoria et al, 2019). It is the fourth largest city in Kenya and also the most recent one to gain city status, receiving its city charter in December 2021. Per 2019, the city's population amounts to 570.674 inhabitants. The rapid population growth can be explained by the city's strategic location in the rift valley and position along the transit corridor between Uganda and Kenya's interior. The city capitalized on this position and cemented its position as a major urban center. It was named the administrative capital of Nakuru County in 2013 and has since then attracted major investment in local infrastructure and services including expansion of roads, housing projects and health facilities (Naikumi et al. 2024). In an UN-habitat report on State of World's Cities (2011) Nakuru was selected as the fastest growing city on the continent with a growth rate of 13,3% between 1990 and 2006.

4 *The urban fabric of Nakuru, road networks and buildings, (Image by author, 2025).* ▶


Ngosur river
Nakuru (city)
Njoro river
Njoro (city)
Makalia river
Nderit river
N
0
2,5
5 km

URBAN GROWTH PRESSURE As the city grows, so does the claim on land. Forests make way for agriculture, industry and settlements. Deforestation in Nakuru county has caused siltation due to erosion and rivers drying up downstream (Gichuhi, 2013). The Mau Forest Complex, a large closed-canopy mountainous ecosystem stands in direct contact with the Lake Nakuru Basin (Chrisphine et al., 2016). Montane closed-canopy forests also referred to as 'water towers' play an important role in the Rift Valley ecosystem and hydrological cycle. The mountains trigger cloud formation, leading to precipitation in the form of rain or mist. The numerous plant species present in a mountain forest absorb far more water than farmland or other types of vegetation (Morara & Kipto, 2018). The roots of trees allow the water to flow and settle deep into the ground. The soil becomes a reservoir that retains water and consequently releases it slowly into the water table, streams and rivers, securing a steady flow throughout the year. The Mau Forest is the main catchment area for (among others) the rivers Njoro and Nderit which drain into Lake Nakuru. It is under pressure because of land cover change. Cultivated land and plantations pose the biggest threat and cause forest depletion. This change in land use, paired with the illegal logging has resulted in a decline in the sizes of dense forests, which negatively impacts the lakes that draw their water from the rivers in the Mau Forest, including Lake Nakuru (Chrisphine et al., 2016).

PROBLEM STATEMENT In the last three years the rivers have significantly declined in discharges and water quality. Forest cover binds soil together, when forests are destroyed this leads to increasing land erosion and sediment discharge. This reduces lake water quality and restricts the amount of light that passes through the water column. The volcanic soil near Nakuru is characterized by its permeability, porosity and loose composition, which makes it susceptible to erosion and subsidence, especially during or after periods of heavy rainfall. Consequently, deforestation reduces the natural infiltration of water into underground aquifers, causing an increase in surface runoff (Chrisphine et al., 2016). Deforestation in the Lake Nakuru catchment harms biodiversity and disrupts hydrology, which is crucial for maintaining lake levels. With its shallow depth, high evaporation, and reliance on seasonal rivers, the lake is highly vulnerable to changes in the catchment (Chrisphine et al., 2016). With the fast-growing population and increasing activity in the river catchments, the water towers have become environmentally unstable (Morara & Kipto, 2018). Human activity – such as destruction of riparian vegetation, urbanization and waste production – brings the river catchment system out of balance.

5 *Flooded homes in Barut East (Nakuru) (Image by author, 2025).* ▶

6 *Clothes drying on the property of a church in Langa Langa (Nakuru) (Image by author, 2025).* ▲

1. Introduction

1.3. Reading itinerary

This report explores how spatial design can contribute to regenerative development in the Njoro River catchment, located in Nakuru County, Kenya. The structure of the document follows the design process from context and observation to spatial strategy and phased implementation.

The report is divided into six parts.
PART 1 introduces the broader context and outlines the urgency of the research. It sets the stage by identifying key themes such as climate pressure, landscape fragmentation, and the increasing demand for water and land in Nakuru and its surroundings.

PART 2 explains the theoretical framework and research methodology. It introduces the core concepts that guide the project, such as the layer approach and regenerative design thinking. It also describes the tools used to analyse the landscape, including mapping, site reading and co-design workshops.

PART 3 presents an analysis of the Nakuru region using the layer model. It provides a spatial reading of the territory in terms of its natural systems, infrastructure and land use patterns. The chapter offers insight into the underlying dynamics that shape the region and highlights key challenges.

PART 4 focuses on the Njoro River as a case study. The river is the largest tributary to Lake Nakuru and one of the major natural features in the region. This chapter combines spatial analysis, literature, photography and field observations to build a layered portrait of the river landscape and its current condition.

PART 5 introduces a design framework for the Njoro catchment. It translates research into a spatial strategy through context-specific interventions, proposing new connections and synergies between ecological systems and human activity.

PART 6 concludes the report with a reflection on the research and design process. It revisits the main question, discusses the outcomes, and reflects critically on the relevance and limitations of the approach.

2. Research base

2. Research base

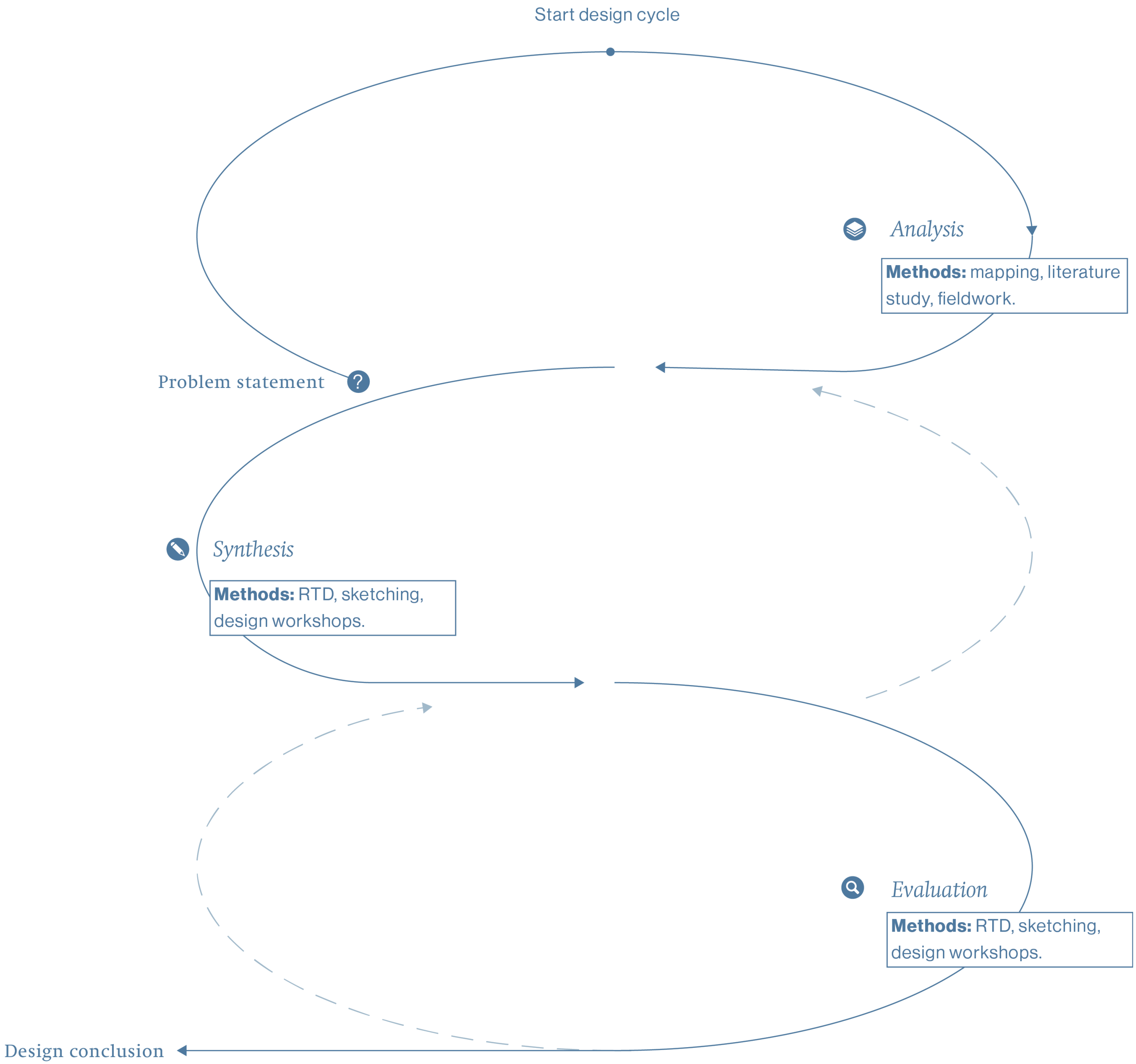
2.1. Methodology

RESEARCH THROUGH DESIGN This research is based on the research through design (RTD) method. In a study on the RTD method Lenzholzer et al. (2018) understands RTD as a “research [process] actively employing the act of designing”. In a RTD process the design is not based on intuition, but supported by research, testing and evaluation (Lenzholzer et al. 2018). According to the same research, the RTD method has two lines of output, either answering a site-specific design assignment or generating generalizable knowledge that can be used in practice (Lenzholzer et al. 2018). The output of this research will predominantly be the latter, applied design research for a site in Nakuru, Kenya. However, through evaluation and reflection general principles can be derived, which can be applied to other cases.

Another study on RTD by Nijhuis & De Vries (2020) identifies four stages in RTD: analyzing, synthesizing and evaluating. According to the same study “these phases are preceded by a design problem statement and are concluded with a design solution”. The design problem statement of this research has been discussed previously and is based on a literature study. Following this chapter, this research will cycle through the three stages, beginning with the analysis phase.

RTD APPLICATION In the analysis phase, information is gathered and interpreted. The goal of this phase is to find a deeper understanding of the design context and to identify possible solutions. The synthesis phase produces design solutions that together form an answer to the design problem statement. The synthesis phase “entails a cycle of emergence and development” (Nijhuis & De Vries, 2020). Emergence involves translating “half-formed internal imaginations” into a “tentative shape” (Nijhuis & De Vries, 2020). Development “concerns further refinement of the initial idea” (Nijhuis & De Vries, 2020). The evaluation phase assesses the solutions according to the research objective and identifies alternative problem solutions and limitations. These phases form an iterative process, the results of each phase are not set in stone as soon as a phase is over. By cycling back after each phase, the other phases are refined. These phases will be approached in two different ways: a theoretical study based on literature, geo-data and precedents and a practical study which will consist of on-site interviews, sketches, photographs and experiences.

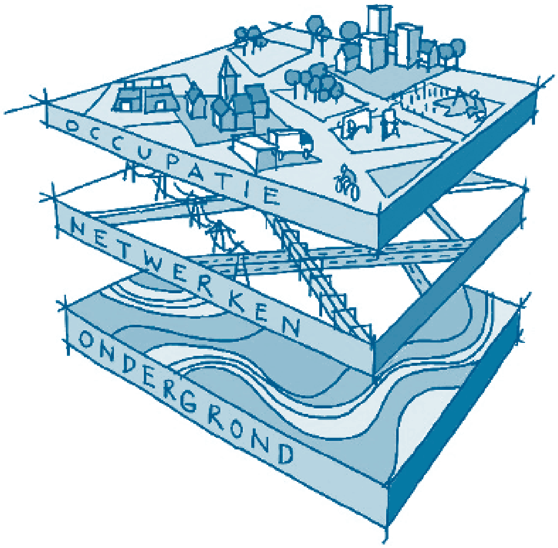
RESEARCH OBJECTIVE AND RESULTS Finally, the aim of this research goes beyond answering the research question. The result should be a workable framework that is used and supported locally by the people of Nakuru. Therefore, it is important that the results are translated into a product that is easy to use and is embedded in local knowledge and culture. This will be considered in all phases, but specifically addressed in the evaluation phase.



7 *Methodological framework (by author, adapted from Nijhuis & de Vries, 2021).*

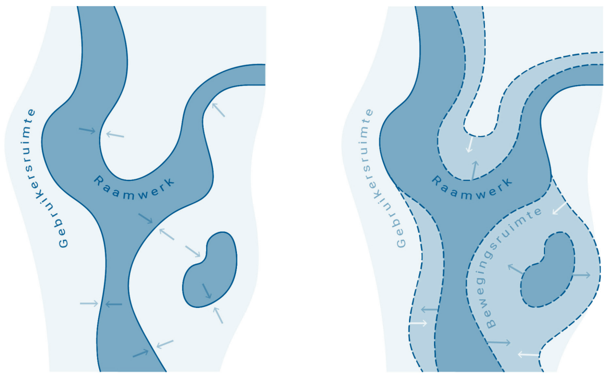
2. Research approach
2.2. Theoretical framework

In this chapter, four theories are introduced that will provide the foundation of the research and design process.



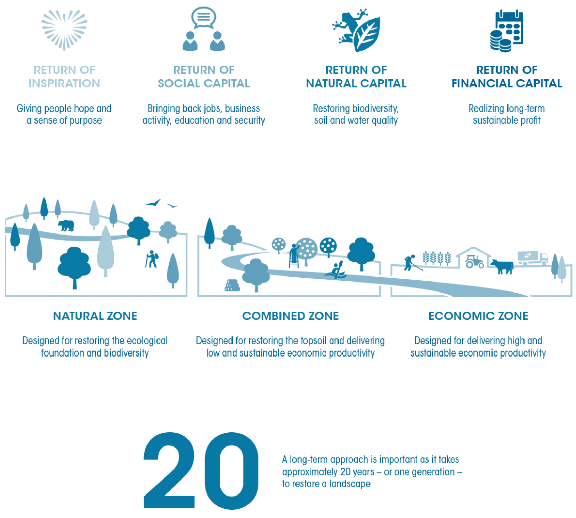
8 *The layer model (Image by Van Dauvelier Planadvies (2003).*

1, 2. LAYER/TRIPLEX MODEL (KERKSTRA) AND THE LAYER APPROACH (DE HOOG, SIJMONS & VERSCHUREN) The layers model was introduced in the seminal Design with nature by Ian McHarg, and later simplified by Bijhouwer and Vroom. The triplex model by Bijhouwer and Vroom exists out of three layers; the abiotic layer (soil and water), the biotic layer (flora and fauna) and the anthropogenic layer. This model is an analysis tool that helps explain complex landscape systems and the relation between i.a. cultural geography, vegetation and soil. The most recent version of the layers model was redefined in the Fifth Nota Ruimte released by the Dutch government. It adapts the three layers of the layer approach (De Hoog, Sijmons & Verschuren): the subsoil layer, network layer and occupation layer. The layer approach is a planning tool that was first developed for the Fourth Nota Ruimte in the 1980's. The difference between the layers approach and –model is that the approach is a planning tool that helps prioritize regional challenges, the model is a tool strictly used for analysis and explaining landscape system relations and coherence (Schengenga et al., 2023). The three layers can be defined as follows: *Layer 1: the subsoil (or natural system)*. This layer consists of the soil- and watersystem, flora, fauna and climate. These are slow processes that take around fifty to two hundred years. *Layer 2: networks*. This layer includes highways, railways, dykes, waterways and electricity lines. The development time of these big infrastructural networks takes twenty to fifty years. These networks are often in direct relation with the subsoil. *Layer 3: occupation*. This layer describes the actual landuse, which can be highly dynamical with a development time ranging between one year or a few decades. This research will use both the layer model and layer approach. The layer model will be used to analyze the site (Nakuru) and explain the landscape system. The layer approach will provide guidance in determining priorities for the regional framework for Nakuru.

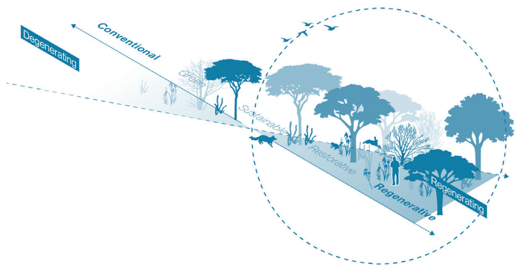


9 *The Casco concept (Image by H+N+S (2023).*

3. CASCO FRAMEWORK (SIJMONS) In the Netherlands in 1985, the first Eo Wijers competition took place, the competition historically asks for and stimulates daring and innovating regional designs. The first winner was *Plan Ooievaar*, a vision and radical new approach to river management. The Casco framework originates from this winning design and offers a spatial planning tool that makes a distinction between stable *frameworks* like ecosystems and hydrological networks and dynamic *usage zones* for e.g. city and agriculture. The aim of the concept is to minimize conflict between these slow and fast processes and stems from the notion that slow (natural) processes need time to develop (Schengenga et al. 2023).



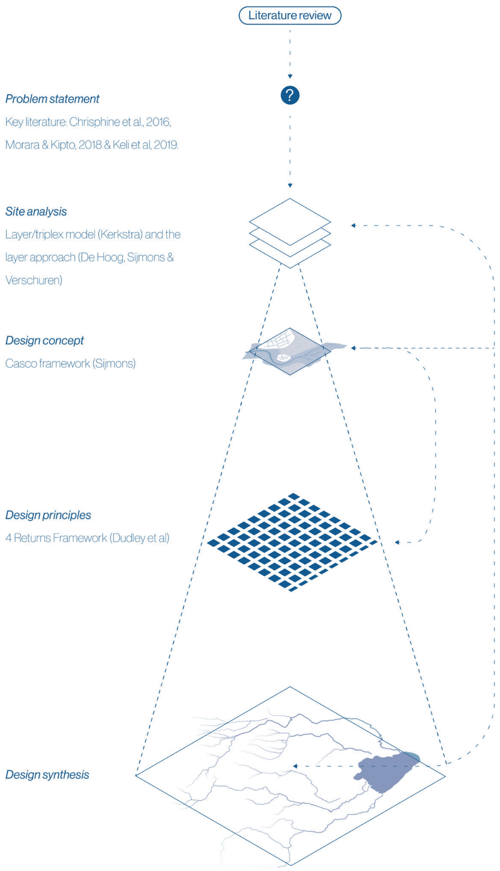
10 *The four returns framework (Image by Dudley et al. (2021).*



11 *Regenerative design concept (Image based on Regenesis design group, (n.d.).*

4. 4 RETURNS FRAMEWORK (DUDLEY ET AL) The 4 Returns Framework is a framework for landscape restoration connecting ecology, community values, spirit and culture. The framework states that all landscape restoration plans should establish four returns: inspiration ('encouraging a collaborative approach to build a long-term (…) vision'), natural returns ('large scale restoration efforts to ensure (…) critical ecosystem functions and biodiversity'), social returns ('… network building, job creation (…) gender equity and resilience.') and financial returns ('A restored landscape can generate significant interest and investment from financial returns.') (Dudley et al. 2021). The framework then provides a path to achieve these four returns through 5 elements, which are steps that are needed to guide the process (monitoring & learning, acting, landscape partnership, shared understanding and collaborative vision & planning.). Finally, the four returns and five elements are integrated with three zones: natural, combined and economic zones. This part of the 4 Returns Framework has similarities with the casco framework: it also divides the landscape in natural and economic zones but adds an interstitial zone: the combined zone (Dudley et al. 2021).

5. REGENERATIVE DEVELOPMENT AND DESIGN (REGENESIS & LYLES) Regenerative design is a concept that first emerged in the field of ecology, spearheaded by Regenesis & Lyles in the 1990s. It builds on the concept of sustainable development, but whereas sustainable design aims for neutral or reduced environmental impacts, regenerative design advocates for the reversal of ecological degeneration (Reed, 2015). In a 2015 study that evaluates the concept of



12 *Theoretical framework (Image by author (2025).*

regenerative design, Reed states that "regenerative design solutions regenerate rather than deplete underlying life support systems". Reed derives four premises from the work of Regenesis & Lyles: 1. Place and potential (understanding the evolutionary dynamics of a place). 2. Goals focus on regenerative capacity (goals defined by local capacity and embedded in local nature and culture). 3. Partnering with the place (working in partnership with a place and its processes). 4. Progressive harmonization (continually increasing pattern harmony between human and natural systems).

APPLICATION Theories, frameworks and concepts provide a theoretical and scientific guidance during the research and design process. The previously discussed theories were selected based on relevance to the research question and site context. The layer approach and -model and the casco framework are pillars of Dutch regional planning and the hypothesis is that they are applicable in a foreign context as well. The 4 Returns Framework adds depth to these strategies as it has a broader consideration for community values and culture. It also provides steps that can help regional design concepts be implemented in reality. In this project, the layer model will be used to analyze the site and find a deeper understanding of the landscape around Nakuru. By using the layer approach, priorities will be set, and a diagnosis will be made. Consequently, by using the casco framework a regional design concept will be developed. Based on this design concept, the 4 Return Framework will help set design guidelines, embed the project in the context of Nakuru and find steps and paths to implementation.

2.3. Research questions

RESEARCH RELEVANCE AND KNOWLEDGE GAP Studies on land use and planning by e.g. Mubea & Menz (2012), Baker et al. (2010), Ehrensperger et al. (2004) all underscore the importance of better regional planning Nakuru and Kenya in general. Especially because of the effects and risks that come with climate change. The fact that there are many studies on the relationship between landcover change and water challenges (such as flooding and water scarcity) proves the relevance of this topic. While studies exist on regional (river) planning strategies, this topic has been understudied in the context of developing countries. Therefore, this research adds to the scientific discourse on regional planning for regenerative rivers in developing countries, paying special attention to local knowledge and values.

RESEARCH OBJECTIVE The research objective is to design a possible method for regenerative urban growth in Nakuru that is sensitive to the natural river catchment system, aiming to mitigate climate pressure and restore ecosystem services in and around the Lake Nakuru catchment. The research will explore and test nature-based solutions and urban planning strategies that improve water management. The intended outcome is a both a workable framework that can be used by government officials, researchers and local residents in Nakuru, as well as generalized design guidelines that can be applied to other cases in the world.

RESEARCH QUESTIONS To complete this objective and answer the problem statement, research questions were formulated. The main research question is: *What possible spatial strategy can guide planning for a regenerative river catchment that supports sustainable urban development in Nakuru, Kenya?*

Five sub-research question are stated to help answer this question. The first two relate to the analysis phase of the RTD method. The goal is to find a deeper understanding of the natural, network and cultural layers of the site to guide and inform design measures later in the process.

SRQ1: How do the natural system, networks and land-use relate to each other in the Nakuru river catchment?

SRQ2: What is the (cultural, historical, natural) significance of the Njoro river catchment in relation to Nakuru City?

The third and fourth sub-research-questions are related to the synthesis phase, by answering these questions a design concept and design guidelines will be formulated that will result in a possible spatial strategy for Nakuru's river catchment.

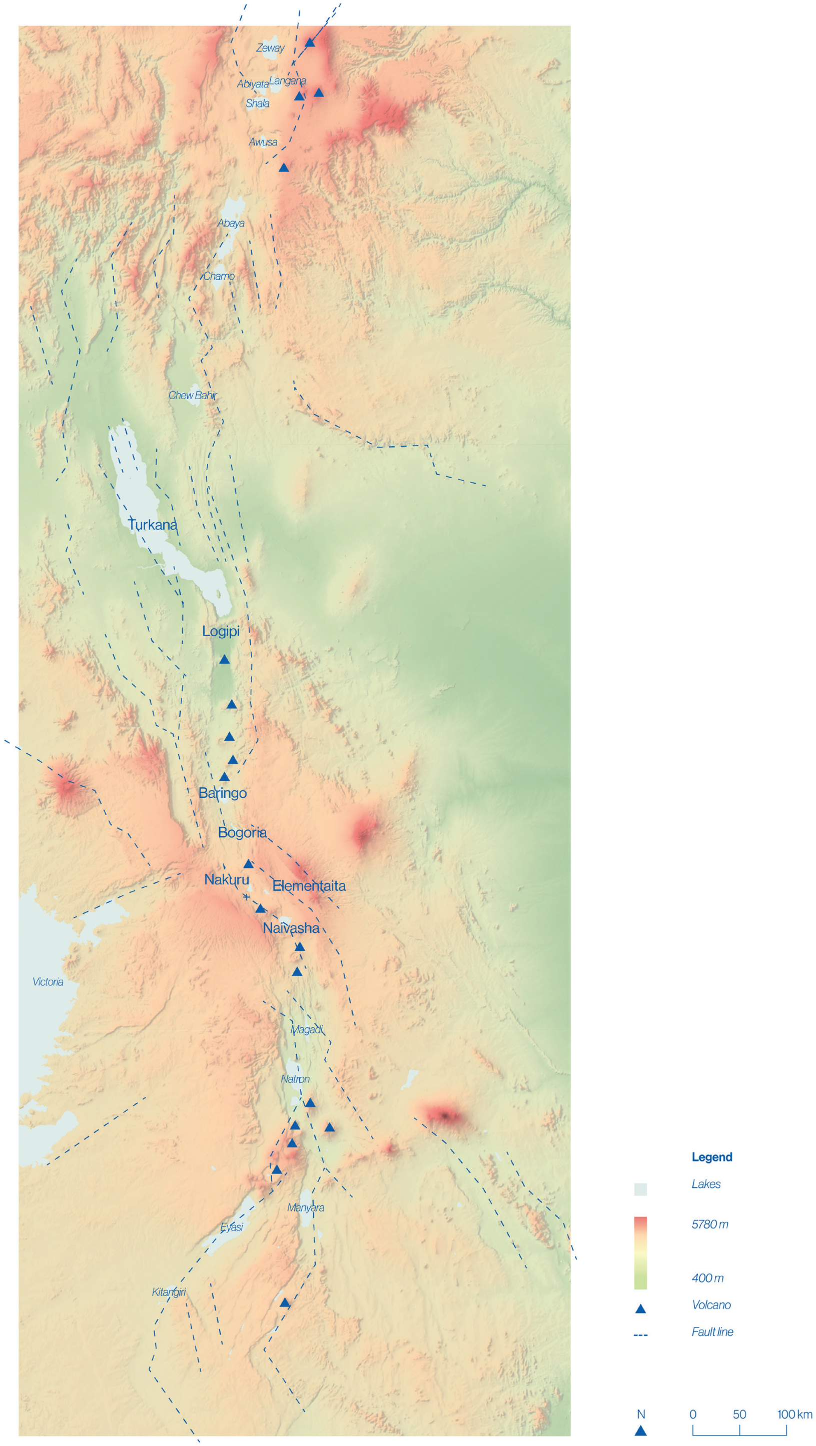
SRQ3: Which landscape design theories and strategies are suitable for regenerating the Nakuru river catchment and facilitating sustainable urban development?

SRQ4: How can these theories and strategies be applied to shape a healthy and resilient future for the Nakuru river catchment?

The final sub research question relates to the evaluation phase and is intended to help evaluate the outcomes of the synthesis phase and to a lesser extent the analysis phase.

SRQ5: What lessons can be learned from this framework that are applicable to other cases around the world?

3. *Nakuru, City of dust*


Zeway
Abiyata
Langana
Shala
Awusa
Abaya
Chamo
Chew Bahir
Turkana
Logipi
Baringo
Bogoria
Nakuru
Elementaita
Naivasha
Victoria
Magadi
Natron
Manyara
Eyasi
Kitangiri
Legend
Lakes
5780 m
400 m
Volcano
Fault line
N
0
50
100 km

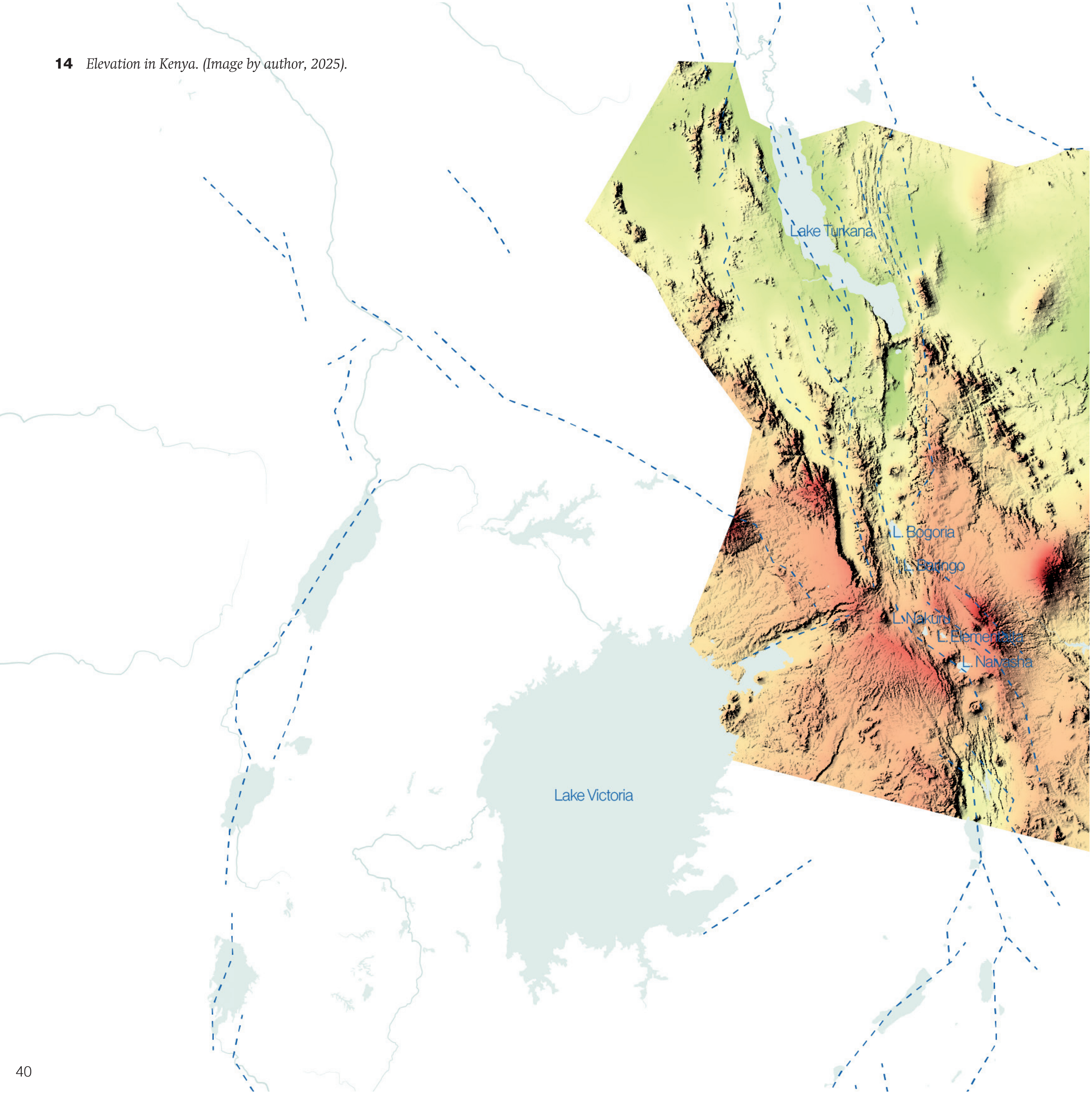
3. Nakuru, city of dust

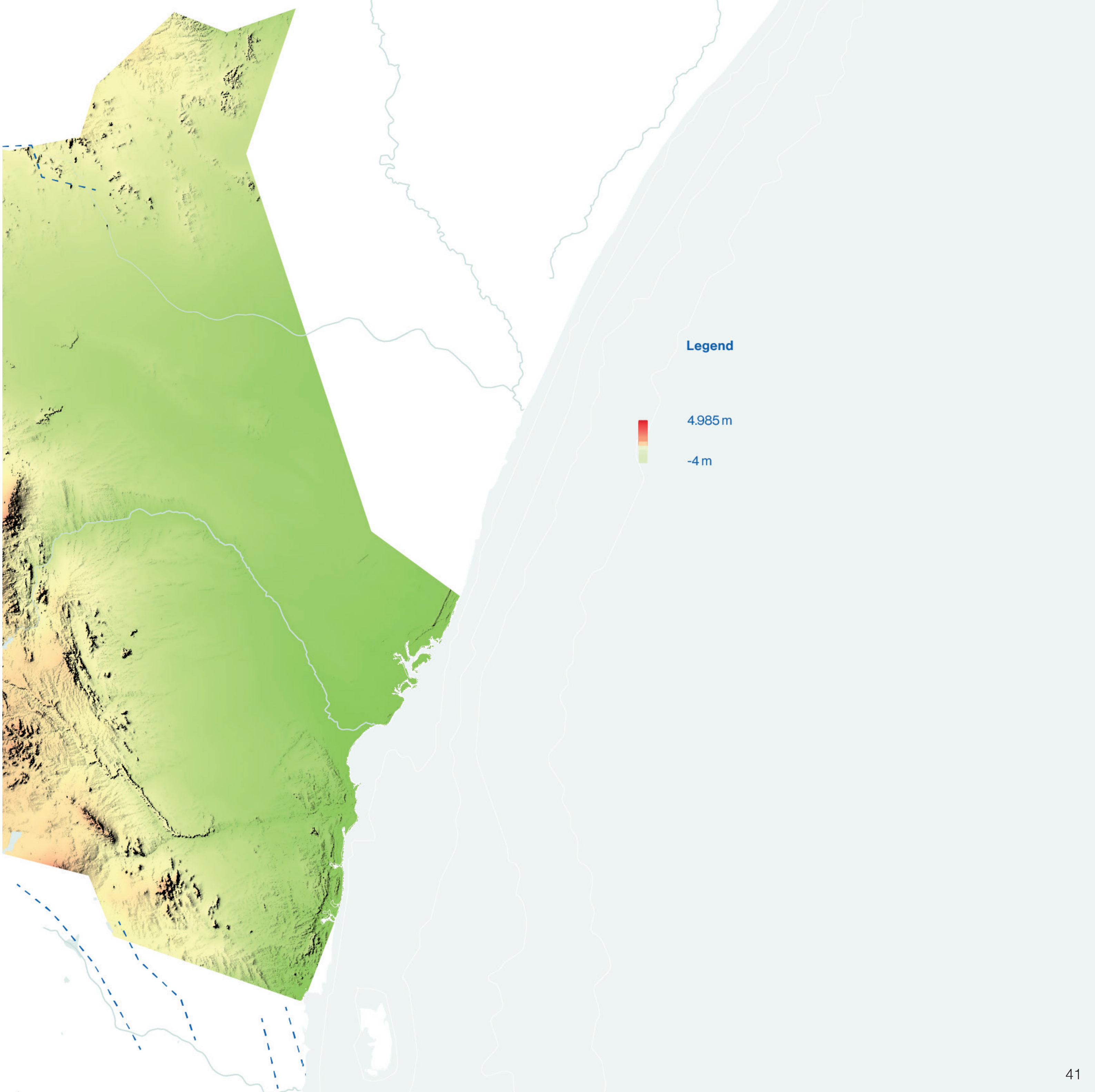
3.1. Natural system

THE EAST AFRICAN RIFT SYSTEM Nakuru is situated in the East African Rift System (EARS) that runs through East Africa, crossing Ethiopia, Kenya and Tanzania. The East African Rift System (EARS) is a geological occurrence that has shaped the landscape, ecosystems, and human activities of East Africa. The EARS is the result of rifting, the geological process of a tectonic plate breaking apart. The EARS is an intercontinental rift system that separates the Somalia sub-plate from the rest of the African plate (Kutukhulu, 2010) and is considered an active system (Scoon, 2018). The EARS runs from north to south and is compartmentalized by faults (fractures), with varying orientations at a range of angles. The EARS is shaped by a 'horst-graben' structure (Kutukhulu, 2010)., where blocks of the Earth's crust are uplifted (horsts) or sink (grabens) due to tectonic activity. The Kenyan part of the rift is compartmentalized into basins that range in width between 50 and 100 km long. The basins are separated by volcanic features, which characterize the rift valley. In Nakuru, the Menengai Caldera separates the Baringo Bogoria basin from the Nakuru basin (Grove, n.d.), it is the main topographical feature nearby Nakuru, and it is a major geothermal field in Kenya. (Conti et al, 2021) From west the east the Kenya rift can be divided into the western rift shoulder (Mau Escarpment), the inner through (Lake Nakuru), the intra rift plateau (Bahati-Kinangop plateau) and the eastern rift shoulder (Aberdare range) (Conti et al, 2021). The geology consists of volcanic rocks including basalts, phonolites, tuffs and trachytes which originate from the past four million years (Kutukhulu, 2010), which is relatively young on the geological timescale and underlines the activity within the region.

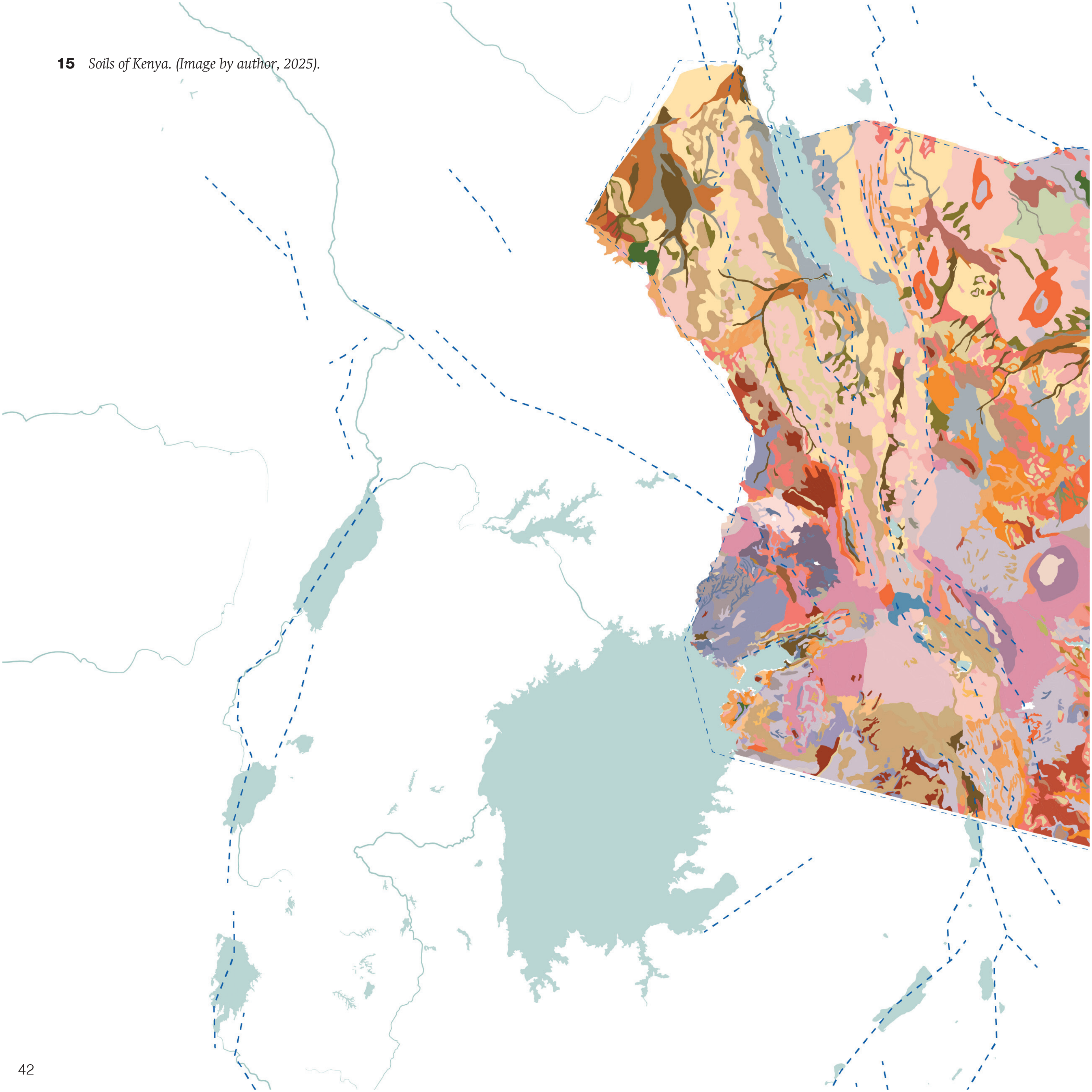
◀ **13** *The East African Rift System (Image by author, 2025).*

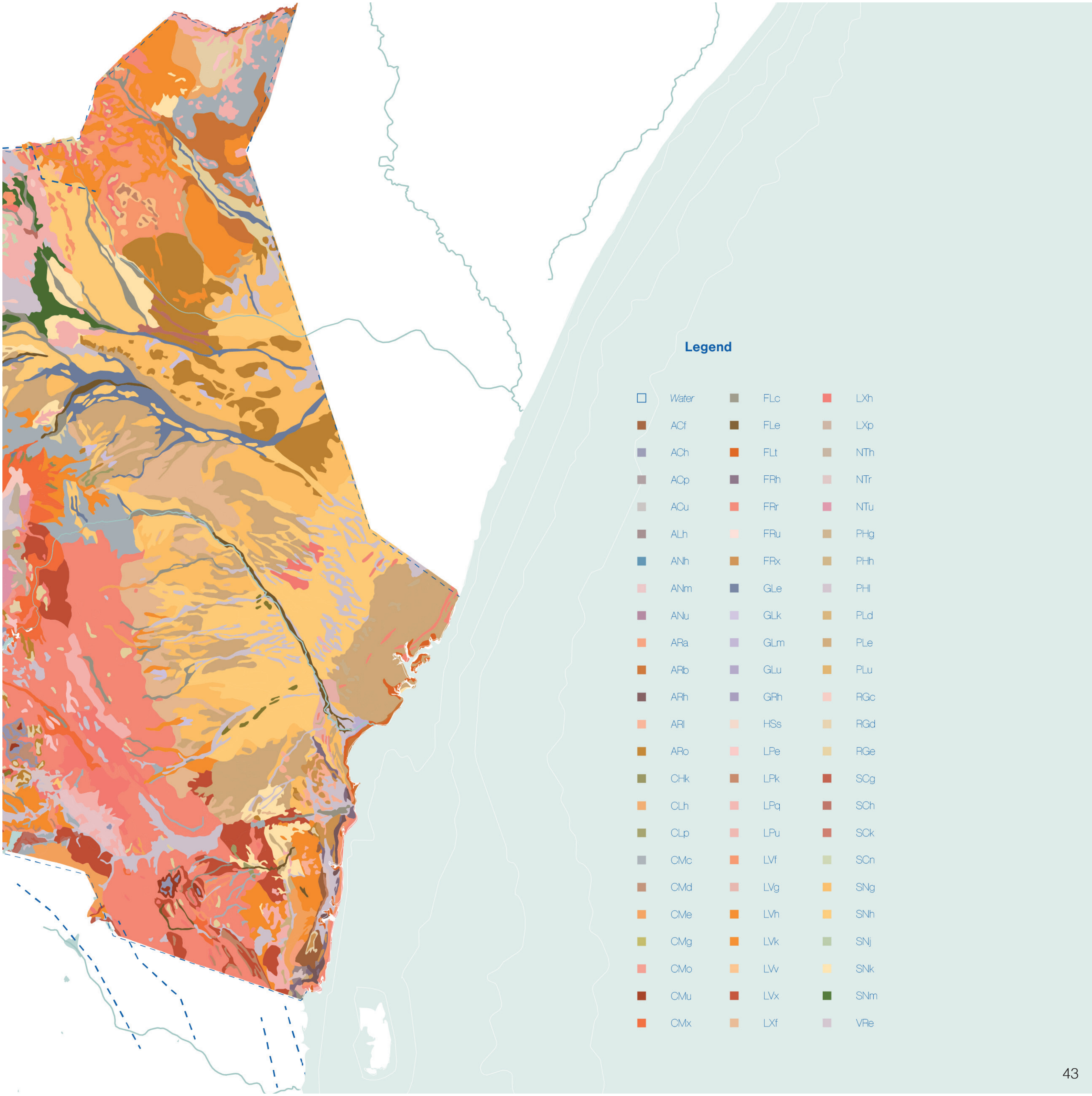
14 *Elevation in Kenya. (Image by author, 2025).*

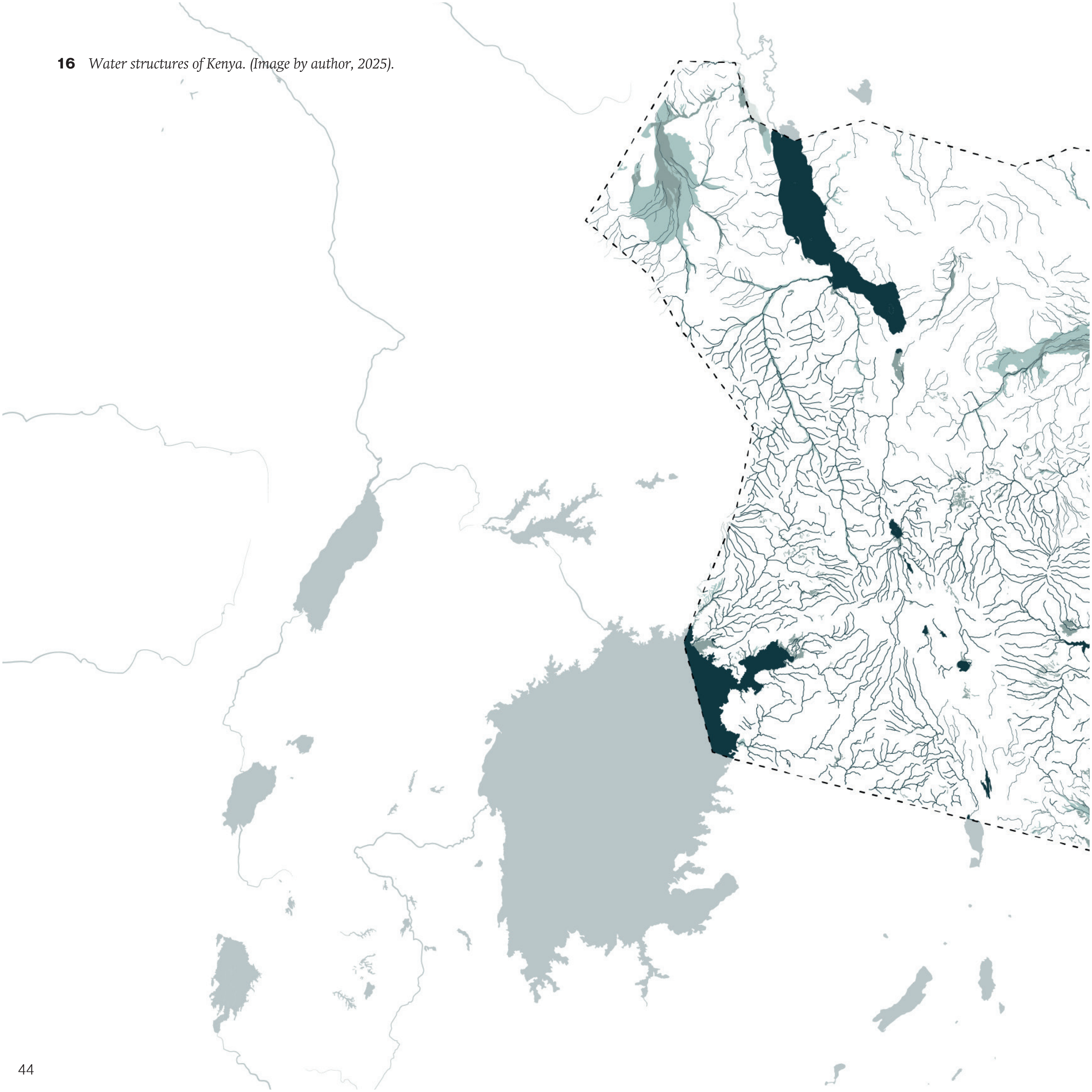



Legend
4.985 m
-4 m

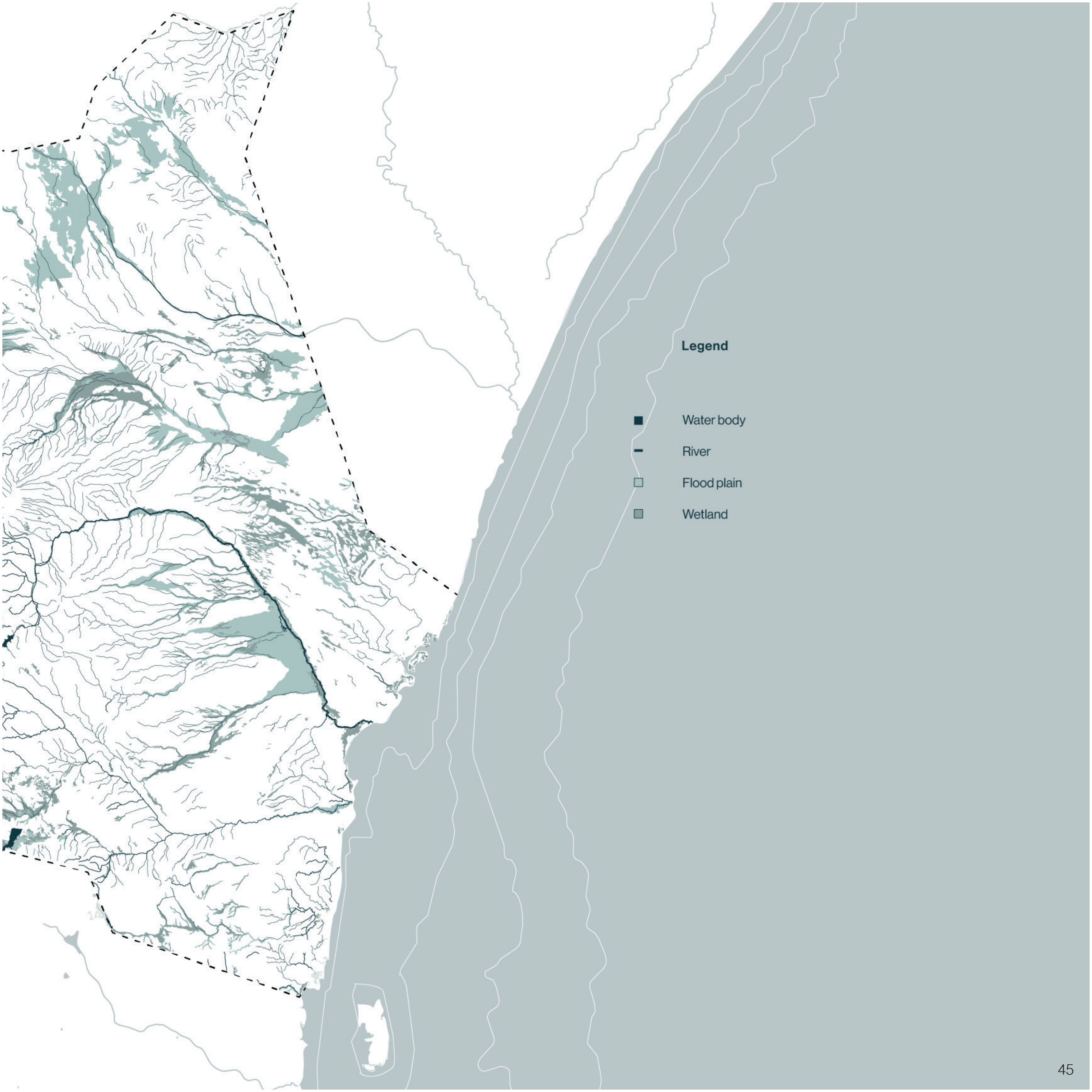
15 *Soils of Kenya. (Image by author, 2025).*



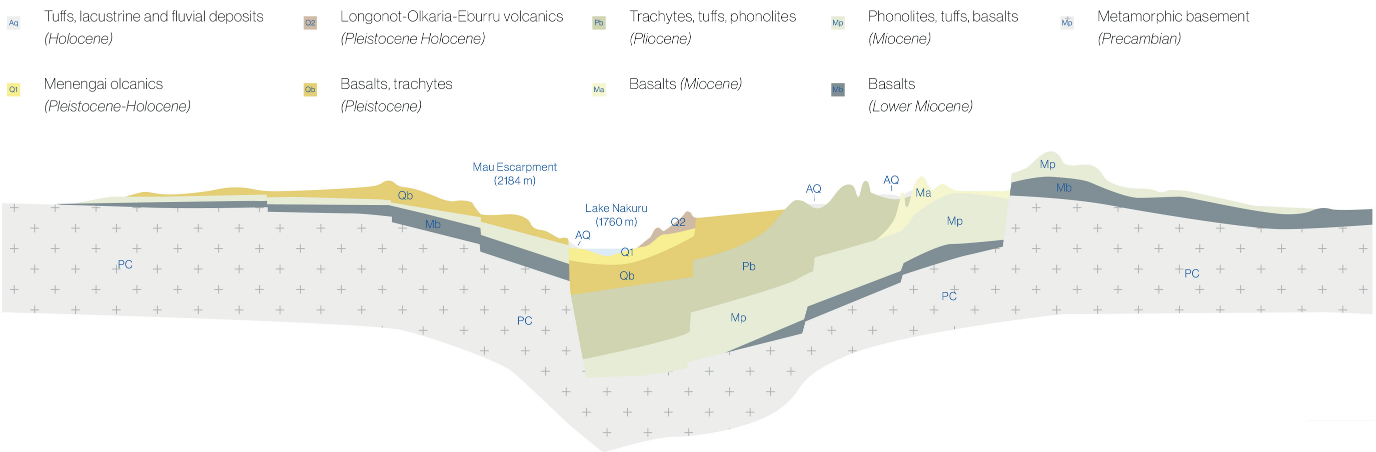

Legend
Water
ACf
ACh
ACp
ACu
ALh
ANh
ANm
ANu
ARa
ARb
ARh
ARl
ARo
CHk
CLh
CLp
CMc
CMd
CMe
CMg
CMo
CMu
CMx
FLc
FLe
FLt
FRh
FRr
FRu
FRx
GLe
GLk
GLm
GLu
GRh
HSs
LPe
LPk
LPq
LPu
LVf
LVg
LVh
LVk
LVv
LVx
LXf
LXh
LXp
NTh
NTr
NTu
PHg
PHh
PHl
PLd
PLe
PLu
RGc
RGd
RGe
SCg
SCh
SCk
SCn
SNg
SNh
SNj
SNk
SNm
VRe



16 *Water structures of Kenya. (Image by author, 2025).*

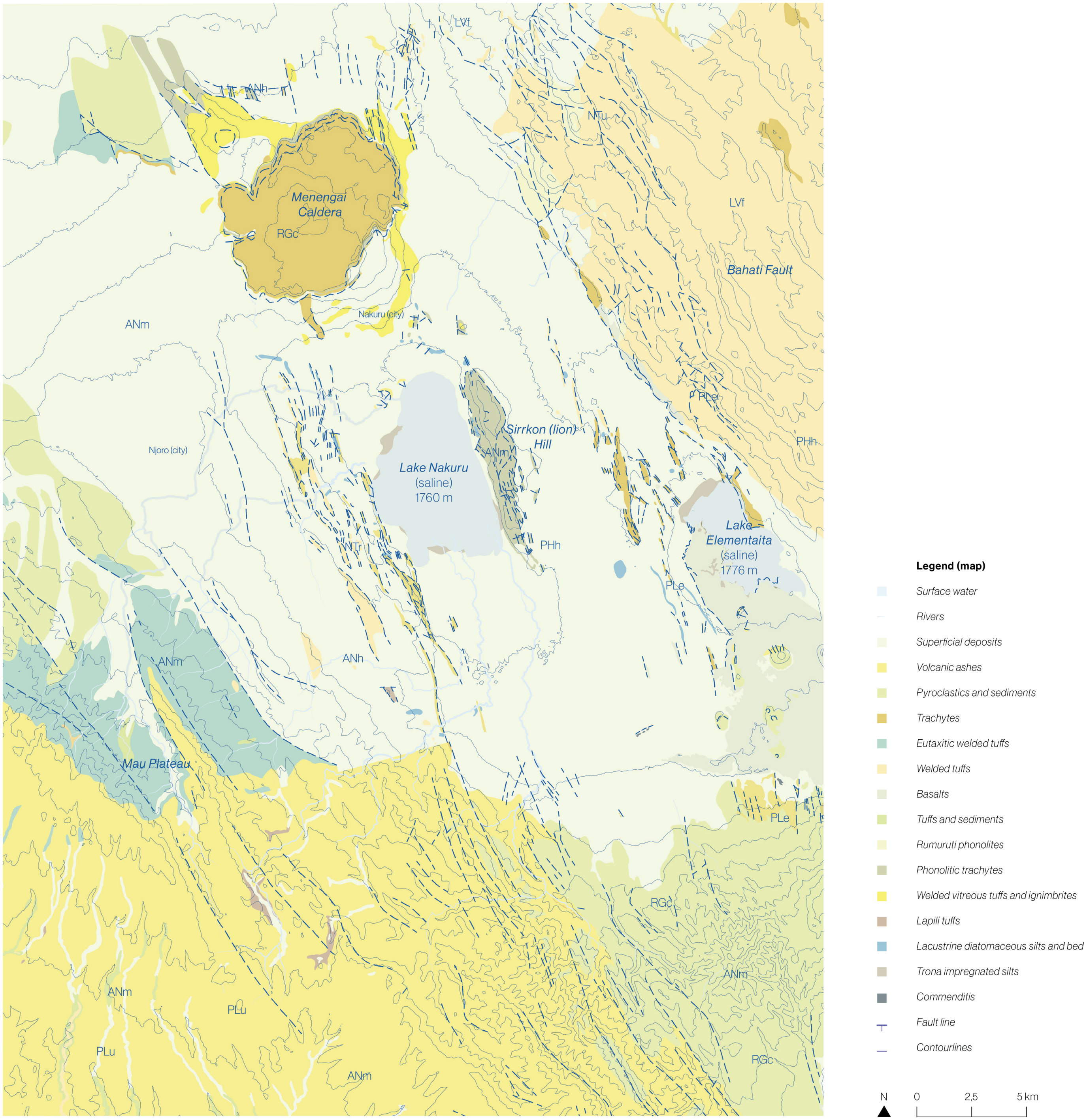

Legend
Water body
River
Flood plain
Wetland

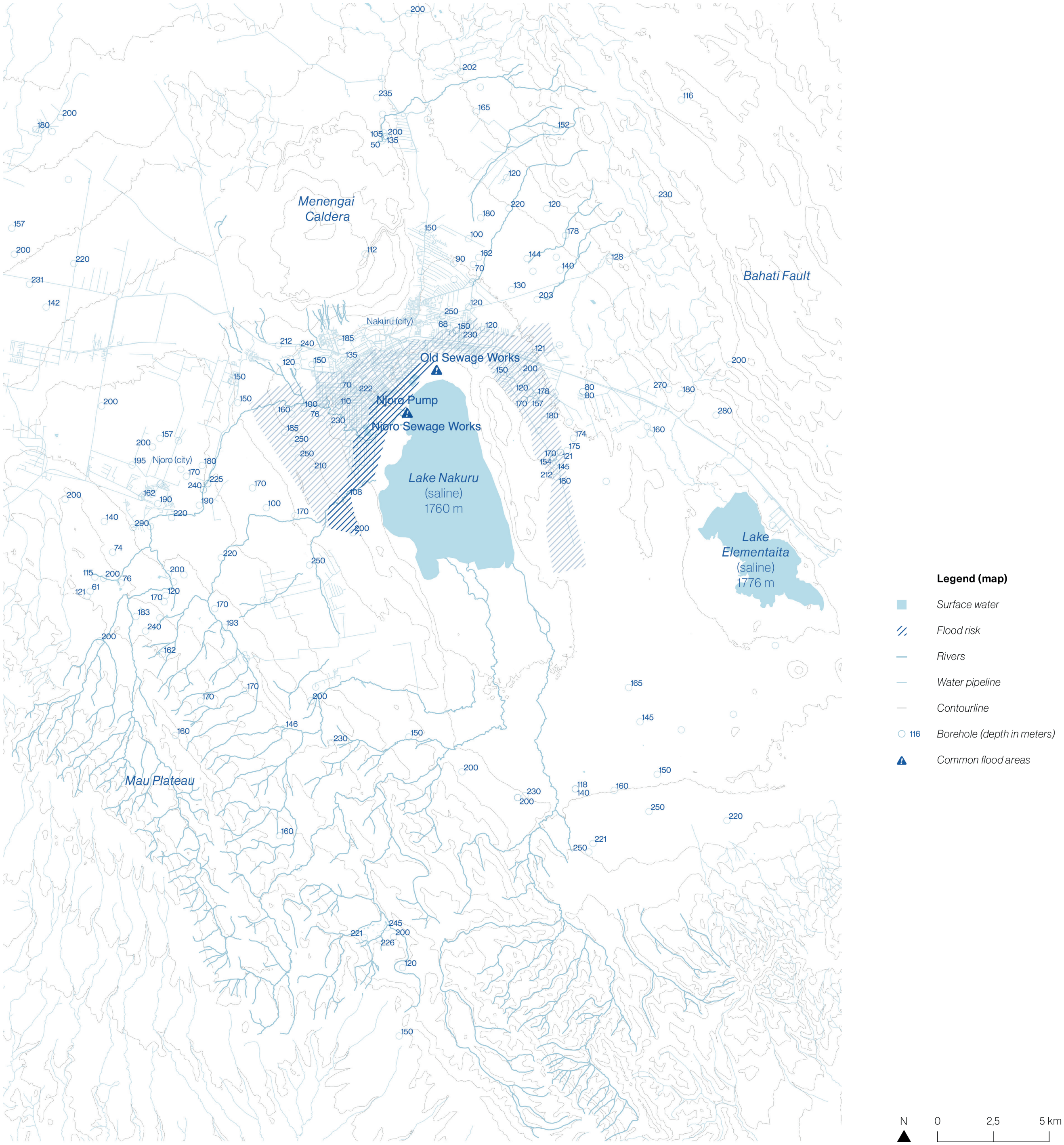
SOILS Various types of soil are found near Nakuru, many of which are volcanic in origin and influenced by the Menengai Caldera. South of Menengai and west of Lake Nakuru, the dominant soil type is mollic andosol (ANm). This soil forms from volcanic materials such as ash, pumice, or lava. It has a dark, fertile top layer (called a mollic horizon) that is rich in organic matter. Mollic andosols are highly porous and retain water well, making them excellent for agriculture. To the north of Menengai, and in smaller areas to the southwest, haplic andosols (ANh) are common. These soils are also derived from volcanic materials but have a simpler, less developed structure than mollic andosols (the term haplic indicates a simple and little differentiated profile). Like ANm, they are fertile and well-draining. Two other types of volcanic soils found in Nakuru are humic nitisols (NTu) and rhodic nitisols (NTr). These soils form in tropical regions from weathered volcanic materials. Humic nitisols have a clay-rich structure with high levels of organic matter in the upper layers, while rhodic nitisols are similar but are characterized by their reddish color, which reflects a high content of iron oxide. Both are fertile and suitable for agriculture. In addition to volcanic soils, haplic phaeozems (PHh) are also found in Nakuru. These soils, typically associated with temperate grasslands like steppes, are rich in organic matter and nutrients such as calcium and magnesium (Van Waveren, 1995).



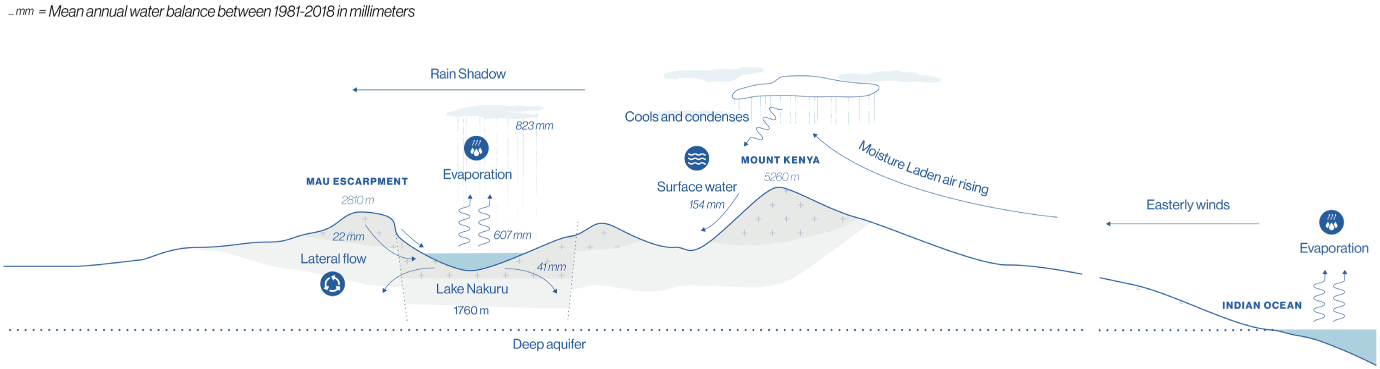
17 *Geology of the Rift System in Nakuru (Image by author, 2025).*

18 *Geology and fault lines in Nakuru (Image by author, 2025).* ▶


LVf
ANh
NTu
Menengai Caldera
RGc
LVf
Bahati Fault
ANm
Nakuru (city)
Sirrkon (lion) Hill
ANm
PHh
Lake Nakuru
(saline)
1760 m
Njoro (city)
PHh
Lake Elementaita
(saline)
1776 m
PLe
ANm
ANh
Mau Plateau
PLe
RGc
ANm
ANm
PLu
PLu
ANm
RGc
Legend (map)
Surface water
Rivers
Superficial deposits
Volcanic ashes
Pyroclastics and sediments
Trachytes
Eutaxitic welded tuffs
Welded tuffs
Basalts
Tuffs and sediments
Rumuruti phonolites
Phonolitic trachytes
Welded vitreous tuffs and ignimbrites
Lapili tuffs
Lacustrine diatomaceous silts and bed
Trona impregnated silts
Commenditis
Fault line
Contourlines
N
0
2,5
5 km


Menengai
Caldera
Nakuru (city)
Old Sewage Works
Njoro Pump
Njoro Sewage Works
Njoro (city)
Lake Nakuru
(saline)
1760 m
Bahati Fault
Lake
Elementaita
(saline)
1776 m
Mau Plateau
Legend (map)
Surface water
Flood risk
Rivers
Water pipeline
Contourline
116
Borehole (depth in meters)
Common flood areas
N
0
2,5
5 km

WATER The Nakuru Catchment is a closed water system with Lake Nakuru as the single outlet and endpoint of the watercycle. Lake Nakuru is one of several shallow alkaline-saline lakes located in the EARS. Lake Nakuru is one of the highest lakes in the Kenyan part of the EARS, lying at 1.759-meter asl. Other, lower-lying Rift Valley Lakes have a steady water supply though hot and freshwater spring, but Lake Nakuru's underground inflow is minimal. The lake's mean depth is 2,5 meters and the maximum depth is 4,5 meters, and a water volume of about 92 x 106 m3.



▲ **19** *Water cycle of Lake Nakuru catchment (Image by author, 2025).*
◄ **20** *Boreholes, major rivers, flood risk and surface water in Nakuru (Image by author, 2025).*

The catchment supply depends on rivers in order to sustain the lake water level, five seasonal rivers drain into the lake (Makalia, Nderit, Naishi, Njoro and Larmudiac) of which Njoro is the most important. The streamflow responds strongly to precipitation peaks. The first peak flow in the year occurs in May, a month after peak rainfall and the second peak flow coincides with the rainfall peak in August (Odada et al, 2004). The climate in Nakuru is semi-arid, however the higher elevation of the eastern and western rift shoulders make that parts of the drainage basin are cooler and wetter. In the higher parts the mean annual temperatures are approximately 12 °C, in the lower parts the mean temperature is 18 °C. In the uplands the mean annual rainfall is about 1000 mm, in the valley floor it is around 730 mm (Renaut & Owen, 2023).

3.2. Networks

NORTHER CORRIDOR Nakuru is an important transport node in the Northern Corridor, which is a transport corridor that connects the port of Mombasa to Kampala (Uganda) and other landlocked countries in the Great Lakes region (e.g. Rwanda, Burundi). In 1985 these countries together with Kenya signed the Transit Agreement, which provides for the development of transport infrastructure to facilitate transit transport (TTCA, 2004). The groundwork for the Northern Corridor was laid down by the British colonizers. When they set foot in East Africa in Kenya, they were hardly interested in Kenya and instead set their eyes on Uganda for its natural resources and position close to Lake Victoria, because of its importance and influence on the Nile catchment. As Kenya was hard to traverse by waterway, the British aimed to establish a railway from the port of Mombasa (Kenya) all the way to Kampala (Uganda) (Otiatio, 2018). The colonial infrastructure also shaped the land use of lands near the railway. After construction, the British settlers found need to justify the investments. According to Otiato (2018) the British settlers "alienated lands along the railway for cash, crop farming including tea and coffee to feed the railway with cargo" (p. 34). Towns also developed along the railway and Africans came to work on white owned farms.

RACE TO LAKE VICTORIA At the same time, German colonizers in Tanzania built a competing railway system in an attempt to first reach and claim control of Lake Victoria. The race to Lake Victoria resulted in two parallel railways that later developed into the current transit routes the Northern and Central corridor (Otiatio, 2018). The Ugandan Railway line (British) used the metre gauge for its tracks, while the Tanganyika railway (German) was built with the 1000mm narrow gauge, making the lines incompatible. Therefore, a new railway line is being built using a standard gauge. This is a planned new railway connection (the Standard Gauge Railway (SGR) that will pass through Mai Mahiu (Naivasha) all the way to Malaba. The SGR will establish a dry port in Naivasha, which is expected to significantly boost the economic activity within the county (NKG, 2018). Several major highways of national and international importance, such as the A104 from Nairobi to Malaba (which also crosses Kisumu and Eldoret), also cross Nakuru. Its central position on national and international trade routes makes Nakuru an attractive city for business.

URBAN EXPANSION Much like other urban centers in Kenya, Nakuru is a fast-growing city with a young population. The population expanded from 19.600 in 1950 to 437.000 in 2024 (UN, 2024). The rapid growth in population has led to a significant need of expansion of the city's road network and housing program. A lot of the urban development is unplanned and informal, big slum areas such as Kaptembwa, London, Bondeni and Free Area

21 *Nakuru as a node in the East African transport corridor (The Northern Corridor) (Image by author, 2025).*

are found on the outskirts of the city (Kosgey et al., 2024). These areas face challenges such as poor sanitation, limited access to clean water and overcrowding (Kosgey et al., 2024). The complete road network in Nakuru County amounts to about 12.491,0 km, consisting of 993,7 km paved roads, 4.500,0 km gravel roads and 6.998,0 km earth roads. According to a report by the County of Nakuru (2018), 45% of roads are in inadequate conditions, especially in agricultural areas (e.g. Njoro Subukia). This leads to a delay in transport of agricultural produce, causing losses for farmers (NKG, 2018).

ENERGY According to a County Energy Plan published by The Covenant of Mayors in Sub-Saharan Africa (CoM SSA) in 2022 90,7% of households in Nakuru County have access to electricity. A majority (61,0%) is connected to the national energy grid and 26,9% of households have access through independent solar energy systems (photovoltaic (PV) systems). The national energy grid is regulated by two parties the Kenya Electricity Generation Company (KenGen) and Kenya Power and Lighting Company (KPLC). Both companies are publicly traded on the Nairbo stock exchange, but the Kenyan government is the majority shareholder. KenGen generates roughly 80% of the electricity consumed in Kenya, “approximately 62% of which comes from hydropower, 26% from fossil fuels and 12% from geothermal plants in the rift valley” (Parshall et al. 2009). Hydropower generation occurs most frequently along the Tana River and its tributaries. KPLC then buys up energy from KenGen and distributes it to households in Kenya. KPLC owns and operates the national distribution and transmission network (Parshall et al. 2009).

Compared to other counties, Nakuru’s electricity grid is highly developed, illustrated by the dense network of electricity infrastructure. However, the infrastructure is distributed unevenly. The grid in rural neighborhoods like Kuresoi North and South is not as developed compared to urban neighborhoods like Nakuru East and West (CoM SSA, 2022). The report lists the “moderate access to clean, affordable and reliable energy” as one of the core challenges for the region (CoM SSA, 2022). As a result, many households around Nakuru use biomass, such as wood fuel to complement electricity as a source of energy. A case study on Likia, a small village near the Mau Forest in the Njoro Sub County of Nakuru County, found that woodfuel is the primary source of energy for cooking (Eshiamwata et al., 2019). In a questionnaire, 90% of respondents indicated they use firewood for cooking. This is consistent with other studies that indicate 70% of all energy requirements in Kenya rely on biomass (Eshiamwata et al., 2019). The unsustainable increase of biomass energy leads to (illegal) logging, deforestation and in turn land degradation (Kairu & Tobias, 2015).

22 *Electricity and infrastructure networks in Nakuru (Image by author, 2025).* ▶

Legend

- Surface water
- Rivers
- 33kV line
- 11 kV line
- Primary road
- Secondary road
- Tertiary road
- Residential road
- Railway
- Railway station
- Bus station
- Wastewater plant
- Communication tower
- Industry

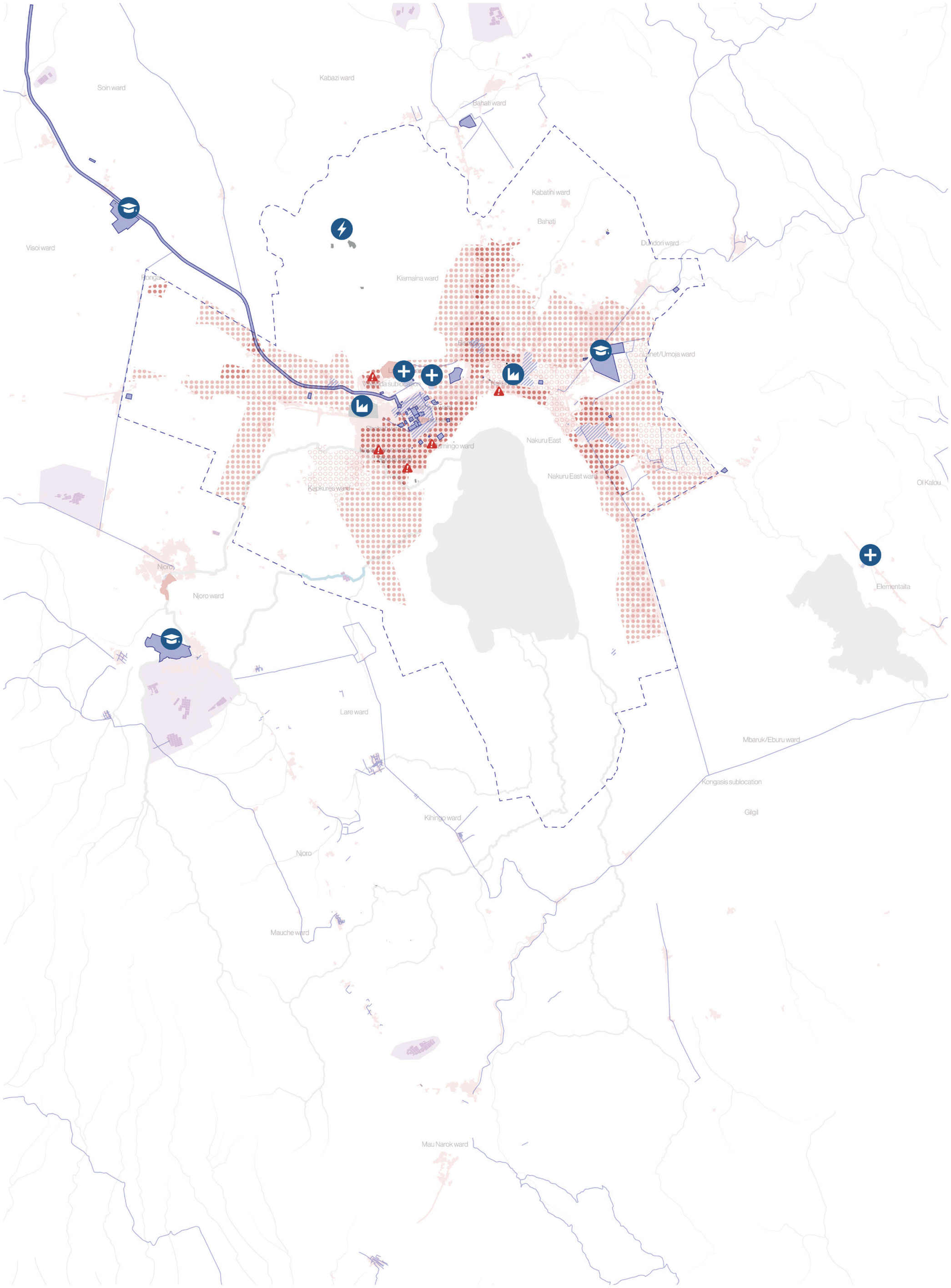
N 0 2,5 5 km

3.3. Occupation

As mentioned earlier, the British settlers needed to justify the costs of the Ugandan railway. The Protectorate's Commissioner at the time (Sir Charles Eliot) stated that "unless greater effort was made to develop the East African territories, it was unlikely the Uganda line would repay the costs of its construction" (Duchhart, 2007, p. 40). According to Duchhart (2007) the Foreign Office deemed traditional African farming methods as incapable of generating the volume of crops needed to sustain a viable export (Duchhart, 2007). It was believed that intensive, high-volume agriculture grown on European owned farms was essential. The European farmers changed tropical forests and savannah into large-scale open landscapes. Because of its relatively cool temperature and fertile volcanic soil, the Rift Valley was a popular place for the European colonists to settle. Nakuru became a major agricultural center, and large amounts of land were deforested in favor of agriculture. Agriculture remains the dominant land use type in Nakuru. According to Mulwa et al. (2023) "Nakuru is one of the high potential agricultural regions of Kenya, contributing 20% to the food basket of the country" (p. 157).

It is no coincidence that the country's most established agricultural university was founded in Nakuru. Founded in 1939 as an agricultural college by Lord Egerton, the Egerton University was granted the status of university in 1986 (Sternitzke & Stoddart, 2011). The city is also home to the Rift Valley Institute of Science and Technology (RVIST), which provides more practical education also in – among others – agriculture and agricultural technologies.

23 *Land use and social networks in Nakuru (Image by author, 2025).* ▶



Legend

Surface water
Rivers
Urban area
Major roads
High urban density
Medium urban density
Low urban density
Commercial center
Educational facilities
Light industry
Geothermal energy plant
Healthcare facilities
Greenhouse horticulture
City planning extent (2013)
Sport facilities
Informal neighborhoods

N

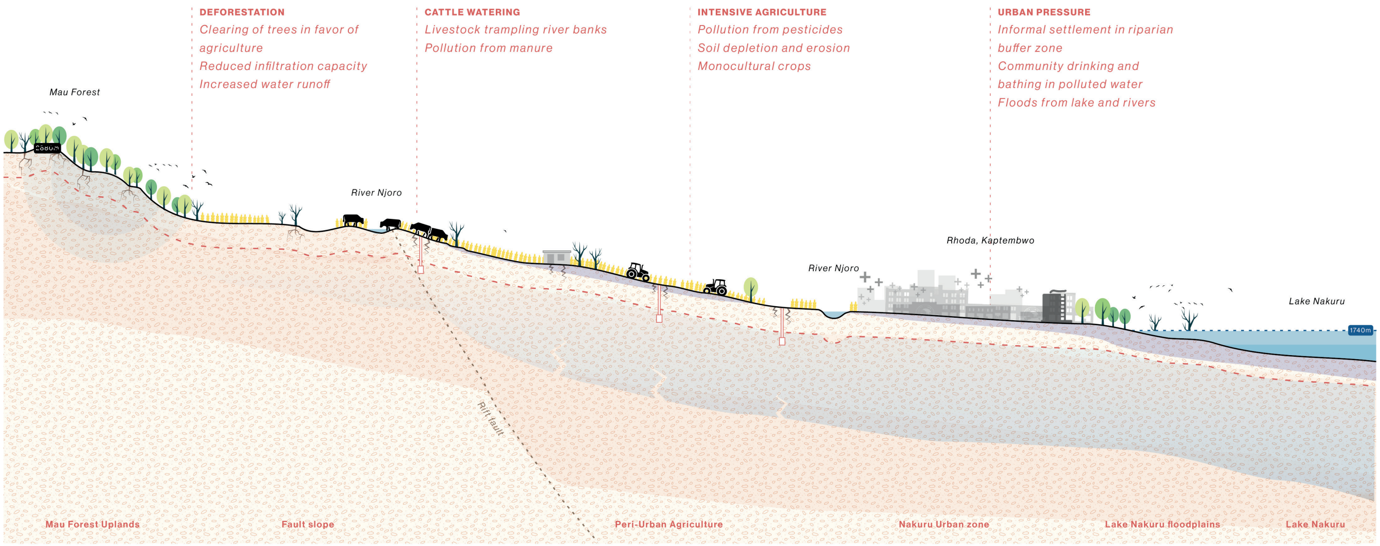
0 2,5 5 km

3.4. Diagnosis

Within the Njoro River catchment (and the greater Nakuru region) natural systems, infrastructure and human activity are in increasing tension. The unique geomorphology of the EARS has shaped the natural conditions defined by a hilly landscape, porous and fertile volcanic soils and a closed water cycle. The Njoro River forms a strong hydrological backbone that is able to sustain both ecosystems and human livelihoods. However, widespread deforestation, sedimentation, and climate-induced variability have severely disrupted this system's balance. The network layer is originally shaped by colonial infrastructure and recently expanded through urban development. It demonstrates how transport, energy, and water infrastructure have outpaced ecological considerations. The inadequacy of road and sanitation systems, particularly in informal settlements, increases runoff and pollution, compounding pressure on the river system.

Finally, the occupation layer reveals the socio-economic complexity of the region. Intensive agriculture, informal urban expansion, and energy reliance on biomass all contribute to land degradation and deforestation. Yet, this layer also holds significant potential: the region's agricultural heritage, educational institutions, and community-based energy and water initiatives suggest pathways for sustainable, regenerative development.

Together, these layers form a fragmented landscape where fast, anthropogenic processes undermine the slower rhythms of the natural system. The analysis highlights the urgent need for spatial strategies that harmonize these layers. This diagnosis forms the foundation for a regenerative design framework, in which the river system can act as both a physical and conceptual spine for integrated, long-term planning.



24 *System diagnosis of the Njoro catchment (Image by author, 2025).*

4. Portrait of a river

25 *The Njoro River in motion (Image by author, 2025).*

“The forests on and around the mountains were Kenya’s bathrooms. Around them, it rained almost every day. Rising hot air crashed against the trees in the mountains, where the rain from the broken-open clouds was absorbed into the spongy soil. The forest slowly released the water into countless rivers, feeding the lakes. But now, Kenya had hardly any deep jungle left, and sometimes the bathrooms ran dry. Other times, they overflowed completely. Due to deforestation, the mountains no longer held the water back and instead spewed it down in a raging, brown flood.”.

Exempt from “Een wolkenkrabber op de savanne” by Koert Lindijer (2023).

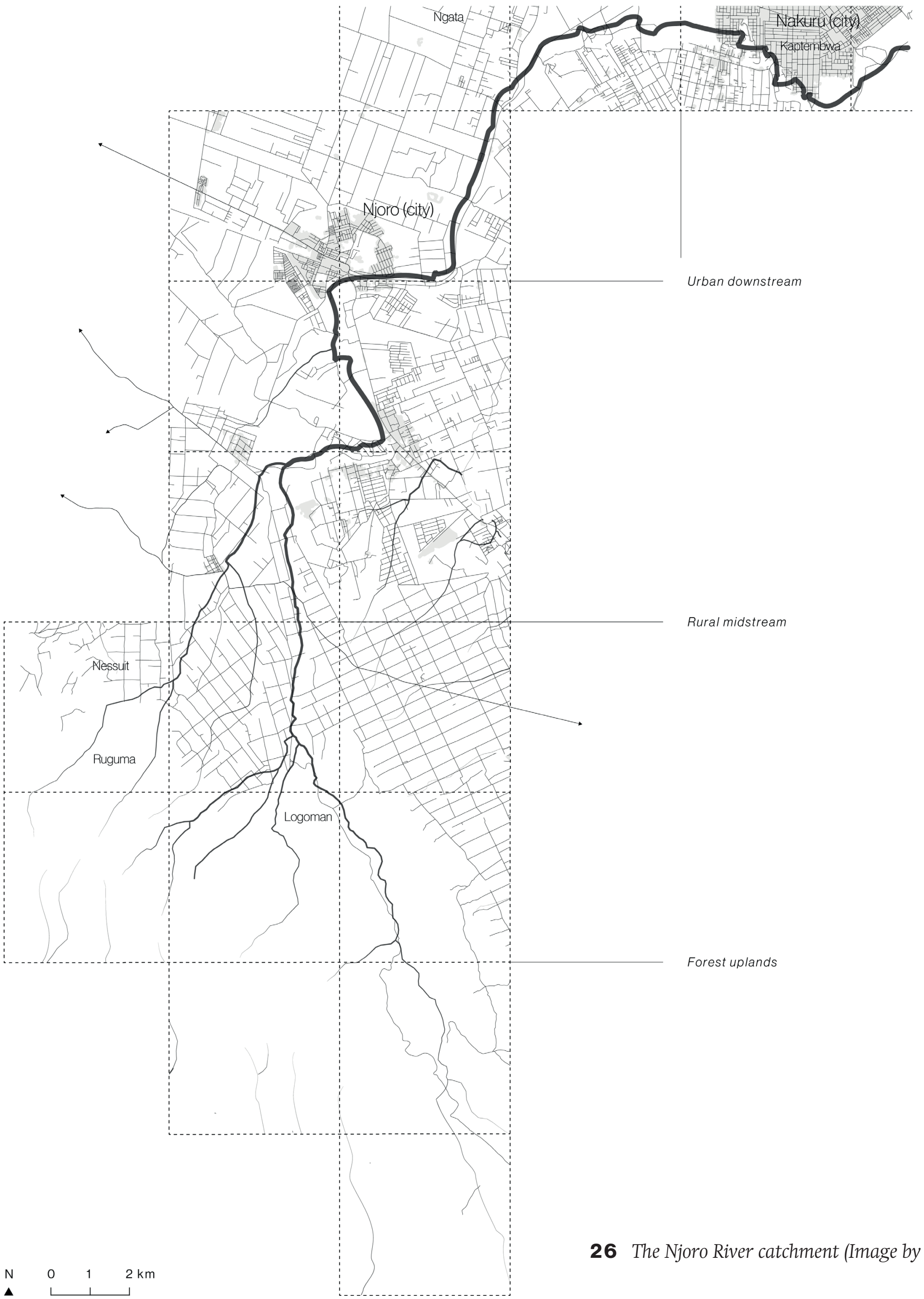
(Translation by author)

4. Portrait of a river

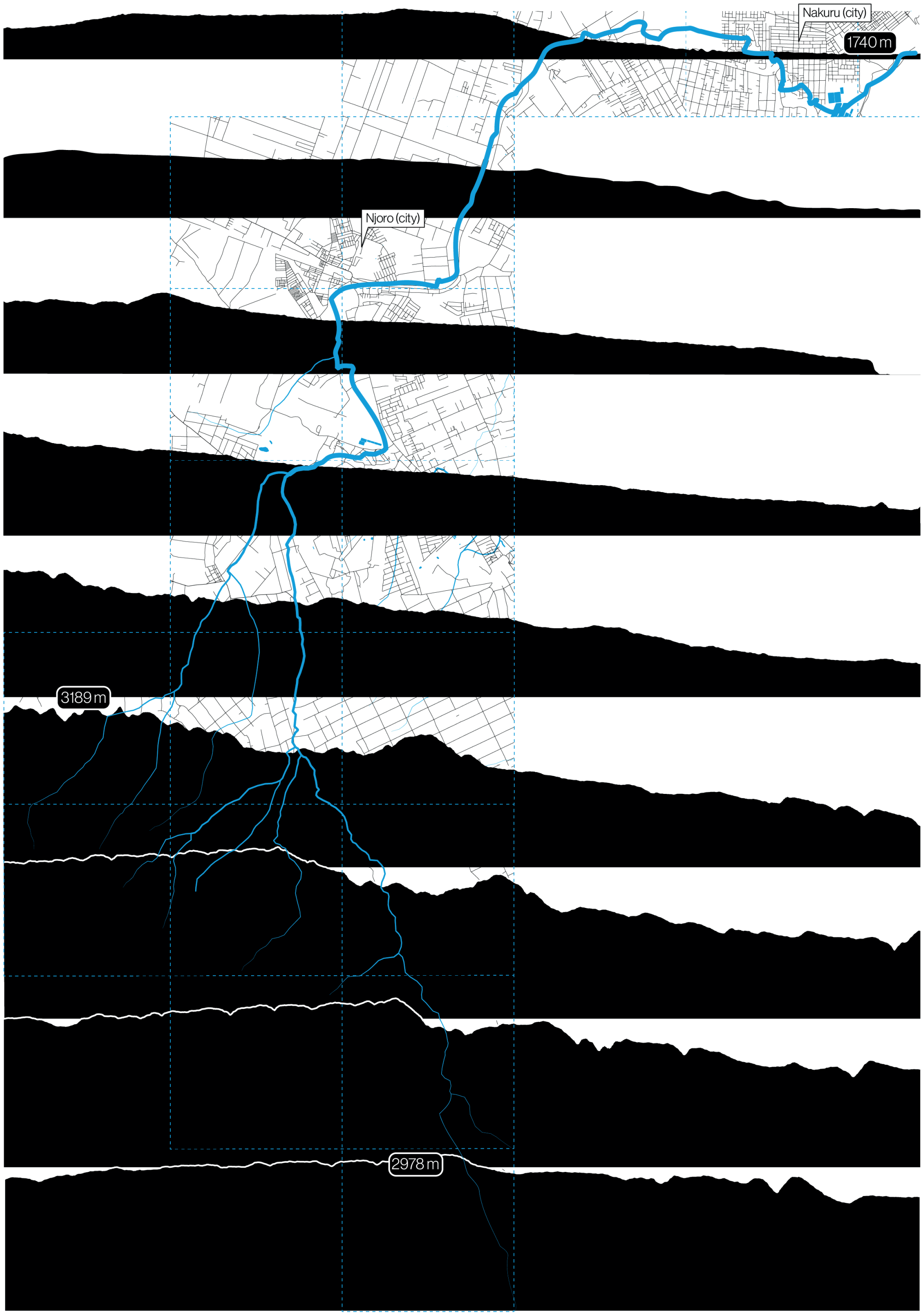
4.1. River characteristics

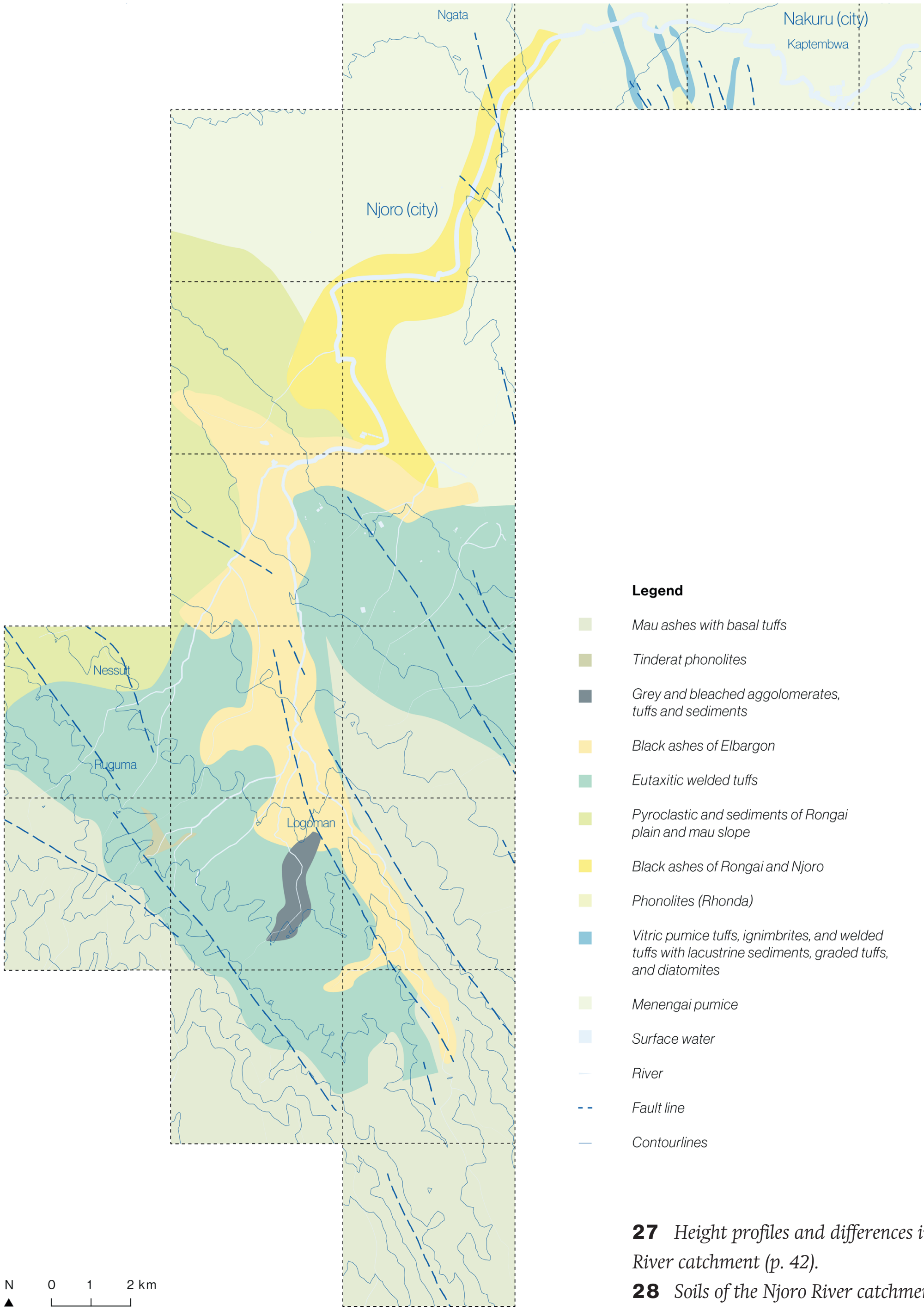
INTRODUCTION The Njoro River is the largest contributor to Lake Nakuru and classified as a second-order stream with a catchment of approximately 200 km2. Its source is found in the Mau Forest, the largest montane forest in East-Africa (ca. 2900 meters above sea level). It discharges into Lake Nakuru at ca. 1700 meters a.s.l. The mean discharge is about 150 x 103 liters per day. The topographical differences (e.g. the steeper slopes in the uplands, the gentler slopes in the midstream) influence the river's flow dynamics and sediment transport. The upper catchment area is dominated by loamy soils while the downstream consists of more erosive lacustrine soils. This distribution affects erosion rates and sediment deposition (Osano, 2016).

POOL-RIFFLE SEQUENCE The Njoro River follows a typical pool-riffle sequence. Pools are deep with a low flow velocity; riffles are shallow with higher water-surface slopes and faster velocities. Pool-riffle sequences often develop in medium-sized, meandering rivers with a gravel- or sand bedding (all of which applies to the Njoro). Water in a river rarely flows evenly. Small disruptions like obstacles or variations in sediment size slow down or speed up the flow velocity. Pools form in areas of the river where the flow velocity is relatively fast. Sediment is washed away, shaping a deep zone. Riffles are established in areas where velocity slows down, leading to sediment deposit. The deposition of sediments leads to shallow, gravel- or sand-rich zones (Thompson, 2018).
The river is rainwater-fed and highly susceptible to seasonal differences. It dries up almost completely during the dry season and can rise 5-7 meters in the rainy season, flooding bridges and infrastructure. In the forest uplands the average annual rainfall is approximately 1200 mm, while at the mouth of the river at Lake Nakuru the average annual rainfall is 800 mm (Osano, 2016).
To further investigate the Njoro river a simplified model is proposed. Based on the morphometric and hydrological qualities, it is possible to derive three landscape types: the forest uplands, the rural midstream and the urban downstream.



26 *The Njoro River catchment (Image by author, 2025).*


Nakuru (city)
1740 m
Njoro (city)
3189 m
2978 m



Legend

- Mau ashes with basal tuffs
- Tinderat phonolites
- Grey and bleached aggolomerates, tuffs and sediments
- Black ashes of Elbargon
- Eutaxitic welded tuffs
- Pyroclastic and sediments of Rongai plain and mau slope
- Black ashes of Rongai and Njoro
- Phonolites (Rhonda)
- Vitric pumice tuffs, ignimbrites, and welded tuffs with lacustrine sediments, graded tuffs, and diatomites
- Menengai pumice
- Surface water
- River
- Fault line
- Contourlines

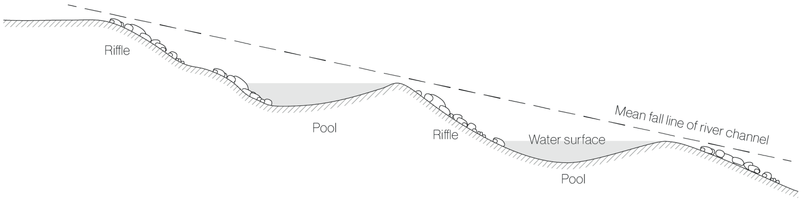
27 *Height profiles and differences in slope within the Njoro River catchment (p. 42).*

28 *Soils of the Njoro River catchment.*

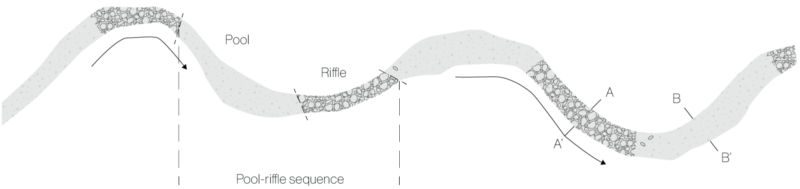
POOL-RIFFLE SEQUENCE

A pool-riffle sequence is a natural pattern in stream channels where deep, slow-moving pools alternate with shallow, fast-flowing riffles. Pools typically form in bends or downstream of obstructions, while riffles occur in straighter sections.

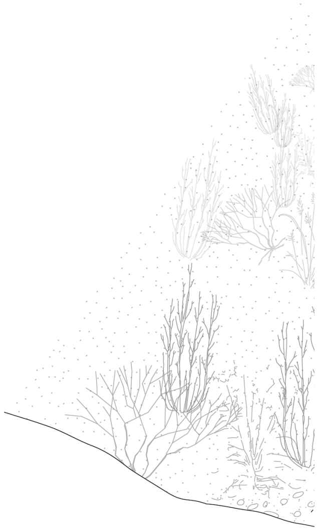
Section



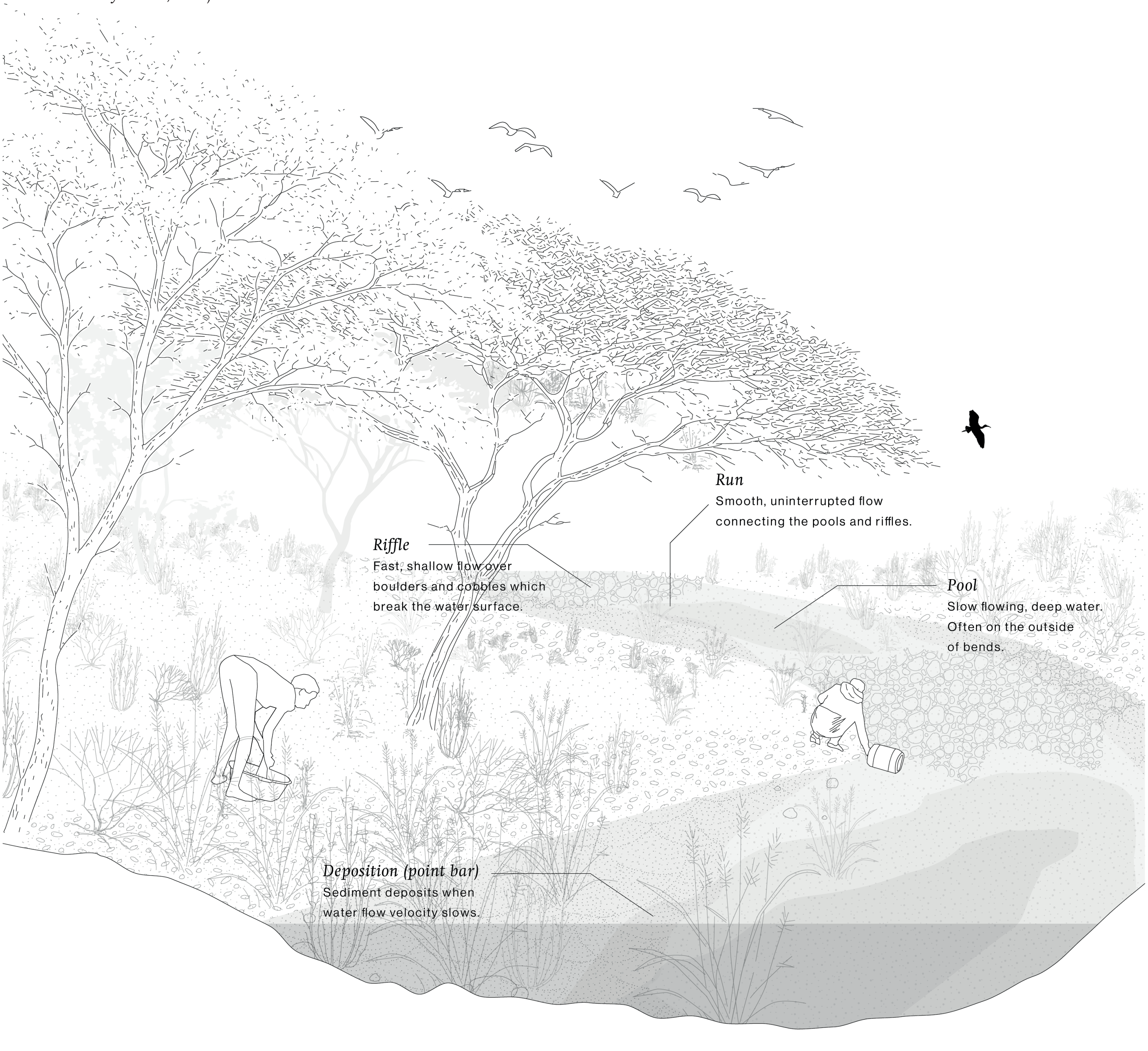
Plan



Profiles



29 *Pool-riffle characteristics of the Njoro River (Image by author, 2025).*



4. Portrait of a river

4.2. The forest uplands

INTRODUCTION The upper catchment of the Njoro River lies within the Logoman area of the Mau Forest. It is characterized by steep slopes and lush forest (Shivoga, 2007). The forest is a protected nature area guarded by the Kenyan Forestry Service (KFS). Indigenous forest is mixed with productive forest for timber. In the Mau Forest several tributaries of the Njoro are found. Nearby communities - such as the Ogiek - are allowed to practice beekeeping and harvest plants for traditional medicine. After passing the KSF outpost Logoman Station, the forest ends abruptly. Compared to lower lying rural land and the city (Nakuru), the deforested rural lands in the upper Njoro catchment are world of their own. These lands lie far up on the Mau Escarpment (2300 – 2600 meters high), the air feels thinner than in the city and the temperature is cooler. A lot of the infrastructure is eroded and in bad condition. While the city is only 20 km downwards, this area feels remote and isolated. The architecture is more traditional and lower tech. Almost all houses downstream are built out of bricks and corrugated sheets. Here, houses are built out of organic materials such as clay and reeds.

MONTANE FOREST VEGEGATION The area just before Logoman is covered by a dense natural montane forest (predominantly the J. procera community). (Mathooko and Kariuki, 2000). Mathooko and Kariuki (2000) states that it is “the only section of the Njoro River system with limited human impact

30

31

30 *Indigenous trees in the Mau Forest (Image by author, 2025).*
31 *Natural riparian vegetation along the Njoro (Image by author, 2025)*

32 *KFS officer crossing a tributary of the Njoro River within the Mau Forest complex (Image by author, 2025).*

on the natural vegetation." (p. 125). The forest landscape along the river consists of shrubs and trees from the Fabacae family (e.g. Tipuana tipu, crotalaria agatiflora) Oleacea family (e.g. Olea europaea subsp. Africa) and Euphorbiacea families (e.g. Podocarpus latifolius). Dominant shrub species are Rubus steudneri and Rumex orthoneurus (Koskey et al. 2021). The fringe to the bordering grasslands consists of thick E, arborea shrubs and patches of bamboo thicket (Arundinaria alpina near the riverbanks (Mathooko and Kariuki, 2000).

AGRICULTURE

While the steep slopes make this region less ideal for agriculture, it is still the dominant land use and source of income for its inhabitants. Large amounts of forest have made place crops such as maize and carrots. The plots are relatively small scale and scarcely planted. The riverbanks are usually planted with natural vegetation and hard to access as the slopes are very steep. However, as slopes diminish, the riparian buffer zone of 30 meters is not upheld and land is cultivated very close to the steep banks.

33

34

33 *Traditional housing far up on the Mau Escarpment, this looks like a Kipsigis house with its typical conical thatched roof. (Image by author, 2025).*
34 *Indigenous Ogiek beehive on the Mau escarpment. (Image by author, 2025)*

35 *Carrots are washed using water from the Njoro River (Image by author, 2025).*

36

37

38

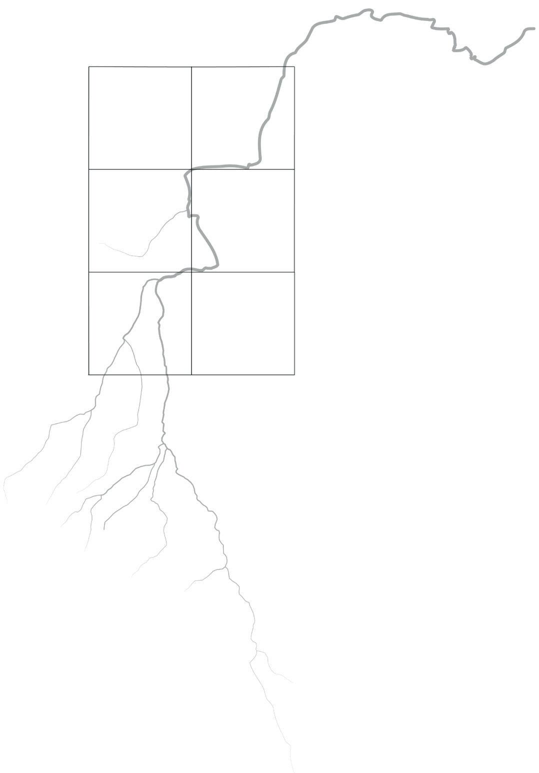
36 *Bare carrot field and solitary Eucalyptus trees (Image by author, 2025).*
37 *Riverbanks in rural highlands, near the Njoro Caves (Image by author, 2025).*
38 *Carrots are sorted and washed alongside the Njoro River.*

39 *Uplands of the Njoro River catchment (Image by author, 2025).*

Beeston
Egerton Dam
Egerton Botanical Garden
Njoro caves
Kiptenden
Egerton University campus
Ahero Village
Bliss Flora
Egerton

4. Portrait of a river

4.3. The rural midstream



INTRODUCTION As the river descends into the midstream area near Egerton University, the gradient becomes gentler with a slope of mostly <4%. This section is subject to increased human activities, including agriculture and urban development.

HUMAN ACTIVITY The middle catchment is mostly agro-pastoral but flows through densely populated areas near the Egerton University Campus and Njoro (town). According to Yillia et al. (2008) “the riparian population is largely poor and inadequately provided with basic sanitation or portable clean water.” (p. 730). Therefore, most inhabitants depend on the river for daily water needs. The river is a lifeline for nearby communities, especially during the dry season when water is scarcely available. During dry periods human pay frequent visits to the river. Common activities include livestock watering, bathing, waste disposal, washing of clothes or abstraction for domestic needs (Yillia et al. 2008).

POLLUTION HOTSPOTS As mentioned previously, the river is structured in a pool-riffle sequence and the pools are most fit for human use, as they are broad and easy to access. The pool-riffle sequence is especially characteristic for the middle catchment of the Njoro River, featuring soft substratum of erosion prone fine sediments in the pools, and bedrock in the riffle sections. Most pools in the midstream are pollution hotspots

40 *Cows are watered in the Njoro River, nearby Egerton University (Image by author, 2025).*

because they are so frequently visited and the pools are commonly littered with solid waste and faeces (Yillia et al. 2008).

VEGETATION The land in the midstream is mostly used for intensive agriculture. There is a small strip of riparian forest, but according to Mathooko & Kariuki (2000) "…it is heavily disturbed by cattle and people who go to fetch water for domestic use" (p. 127). The midstream features submontane forests with Syzygium cordatum, Pittosporum abyssinicum and Hibiscus diversifolius. It appears as either a dense belt along the river stream or an open disturbed forest without a shrub layer (Mathooko & Kariuki, 2000). Wherever a shrub layer does occur, the most common species is H. diversifolius, which forms impenetrable thickets. The grass layer consists predominantly of Kikuyu grass (Pennisetum, clandestinum) that is continuously grazed (Mathooko & Kariuki, 2000).

41

42

43

41 *Lady washes clothing using river water (Image by author, 2025).*
42 *Textile and plastic waste indicate the water level during rainy season (Image by author, 2025).*
43 *The Njoro River in the flatter rural midstream.*

44

45

44 *Water abstraction in the tail end of the dry season (Image by author, 2025).*
45 *Eroded riverbank (Image by author, 2025)*

46 *Midstream of the Njoro River catchment (Image by author, 2025).*


Kapkoros
Kapchorwa
Kerma
Sunrise farm
Kapkatet

4.4. The urban downstream

INTRODUCTION In the downstream stretch to the river's estuary Lake Nakuru, the Njoro River passes through several neighborhoods of the densely populated inner city of Nakuru such as Rhoda, Kaptembwo and Ponda Mali, these are relatively poor and marginalized neighborhoods. The riverbank is highly disturbed by human activity. In this stretch of the river the highest concentrations of nitrogen and phosphorus are detected, attributed to anthropogenic influence and higher than maximum permissible levels for water set by the World Health Organization (WHO) (Chui et al. 2024). A study by Chui et al. measured water quality in the uplands (Logoman), midstream (Kenyatta Bridge) and downstream (near the river mouth) and the sample point in the downstream of the river scored highest on microplastic abundance and turbidity (a measure of cloudiness of the water).

VEGETATION The riparian forest in the downstream segment of river is dominated by the fever tree (vachellia xanthophloea). The herb layer consists of weeds such as Galinsoga parviflora, Bidens Pilosa, Solanum incanum, Galinsoga parviflora, Tagetes minute, and A. aspera and spreaded form nearby farms. Besides fever trees, the sycamore fig (Ficus Sycomoros) is also a very common tree in this segment of the river. Other trees found in the downstream include Dombeya burgessiae and Croton megalocarpus (Mathooko & Kariuki, 2000).

47


48


47 *Housing and urban agriculture very close to the river (Image by author, 2025).*
48 *Enock washes his head in the river (Image by author, 2025)*

49 *A sewer pipe empties into the Njoro River while a lady enters her house on the river bank. Faded graffiti reads "Keep water clean" (Image by author, 2025).*

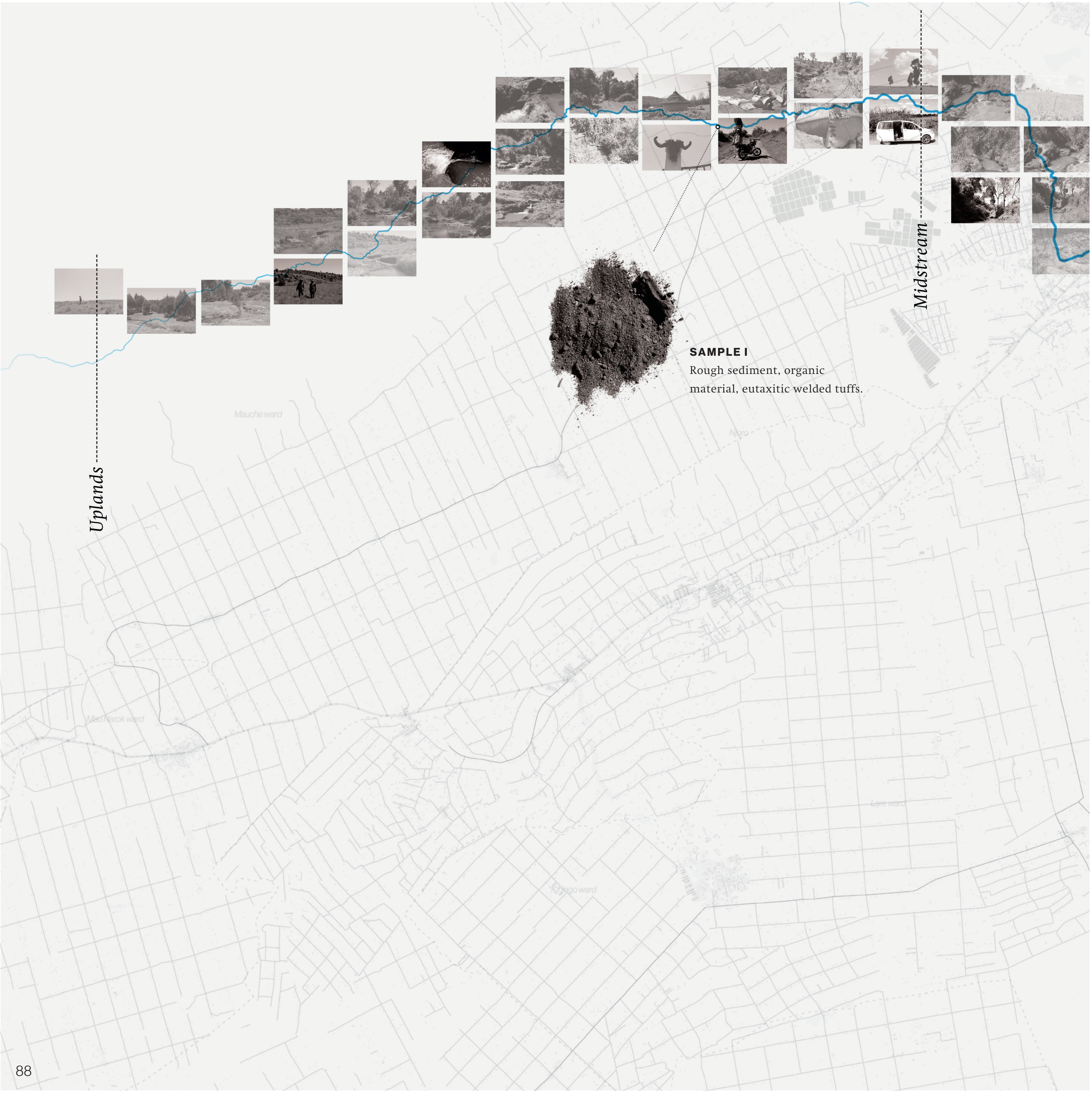
50

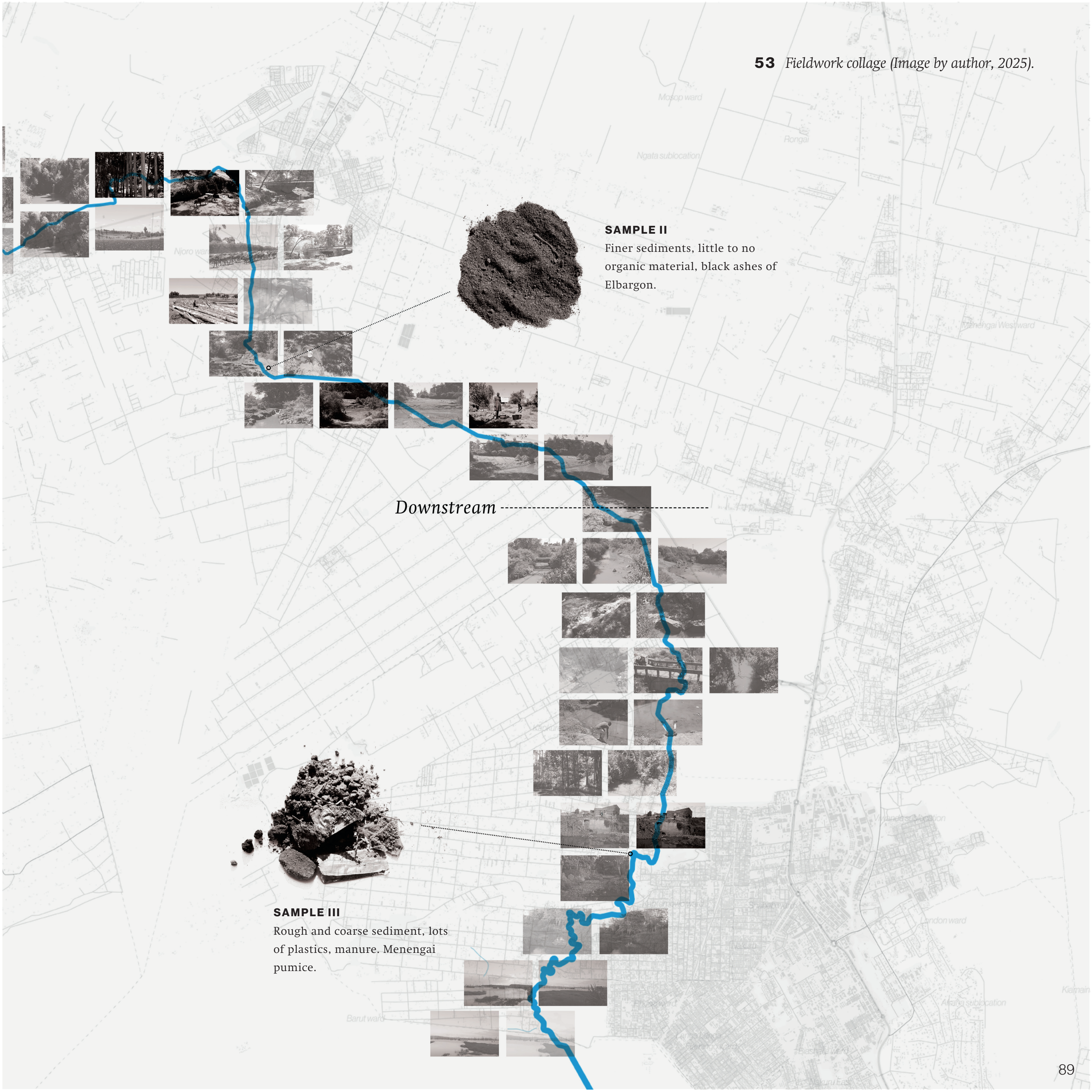
51

50 *The last bridge before the river enters the gated Nakuru National Park, flooded by waste. (Image by author, 2025).*
51 *Herron devours a frog in the marshland within the national park (Image by Jesper Kuipers, 2025)*


Rift Valley Insitute of Science and Technology
Kapte
Kapkures
Nakuru W
N
0 100 200 300 400 500 m

52 *Downstream of the Njoro River catchment, including the river mouth ending in Lake Nakuru (Image by author, 2025).*


Uplands
Midstream
SAMPLE I
Rough sediment, organic material, eutaxitic welded tuffs.
Mauche ward
Njoro



53 *Fieldwork collage (Image by author, 2025).*

4.5. Challenges in the Njoro watershed

INTRODUCTION Land-use change and climate extremes have disrupted the river eco-system significantly, impacting wildlife and livelihoods.

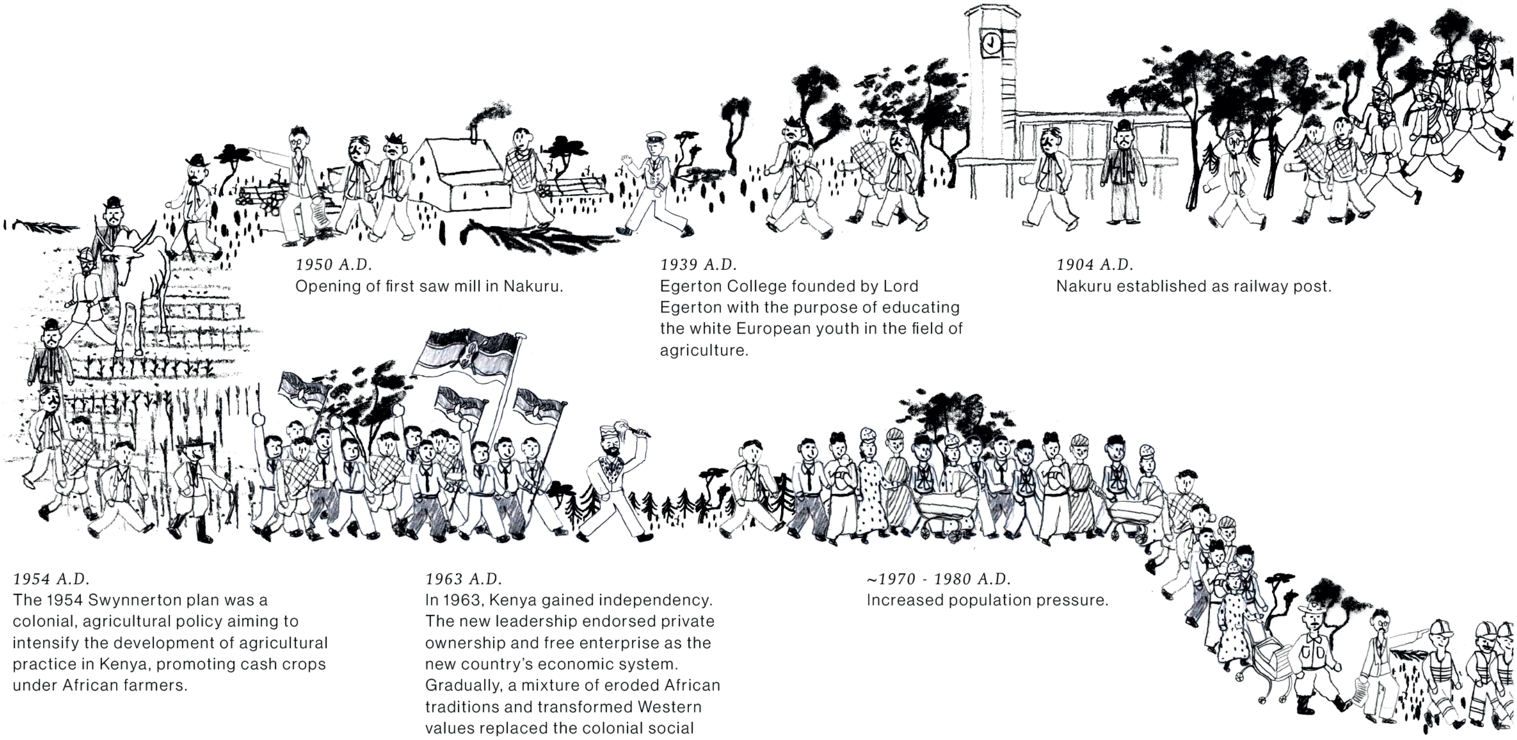
TIMELINE In 1938 the remains of at least 78 individuals and a range of grave goods were discovered in the Njoro Caves. Objects included stone bowls, grindstones, beads and ivory pendants. The caves were used for burials and cremation approximately 2500 years ago. The relationship between humans and the river has always been close. It has been theorized that the caves along the river have also been used as fortresses during attacks, or to protect food and belongings from wild animals. The caves have also been used as a place of worship and burial. This history alludes to the mythical and spiritual value humans found near and along the Njoro River (Faugust & Sutton, 2010). Since then, land-use and land cover have changed dramatically in the Lake Nakuru Catchment (including the Eastern Mau Forest) since the pre-colonial times to date. Before the British settlement, the area was scarcely populated and covered by indigenous forest. The Ogieks, a culture of beekeepers and hunter-gatherers, inhabited the montane Mau Forest. Pastoralists and shifting cultivators occupied the valley (Kennedy Okello Were, 2014). By 1900 the British controlled the area. They were interested in extracting timber from the forests and settling in the fertile lands. The exploitation of forests for timber began during the construction of the Ugandan Railway, wood was needed for construction and fuel. During and after World War II the timber industry in Kenya surged, Kenya's export markets of wood were bigger than those of other East African countries, because of its technically and strategically superior location. Most of the export was destined for the European market. Until 1949 the Mau Forest was largely spared from commercial exploitation. The establishment of the first sawmill in 1950 in the Mau Forest led to a rush on applications for exploitation and the Mau Forest soon became a major input for Kenya's wood export. At the same time, the European settlers cleared large amounts of forest and natural forest in the Rift Valley as part of the 'White Highlands' policy. This policy stated that certain agricultural lands in Kenya should be reserved for Europeans. The settlers deemed the lands appropriate for European settlement because of its cool climate and sparse population combined with good soil fertility. They produced crops like coffee, sugar and tea, but the majority of land was reserved for cattle (Morgan, 1963). Following independence in 1963, land was allocated back to indigenous communities who had lost their land during colonization. Large-scale farms of the European settlers were divided into smaller scale farms and allocated to landless individuals. The population of Kenya (and Nakuru) grew increasingly leading to an increasing demand for land in the 1980's and 1990's. This demand resulted in illegal encroachments and loggings of indigenous forest (Kennedy Okello Were, 2014).

ENCROACHMENT As the population of Nakuru increased steadily throughout the years, land grew increasingly scarce. Because of a disparity in question and demand, people have been illegally settling and practicing agriculture in protected forested areas. This led to encroachment of the indigenous forest that is crucial for the Njoro River watershed. The encroachment has resulted in considerable land fragmentation, destruction of wetlands in the fertile upstream parts and deforestation of the headwater catchments (Chrisphine et al., 2016). While encroaching is a problem in the whole catchment area of the Njoro River, it has been most extreme in the Mau Forest (the uplands of the catchment). The Mau Forest traditionally was home to the Ogiek forest dwelling communities, whose livelihood largely depended on the forest. The Ogiek are hunter-gatherers who live in small communities in the Mau Forest. While they have dispersed and separated into smaller groups, their sense of communal identity is strong. Their lifestyle is based on hunting forest animals and notably beekeeping and the production of honey. Honey is of significant importance in Ogiek culture, owning a beehive as an Ogiek man symbolizes wealth (similar to cows in other cultures). The Ogiek differ from other East African hunting communities in their emphasis on adaptation to a montane forest environment. While oral and written histories are scarce, most Ogiek people confirm that their people have been living in the forest for many generations (Blackburn, 1974). The Ogiek maintained their lifestyle until the early 1970s. During the general land demarcation of 1969, some of the Ogiek communities were omitted from land allocation, because of their traditional way of living. In 1987 the Kenyan government banned hunting and livestock keeping in the forest (Spruyt, 2011). Because of this new legislation, the Ogieks were evicted from the forest. The eviction destabilized their traditional system of forest conservation. As they struggled to adapt, they soon returned to the forest but adopted farming techniques from other communities such as slash and burn to clear land for farming (Kinyanjui, 2009). Conclusively, the British colonization of Kenya from 1880 to 1963 has disrupted the indigenous communities in their ways of living and traditional systems for landownership. Additionally, the settlers cleared forest and introduced intensive and large-scale farming techniques. After decolonization, a large share of indigenous forest had already disappeared and the complexities coming with land allocation and demarcation have led to further degradation and encroachment of the indigenous forest adjacent to the Njoro River catchment.

DEFORESTATION Between 1986 and 2003, 20% of indigenous Mau Forest in the uplands of the Njoro River catchment was lost (Shivoga et al., 2007). Considering the whole Lake Nakuru basin paints an even more extreme image. According to a landcover classification analysis by Kundu (n.d.), the dominant land use in 1969 was still forest (75%), by 2003 this number had shrunk to just 3% of total land use cover, while agriculture accounted for 82% (13% in 1969) (Kundu et al., n.d.). Forest cover bonds soil, and when forest in a lake basin is degraded, the result is an increase in land erosion and sediment transport. The highly porous volcanic soil in and around Nakuru is already highly susceptible to erosion,

~ 35-25 million B.C.
Tectonic activity began splitting the African Plate, forming the rift valley. This tectonic rifting created the topographic depression where the Njoro River catchment now lies.

~ 1 million B.C.
Volcanic activity and formation of Menengai crater. The ash from eruptions of the caldera forms the basis of the fertile volcanic soil found in the Nakuru area.



1950 A.D.
Opening of first saw mill in Nakuru.

1939 A.D.
Egerton College founded by Lord Egerton with the purpose of educating the white European youth in the field of agriculture.

1904 A.D.
Nakuru established as railway post.

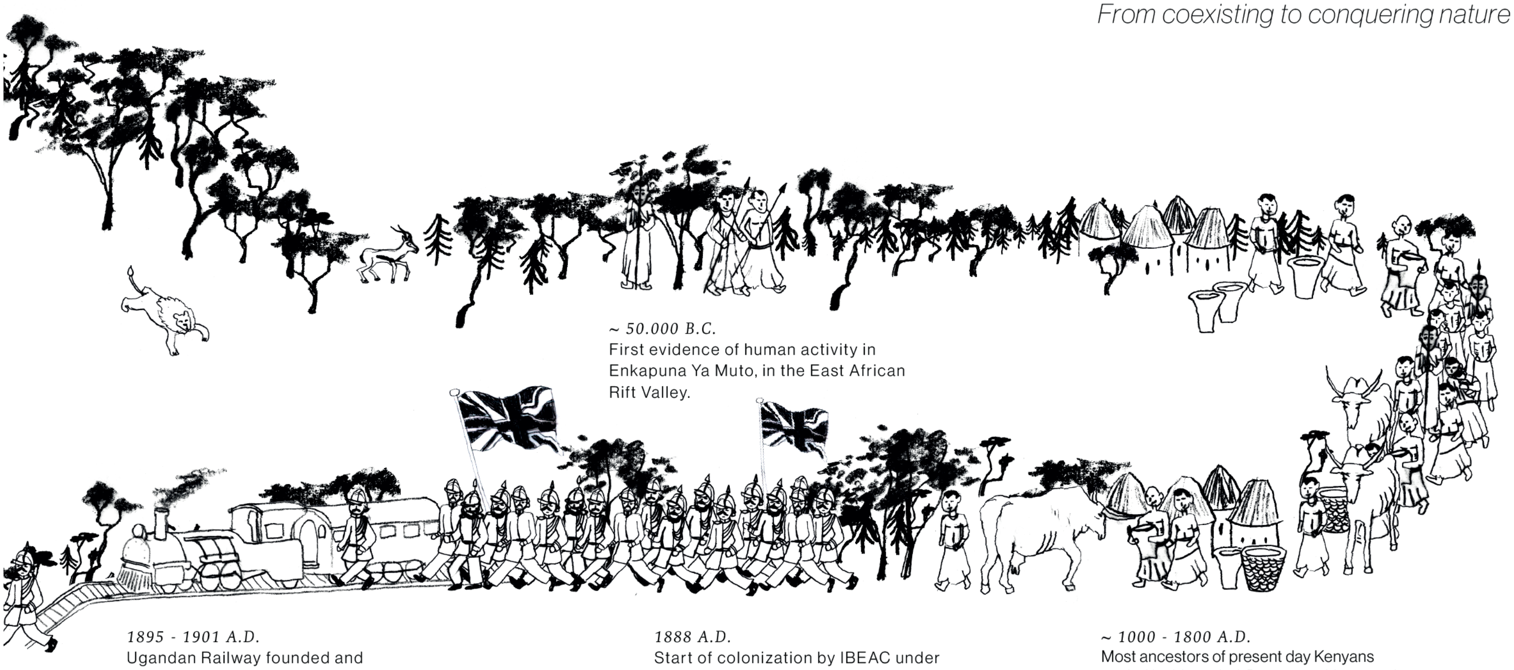
1954 A.D.
The 1954 Swynnerton plan was a colonial, agricultural policy aiming to intensify the development of agricultural practice in Kenya, promoting cash crops under African farmers.

1963 A.D.
In 1963, Kenya gained independency. The new leadership endorsed private ownership and free enterprise as the new country's economic system. Gradually, a mixture of eroded African traditions and transformed Western values replaced the colonial social organisation.

~1970 - 1980 A.D.
Increased population pressure.

50.000 years of human development in the Rift Valley

From coexisting to conquering nature



~ 50.000 B.C.
First evidence of human activity in Enkapuna Ya Muto, in the East African Rift Valley.

1895 - 1901 A.D.
Ugandan Railway founded and completed, connecting Mombasa to Uganda to export resources from the inland of Uganda to European industry.

1888 A.D.
Start of colonization by IBEAC under British Influence.

~ 1000 - 1800 A.D.
Most ancestors of present day Kenyans settled in this period. Bantu speaking people cultivated grain, root and tuber crops and kept some livestock. Nilotic practiced cattle pastoralism. Extensive cattle farming was predominant in the Rift Valley.

1994 A.D.
Forest excisions approved by the government

2006 A.D.
The Riparian Reserve Regulation was installed. it mandates a protected buffer zone of 30 meters along all rivers, including Njoro River.

2021 A.D.
Nakuru granted city status.

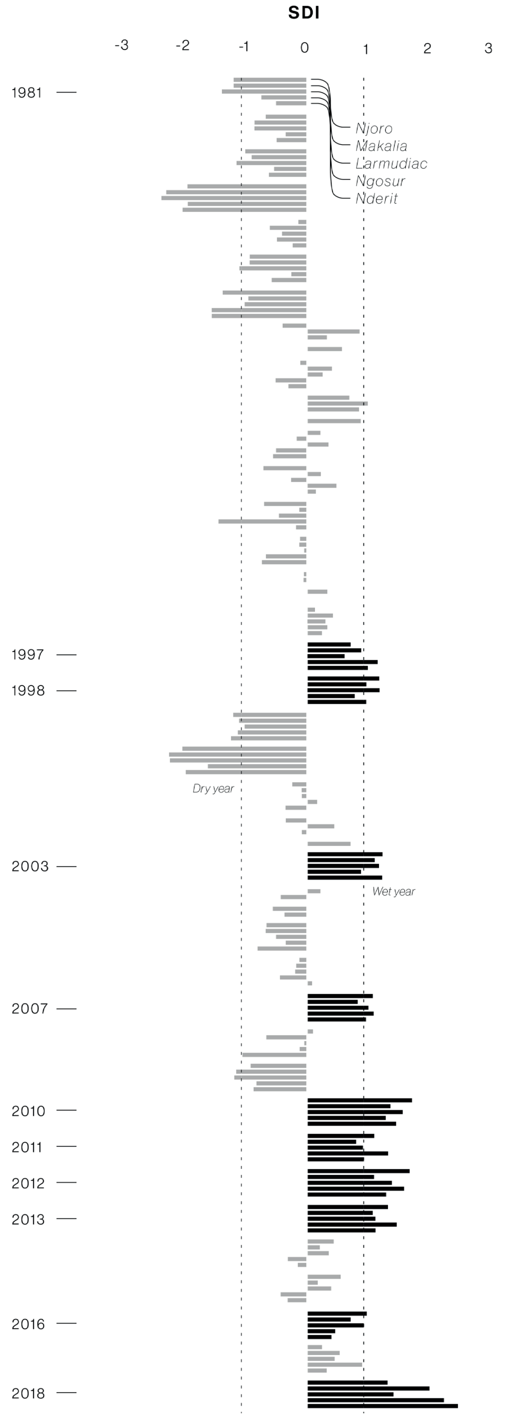
during heavy rainfall. The loss of the porous volcanic topsoil through erosion leads to a decrease of natural seepage into the underground aquifers which results in accelerated surface runoff (Chrisphine et al., 2016). In short, land-use change from forest to rural and built-up land increases surface runoff while surface and groundwater quantity will reduce (Ontumbi & Sanga, 2018). In their study, Amisi et al. (2020) investigated the relation between soil qualities and deforestation in the Njoro River watershed. According to the study, the infiltration capacity of the soil is significantly lower in deforested areas, compared to forested areas. A potential cause is the loss of macropores and inconsistent pore space of the sub surface soil as a result of logging and human activities, as well as a loss of soil bonding vegetation cover. Soils in deforested areas were also found to be more water repellent, leading to faster ponding and runoff generation (Amisi et al. 2020).

EROSION AND SEDIMENTATION The increased soil erosion as a result of land-use change from forest to agriculture, leads to a higher sediment deposit. Meanwhile, the increased runoff and discharge speed leads to an increased sediment deposit velocity. Erosion is a three-phase process: first, particles are detached from the soil mass. Then, transported by erosive agents such as flowing water or wind. Finally, the particles are deposited, when sufficient energy for transportation is no longer available (Otieno, 2006). According to a report by Otieno (2006) "the deforestation in the uplands has led to increased soil erosion, low recharge and increased sedimentation" (p. 1). Eroded soil and additionally undisposed waste accumulate in the lake by discharging rivers and rainwater runoff. According to Sang & Maina (2022) "The deforestation of the Mau Forest and the degradation of vegetational riparian zones have increased the sedimentation levels of the lake" (p. 2). The Njoro River is the main origin of sediment into Lake Nakuru, contributing 70% of all sediment (Sang & Maina, 2020). The higher sedimentation rate of the lake has been one of the factors leading to a rise in water level in Lake Nakuru, which has already resulted in the flooding of the neighborhood Barut-East, which was one of the locations visited on site. The floods in Barut-East have caused displacement and loss of livelihoods. This has transformed Barut-East into a grim place. Empty houses are decaying quickly and the shore of Lake Nakuru that used to end in the protected national park has moved beyond people's doorsteps.

HUMAN ACTIVITY The Njoro River is a vital lifeline for adjacent communities. During the dry season it is one of the last places where people can fetch water (together with the various government- or community-owned deep lying boreholes). Its shores are often bustling with activity and a place where all types of lifeforms come together. Water is a connecting factor and a condition for life. In his study, Mathooko (2001) documented human activity at a specific site along the Njoro River. According to his research, the river near human settlements is constantly disturbed during the day. Activities include bathing, washing clothes, water abstraction and watering cattle. Some of the upstream activities have immediate or long-term effects on the river ecology (Mathooko, 2001). A study by Shivoga et al. (2007) found that the sub watershed near Egerton University accounts the highest percentage contribution of nutrients and phosphorus to the river. This is explained by the major land-use activities around the university such as small-scale agriculture, a vegetable canning factory and a dairy plant. Other pollutants contributing to the poor water quality of the Njoro river are sewage water, fertilizer and manure in run-off from drained grasslands and detergents used for washing and cleaning. Lower phosphate and nitrate levels were found in sequences of the river were riparian forest and in-stream were largely undisturbed. This sequence is surrounded by large-scale farms that pump water from boreholes and the river, which reduces the need for frequent visits to the river by people and livestock (Shivoga, 2007).

CLIMATE CHANGE Deforestation has had a significant negative impact on the Njoro River watershed. Major negative effects such as floods are aggravated by climate change. According to Ambani (2023), climate change is an impactful contributor to the rising lake level in Nakuru. From 2010 and onwards, the variation in precipitation is large. Since 2010, a notable shift in weather patterns in the Lake Nakuru basin has taken place, namely an increase in rainfall. Mean precipitation in the period between 1990 and 1999 was 73.7 mm per month. In the period between 2010 and 2019, mean precipitation was 86.6 mm per month. Combined with deforestation and encroachment, the change in climate increases the variation of flows in the Njoro River. Since 2010, droughts have become more extreme. Barely

54 *Streamflow Drought Index of the five major contributors to Lake Nakuru. "The observations made from 2009 to 2018 show a higher frequency of wet periods compared to dry periods" (Kimaru et al. 2019).* ▶



any rain falls during the dry season, turning the Rift Valley into a dusty, dry steppe. During the rainy season, water gushes from the higher-lying areas (e.g. the Mau Escarpment or the Menengai caldera) down to the slums in the valley floor due to extreme rainfall and quick runoff (Ambani, 2023). When the rainfall intensity exceeds the infiltration capacity rate or the saturated hydraulic conductivity of the surface soil, flooding of the river occurs, leading to ponding (Otieno, 2006).

THE NJORO WATERSHED Climate change and deforestation in the Njoro River (and Lake Nakuru) watershed create a vicious cycle. The removal of forest and riparian vegetation reduces the soil's ability to retain water, leading to erosion and sedimentation of the porous volcanic topsoil. As topsoil is lost, the remaining subsurface layers (characterized by lower saturated hydraulic conductivity) cause even faster runoff. The drainage density of the Njoro river catchment area is 0.95175 Km/km2, indicating a high drainage density, pointing to a low permeable sub-soil and poor vegetative cover (Osano, 2015). Meanwhile, climate change extends dry periods, further compacting the soil and reducing its infiltration capacity. Dry soils initially have a higher infiltration rate than wet soils, but in a period of prolonged drought the infiltration rate decreases and reaches an equilibrium with wet soils (Reinsch et al., 2024) When the rainy season finally arrives, water flows into the lake at extreme velocities, intensifying erosion and triggering severe floods. This erosion depletes soil fertility, making it even harder for vegetation to recover, perpetuating the cycle.

Acknowledging an imminent connection between what's going on in the lake and what's going on in its watershed must be proposed and executed for manageability of Lake Nakuru or other natural resources (Sang & Maina, 2020).

55 *Eroded and deforested riverbanks along the Njoro River (Image by author, 2025).*

5. Design for a regenerative river system

5. Design for a regenerative river system

5.1. Design aim

DESIGN AIM The goal of this project is to develop a spatial framework for regenerative planning in the Njoro River catchment that restores ecological balance while supporting the needs of its users. Rather than proposing one fixed design, the framework offers a set of place-specific interventions, strategies and principles that respond to local conditions and can evolve over time. The project addresses challenges related to land degradation, erosion, flooding, water scarcity and biodiversity loss, while also aiming to create opportunities for sustainable livelihoods, education and community stewardship. The design builds on the diagnosis that the natural, infrastructural and occupational layers of the catchment are currently misaligned. A regenerative approach requires that spatial planning reconnects these layers through landscape interventions that work with, rather than against, the natural system.

In the end, the design aim is a regenerative river system that supports sustainable urban growth (by mitigating climate effects, creating economic opportunities and a healthy and inspiring living environment).

To reach this objective, three different strategies and applications are developed for the three different sub-catchments addressed earlier. Design choices are based on literature, field observations and most importantly, two design workshops with local stakeholders, researchers and students.

The information gathered during those workshops has played a major role in the development of the final design. This chapter will first state the results of the design workshop, followed by the application on the three design locations. The last part includes a reflection on implementation and provides a phased approach to realize the design.

EVALUATION Design measurements are evaluated based on the 4 returns framework. Preferably, a measure or design idea should harbor all four returns (inspiration, social, financial and natural). The evaluation of the four returns can be recognized by these four symbols:

- Returns of natural capital
- Returns of financial capital
- Returns of social capital
- Returns of inspiration

5.2. Co-design, learning together

INTRODUCTION Smithwick et al. (2023) name co-designing with local stakeholders and actors as a key part of regenerative landscape design (RLD) stating that "designing regenerative landscapes requires the use of co-design methodologies…" (Smithwick et al. 2023, p. 2.). During the site visit to Nakuru, I participated in two design workshops. The first one was organized by a consortium of Witteveen + Bos and Felixx landscape architects and TU Delft for the Water as Leverage programme hosted by the RVO. The second workshop was organized by me and my fellow students in collaboration with Egerton University. These workshops helped me to understand the local context better and gave me an opportunity to exchange knowledge and ideas with local actors.

WATER AS LEVERAGE DESIGN WORKSHOP: KICK-OFF Water as Leverage is a program facilitated by the Netherlands Enterprise Agency (RVO) originally initiated to 'generate innovative and integrated climate-adaptive concepts' (World Water Atlas, n.d.). Research and pilot projects were realized in i.a. Cartagena (Colombia) and Chennai (India). Recently, a new initiative is being developed in Nakuru (Kenya) by a consortium of Felixx landscape architects, Witteveen+Bos, Bantu Studio and the TU Delft, with the support of RVO. While independent, this master thesis is intertwined with the Water as Leverage Nakuru, and as part of our visit to Nakuru we were invited to join the workshop week. During the workshop week the design consortium got together with local and international partners such as the Nakuru County Government, UN Habitat, KIFFWA, VEI, NAWASSCO, SNV among others.

During the first day of the workshop, the project was introduced, and all of the attendants were assigned to different groups with the goal of co-creating a vision for Nakuru on four topics: challenges, systems, nature and implementation. People were invited to join the group that aligned closest to their personal interest or expertise. Several nature-based solutions and nature-based design strategies were discussed within the group focusing on implementation. The group was highly skeptical of nature-restoration or water-safety projects. These types of projects often take decades to become profitable and the value is found in e.g. cost-saving, improved health benefits, all in all less tangible value as opposed to monetary value. According to the groups experience, projects that don't provide immediate monetary profit, are less likely to succeed in finding long-term financing and *'won't fly'*.

Key take-aways were that projects should be bankable on a short term (2-3 years), interesting from different angles to attract multiple investors (blended financing) and should be bottom-up (preferably with as less government interference as possible). The group also advised to look for already existing initiatives that could use support

56 *Group discussion during the Water as Leverage workshop in hosted in the Midland Hotel, Nakuru. (Image by J, 2025).*

rather than starting new ones from the ground up. A systemic approach is valuable to identify challenges, but hard to implement in the current political climate of Kenya. It is wise to start with small initiatives on a local, community-level scale. When these projects find success, they have the ability to inspire neighboring communities to adopt the strategy so that it eventually can spread on a systemic level. In short, connecting economically viable activities to a systemic strategy. Several bankable projects were proposed such as water harvesting ponds combined with agroforestry or the direct re-use of water. Finally, the group discussed the possibility of redirecting a certain percentage (1-2%) of revenues to nature restoration via an escrow arrangement.

The second day consisted of another workshop session and also the opportunity for the TU Delft students to present their work to and audience of local and international experts. Their feedback and additions were of great value to this report as the experts provided local insights and knowledge and suggested relevant literature. The intention of the second workshop was to find relevant stakeholders, form a vision for 2050 and come up with a pilot project for one of the seven hotspots identified in Nakuru. For the Njoro River – named as one of the hotspots – the team identified key actors such as: the communities (Njoro RUA, Nakuru Farmers Association, the Environment Climate Association and Kenya Youth Ambassadors. The county (Department of Agriculture, Livestock and Farmers). The government and government-owned organizations (NAWASSCO, NARUWASSCO, WRA, NEMA and KFS). The national government (Water Resource Agency and the Ministry of Water, Sanitation and Irrigation). NGO's and other organizations (Egerton University, World Vision-WASH, Aqua for All and SNV). Next, a vision for the Njoro River was discussed. The most important aims were cleaning the river (by reducing waste inflow and sedimentation), restoring riparian vegetation and afforestation of the uplands. The identification of a suitable pilot project proved to be more complex. The scope of the hotspot was relatively narrow, only accounting for the downstream of the Njoro, in urban context. It was agreed that afforestation and consequently reducing siltation would be more effective to implement upstream, in the uplands of the Njoro watershed. Also, finding a business case for restoring riparian vegetation alongside the riverbanks proved to be difficult. Previous attempts of restoring the vegetation by Egerton University were moderately successful, but without a proper business case maintenance remains a challenge. So far, the university has restored 7km of the 60 km river course. However, limited funding complicates rehabilitating the whole river and sustaining already regenerated sites, leading to a tree survival rate of 80%. Other challenges include uncontrolled waste dumping, weak enforcement of environmental law and low adoption by the community (M'Erimba, 2023).

One of the concepts that came up was the planting of bamboo alongside the river to bond soil and strengthen the riverbanks. The bamboo could be sold and used for roofing, construction or the production of furniture. Ultimately, the outcome of the workshop session was a proposal for a water harvesting pond combined with agroforestry. The pond could be connected to the river through a canal, allowing flooding during periods of heavy rainfall and storing the water for use during the

57 58
59

57 *Design team works on vision and possible pilot project for the Njoro River (Image by Joy Chege, 2025).*
58 *Workshop attendants present their work. (Image by Joy Chege, 2025).*
59 *Making challenges and opportunities spatial by placing post-its on a map. (Image by Joy Chege, 2025).*

60

61

62

60 *Presenting the design assignment at Egerton University (Image by Xuejing He, 2025)*
61 *Students presenting and discussing their work (Image by author, 2025).*
62 *Student design for the Njoro River (image by author, 2025).*

dry season. This would increase water safety by reducing floods, reduce siltation by bonding soil through the planting of new trees and shrubs while creating new livelihoods in agroforestry.

As the goal was to identify a pilot-project that could be delivered in 1-2 years (one of the aims of the WaL program), landownership was also considered as an important factor, preferably identifying a plot of government-owned land. This was a challenge, as the river crosses many privately owned plots. By a lack of government property, the Rift Valley Institute of Science and Technology (RVIST) was considered as a key partner, as they are a public organization and own a large amount of land adjacent to the Njoro River. In the end, a more suitable strategy for this hotspot was considered: promoting good agronomic practices and shared ownership and responsibility, for example by supporting an agroforestry start-up and spreading knowledge and information on the importance of a regenerative water cycle.

During the two days of workshop hosted by RVO and the design consortium, many local stakeholders and experts were happy to share their stories and personal experiences with water challenges in Nakuru. A local resident and educator at Egerton University explained how the Njoro River used to dry up completely during the dry season. Recently, with the increase of heavy rainfall the river is in constant flow, even in the dry season. During the wet season, the river rises in level by 4 to 5 meters, even flooding bridges and destroying infrastructure. Another resident explained how in the past the rivers water in the forested uplands was crystal clear, while enthusiastically pointing to his bottle of drinking water. Then, they cleared the Mau Forest as part of a massive operation, in his perception it almost happened from day to day. Afterwards the river turned brown and cloudy, even in the uplands.

EGERTON UNIVERSITY STUDENT WORKSHOP On the 19th of February (2025) we planned a design workshop at the Egerton University. We worked together with 29 civil engineering students working under Nancy Matheri. They are all working on similar topics in water management, waste management and other environmental challenges. During the workshop, we asked them to think about challenges and possible solutions related to water in the Nakuru region. The workshop was divided into two parts, in part one we established future and current challenges, in part two we worked on possible designs with the students. We also presented three scenarios and assigned every group a different scenario to guide them in their design process. The goal of the workshop was to gain valuable local insights and perspectives from a group of young and ambitious students. To kick off the workshop, we briefly presented our topic of interest and our findings in the first week. Then we explained the goal of the design workshop and introduced the three scenarios (see annex 1).

MAPPING WISHES AND CHALLENGES We first asked the students to write down their wishes for the future of Nakuru on sticky notes and to then place it on a map of the Nakuru urban area (see table 1). A total of 29 students (n = 29) participated in the workshop, organized in smaller discussion groups of approximately ten students. Not all participants contributed to both categories, therefore the

TABLE 1. FREQUENCY OF WISH THEMES (N ≈ 29 PARTICIPANTS)

Theme	*Frequency*	*% of Students*	*Example Statements*
Access to clean and safe drinking water	7	24%	“Safe drinking water, without damaging teeth (fluor)”, “Provision of fresh water”
Improved water infrastructure	6	21%	“Better water supply system”, “Rainwater harvesting”, “Water transportation”
Enhanced wastewater treatment	5	17%	“Re-treatment of wastewater”, “Local treatment plants”, “Greywater recycling”
Ecological restoration (rivers, forests)	4	14%	“Reforestation of Mau Forest”, “Restoration of River Njoro”
Green urban development	5	17%	“Green buildings”, “Sustainable urban drainage”, “Green spaces”
Improved waste management	4	14%	“Better waste collection and disposal”, “Recycling systems”
Affordable housing / slum upgrading	2	7%	“Managing the housing prices”, “Public-private partnership for the slum”
Community education and awareness	3	10%	“Awareness programs”, “Community-based action plans”

TABLE 2. FREQUENCY OF CHALLENGE THEMES (N = 29 PARTICIPANTS)

Theme	*Frequency*	*% of Students*	*Example Statements*
Water pollution (lakes and rivers)	6	21%	"Pollution of River Njoro", "Lake Nakuru contamination from industry and communities"
Inadequate waste management	6	21%	“Burning of waste”, “Inefficient garbage collection”, “Foul smell from dumpsite”
Unreliable water supply	4	14%	“Failed pumps”, “Scarcity and inequity in distribution”
Flooding and poor drainage infrastructure	4	14%	“Seasonal flooding”, “Insufficient drainage systems”
Air and dust pollution	3	10%	“Dust pollution in the CBD”, “Harmful industrial emissions”
Housing shortages and urban encroachment	2	10%	“Encroachment due to lack of land”, “Private land restrictions”
Crime, unemployment, and safety	2	7%	“Youth-related crime”, “Drug use and neighborhood safety”
Lack of financial and political support	2	7%	“Insufficient funding”, “Lack of political will”

number of responses does not exactly match the participant count. Clean and safe drinking water was one of the most frequent wishes among students (mentioned seven times by 24% of the students). Four students (14%) specifically mentioned river restoration and afforestation, or as one student wrote down; “Restoration and rehabilitation of the River Njoro which is the major source of water for Lake Nakuru”.

Similarly, we asked the students to map the most urgent challenges (see table 2). 21% of students mentioned water pollution of lakes and rivers a challenge in Nakuru, with one student stating “Water pollution in Lake Nakuru, majorly from its sources (River Njoro), affecting human consumption and aquatic life. From industries and local communities”. Also, the references to green city infrastructure, public-private housing solutions, and community education expresses a desire for holistic, long-term thinking solutions that combine environmental, social, and governance issues.

CO-DESIGNING WITH LOCAL STUDENTS During the second part, we stimulated students to explore possible futures for Nakuru. We provided them scenarios to work with and inform their design decisions (a top-down ecological, a bottom-up ecological and a bottom-up technological approach). To spark the conversation, we also introduced several Nature Based Solutions that were then discussed within the groups.

Group 1 worked on the catchment of Njoro River and came up with a design for the upper, middle and lower catchment. For the upper catchment the students proposed an afforestation plan to delay surface runoff. The strategy for the middle catchment was to reduce sedimentation, e.g. by building water harvesting ponds that capture storm water, allowing it to steadily infiltrate in the groundwater table, by reinforcing the riverbanks with gabions (with stones) or expanding and improving the stormwater drainage pipelines. For the downstream, the students proposed a focus on reuse and better waste management. Measures such as river waste screens (collecting waste from the river), local wastewater treatment plants and the reuse of materials and waste were identified as suitable projects for the downstream.

During the workshop, it was also notable that out of all the scenarios, students drifted towards a bottom-up approach. These approaches were often seen not only as solutions but as prerequisites for the success of landscape interventions.

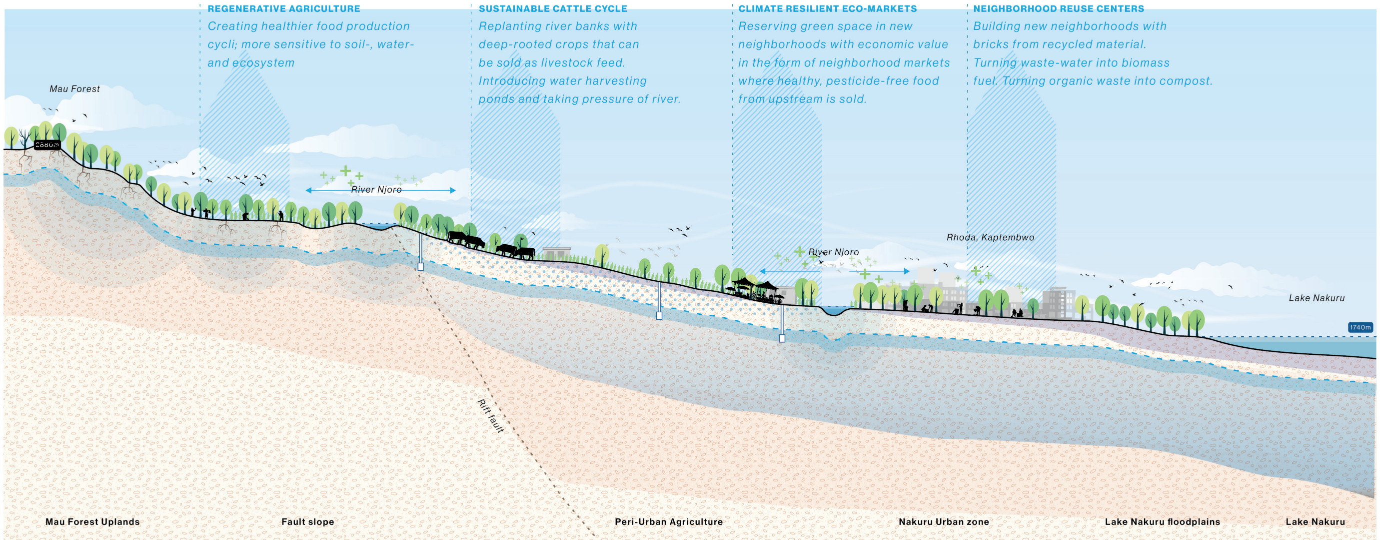
5.3. Design vision

REGENERATIVE FRAMEWORK The Njoro River system is more expansive than just the river and its banks. In restoring the river's ecosystem, it is important to acknowledge the influence of land use across the entire Njoro River catchment on the river stream, and vice versa. Anthropogenic pressures such as deforestation and unsustainable farming have degraded vital landscape functions. Setting the regeneration of the Njoro River as a goal can lead to developments throughout the catchment, contributing to a more climate-resilient and healthier living environment.

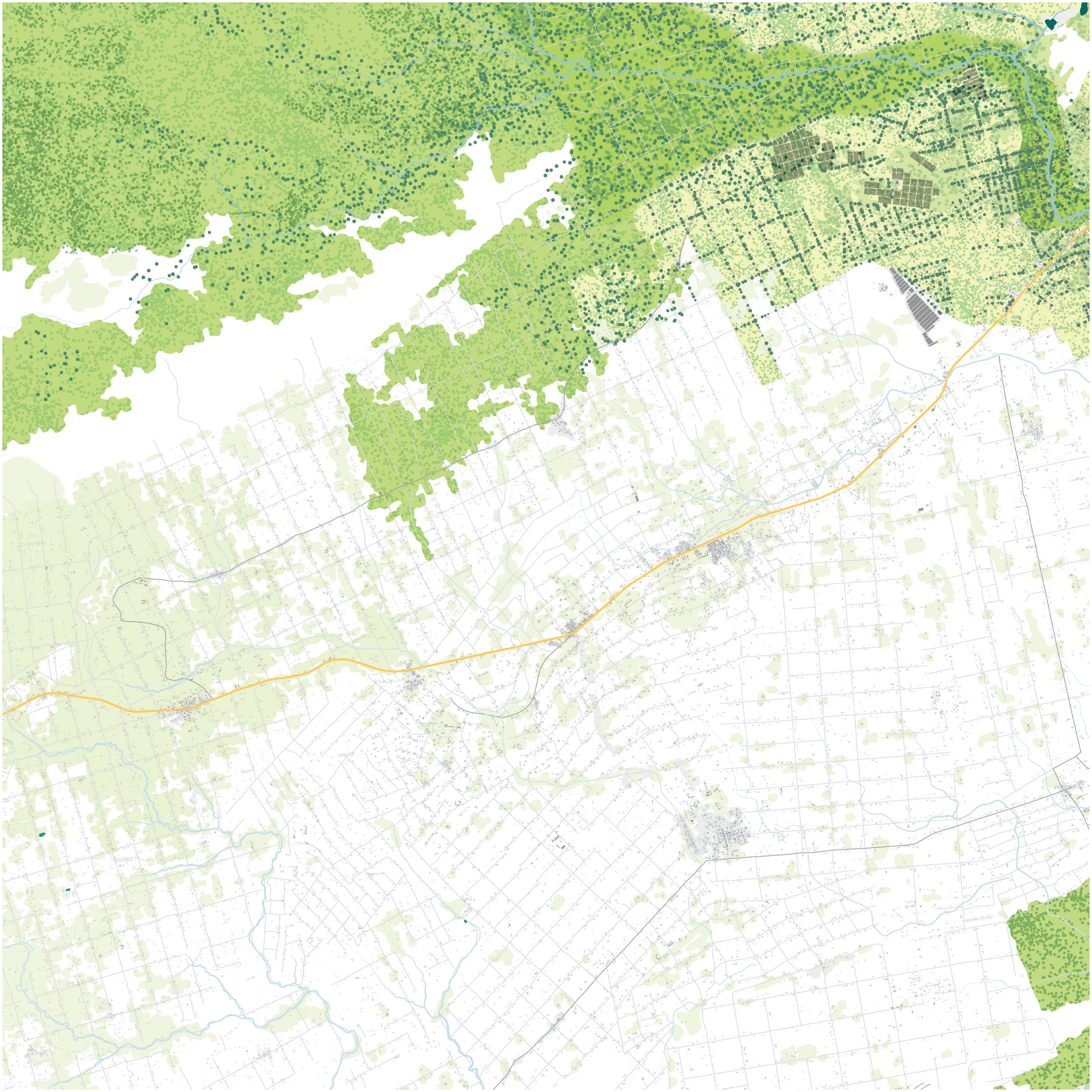
This hypothesis will be tested in the design process of this RTD study. A regenerative framework offers the capacity to reorganize systems and guide landscapes into "desirable, self-sustaining states" (Smithwick et al., 2023, p. 8).

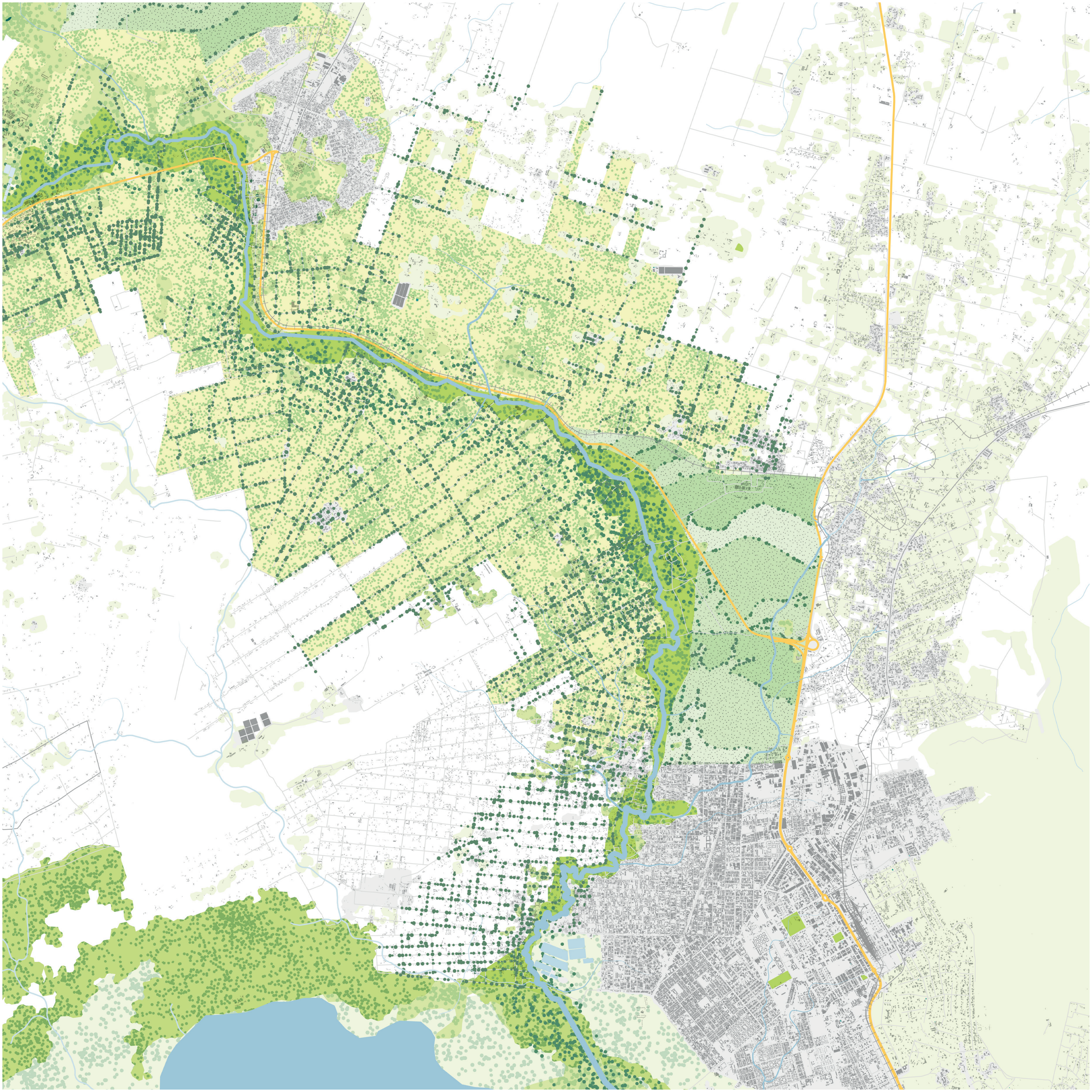
CASCO CONCEPT The Casco concept can be used as a tool to spatialize and structure a vision for regenerative landscape design (RLD). As stated earlier, the Casco concept distinguishes between slow (natural) and fast (anthropogenic) processes in landscape planning; minimizing the conflict between the two allows slow processes to unfold. The river system can be identified as a slow process, one that requires time to redevelop and be restored into a functioning ecosystem. Therefore, the Njoro River can serve as a guiding structure and backbone of the regenerative framework.

VISION To initiate the design process, a vision is proposed for a regenerative Njoro River catchment. This vision is based on the intersection of systemic landscape analysis (layer analysis), landscape design theory, and design-led speculation. It is not a fixed blueprint, but a possible outcome, a spatial hypothesis that explores how regenerative principles might transform the ecological, socio-cultural, and hydrological dynamics of the catchment over time. To develop the Njoro River catchment into a regenerative river system, a few key steps can be considered. Based on literature, the current agricultural system leads to soil degradation and erosion, which in turn causes siltation and flooding. Therefore, land use change and improved agricultural practices can act as drivers for catchment regeneration. The presence of fertile soil and a high-level agricultural university makes the transformation to a regenerative agricultural landscape plausible. Improved infrastructure, integrated with a green structure in the agricultural hinterland, can connect this emerging sector to local and international markets, building on Nakuru's strategic position along an international transit corridor. River restoration could be a positive outcome of such development, supported by reinvestment of profits through an escrow arrangement. The Njoro area could thus evolve into a leading region for sustainable farming in East Africa, with a restored Njoro River as its crowning achievement.



63 *System diagnosis of the Njoro catchment (Image by author, 2025).*





5. Design for a regenerative river system

5.4. Design uplands: Delay

STRATEGY The uplands of the Njoro River catchment form the hydrological starting point of the river system. These highland zones are characterized by steep gradients, porous volcanic soils and remnant patches of montane forest. Over the past decades, large-scale deforestation and unsustainable land use have dramatically reduced the uplands' capacity to absorb and regulate rainfall. What once functioned as a sponge now behaves more like a slope, accelerating surface runoff, triggering erosion and sending heavy sediment loads downstream. The strategy for this zone is to slow water down. By increasing infiltration and reactivating natural buffers, the river's baseflow can be stabilized while reducing pressure on the lower catchment.

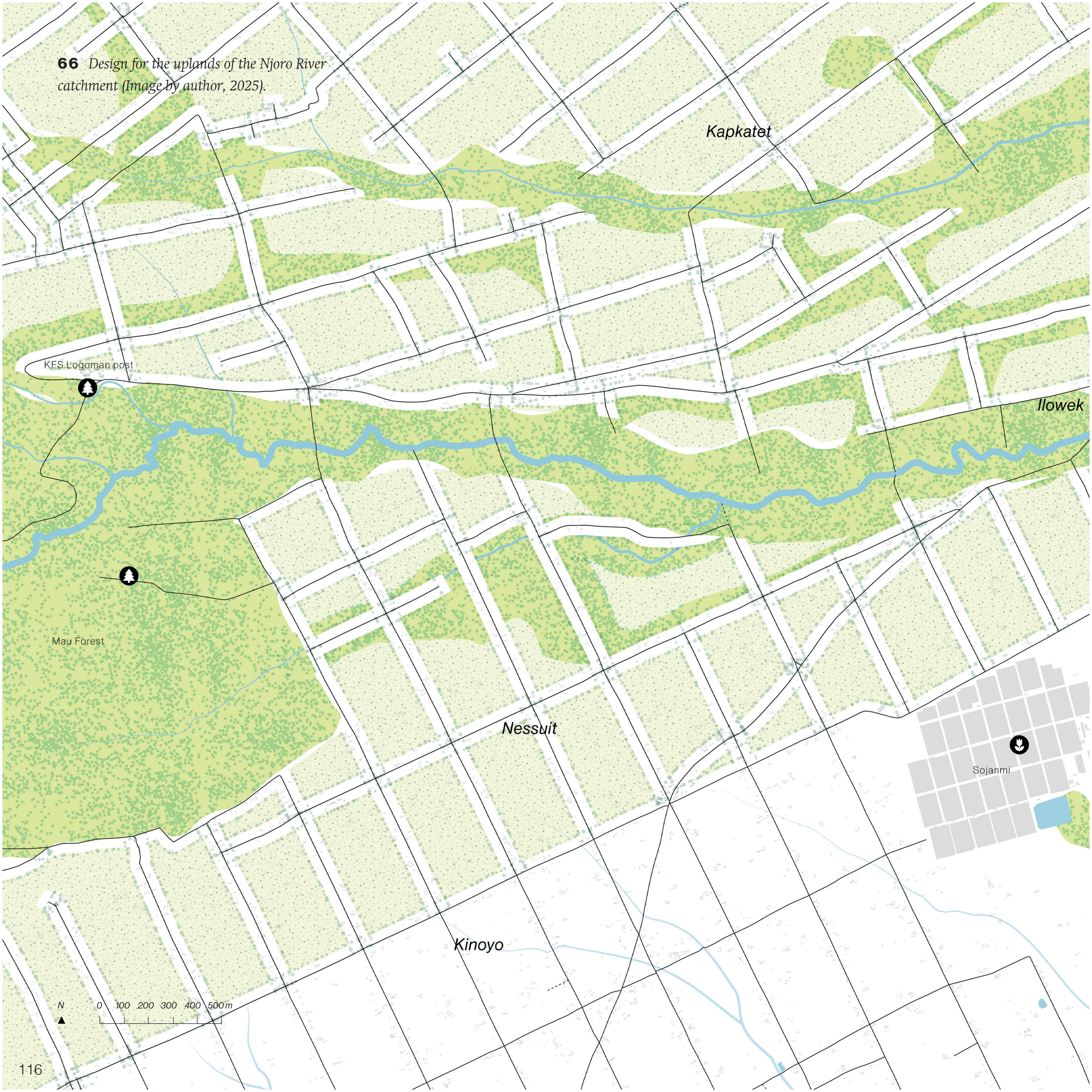
Infiltration and delay can be achieved through a range of spatial measures: reforestation with native species, contour planting, living terraces, and protection of natural springs. Where human settlement meets the forest edge, small-scale agroforestry plots and water retention features like swales or check dams can reduce erosion while supporting livelihoods. Areas near the Njoro Caves offer potential for eco-tourism, forest education and nature-based employment, if planned in harmony with ecological restoration goals.

SYNERGIES Delaying runoff is not only a technical goal but also a social and ecological opportunity. Forest regeneration improves water quality and biodiversity, but also provides long-term benefits to local communities in the form of cleaner springs, climate resilience and access to sustainable resources. Agroforestry near forest edges can offer a transition zone that supports both conservation and production. Where the forest is respected and restored, nature-based tourism can thrive, creating jobs linked to landscape care and environmental education.

64

65

64 *Njoro Caves site. (Image by author, 2025).*
65 *Terrace farming (fanya juu) just outside Nakuru. (Image by Thamar Zeinstra, 2025)*



66 *Design for the uplands of the Njoro River catchment (Image by author, 2025).*


Beeston
Egerton Dam
Egerton Botanical Garden
Njoro caves
Kiptenden
Egerton University campus
Ahero Village
Bliss Flora
Egerton

TERRACING/CONTOUR FARMING (FANYA JUU)

According to Njiru (2023) "terracing is a soil and water conservation practice that is mostly adopted in hilly, arid, and semi-arid areas." (p. 6.). Terraces are physical (constructed) structures that reduce the length and/or steepness of a slope by dividing the land into strips (Njiru, 2023). The reduction in slopes results in slower runoff and a decline in soil erosion (Njiru, 2023). The two most common types of terraces are cut-and-fill bench terraces and "fanya juu" terraces. "Fanya juu" is Kiswahili for "throwing upwards" and involves the practice of digging out trenches and throwing the soil uphill to form a bank (Masereka, 1983). The embankments are enforced by grass cover or fodder crop and the trenches are sometimes planted with fruit trees (e.g. pawpaws, bananas or citrus) to optimize use of the retained water (Njiru, 2023). The most suitable species of grass for enforcement are deep-rooted species such as napier grass or bana grass. A potential disadvantage of planting the banks is that grasses compete with crops for nutrients, moisture, light and space. However, using the grass for cattle fodder may compensate the decrease in crop yield (Masereka, 1983). A study by Farahani (2016) reported that terrace cultivation reduced runoff by 10% and planting along contour lines reduced soil losses and water losses by 49.5% and 32% respectively (Farahani, 2016). Another study by Gathagu et al. (2018) found that terrace farming reduced sediments by 35.8% (Gathagu et al. 2018). Terracing and agroforestry practices can be combined for optimal results, planting trees or long grasses along contour lines or in trenches.

TERRACING/CONTOUR FARMING (FANYA JUU)

SHORT DESCRIPTION *Fanya juu (meaning "throwing it upwards") is a tradtional way of managing soil erosion and water infiltration by creating small trenches and reducing slopes.*

SUITABILITY *Agricultural fields with steep slopes, best fit for larger scale agricultural operations.*

COSTS/BENEFITS *Initial costs are in the labour of digging out the trenches and planting strip crops. Benefits are in reduced loss of soil and water.*

67 *Cross section of an example of applied agricultural fanya juu practices. (Image by author, 2025).* ▶

0,6 m
0,6 m
0,6 m
0,6 m
0,6 m
0,6 m
Intercropping zea mays + phaseolus vulgaris
Dyke + drainage channel on contour border
Intercropping spinach, onion and garlic
Riparian buffer (30 m)

AGROFORESTRY Agroforestry is the process of integrating trees into agriculture. It is seen as a triple-win for smallholder farmers, potentially mitigating environmental damage, increasing income and improving climate resilience. Agroforestry technologies include different types of tree planting patterns, such as alley cropping (intercropping trees or shrubs with annual crops), boundary planting (planting trees and shrubs as land demarcation) or tree planting along soil erosion control structures (Hughes et al. 2019). Agroforestry has many benefits as compared to traditional agriculture. However, many farmers are reluctant to adopt agroforestry practices. A survey by De Giusti et al. (2019) in the Nyando river basin (Kenya) found that a majority of farmers perceive agroforestry as unprofitable and too much labor. However, multiple studies contradict this view and prove that agroforestry and tree planting can be a profitable addition to a small-scale farm. For example, Tamubula & Sinden (1998) studied the sustainability of agroforestry crops (such as napier grass) compared to traditional agricultural practices in the Embu District (Kenya). Similarly to Nakuru, steep slopes, high rainfall and intensive cultivation led to soil erosion in Embu, where coffee is the most prominent agricultural crop. Introducing napier strips or calliandra hedges by alley cropping can resolve these problems (Tamubula & Sinden, 1998). The study found the calliandra alley farming system to be most sustainable, especially compared to the traditional system, the study also confirms the lower rates of soil loss in the calliandra and napier grass system. Average annual soil loss rate was estimated at 42.9 t/ha for the traditional system, 17 t/ha for the napier grass system and 18.1 t/ha for the calliandra system. The study also found the calliandra system to be the most profitable, with a mean net present value of Ksh 1.135.000, compared to a mean net present value of Ksh 667.000 for the traditional system (Tamubula & Sinden, 1998). Mandila et al. (2022) did a cost-benefit analysis on establishing agroforestry practices in semi-arid regions. The costs can be grouped into land preparation costs, purchase of tools, purchase of seedlings, maintenance costs (e.g. weeding) and harvesting and storage costs. The benefits include environmental services (e.g. water purification, protection against strong winds), food products, fuel wood and carbon sequestration (Mandila et al. 2022).

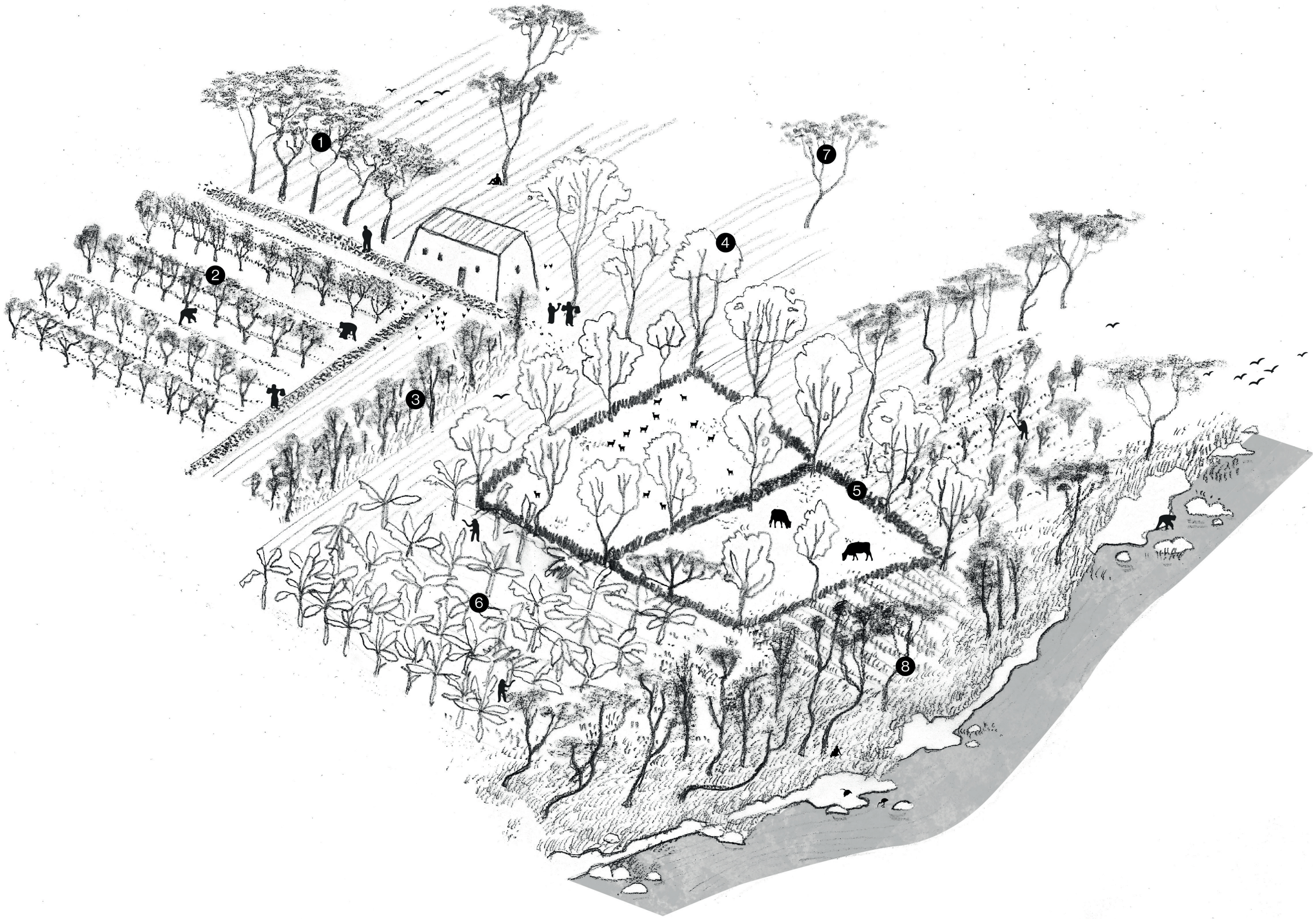
AGROFORESTRY

SHORT DESCRIPTION *Agroforesrtry is the practice of integrating trees into agriculture. There are various strategies in agroforestry, with the aim of increasing biodiversity, reducing soil erosion and increasing infiltration.*

SUITABILITY *Small-holder farms, small scale agriculture.*

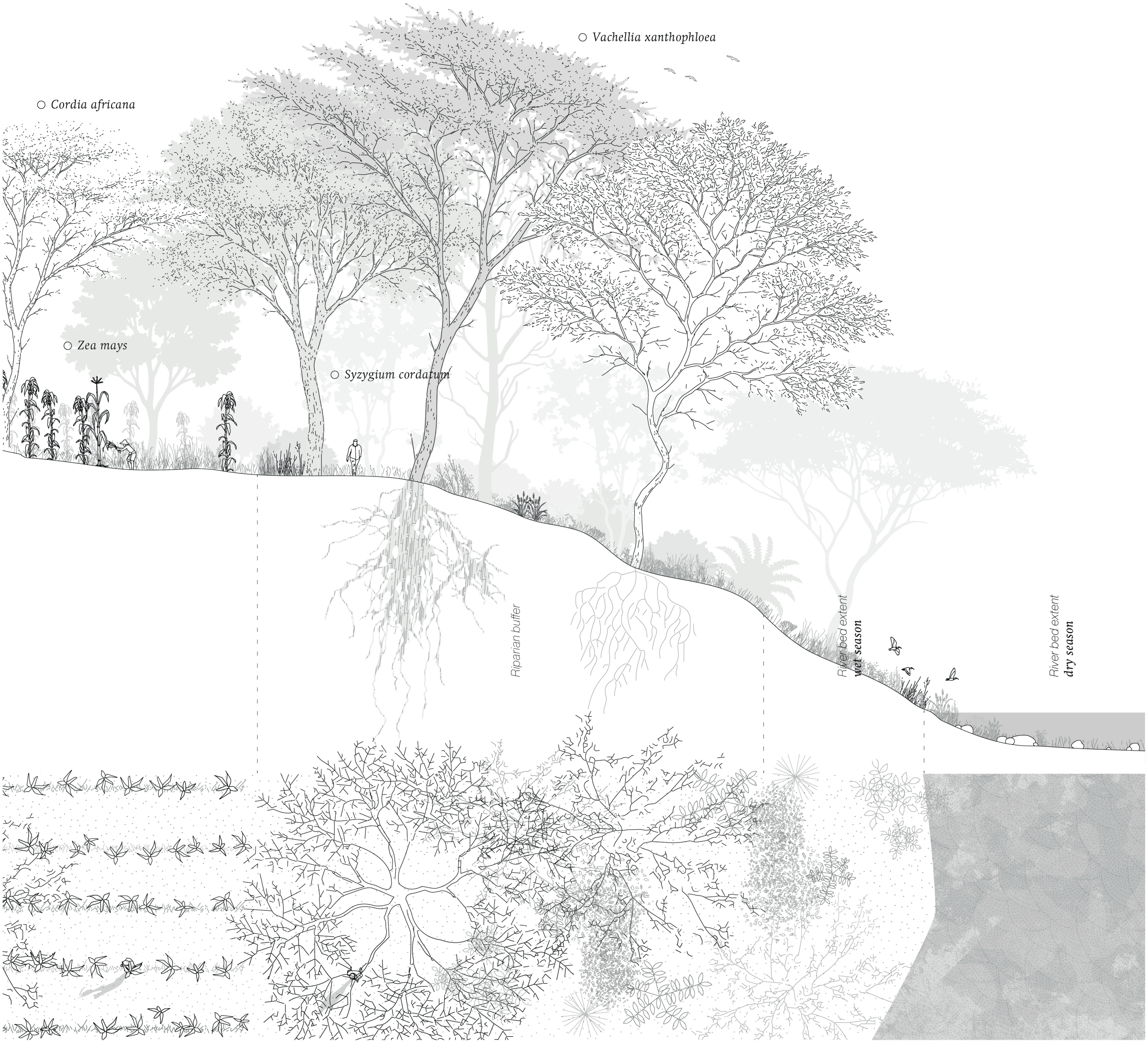
COSTS/BENEFITS *Initial investment is high (land preparation, purchase of tools and seedlings and maintenance). Trees take a while to mature, but after a period of ~5 years, agroforestry becomes a profitable practice. Other benefits include enfvironmental services, food products and fuel wood.*

68 *Sketch for different agroforestry strategies. (Image by author, 2025).* ▶



1. Tree lanes along infrastructure
2. Alley cropping
3. Wind protection tree lanes
4. Trees as land demarcation
5. Live fences
6. High value crop trees
7. Dispersed trees
8. Riverine trees

69 *Cross section of an example of applied agroforestry strategies. (Image by author, 2025).*


Vachellia xanthophloea
Cordia africana
Zea mays
Syzygium cordatum
Riparian buffer
River bed extent
wet season
River bed extent
dry season

1 Agroforestry
2 Terrace farming
1

70 *Bird's-eye impression of the uplands design. (Image by author, 2025).*

5. Design for a regenerative river system

5.5. Design midstream: Recharge

VISION The middle stream of the Njoro River catchment entails the agricultural heart of the region. The gentle slopes and fertile soil make it very suitable grounds for farming. (Re)planting of trees and other deep-rooted plants is crucial for slowing down surface water runoff and reducing erosion in the catchment. As farming is the most dominant land use in this segment of the catchment, agroforestry is an important strategy to increase tree cover. Changing land use from intensive and polluting agriculture to sustainable agroforestry can increase infiltration and recharge the groundwater aquifers that are currently being depleted. Sustainable farming systems like agroforestry reduce the need for pesticides. Pollution of river water from agricultural pesticides is a big challenge, and a move away from pesticides means improved water quality for both humans and ecosystem.

SYNERGIES Regeneration of the river brings both challenges and opportunities. Restoration of natural riparian vegetation and ecosystem services asks for an investment of both time, money and energy. Systemic change also brings opportunities for new ways of living and making a living. Nature development and agriculture (or other economic opportunities) can sometimes lead to a conflict of interest and are often seen as mutually exclusive. This design for the middle stream catchment explores possible new synergies and symbiosis between nature and livelihoods, with the intention of reconnecting people and planet.

71

72

71 *Banana trees on a nearby farm visited in Kiamunyi, Nakuru. (Image by author, 2025).*
72 *Trees planted to provide shades for drought- and heat prone crops. (Image by Author, 2025)*

73 *Design for the midstream of the Njoro River catchment (Image by author, 2025).*


Kapkoros
Kapchorwa
Kerma
Kapkatet
Agroforestry

WATER HARVESTING PONDS Weather extremes such as prolonged periods of drought impact agricultural yield, especially rain-fed agriculture in Kenya. The unpredictability and variability of rainfall and rainy seasons lead to food insecurity. Especially in the long dry seasons the demand for water is high and Nakuru is dependent on deep-lying boreholes. Small-scale water harvesting techniques provide a direct solution in response to water scarcity (Ahmed & Gemeda, 2021). According to Ahmed & Gemeda (2021) water harvesting is defined as "all activities to collect available water resources, temporarily storing excess water for use when required." (p. 2.). Farm ponds, or water harvesting ponds are a low-cost solution for water harvesting. A pond is a way to store water during runoff resulting from rainfall and harvesting it for use in the dry season (Dabral et al. 2017). Research by Safari et al. (2020) studied the productivity and incomes of farms in Rwanda using rainwater harvesting (RWH) ponds and found a significant increase in productivity and income in farms that had adopted RWH ponds (Safari et al. 2020). Supplementary irrigation boosts food security and income of farmers (Kiggundu et al. 2018) by increasing crop production.

Community participation is very important in implementation, involving farmers and local communities creates ownership, which ensures sustainability (Kiggundu et al. 2018). According to Kiggundu et al. (2018) the challenges of RWH ponds lie within implementation and maintenance. It is crucial to convince the farmers that RWH ponds are worthwhile investments and to show them the positive impact on crop yield and income. The same report also pleas for fencing off the ponds and planting grass to keep out unwanted animals and people from the reservoir. The grass also helps trapping sedimentation and prevent siltation (Kiggundu et al. 2018).

Water harvesting ponds can also help in taking pressure of the Njoro River by placing them strategically near busy cattle watering points. For example, there is a bridge near the main entrance of the Egerton University which is a very popular watering spot used by pastoralists. Cows bring manure into the river, spiking nitrogen and bacteria levels. They also trample the riverbed increasing sedimentation flows. Building a water harvesting pond near the river reduces the need for watering in the Njoro River. A water harvesting pond designed for cattle can also be combined with the sale of sustainable cattle feed (such as napier grass) produced on agroforestry plots nearby the river.

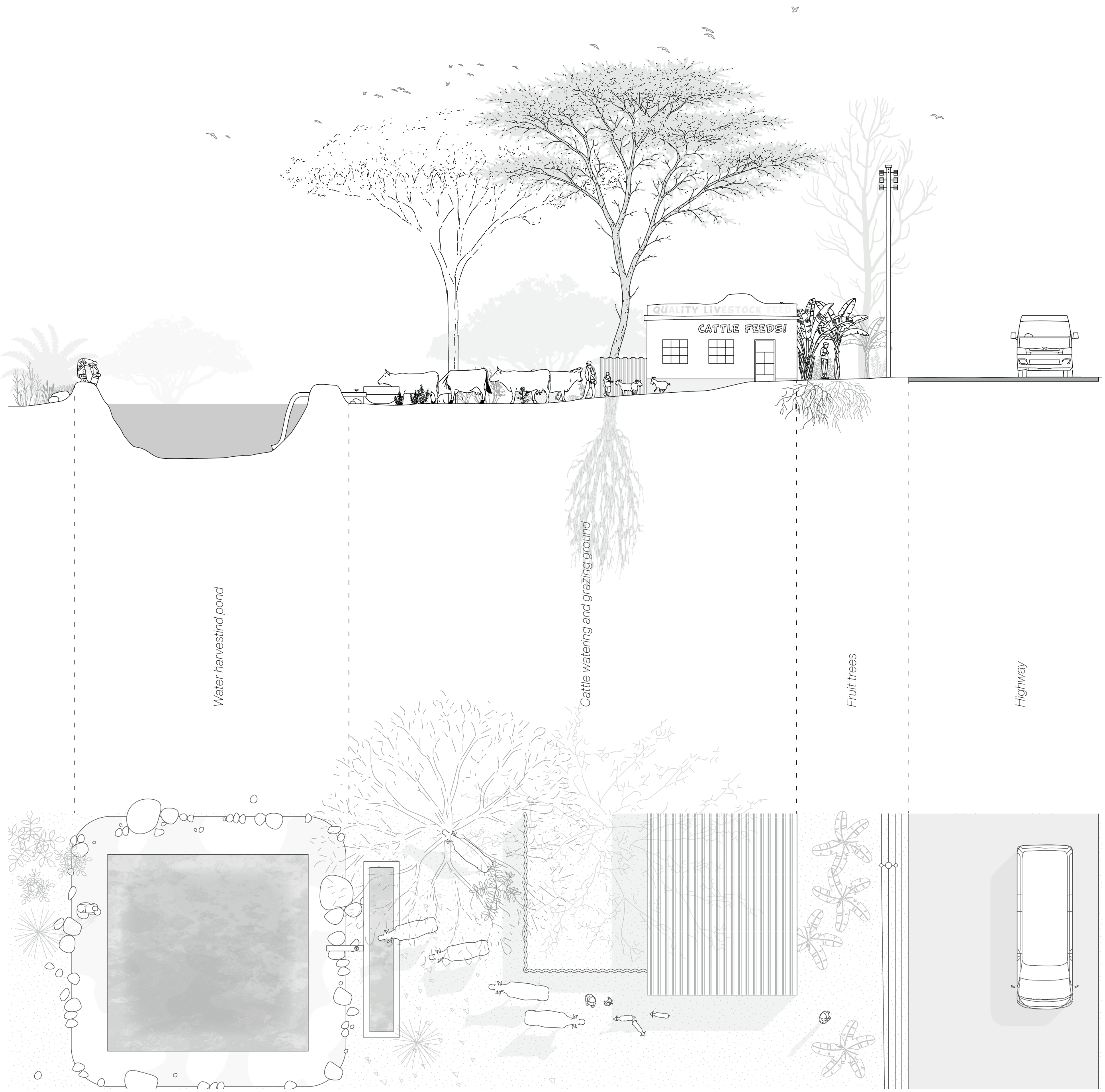
WATER HARVESTING PONDS

SHORT DESCRIPTION *Ponds that can store rain water during peak discharge for use in drier periods.*

SUITABILITY *On farms adjacent to rivers, especially near bridges or 'pools', where the river is most accessible.*

COSTS/BENEFITS *Costs are relatively low, mainly in labour and materials. Benefits are environmental (released pressure on river) and increased productivity and water availability.*

74 *Cross section of a sustainable cattle center with water harvesting pond (Image by author, 2025).* ▶


QUALITY LIVESTOCK
CATTLE FEEDS!
Water harvestind pond
Cattle watering and grazing ground
Fruit trees
Highway

Deep rooted grasses for fodder (cattle feed)
Bamboo for soil conservation and building materials
Footpath
Rewilding and restoration of river bank
River bed
Check dam

(LIVE) CHECK DAMS Live check dams are constructed by planting or plugging cuttings or grasses in gully bottoms to reinforce or replace physical check-dams. It is a cost-effective way of establishing a physical check-dam. A check dam is constructed on gully or riverbed courses to harvest runoff water and control erosion (Adimassu et al. 2022). They are most effective in areas that suffer severe soil erosion. They are designed to trap and safely discharge water and are created as a stepped canal bed profile. This reduces the runoff velocity, which slows down soil erosion (Kumarasinghe, 2021). Live check dams work especially well in the upper reaches of a watershed, grass or bamboo can be employed as a live check (Gupta, 2016).

(LIVE) CHECK DAMS

SHORT DESCRIPTION *Check dams are small obstructions in the river bed that delay runoff and catch sediment.*

SUITABILITY *Most effective in the upper reach of a watershed.*

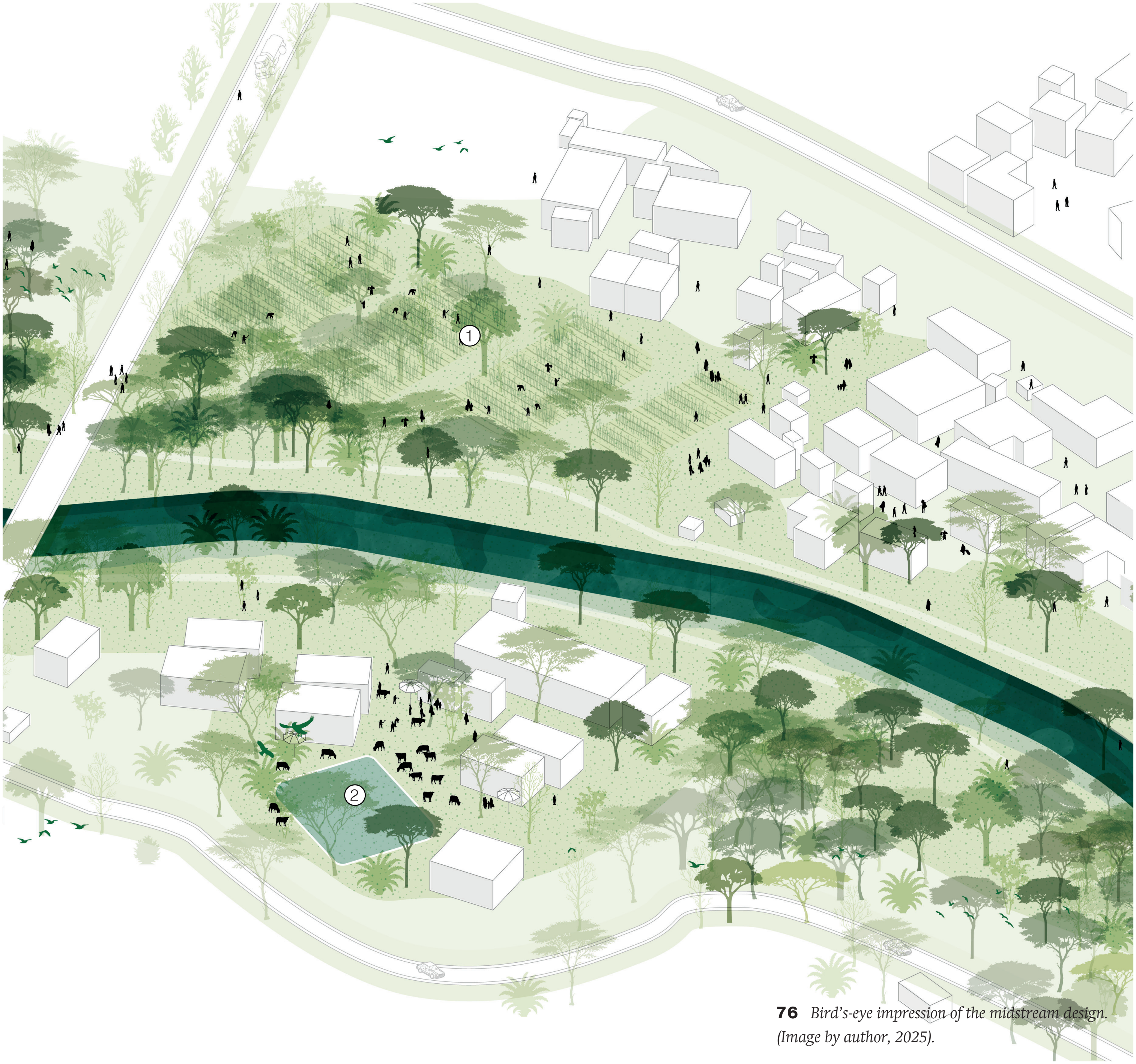
COSTS/BENEFITS *Costs are relatively low, mainly in labour and materials. Benefits are environmental (reduced siltation and increased water safety).*

RIPARIAN VEGETATION REHABILITATION The encroachment of the 30-meter riparian buffer zone (on both sides of a river) that is legally prescribed is frequently encroached. The result is increased runoff, bank instability and declining water quality. Restoring the 30-meter buffer is essential in regenerative catchment management and conservation of ecosystem services. Replanting the riparian zones with appropriate vegetation is crucial. The design for the riverbank in this part of the catchment proposes rewilding where possible, and replanting (with economically viable crops) where necessary. This means that undisputed zones of the buffer area are replanted with indigenous plants and trees, natural succession is allowed to occur. This is the preferred strategy, but in areas where people's livelihoods depend on encroached riparian land, a compromise is needed. Deep-rooted grasses such as napier (pennisetum purpureum) protects and stabilizes the riverbank but can also be sold as a high-quality fodder crop. Indigenous and non-invasive bamboo species (e.g. oxytenanthera abyssinica) can strengthen the riparian buffer and provide communities with materials for construction and handicrafts. In combination with multipurpose trees (e.g. calliandra calothyrsus, grevillea robusta), these plants form an agroforestry buffer zone that not only protects the river from siltation and pollution, but generates new livelihood opportunities through fodder, fuelwood and fruit production.

◀ **75** *Cross section of a rehabilitated river bank with economically viable crops (Image by author, 2025).*

① Agroforestry (fodder crops)

② Water harvesting pond



76 *Bird's-eye impression of the midstream design. (Image by author, 2025).*

5. Design for a regenerative river system

5.6. Design downstream: Reuse

STRATEGY The downstream of the Njoro River is the most polluted segment of the river. At the same time, it is also the stretch where interaction between people and river is most intensive. The river is an important source of drinking water, but its quality does not meet WHO standards. Studies show that drinking from the river leads to infections and illness. Various waste products end up in the water, roughly divided into organic waste (such as faeces, manure and household organics) and inorganic waste (like plastics and pesticides). By identifying new patterns in these waste flows, the input into the Njoro can be reduced. This would support a healthier river ecosystem, and benefit the people living in the marginalized neighborhoods of Kaptembwo, Ponda Mali and Rhoda, which the river flows through.

77

78

77 *NAWASSCOAL briquette production in the old wastewater treatment plant. (Image by author, 2025).*
78 *Worker demonstrates the process of producing the briquettes. (Image by Author, 2025)*

Rift Valley Insitute of Science and Technology
Water harvesting pond
City forest
Kapte
Kapkures
Nakuru W
Green market park
N
0 100 200 300 400 500 m


Entrance Nakuru National Park
Flamingo
Pondamali Market
Langa Langa
mbwo
Sewage Treatment Plant
Expansion of NAWASSCOAL
Anaerobic wetlands
/est
River waste screen
Plastic recycling station
Barut

WASTE RECYCLING POINT Each waste type requires a different approach. Cattle manure, for example, mostly enters the river in the midstream section and can be reduced by introducing cattle watering ponds, as dis-cussed in the previous subchapter. The main pollutants in the downstream are household waste, faeces and plastics. Reusing, repurposing and recycling waste can be stimulated by setting up recycling centers in the neighborhoods, where residents can drop off household organic waste and plastics. These centers could also create job opportunities, particularly for youth involved in waste collection. Within the centers, organic and plastic waste can be repurposed into other materials. NAWASSCOAL, a successful initiative by NAWASSCO, is already turning organic waste into cooking briquettes, helping reduce the need for firewood and saving trees in the process. As the city continues to grow, so does the demand for building materials. Plastic waste could potentially be repurposed into construction materials such as eco-bricks.

A recycling center that combines these practices could significantly reduce waste flowing into the river, while also creating new livelihoods for residents in these underserved neighborhoods. To deal with remaining waste, river waste screens can be placed under bridges to collect debris. These nets would need regular clearing, ideally by a dedicated group of local residents. Recy-cling and repurposing demand a community-led approach and a strong local commitment. A pilot recycling project could help raise awareness and shift how people perceive waste. River clean-ups, like those previously organized by WWF, can help connect communities who share the same watershed and emphasize the importance of clean water. Finally, with the old wastewater treatment plant likely to flood, operations will be relocated to the newer facility near the river mouth. There, a constructed wetland can be integrated to filter out bacteria and toxins from both sewer and river water, enabling safe reuse.

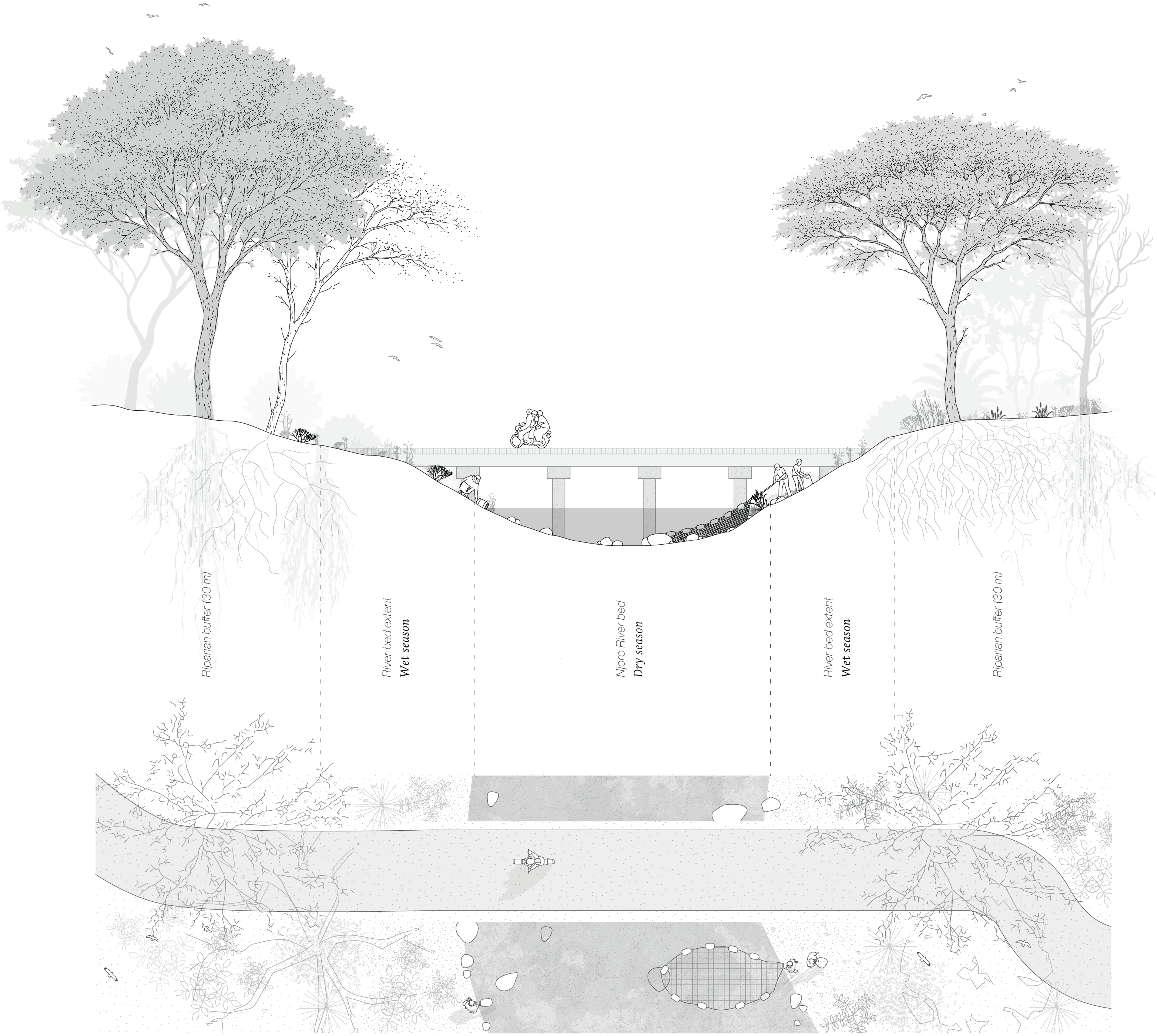
WASTE RECYCLING

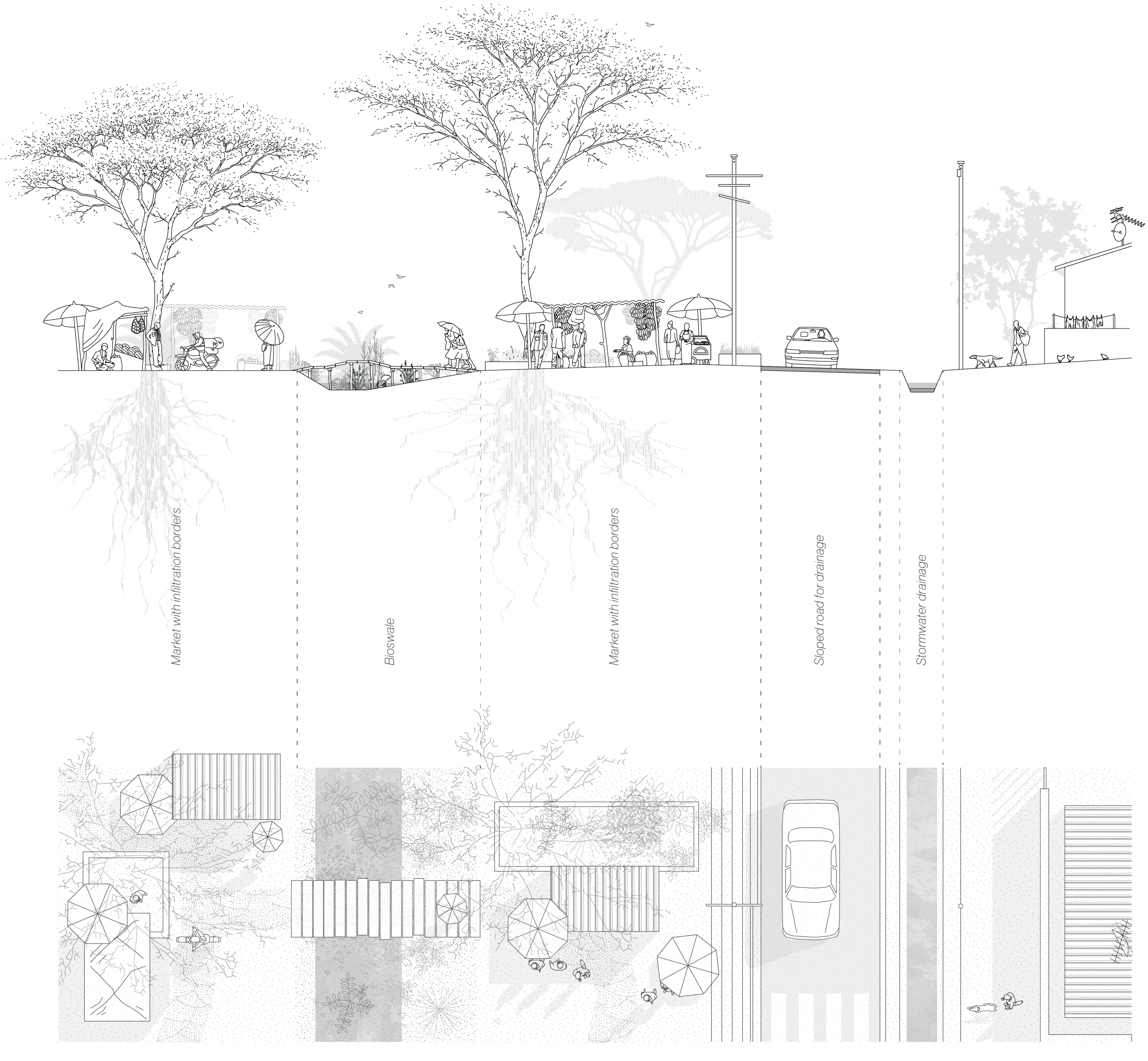
SHORT DESCRIPTION *The Njoro River is the end point of the current waste cycle. Waste flows should be redirected to community collection points to improve water cleanliness.*

SUITABILITY *Close to community centers and at strategic points adjacent to the river (e.g. bridges or near gutter outlets).*

COSTS/BENEFITS *Program relies on community effort, benefits are job creation and improved river water quality.*

79 *Cross section of a rehabilitated river bank with river waste screen (Image by author, 2025).* ▶


Riparian buffer (30 m)
River bed extent
Wet season
Njoro River bed
Dry season
River bed extent
Wet season
Riparian buffer (30 m)



Market with infiltration borders
Bioswale
Market with infiltration borders
Sloped road for drainage
Stormwater drainage

ECO-MARKET While the rapid growth of the city continues, undeveloped and green space is often short-lived. Without a defined economic purpose or protection, green space tends to be encroached or informally settled. To reserve space for crucial green infrastructure (e.g. bioswales or infiltration zones), there is a need for concepts are not only ecologically functional but also bankable and socially embedded. A possible concept could be integrating the green infrastructure into a public program such as a green market. The city already employs several (informal) markets scattered across different neighborhoods (e.g. Ponda Mali market). A formalized market space could be designed combined with ecological functions. Maintenance of the green space would be the responsibility of the shopkeepers, who in turn are offered a pleasant anf formalized space to sell their goods.

The proposed green market would provide space for the sale of products grown in agroforestry systems, terraced farming plots and other sustainable agricultural practices introduced earlier in this study. By offering a platform for these products, the market creates a direct link between regenerative agriculture and urban consumers. The stalls could be arranged around planted swales or retention areas, which collect and filter stormwater. Shaded areas created by tree canopies offer a more comfortable microclimate for both vendors and visitors, while permeable paving and green buffers help reduce surface runoff. In addition to selling goods, the market can also function as a community anchor point, a place where knowledge about sustainable farming, composting, and reuse can be exchanged. Market infrastructure can be built incrementally, using local materials, and maintained by cooperatives or vendor associations. This gives the space a degree of flexibility and adaptability while reinforcing local ownership.

ECO-MARKET

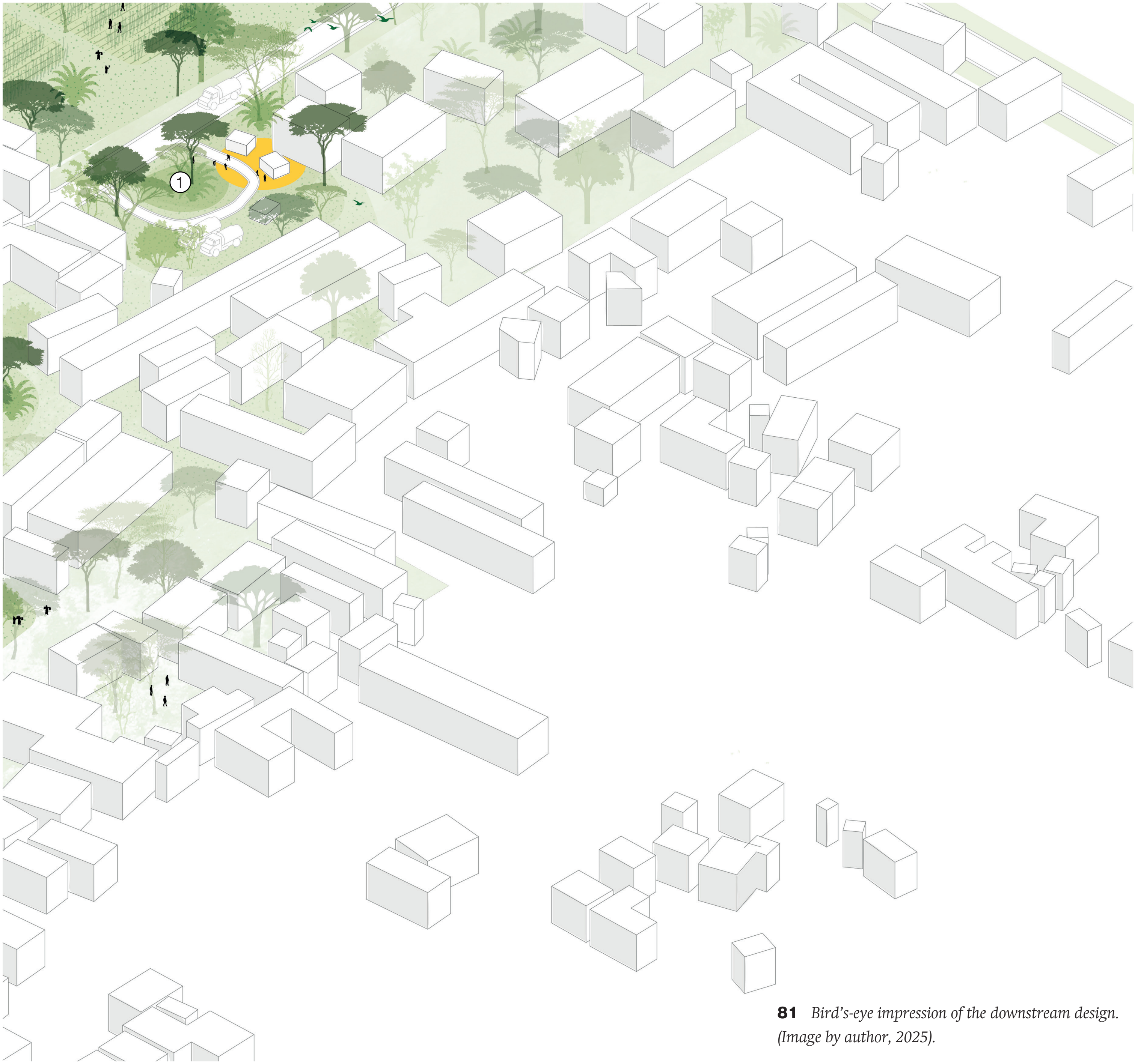
SHORT DESCRIPTION *Community market centers for selling fresh, locally produced food, while also offering pleasant green space to the local community and harvesting rainwater through (for example) bioswales.*

SUITABILITY *Existing markets can be enhanced with qualitative green space, new markets can be build adjacent to important roads.*

COSTS/BENEFITS *Costs are in seedlings/saplings and labour in planting and constructing bioswales. Benefits are in creating pleasant places to visit, increasing sales numbers and creating places for community to socialize.*

◄ **80** *Cross section of eco-market with bioswale (Image by author, 2025).*


2
3
1 Neighborhood recycling point
2 Eco-market
3 Water retention and small-scale purification



81 *Bird's-eye impression of the downstream design. (Image by author, 2025).*

5.7. Implementation framework

ROLE OF COMMUNITIES To implement systemic change in the Njoro River catchment, collaboration between different actors is essential. In particular, the role of local communities should not be underestimated. While the government has an important role in planning and regulation, projects that are fully led by government institutions often face challenges in execution. This is partly due to limited capacity, but also linked to Kenya's history of centralized governance (a structure inherited from colonial times) (Mogaka et al., 2006; Swallow et al., 2009). In practice, local communities in Kenya are often better organized than top-down systems assume. Many people come together through neighbourhood groups, churches or cultural communities. These groups are often led by respected elders and are already involved in collective action (for example, by contributing to the construction of boreholes with support from organizations like NAWASSCO). Research shows that when people contribute to and help manage a project, they feel more ownership and are more likely to maintain it over time (Harvey & Reed, 2007; Hope, 2015).

PARTNERSHIPS This suggests that involving communities directly in projects such as riparian restoration, river clean-ups or agroforestry can be an important step toward implementation. If people see the value of an initiative and are involved from the beginning, they are more likely to take care of it in the long run. Community-led efforts can bridge the gap between planning and what happens on the ground (Whaley & Cleaver, 2017). NGOs and research institutions can support this process by providing funding, technical knowledge and training. Egerton University is already active in restoring parts of the Njoro River buffer zone and has organized workshops and student projects in the area. NGOs like the Green Belt Movement, World Vision, SNV and WWF-Kenya work with farmers and local water user groups to support planting, water harvesting and land restoration efforts (WWF-Kenya, 2020; Green Belt Movement, 2023). A regenerative approach depends on this kind of collaboration. When communities are not just involved but are empowered, projects have a greater chance of being maintained over time.

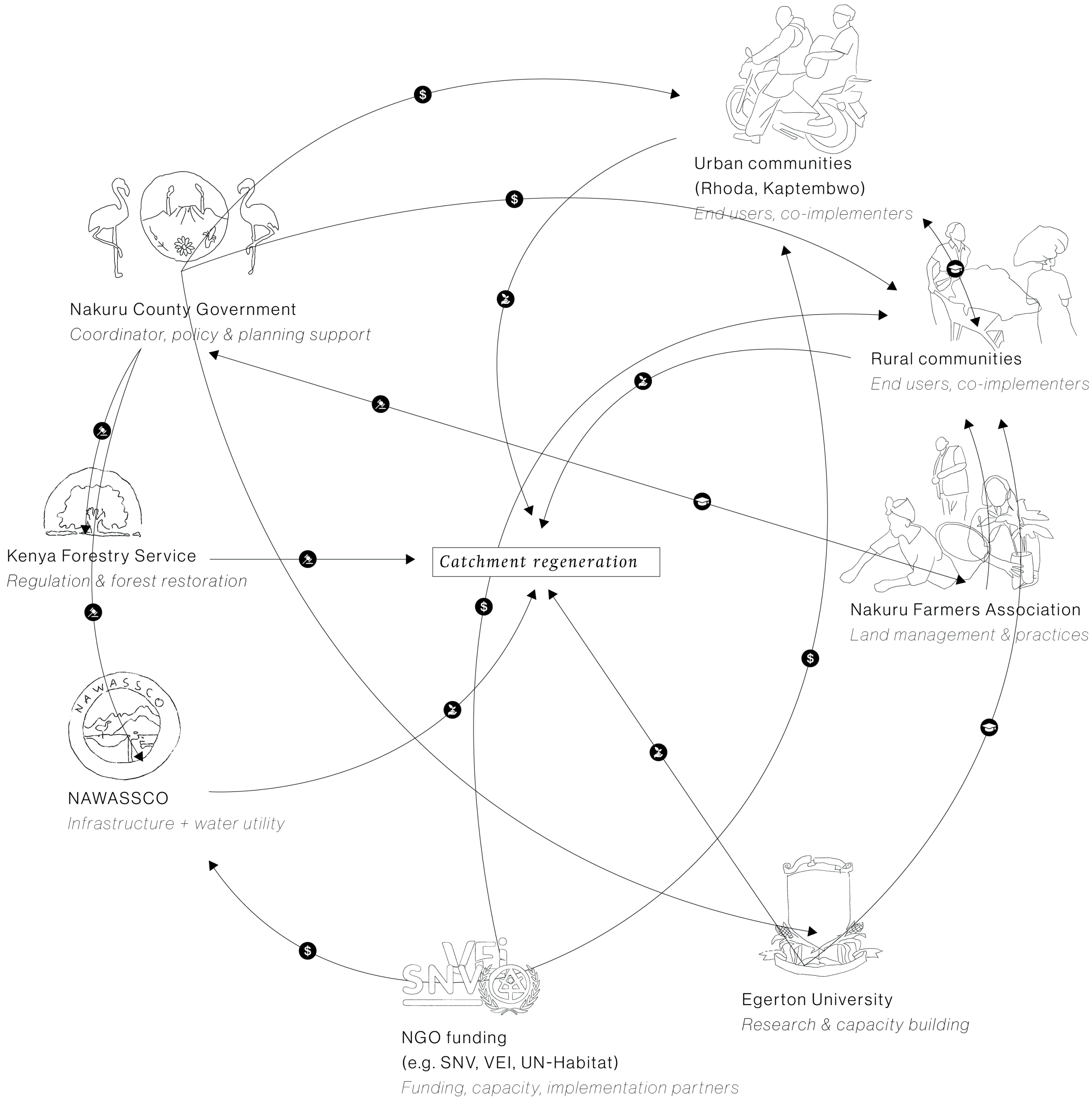
82 *Stakeholder role and network mapping (Image by author, 2025).* ▶

Legend

Financing

Jurisdiction and policy-making

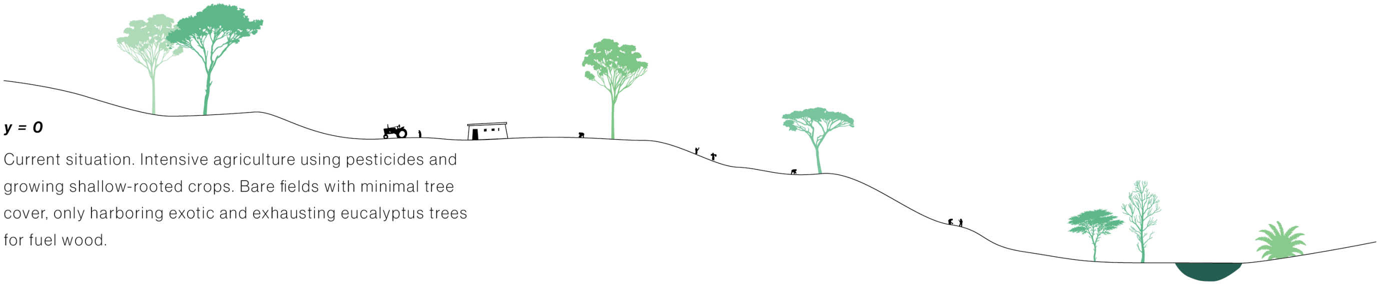
Implementation and maintenance (e.g. planting and construction)


Urban communities
(Rhoda, Kaptembwo)
End users, co-implementers
Nakuru County Government
Coordinator, policy & planning support
Rural communities
End users, co-implementers
Kenya Forestry Service
Regulation & forest restoration
Catchment regeneration
Nakuru Farmers Association
Land management & practices
NAWASSCO
Infrastructure + water utility
Egerton University
Research & capacity building
NGO funding
(e.g. SNV, VEI, UN-Habitat)
Funding, capacity, implementation partners

5.8. Implementation phasing

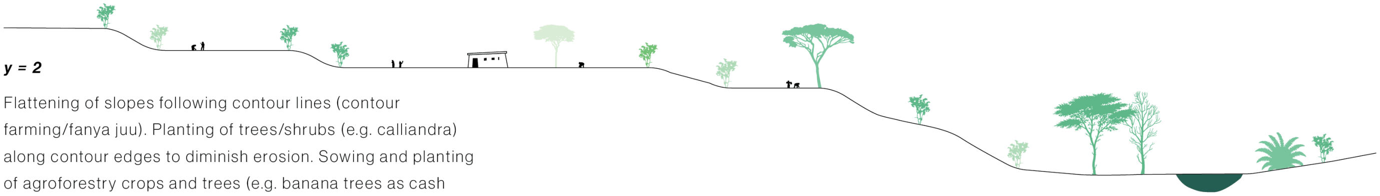
PHASING A phased implementation is critical to steer the Njoro River catchment toward full ecological recovery and sustainable community stewardship. Early phases focus on baseline assessment and pilot restoration actions, while later phases build on initial successes to fully regenerate riverine habitats and social-ecological functions. This stepwise approach allows natural systems to re-establish gradually and local people to adjust and assume ownership of conservation measures. In the initial phase, comprehensive surveys and monitoring establish reference conditions and degradation causes (e.g. water quality, vegetation cover, erosion sites) so that targets and indicators can be set. Active measures (tree planting, bioengineering of eroded banks, waste cleanup) are introduced carefully, with simultaneous community education and formation of river user groups. Early engagement of stakeholders (farmers, local leaders, NGOs and agencies) is essential; this fosters local "buy-in" so that later phases are community-driven.

TIMELINE Over successive phases, interventions shift from stabilization to enhancement. By year 2–5, riparian buffers and assisted natural regeneration begin to reconnect fragmented habitats. Wetland cells, check dams and infiltration trenches built early on help normalize stream flow and sediment transport.
Indigenous vegetation regrows in hollowed-out valleys, and pilot agroforestry plots or eco-tourism trails demonstrate sustainable livelihoods. With monitoring loops in place, each phase is adjusted: invasive species are removed, designs are refined, and successes (e.g. regrowth rates, community income data) are shared to maintain momentum. By the 10–20 year horizon, the river corridor is largely selfsustaining: forest canopies are closed in headwaters, meadows and farmed land buffer the middle reaches, and green infrastructure fully lines the urban segments. Communities by then manage much of the stewardship (via cooperatives or local agencies) and enjoy diversified incomes from forest products, fisheries, eco-tourism, or sustainable agriculture. In sum, phasing ensures a "characteristic, self-sustaining, dynamic" river ecosystem over time , while simultaneously nurturing resilient livelihoods and a sense of local ownership.



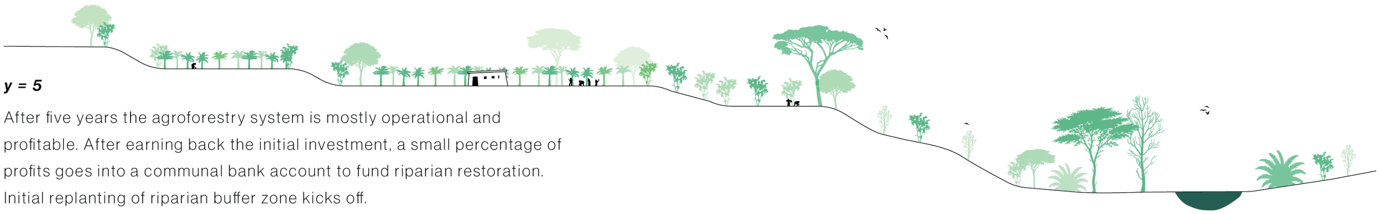
y = 0

Current situation. Intensive agriculture using pesticides and growing shallow-rooted crops. Bare fields with minimal tree cover, only harboring exotic and exhausting eucalyptus trees for fuel wood.



y = 2

Flattening of slopes following contour lines (contour farming/fanya juu). Planting of trees/shrubs (e.g. calliandra) along contour edges to diminish erosion. Sowing and planting of agroforestry crops and trees (e.g. banana trees as cash crops, syzygium as shade/land demarcation tree).



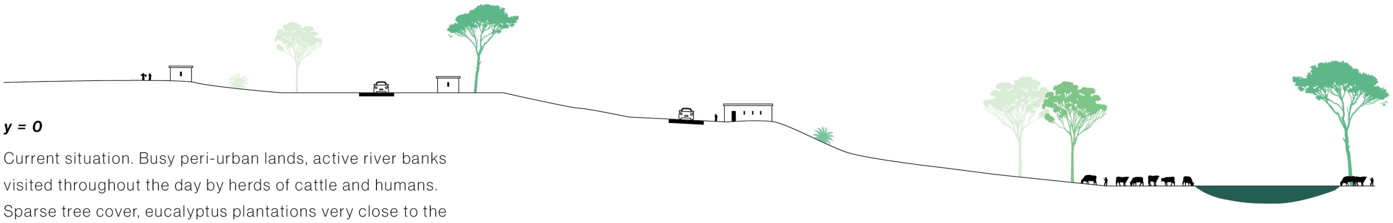
y = 5

After five years the agroforestry system is mostly operational and profitable. After earning back the initial investment, a small percentage of profits goes into a communal bank account to fund riparian restoration. Initial replanting of riparian buffer zone kicks off.

y = 20

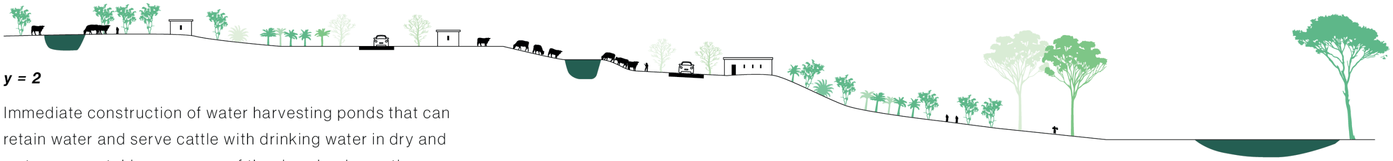
Twenty years later, the riparian vegetational buffer is replanted and restored. Erosion is under control through terracing and agroforestry strategies. The water and ecological system is adaptive to climate change and weather extremes. Agroforestry farming creates more rewarding forms of livelihoods (both socially and financially).

83 *20-years phasing Uplands (Image by author, 2025).*



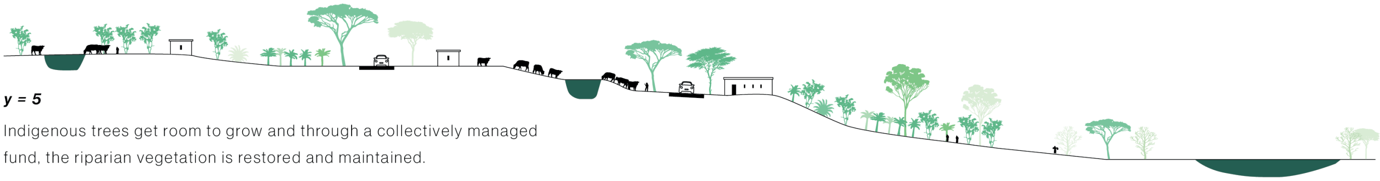
y = 0

Current situation. Busy peri-urban lands, active river banks visited throughout the day by herds of cattle and humans. Sparse tree cover, eucalyptus plantations very close to the river shores.



y = 2

Immediate construction of water harvesting ponds that can retain water and serve cattle with drinking water in dry and wet seasons, taking pressure of the river. Implementing agroforestry systems in intermediate zone between productive land and (protected) riparian buffer.



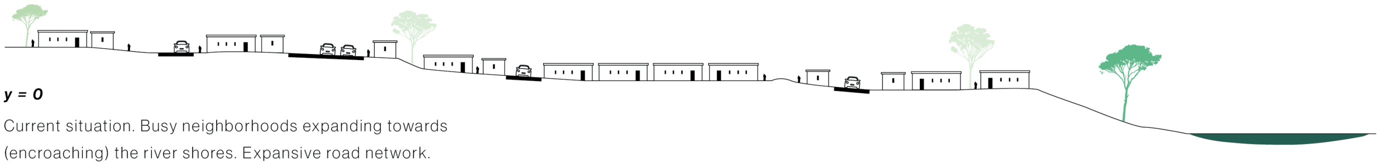
y = 5

Indigenous trees get room to grow and through a collectively managed fund, the riparian vegetation is restored and maintained.

y = 20

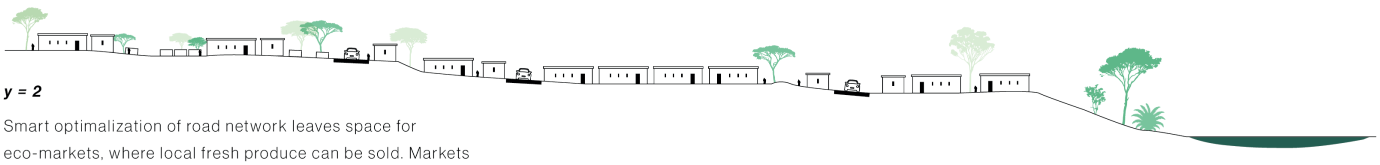
Diverse mosaic: wooded riparian fringe, shaded pastures, fruit orchards. River meanders freely through a partly open floodplain.

84 *20-years phasing Midstream (Image by author, 2025).*



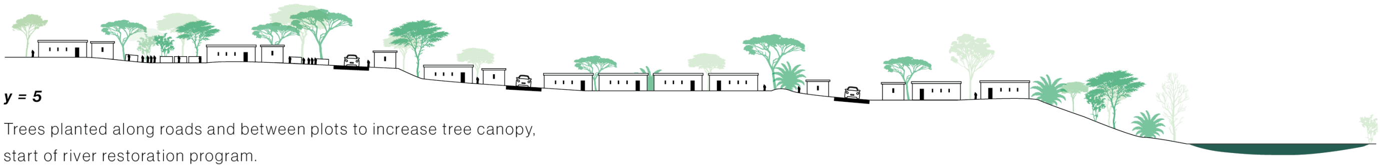
y = 0

Current situation. Busy neighborhoods expanding towards (encroaching) the river shores. Expansive road network.



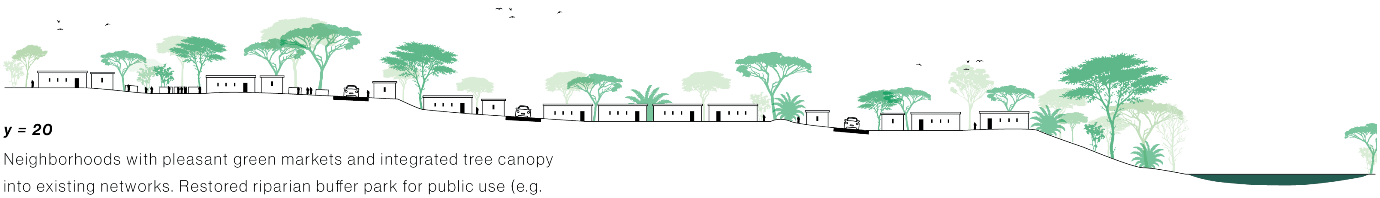
y = 2

Smart optimalization of road network leaves space for eco-markets, where local fresh produce can be sold. Markets are integrated with bioswales, young trees are planted. Start of neighborhood-scale waste recycling programs.



y = 5

Trees planted along roads and between plots to increase tree canopy, start of river restoration program.

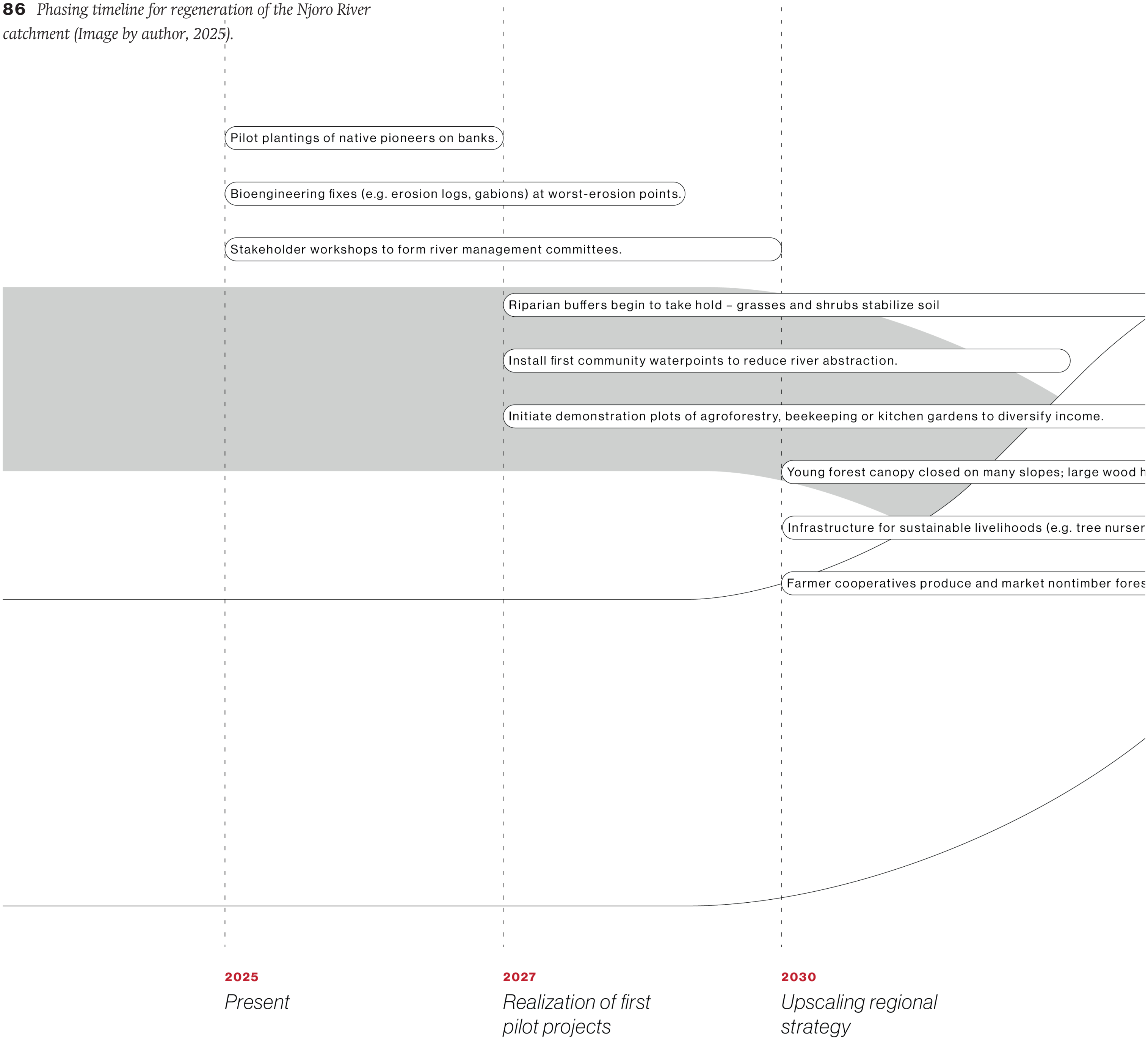


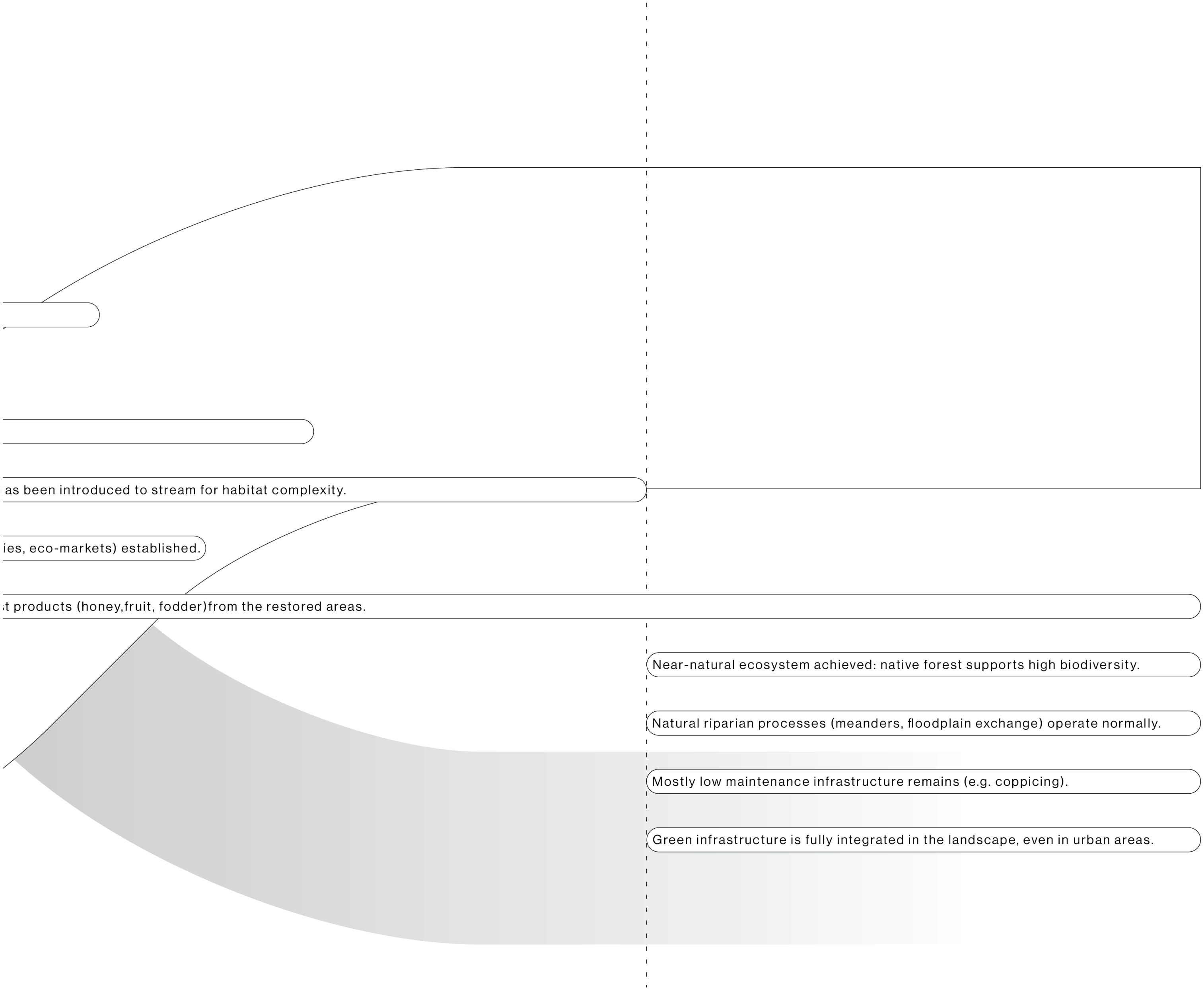
y = 20

Neighborhoods with pleasant green markets and integrated tree canopy into existing networks. Restored riparian buffer park for public use (e.g. leisure walks).

85 *20-years phasing Downstream (Image by author, 2025).*

86 *Phasing timeline for regeneration of the Njoro River catchment (Image by author, 2025).*





2045

Moving towards systemic change

6. Conclusion, discussion & Reflection

6. Conclusion, discussion & reflection

6.1. Conclusion

INTRODUCTION This thesis explored how regenerative landscape design can support both ecological restoration and human well-being within the Njoro River catchment in Nakuru, Kenya. Through a Research Through Design methodology, the project developed a spatial framework that applies nature-based solutions across three landscape zones, uplands, midstream, and downstream, each with its own challenges and opportunities. Rather than proposing a singular intervention, the resulting framework offers a layered and adaptable strategy that integrates ecological logic with local knowledge and community agency.

SRQ1: *How do the natural system, networks and land-use relate to each other in the Nakuru river catchment?*

Because of its position in the Rift Valley (used by our prehistoric ancestors as a migration corridor), Nakuru has been inhabited by humans for centuries. Its current urban development was kickstarted by British colonization in the 1880's. Because of its location on the way to Uganda (in pursuit of natural resources and access to the source of the Nile) a small railway post was founded in between the natural landmarks the Menengai Caldera and Lake Nakuru. As the British enforced and imposed their Western way of living on the local population, Nakuru transformed from a lush semi-arid forest to a major agricultural hub. This development is directly related to Nakuru's geographical position in between Mombasa (Indian Ocean) and Kampala (Uganda), as well as its geological properties (fertile volcanic soil). Because of the colonial intensive agricultural system and rapid population growth, the land-use and natural system are increasingly out of balance.

SRQ2: *What is the (cultural, historical, natural) significance of the Njoro river catchment in relation to Nakuru City?*

The Njoro River (or Ndarugu River) is the largest contributor to Lake Nakuru. It drains the Njoro River catchment into the Lake Nakuru and it is also the biggest distributor of sedimentation, increasing the lake's water level. Besides the Menengai Caldera and the lake itself, the Njoro River is one of the major natural landmarks. It is important to local communities for drinking water, cattle watering, washing and religious reasons.

SRQ3: *Which landscape design theories and strategies are suitable for regenerating the Nakuru river catchment and facilitating sustainable urban development?*

The casco framework was used in this research to guide land-use and spatialize design solutions. The Njoro River was used as the framework, reinstating the 30-meter riparian buffer that is protected by law and defining a new intermediate zone for ecologically friendly practices such as agroforestry. Strategies are mostly low-cost, small scale and community oriented, but implemented in a larger scale framework for the entire Njoro catchment.

SRQ4: *How can these theories and strategies be implemented to shape a healthy and resilient future for the Nakuru river catchment?*

Implementation depends on community commitment. With initial funding from NGOs and government agencies, pilot projects (for example, community nurseries, sediment traps, living fences) can demonstrate benefits for both ecology and livelihoods. These small successes then build local ownership and pave the way for scaling up, with feedback loops for monitoring and adaptive management.

SRQ5: *What lessons can be learned from this framework that are applicable to other cases around the world?*

While the framework remains conceptual, it demonstrates the potential of landscape architecture to operate in a Global South context when it is grounded in systems thinking and cultural sensitivity. The approach highlights the value of spatial design in clarifying complex relationships and shaping tangible strategies that can guide long-term, community-based action.

To answer the main research question: a regenerative spatial strategy for the Njoro River catchment must be layered, adaptive, and community-anchored. It should position the river as the guiding framework, reinstating protected riparian buffers, establishing ecologically productive intermediate zones, and reconnecting upland, midstream, and downstream dynamics. By integrating nature-based solutions with cultural practices and local stewardship, such a strategy enables both ecological recovery and sustainable urban growth. It is not a fixed blueprint but a living framework that evolves over time.

6. Conclusion, discussion & reflection
6.2. Reflection

INTRODUCTION This thesis project was written under the supervision of Nico Tillie, as a contribution to the Water as Leverage project initiated by the Netherlands Enterprise Agency. For me as a student of landscape architecture, it offered a unique opportunity to look beyond borders and experience what it means to work on a design project in a foreign and unfamiliar context. I found it both exciting and challenging to explore this new environment and to learn more about natural systems, such as the unique geology and plant species found in Kenya. The time I spent in Nakuru (a total of three weeks) was unforgettable; the design workshops and excursions along the river are experiences I will always treasure.

ROLE AS DESIGNER At the same time, it was not always easy to work as an outsider in a postcolonial context. During my visit, it was announced that the United States would withdraw all funding from USAID (the American government's development agency). In an article for NRC (2025), Han Seur reflected on this event and the West's role in Africa: "Perhaps this is the moment when we start interfering less in Africa and realize that countries on this continent have the right to true independence," he stated. Africa and the West share a complex relationship and history. It is therefore not my intention as a designer to give the impression that I know better than Kenyans themselves. I believe the value of this thesis lies in its exploration of the role landscape architecture can play in a Global South context, and more specifically in Kenya. Kenya does not have a tradition of spatial planning or landscape design in the way we know it in the Netherlands. Large-scale, centralized visions (for example the Dutch Room for the River program) would be less effective in the Kenyan context. Change at the community level is often more feasible and impactful. Even so, I do think design research has value here. Kenya is one of the fastest-growing countries in Africa and has long been a stabilizing force in East Africa. It is also a frontrunner in sustainability and climate adaptation on the continent. I believe that the "layer approach" used in this research can help to reveal complex relationships between people and landscape, and at the same time offer a logic and strategy grounded in the landscape itself. The landscape scale also makes abstract concepts (such as erosion or pollution) more tangible. Once placed in the context of a river, such issues suddenly become understandable to everyone.

DESIGN PROCESS Throughout the process, I often questioned my role as a designer and the uncertainties involved in working within an unfamiliar and sensitive context. I aimed to maintain an open and curious attitude, especially during our visit to Kenya. I tried to learn as much as possible from the Kenyans I met (even a few words of Kiswahili), and did my best to integrate their insights and knowledge into the design. I also aimed to be respectful in my drawing and writing style. In my drawings, I tried to depict people in a way that would be recognizable to Kenyans, spending extra time illustrating local clothing, appearances, and indigenous tree and plant species. The design is based on a combination of my own analysis of the natural, infrastructural, and occupation layers, and the design workshops with local stakeholders and students in Nakuru. The proposal does not offer a singular, all-encompassing solution but rather a flexible and scalable framework. By combining interventions and seeking new synergies, a different way of engaging with the landscape is found, one that contributes to system change. I deliberately left room for local interpretation and collaboration. At the same time, there are clear limitations. One year is not enough to fully understand the complexities of an unfamiliar place. My knowledge of the social, cultural, and political dynamics in Nakuru remains limited. Some parts of the strategy (such as long-term governance and implementation) also remain quite abstract. As a result, the framework is strong as a conceptual tool but needs further translation and embedding in practice.

Despite the challenges and complexities of design research, my curiosity and interest in Nakuru have only grown. It is an incredibly fascinating region with a remarkable population and beautiful natural surroundings. I could read about it endlessly. I hope that this enthusiasm is, in some way, evident in this thesis.

87 *Cattle herd and eucalyptus plantation on shores of the Njoro River. (Image by Author, 2025).*

88 *Njoro River's natural flow and appearance in the protected Mau Forest. (Image by Author, 2025).*

89 *Encroachment and pollution near the Njoro River in Kaptembwo (urban downstream). (Image by Author, 2025).*

90 *Njoro River's natural flow and appearance in the protected Mau Forest. (Image by Author, 2025).*

TUDelft

Literature

Adimassu, Z., Tamene, L., Kibret, G., Assefa, A., & Dawit, M. (z.d.). Catalogue of Sustainable Land Management and Climate Smart Agriculture Practices in Ethiopia.

Agricultural Water Management Delivers Returns on Investment in Africa. (z.d.).

Albertazzi, S., Bini, V., Lindon, A., & Trivellini, G. (2018). Relations of power driving tropical deforestation: A case study from the Mau Forest (Kenya). Belgeo, 2. https://doi.org/10.4000/belgeo.24223

Ambani, O. M., & Obiero, D. J. P. (z.d.). Analysis of the Impact of Climate Change on River Flows and Rising Water Levels of Lake Nakuru.

Amisi, L. (2018). Heterogeneity in Event-Based Soil Hydrologic Response to Different Land Use Types in Upper River Njoro Catchment, Kenya. International Journal of Engineering Management, 2(3), 47. https://doi.org/10.11648/j.ijem.20180203.11

Baptiste Safari, J., Abias, M., & Mupenzi, C. (2020). Assessing the Use of Hillside Rainwater Harvesting Ponds on Agricultural Production, a Case of Unicoopagi Cooperative Union. International Journal of Natural Resource Ecology and Management, 5(2), 64. https://doi.org/10.11648/j.ijnrem.20200502.15

Butterbach-Bahl, K. (2016). Long-term assessment of soil and water conservation measures (Fanya-juu terraces) on soil organic matter in South Eastern Kenya. Geoderma, 274, 1-9. https://doi.org/10.1016/j.geoderma.2016.03.022

Blackburn, R. H. (1974). The Okiek and Their History. Azania: Archaeological Research in Africa, 9(1), 139-157. https://doi.org/10.1080/00672707409511720

Bruin et al. & H+N+S Landschapsarchitecten. (2023). Reflecties op drie instrumenten in het herontwerpen van de Nederlandse delta.

Chemelil, P. K., Chacha, B. K., & Peter, W. (z.d.). Logging Dividends: The Maasai, Politicians and Timber Extraction in the Mau Forest, 1895-1960. 08(05).

Chrisphine, U. M., & Maryanne, O. A. (2015). Assessment of Hydrological Impacts of Mau Forest, Kenya. Hydrology Current Research, 07(01). https://doi.org/10.4172/2157-7587.1000223

Dabral, P. P., Kumar, S., & Kiku, K. (2017). Economic Evaluation and Overall Assessment of Water Harvesting Ponds based on Scorecard System: A Case Study. Journal of The Institution of Engineers (India): Series A, 98(4), 561-570. https://doi.org/10.1007/s40030-017-0235-x

Dangiso, Y., & Wolka, K. (2024). Fanya Juu terraces improve soil properties of cultivated land in erosion-prone semi-arid area of Ethiopia. Scientific Reports, 14(1), 25485. https://doi.org/10.1038/s41598-024-77229-5

Ehrensperger, A., & Mbuguah, S. (2004). Fostering sustainable urban development in Nakuru, Kenya Rift Valley. Mountain Research And Development, 24(3), 210–214. https://doi.org/10.1659/0276-4741(2004)024[0210:FSUDIN]2.0.CO;2

Farahani, S. S., Fard, F. S., & Asoodar, M. A. (z.d.). Effects of

Contour Farming on Runoff and Soil Erosion Reduction: A Review Study.

Gichuhi, M. & Jomo Kenyatta University of Agriculture and Technology. (2013). ECOLOGICAL MANAGEMENT OF THE MAU CATCHMENT AREA AND IT'S IMPACT ON LAKE NAKURU NATIONAL PARK. In JAGST (Vol. 15, Nummer 1, pp. 81–84). Jomo Kenyatta University of Agriculture and Technology.

De Giusti, G., Kristjanson, P., & Rufino, M. C. (2019). Agroforestry as a climate change mitigation practice in smallholder farming: Evidence from Kenya. Climatic Change, 153(3), 379-394. https://doi.org/10.1007/s10584-019-02390-0

Gupta, D. A. K. (z.d.). Water Harvesting Check dams in Rainfed Regions: A review article.

H., Gutierrez, V., Madgwick, J., & Christophersen, T. (2021). The 4 Returns Framework for Landscape Restoration. In UN Decade On Ecosystem Restoration Report (p. 1). Commonland. https://www.commonland.com/wp-content/uploads/2021/06/4-Returns-for-Landscape-Restoration-June-2021-UN-Decade-on-Ecosystem-Restoration.pdf

Hughes, K., Morgan, S., Baylis, K., Oduol, J., Smith-Dumont, E., V gen, T.-G., & Kegode, H. (2020). Assessing the downstream socioeconomic impacts of agroforestry in Kenya. World Development, 128, 104835. https://doi.org/10.1016/j.worlddev.2019.104835

Iradukunda, P., Sang, J. K., Nyadawa, M. O., & Maina, C. W. (n.d.). Sedimentation Effect on the Storage Capacity in Lake Nakuru, Kenya.

IPCC (2022). Intergovernmental Panel on Climate Change. (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability – Summary for Policymakers (H.-O. P rtner et al., Eds.). Cambridge, UK: Cambridge University Press ipcc.ch.

Kiage, O. E. (2019). The Ogiek Peoples' Indigenous Knowledge: A pathway towards Sustainable Natural Resource Management in the Mau Forest, Kenya. Tourism and Leisure, 8.

Kiggundu, N., Wanyama, J., Mfitumukiza, D., Barasa, B., Katimbo, A., & Kyazze, F. B. (z.d.). Rainwater harvesting knowledge and practice for agricultural production in a changing climate: A review from Uganda's perspective.

Klopp, J. M., & Sang, J. K. (z.d.). Maps, Power, and the Destruction of the Mau Forest in Kenya.

Kumarasinghe, U. (2021). A review on new technologies in soil erosion management. 2(1).

Kutukhulu, A. W., b. (2010). Geophysical mapping of buried river channels and other shallow structures recharging major aquifers in the Lake Nakuru basin, Kenya rift: case study from Kabatini aquifer (Door University of Nairobi & J. O. Barongo).
Leal Filho, W., & De Trincheria Gomez, J. (Red.). (2018). Rainwater-Smart Agriculture in Arid and Semi-Arid Areas. Springer International Publishing. https://doi.org/10.1007/978-3-319-66239-8

Lenzholzer, S., & Cortes o, J. (2018). RTD in Landscape Architecture: a first State of the Art. Proceedings Of DRS, 1. https://doi.org/10.21606/drs.2018.293

Leal Filho, W., & De Trincheria Gomez, J. (Red.). (2018). Rainwater-Smart Agriculture in Arid and Semi-Arid Areas. Springer International Publishing. https://doi.org/10.1007/978-3-319-66239-8

Mang, P., Reed, B., & Regenesis Group and Story of Place Institute. (2112). Regenerative Development and Design. In Encyclopedia Sustainability Science & Technology. https://doi.org/10.1007/978-1-4614-5828-9_303

Martin, R. P. (z.d.). Landscaping and Bio-Engineering of Slopes in Hong Kong. 1.

Masereka, E. M. (1983). A study of design, construction and bank stabilization of fanya juu terraces at Kabete, Kenya (Postgraduate Diploma thesis). University of Nairobi arccjournals.com.

Mathooko, J. M. (z.d.). Disturbance of a Kenya Rift Valley stream by the daily activities of local people and their livestock.

Mbugua, M. W. (z.d.). I, Margaret W. MBUGUA, hereby declare that this research project is my original work and has not been submitted for a degree in any other University.

Mcharo, M., & Maghenda, M. (2021). Cost-benefit analysis of sustainable land and water management practices in selected highland water catchments of Kenya. Scientific African, 12, e00779. https://doi.org/10.1016/j.sciaf.2021.e00779

Morara, O. G., & Kiptoo, S. J. (2018). Kenya's Water Towers; A Scenario.

McGuire, O., Gellert, R., Commonland, Landscape Finance Lab, Wetlands International, IUCN Commission on Ecosystem Management, Dudley, N., Baker, C., Chatterton, P., Ferwerda, W.

Mell, I., Scott, A., Institution of Civil Engineers, & Derry City and Strabane District Council. (2023). ICE Manual of Blue-Green Infrastructure [Book]. https://www.icevirtuallibrary.com

Morgan, W. T. W. (1963). The "White Highlands" of Kenya. In The Geographical Journal (Vol. 2, pp. 140–155). The Royal Geographical Society (with the Institute of British Geographers). https://www.jstor.org/stable/1792632

Mubea, K., & Menz, G. (2012). Monitoring Land-Use change in Nakuru (Kenya) using Multi-Sensor satellite data. Advances in Remote Sensing, 01(03), 74–84. https://doi.org/10.4236/ars.2012.13008

Munyaneza, O., Majoro, F., Hagenimana, E., & Usabyisa, W. (2016). Impact Assessment of Hillside Rainwater Harvesting Ponds on Agriculture Income: Case Study of Ntarama Sector in Rwanda. Journal of Water Resource and Protection, 08(09), 844-854. https://doi.org/10.4236/jwarp.2016.89069

Muoria, E. W., Moturi, W. N., & Eshiamwata, G. W. (2019). Effects of Population Growth on Urban Extent and Supply of Water and Sanitation: Case of Nakuru Municipality.

Mwakikagile, G. (2010). Life in Kenya: The Land and the People, Modern and Traditional Ways. Nairobi, New Africa Press.

Naikumi, M., Njogu, H., Ngugi, H., & Kenya Institute for Public Policy Research and Analysis. (2024). Smart and Sustainable Cities in Kenya: A Path to Progress. In KIPPRA Discussion Paper 340. Kenya Institute for Public Policy Research and Analysis.

Ng'ang'a, G. J. M., Omondi, O. B., & Mourad, K. (2017). Soil and water conservation in Thika–Chania catchment, Kenya. International Journal of Sustainable Water and Environmental Systems, 9(2), 59–65 researchgate.net.

Nijhuis, S., De Vries, J., & Delft University of Technology. (2020). Design as Research in Landscape Architecture [Research Article]. Landscape Journal, 38–1–2, 87–103. https://doi.org/10.3368/lj.38.1-2.87

N. Njiru, E., K. Gachene, C., & W. Baaru, M. (2022). Fanya juu Terraces Improve Maize (Zea mays L.) and Bean (Phaseolus vulgaris L) Grain Yields on Hardsetting Soils of Semi-arid Eastern Kenya. International Journal of Plant & Soil Science, 682-693. https://doi.org/10.9734/ijpss/2022/v34i2231423 Kenya. Environmental Management And Sustainable

Development, 8(1), 42. https://doi.org/10.5296/emsd.v8i1.14193

Njiru, E. N. (z.d.). Effect of Fanya Juu Terraces With Varying Ditch Dimensions on Selected Soil Properties and Crop Yields in Semi-arid Eastern Kenya.
[No title found]. (z.d.-a). International Journal of Scientific and Research Publications.
[No title found]. (z.d.-b). International Journal of Scientific and Research Publications.

Njuguna, G. W. (z.d.). TRANSFORMATION OF WHITE SETTLER AGRICULTURE IN COLONIAL KENYA: THE CASE OF MOLO, NAKURU DISTRICT, 1904-1963.

Nyaga, J., Barrios, E., Muthuri, C. W., born, I., Matiru, V., & Sinclair, F. L. (2015). Evaluating factors influencing heterogeneity in agroforestry adoption and practices within smallholder farms in Rift Valley, Kenya. Agriculture, Ecosystems & Environment, 212, 106-118. https://doi.org/10.1016/j.agee.2015.06.013

Nyaga, J., Muthuri, C. W., Barrios, E., born, I., & Sinclair, F. L. (2019). Enhancing maize productivity in agroforestry systems through managing competition: Lessons from smallholders' farms, Rift valley, Kenya. Agroforestry Systems, 93(2), 715-730. https://doi.org/10.1007/s10457-017-0169-3

Ochir, A., Boldbaatar, D., Zorigt, M., Tsetsgee, S., & Van Genderen, J. L. (2018). Site selection for water harvesting ponds using spatial multi-criteria analysis in a region with fluctuating climate. Geocarto International, 33(7), 699-712. https://doi.org/10.1080/10106049.2017.1289563

Onduru, D. D., Muchena, F. N., Critchley, W. R. S., & Mollee, E. M. (z.d.). Cost-Benefit Analysis of Land Management Options in the Upper Tana, Kenya.
Onduru, D. D., Muchena, F. N., Critchley, W. R. S., & Mollee, E. M. (z.d.). Cost-Benefit Analysis of Land Management Options in the Upper Tana, Kenya.

Ontumbi, G. M., B. Ed. ,. Msc. Ph. d on going, & Sanga, J. K. (2018). Kenya's Water Towers; A Scenario Scrutiny of Njoro Sub Catchment, Eastern Mau Towers. International Journal Of Scientific And Technological Research (IJSTER), 6–15. https://www.oircjournals.org

Otieno Amisi, E., Musula Kundu, P., & Muli Wambua, R. (2020). Modeling Climate Variability Influence on River Regime in Upper Njoro Catchment, Kenya. Journal of Civil, Construction and Environmental Engineering, 5(5), 126. https://doi.org/10.11648/j.jccee.20200505.14

Rai, P., & Dubey, A. (z.d.). Design and Construction of Rainwater Harvesting Plastic Lined Pond.

Raini, J., & Ndetei, R. (2000). Lake Nakuru Experience and Lessons Learned Brief. In Lake Nakuru.

Saiz, G., Wandera, F. M., Pelster, D. E., Ngetich, W., Okalebo, J. R., Rufino, M. C., &

Tamubula, I., & Sinden, J. A. (2000). Sustainability and economic efficiency of agroforestry systems in Embu District, Kenya: An application of environmental modelling. Environmental Modelling & Software, 15(1), 13-21. https://doi.org/10.1016/S1364-8152(99)00028-6

Teshome, A., Adgo, E., & Mati, B. (2010). Impact of water harvesting ponds on household incomes and rural livelihoods in Minjar Shenkora district of Ethiopia. Ecohydrology & Hydrobiology, 10(2-4), 315-322. https://doi.org/10.2478/v10104-011-0016-5

Tuna, A., & G ker, P. (z.d.). Re-naturalization with Soil-Bioengineering Technic on the Stream Landscape: An Experience in M dling of Lower Austria.

United Nations (2022). United Nations, Department of Economic and Social Affairs, Population Division. (2022). World Urbanization Prospects 2022. Retrieved from United Nations website ipcc.ch.

Wambua, R. M., Mutua, B. M., Nyaanga, D. M., & Kundu, P. M. (z.d.). Classification of catchment risk areas using spatially distributed event-based soil erosion: a case of upper Njoro River catchment, Kenya.

Wanjira, E. O., & Muriuki, J. (2020). Review of the Status of Agroforestry Practices in Kenya. Background study for preparation of Kenya National Agroforestry Strategy (2021-2030). https://doi.org/10.13140/RG.2.2.35739.59681

Glossary

AGROFORESTRY A farming approach that integrates trees and crops on the same land. Trees in agroforestry help hold soil and water, reducing erosion. Agroforestry can increase water infiltration and provide both conservation and income benefits.

CASCO FRAMEWORK A Dutch landscape planning tool that separates slow natural processes (like ecosystem regeneration) from fast human activities. In practice, it means using features like rivers as stable "backbones" for long-term design, so that natural processes can unfold with minimal conflict.

EROSION The wearing away of soil or rock, usually by water or wind.

FANYA JUU (TERRACE FARMING) A Kenyan term (Swahili for "throwing it upwards") describing a traditional hillside farming method. Farmers dig small trenches on a slope and throw the dug-out soil uphill to form a raised berm (a low wall). These terraces slow water runoff and reduce soil loss, improving infiltration.

HYDROLOGICAL CYCLE The continuous circulation of water on Earth. Water evaporates from surfaces, forms clouds, falls as precipitation (rain or mist), and then flows over land or infiltrates into the ground.

INFILTRATION The process of water soaking into the soil. When rainwater or runoff is captured and held (for example by a pond or vegetation), it slowly percolates down to recharge the groundwater.

NATURE-BASED SOLUTIONS Strategies that solve problems by working with nature. For example, protecting wetlands or planting trees to clean polluted water or prevent floods. Such solutions use living systems (plants, soil, water) instead of built structures.

POOL–RIFFLE SEQUENCE A natural repeating pattern in many streams where a deep pool alternates with a shallow, fast-flowing riffle. In this sequence, pools (deep, slow-flowing stretches) are often followed by riffles (shallow areas with faster flow and higher slopes).

REGENERATIVE DESIGN A design philosophy that aims to improve ecosystems rather than just avoid harming them. It goes beyond sustainability by seeking to reverse environmental damage and support the life and health of the landscape.

RUNOFF Water (from rain or irrigation) that flows over the land surface instead of soaking in.

SEDIMENTATION The settling of particles (like sand, silt or clay) carried by water (or wind). Over time sedimentation can fill up rivers and lakes.

Register