Regenerative runoff

Highlighting the value of the city, while promoting biodiversity and water management in Nakuru

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Master thesis 2025
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Study year: 2024-2025

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STICHTING N·H·BOS
ter bevordering van de landschapsarchitectuur

STYLOS FUND

EFL STICHTING

TU Delft

Acknowledgement

Firstly, I would like to thank my mentors Nico Tillie and Remon Rooij. Nico, thank you for your positive attitude, for helping me structure and prioritize my findings and you guidance with my thesis. Remon, thank you as well for your guidance especially on the methodology and encouraging me to look deeper into the role of stakeholders and community dynamics.

A special thanks to Joy Chege from Nawassco for her time and insights during my visit. Showing me around and connect me to different stakeholders. Also, I would like to thank Dr. Daniel Patrick Kisangau the botanist from Egerton University, for his incredible patience in answering my (very long) list of questions regarding local ecology and potential species. Your knowledge greatly enriched this thesis.

I am also grateful to Felixx for giving us students a stage during the Water as Leverage workshop, an opportunity that allowed us to share ideas and gain valuable feedback from professionals.

I would like to thank Stylos, Stichting NH Bos, and the EFL Stichting for funding my site excursion and enabling me to experience the local context firsthand.

Thanks to my fellow students for supporting each other during long study sessions, being the cheerleaders during presentations and for being a constant source of motivation.

Abstract

Rapid urbanisation in sub-Saharan Africa is placing increasing pressure on ecologically sensitive regions. In Nakuru, Kenya, situated between the Menengai Crater and Lake Nakuru, this growth threatens water systems, biodiversity and overall resilience. Unregulated development, combined with limited green infrastructure and inadequate water management, has intensified urban sprawl, deforestation, flooding and habitat loss.
At the same time, Nakuru's unique ecological and cultural landscape offers the potential for a regenerative design approach that connects people and nature through multifunctional green-blue systems.

This thesis explores how regenerative urban landscape design can foster a more resilient future in Nakuru, balancing water management and biodiversity restoration. The goal is to develop a systemic approach connecting ecological infrastructure with the water network.

Using a research-by-design methodology, this project analyses the socio-ecological impacts of urban growth, through layered spatial analysis, precedent studies, stakeholder engagement and site-specific observations. The findings are translated to a spatial strategies.
These insights are translated into spatial strategies that structure the city around three hydrological zones: upland (control), midstream (store) and downstream (use).
Grounded in systems thinking and landscape-based urbanism, informed by theoretical framework, the resulting regenerative framework proposes design interventions such as water retention parks, green-blue corridors and multifunctional landscapes including urban agriculture and reforested catchment zones.
These strategies simultaneously address ecological goals (biodiversity, water quality), social goals (health, education, participation), and infrastructural goals (flood control, runoff management).

The proposed framework is site-specific but grounded in transferable principles such as systems thinking, multifunctionality and community-driven stewardship. Ultimately, the project repositions nature from a passive backdrop to an active urban agent; essential for both human and ecological well-being.

Glossary

Regenerative: The renewal, regrowth, or restoration of a place or system,. Improving it so it becomes more successful or vibrant. Looks at underutilised assets and uses them as an opportunity.
(Urban Regeneration | UN-Habitat, n.d.)

Urban Regeneration: Development built on improving and restoring the environment of the natural systems from which the city draws resources for its sustenance. The initiatives promote social inclusivity and energy efficiency in cities to create diverse and integrated urban environments that can accommodate different functions, activities and people
(What Is Urban Regeneration? Definition and Types | Enel X, n.d.)

Framework: A basic structure/foundation underlying a system, concept, or text. A framework provides a structured approach to understand, implement, or evaluate concepts and relationships. It can be conceptual (focusing on key variables and their relationships) or procedural (detailing stages or steps). Frameworks guide how theories or models are applied to solve problems, especially in fields like health, social sciences and implementation science.

Guidelines: a piece of information that suggests how something should be done. a rule or principle that provides guidance to

Sustainable: clasting for a long time while causing little to no harm to the environment. Fulfilling the needs of today's world without jeopardising the world for future generations.

Biodiversity: The range of animals, plants, fungi and even microorganisms like bacteria that comprise our natural world are all found in one place. The diversity of life on Earth, ranging from ecosystems to genes. (of an area or habitat) with a high biodiversity level.

Climate Resilience: Refers to communities, ecosystems or programs to anticipate, absorb and particularly the capacity to 'bounce back' from climate-related disasters (Tucci and Cesare, 2020).

Mitigation: It focuses on addressing the root causes of climate change, for example, by reducing greenhouse gas emissions, aiming to minimise future climate disruption.(Tucci and Cesare, 2020).

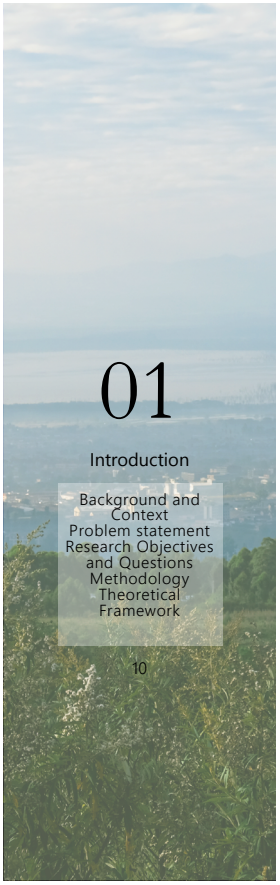
Adaptation: adjusting existing systems that involve both human and ecological to cope better with changing climate conditions to reduce vulnerability and enhance resilience (Tucci and Cesare, 2020).

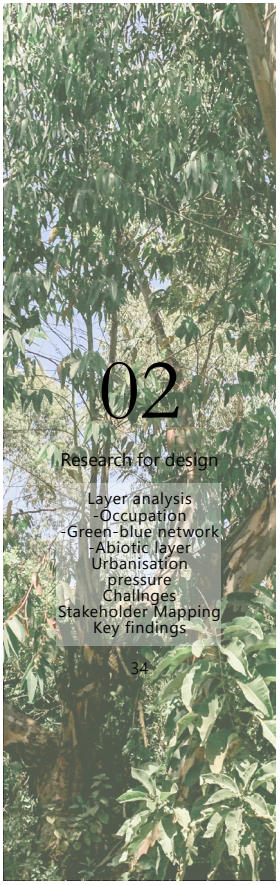
Fascination

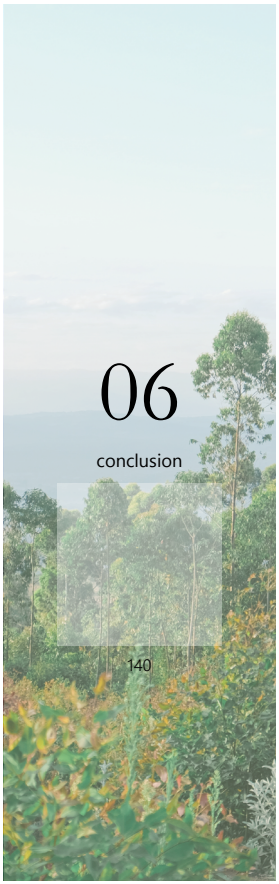
I'm interested by what Landscape architecture can mean for a city and its inhabitants. Its ability to protect certain areas by highlighting their intrinsic value. I believe this is a vital approach in areas where the government takes a less top-down approach and with a rapidly urbanising area. Landscape architecture plays a pivotal role in bridging urban and natural systems, emphasising the need for solutions that are ecologically sustainable, socially inclusive and functionally efficient (McHarg, 1969).
Nakuru and its conflict between ecology and urbanism presents a compelling opportunity to explore how innovative design approaches can create synergies between nature and city life.
I aim to address the interconnected social, ecological and infrastructural complexities of Nakuru, by applying systems thinking. The challenge of holistic design excites me, blending creativity, science and community engagement to craft transformative and innovative solutions.

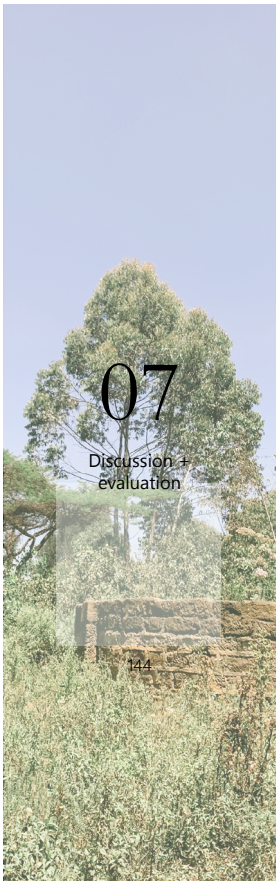
(Jaynes, 2024)

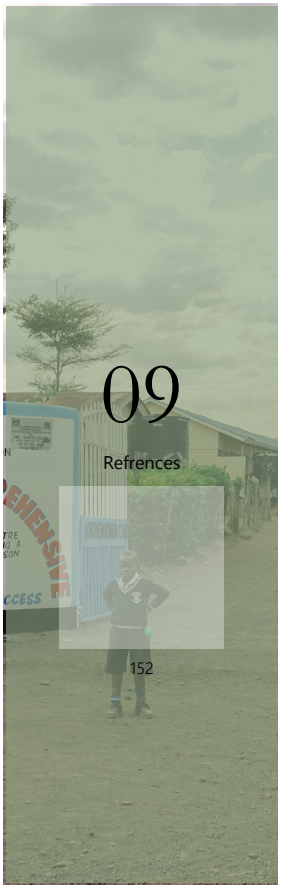
Table of contents











01 *Introduction*

This is an introduction of the city Nakuru, from country to county to city, explaining the challenges that Nakuru has. A presentation of the research objective with the research questions. The thesis structure is explained with the appropriate methods. Presents foundational theories that shape the research. .

Introduction

For centuries, people all over the world lived in small, sparsely populated communities. However, now the world population is moving to cities. Today, urbanisation is accelerating globally and more than half of the world's population currently lives in urban areas. Urbanisation is transforming environmental geographies around the world with deep consequences on ecosystems, societies and economies (Ritchie et al., 2024).

The challenges of urbanisation are biodiversity loss, resource depletion and increased vulnerability to climate change. Nakuru, Kenya, has these challenges. The pressures of rapid urbanisation arise in ecologically sensitive areas. Nakuru is located in the central Great Rift Valley. The central part of the city lies on the slope between the Menengai Crater and Lake Nakuru. The eastern and western edges of the city are more rural. The city is situated near active volcano ridges with a unique ecosystem (Defacto Urbanism & RebelGroup, 2024). Being close to a UNESCO World Heritage site, rapid urban growth in Nakuru put significant pressure on local biodiversity and ecosystems. The fast growth can make problems like deforestation, water scarcity and urban heat islands, which threaten both environmental and social resilience. However, it also provides a unique setting to explore regenerative urban design principles that balance human needs with ecological health.

The role of a landscape architect is to bridge urban and natural systems while emphasising the need for solutions that are ecologically sustainable, socially inclusive and functionally efficient. Landscape architecture is a mixture of ecology, urbanism and architecture.
A design should be:

- Ecologically sustainable: integrating natural systems into urban settings to enhance biodiversity, manage water and combat climate change. In the words of Ian McHarg, the role of the landscape architect is to "design with nature," ensuring that urban growth harmonizes with environmental systems (McHarg, 1995).
- Socially inclusive: the design is for everyone, prioritising community, equity and well-being, ensuring that spaces serve diverse needs.
- Functionally efficient: Supporting urban infrastructure through flood control, green transportation networks and aesthetic urban development.

As highlighted in my fascination with this subject, I aim to protect ecologically and culturally significant areas by emphasising their intrinsic value to local communities. Nature can safeguard urban spaces and enhance social and economic development through a blue-green framework. This aligns with the Sustainable Development Goals (SDGs) "wedding cake", where the economic and social aspects are within the sustainable ecological foundation, emphasising the need for a Regenerative approach (The SDGs Wedding Cake, 2016).

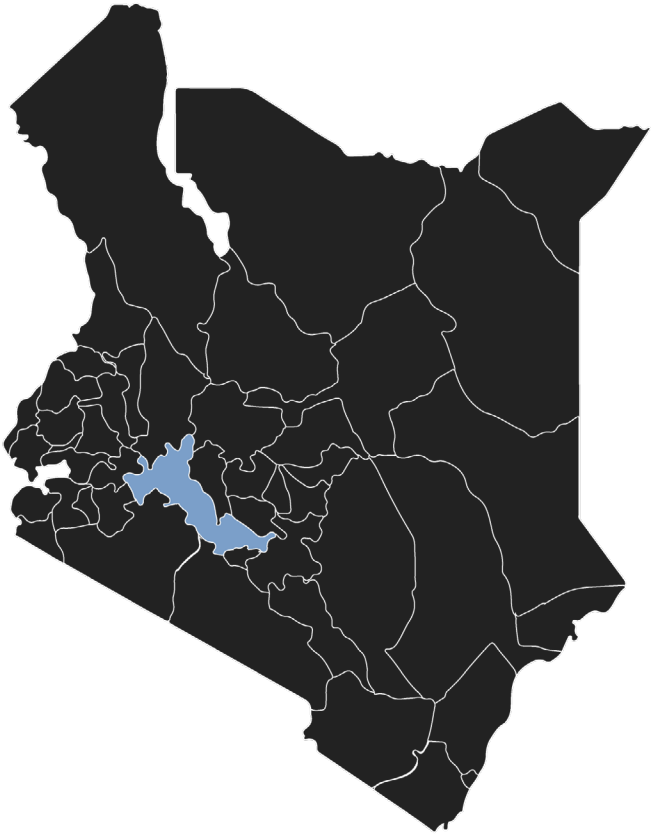
This thesis aims to develop a regenerative urban framework grounded in Nakuru's specific ecological and social dynamics. A framework can help set a certain amount of guidelines that can help a certain development but also think about the future, as James Corner (2014) highlights "The role of the designer is to anticipate how places will change over time and to shape those changes in ways that enhance the experience of urban life." The framework seeks to balance urban and rural needs, emphasising

Kenya

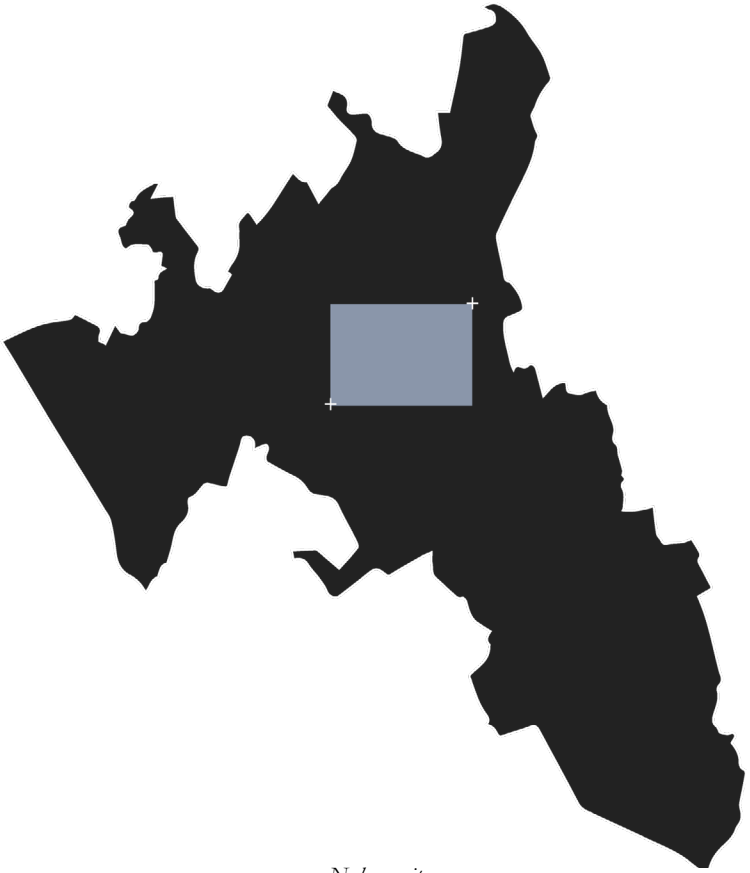
biodiversity conservation, water management and green infrastructure. This research will gain a comprehensive understanding of Nakuru's unique socio-ecological landscape through an integrated approach that combines literature reviews, site observations and dialogues with local stakeholders. It will also learn from similar cities and cases dealing with similar challenges.

This thesis offers a place-based approach for Nakuru, showcasing a regenerative design to transform the challenges of urbanisation into opportunities for resilience, social equity and ecological balance (Howard, 1898) (Couch, 2016).

The goal is to contribute to the global challenges of sustainable urban development and showcase an example from which other ecologically sensitive, rapidly urbanising cities, particularly in East Africa, can draw inspiration. The ultimate goal is to support Nakuru in having a resilient, inclusive and environmentally integrated urban future.



Nakuru county



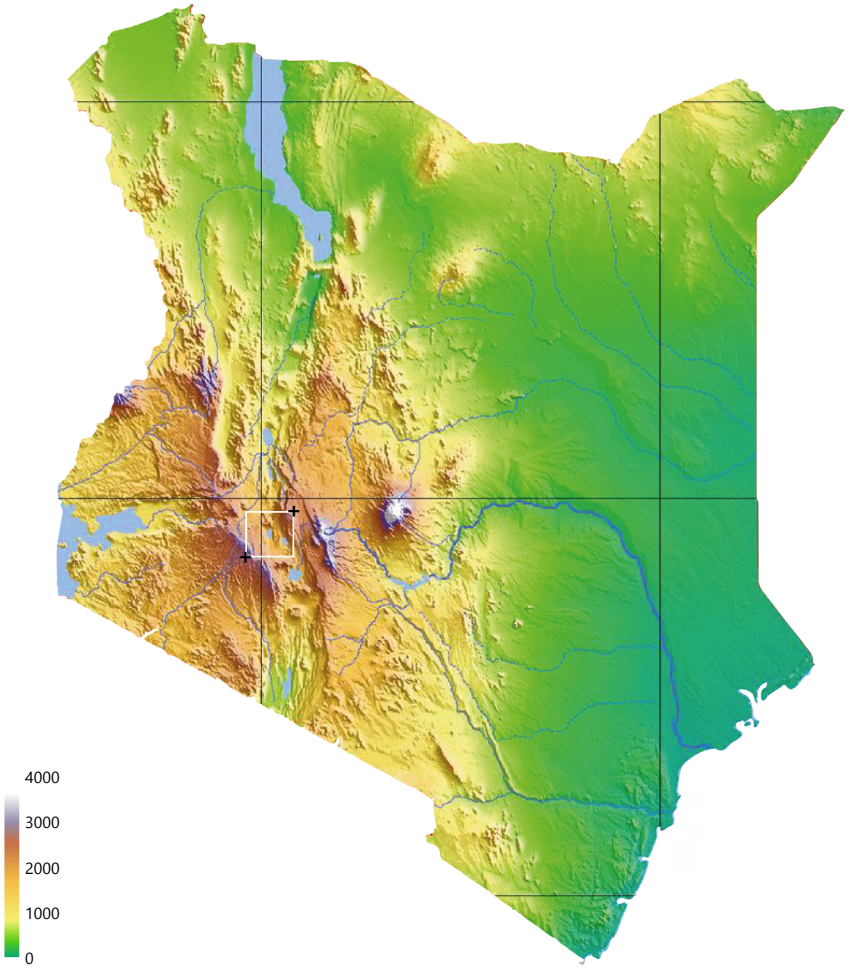
Nakuru city

Site location

Kenya, located in East Africa, is a country of diverse geographical and cultural landscapes. The country can be divided into several geographic zones: coastal plains, lowland savannas, the Great Rift Valley and highlands. The country's topography significantly influences its climate, agriculture and biodiversity.

The central and western highlands, which include regions such as Nairobi and Nakuru, are characterised by elevated plateaus. The country's agriculture benefits greatly on these highlands because of their fertile soils and consistent precipitation. Livestock is raised here and where the most successful large- and small-holder farms are situated.

The Great Rift Valley, a prominent geological feature running from north to south through Kenya, is a remarkable area with escarpments and volcanic formations. It is home to Nakuru's Menengai Crater, one of the area's notable geological landmarks. The Rift Valley contains a series of lakes, including those in Nakuru, providing important water sources and influencing local ecosystems (Geography/ Topography – Embassy of the Republic of Kenya in Stockholm, n.d.)



Kenya

Context District level

Nakuru is situated in the central Great Rift Valley at 1850 meters above sea level, between Menengai Crater and Lake Nakuru. Nakuru City is the fourth largest city in Kenya, located in the Great Rift Valley within Nakuru District. The region is characterised by a mix of urban and rural landscapes. Nakuru experiences a subtropical highland climate, with mild temperatures throughout the year due to its elevation. However, there are distinct wet and dry seasons.

Nakuru's location within the Rift Valley and its elevation influence its urban planning and infrastructure development. The hilly terrain requires careful consideration for drainage and slope management (Defacto Urbanism & RebelGroup, 2024.)

Nakuru County

0 10 20 30 40

Image by author with Arcgis data

Problem statement

Nakuru is the fourth largest city in Kenya and is still growing rapidly. Its population is increasing and the urban areas expand into the surrounding countryside. Rapid population increase and urbanisation create environmental, social and infrastructure problems that endanger the sustainability of the environment and the welfare of its residents. This is especially pressing given the city's proximity to a sensitive and valuable ecosystem, the volcanic ridge and Lake Nakuru, a UNESCO World Heritage site.

Unplanned informal expansion occurs, leading to low-density expansion into agricultural fields and forest slopes, which results in increased, high-velocity rainwater runoff towards the city centre. The high-velocity runoff water erodes fertile ground. This increases the potential for flash floods and landslides in urban areas, along the ridges of the Menengai Crater, near the Njoro and Ngosur rivers and the edges of Lake Nakuru National Park. Deforestation destabilises water flow and decreases water quality, which, in addition to the urban runoff into the lake, leads to human-nature conflict.
Other issues of urban densification are pressure on water facilities and issues with waste management.
Another consequence of urbanisation and higher densification of the city is the urban heat island effect, interconnected with the current lack of green infrastructure to provide cooling.
The bad quality and lack of water will cause health problems for inhabitants and problems for nature. The consequences are already being felt and will intensify as the city continues to grow, from its current population of 500,000 to 2 million (Water as Leverage, 2024). There is a need for sustainable urbanisation. If these challenges are not addressed, the city will face severe socio-economic and environmental consequences, including increased poverty, food insecurity and human-wildlife conflict.

Urban planning principles could help with these problems and can improve Nakuru's resilience to urbanisation challenges. This will frame how cities like Nakuru can manage growth without compromising the environment.

Urbanisation, such as in the Nakuru region, is a global phenomenon and by 2050, it is predicted that 68% of the world's population will live in cities (UN, 2018). Issues brought on by rapid urbanisation include poor infrastructure, rising city temperatures, a lack of resources and environmental damage. Due to high birth rates, rural-to-urban migration and expanding economic prospects in metropolitan regions, Africa and Asia have the fastest-growing urban populations. By 2050, 90% of the 2.5 billion people moving to urban areas will live in cities on these two continents (UN, 2018). However, these cities in Africa and Asia are particularly vulnerable to the effects of climate change and have the least capacity to adapt to them. They often lack the financial, human and technical resources required to address their impacts. With weak governance structures for disaster preparedness, their minimal contributions to global warming make their struggles disproportionately severe (UN-Habitat, 2020).
Cities like Nakuru, with constrained water resources and ecologically important landscapes, require site-specific, landscape-based strategies to balance growth with environmental resilience. By focusing in detail on Nakuru, this research aims to create a design framework that addresses the tension between urban expansion and ecological stability.

The landscape of this area, particularly its ecology and water management, is the main focus of this thesis, which highlights the necessity of a regenerative urban landscape framework that promotes sustainable development and biodiversity restoration. It will not address urban governance, economic policy or political dynamics, or delve deeply into engineering or policy aspects.

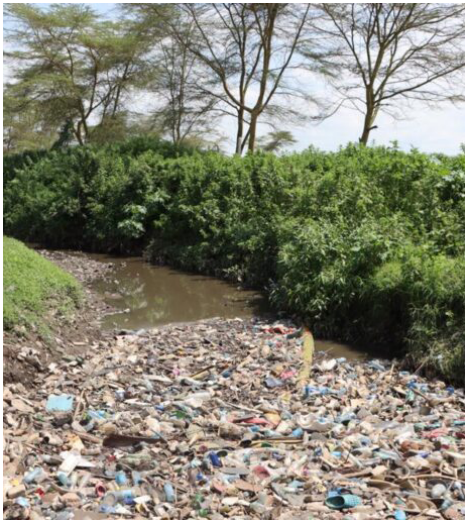
Urbanization and Challenges in Nakuru

Seasonal flows Menegai crater

Illegal tree logging Menegai forest

Lost crops because of floods

Rapid urbanization



Filty river (Nation.africa, 2020)

Research
Research Objective:

The primary objective of this research is to develop a regenerative urban landscape framework that enhances water resilience and promotes biodiversity in Nakuru. This will make Nakuru a more resilient city with a system that can heal and regrow itself.

Research question

What **regenerative urban landscape framework** can guide rapidly growing Nakuru to balance **water management** and **biodiversity restoration**?

Sub questions

Research for design: s-RQ1: What are the social and environmental impacts of the rapid urban growth in Nakuru, particularly on water management, biodiversity and open spaces?

Research about design: s-RQ2: What regenerative design principles can enhance water resilience and biodiversity restoration in urban areas with tropical highland areas with moderate temperatures like Nakuru?

Research by design: s-RQ3: Which spatial-ecological interventions are appropriate for restoring ecological balance under Nakuru's specific socio-environmental conditions?

Design strategy s-RQ4: How can the proposed regenerative urban framework translate into spatial strategies and design interventions for Nakuru, fostering ecological balance and sustainable urban expansion?

Regenerative: The renewal, regrowth, or restoration of the natural place or system. Improving it so it becomes more successful or vibrant. Looks at underutilised assets and uses them as an opportunity.
(Urban Regeneration | UN-Habitat, n.d.)
The initiatives promote social inclusivity in cities to create diverse and integrated urban environments that can accommodate different functions, activities and people
(What Is Urban Regeneration? Definition and Types | Enel X, n.d.)

Methodology

Research by Design is a methodological approach where design itself is used as a tool to investigate and generate knowledge (Frankel and Racine, 2010). I have organised my research into four chapters, each addressing a different aspect of the research process. The first chapter focuses on understanding the site and its inhabitants through analysis and exploration. In the second chapter, I investigate how the design process might unfold, studying relevant frameworks and approaches. In the third chapter, I apply research by design, using design as an active tool to test and develop a vision for the area, which means using design as an experimental tool to test hypotheses and generate insights. For this, I will use all my findings and research. In the chapter after that, I will include zoom-ins to highlight specific aspects of the design. This will show a more specific and in-depth design strategy. After that, I will conclude my research, summarise my main findings and discuss and reflect on the act of designing, translating strategic frameworks into detailed designs and refining interventions.

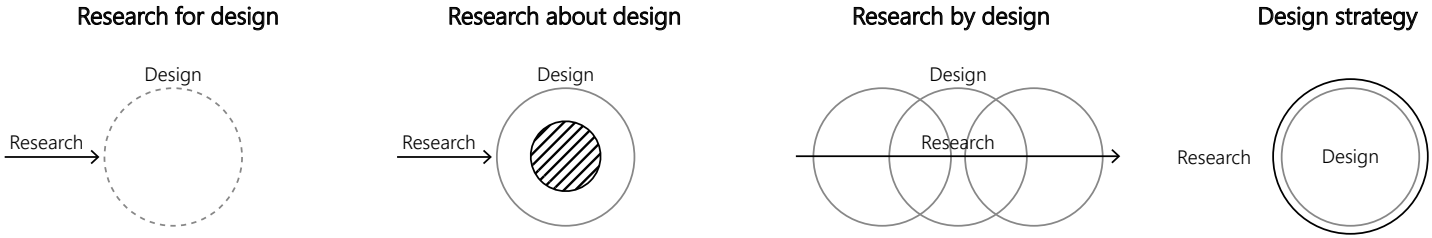
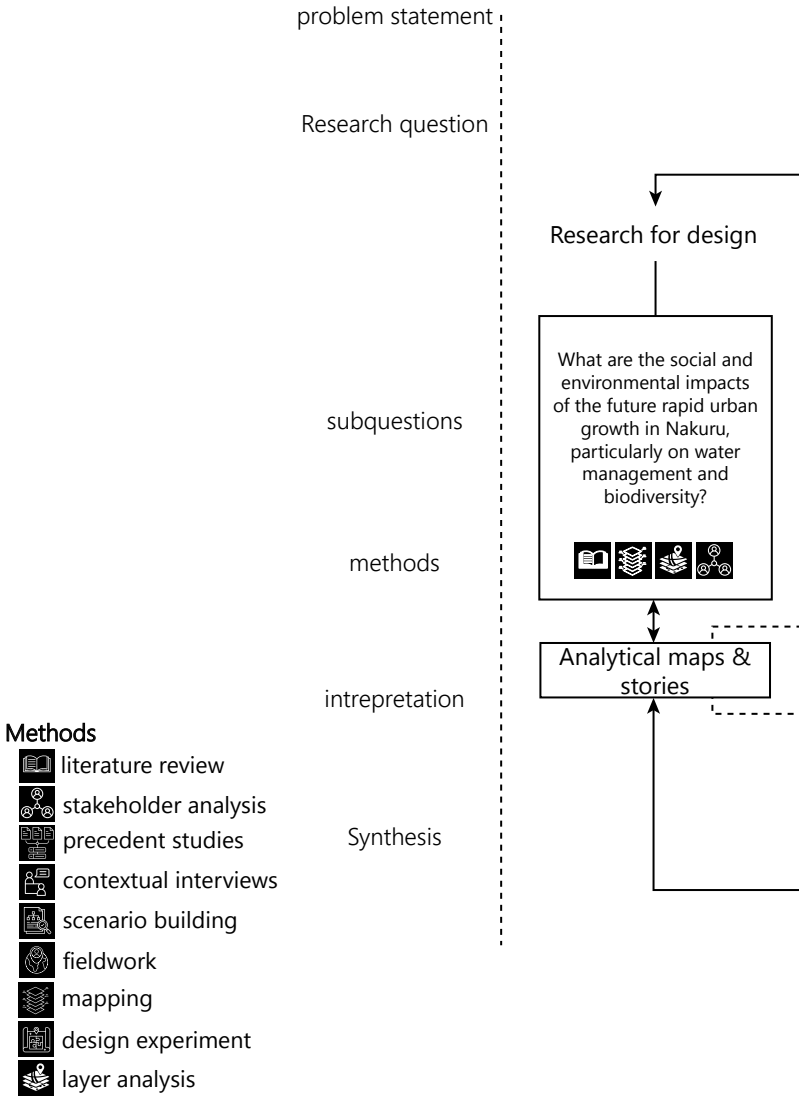


Image by autor, inspired by Manolakelli, 2023

Methodology



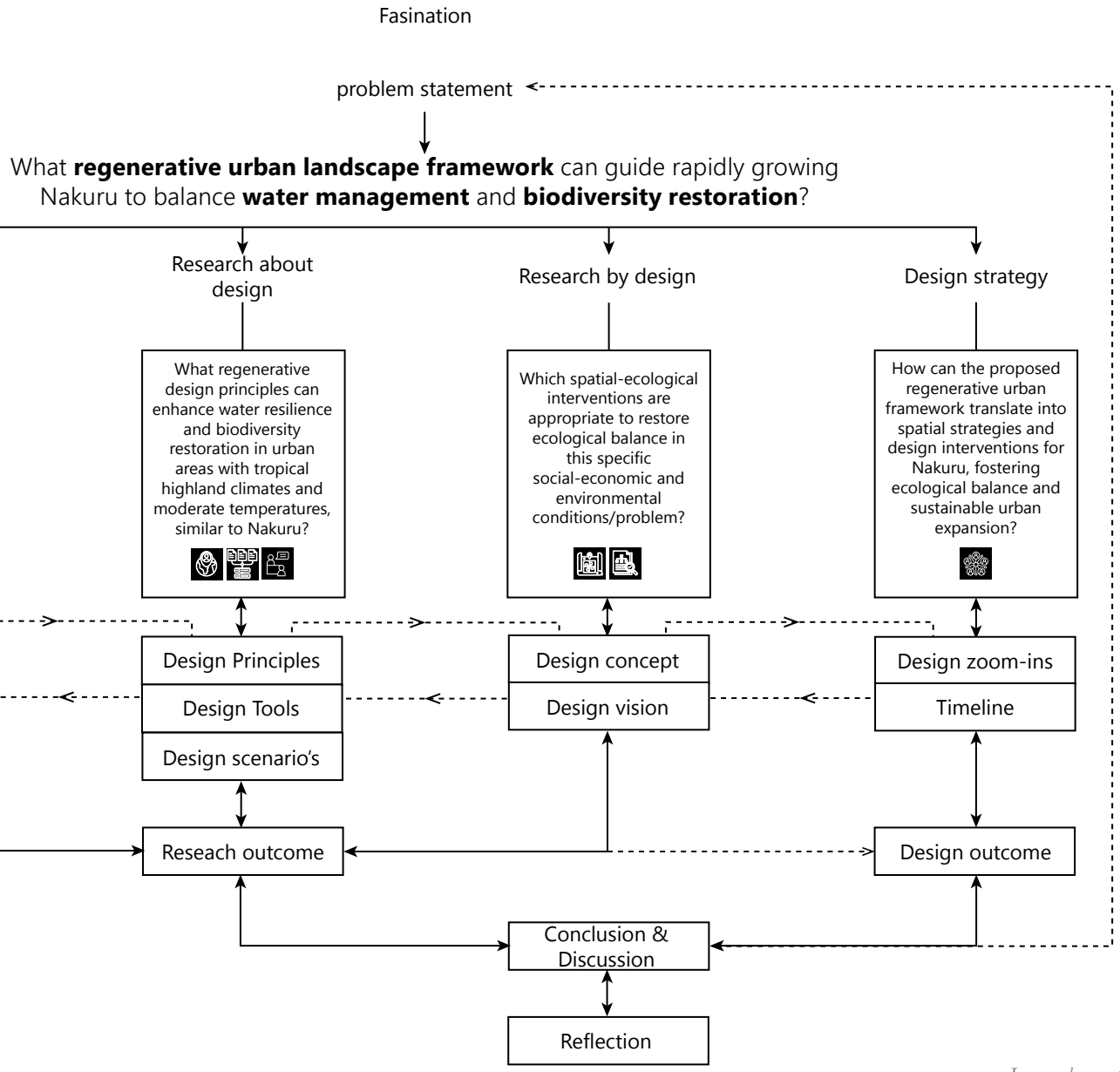


Image by autor

The starting point of this research was a personal fascination with the human–wildlife conflict occurring in highly ecologically valuable areas. The structure of the project follows a research-by-design methodology, as previously outlined.
Each phase of the research is guided by a specific sub-research question. This approach ensures a holistic and systematic understanding of the challenges and opportunities for regenerative urban development in Nakuru, linking theoretical insights with practical design responses.

Research for Design

This phase focuses on gathering information about the social and environmental impacts of rapid urban growth in the future. The methods applied in this phase are:

Literature Review: A comprehensive review of academic and professional sources related to regenerative design, urban ecology and water management. This helps identify key theoretical concepts and frameworks (such as systems thinking and regenerative urbanism) and provides a foundation for understanding the challenges and opportunities in Nakuru (Tillie, 2024).
Mapping: GIS tools are employed to create maps from online data. These maps are used to analyse topography, hydrology and land-use patterns to understand the flow of water and the ecological processes at play (McLoughlin, 1969).
Layer Analysis: The analysis involves examining the interconnected layers of Nakuru's landscape (Frieling et al., 1998)
Stakeholder Analysis: Stakeholders are identified for later steps. This gives a clearer image of local challenges, needs and opportunities.

Research about Design

This phase explores the regenerative framework that could guide the design. The methods for this step include:

Fieldwork: Site visits in Nakuru to observe environmental conditions firsthand, understand water management systems and assess biodiversity in real-life contexts.
Interviews: Interviews with local community members and stakeholders enlighten the in urban planning and environmental management. These findings provide valuable insights into the feasibility and relevance of potential design solutions for Nakuru's urban growth and ecological restoration.
Precedent Studies: Case studies from regions with comparable climate conditions and facing similar challenges, such as water resilience, biodiversity restoration and sustainable urban growth, offer valuable lessons for Nakuru.

The outcome will have design principles that help to translate theory to a concept and vision.

Research by Design

The research-by-design phase is where the theoretical knowledge and potential interventions are applied to generate design solutions. The methods used include:

Scenario Building: Using the insights gained from the research phase, different urban scenarios will be developed that explore how various interventions might work in Nakuru.
Design Experiments: Iterative design testing is conducted to refine the design.

The outcome is a concept and vision, a strategic plan that outlines the spatial and infrastructural layout of Nakuru, integrating regenerative design principles, water resilience strategies and biodiversity restoration.

Design strategy

The research was conducted to make a site-specific design for Nakuru. This is the final design phase in which I will create a vision for the whole landscape, but I will also zoom in on three areas within Nakuru. During this phase I will take the different stakeholders into account but also the timeframe. This will include:

- Zoom ins: Develop detailed design proposals for specific sites identified during the mapping and fieldwork phase. These proposals will focus on creating ecologically rich spaces, integrating water systems with urban areas and ensuring social accessibility and equity (Tillie, 2024). This plan will propose solutions for certain species.
- Timeline: This is the phasing of the design, how it will develop and what stakeholders are involved in which part of planning, implementation and management.

Conclusion: Synthesising Key Findings

This chapter concludes the research by summarising my findings. The research findings reflect on how a regenerative urban framework can contribute to socio-ecological resilience by addressing water management and biodiversity restoration. The conclusion links outcomes to the research objective and questions.

Discussion: Evaluating the Design Framework

This section evaluates the effectiveness of the design solutions in addressing the identified challenges in Nakuru. It includes a discussion of the research findings and the outcomes of the design process. It focuses on the social and ecological impacts of the design on local ecological resilience, social cohesion and long-term sustainability, how the design responds to the needs of both human and non-human systems, aligning with the principles of regenerative urbanism (Cheshire, 2024). This evaluation leads to key conclusions and identifies areas for further research or refinement.

Reflection: My personal process

I reflect in this chapter on my personal learning and design process this past year. It explores what I learned from working in a complex governance and ecologically valuable Nakuru's landscape. I reflect on how my approach evolved during the project, what I would do differently in the future and how my understanding of regenerative design deepened. The reflection also considers the transferability of my framework, as well as the ethical dilemmas and challenges I encountered while working across disciplines and cultural contexts.

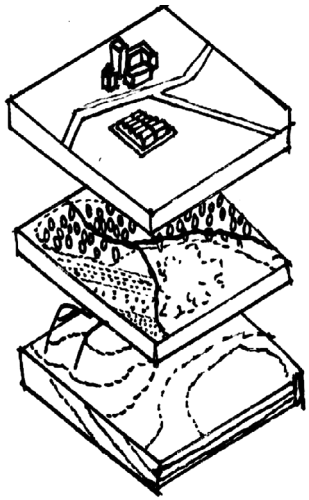
Theoretical framework
Layer model

The theoretical framework for this study integrates principles of regenerative design and landscape-based regional planning to address the environmental and social challenges of urbanization. The concept of "Regenerative design" is important because it calls for a transition from sustainability, which often focuses on mitigating harm, to regeneration, which aims to create net-positive impacts on ecological, social and economic systems. The regenerative design approach prioritizes ecological restoration, systemic thinking and community well-being. This framework provides a holistic lens for addressing urbanization issues, such as climate change, biodiversity loss and resource degradation.

Layer model

A landscape architect focuses on all the layers of a site, as they are interconnected. The ground layer, including soil and topography, determines the water system's flow. Above this lies the network layer, with infrastructure and ecological systems. Finally, the human layer, shaped by urbanisation patterns, interacts with and modifies the natural environment. By integrating these layers, landscape architects design environments that balance natural systems with human needs, fostering resilience and harmony (Frieling et al., 1998). I believe that systems thinking (McLoughlin, 1969) is vital, viewing Nakuru's landscape as an interconnected social, ecological and infrastructural network. By prioritising local knowledge, equity and ecological stability, the project can set a precedent for sustainable urban development.

These frameworks provide a foundation for understanding Nakuru as a system where environmental dynamics (water flow, biodiversity) and human activities must coexist.
This will guide the investigation into the social and environmental impacts of rapid urban growth, addressing sub-question 1.



The layer model
Image by author, inspired by (Frieling et al., 1998)

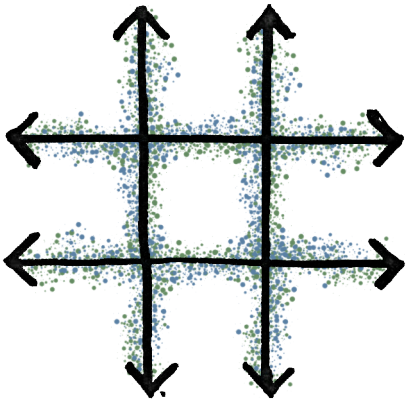
Landscape-based urbanism Steffan Nijhuis

Landscape-based urbanism, as introduced by Steffen Nijhuis (Nijhuis et al., 2023), provides a comprehensive framework for organising physical structures (hardware), knowledge systems and human interactions (software) and governance frameworks (orgware) across spatial and temporal scales. The landscape is placed as the foundational layer in regional development, this approach seeks to foster a sustainable and coherent spatial transformation that also preserves resources and maintains the local identity

Landscape-based approaches in regional design strive to accommodate spatial development via the application of principles of bioregional planning and design that regard the urban landscape as a dynamic complex system.

Landscape-Based Regional Design Approaches
•Two Key Approaches:
1. Framework Approaches:
Develop long-term networks of landscape structures to support spatial coherence, safeguard resources and enable local developments.
2. Corridor Approaches:
Establish landscape structures that guide urban and rural development, fostering social and ecological interactions.

These strategies emphasize the need for holistic and coherent spatial planning that fosters a sustainable urban landscape. For my research the focus is on the framework approach in which the corridor approach fits. Landscape-based regional design emerges as a transdisciplinary, context-driven and solution-focused field, offering spatial design new operational power to address regional urban challenges (Nijhuis, z.d.).



Framework and corridor approaches

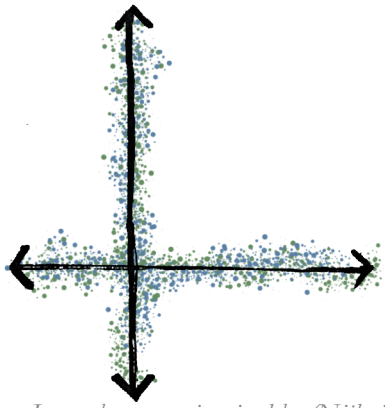


Image by autor, inspired by (Nijhuis, n.d.)

Theoretical framework

Ecopolis: Strategies for Ecologically Sound Urban Development Sybrand Tjallingii

The concept of Ecopolis, developed by Sybrand Tjallingii (1995), envisions cities evolving from resource-draining entities into self-sustaining ecosystems that integrate human activity with natural processes to create regenerative urban systems. Ecopolis means that ecology could only be preserved if the population attempts to take care of their environment for the ecosystem, which isn't a given.
Drawing on green infrastructure principles and ecological management, Tjallingii emphasises viewing cities as dynamic ecosystems embedded within global biotic and abiotic systems. The purpose is to encourage a shift in urban planning towards ecological principles, fostering cities that operate within ecological boundaries while contributing positively to the environment.

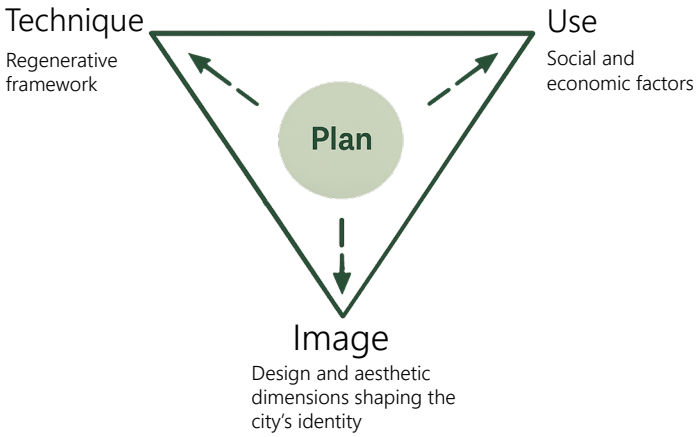
Triangle model

Tjallingii proposes a triangle model linking three key disciplines:
1.Technique; Regenerative framework addressing technical systems, flows and environmental impacts.
2 Use; Social and economic factors determining urban functionality and viability.
3 Image; Design and aesthetic dimensions shaping the city's identity and sense of place.

Ecology primarily operates within the technical side, where environmental analysis informs sustainable alternatives. However, a successful Ecopolis plan must integrate all three dimensions to fit local contexts and meet ecological, practical and cultural needs.

Three Main Themes:

The Responsible City:
Environmental issues like depletion, pollution and disturbance stem from city input and output flows. Urban design and management must focus on the quality of the environment both within and beyond the city, including strategies for regulating flows (chain management).
The Living City:
The urban ecosystem must provide a healthy habitat for people and the environment. Local ecological potential (climate, water, soil, vegetation) contributes to the city's identity and sustainability. Urban strategies should address both built and open areas (spatial policy).
The Participating City:
Urban issues like vandalism, noise pollution and waste arise from a lack of public involvement. Effective strategies must engage different lifestyles and types of businesses to promote participation in maintaining the environment.
These are not different cities but all aspects that should be combined in an urban ecological approach. They need to support each other



The triangle model *Image by Tjallingii (1995)*

Ecopolis emphasizes cities function like self-sustaining ecosystems, mimicking natural processes such as nutrient cycling and energy flow. This approach is aligns with my goal of developing regenerative urban frameworks that go beyond sustainability and actively restore ecological systems, addressing water management, biodiversity restoration and sustainable growth.
Ecopolis advocates for using local ecological potential, including climate, water, soil and vegetation, to contribute to a city's identity and sustainability.
Ecopolis offers a strategic approach to managing urban ecosystems with an emphasis on responsibility, such as regulating flows (e.g., water, waste) and focusing on environmental health. .
Finally, Ecopolis stresses the importance of the participating city, where communities are engaged in maintaining environmental quality. This aligns with the need to involve Nakuru's residents in creating sustainable urban environments through collective action on biodiversity and water management, promoting social ownership of the city's ecological processes.

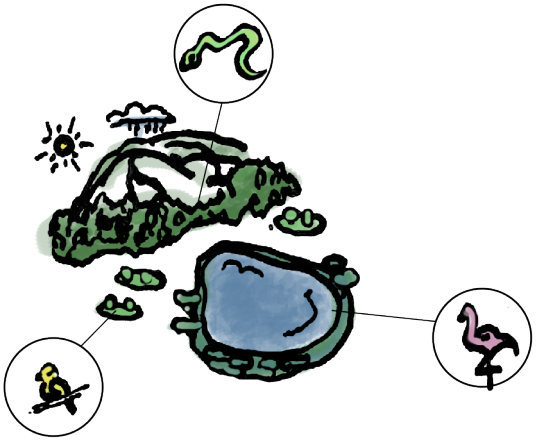
Urban ecology TU Delft Nico Tillie

With this theory, Nico Tillie (2024) highlights the importance of creating habitats that foster biodiversity and resilience in urban environments. A regenerative landscape is created using design and urban ecology principles.

The three cornerstones of this are system, habitat and species:
System-based: understand the system and create the conditions for habitats to evolve.
Habitats: active habitat creation, to create conditions for species/humans to thrive.
Species (also humans): Considering the needs of species, such as food, safety, reproduction, variation and connection, in urban environments.

Regenerative design uses landscapes to regulate flows and recycle resources, protect the life-support systems of nature and foster self-renewing cycles of energy and materials. By using ecosystems, it applies strategies that restore socio-ecological systems and sustain their inherent capacities for renewal and resilience.
His main message is to pick target species in the city and to create habitat and ecological corridors for different species aiming for a dynamic balance between urbanization and ecological vitality.

Tillie talks about the switch from nature-based to landscape-based solutions because this emphasises the importance of integrating local cultural and ecological knowledge.



System-habitat-species *Image by autor, inspired by (Tillie 2024)*

Theoretical framework

Regenerative by Design: Creating living buildings and cities: David Cheshire

"In our cities, it is easy to forget that we are utterly dependent on natural systems for every breath of fresh air, a sip of clean water and a mouthful of food." (David Cheshire, 2024)

Cheshire (2024) outlines three overarching principles for regenerative design:
• Design within planetary limits: Use renewable inputs like rainwater, solar energy and locally sourced materials.
• Valuing Ecosystem Services: Mimic essential ecosystem services, such as purification, water filtration, climate regulation, to restore ecological balance.
• Embracing Systems Thinking: A holistic view of design that considers the broader impact of urbanization on global systems and natural cycles.

These principles can be applied through three strategies:
• Circular Economy: Minimizing waste and resource use by utilizing biogenic materials.
• Blue and Green Infrastructure: Integrating natural systems into urban areas to mitigate environmental challenges.
• Bio-Inspired Design: Drawing from nature to develop technologies.

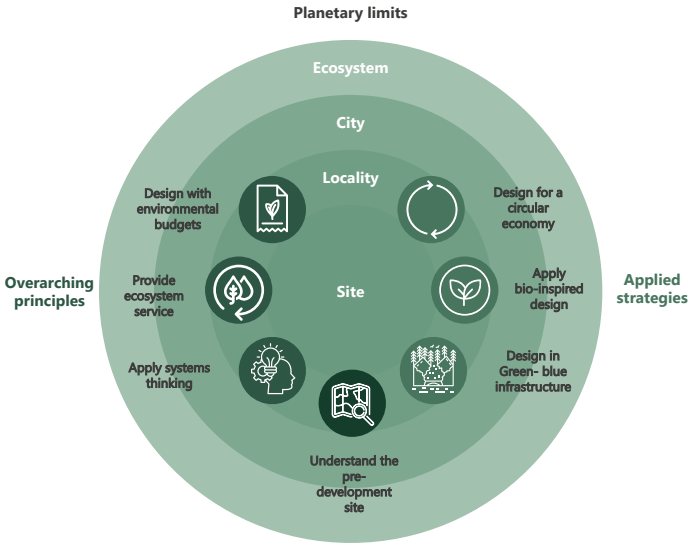


Image by author, adapted from (David Cheshire, 2024)

Nature is a partner in this approach, with benefits like climate resilience, reduced urban heat effect an improved well being. Regenerative design demands expertise in ecosystem functioning.

Rob Roggema regenerative framework

The regenerative framework for regional planning highlights the need for a holistic, adaptive approach to urban development. Some of the concepts discuss the understanding of time and the past (WHEN), others focus explicitly on the content (WHAT), the way to achieve regeneration (HOW), or the responsible people, institutions, or groups (WHO).
The framework development involved analysing multiple regenerative models, resulting in a composite "framework of frameworks" that focuses on:

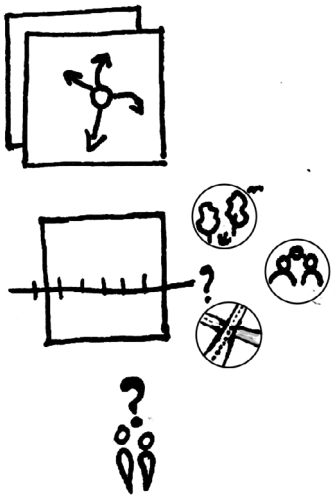
- What actions are necessary for regeneration.
- When and how these actions should be implemented.
- Who is responsible for driving these changes.

A central metaphor in the proposed framework is the "river," symbolising the continuous flow and interconnectedness of life, emphasising the need for harmony between human and natural systems. This metaphor guides the integration of historical context, long-term vision and the interconnected processes of regeneration.
About the SDG. When we assessed the top five aspects in every region and correlated these to the SDGs, the dominant group of aspects belonged to the biosphere base of the SDG wedding cake, with a second large group connected to the social layer and, except for land ownership, an even smaller portion connected to the economic and political layer
The proposed framework provides a practical roadmap for transitioning from environmentally harmful urban models to sustainable, regenerative ones. It prioritises collaboration, systemic integration and long-term thinking, offering inspiration for landscape architects.

1. Map a backtracked equilibrium (1st generation city) and identify balance in natural – social economic systems
- Indigenous understanding of the first settlement
- backtracking through backward mapping

2a. understand the equilibrium and map the desired future (3rd generation city)
- Biosphere: natural conditions: landscape, elevation, ecology, water
- Land ownership and politics
- Social system
- Economic system: infrastructure/ mobility, industries/ work
2b. with whom?

3a. map the difference with present and decide what to change
1. Map the current region (2nd generation city)
2. Confront with desired future
3. Locate and identify the differences
3b. determine how to enforce that change
3c. By whom?



Tree steps of creating a regenereative framework
Image by author

Theoretical framework

Theory	Main message	How?	Where in my thesis?
Urban Ecology	Create conditions for habitats to evolve and that integrate ecological cycles in urban areas. Identify the target specis. Design eco-corridors for biodiversity	Species: Target habitat creation for species/humans Regeneration: System-based, create conditions for habitats to evolve.	Analysis for the species + informs design principles: Habitat corridors and biodiversity focused
Landscape based urbanism	Apply framework and corridor approaches to guide a long-term urban growth	Regeneration: Long-term urban growth using ecological, social and infrastructural integration.	forms the framework approach shapes the vision
Regenerative by design	Designing with planetary boundries. Value ecosystem services. Use systems thinking to consider the broader impact of urbanization. with Circular economy Blue green infrastructure. bio-inpsired	Ecosystem services: purification, water filtration, climate regulation. Regenerative systems: systems thinking, blue-green infrastructure, bioinspired.	Regenerative strategy goals: integration of Ecology, public participation and urban livability
Reconciling the mismatch+ Gap the green in the city	1. Map historical balance to identify nature+ social balance 2. Define desired future: eco, social system and infrastructure 3. Analyse the present and engage stakeholders in implementing regenerative changes A central metaphor in the proposed framework is the "river," symbolising the continuous flow and interconnectedness of life, emphasising the need for harmony between human and natural systems. This metaphor guides the integration of historical context, long-term vision and the interconnected processes of regeneration.	Regenerative: Harmonizing human and natural systems in planning. River metaphor: "the continuous flows of life"= a need for harmony between humans and nature.	Forms vision by connecting history, vision and adaptation. Applied in final visioning phase.
Ecopolis	Think about technique + use + image Promote local ecological potential (climate, water, soil, vegetation)	Ecology: Utilize the ecological potential to improve the city's identity. People: Promote public participation and local knowledge.	Informs specific design principles for enhancing water resilience and biodiversity.

Connect through local potential

Designing with eco-corridors, promoting local ecological potential and Value ecosystem services.

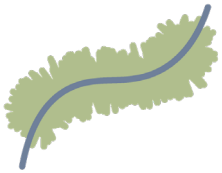
Urban ecology + Ecopolis + Regenerative by design

For humans and species

Engage stakeholders, a harmony between human and natural systems.
Landscape-based solutions to integrate local cultural and ecological knowledge.

Reconciling the mismatch + Urban ecology

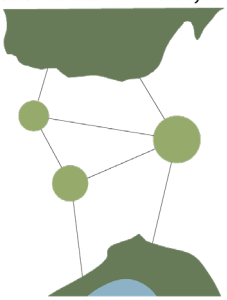
Green-blue connections



Green-blue infrastructure and water as the symbol of the interconnectedness of life.

Regenerative by design + Reconciling the mismatch

Create habitats within the system



Develop long-term networks to support social and ecological interactions.

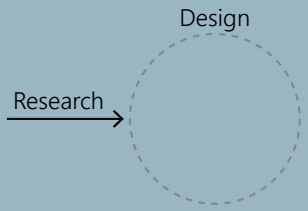
Landscape based urbanism

Image by author

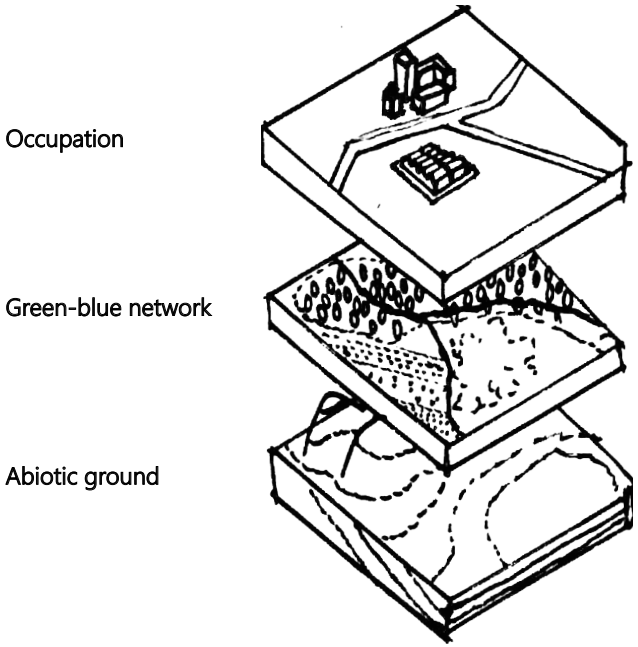
02 *Research for Design*

s-RQ 1 : What are the social and environmental impacts of the future rapid urban growth in Nakuru, particularly on water management, biodiversity?

A deep dive into Nakuru's layered landscape through mapping, analysis, and field-based investigation. This chapter uncovers spatial and ecological conditions to guide informed design.



The Layers of Nakuru County



The layer model
Image by author, inspired by (Frieling et al., 1998)

The effect of the different layers is clear in the image on page 37. Elevation has an effect on the water system as the rivers flow to the lowest point where Lake Nakuru is formed. Elevation, hydrology and soil type have an effect on the land-use, so the agriculture adn nature. In the south of the county, there's more rangeland. The closed forest is on the highest elevation.

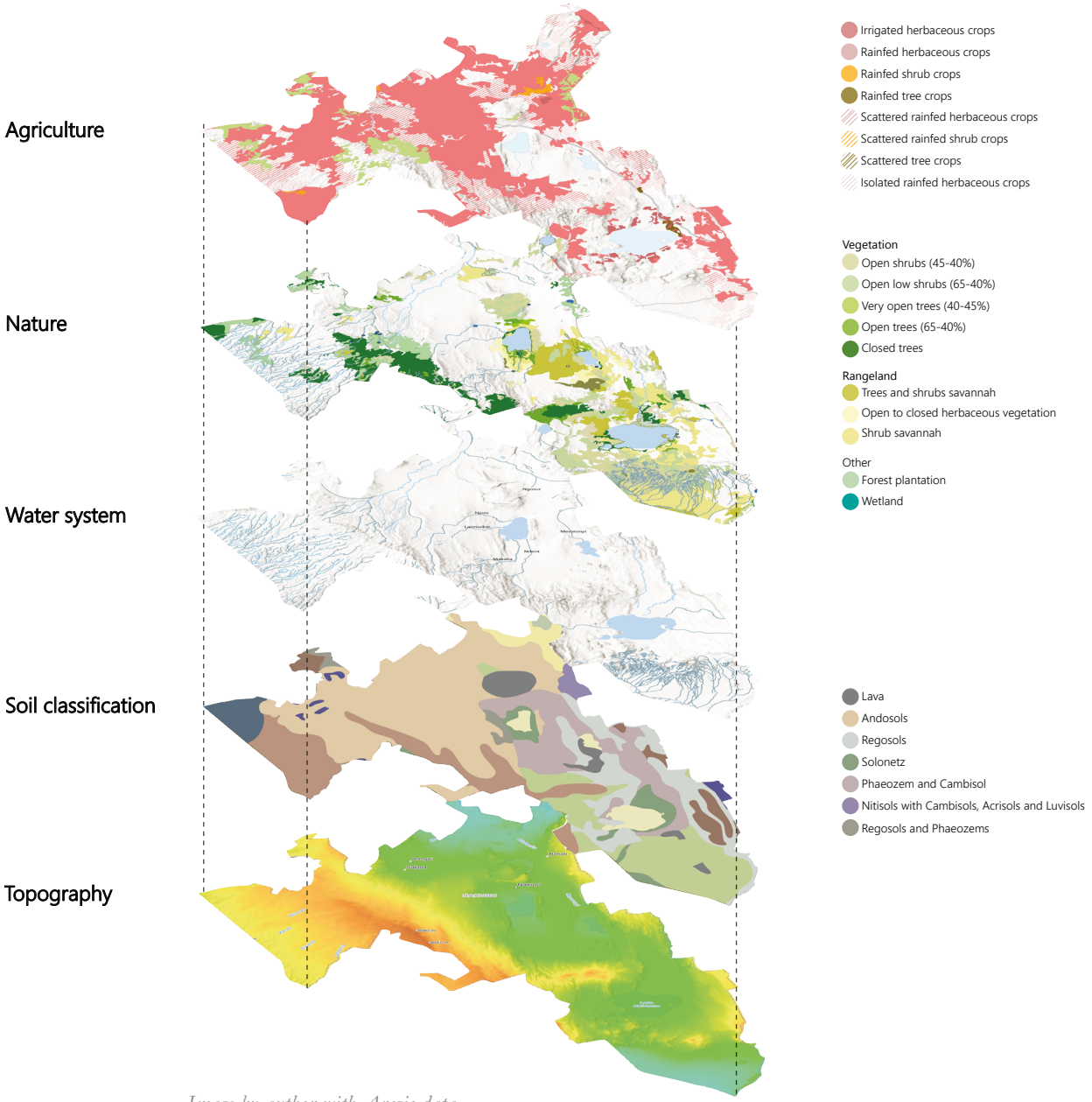


Image by author with Arcgis data

History

The name Nakuru derives from the Masai word "Nakurro," which translates into "the dusty place" (Braker, 2025). Before the Masai arrived, one of the earliest known inhabitants was the Sirikwa people. They founded settlements on the beaches of a much larger Lake Nakuru around 6,000 years ago. Between the 17th and 18th centuries, the Sirikwa were gradually absorbed into the expanding Maasai clans (Sutton, 1994).

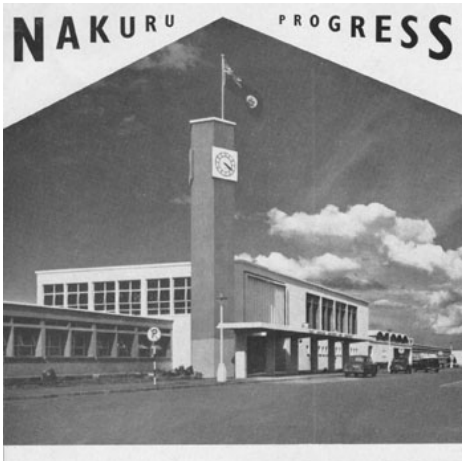
Before colonial settlement, the area served as an important grazing land for the Masai (Openda, 2023). The construction of the Kenya-Uganda Railway (1901) marked a turning point, transforming the area from grazing land into a significant transport and trade hub (Openda, 2023). Settlers from Europe established large farms, attracted by Nakuru's fertile soils, moderate climate and reliable rainfall, making it a key agricultural center within the "White Highlands" (Sanya, 2023).

Following Kenya's independence in 1963, land ownership gradually shifted to African farmers. Today, Nakuru remains a vital agricultural hub. Agriculture, trade and eventually industrial development have propelled the growth of what was once a modest railway stopover town into a full-fledged city (NaxCity, 2024). In 2021, Nakuru officially attained city status,
Nakuru continues to play a significant role in Kenya's growth because of its rich history, varied cultural legacy and solid economic base. Its status as a city and promise for the future is cemented by its history as a center of trade and agriculture as well as its natural beauty, exemplified by Lake Nakuru (Nakuru City – County Government of Nakuru, n.d.).

(History of Nakuru – County Government of Nakuru, n.d.)

(Nakuru | Eawl, n.d.)

(Kalenjin history, 2016)



(Farnworth, 2022)

Geografic context

Location & Climate

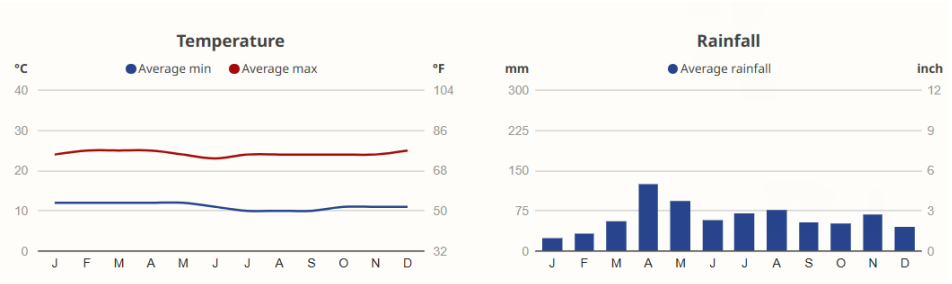
Nakuru City is the fourth largest city in Kenya, located in the Great Rift Valley within Nakuru District. The region is characterised by a mix of urban and rural landscapes. Nakuru experiences a subtropical highland climate, with mild temperatures throughout the year due to its elevation. However, there are distinct wet and dry seasons. Nakuru sits within the Rift Valley at approximately 1,800 meters above sea level.

Nakuru's location and elevation in the Rift Valley influence its urban planning and infrastructure development. The steep terrain requires careful consideration for drainage and slope management (Defacto Urbanism & RebelGroup, 2024.)

Nakuru experiences a subtropical highland climate (Köppen classification: Cwb), characterized by moderate temperatures year-round due to its elevation. The temperature ranges between 10°C and 26°C annually (Defacto Urbanism & RebelGroup, 2024).

Rainfall Pattern

The region has a wet and dry season. The rainy season is typically from March to May (long rains) and from October to December (short rains). Annual precipitation is about 1171 mm. Periods of drought pose water scarcity challenges, making sustainable water management a critical issue (Ham, n.d.).



(Ham, n.d.)

Hydrology

Lake Nakuru:
Lake Nakuru, located in the semi-arid central Kenya Rift, has undergone significant changes in recent years. Historically, a shallow, saline and alkaline lake with a high pH and salinity, it is now transitioning into a freshwater lake due to shifts in hydrological conditions. The lake is primarily fed by seasonal rains, ephemeral streams and groundwater discharge. Although rainfall remains the primary water source, changes in land use since the 1970s have altered the lake's hydrological balance, increasing surface runoff and reducing groundwater inflow.

The water chemistry of Lake Nakuru once consisted of Na+–HCO3––CO32––Cl–, making it highly alkaline. While it remains shallow (less than 5 meters deep), the water's salinity has decreased, reflecting the shift to freshwater conditions. The lake, which was once characterised by temporary stratification, now experiences different ecological dynamics. Its nutrient-rich waters continue to support phytoplankton, which is vital for sustaining populations of lesser flamingos and other wildlife (Renaut, 2023).

The rising water levels in Lake Nakuru have brought about a significant shift in its water chemistry, as evidenced by changes in major ions and anions. The salinity has dropped below 5g/l, a clear sign of the transition to a freshwater environment. Water quality data from January 2021 reflects the ongoing transformation. Recent estimates of the population have indicated a rise in the numbers of waterbirds associated with freshwater systems (County Government of Nakuru Department of Water, Environment, Energy and Natural Resources, 2021).

Lake Nakuru receives water from the perennial Ngosur River and four seasonal rivers: Njoro, Nderit, Makalia and Larmudiac, which originate in the Mau Forest uplands. The Ngosur River feeds the lake through underground flows and contributes to the Kabatini aquifer, while the Njoro River provides significant water and sediment. Minor inflows also come from nearby sewage-treatment plants (Renaut, 2023).

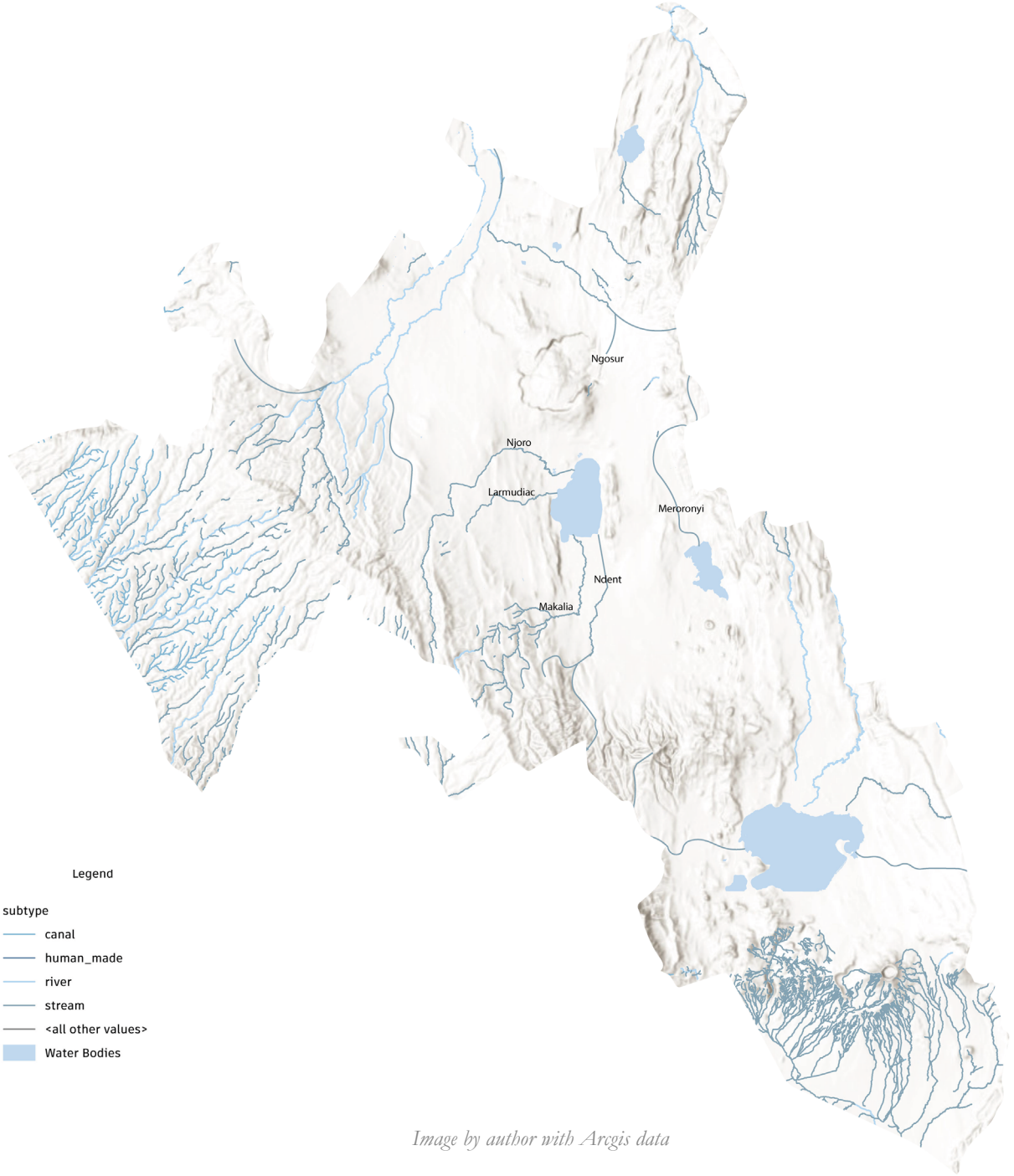


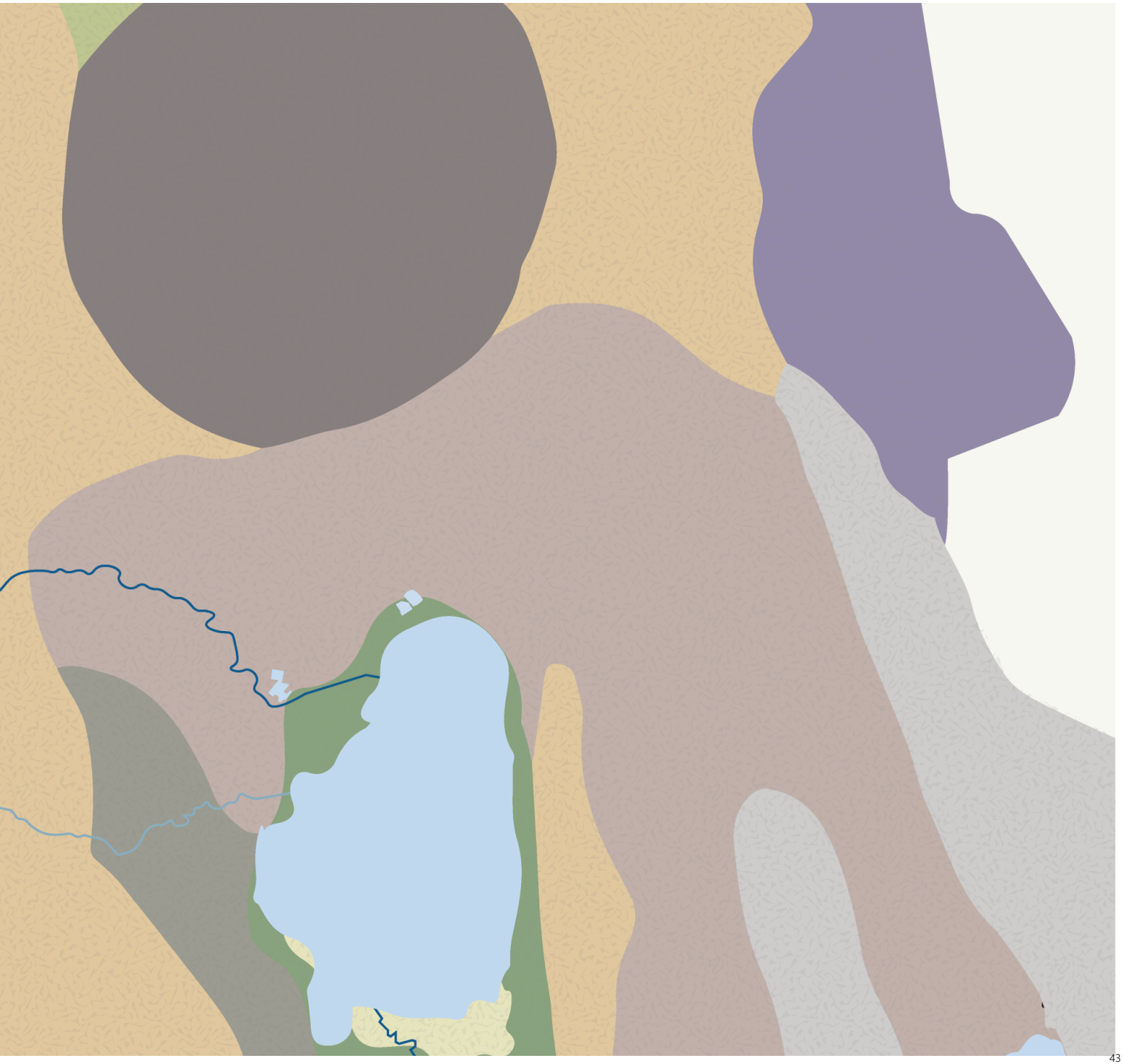
Image by author with Arcgis data

Topography & Soil

City scale

Around the lake, Cambisols and Phaeozems dominate, alongside Lithosols, Regosols. The city area primarily features Solonetz, transitioning westward near the lake into Regosols and Phaeozems. To the east of the lake, the rift zone contains Andosols embedded within Cambisols and Phaeozems. The eastern hills are underlain by trachyte, an igneous rock formed by rapidly cooled lava (Conti P. et al., 2021). Around the lake, the drainage is the lowest, based on elevation. To the east the soil is moderately well drained and to the west of the lake it is well drained, so that side is drained less. The top of the crater is excessively drained because of the lava soil (soil data map, 2019).

Image by author with Arcgis data



Nature: Ecotypes

The ecotypes map reveals the ecological potential of Nakuru's landscape. Upland zones host moist evergreen montane forests, critical for water retention and biodiversity. In contrast, the lower areas transition into acacia woodlands and savannas, which are more drought-tolerant. Understanding these ecotypes allows me to select appropriate native species for reforestation, retention parks, and urban agriculture zones, ensuring that the design builds on the natural resilience of each system.

Image by author with Arcgis data


; IASA, NGA, USGS

Nature

Vachellia drepanolobium

Senegalia mellifera

Euphorbia spp.

Thunbergia

Eastern african acacia - commitphora woodland

This woodland is typically found in semi-arid areas, acting as a transition zone between the East African savannas and the semi-deserts of the Horn of Africa (Acacia-Commiphora Bushlands and Thickets | EBSCO, n.d.).
Dominant are the drought-resistant Acacia and Commiphora trees, which conserve energy by remaining leafless for up to nine months. After rainfall, the landscape rapidly transforms with new greenery, blooming wildflowers and a surge of wildlife activity. The ecosystem thrives in extreme climatic conditions, alternating between dormancy and explosive growth after rains.
Species:

- Trees and shrubs: Vachellia drepanolobium (Whistling-thorn acacia), Senegalia mellifera (Black-thorn acacia) (Supports bees and wildlife with its flowers) (Wolfer, 2024), Vachellia tortilis (Umbrella thorn acacia), Balanites aegyptiaca, Boswellia sacra (Frankincense tree), Commiphora spp., Combretum spp., Terminalia spp., Capparis spp., Acalypha spp., Aerva sp. (Ethiopian Biodiversity Institute – EBI, n.d.)
- Succulents: Euphorbia spp.
- Wildflowers and herbs: Thunbergia, Ipomoea spp., Aloe spp., Boophone disticha, Craterostigma spp., Ocimum, Orthosiphon (Acacia-Commiphora Bushlands and Thickets | EBSCO, n.d.)

Vachellia xanthophloea

Vachellia gerrardii

Lantana camara

Grewia similis

Eastern African Acacia Woodland

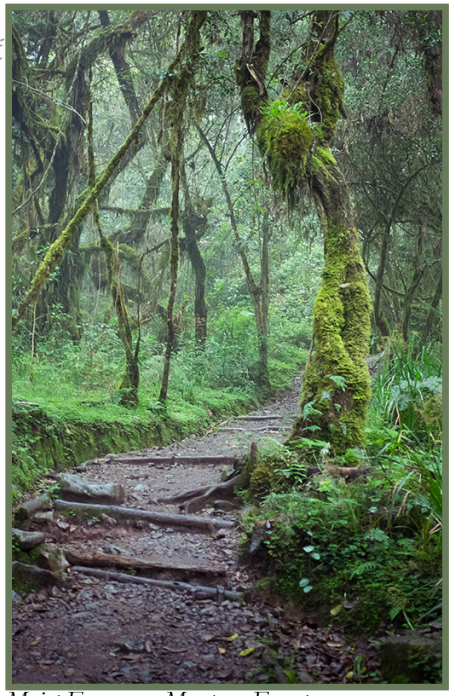
A drier woodland type characterised by scattered acacia trees, adapted to semi-arid conditions. Often found in areas with seasonal rainfall. Found mainly on the lower slopes of hills and valley bottoms across Eastern Africa (Acacia Woodland, 2010).
Acacia woodlands function as crucial "nutrient pumps" for the savanna ecosystems. Thanks to their nitrogen-fixing ability, Acacia trees enrich the soil, supporting both flora and fauna. These woodlands offer nutrient-rich foliage highly favoured by browsing herbivores.
Species:

- Trees: Vachellia gerrardii (Gerrard's acacia) (Wolfer, 2024), Vachellia xanthophloea (Yellow-barked acacia), Terminalia brownii (Kindt, 2014)
- Shrubs and plants: Lantana camara, Abutilon mauritianum, Achyranthes aspera, Senna bicapsularis, Grewia similis, Toddalia asiatica, Microglossa pyrifolia, Maytenus heterophylla, Hibiscus calyphyllus, Solanum incanum (Dharani, 2006)

Diospyros abyssinica

Juniperus procera

Podocarpus latifolius



Moist Evergreen Montane Forest

The ecoregion consists of montane forests, grasslands and savannas. Found above 1,500 meters elevation, mainly in East Africa's mountain ranges like the Aberdares, Mount Kenya and Mau Forest (one earth, 2025).

These "cloud forests" are cooler, humid environments where mist and fog are frequent. They are rich in epiphytes and mosses, with isolated conditions that lead to high levels of species endemism. The canopy is lower and denser compared to lowland forests. Trees are often covered in mosses, orchids and bromeliads that thrive in the abundant moisture. Rainfall ranges between 1,200–3,000 mm annually. This ecotype is the habitat where numerous hummingbirds, amphibians and epiphytes can be found. However, larger mammals are rare because of a lack of fruiting trees (Types of Forests, 2012). .

Species:

- Trees: Ocotea usambarensis (East African camphorwood), Juniperus procera (African pencil cedar), Podocarpus falcatus (Outeniqua yellowwood), Podocarpus latifolius (Broad-leaf yellowwood), Nuxia congesta, Newtonia buchananii, Diospyros abyssinica, Ficus exasperata, Manilkara butugi, Premna maxima (Paulo van Breugel, n.d.)
- Species: lots of amphibians and reptiles like, Tilbury's chameleon, Mount Kenya hornless chameleon, Ashe's bush viper (One Earth, 2025)

Vachellia xanthophloea

Vachellia tortilis

Vachellia abyssinica

Combretum spp.

Moist Acacia Woodland & Savanne

This ecotype is the main ecotype in the Menegai forest. The crater supports a diverse range of wildlife, including species such as duikers, hyenas and primates like baboons. It is also home to various bird species and livestock (The Uniqueness of Menengai Crater, 2021).

Occurs in areas where savanna and woodlands merge, typically on slightly wetter and better-drained soils (Ssemmanda, 2014).

This ecotype features a mixture of trees and grasses. Trees such as Acacia, Combretum and Euphorbia dominate, while grasses like Pennisetum purpureum and Themeda triandra form a persistent underlayer (Ssemmanda, 2014). These ecosystems are seasonally dynamic, responding quickly to rainfall.

Species:

- Trees: Vachellia abyssinica (Flat-top acacia), Vachellia seyal fistula (White-thorn acacia)(Wolfer, 2024), Vachellia tortilis (Umbrella thorn acacia); an infixing species that can increase below-crown productivity in savannas (Ludwig, 2001), Combretum spp., Euphorbia spp. (Ssemmanda, 2014)
- Grasses: Pennisetum purpureum (Elephant grass), Themeda triandra (Red oat grass)

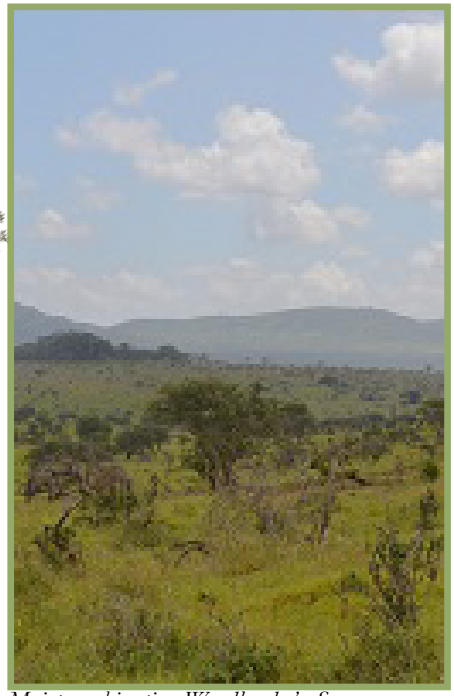
Nature

Vachellia xanthophloea

Vachellia seyal

Euclea divinorum

Grewia similis



Moist combination Woodland & Savanne

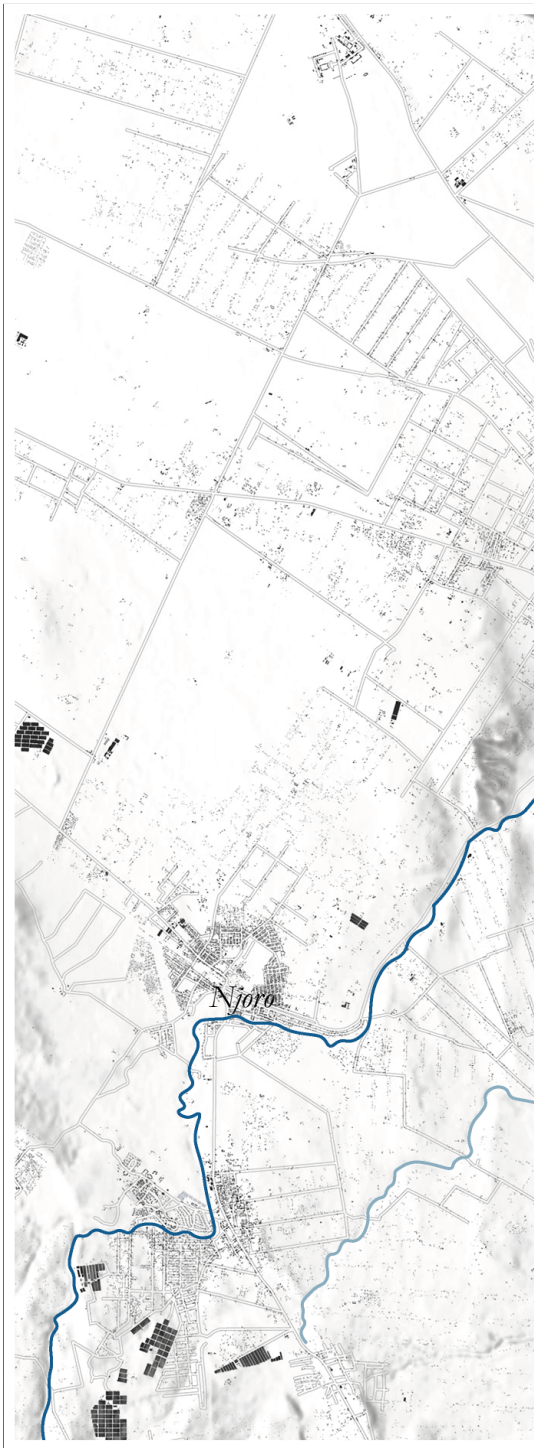
This ecotype is found in transitional zones between dry savannas and wetter forests in East Africa, including parts of Kenya and Tanzania. It features open woodlands with a mix of moisture-tolerant Acacia species and a diverse understory of grasses and shrubs. The area experiences seasonal rainfall, supporting a rich biodiversity.

Species:

- Trees: Vachellia seyal (White-thorn acacia), Vachellia xanthophloea (Yellow-barked acacia) (Wolfer, 2024) (Kindt, 2014), v (Apple-ring acacia) (Wolfer, 2024), Vachellia polyacantha (White thorn) (Lillesø, 2011).
- Grasses: Themeda triandra (red oat grass), Pennisetum purpureum (elephant grass), Panicum maximum (Guinea grass).
- Shrubs: Grewia spp., Euclea divinorum (Kindt, 2015).

Nature

The nature map shows a highly fragmented landscape, with dense forest patches near Menengai crater and more open shrub and savanna vegetation downstream. Urban expansion has increasingly disconnected these patches. My design framework proposes green-blue corridors that bridge these fragmented zones, allowing for species migration, water filtration, and urban cooling across the city.



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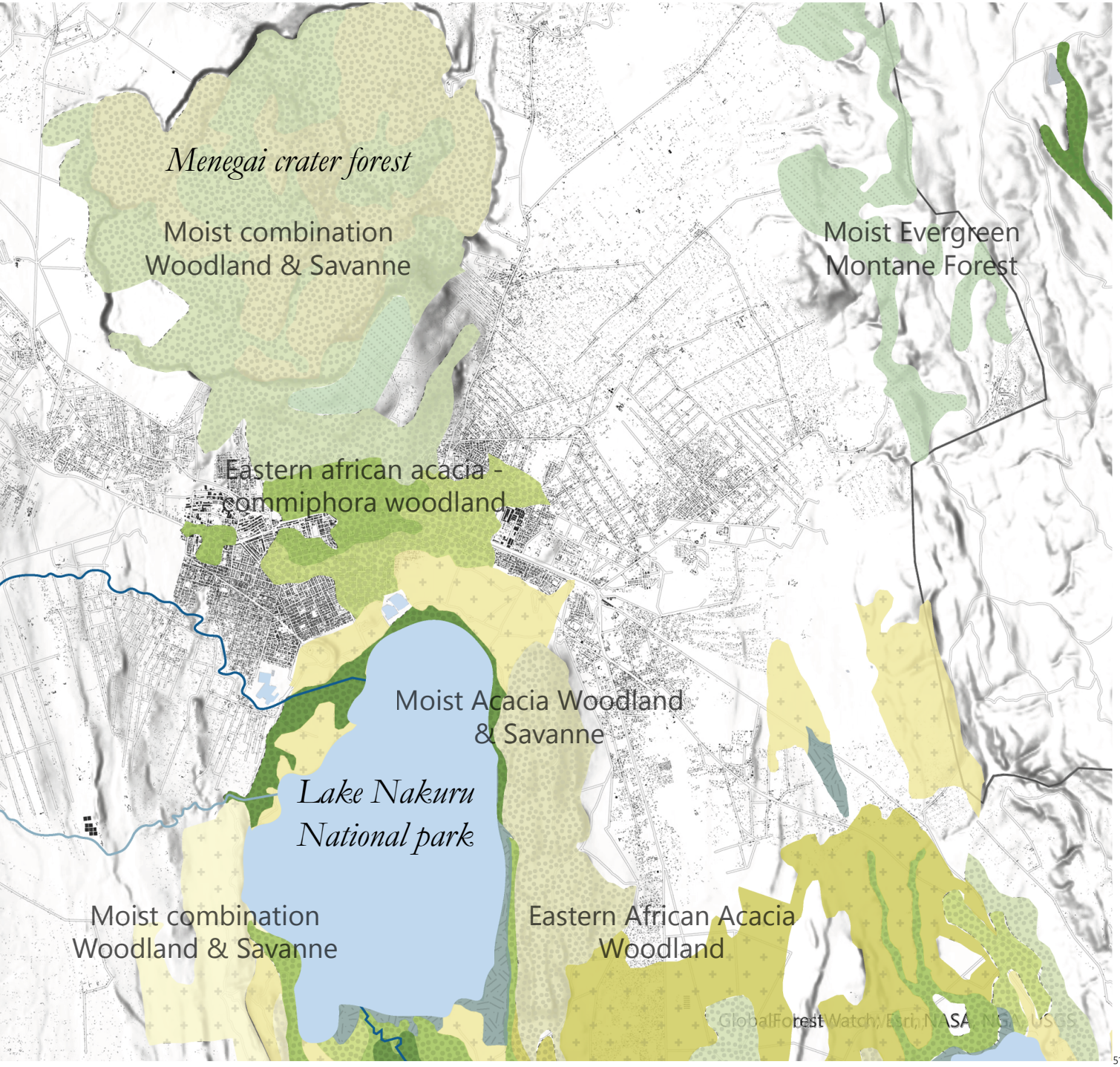

Menegai crater forest
Moist combination
Woodland & Savanne
Moist Evergreen
Montane Forest
Eastern african acacia -
commiphora woodland
Moist Acacia Woodland
& Savanne
Lake Nakuru
National park
Moist combination
Woodland & Savanne
Eastern African Acacia
Woodland
GlobalForestWatch, Esri, NASA, NGA, USGS

Landuse

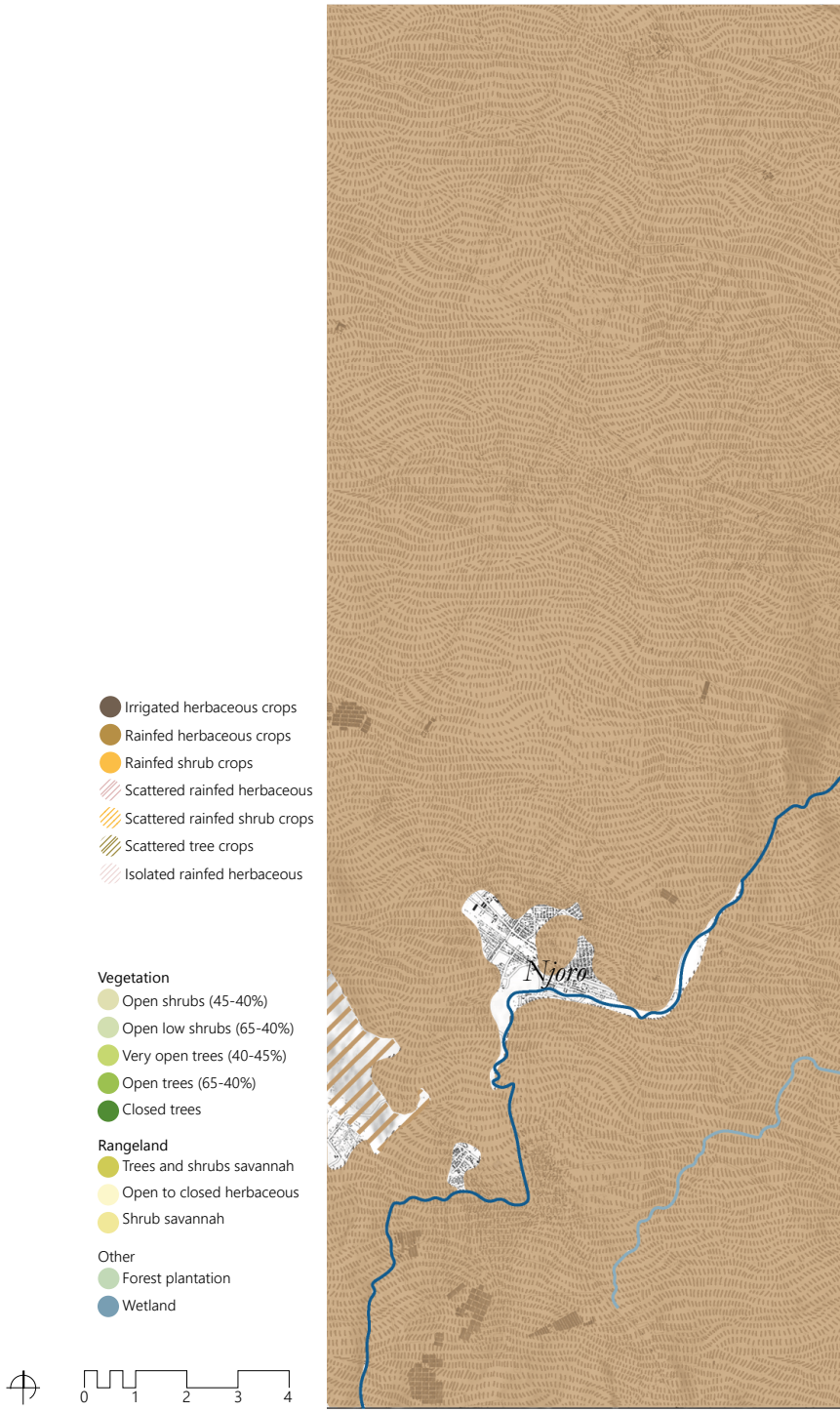
Agriculture

The fertile soils, favourable temperatures and regular distribution of rain throughout the year enabled regular farming patterns to take shape (Sanya, 2023.).

Following Kenya's independence in 1963, President Jomo Kenyatta assured white settlers that there would be no retaliation. However, land ownership gradually shifted and African farmers took over the farms. Small-scale farming flourished, with farmers cultivating maize and beans in areas like Manyani and Milimani, while large-scale farming continued in Rongai, Molo and Gilgil, mainly focusing on wheat production (Sanya, 2023).

Farming continued, with small-scale farmers focusing on crops like maize and beans in areas such as Manyani and Milimani, while large-scale farming thrived in Rongai, Molo and Gilgil, primarily cultivating wheat (Sanya, 2023.)

Today, Nakuru remains a crucial agricultural hub, producing 70% of the county's food and exporting a substantial portion globally. The main crops grown and marketed in the city include coffee, wheat, barley, maize, beans and potatoes (Sanya, 2023).



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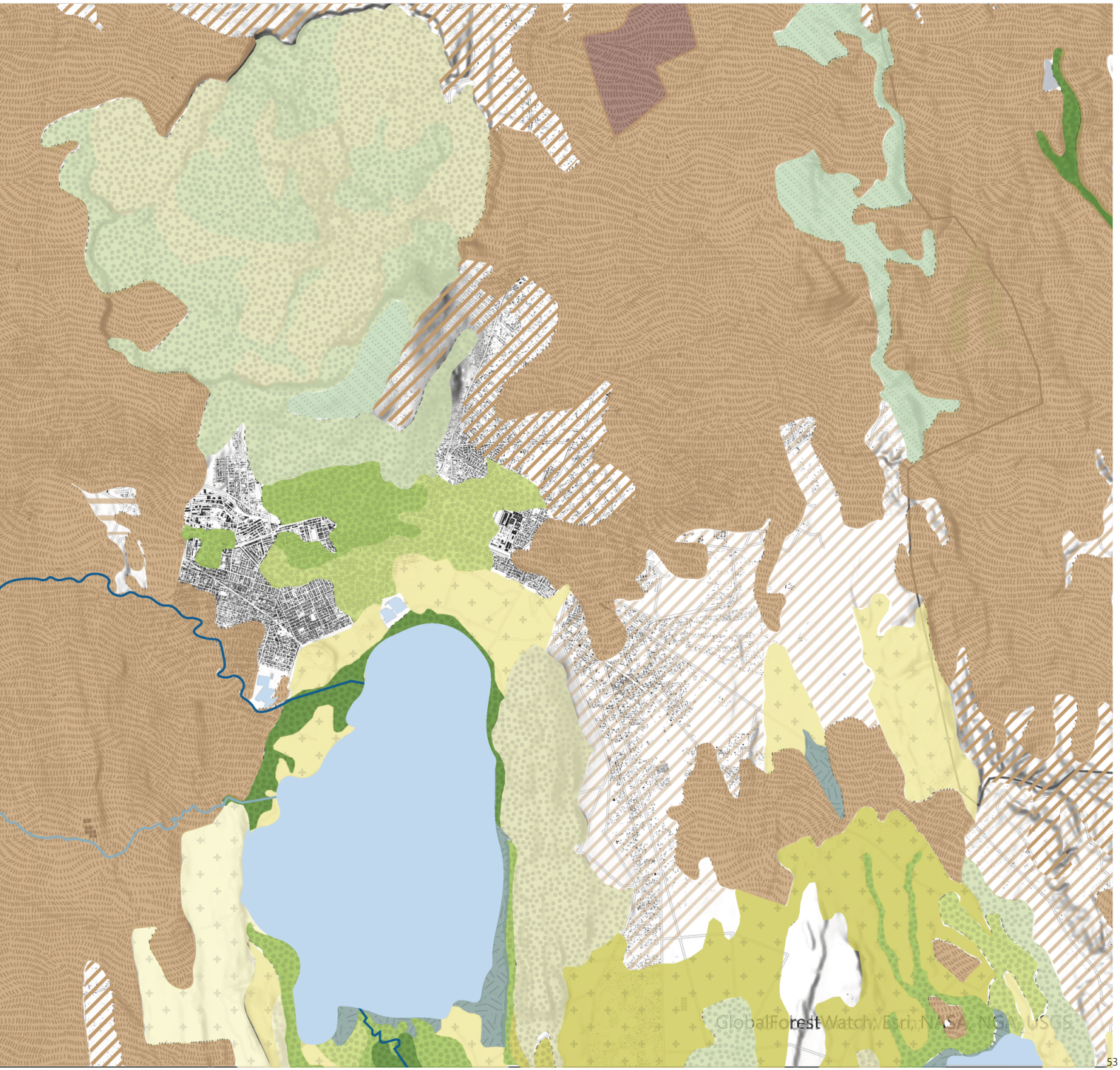
Forest
GlobalForestWatch, Esri, NASA, NGA, USGS

Nature

These images illustrate the dual character of Nakuru's landscape. In upland areas like Menengai crater with its forest and steep vegetated hills, intensive eucalyptus plantations and illegal logging threaten native ecosystems, while downstream agricultural fields expand into wetland zones. Further downstream, open landscapes like the area near Rhoda and the Lake Nakuru wetland demonstrate the ecological importance of wetland zones and biodiversity hotspots.

These challenges also offer opportunities: degraded slopes can be reforested with native species, while urban agriculture in flood-prone areas can combine food production with stormwater management.

Menegai forest

Menegai crater

Open area near Rhoda

Lake nakuru

Barut west

Nakuru national park, zebra with acacia trees

Agriculture

Agricultural fields, including large-scale maize farming in Ngata, private crop fields, and scattered fields along the main road, continue to expand into peri-urban and flood-prone areas. These pressures contribute to increased surface runoff, erosion, and water pollution. However, these challenges also offer opportunities: degraded slopes can be reforested with native species, while urban agriculture (as seen in Njoro district and maize fields during dry seasons) can serve as a multifunctional solution to combine food production with stormwater managemen.

Aerial view of maize farm with harvester in Ngata, Nakuru, Kenya.

Private crop field

Nakuru county, Kenya.

Maize during dry season

Njoro district in the Rift Valley Province, Kenya

Cropfield near main road

Landcover

Over the past few decades, Lake Nakuru has experienced significant land cover changes, reflecting shifts in both natural and human-influenced landscapes. Grasslands, once dominant, have gradually been replaced by agricultural development, particularly in the western and northeastern parts of the area. This transformation has been driven by expanding agricultural activities, which have encroached upon the previously more natural habitats.

A northern forest fragment, heavily reduced by 2011, has shown some signs of recovery by 2016, although the overall trend indicates a decline in forested areas within the regio (Appenix b).

The lake itself has also fluctuated in size over the years. In 2011, water levels were significantly lower, leading to a reduction in lake size, but by 2016, water levels had increased again, altering the surrounding ecosystems. The growth of built-up areas around the lake has further contributed to the loss of natural spaces, while the southeastern grasslands were gradually converted into agricultural fields.

Mixed bushland and the spread of invasive plant species have become more prominent inside the park, presenting challenges to the region's biodiversity. These ongoing changes highlight the dynamic and evolving landscape of Lake Nakuru, with increasing pressures from agriculture and urbanisation, alongside the natural fluctuations in the lake's water levels (Kaloki, 2017).

Socioeconomic & Cultural Aspects

Demografie
The Population of Nakuru in 2014 was 330 000, in 2000 it was 190 000 and in 1989 its population was 120 000 (Atlas of Urban Expansion - Nakuru, n.d.) The current population is 500 000 (Defacto Urbanism & RebelGroup, 2024).

The highest populations are found on the southern side of the Central Business District in neighbourhoods of Shabaab, Kaptembwo, Rhoda, Langa Langa and Kivumbini, which include many informal settlements (Defacto Urbanism & RebelGroup, 2024).

Culture
In Nakuru City and County, income sources are primarily derived from a mix of agriculture, public revenue and trade-related activities. The economy is primarily driven by agriculture, manufacturing and tourism, with key crops such as coffee, maize and potatoes
Agriculture, manufacturing and tourism are the backbones of the economy of Nakuru. The area surrounding the city is known for its vast agricultural potential with numerous small farms and also vast agricultural enterprises (History of Nakuru – County Government of Nakuru, n.d.)
Artistic traditions are prominent in Nakuru, celebrated through music, dance and visual arts. Traditional music and dance are integral to social gatherings and community celebrations, while modern artistic outlets, such as the Nakuru Players Theatre, support contemporary and folk arts performances. Nakuru's street art scene also reflects the city's artistic diversity, with murals and graffiti adding cultural vibrancy to urban spaces. The country's selection as a UNESCO Creative City for Folk Art underlines its commitment to preserving and promoting cultural heritage, making it a centre for both traditional and modern cultural practices.

Infrastructure & Urbanization Trends

Infrastructure

Infrastructure Support:

The A104 road connecting Nakuru to Nairobi and Kampala, along with the railway line, facilitated the transport of agricultural produce to other regions (Sanya, 2023).

According to a Nawassco employer and Nakuru inhabitant, people follow the road. A new road provides new opportunities (personal communication, February 2025).

Rapid Urbanisation:

Like many other cities in Kenya, Nakuru is growing rapidly, with an increasing population and the expansion of urban areas into surrounding natural areas. In 2021, the city ranked as the fourth-largest in Kenya and is one of the fastest-growing urban centres in the country (Atlas of Urban Expansion – Nakuru, n.d.). The urban expansion is moving from west to east, where there are fewer geographic obstacles.

Urban Infrastructure Challenges:

The rapid expansion has strained infrastructure, including insufficient planning for residential areas, waste management and water supply.

Urban Infrastructure Issues:

The rapid growth of Nakuru has led to infrastructure challenges, such as the development of new residential areas without adequate planning, waste management and water supply. Additionally, urban expansion is contributing to increased pressure on nearby natural areas, particularly Lake Nakuru National Park.

Urban Expansion:

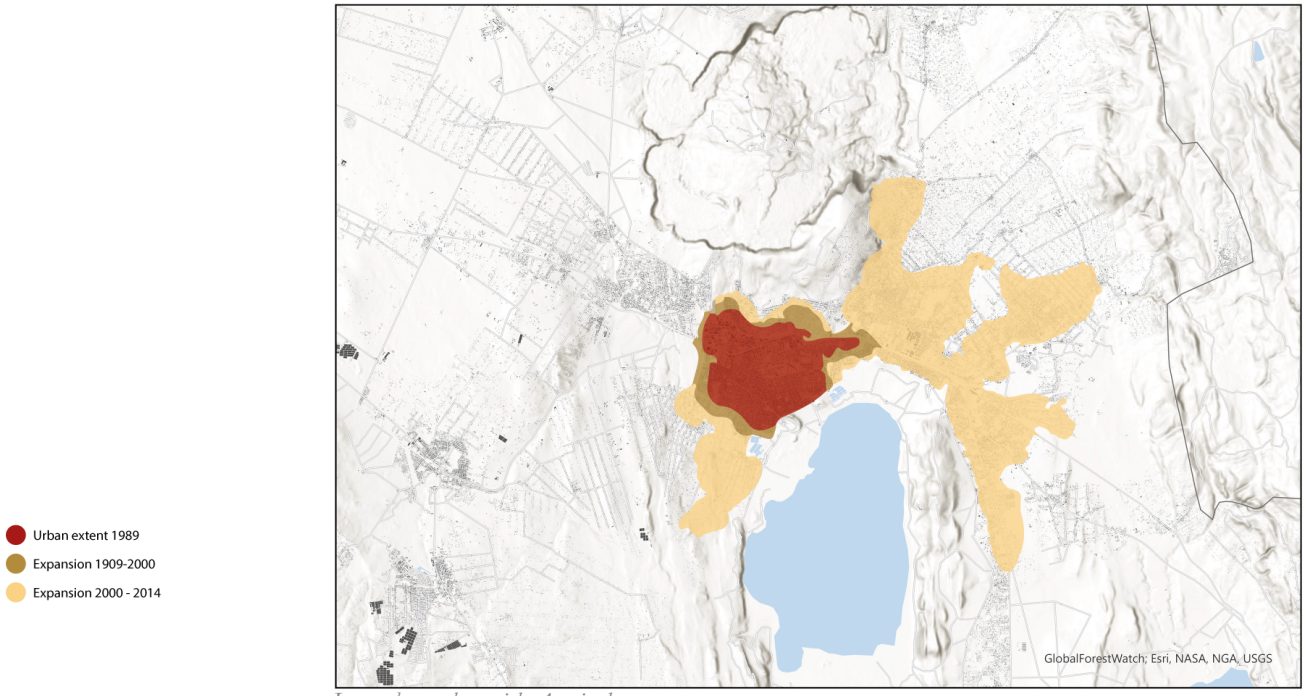

Image by author with Arcgis data

Urban Expansion

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Image Google Earth 2024

0 1 2 3 4

Lake Nakuru ecological pressures

Lake Nakuru is under pressure from pollution (especially agricultural runoff), deforestation and sedimentation. These factors negatively impact the water quality and the overall ecological health of the lake.

The city of Nakuru faces frequent flooding and has experienced rapid and unsustainable urban development. The need for sustainable and effective interventions is becoming increasingly urgent.

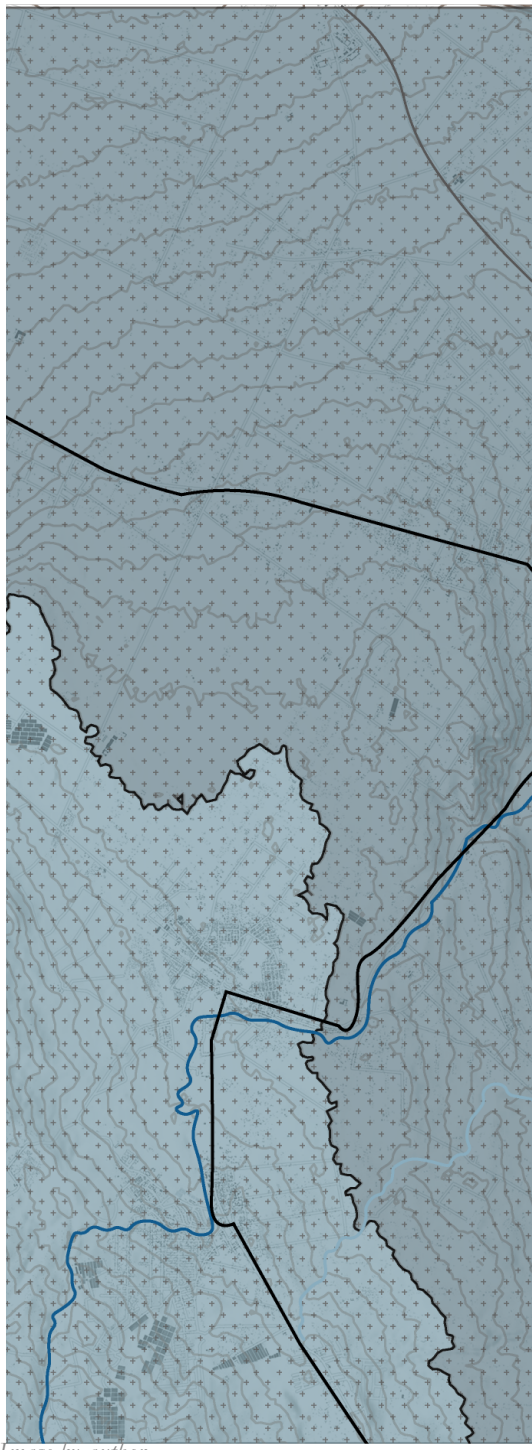
Pollution & Environmental Stressors:

Lake Nakuru is increasingly affected by pollution from multiple sources:

- Agricultural runoff carrying fertilizers and pesticides.
- Deforestation and soil erosion, leading to increased sedimentation.
- Sewage discharge from treatment plants near the lake.

Challenges
Catchment areas

Three different areas are identified based on water flow: The upland area, which is steep (such as forest edges and hillsides), the midstream area, which is flatter and more densely built (like the CBD) and the downstream area, which is even flatter and prone to flooding, where the lake receives and discharges water In these area there is no river, but the areas are categorised by run-off streams.



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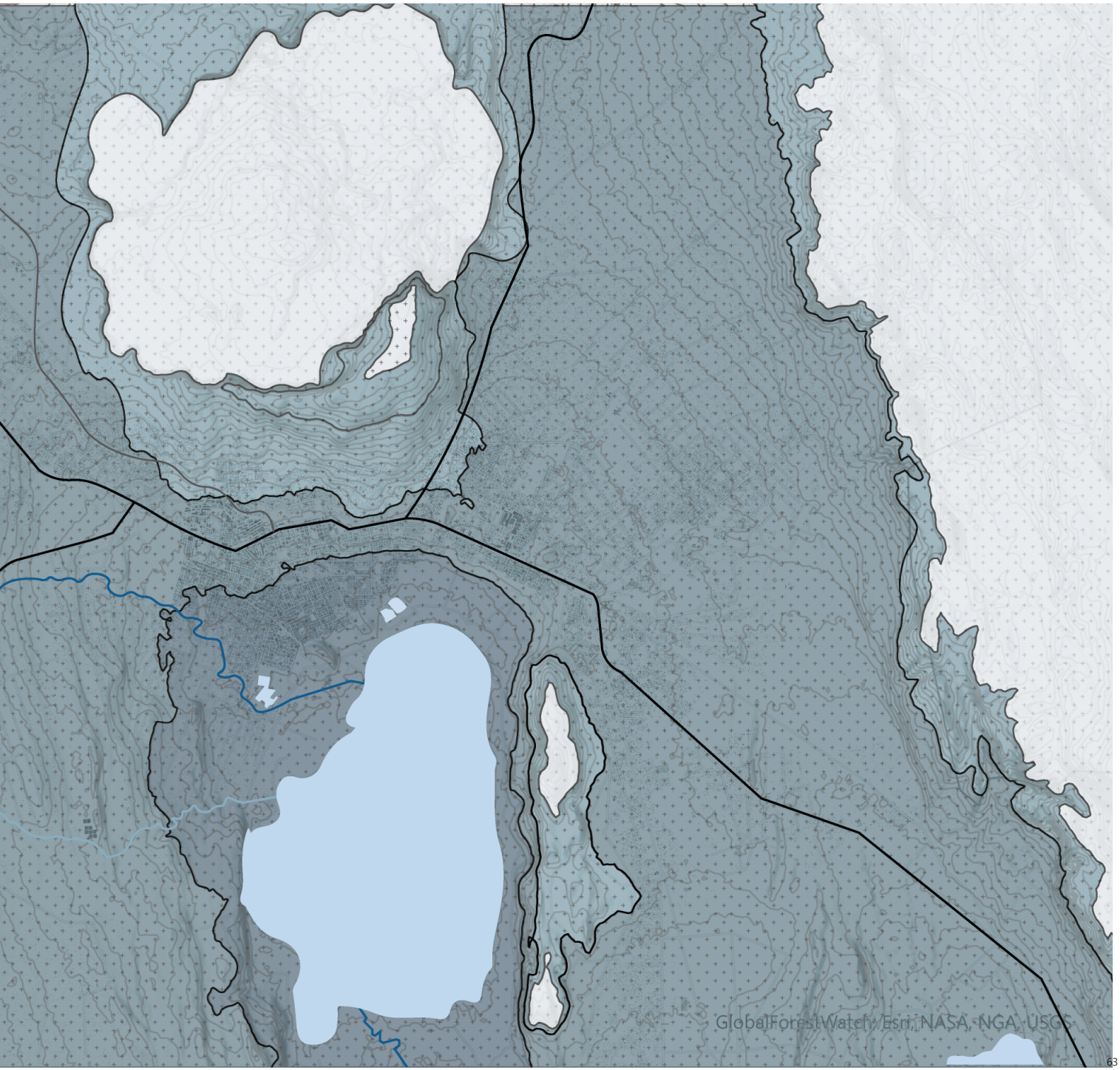

GlobalForestWatch, Esri, NASA, NGA, USGS

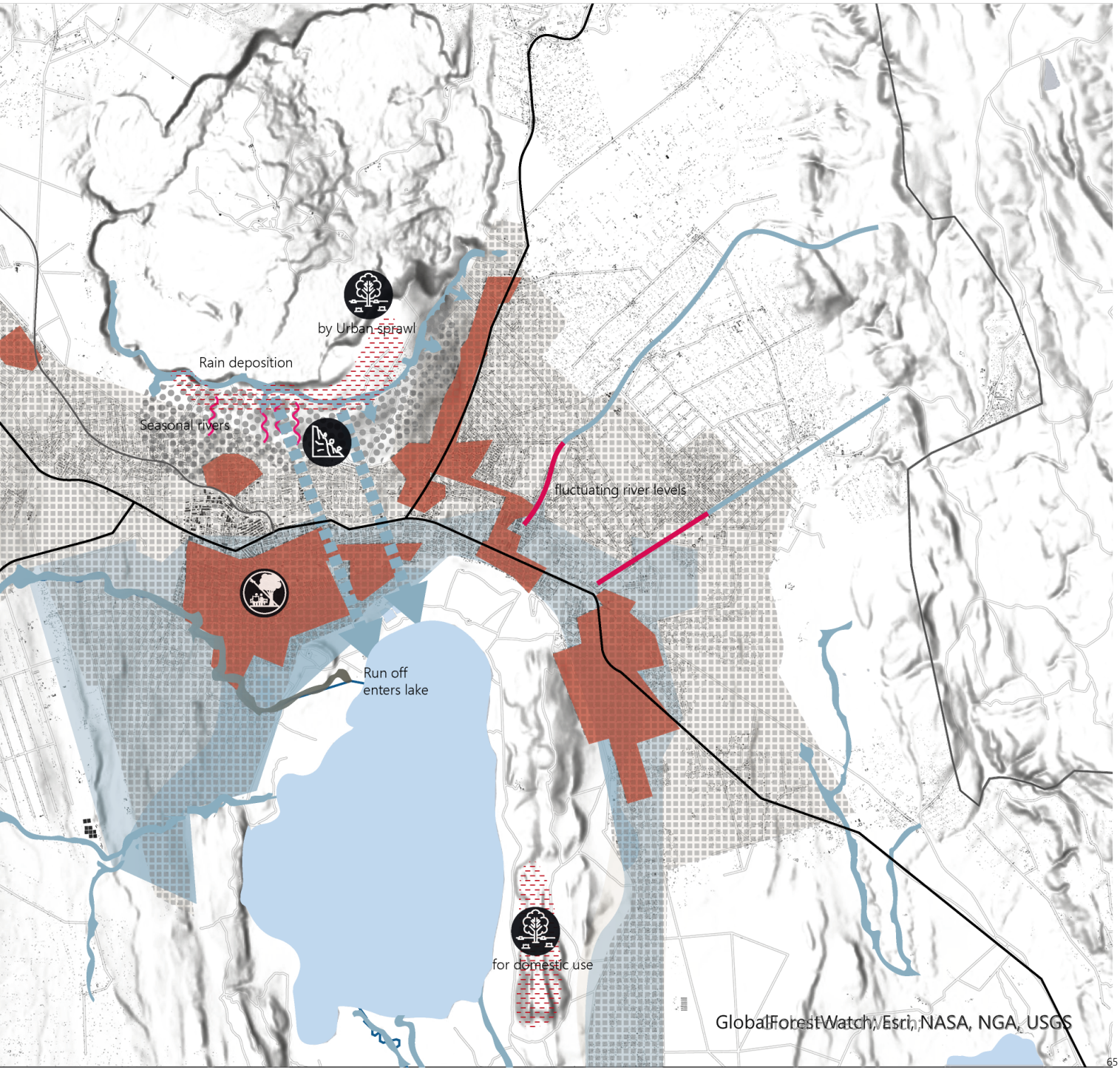
Challenges
Challenge map

From the urbanisation map the densities are near roads and near the first settlements.

Near the Menegai crater, logging is taking place. Bare soil is more loose and with the extreme seasonal rains, landslide occurs.

The lake levels are rising and the lower areas risk getting flooded. The lake also gets polluted by runoff over the city.

Image by author


by Urban sprawl
Rain deposition
Seasonal rivers
fluctuating river levels
Run off
enters lake
for domestic use
GlobalForestWatch, Esri, NASA, NGA, USGS

Challenge
Challenge diagram

The challenge diagram summarizes the key pressures Nakuru is facing. On the left, there is deforestation by the rapid urban expansion which is causing landslides. In the center, this growth directly affects water management: heavy rainfall and poor drainage create frequent flooding, while deforestation upstream reduces water retention capacity. Urban growth leads to increased impervious surfaces and fragmented green spaces.

Further downslope, in the low-lying agricultural and wetland zones, agricultural intensification and informal land use pressure the ecological functioning of Lake Nakuru. The water system receives both polluted urban runoff and agricultural runoff, creating both water quality and biodiversity degradation.

This section-based challenge diagram reinforces why a regenerative runoff framework is needed, where water retention and ecological restoration begin upstream, urban greening and retention occur midstream, and adaptive multifunctional uses like urban agriculture are implemented downstream. The vertical structure of the landscape thus becomes the organizational logic for my design framework.

URBAN

ECOLOGY

WATER MANAGEMENT

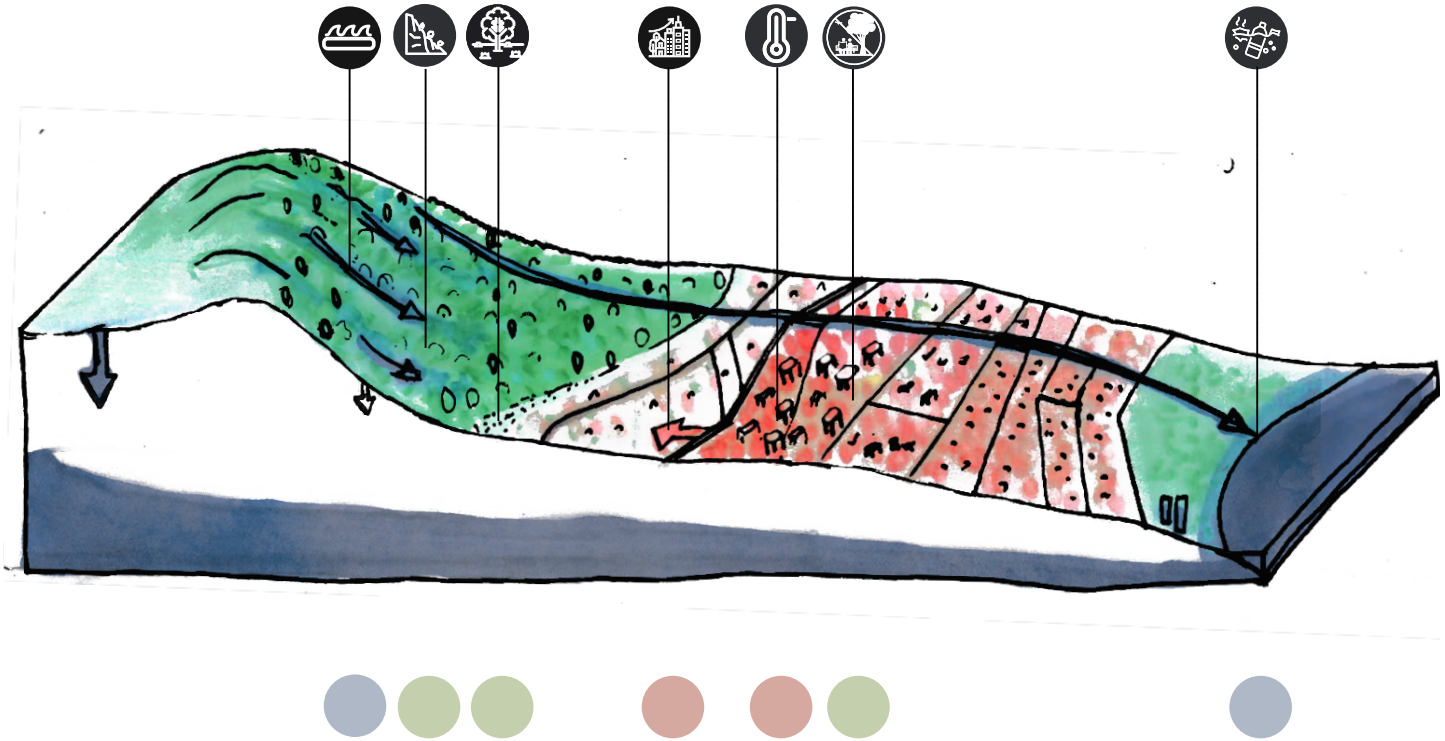


Image by author

Stakeholders

To realise a regenerative urban development in Nakuru, it is important to identify the stakeholders to engage them later on in implementations (Roggema, 2024). Stakeholders give a better image of the local needs, challenges and opportunities. This aligns with Tjallingii's Ecopolis model, which emphasises the importance of integrating technical systems, social use and spatial identity. Different stakeholders play roles across these dimensions

The primary stakeholders are the communities, the government and municipality, the environmental and the ecological, universities and donor agencies and for secondary we have the tourism sector, real estate developers and visitors.

Stakeholders and main ideas, image by author

Table: Stakeholders positions

Category	Stakeholder	Role / Interest	Societal Position
Community	Educational institutions	Support environmental education, research collaboration and youth engagement.	Civil society / Academic
	Faith-based institutions	Influence social norms, support stewardship, education	Civil society
	Local CBOs	For the implementation phase, as they offer maintenance and involvement in the project.	Civil society
	Residents	End-users of urban interven-tions and source of local knowledge	Civil society (in-formal/ formal)
Economy	Farmers	Important in peri-urban are potential adopters of agroforestry, water retention and reuse practices.	Private
	Local businesses	May contribute funding or maintenance; benefit from improved public space and stormwater management.	Private
	Private landowners	Critical for land access, negotiation and implementention of green or sponge measures.	Private
	Tourism sector	Has an interest in maintain-ing ecological health and beautification for tourism appeal (e.g., Lake Nakuru, Menengai).	Private sector / Services
Environmental & Ecological	Environmental NGOs	Expertise in restoration, biodiversity, policy advocacy and can offer funding support for ecological measures.	Civil society
	Kenya Forest Service	Forest protection, reforestation, policy enforcement	Public
	Kenya Wildlife Service (KWS)	Conservation and protection of ecosystems like Lake Na-kuru National Park, could also do this for a new project.	public National government agency
Government	Municipality	Overseeing implementation and ensuring design aligns with city-level policies and priorities.	Public
	Urban Planning Department	Integration of your design into spatial planning and land-use regulations.	Public
Water Management	Borehole owners	Communities with a decentralised water access.	Local / Private
	NAWASSCO	Responsible for integrating sustainable drainage, grey water reuse and infrastruc-ture maintenance.	Public
	Water NGOs	Technical support, community outreach and policy input on sustainable water management.	Civil society
Donors	UN-Habitat	Strategic funding, knowledge sharing, alignment with SDGs	Public

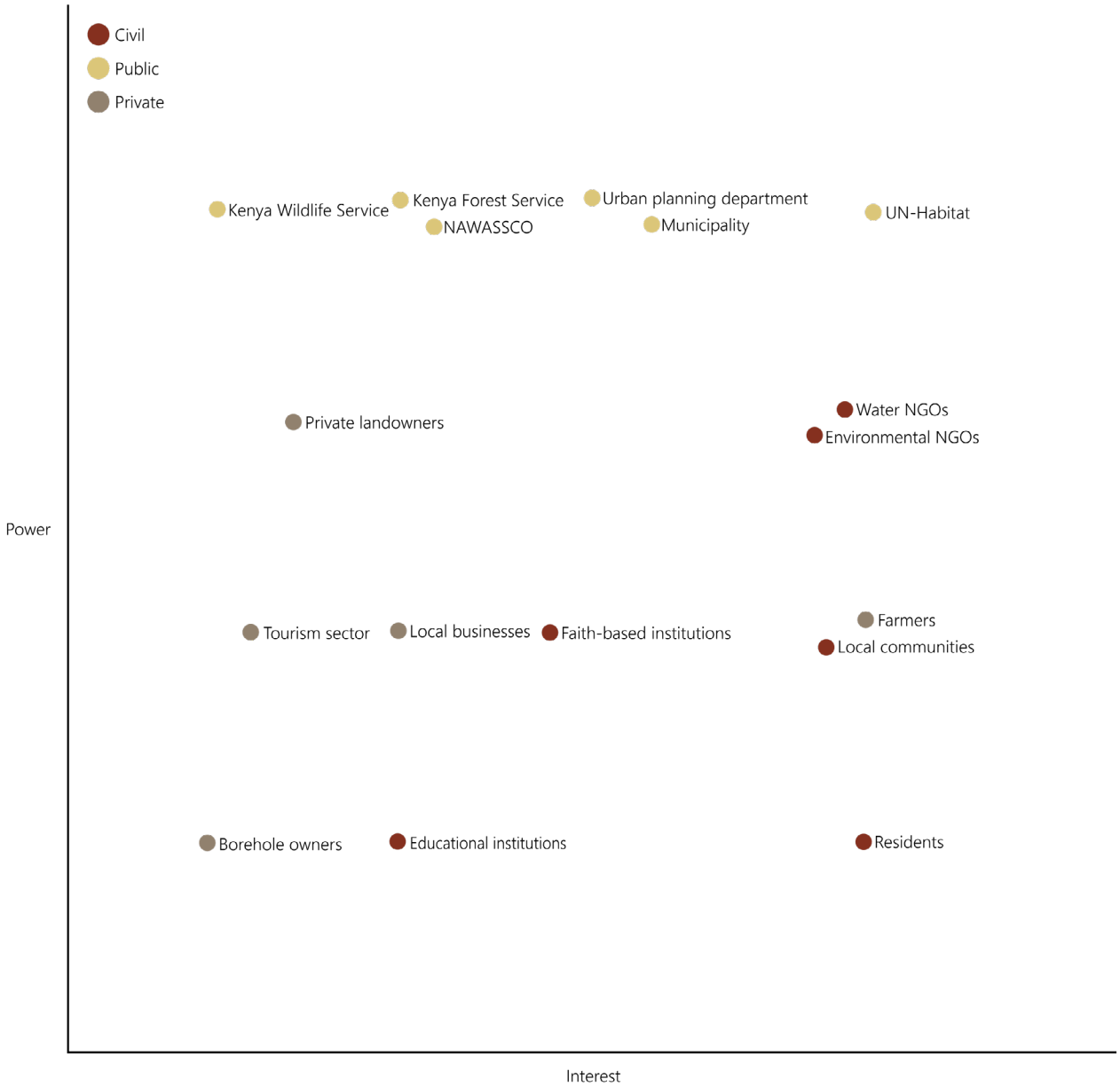
How the key stakeholders relate to each other. In this matrix, power refers to a stakeholder's ability to influence decisions or control resources, while interest reflects their level of concern, benefit, or engagement in the project's outcomes. For instance, residents show high interest due to the direct impact of urban interventions on their daily lives, yet have low formal influence. In contrast, private landowners may control key land parcels but show limited engagement unless clear benefits are articulated. Understanding these dynamics helps target engagement strategies accordingly.

Stakeholders such as the Urban Planning Department, Municipality, NAWASSCO, UN-Habitat, also the public sector, have the high-power and high-interest quadrant, are core partners and should be involved in the co-creation, policy integration and long-term implementation.

Local communities, farmers, environmental NGOS and water NGOS are good for the implementation phase. They have medium power and a high interest. When they are involved early, they can give training and do local monitoring.

Some stakeholders that are a bit more in the background are the high-power and medium-interest stakeholders, the Kenyan Wildlife Service, the Kenya Forest Service and the private landowners. These actors control access to key resources or land but are less proactive. The other category of a bit more background stakeholders are those with medium power and medium interest. The faith-based institutions, the tourism sector and local businesses. They can have benefits from the design interventions, but less than others and they are also less actively involved in those interventions.

The stakeholders with low power but high interest are the residents and educational institutions. They benefit from the design interventions and are part of the plans for the future.



Stakeholder power and interest matrix in developmentNakuru

Key findings

Nakuru has two large natural areas, the Menengai Crater with its extensive forest and the Lake Nakuru National Park. Within these areas, a lot of habitats for different species can be found, these two large ecological areas form strong anchors on either side of the city. In between lies the city, which has expanded at the cost of natural systems. However, I propose to see these same natural areas as an inspiration for restoring ecological functions and creating new habitats within the city. This aligns with the system-habitat-species model, where we create urban conditions that support both human and ecological life.

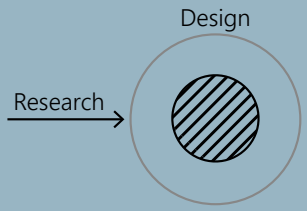
The soil in Nakuru has good infiltration capacity. However, much of the rainwater is lost through deep underground fractures, which reduces the potential for local reuse, ultimately draining into the lake. This reflects the challenges described in Tjallingii's "Responsible City" model, where the city's input-output flows must be carefully managed to avoid environmental degradation and support long-term resilience.
The city's rapid urbanisation, rooted in colonial-era infrastructure, has led to sprawling development that increasingly encroaches on natural systems. Urban growth has placed increasing pressure on water infrastructure, raised flood risks and reduced the quality and connectivity of habitats. Forest fragments have diminished, grasslands have been converted to agriculture or built-up areas and wetlands face pollution and degradation. This threatens not only biodiversity, such as the Acacia-Commiphora bushlands and the lake's iconic flamingo populations, but also the ecological functionality of the broader landscape.

To ensure a regenerative future for Nakuru, planning must be inclusive and system-oriented. This requires active engagement of a broad range of stakeholders, from local communities and municipal authorities to environmental NGOS, water managers and private sectors such as tourism and real estate. Such an approach is consistent with Tjallingii's Ecopolis model, which emphasises the integration of technical systems, social dynamics and spatial identity in sustainable urban development.

03 *Research about Design*

s-RQ 2: What regenerative design principles can enhance water resilience and biodiversity restoration in urban areas with tropical highland climates and moderate temperatures, similar to Nakuru?

Gains insights by analysing relevant precedents. The findings from the fieldwork are listed. This section helps define the principles for regenerative design strategies.



Global regenerative design principles

In an urbanizing city, we should think about: Efficient density. As Nakuru continues to grow the same way, low-density development will no longer suffice as that will take over the natural and ecological surroundings. To address this, vertical zoning could serve as a viable solution. By increasing the density of development and activity, the effective use of urban land can be achieved (UN-Habitat & Ignatova, 2024).
The concept of regeneration focuses on improving a place through renewal, regrowth, or restoration (Urban Regeneration | UN-Habitat, n.d.). A key element of this is resilience within the urban environment, which calls for a diverse mix of species and land uses. Ecological enrichment is critical to support regrowth, particularly through the integration of blue-green infrastructure (David Cheshire, 2024). The fundamental nature of landscape systems lies in the interconnectivity of green spaces, lakes and rivers, they cannot be considered in isolation (Forman, 1995). Examples of blue-green elements include water retention zones, rain gardens, green roofs, vertical greening systems and permeable pavements (Pochodyła-Ducka et al., 2021).

From the Urban ecology theory, the importance of regenerative design strategies like the use of native plant species to restore ecosystems and improve biodiversity. Native plants are adapted to local climatic conditions, requiring less water and maintenance. They also provide a habitat for the local fauna. Vegetating areas along rivers and streams with native plants prevents erosion and filters pollutants. For this, I went to Nairobi Arboretum (Birnie, 2002). To address challenges posed by steep slopes and landslide risks, terraces and afforestation present potential solutions.

Precedent studies

The following cases highlight key regenerative principles, technical solutions and community engagement approaches that are relevant to the design of water-resilient and biodiversity-restorative urban areas in Nakuru, Kenya.

Medellin's Green Corridors

What was done? In 2016 the city Medellín, Colombia, launched an innovative "green corridors" initiative to mitigate air pollution and urban heat. Comprising over 30 interconnected green spaces, including vertical gardens, green infrastructure and parks, this programme enhances environmental health and urban biodiversity (De Andrade, 2023).

Why this case? Medellín, Colombia, shares key challenges with Nakuru; rapid urbanisation, climate impacts and ecological degradation, making it a useful precedent for green infrastructure interventions in a tropical highland context.

The results are great and the city is looking into even more regenerative options. New vegetation growth would absorb 160 787 kg of CO_2 per year.

Improved air quality is reducing the morbidity rate from acute respiratory infections from 159.8 to 95.3 per 1,000 people.It has also encouraged a rise in cycling and the return of local wildlife, contributing to biodiversity recovery (Yeung, 2024). These green corridors are in line with landscape-based urbanism (Nijhuis et al., 2023), the framework and corridor approaches, that emphasise long-term spatial structures that support both ecological coherence and urban development.

In comparison with Nakuru, Medellín has higher humidity and more consistent rainfall, while Nakuru experiences drier winters and more distinct wet and dry seasons. The mild and stable temperatures year-round in Medellín make it easier to grow a wide variety of vegetation. Nakuru's drier winters mean that water availability for maintaining green infrastructure could be a challenge during these months.

Takeaways for Nakuru: Medellín demonstrates how ecological corridors can serve as multi-functional infrastructure. While Nakuru's climate differs, with more seasonal droughts, similar principles can be adapted through context-sensitive planting and water-sensitive design.

(Yeung, 2024).

Sponge town, Kitui

Why this case? For Nakuru, lessons from the Sponge Town project in Kitui, offer valuable insights as it shares Kenya's water-stressed conditions and socio-economic dynamics. It demonstrates how regenerative frameworks can address both flooding and drought by absorbing, storing and gradually releasing water.

What was done? Implemented from 2016–2018, the project used water-sensitive urban design (WSUD), local knowledge community engagement and green infrastructure to improve resilience.

1. Community engagement
- Objective: Use existing citizen platforms for inclusive decision-making and validation.
- Takeaway: Sustainable water management starts with engaging existing community structures, for better social acceptance.
- Impact: Builds long-term ownership and avoids artificial or short-lived initiatives.

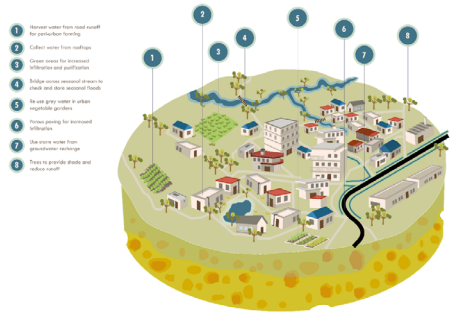
2. Combine local knowledge with a technological understanding
- Objective: Gather hydrological, environmental and socio-economic data and collaborate with local experts and students.
- Takeaway: Combining local knowledge with scientific expertise ensures context-specific solutions.
- Impact: Provides a reliable foundation for designing and monitoring effective interventions.

3. Develop stormwater and runoff management plans
- Objective: Develop stormwater and runoff management plans for hydrological units (neighbourhoods).
- Takeaway: Emphasis on integrated drainage mapping, hazard identification (e.g. pollution) and nature-based solutions like green infrastructure.
- Impact: Translates technical understanding into actionable, site-specific planning for water retention and pollution prevention.

4. Implementation through local action
- Objective: Pilot sponge neighbourhoods by mobilising local artisans, citizens and government.
- Takeaway: Two-tiered implementation:
  - ◊ Large-scale structures (e.g. sand dams) require external and county support.
  - ◊ Small-scale actions (e.g. rain gardens, rooftop harvesting) empower households.
- Impact: Strengthens local capacity and ensures scalability and affordability of measures.

5. Scaling and knowledge sharing
- Objective: Create guidelines and communication tools to enable replication in other parts of the city and outside.
- Takeaway: Transparent documentation, harmonised with other pilots, ensures transferability of insights.
- Impact: Facilitates upscaling, inspires other cities and ensures lessons reach both grassroots and policy levels through innovative media. (Aqua for All, 2018)

Takeaways for Nakuru:
Kitui illustrates the need for stakeholder ownership, hybrid knowledge systems and site-specific design. Its dual-scale approach, with community-led small actions and government-supported large infrastructure, is particularly relevant.



(Aqua for all, 2018)

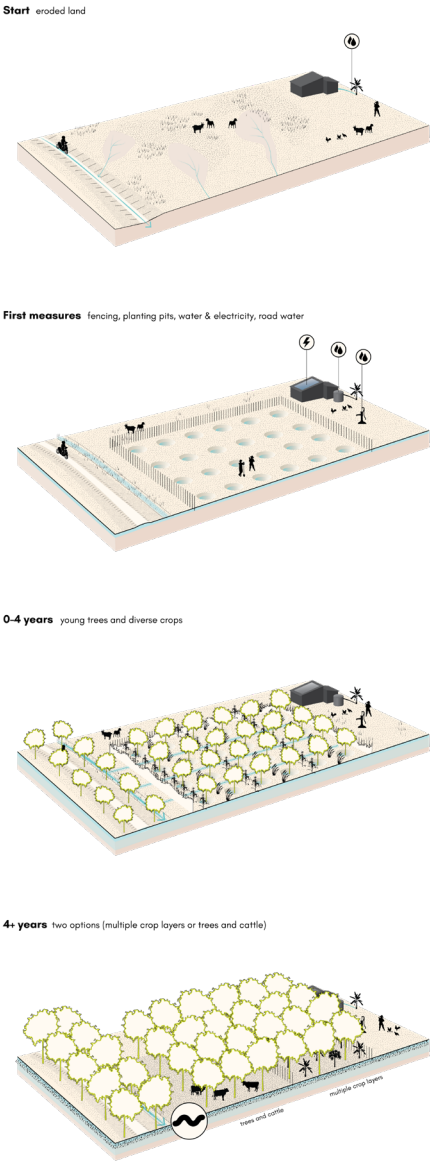
African Wood Grow

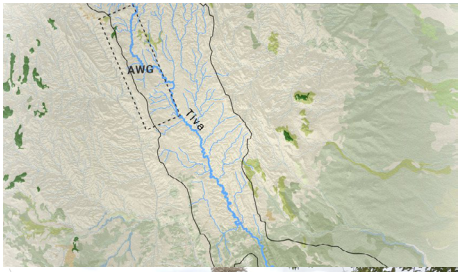
What was done? The African Wood Grow project, established in 2010, is a long-term reforestation initiative to plant more trees to restore degraded land in Sub-Saharan Africa.

Why this case? Advantages are reduced soil erosion, increased vegetation cover and biodiversity and improved soil fertility. Socially, the project contributes to increased water and food security through enhanced soil fertility. The project adopts a bottom-up approach, involving local communities in all stages of the process, with farmers voluntarily choosing to participate.

However, there are some challenges associated with this approach. One limitation is the fragmentation of green spaces, as the project relies on small, individual plots managed by farmers. Not all farmers are willing to participate, leading to disconnected green areas rather than a cohesive landscape restoration effort.
Additionally, while tree planting is an important aspect of environmental restoration, the hyper-focus is limiting. A more holistic approach to land restoration that involves other species, soil management and water conservation could provide more long-lasting positive impacts.

Takeaways for Nakuru: From this precedent, Nakuru can adopt community engagement strategies. A more integrated landscape approach, combining tree planting with water conservation and diverse species restoration, can lead to a more cohesive and effective restoration effort (Africa Wood Grow, 2024).





(Africa Wood grow, 2024)

International Tree Foundation, Nakuru

What was done? In Nakuru County, a tree planting initiative has started at Kirengero Forest, an area north-west of Nakuru city. Launched in 2023, the project aims to plant over 1000 trees with the involvement of more than 10 local schools. The project engages children in planting indigenous trees, with a focus on 6,500 indigenous species, fostering an understanding of the local and global importance of trees and forests (International Tree Foundation, 2023). This initiative contributes to Nakuru County's goal of planting 10 million trees and the national target of 15 billion by 2030.

Images from Globe Gone Green's past school projects (International Tree Foundation, 2023)

Why this case? This case is relevant because it is local to Nakuru and demonstrates how tree planting and environmental education can be scaled through institutional partnerships, such as schools. It illustrates how a youth-centered approach can contribute to broader environmental goals like catchment restoration, climate resilience and biodiversity conservation.

Takeaways for Nakuru:

The holistic approach, integrating environmental conservation with community health, demonstrates the potential for long-term sustainable development in Nakuru. This collaborative effort is a prime example of how local communities, educational institutions and governmental organisations can work together to tackle the region's environmental challenges while simultaneously fostering social cohesion and engagement.

To conclude

By combining these regenerative v, Nakuru and similar urban areas can enhance water resilience, restore biodiversity and create vibrant, sustainable environments tailored to their unique tropical highland climates.

Medellín's Green Corridors provide a model for integrating biodiversity recovery with urban infrastructure. The African projects have similar climatic areas. The African Wood Grow project underscores the importance of community involvement and the need for holistic landscape restoration. The International Tree Foundation initiative demonstrates how education and community engagement can drive reforestation efforts and foster long-term environmental stewardship.

Site visit

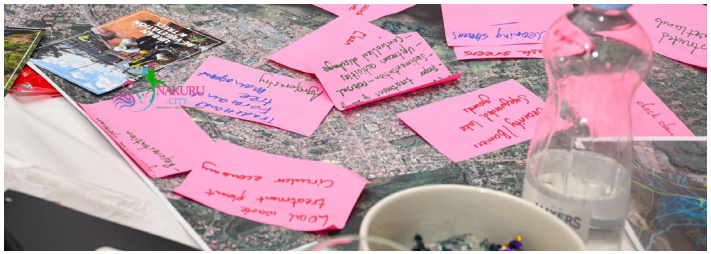
Fieldwork is an essential method for good design, so after preliminary research, done through maps, reports and climate data, the visit was planned.
During my fieldwork, I visited different neighbourhoods of the city to observe water flows and problems, green spaces, informal settlements and areas where biodiversity is under pressure. Being physically present allowed me to see the way people interact with their environment, the informal systems that exist and the local conditions shaping water and land use.
I had the opportunity to participate in a workshop from Water As Leverage, where I engaged with urban planners, residents, landscape architects and representatives from NAWASSCO (the Nakuru water management and sanitation). These conversations gave me valuable insight into current water challenges, different nature-based solutions and how different stakeholders view the city's environmental future.
At Egerton University, I organised a workshop with other students from TU Delft with their students and faculty. Their knowledge of local ecosystems and regional planning added an academic depth to what I had observed in the field. Here I also talked to an ecology professor who answered my questions about species for my project.
Finally, in meetings with the Nakuru City Manager and county planners, which gave a chance to talk more directly with municipal planners about Nakuru's growth, planning constraints and opportunities for regenerative interventions.
These experiences helped me connect theory to reality. It also gave me a more nuanced understanding of what water resilience and biodiversity restoration could mean in a place like Nakuru.

Methods
- Interviews
- Workshops (Water as Leverage and Egerton University).
- Observations and field notes

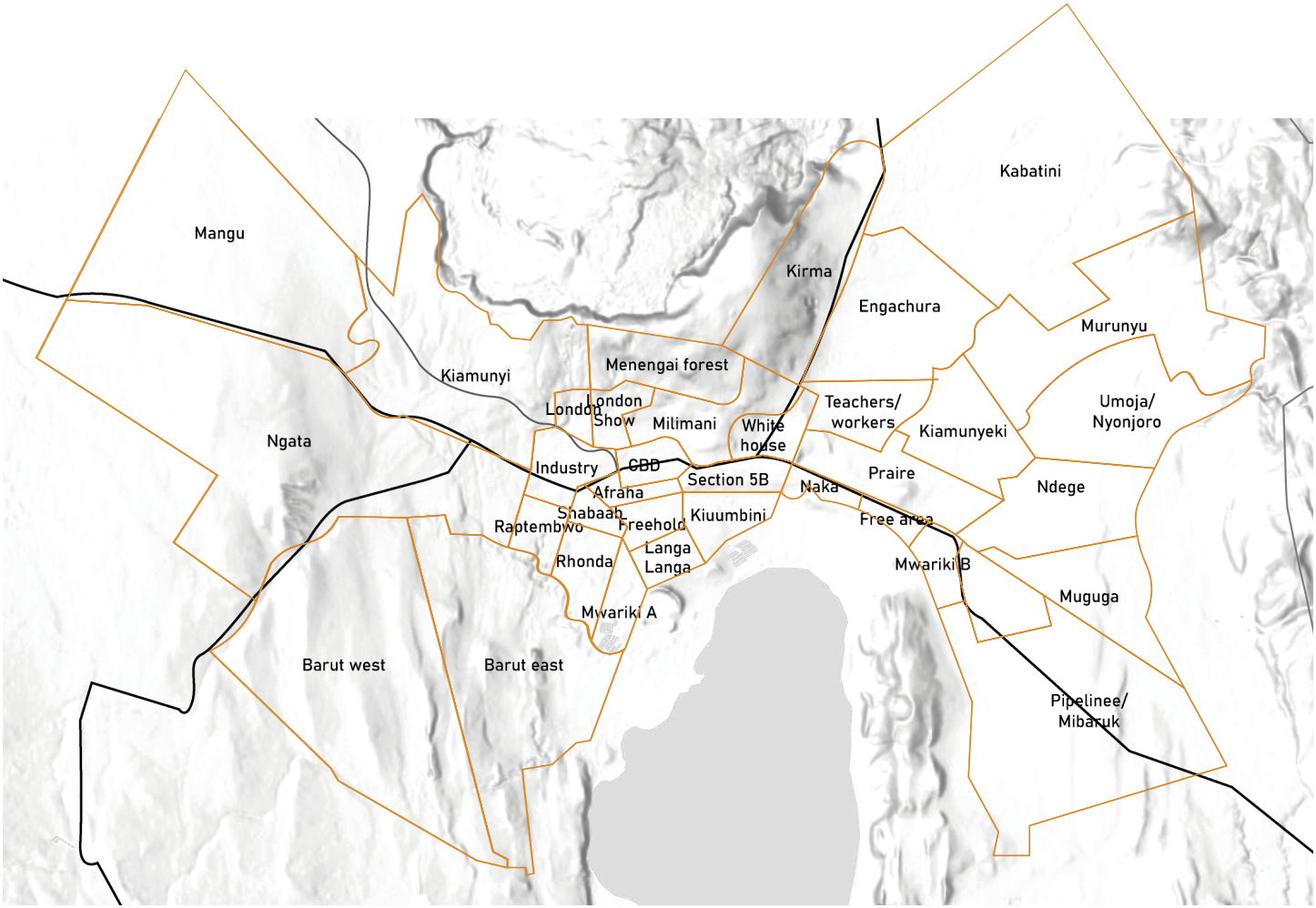
Interview with city planner


Workshop with Egerton students organized by us students

Workshop Water as Leverage



Workshop Water as Leverage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Mangu
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Section 5B
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Barut east
Pipelinee/
Mibaruk

Menegai Crater

Nature is biodiverse, but there are a lot of eucalyptus trees and tree plantations in the forest, which impact the native ecosystem and water retention.
Steep hills and remaining water flows are visible.
Use: There is tree logging taking place, but also collecting branches from the ground as firewood. People also come here to hang out.
There are tourists, mainly from Kenia. Also, people go to the caves in the crater to pray.

Tree logging is active and the collection of branches from the forest floor for firewood is common.
Recreational use: Visitors and locals come to hang out, hike, or enjoy the scenery.
Spiritual site: Caves within the crater are used for prayers and religious retreats.

Future: If you want to protect this forest, the fence they are currently placing needs to go all around. Reforestation with indigenous species to support water retention and biodiversity.

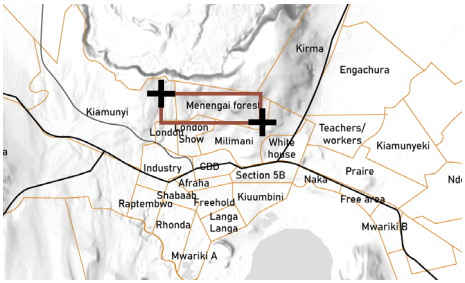


Image by autor

CBD

Nature: There are two public parks, they are open 6 days a week during the day.
This is the business area with higher buildings and more built-up areas. On the right images are the effects after only a day of rain: Pooling and water in the gutter. Caused by clogged drainage due to poor solid waste management.
Use: Busy commercial and transportation hub with high foot and vehicle traffic.

Future: There are no more plans for parks as the municipality doesn't own more ground. Invest in green-blue infrastructure (e.g., rain gardens, bioswales) within streets and small public spaces. multifunctional green spaces, combine buildings with open public green space.

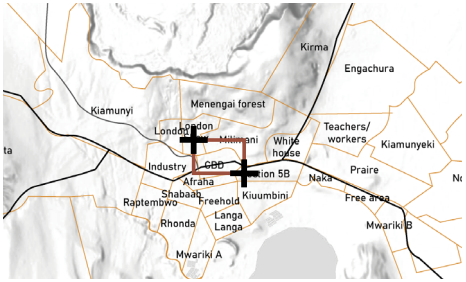


Image by autor


COUNTY GOVERNMENT OF NAKURU
WET WASTE
DRY WASTE


KDG 620N

Rhonda

Nature: There is limited green space and the soil is under pressure due to the lack of vegetation. Some small open areas remain, but they are often informally used or under pressure from development.
Use: The area is primarily residential, with many informal businesses and local markets. Open spaces are frequently used for waste dumping or livestock grazing. On weekends, the Nijoro becomes a recreational spot where local boys gather to play and wash.
Water & Environment: Frequent flooding occurs during rains, especially in low-lying areas near the lake. Poor drainage infrastructure and the accumulation of solid waste block water flow, as the city's drainage channels end and discharge here.

Future: Community-led drainage and solid waste initiatives could greatly improve local conditions.

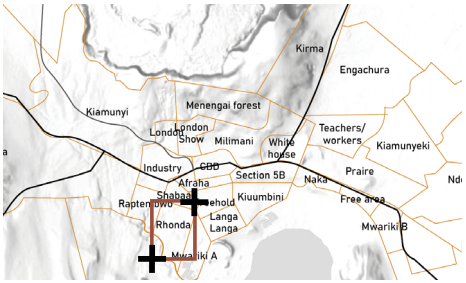









Image by autor

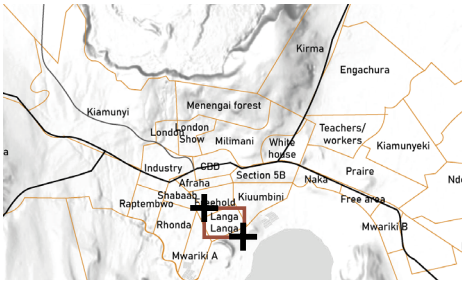
Langa Langa

Nature: This is a high-density urban area with very little visible vegetation. Some government housing exists here, mainly accommodating people relocated from flood-prone areas.

Use: The area borders Nakuru National Park and residents often come here to have lunch. The community is very active, with a high population, numerous informal businesses, churches and schools. Open spaces frequently serve as gathering spots for the community.

Water & Environment: Drainage is a significant issue and flooding occurs frequently, especially in shared access lanes. Open sewers and greywater disposal are common in some locations.

Future: There is strong potential for community mobilization around improved sanitation and water management. Creating new green areas could be paired with urban agriculture. School and church grounds offer opportunities for green infrastructure or tree-planting initiatives.



Mwarika

Image by autor

Shahaab

Shahaab
Older, established neighbourhood with a mix of formal and informal housing.
Nature: Few public green areas remain, as most open land has been encroached upon or built over.

Use: This is a mixed-use area, combining residential buildings with small businesses and light industry. The streets are busy and pedestrian infrastructure is limited, making mobility challenging.

Water & Environment: Wastewater and stormwater systems are often overwhelmed during heavy rains. In response, some residents have created makeshift channels to redirect water. Illegal dumping is frequently seen in the remaining open spaces.

Future: There are opportunities to train the community in stormwater management and introduce nature-based infrastructure along roads or rivers. Small multifunctional open spaces could be developed to manage flooding while also providing recreational areas.

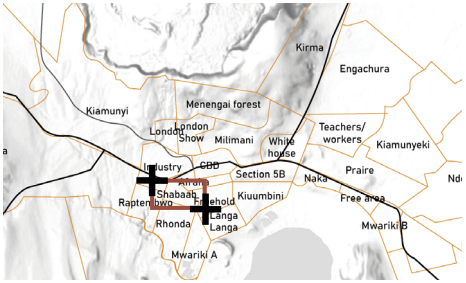


Image by autor

Afraha

Nature: Drier and bare areas, sparse vegetation contribute to soil erosion and surface runoff issues.
Use: there is a new football station.

Image by autor

To conclude, for all these neighbourhoods, it is essential to work with existing community structures and to recognise the unique role that nature plays. Some areas (Menegai) have rich natural value but face pressure from deforestation, unregulated use and incomplete protection efforts. Others (CBD, Rhonda, Shaabab) are heavily urbanized with limited or poorly maintained green spaces. Water management strategies must respond to the specific conditions of different areas. It is important to differentiate between upstream, midstream and downstream designs. This is supplemented by Ecopolis' Responsible City theme (Tjallingii, 1995), which advocates for managing urban flows (like stormwater and greywater) within ecological boundaries.
Conversations with local communities revealed that nature is often valued more for its direct benefits, such as wood, water and fish, than for its indirect contributions like clean air, climate regulation, or ecological health. Therefore, I want to design with nature in a way that direct benefits are visible.
By acknowledging these spatial and ecological differences, it becomes clear that Nakuru requires a flexible, participatory and context-specific approach.

Key findings this chapter

Learn from Precedents, I learned to engage existing community structures in co-design, management and maintenance of nature-based solutions. Medellín shows how corridor-based greening can support air quality, urban cooling and biodiversity recovery, but also outdoor recreation. Kitui demonstrates how small-scale, affordable water-sensitive urban design interventions can be effective, especially when communities are engaged in co-design and implementation.
Africa Wood Grow gives us an example of a project in Kenya. Tree planting can improve biodiversity, water retention and soil quality. This project also shows a way of community engagement, the use bottom-up approaches as shown in Kitui (Sponge Town) and African Wood Grow, ensuring solutions are socially embedded. These examples support the idea of a "Living City" (Tjallingii), where urban areas must serve as healthy habitats that are shaped by local ecological potential; climate, water, soil and vegetation.
From my site visit and spatial analysis, I distinguish between upstream (e.g., Menengai), midstream (e.g., CBD, Afraha) and downstream (e.g., Rhonda, Langa Langa) areas with differing water flows and ecological needs. There is a need for a flexible and adaptive urban framework. Design should be adaptive to seasonality (e.g., Nakuru's dry winters), able to retain water in wet periods and reduce runoff in rains.

To succeed, these interventions must also be socially embedded. Engaging existing community structures in the co-design, management and maintenance of nature-based solutions reflects the essence of the "Participating City" in the Ecopolis model.

Applying the findings: Green-blue design

In designing resilient urban environments, there is a growing need for both systemic and site-specific approaches that integrate blue-green infrastructure and nature-based solutions. These strategies not only address environmental challenges such as flooding, drought and urban heat, but also bring co-benefits like public green space, recreation and improved air quality (Blue-Green Team, 2020). Water emerges as a key structuring element in urban resilience, linking natural and urban systems across entire catchments. Recognise cities as part of larger hydrological systems. Stormwater needs to be stored or discharged based on runoff intensity and drainage capacity. Importantly, infiltration systems significantly delay water flow, making them vital in managing stormwater sustainably (Blue-Green team, 2020).

Inspired by Miguez et al. (2024), urban green-blue management can enhance resilience by differentiating strategies across the catchment. In upstream areas, the focus is on protecting natural retention zones like hillsides and forests while avoiding dense development. Midstream areas should integrate green and permeable spaces into urban growth, with multifunctional parks that manage floodwaters and offer recreational benefits. Downstream, attention shifts to controlling discharge, improving drainage systems and ensuring water quality before release into larger bodies like lakes or rivers.

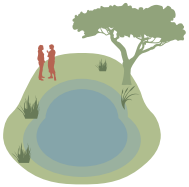
Design principles

How will the city of Nakuru become more resilient and regenerative in the future?

Ecological regeneration

Restore green areas using native vegetation to enhance biodiversity and water infiltration.

Multifunctional design

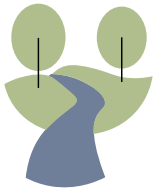


Create multifunctional water retention areas for flood mitigation with public use

Purpose-driven protection

Protect natural areas by assigning a purpose

Systemic design approach

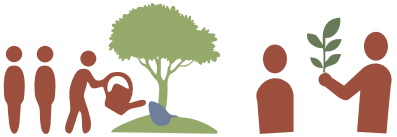


The framework follows a systemic approach based on the natural watercourses of run-off water.

Water as structuring element

Green-blue networks to enhance water retention, improve urban resilience and cool the city

Community and care



Engage local institutions for long-term greening and care

Building blocks

The regenerative design framework for Nakuru is translated into a series of spatial building blocks. Each building block represents a specific intervention that addresses multiple dimensions of regeneration; combining water management, ecological restoration, social value, productivity, and health benefits.

The socio-productive interventions directly support local communities by providing space for urban agriculture, education, and social gathering.

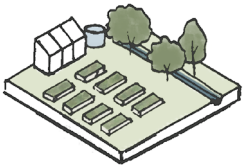
The ecological infrastructure blocks strengthen ecological connectivity and habitat restoration, by reintroducing native vegetation and connecting fragmented green spaces, these interventions restore ecosystem functions, enhance biodiversity, and improve infiltration capacity.

For water management interventions, water is treated as a structuring element, guiding the placement of green infrastructure that retains, stores and filters water across the landscape. These elements allow for controlled runoff, improve water quality, and reduce flood risks while providing public amenities.

Stakeholder engagement further shaped the design, with schools activly engaging in educational gardens, communities emphasizing food production and social space and local authorities identifying locations for public parks that integrate water management.

Each building block is grounded in both systemic regenerative principles and the specific spatial and social realities of Nakuru.

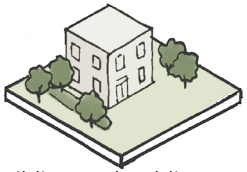
Socio-economical



Community garden

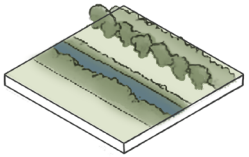
School garden

Agroforestry

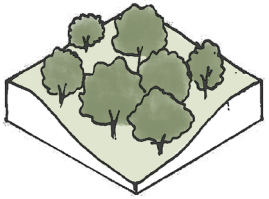


Building and public space

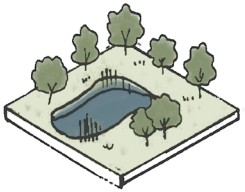
Ecological Infrastructure



Nature inclusive corridor

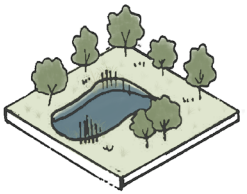


Indigenous trees

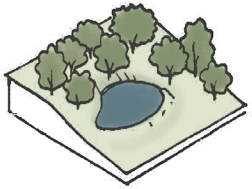


Water retention and park

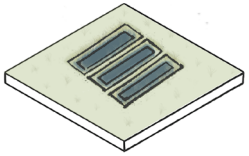
Water management



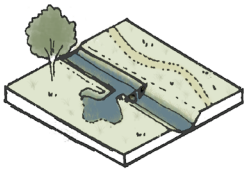
Water retention and park



Retention pond



Water filtration ponds

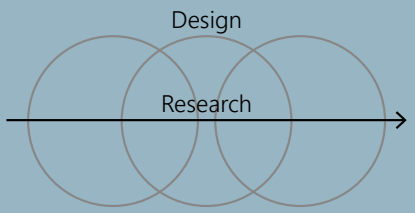


Slow delay

04*Research by design*

s-RQ 3 Which spatial-ecological interventions are appropriate to restore ecological balance in this specific social-economic and environmental conditions/problem?

In this chapter the design principles and other research findings become spatial. First conceptual then a more detailed plan. A watershed approach for 3 different catchment areas is explained.



Vision

How will the city of Nakuru become more resilient and regenerative in the future?

This framework envisions a green-blue network running through the city, connecting Nakuru's inherent value with beautiful and ecologically valuable sites through nature enhancing the community's well-being. This green-blue network enhances water retention, improves urban resilience and fosters a deeper relationship between people and place.

The framework follows a systemic approach based on the natural watercourses of run-off water. Three different areas are identified based on water flow: The upland area, which is steep and green (such as forest edges and hillsides), the midstream area, which is flatter and more densely built (like the CBD) and the downstream area, which is even flatter and prone to flooding, where the lake receives and discharges water In these area there is no river, but the areas are categorised by run-off streams. Manage water at the catchment scale by retaining it upstream through vegetation, reforestation and open water storage. Strengthen the CBD's resilience through regreening, allowing downstream areas to benefit from delayed, better-managed water flows.

Protect natural areas by assigning a purpose that is relevant to the communities over there, such as spiritual use, recreation, food source or education. Where that is not feasible, protective zones can be established through controlled access, for example, by fencing where appropriate.

Create multifunctional water retention areas that combine flood mitigation with public use, such as a water retention park.

Expand and restore green areas using native vegetation to enhance biodiversity and water infiltration.

Engage local institutions for community-driven greening efforts to ensure knowledge-sharing and long-term care.

In this vision I want to connect the green areas a the edges of the city with more green on the inside. This improves biodiversity, but also the water retention and living qualities. Another connecting green corridor is from North to South to connect the Menegai forest with lake Nakuru. This forms bridges for wildlife but also cleans the run-off. The existing Njioro and the other seasonal rivers have Green-blue connections. In the east the forest protector zone is created.

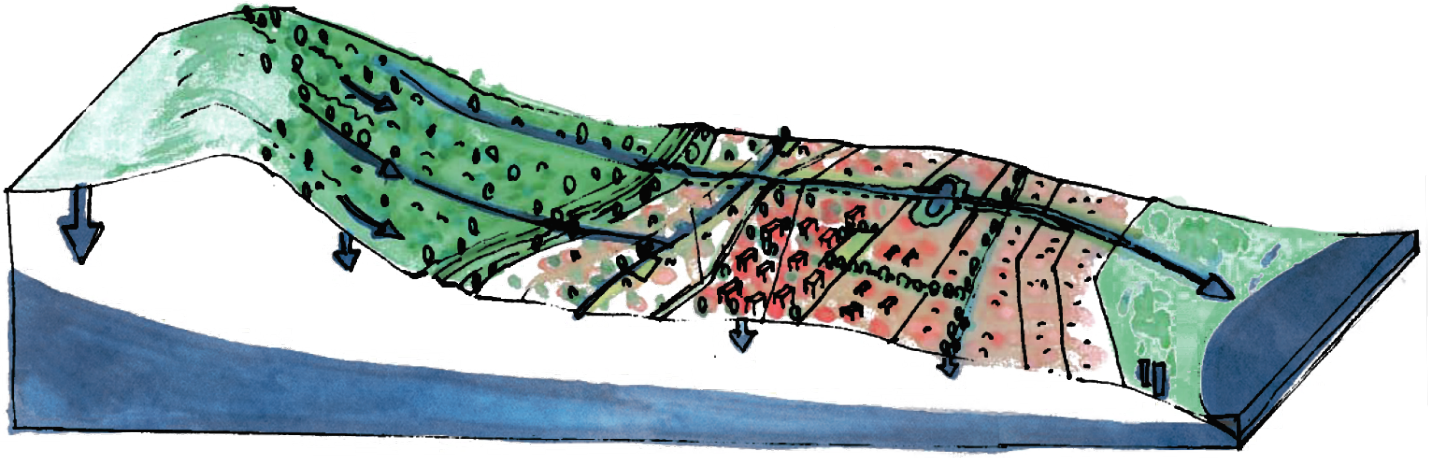
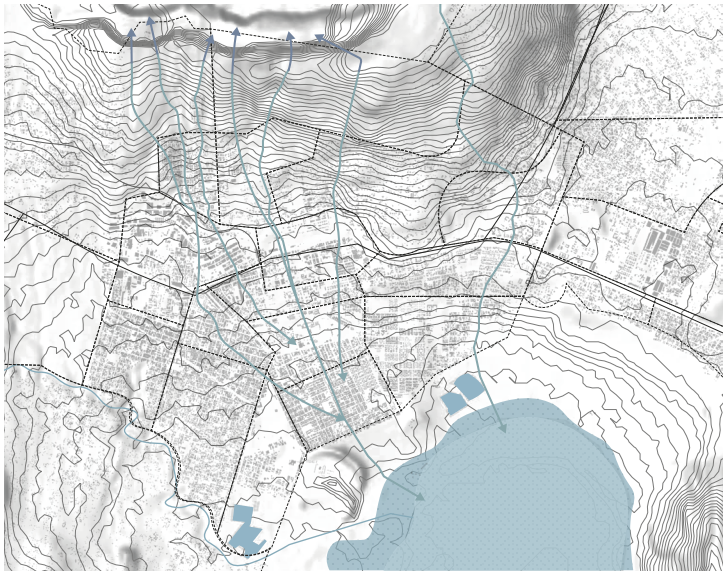


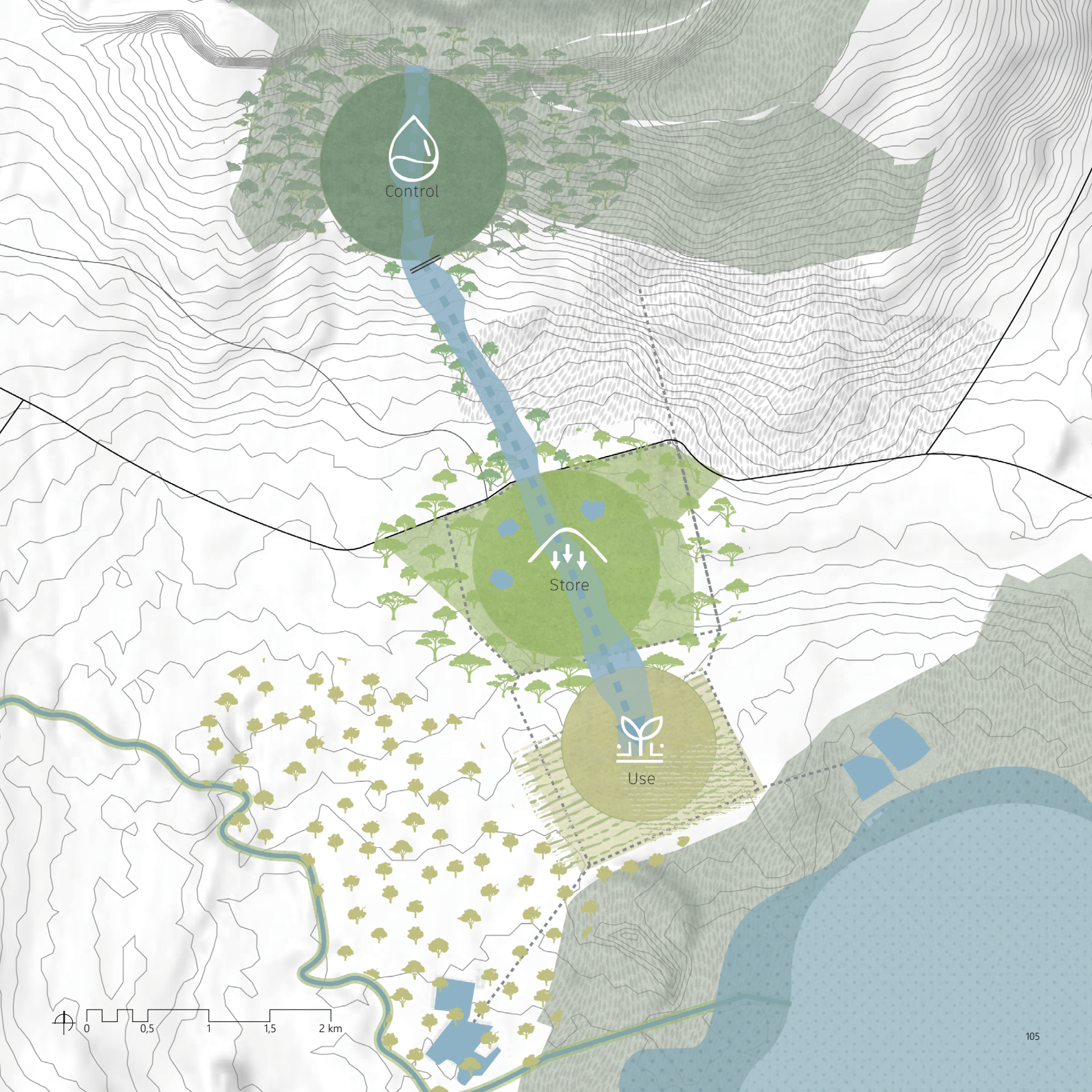
Image by author

Concept

The regenerative urban landscape framework follows Nakuru's natural catchment logic, structured into three zones: Control (upland infiltration and slope stabilization), Store (midstream retention and green-blue urban networks), and Use (downstream multifunctional agriculture and productive landscapes). Water flows from the upland forested zones towards urban centers and into agricultural and wetland areas, with each zone addressing both ecological and social functions to create a resilient urban landscape.



Natural water flow


Control
Store
Use
0
0,5
1
1,5
2 km

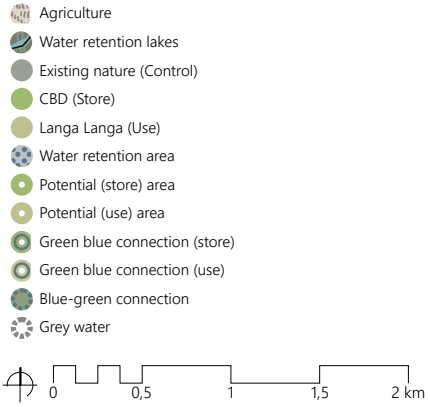
Masterplan

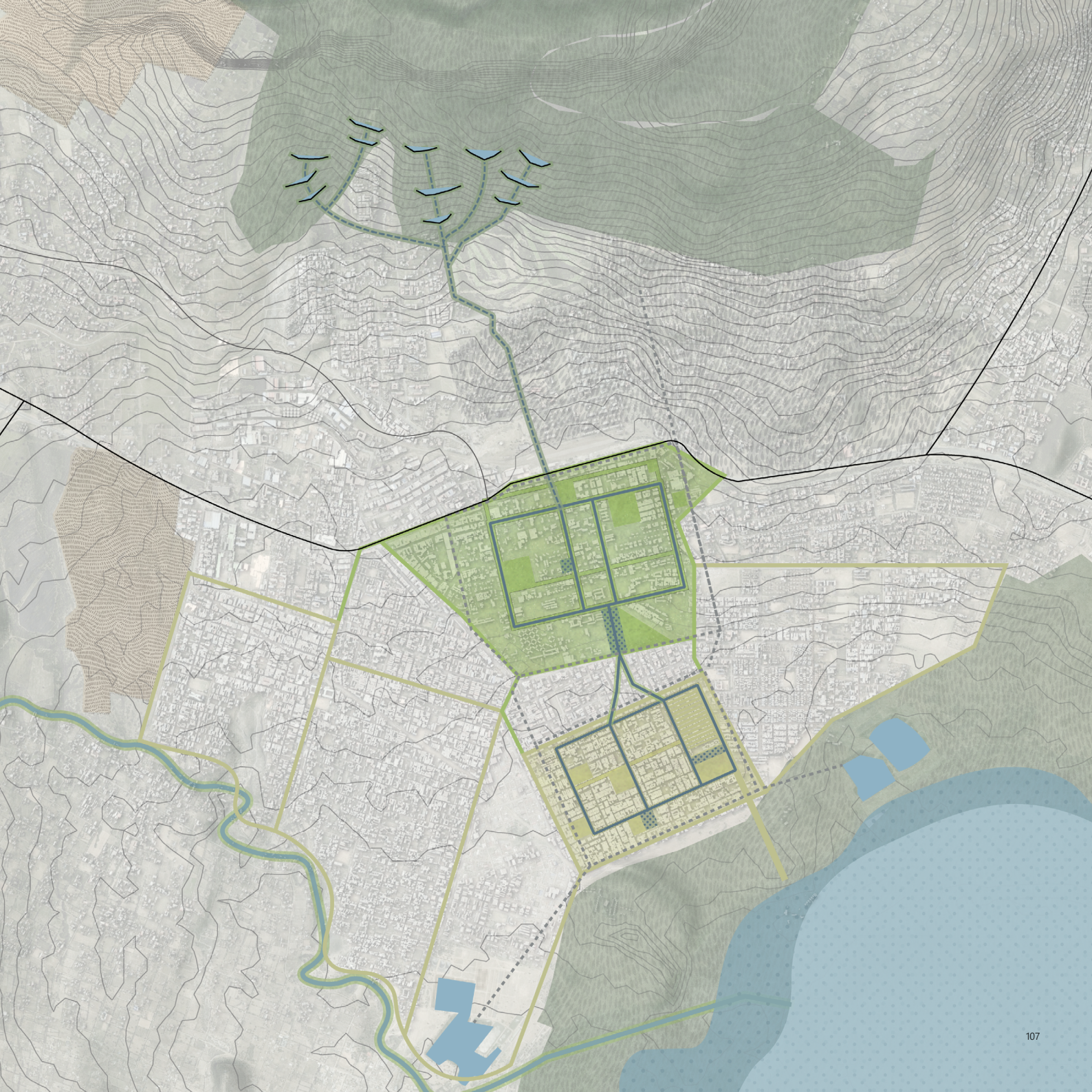
This vision guides Nakuru's growth by restoring the city's connection to its natural systems. Building on the flow of water through the landscape, the design establishes a green-blue network that captures rainfall, filters runoff, and supports biodiversity across the urban fabric.

Urban growth is organized around this network, where water becomes the structuring element. In upland zones, forests and retention areas capture runoff. In the urban core, green spaces store and filter water, while downstream, water is reused through productive landscapes like agriculture and wetlands.

The design integrates biodiversity restoration, water management, and social spaces into multifunctional interventions that foster resilience. Local institutions and communities play a key role in maintaining and co-owning these spaces, ensuring long-term care.

Rather than separating urban development from ecology, this regenerative framework allows Nakuru to grow within the capacity of its landscape, transforming challenges into opportunities for ecological renewal, social well-being, and climate resilience.





Design strategy

The three zones can be categorised: Capture, store and use.

1. Control / Capture (Upland – Steep & Vegetated)
In the upland zones, forest edges and hillsides, the main goal is to slow and capture runoff before it enters the urban core. Interventions include:

- Reforestation with native species (replacing invasive eucalyptus).
- Check dams, swales and open water storage.
- Erosion control measures.
- Install fencing or controlled access to prevent land encroachment.
- These areas support resilience, ecological and touristic value.

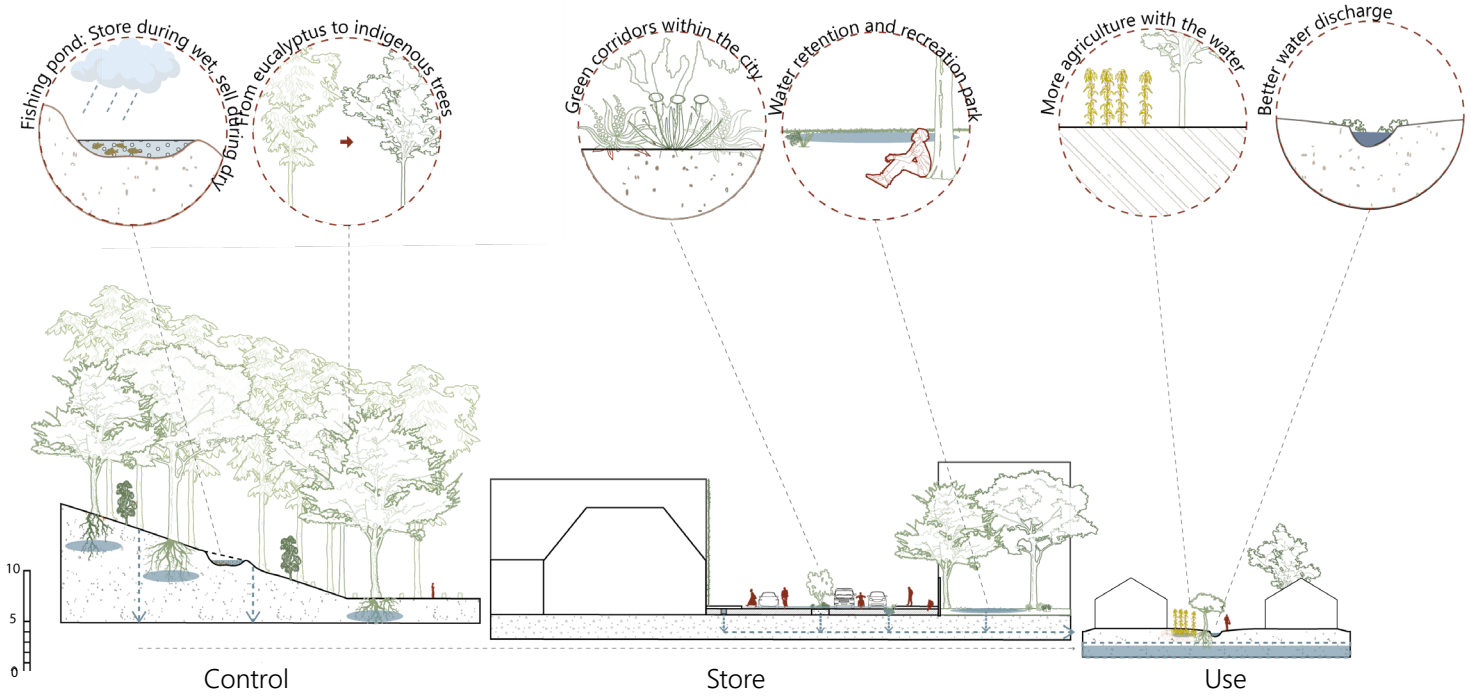
2. Store (Midstream – Urban & Dense)
Midstream areas like the CBD serve as zones of temporary storage and urban greening.

- Multifunctional green parks for drainage retention and recreation.
- Permeable paving and to store and filter water.
- Slow down drainage

3. Use (Downstream – Flat & Flood-Prone)
In the downstream areas near the lake, this area has water excess during heavy rain, worsened by the lake's rising.

- Urban agriculture uses the water in a way that serves a direct purpose
- School grounds and public spaces are partly used for urban agriculture. This has an additional purpose of education and maintenance.

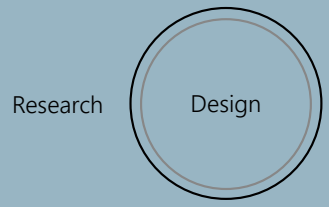
To promote ecological health and deliver social benefits through multifunctional green spaces. This strategy ensures that each part contributes to a system-wide, regenerative urban future.


Fishing pond: Store during wet, sell during dry
From eucalyptus to indigenous trees
Green corridors within the city
Water retention and recreation park
More agriculture with the water
Better water discharge
10
5
0
Control
Store
Use

05 *Design strategy*

s-RQ4: How can the proposed regenerative urban framework translate into spatial strategies and design interventions for Nakuru, fostering ecological balance and sustainable urban expansion?

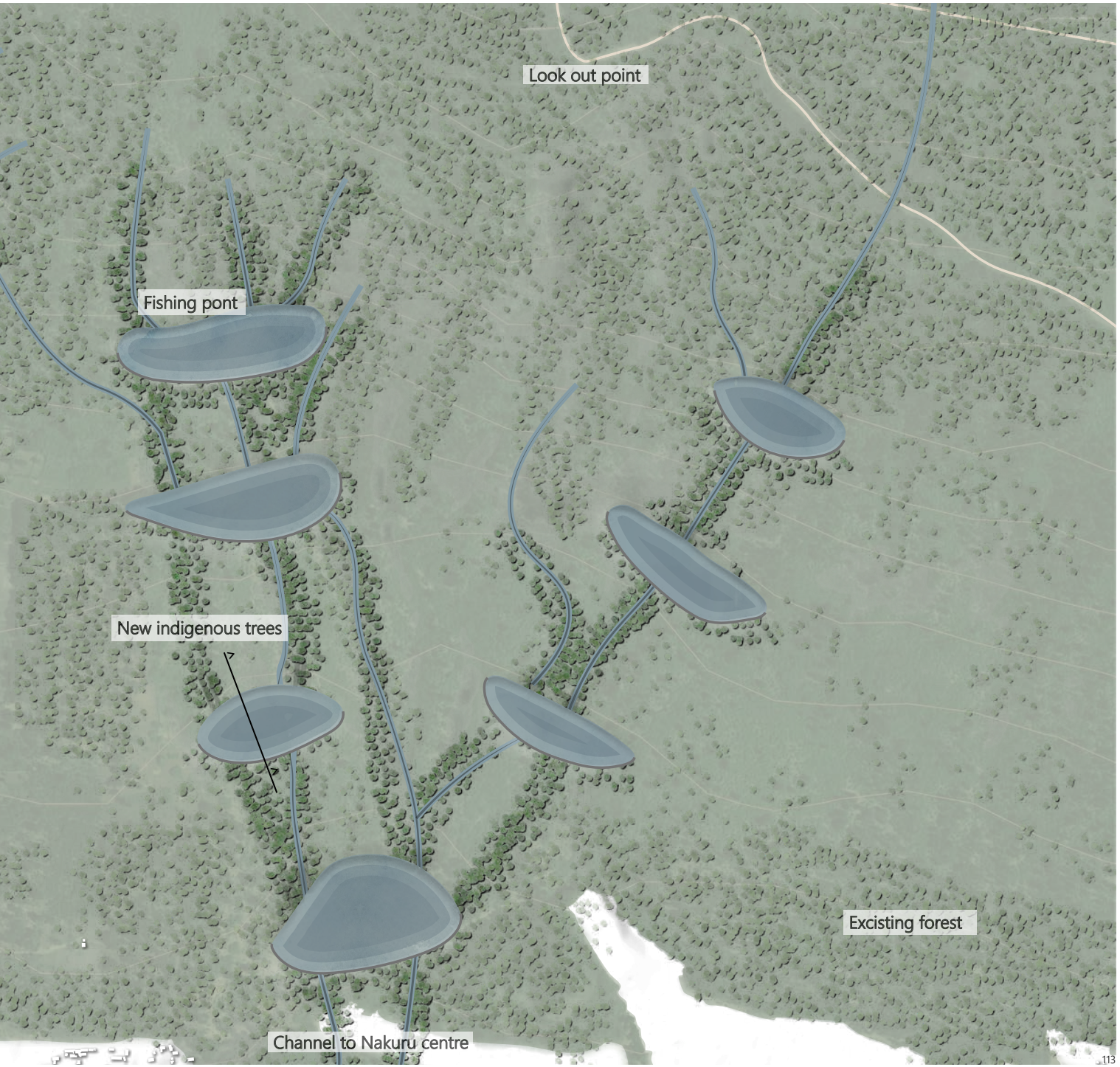
Detailed explorations of three key intervention areas: CBD, Langa Langa, and Menengai Crater. This chapter demonstrastes how regenerative principles are applied at a human and ecological scale.



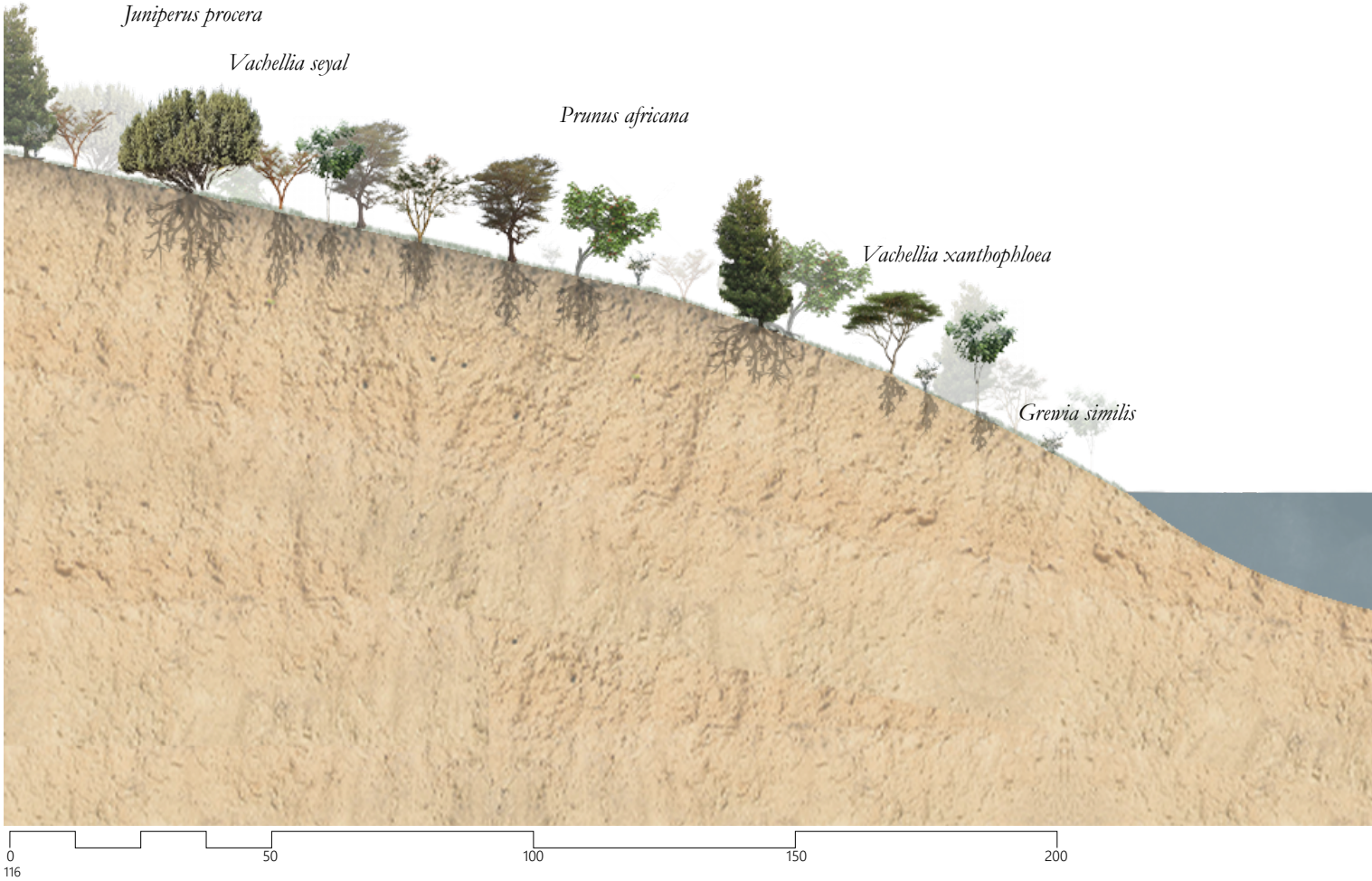
Site-Specific proposals

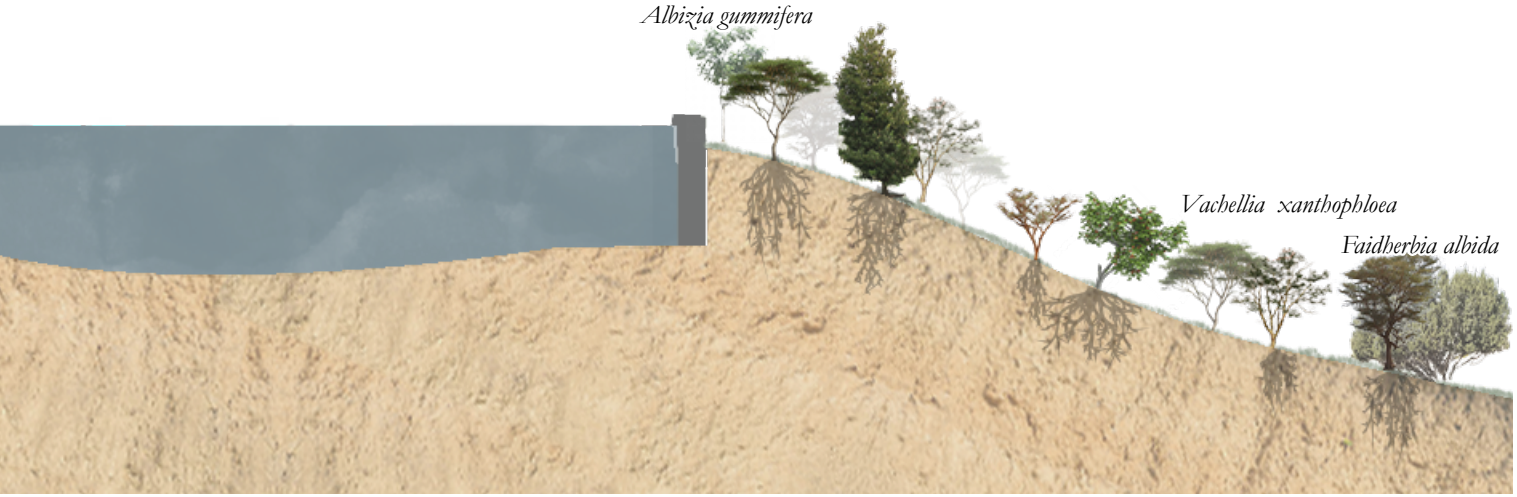
Control: Menegai crater

Here we store water. Some of these ponds are combined with fishing to make it even more bankable. The water is stored here during the wet season and distributed during the dry season. The money gained can be used to change the Eucalyptus trees to indigenous trees that retain water better and fit in this ecosystem.


Look out point
Fishing pont
New indigenous trees
Excisting forest
Channel to Nakuru centre

Section Menegai crater

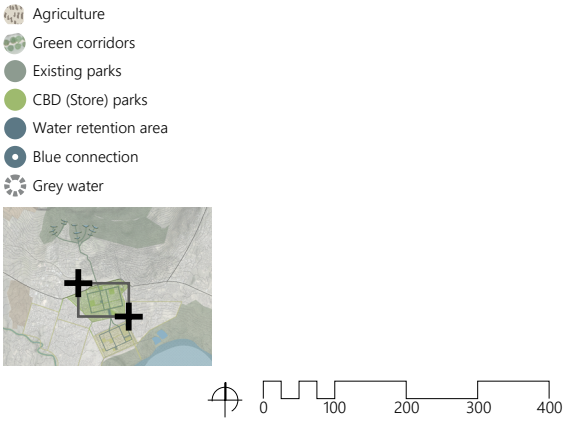



Albizia gummifera
Vachellia xanthophloea
Faidherbia albida

Site-Specific proposals

Store & Regreen: CBD

The CBD is densely built, with large areas covered by impermeable surfaces. The areas that are still free should have a public function, but also a water retention function. For new developments, a balanced approach is recommended: 50% of the site can be built up, while the remaining 50% should be preserved as open, green space to support infiltration and urban cooling. Drainage channels in the area should be redesigned to slow water without blocking flow. This can be achieved through blue-green corridors and the integration of retention pockets or loops along the drainage paths, helping to buffer runoff while enhancing ecological and social value.



Inled

Water retention park

Green + buildings mix

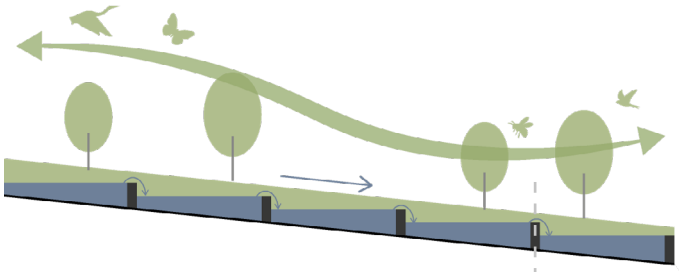
Green + buildings mix

Water retention park

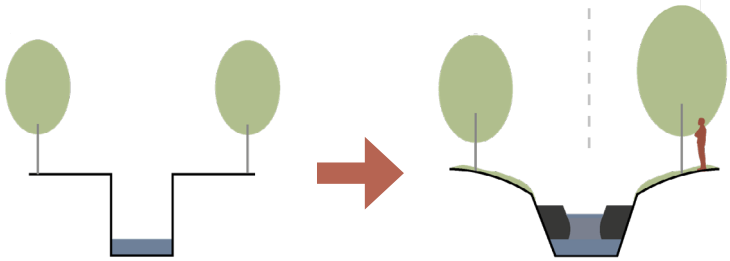
Water filtration

Green + buildings mix

Outled to Langa Langa



Slow drainage with weirs



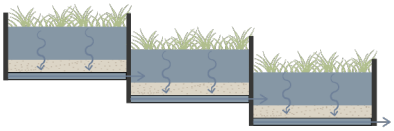
Old and new drainage channels

Weirs in the drainage channels

To slow down water drainage, weirs are added so that water is held along the entire channel. Currently the most floodings are were drainage channels meet, as most are not following the elevation, but roads. This means that some channels are parralel to the elevation.

From my site visit, I learned that previous renaturation measures had failed because the water flowed too fast. This design intervention helps slow the water down and improve retention.

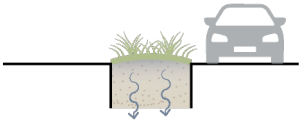
Along the channel, green areas are created. The current paved surfaces are replaced with softer, vegetated banks. A walk along this green-blue connection is encouraged, creating space for people to experience water and nature in the urban core.



Water filtration

Water retention and filtration park

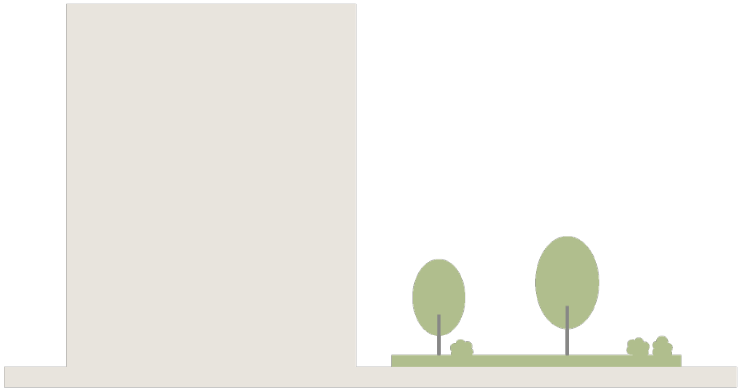
At the south of the CBD area, water is gathered and filtered through a series of water filtration ponds. During the dry season, water from other parts of the area can be retained and directed to these ponds to prevent the filtering vegetation from drying out.



Green buffer near road

Green corridors

In the dense urban area, streets are narrower and paved. Removing part of this pavement in these areas improves water retention, while adding vegetation helps enhance air quality and provides cooling.



New building mixed with green

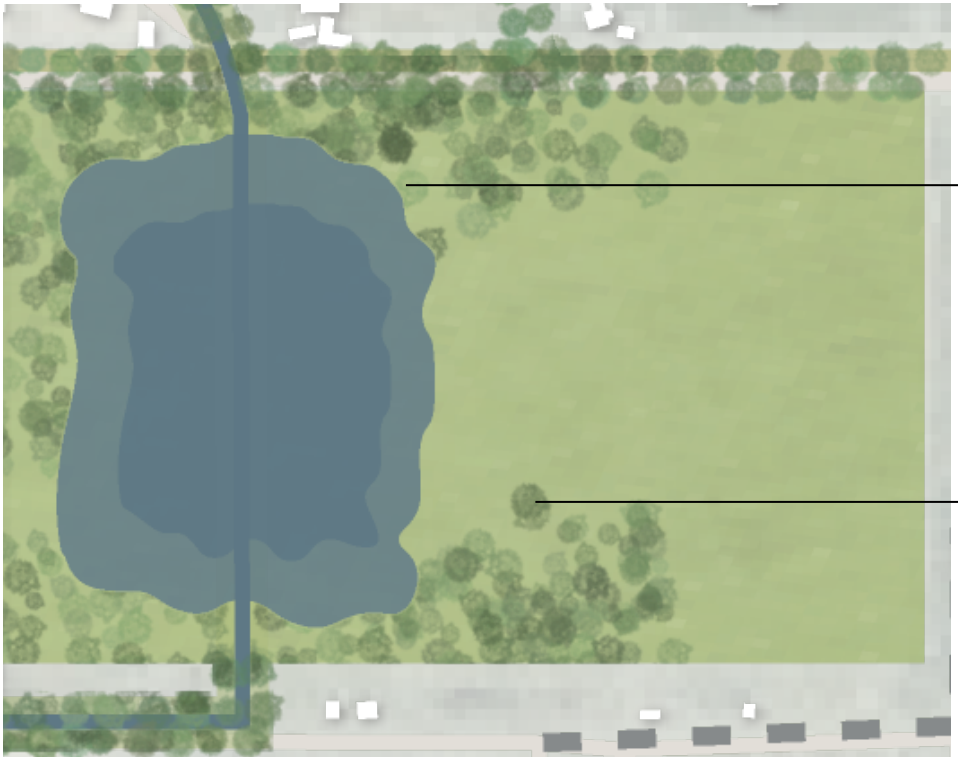
Mixed uses

With the municipality not owning that much ground in the dense urban core, management rules are important. New developments in the CBD are designed with a balanced ratio of built and open space. A mix of buildings and integrated green areas allows for water infiltration, shade, and improved living conditions for everybody. These green pockets not only enhance biodiversity but also create a healthier, more pleasant urban environment. For this mostly hotels are contacted. They can benifit from a nice outside area and stakeholders like Egerton University and urban planners can help to achieve this in exchange.

Tree species

Different tree species are used in my design. For my water retention park I want tree that can handle wet and dry conditions, like the Fever tree. I also want species that make the park more pleasant, a flowering species like the Peacock flower tree is a good tree for this. This tree is higher than the Fever tree and does not need to resist really wet conditions.

Water retention park



Fever tree
Vachellia xanthophloea

Tree
River banks

Key Characteristics:
Soilstabilisation, improves water infiltration, enhances biodiversity by nitrogen-fixing, fast-growing

Flowers:
yes, late summer to autumn (can vary regionally)

Peacock flower tree
Caesalpinia pulcherrima

Tree
Drought tolerant

Key Characteristics:
Soil stabilization, improves water infiltration suitable for urban areas

Flowers:
yes, all year peak during warm dry seasons.

Selected species for water retention parks

Zone	Species (Common / Scientific Name)	Type	Flowers	Flowering Season	Key Characteristics	Native To	Leaves	In CBD Ecotype List?
Drier Mid-high	Chloris gayana	Grass	Varies	Varies	Forage grass, tolerant to dry periods	Upland, dry meadows	Loses leaves in drought	Yes
Mid	Buffel Grass (Cenchrus ciliaris)	Grass	Varies	Varies	Grazing, erosion control	Mid-elevation dry areas	Partial leaf loss in drought	Yes
Mid	Crinum macowanii	Bulb Flower	Yes	Summer	Moisture-loving, ornamental	Wet borders	Deciduous	No
Mid to Wet	Vetiver Grass (Chrysopogon zizanioides)	Grass	Yes	Late summer	Erosion control, drought-tolerant	Slope stabilization	Drought-tolerant	No
Mid to Wet	Canna indica	Herbaceous	yes	Sping-autumm	Water tolerant	Rain gardens	Evergreen wet condition	no
Shaded/ moist	Commelina benghalensis	Groundcover	Yes	Year-round	Fast spreading, under canopy	Shaded groundcover	Evergreen	No
Shaded/ moist	Impatiens hawkeri	Flowering underestory	yes	Sping-autumm	Shade loving	Understory	Evergreen	no
Wet	Mimosa pigra	Shrub	Yes	Late summer	Nitrogen-fixing, invasive potential	Wetlands, riparian areas	Semi-deciduous	No
Wettest (Low)	Cyperus papyrus	Shrub	Yes	Year-round	Water retention, habitat creation	Wetland edges, retention ponds	Evergreen	No
Wettest (Low)	Typha domingensis	Shrub	Yes	Year-round	Water purification, dense cover	Wetland zones	Evergreen	No

Chloris gayana

Buffel grass

Crinum macowanii

Vetiver grass

Canna indica

Impatiens hawkeri

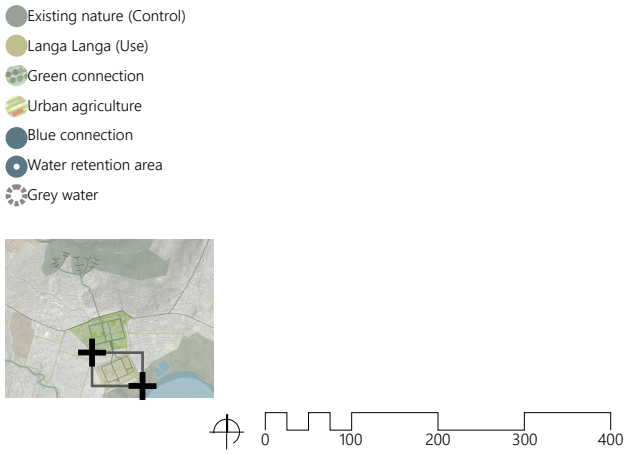
Mimosa pigra

Cyperus papyrus

Site-Specific proposals

Use: Langa Langa

In this area, green spaces are scarce. They experience a big excess of water from the drainage and the lake. The population is primarily composed of middle- and low-income communities, where nature without a clear function will be given the function of firewood. To respond to these challenges, urban agriculture is introduced, using the excess water for growing food while enhancing local resilience. Public spaces such as school grounds and community open areas are partially allocated for this purpose.



Inled of filtered water from CBD

Water retention park

Water retention park

Food forest

Water retention park

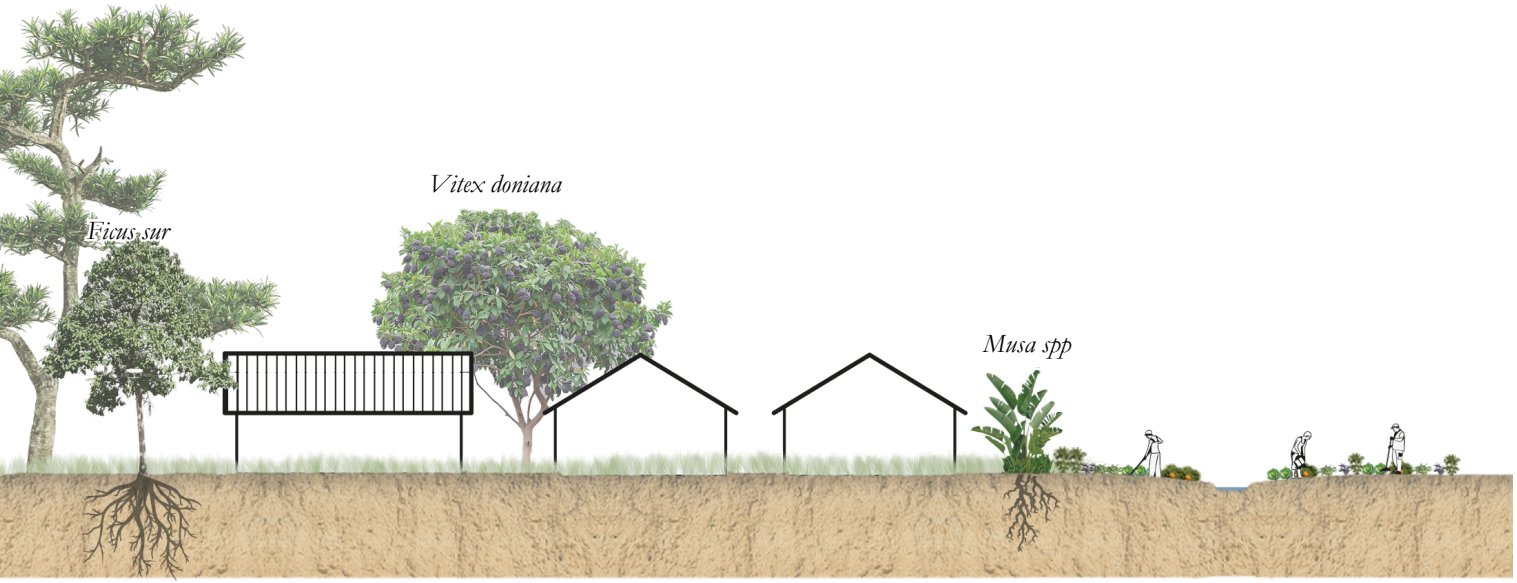
Entrance to Lake Nakuru

Agroforestry, the integration of trees into farming systems, offers a wide range of ecological, economic, and social benefits that are particularly relevant to Nakuru's diverse landscapes. Given Nakuru's varying topography and land- use practices agroforestry provides a nature-based solution that aligns well with climate-smart agriculture strategies (Tracextech, 2024)

Schools can play a crucial role for implementation of gardens combining education with practical action. In Nakuru, where prolonged drought, deforestation and climate change threaten the environments involving students in sustainable land management equips them with essential skills in farming, water conservation, biodiversity, and environmental stewardship. Initiatives such as school gardens, allow students to practice climate-smart farming techniques while contributing fresh food for their families (FCA Kenya, 2025). Programs for implemting school gardens further show how schools can serve as community hubs, promoting organic farming, nutritional health and ecosystem restoration (Transforming 12 Schools in Kenya Through Life Gardens, n.d.). Engaging schools ensures that environmental knowledge is passed to future generations while directly supporting food security and climate adaptation efforts today.


F for Flowers

Section Langa Langa

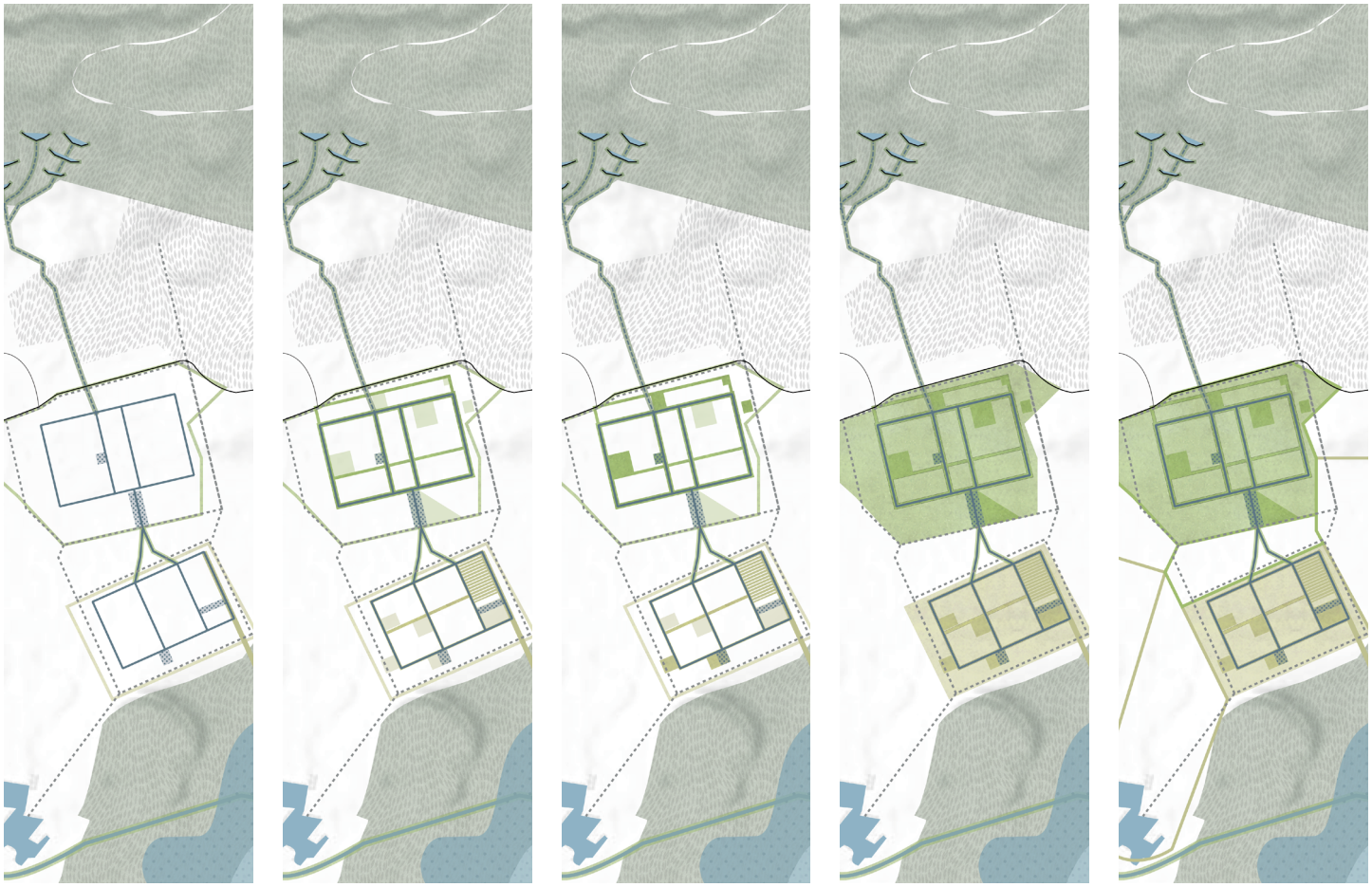

Vitex doniana
Ficus sur
Musa spp

Planting list Agroforestry Langa Langa

Layer	Species (Common / Scientific Name)	Function	Planting Time	Harvest Months	Notes	Source
Cover Crops (Groundcover)	Pumpkin (Cucurbita spp.)	Fruit & cover crop	March	July–August	Soil cover, high value	Maundu (2024)
Cover Crops (Groundcover)	Gourds (Lagenaria siceraria)	Cover crop	March	July–August	Drought tolerant	Maundu (2024)
Cover Crops (Groundcover)	Watermelon (Citrullus lanatus)	Fruit & cover crop	March	July–August	Moisture-dependent	Maundu (2024)
Fruits (Shrub Layer)	Strawberries (Fragaria × ananassa)	Small fruit	March	June	Groundcover fruit	Samuel & Samuel (2023)
Grains (Field Layer)	Maize (Zea mays)	Staple cereal	March	July	Main staple crop	Tracextech (2024)
Grains (Field Layer)	Sorghum (Sorghum bicolor)	Drought-tolerant cereal	March	July	Dryland resilience	Tracextech (2024)
Grains (Field Layer)	Millet (Pennisetum glaucum, Eleusine coracana)	Drought-tolerant cereal	March	July	Semi-arid zones	Tracextech (2024)
Herb Layer	Okra (Abelmoschus esculentus)	Heat-tolerant vegetable	March	June–July	Quick grower	Reforest the World (2024)
Herbs & Spices (Herb Layer)	Basil (Ocimum basilicum)	Culinary herb	March	May–June	Easy container herb	Samuel & Samuel (2023)
Herbs & Spices (Herb Layer)	Mint (Mentha spp.)	Culinary herb	March	May–June	Spreading, easy	Samuel & Samuel (2023)
Herbs & Spices (Herb Layer)	Cilantro (Coriandrum sativum)	Culinary herb	March	May	Fast growing	Samuel & Samuel (2023)
Herbs & Spices (Herb Layer)	Thyme (Thymus vulgaris)	Culinary herb	March	May–June	Drought-tolerant	Samuel & Samuel (2023)
Leafy Greens (Herb Layer)	Lettuce (Lactuca sativa)	Leafy salad green	March, Sept	May, Nov	Cool-season crop	Samuel & Samuel (2023)
Leafy Greens (Herb Layer)	Spinach (Spinacia oleracea)	Leafy green	Feb–Mar, Sept–Oct	May–June, Nov–Dec	Shade-tolerant	Samuel & Samuel (2023)

Layer	Species (Common / Scientific Name)	Function	Planting Time	Harvest Months	Notes	Source
Leafy Greens (Herb Layer)	Kale (Sukuma wiki) (Brassica oleracea var. acephala)	Leafy green	Feb–Mar, Sept–Oct	May–June, Nov–Dec	Continuous harvest	Samuel & Samuel (2023)
Leafy Greens (Herb Layer)	Amaranthus (Terere) (Amaranthus spp.)	Leafy green	March	May–June	Heat-tolerant	Anyango (2022)
Leafy Greens (Herb Layer)	Black nightshade (Managu) (Solanum scabrum)	Leafy green	March	May–June	Indigenous leafy green	Anyango (2022)
Legumes (Herb Layer)	Cowpeas (Kunde) (Vigna unguiculata)	Legume, nitrogen fixer	March	June	Drought-resistant	Anyango (2022)
Mid-story Fruit	Amalera (Vangueria apiculata)	Fruit tree	March	May–July	Drought tolerant	Reforest the World (2024)
Mid-story Fruit	Black plum (Vitex doniana)	Edible fruit, leaves	March	May–July	Multipurpose tree	Reforest the World (2024)
Shrub/Climber	Coral clusterpear (Uvaria scheffleri)	Climber, edible fruit	March	May–July	Sweet fruit	Reforest the World (2024)
Tubers (Root Layer)	Sweet potato (Ipomoea batatas)	Root & cover crop	March	July–August	Excellent groundcover	Maundu (2024)
Upper Canopy	Cape fig (Ficus sur)	Biodiversity tree	March	Year-round	Wildlife food	Reforest the World (2024)
Upper Canopy	Newtonia (Newtonia buchananii)	Shade, timber	March	N/A	Moist forest species	Reforest the World (2024)
Upper Canopy	Podocarpus (Podocarpus falcatus / latifolius)	Canopy tree	March	N/A	Native forest tree	Reforest the World (2024)
Vegetables (Herb Layer)	Tomatoes (Solanum lycopersicum)	Vegetable	March	June–July	Requires staking	Samuel & Samuel (2023)
Vegetables (Herb Layer)	Peppers (Capsicum spp.)	Vegetable	March	June–July	Needs full sun	Samuel & Samuel (2023)

Timeline



Phase 1
0-3 years

Phase 2
3-7 years

Phase 3
7-12

Phase 4
12-20 years

Phase 5
20-50 years

In the first phase, the water system is established. This system is designed with multiple loops, allowing water to be captured, reused and directed to areas where it is most needed. In the Menengai Crater area, retention lakes are created to store water during the wet season and make it available during the dry season to support downstream interventions.

During the second phase, the green-blue corridors are developed. Infiltration zones are designated to handle excess water. In Langa Langa, urban agriculture begins within the government housing areas, allowing early integration of productive landscapes into the urban fabric. In the Menegai Crater area the water ponds are finalized and used for fishing ponds. The fish and water gain more provids that lead to funds for indeginous reforesting projects

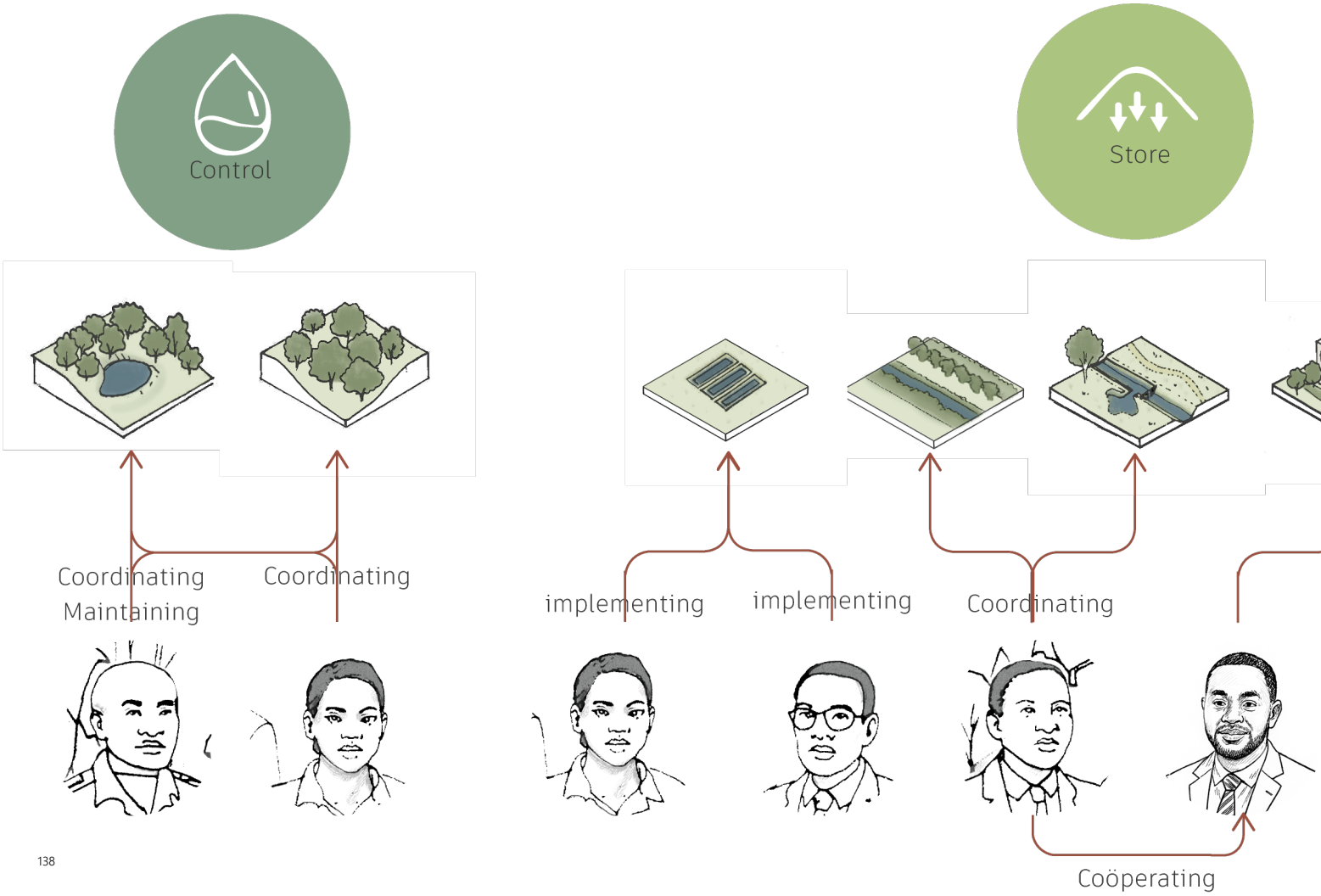
In the third phase, green water retention parks are constructed, combining green infrastructure with new buildings under a 50/50 ratio of built and green space. For example, hotels can secure prime locations if they remain accessible to the public and contribute to the green network. Universities and nature organisations actively contribute by implementing new green spaces and providing ecological expertise.

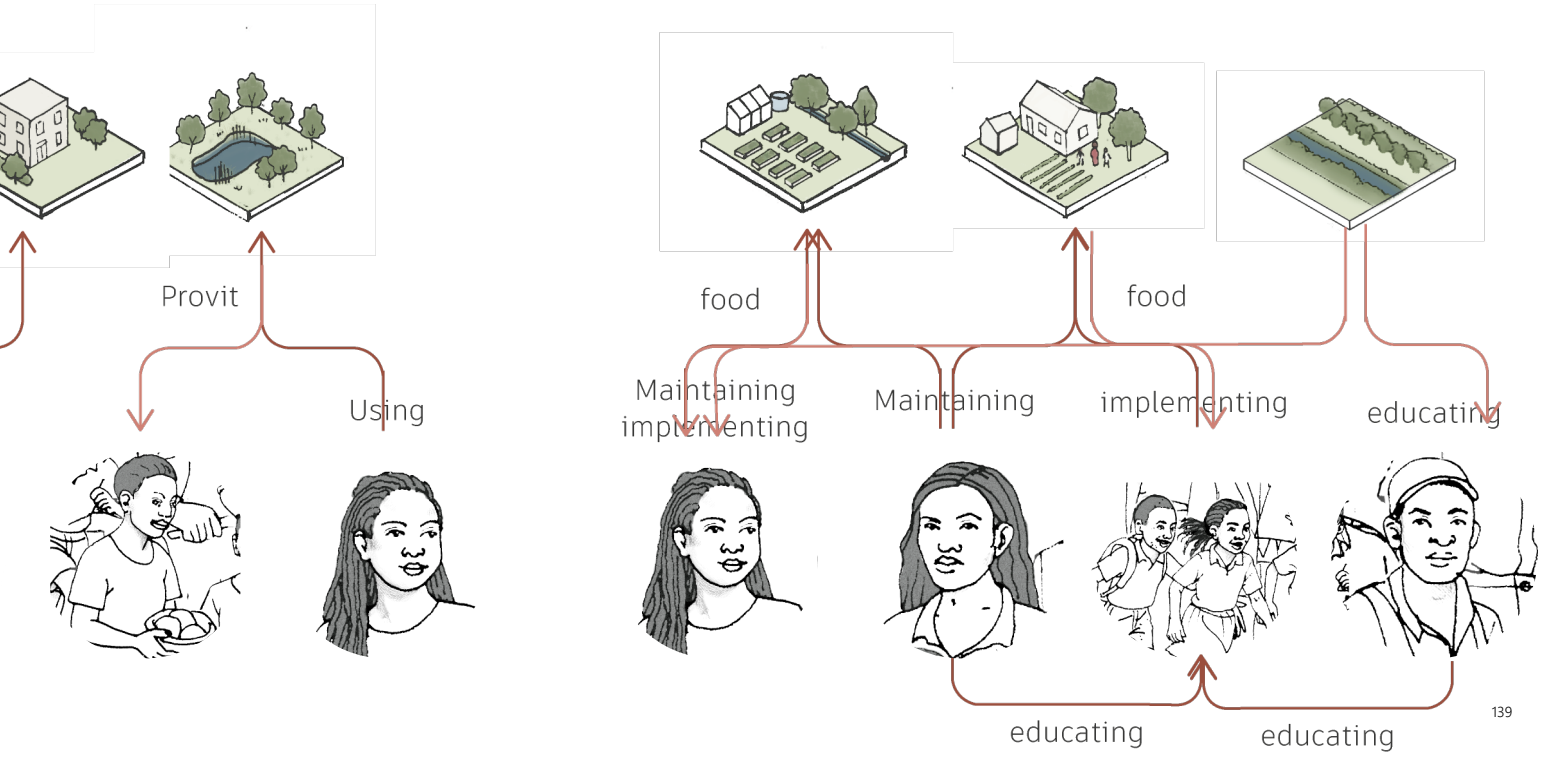
The fourth phase focuses on expansion and full system integration. The final areas are connected, creating a continuous system that links Menengai Crater to Lake Nakuru. Hydrological functions are restored, biodiversity corridors are fully operational, and multifunctional public spaces enhance both ecological health and social resilience.

The final phase represents long-term ecological maturity and adaptive management. Stakeholder governance platforms oversee ongoing maintenance, monitoring, and necessary adjustments to maintain system resilience as urban growth and climate conditions evolve. New connections are established in additional neighborhoods with similar characteristics, allowing the design principles to be replicated and adapted across the wider urban landscape.

Implementation

By mapping these roles across spatial interventions and phasing stages, the diagram illustrates the systemic complexity and collaborative nature required to successfully implement regenerative urban design in Nakuru.The diagram visualizes the integrated regenerative framework, linking spatial zones, interventions and stakeholder responsibilities. Following the Control–Store–Use logic, interventions are assigned across the watershed, while multiple actors coordinate implementation, funding and long-term maintenance.




Use
Provit
Using
food
food
Maintaining implementing
Maintaining
implementing
educating
educating
educating

Planting manual

From my site visit I have selected the following trees. This I found after visiting the Arboretum in Nairobi and talking to a botanist from Eggeton University.

Category	Species (Common / Scientific Name)	Type	Height	Flowers	Flowering Season	Key Characteristics	Suitable For	Leaves
Trees for High Water Table	Fever Tree (Acacia xanthophloea)	Tree	10–25 m	Yes	Late summer to autumn	Riverbank stabilization, enhances biodiversity	Wetlands, riverbanks	May lose leaves during dry season (June–August)
	Croton megalocarpus	Tree	10–35 m	Yes	Intermittent	Multipurpose, biofuel, deep-rooted, groundwater recharge	Urban areas, montane forests	Evergreen
	Prunus africana	Tree	10–20 m	Yes	Spring	Medicinal (prostate), fast-growing, soil stabilizer	Montane forest, urban areas	Evergreen
	Albizia gummifera	Tree	10–20 m	Yes	Late spring to summer	Soil stabilization, improves water infiltration	Urban areas, montane forests	Sheds leaves in dry season (June–August)
Riparian & Wetland Restoration	Cyperus papyrus	Shrub	2–4 m	Yes	Year-round	Wetland restoration	Wetlands	Evergreen
	Typha domingensis	Shrub	1.5–3 m	Yes (spikes)	Year-round in wet zones	Swamps, water filtration	Wetlands	Evergreen
	Phragmites mauritianus	Shrub	2–5 m	Yes (grass plume)	Late summer	Erosion control, tolerant to disturbance	Riverbanks, wetlands	Evergreen
Soil Stabilization	Giant Bamboo (Bambusoideae spp.)	Tree	10–20 m	No	N/A	Erosion control	Urban areas, flood-prone areas	Evergreen
	Vetiver Grass (Chrysopogon zizanioides)	Grass	1–1.5 m	Yes (small spikes)	Late summer	Erosion control, water retention	Slopes, urban, riverbanks	Drought-tolerant
	Chloris gayana	Grass	0.5–1.2 m	Yes	Varies	Deep-rooted, soil stabilization	Drylands, urban green spaces	Partial deciduous in extreme drought

Category	Species (Common / Scientific Name)	Type	Height	Flowers	Flowering Season	Key Characteristics	Suitable For	Leaves
	Gummigrass (Panicum maximum)	Grass	1–2.5 m	Yes	Late summer to early autumn	Moisture retention, fodder	Agroforestry, semi-arid zones	May dry during dry periods; fast recovery
	Buffel Grass (Cenchrus ciliaris)	Grass	0.5–1.5 m	Yes	Varies	Drought-resistant, fodder	Drylands, agroforestry	Partial leaf loss in drought
Agroforestry	Grevillea robusta	Tree	18–30 m	Yes	Spring	Enhances fertility, softwood, multipurpose	Urban, agroforestry	Evergreen
	Faidherbia albida	Tree	15–25 m	Yes Agroforestry, semi-arid	Late dry season	Improves soil fertility and moisture	Agroforestry, semi-arid	Reverse deciduous (sheds during wet season)
	Moringa oleifera	Tree	4–8 m	Yes	Multiple times/year	Fast growing, medicinal, drought-adapted	Drylands, urban agroforestry	Loses leaves in prolonged drought
Wastewater Treatment	Moringa oleifera (repeated)	Tree	4–8 m	Yes	Multiple times/year	Antibacterial, water edge use	Water treatment, wet zones	Same as above
Urban Ornamentals	Corn Plant (Dracaena fragrans)	Shrub	4.5–15 m	No	N/A	Evergreen, slow-growing, good for shading courtyards	Urban areas, courtyards	Evergreen
	Poinsettia (Euphorbia pulcherrima)	Shrub	0.6–4 m	Yes	Fall to Winter	Decorative plant, mildly toxic	Residential gardens	Seasonal leaf colour change
	Pomegranate (Punica granatum)	Shrub	1.8–6 m	Yes	Summer	Edible fruit, ornamental value	Urban gardens, edible landscaping	Deciduous

Top 20 most common trees in Kenya. (n.d.). (Plantitude Kenya, n.d.)

Karibuni Nakuru!

06 *Conclusion*

A summary of the key findings, the meaning of a regenerative framework and my research process.

Conclusion

This thesis explored how a regenerative urban landscape framework can support ecological resilience and water management in the rapidly urbanising city of Nakuru, Kenya.
The city is located between the two ecologically valuable zones: Menengai Crater and Lake Nakuru.
Key problems include:

- Water issues: seasonal flooding during the wet season, water scarcity and polluted water from urban runoff.
- Environmental issues: habitat fragmentation, illegal logging, and the degradation of ecological systems.
- Urban pressures: rapid population growth, increasing impervious surfaces, and the urban heat island effect.

These issues have disrupted natural systems and degraded both biodiversity and human well-being.

To address these, the research applied a research-by-design methodology, guided by the central question:
What regenerative urban landscape framework guides Nakuru's growth while restoring biodiversity and managing water flows?
The framework integrates three core lenses:
Regenerative landscape principles:

- Systems thinking
- Co-evolution of humans and species
- Participatory governance
- Circular flows

Ecological priorities:

- Connected green infrastructure
- Biodiversity
- Ecosystem services

Water-sensitive strategies:

- Water retention
- Stormwater management
- Slowing drainage to support infiltration

These concepts were applied through landscape-based planning, informed by theoretical models including Tjallingii's Ecopolis, Cheshire's regenerative principles, and Tillie's habitat-species-system framework. These theories informed the first set of design principles: adopt systems thinking, connect through local potential, co-evolution and multi-functional area use with water retention and public space.

Fieldwork and spatial analysis reinforced the need for integrated, nature-based water strategies that go beyond conventional engineering. Precedents like Medellín's green corridors and Kitui's community-scale water systems demonstrated the power of multifunctionality, community ownership, and ecological restoration in guiding design.
From this, I changed the set of design principles to:

- Combine water retention with urban agriculture and public space.
- Use stormwater as a structuring element for spatial design.
- Design multifunctional spaces that meet ecological, social, and hydrological needs.
- Assign meaningful functions to nature to ensure protection and local stewardship.
- Engage local institutions for community-driven greening efforts to ensure knowledge-sharing and long-term care.
- Restore ecosystems using native vegetation to improve biodiversity and water infiltration.
- Establish a Green-Blue Network: Connect outer green areas and West-East and a North-South connection, Menengai and Lake Nakuru with the urban core through corridors that support wildlife movement, stormwater filtration, and urban cooling.

My vision showed the framework, which was spatially structured around three hydrological zones; upland, midstream, and downstream, based on the natural watercourses of run-off water. Each zone was assigned a function within the regenerative logic of capture, store, and use, making interventions both ecologically grounded and spatially adaptable.
These principles were applied in three zoom-in areas:

- Menengai Crater (Capture/Control): Focused on reforestation, water retention, and erosion control.
- CBD (Store & Regreen): Densely built area where stormwater is stored and filtered through blue-green corridors and public parks.
- Langa Langa (Use): A flood-prone, low-income area where water is reused in urban agriculture integrated with schools and community institutions.

In this area there is no river, but the areas are categorised by run-off streams.

This regenerative framework demonstrates that urban design can do more than reduce environmental impact. It can actively restore natural systems, support social resilience, and improve long-term liveability. While the design is tailored to Nakuru's unique conditions, its principles are adaptable to other cities in the Global South facing similar socio-ecological pressures.
Ultimately, this thesis contributes to the growing field of regenerative urbanism by offering a place-based, systems-oriented design strategy. It shows that regeneration is not a one-time solution, but a continuous, collaborative process of repair, co-creation, and adaptation, shaping landscapes where both humans and ecosystems can thrive.

Recommendations

The research also highlights the advantages of systems thinking in regenerative urban design. Recognising the connections between nature of water management, biodiversity, infrastructure and social dynamics, systems thinking creates integrated solutions that deliver multiple co-benefits across multiple dimensions

To advance this work, further research is needed. For the city itself the institutional, legal and governance structures should be further investigated as they influence the feasibility of implementing integrated green-blue infrastructure. Modelling of hydrological, ecological and socio-economic impacts will help to evaluate the long-term effectiveness of regenerative interventions under different growth and climate scenarios. These size of the ponds in the Menegai crater need to be meassured, what is necessarry for the rest of Nakuru? This will help with even more adaptive management that can respond to changing conditions over time.

For implementation in Nakuru, the establishment of multi-stakeholder governance platforms is recommended, involving the municipality, NAWASSCO, schools, NGOs, businesses and community organisations. Invest in training programs for ecological management, participatory governance, and technical maintenance, with strong involvement of local institutions such as Egerton University. Schools can serve as demonstration sites for regenerative design, where multifunctional gardens integrate stormwater retention, soil infiltration, food production and shaded recreation, using native climate-adapted species.

For the Global South, solutions should be on different scales and must be highly adapted to local ecological, social and institutional conditions. Flexibility and adaptability are essential, allowing phased implementation, continuous learning, and adjustment in response to socio-political and climate uncertainties. Think about the meaning of green in a certain place and how we can protect it by giving it a value to local inhabitants. In regions facing escalating risks such as drought, floods, and heat stress, regenerative urban design provides practical interventions for climate resilience.

The Control-Store-Use hydrological framework offers a transferable structure for other countries with similar wet and dry seasonal patterns. Many current water management practices focus on rapid discharge during wet seasons, often intensifying downstream risks. Applying this framework enables more controlled retention, reduced runoff, and integrated multifunctional land use, contributing to more resilient urban systems.

07 *Discussion and evaluation*

I evaluate my design approach, the theories I used and methods. I evaluate my zoom-ins and if they align with my goals.

Discussion
Discussion and evaluation

My graduation project focuses on regenerative water-sensitive landscape design in Nakuru, Kenya through its integration of ecological, hydrological, and social processes.

Evaluating the Design Approach
In this project, I create a green-blue network across Nakuru to help manage water, reconnect fragmented ecological zones, reduce urban heat and support biodiversity. Water retention and recreation were combined through multifunctional landscapes designed to slow drainage while reinforcing social and ecological systems.

At the core of this approach was systems thinking. This was essential because Nakuru's challenges: water scarcity, flooding, fragmented green space, and rapid urban growth, cannot be resolved with a quick fix. By viewing the city as a dynamic interaction of slopes, soils, settlements and social networks, the framework offered a way to design with natural processes while supporting health, biodiversity, and long-term resilience. The framework was structured along upland–midstream–downstream dynamics.
This systemic structure informed the placement of key interventions: retention basins in upland hills, vegetated buffers midstream, and adaptive urban agriculture in flood-prone downstream zones. Each intervention was designed not only for ecological function but also for social inclusion, resulting in a network of multifunctional, accessible public spaces. However, while the design intended to improve urban cooling and infiltration, quantitative evaluation or modelling was beyond the scope of this project. Future research could assess the hydrological and thermal impact in detail.

Design Logic and Response to Feedback
I started with a wide range of topics, but this lacked coherence. My mentors emphasised the need for a concise, focused question. This refocusing enabled me to streamline my design logic, sharpen the key challenges, and select methods that all support a single, cohesive narrative. By shortening and honing the research question to emphasise Nakuru's green-blue network, I moved from an overly broad ambition addressing any fast-growing city in a similar climate to a bespoke framework tailored specifically to Nakuru's distinctive terrain, hydrology, and community fabric.

Theory and Methodology
The thesis followed a research-by-design methodology that framed design as both a product and a process. It was structured as a cyclical process in which research guided spatial design, and design revealed gaps for further investigation. Regenerative concepts were drawn from:
- Cheshire (regenerative design within planetary boundaries);
- Roggema (framework for regenerative planning);
- Tillie (system–habitat–species model);
- Tjallingii (Ecopolis triangle of Technique, Use, and Image).t

While the models were conceptually strong, their application varied. Tillie's model helped define spatial targets for biodiversity and habitat creation. Tjallingii's triangle conceptually shaped how infrastructure, social function, and identity were balanced. However, more time would be needed to fully integrate these models into a performance-based evaluation.

Stakeholder Anchoring and Contextual Realism
The project also evolved to integrate more context-specific and socially grounded interventions. Initially, the outsider position of the designer created a risk of abstract or top-down proposals. Through feedback and self-reflection, strategies were better anchored in local institutions such as churches, schools, and market spaces. This improved both feasibility and social ownership, although stakeholder engagement remained limited to a single field phase. Future projects should explore co-design and longer-term partnerships.

Evaluation of Zoom-in Sites

The design was evaluated using five criteria: water resilience, biodiversity, social integration, productivity and health value

Menengai Crater (Control/Capture Zone)

Measurements	Water resilience	Biodiversity	Social Value	Productivity	Health value
Reforestation with native trees	★★★☆☆	★★★★★	★★★☆☆	★★☆☆☆	★★★★☆
water storage ponds	★★★★★	★★★☆☆	★★★☆☆	★★★★★	★★★★☆
Overall	★★★★☆	★★★★☆	★★★☆☆	★★★☆☆	★★★★☆

++Reforestation with native trees supports long-term infiltration.
++Water storage ponds placed effectively based on slope and vegetation.
--Further validation needed on community engagement and maintenance.
-- Feasibility of replacing eucalyptus depends on sustained funding.

CBD (Store & Regreen)

Measurements	Water Resilience	Biodiversity	Social Value	Productivity	Health value
Improved drainage	★★★★★	★★★☆☆	★★★★☆	★★☆☆☆	★☆☆☆☆
Retention parks	★★★★★	★★★★☆	★★★★★	★☆☆☆☆	★☆☆☆☆
Permeable paving & infiltration	★★★★☆	★★★☆☆	★★★☆☆	★☆☆☆☆	★☆☆☆☆
Overall	★★★★★	★★★☆☆	★★★★☆	★☆☆☆☆	★☆☆☆☆

++Retention parks and permeable surfaces support urban cooling and drainage.
++Green-blue corridors link fragmented spaces.
-- Land availability limits full implementation; trade-offs needed with development pressures.
-- Requires strong governance for long-term maintenance.

Langa Langa (Use Zone)

Measurements	Water Resilience	Biodiversity	Social Value	Productivity	Health value
Urban agriculture (community)	★★☆☆☆	★★☆☆☆	★★★★★	★★★★★	★★★★★
green-blue network	★★★★★	★★★★★	★★★★☆	★★☆☆☆	★☆☆☆☆
Overall	★★★★☆	★★★★☆	★★★★★	★★★☆☆	★★★☆☆

++Urban agriculture responds to both water and food needs.
++School integration enables community learning and stewardship.
++Space is used efficiently in a low-income area.
--Risk of overuse without clear governance or ownership models.

08 *Reflection*

Reflecion
Personal process

1. What is the relation between your graduation project topic, your master track (A, U, BT, LA, MBE), and your master programme (MSc AUBS)?

My graduation project fits within the Landscape Architecture track of the MSc Architecture, Urbanism and Building Sciences programme. I have used a research-by-design methodology and the layer model to integrate ecological, hydrological, and social processes, reflecting the track's core emphasis on spatial resilience.

The landscape Architecture track builts upon four pillars: palimpsest, scale continuum, process, and perception. Drawing on the principle of palimpsest, I analysed Nakuru's layered history, past land uses, shifts in vegetation cover and urban development. This informed my future strategies. Embracing the scale continuum, I linked city wide hydrological logic to site-specific interventions, from city wide retention basins to community gardens. The project's process was iterative, evolving through reflection, field feedback and real-world constraints, and its perception dimension emerged from close observation of informal uses, which directly shaped the spatial responses and ensured that design solutions resonate with everyday life.

2. How did your research influence your design/recommendations and how did the design/recommendations influence your research?

This was an interwoven process with research influencing design and vice versa. Research-by-design created a dynamic relationship: early design proposals revealed knowledge gaps that led to targeted research on community practices. The GIS and hydrological analysis informed the spatial structure of the interventions. The result was a cyclical and iterative workflow where each phase of design pushed the research further. With my site visit I found out that regenerative means more than an ecological repair but also includes repairing relationships between people, institutions and government.

3. How do you assess the value of your way of working (your approach, your used methods, used methodology)?

Research-by-design, which had felt abstract in earlier projects, became very real. I discovered how drawing and mapping are not just representations, but tools for asking questions, identifying gaps, and testing ideas. I gained confidence in using drawing as a thinking tool. The iterative process of designing and researching, both influencing each other, helped to refine my research. But a risk is that too many elements are added to it and the main narrative gets clouded. Therefore, I learned that at a certain stage, refinement requires making choices: to finalise, reduce, and let go. This balance between openness and clarity is something I'll carry into future projects.

4. How do you assess the academic and societal value, scope and implication of your graduation project, including ethical aspects?

Academically, the thesis contributes to discussions on nature-based solutions in the Global South, particularly in informal, data-scarce environments. Further research into the natural system in this region is advised. Societally, it offers a practical approach with community involvement that support health, biodiversity, and resilience. But also for this, I would mention that this is not a finished solution, but something that communities, planners and other designers can build on. Ethically, the project emphasises co-creation and avoiding top-down or generic approaches. I did struggle with ethnics a lot as I am an outsider, making plans for a city in a cultural and social setting I am not part of. Through conversations with local residents and stakeholders, I tried to bridge this knowledge gap. These encounters reinforced the value of listening, questioning, and designing with communities.

5. How do you assess the value of the transferability of your project results?

I aspired to make my research understandable to researchers, landscape architects and city planners. Initially, I envisioned this as a broadly replicable case study. However, during my research, I found out that it was such a unique city that required a more context-specific approach a "one size fits all" approach proved unrealistic. However, many of its principles are transferable, for example: thinking in systems, designing for multifunctionality and anchoring interventions in real community structures. I do want to mention that designs must respect local culture and ecology.

Two Personal Reflection Questions

1. What did I learn from my site visit to Nakuru?

Normally, one of the first steps of research and design in Landscape Architecture is the site visit. But as I was only able to visit Nakuru once, I needed to prepare this well.

I talked to a lot of people as I was lucky to be part of the Water as Leverage project. There, I spoke with different stakeholders. I also presented my plans for Nakuru and while people were intrigued, the difficulties of realising projects within the government structures were also pointed out.

Another thing was the meaning that green held. From my background in the Netherlands, nature is valued for its indirect qualities; people taking a stroll through a park and looking at it for pleasure. While this is also the case in Nakuru, some do stay for fun in the Menengai forest and have lunch near the national park. A vibrant ecosystem is, for most, not that important. The declining flamingo population doesn't concern people there. I also expected the religious meaning of a forest to be stronger, as I observed this in Ethiopia, the neighbouring country.

On a personal level, I noticed a difference: in the Netherlands, when something needs to be arranged there is usually a functioning system that takes care of it. During my visit to Nakuru, I saw that this is not always the case. Even well-intended and urgently needed projects often get stuck in bureaucratic processes or fall apart due to lack of long-term governance.

This made me reflect not only on the fragility of systems in different contexts but also on my own expectations as a designer. I realised that in places where formal structures are weak or fragmented, the design must support institutional and community resilience. It taught me to appreciate the stability I come from, and to be more sensitive in how I approach planning in contexts where that stability doesn't exist.

2. How did this project change the way I see the role of a landscape architect?

This project expanded my understanding of the landscape architect's role from a spatial planner to a mediator between systems, people, and institutions. I used to see the landscape architect primarily as someone who designs functional and beautiful spaces. Now, I see our role as someone who also navigates governance, interprets ecological processes, listens to communities and creates frameworks for long-term care. Especially in a place like Nakuru, where formal planning systems are fragmented, the landscape architect becomes a connector, someone who gives form to complex dynamics, while also making them actionable and inclusive. I realised that designing space is only part of the task; designing relationships and processes is equally important.

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