

Rebuild Paradise in Anthropocene

Nakuru,Kenya

A Spatial Strategy for Integrating Urban Agriculture into Urban Design: Guiding Peri-Urban Development in Nakuru Through Local Water System Improvements for Sustainable Growth

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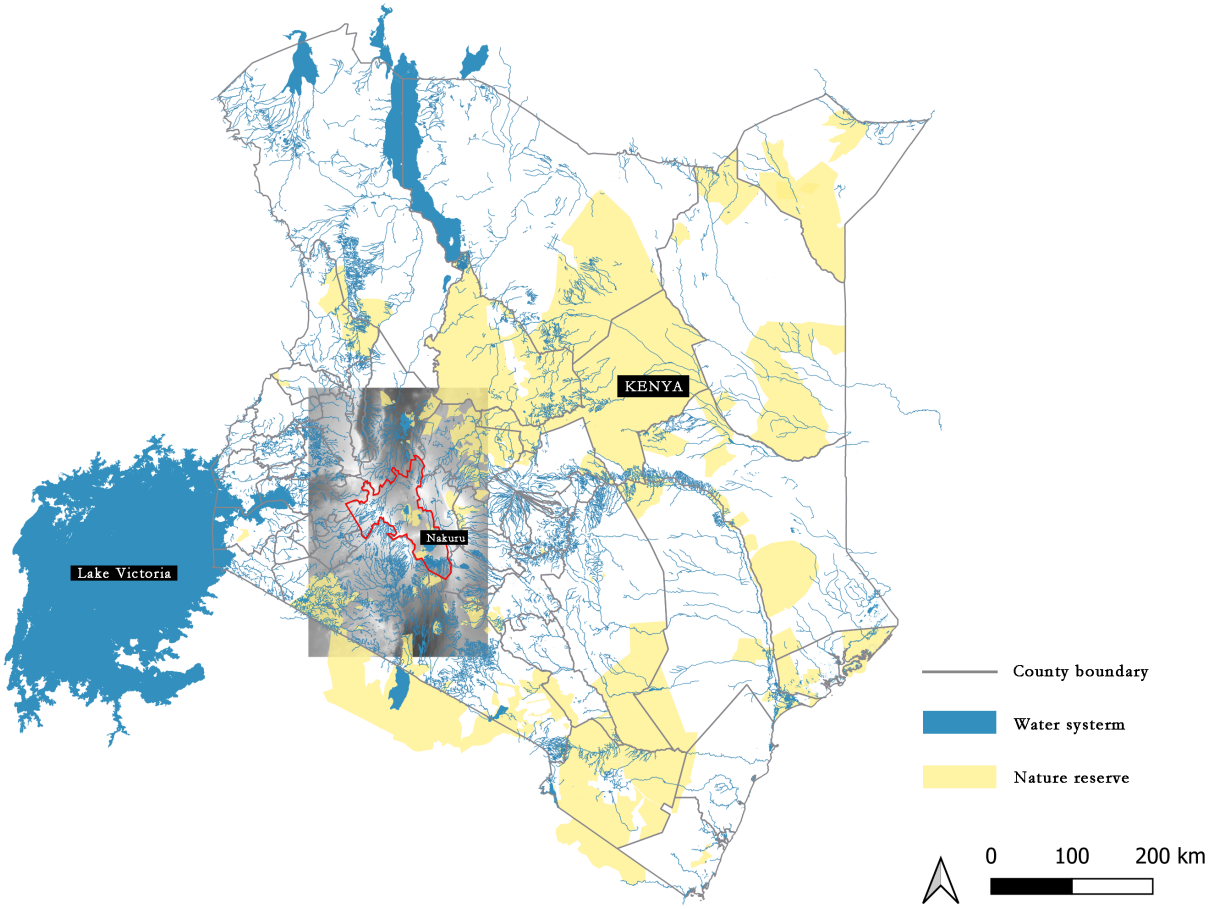


Figure 0-1: location of Nakuru， made by Author

Abstract

Nakuru, situated in the East African Rift Valley, is a rapidly growing city nestled between the Menegai Crater volcano and Lake Nakuru. The fertile yet loose volcanic soil as a result of past eruptions, is supporting agriculture, while Lake Nakuru sustains diverse wildlife, including its famous flamingos by the algae in the lake ,with the lake historically supporting over one million birds at a time as recently as 2000 (Byrne, Aidan, et al. 2024) . However, accelerated urban development has resulted in land sealing, deforestation, soil erosion, and ecological degradation—causing a dramatic decline in flamingo populations to just 6,000 by 2021 (Byrne, Aidan, et al., 2024).

The rapid expansion of the city has disrupted the hydrological balance of Lake Nakuru, leading to frequent flooding, increased surface runoff, siltation, and deteriorating water quality (Water as Leverage Nakuru – Setting the Scene, DeFacto, 2024). Compounding the issue, demand for freshwater is expected to rise by approximately 500% (Acacia Water, 2019).

This thesis argues that a spatial strategy integrating water management and urban agriculture, based on nature-based solutions (NbS), can contribute to a more sustainable future for Nakuru. Focusing on the peri-urban area, which holds significant potential for rapid urbanization, the research explores how seasonal streams and rainwater can be effectively utilized within communities and agricultural zones to support more resilient urban development. Rather than allowing rainwater to flow directly into Lake Nakuru which will result in rising lake levels, rain water storage can help address water shortages during the dry season. Based on the analysis of soil types, wetland agriculture and agroforestry can be applied as new approaches to support reforestation and increase income. Guided by principles of resilient design, this project aims to establish a new balance between rapid urban growth and the preservation of a diverse natural environment.

keywords: Urban agriculture,nature based solution,water management,urban ecology,sustainable strategies

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CHAPTER 1.

Introduction

1.1 Position paper
1.2 Site Introduction
1.2.1 Lake Nakuru
1.2.2 Nakuru County


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1.Introduction

1.1 Position Paper

Balancing Urbanization and Nature in Landscape Architecture

Urbanization often sacrifices nature for development, driven by unsustainable resource use [10]. My hometown, known for its oil industry, grew rapidly but at great environmental cost. My father recalls a clear stream beneath what is now a concrete road with sewage pipes, where hedgehogs rested and summers were spent catching fish. This loss contrasts with his vision of "paradise"—a life in harmony with nature, raising poultry, and connecting with wildlife.

In both Eastern and Western cultures, as seen in *The Peach Colony* and *the Garden of Eden*. However, modern economic growth and urbanization make there is a gap to achieve such ideals [11]. Landscape architecture plays a crucial role in bridging this gap, balancing natural and human-made environments.

Nakuru offers a unique ecosystem of balance. Surrounded by forests and home to flamingos, rhinos, and giraffes, the dilemma is how cities can coexist with rich ecosystems. The coexistence of urban life and biodiversity in such areas underscores the urgent need for sustainable urban planning strategies that integrate natural ecosystems into urban design（McDonnell, M.J. and MacGregor-Fors, I. ,2016）.

Yet, the conflict between urbanization and nature conservation remains a widespread challenge for many developing cities rich in natural resources. As part of nature, humans dominate resource competition, often at the expense of other species. Addressing this imbalance requires a reimagined approach to urban planning and design—one that fosters symbiosis among humans, animals, and plants. By embracing such solutions, we can create a modern, sustainable interpretation of paradise that harmonizes the needs of people and the environment.



Paradise

Figure1.2-1, Adam and Eve in the Garden of Eden, Wenzel Peter (Karlsbad 1745 - Rome 1829), The Vatican Museums



the Peach Blossom Spring

Figure1.2-2, Chou ying (1494—1552), Ming dynasty

1.Introduction

1.2 Site Introduction

1.2.1 Lake Nakuru

Lake Nakuru is a small, shallow, alkaline-saline lake situated in a closed basin with no natural outlet, located in the Eastern Rift Valley of equatorial East Africa. The lake provides critical habitat and abundant food sources, making it an important site for large populations of flamingos. As a result, Nakuru National Park has become globally renowned for its striking "pink bird" phenomenon.

Approximately 10,000 years ago, Lake Nakuru, together with neighboring Lake Elementaita and Lake Naivasha (located about 60 km to the south), constituted a single, deep freshwater lake. Over time, this larger lake dried up, leaving behind the three distinct lakes observed today (World Lake Database, ILEC).

Since then, the water levels of Lake Nakuru have fluctuated significantly, with the lake nearly drying up several times over the past 50 years (World Lake Database, ILEC). The last major decline occurred in the early 1990s. Between 2010 and 2020, the surface area of Lake Nakuru expanded dramatically—from 40 to 68 square kilometers (15 to 26 square miles) (Tobiko, Keriako, 2021). This increase in water volume resulted in the flooding of 677 homes, parts of Nakuru town, and sections of the national park (Baraka, Carey, 2022).

The continued rise in lake water levels not only threatens wildlife within Nakuru National Park (figure 1.2.1-1) but also negatively impacts urban areas outside the park (figure 1.2.1-3). The rising lake water reduces both wildlife and human habitats. Therefore, water management and new urban planning structures can not only protect Nakuru's biodiversity but also contribute to sustainable urban development.



figure1.2.1-1, Baby zebra with rising lake level, photo by author



figure1.2.1-2, Rising lake level with submerged trees, photo by author



figure1.2.1-3, Abandoned houses near Lake Nakuru, photo by Cynthia van Elk

1.2.2 Nakuru County

Ecological structure Nakuru County is situated within the Eastern African Rift Valley, where its geomorphology is strongly influenced by volcanic activity and rift tectonics. The region encompasses volcanic cones such as the Menengai Caldera and slopes descending towards Lake Nakuru. Its geological composition includes Miocene to Quaternary volcanic deposits (lava flows and pyroclastics), overlain by lacustrine sediments of more recent origin (Kanda, 2010). Due to this volcanic origin, the soils are generally rich in minerals, making them highly fertile and suitable for agriculture (Montcoudiol et al., 2019). However, the loose and friable nature of these deposits renders the topsoil vulnerable to water erosion during periods of heavy rainfall, leading to significant nutrient loss and siltation in Lake Nakuru. In extreme cases, saturation of the unconsolidated volcaniclastic sediments has resulted in ground subsidence, posing both environmental and socio-economic challenges (Ngecu & Nyambok, 2000).

Climate Nakuru has a subtropical, plateau-like climate, which means it experiences a dry season and a rainy season instead of the familiar four seasons. The rainy periods occur from March to May and from October to December. The long rainy season, from March to May, brings the heaviest rainfall of the year, often featuring intense downpours and prolonged wet conditions, making this the period when soil erosion and runoff are most severe. The short rainy season, from October to December, brings less rainfall than the long season but still provides enough moisture to support crop growth.(Miller et al., 2021)

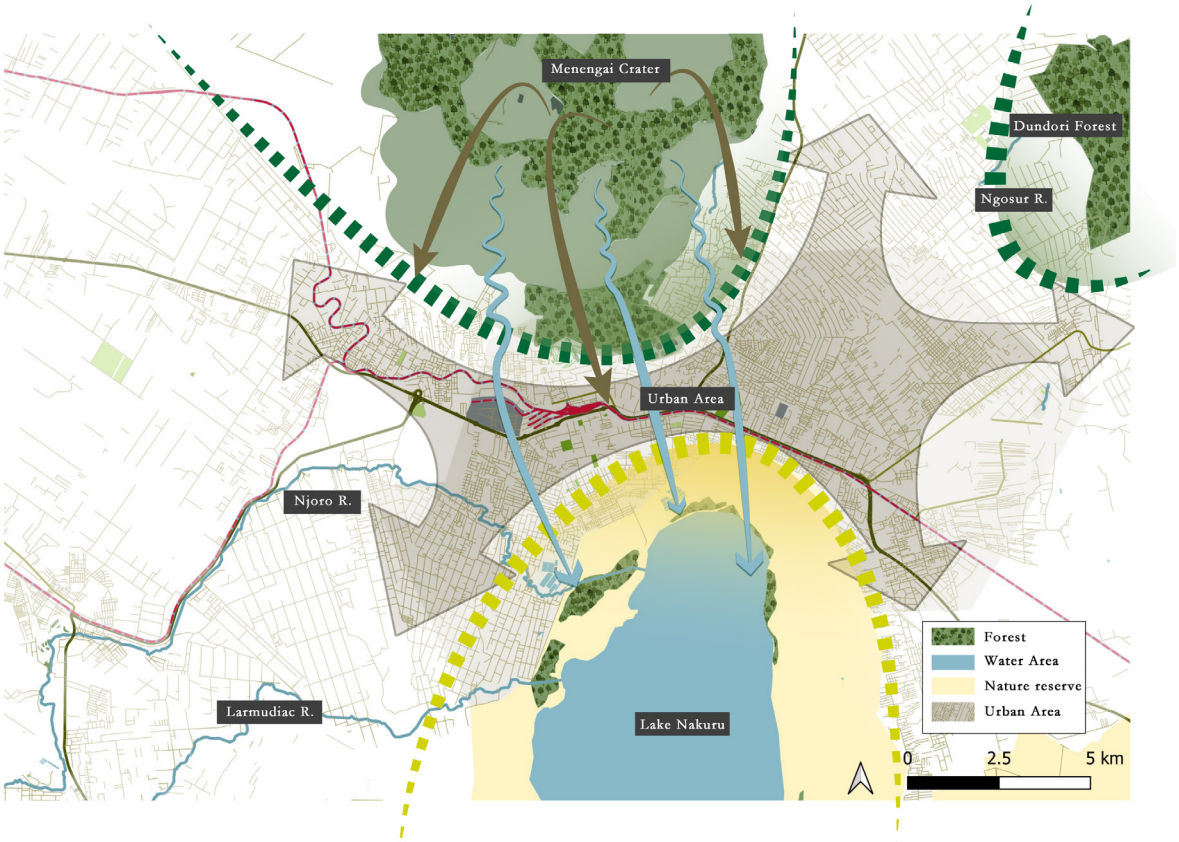


figure1.2.2-1, Ecological Structure of Nakuru, drawing by author.

1.2.2 Nakuru County

Economy Agriculture, manufacturing and tourism make up the economy of Nakuru. Around the city, it is widely known for its agricultural activity. The main crops grown include coffee, wheat, barley, maize, beans, and potatoes.

Urbanization As of 2019, Nakuru's urban population was 570,674 (Archive. org, 2017), making it the largest urban center in the Rift Valley. The city still has a relatively low density and is expected to grow from 500,000 to 2,000,000 inhabitants in 2050 (Defacto Urbanism & RebelGroup, 2024.)
As a result of population growth, rapid urbanization has expanded human settlements into natural areas. The built-up area has been steadily increasing, particularly between 2000 and 2014 (Figure 1.2.2-6). This expansion has led to extensive impervious surfaces in the city, which prevent seasonal streams from infiltrating the soil and recharging the groundwater. Conversely, urbanization has accelerated surface runoff from higher elevations, transporting urban pollutants into Lake Nakuru. At the same time, the growing population has increased demand for water resources, exacerbating water shortages during the dry season.
Therefore, a sustainable urban planning strategy can enable Nakuru to better accommodate future development while managing the pressures of rapid urbanization.

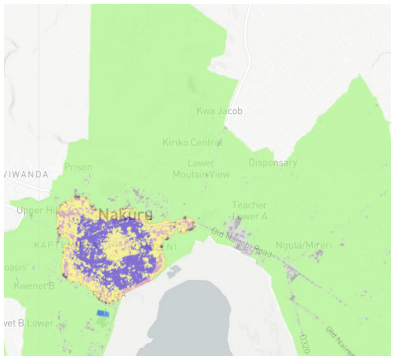


Figure1.2.2-2,Urban Extent of Nakuru,1989
data from Atlas of Urban Expension

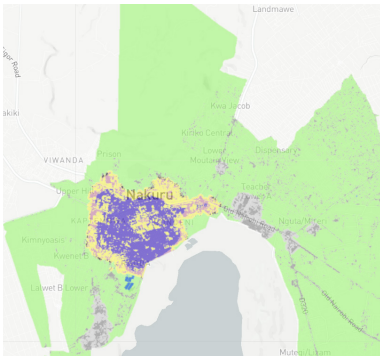


Figure1.2.2-3,Urban Extent of Nakuru,2000
data from Atlas of Urban Expension

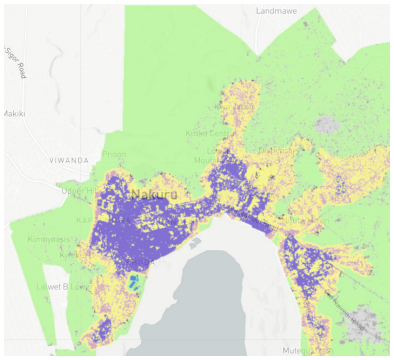


Figure1.2.2-4,Urban Extent of Nakuru,2004
data from Atlas of Urban Expension

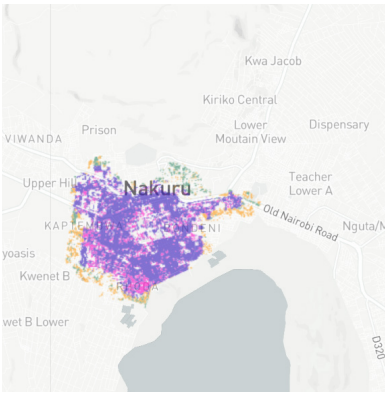


Figure1.2.2-5,Composition of added area,1989-2000,data from Atlas of Urban Expension

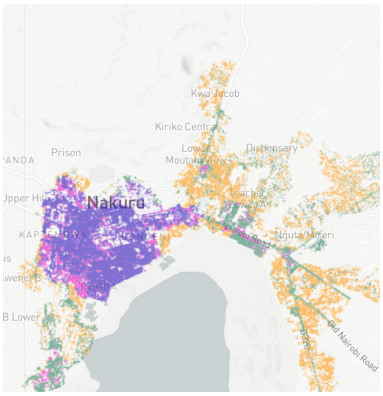


Figure1.2.2-6,Urban Extent of Nakuru,2000-2014
data from Atlas of Urban Expension



CHAPTER 2.

Research Structure

2.1 Methodology
2.2 Theoreticial Framework
2.3 Research Question


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2. Research Structure

2.1 Methodology

1 Resilience approach

Based on the conceptual synthesis presented in Walker & Salt (2011) and extended by insights from Mannakkara & Wilkinson (2014), resilience is not defined simply as the ability to return to a pre-disturbance state, but as the capacity of a system to absorb disturbances, reorganize, and adapt to new conditions while maintaining essential functions.
Some strategies intended to build urban resilience capacity: multifunctionality, redundancy and modularization, (bio and social) diversity, multi-scale networks and connectivity, and adaptive planning and design.

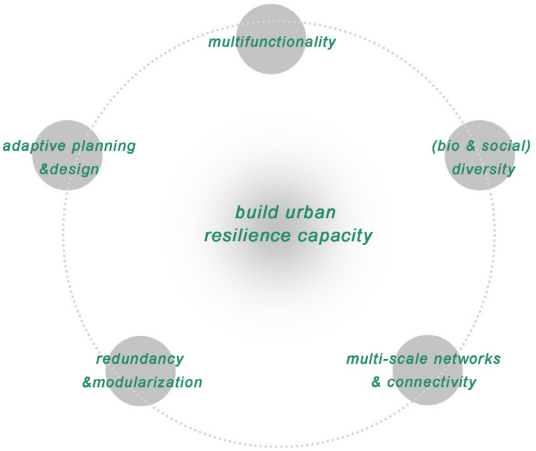


Figure2.1-1,Urban & design strategies for building urban resilience (Jack Ahern, 2011)
Concluded and drawn by author

2 ECOPOLIS

ECOPOLIS presents a vision for an ecologically sustainable and self-sufficient urban settlement, designed to minimize environmental impact while promoting community-oriented living. In 1995, Sybrand P. Tjallingii proposed the concept that "the city is a dynamic and complex ecosystem" —composed of smaller interconnected ecosystems and itself embedded within the global ecological system. Therefore, any strategy for sustainable urban development must also consider the broader goals of global sustainability.
There are three main themes in the ECOPOLIS Strategy Framework:

1. The Responsible City.
Urban areas generate environmental problems such as pollution and resource depletion through their material and energy flows. Cities must take responsibility for these impacts rather than displacing them to other regions or future generations.

2. The Living City.
Cities face problems when they ignore nature. A healthy city should support both people and the environment. Using local natural features like climate and soil can improve well-being and give the city its own identity. Taking care of nature should also make the city better.

3. The Participating City.
Urban challenges such as noise, waste, and vandalism often stem from a lack of public engagement. This disengagement is not only due to ignorance but also to urban systems that fail to encourage or even discourage participation. Sustainable urban development requires active involvement from residents in managing and caring for their everyday environment.

The theory also suggested to use a set of 'guiding models' for chains, areas and organization to help develop dynamic urban systems. These themes emphasize the need for responsibility, ecological awareness, and active public participation in creating ecologically sustainable urban development.

3 Nature based solution

Nature-based solutions refer to the design, development, and application of natural systems—including biodiversity and ecological processes—to address a wide range of socio-environmental challenges (Girardin, C é cile A. J., et al., 2021). These challenges include climate change mitigation and adaptation, human security concerns such as water and food security, and disaster risk reduction (Sisay Debele et al., 2023). The core objective is to utilize resilient ecosystems—whether natural, managed, or newly created—as solutions that benefit both human societies and biodiversity.

Nature based interventions were grouped into 10 main groups(Sisay Debele, et al. 023):

(1) groundwater storage
(2) creation of green and built environments,
(3) creation of blue-green space,
(4) soil-water conservation,
(5) afforestation and revegetation,
(6) stream or river restoration,
(7) infiltration and biofiltration,
(8) streambank and slope stabilisation,
(9) coastal protection and management,
(10) sustainable drainage of urban runoff and surface water.The functions by which the NBS interventions were classified also refer to multiple environmental compartments and to the ecosystem for which they are intended.

In Nakuru, facing the problems of climate change and ecological degradation, nature based solutions can provide more sustainable development strategies for urban stormwater management, agricultural production and urban development with lower intervention.



Figure2.1-2, NbS as an umbrella term for ecosystem-related approaches,data from IUCN Nature-based solutions to address global societal challenges

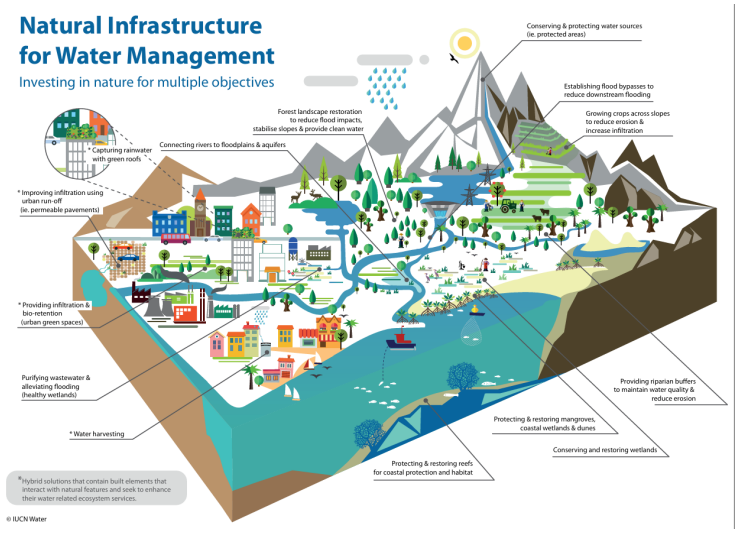


Figure2.1-3, Natural infrastructure for water management, data from IUCN Nature-based solutions to address global societal challenges

2. Research Structure

2.2 Thoretical framework

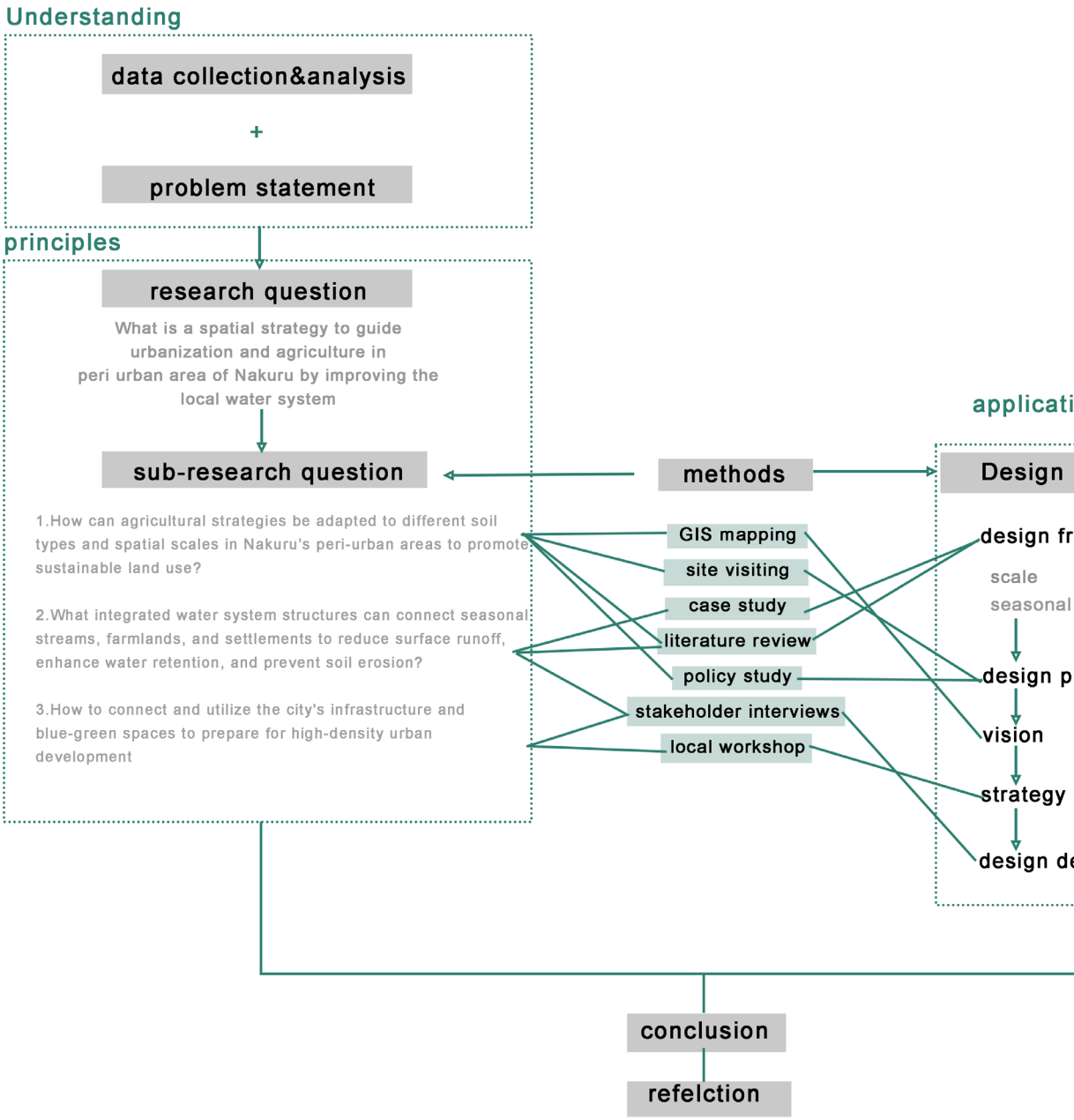


Figure2.2-1, Natural infrastructure for water management, data from IUCN Nature-based solutions to address



This project explores the relationship between rapid urbanization and the ecological system in Nakuru by applying landscape architecture principles and methods. The research is structured around three core stages: understanding, principles, and application, as outlined in the diagram.

Beginning with the understanding phase, the issues of rising lake levels and rapid urbanization were identified through data collection and analysis. This initial understanding led to the formulation of the main research question and three sub-research questions, which serve as guiding principles throughout the design process.

To investigate these questions, a set of methods is applied. These methods provide both spatial and contextual insight, ensuring that the proposed strategies are grounded in real-world conditions.

The design assignment serves as the application of these principles, structured through a multi-scalar design framework at the county, city, and site levels. The seasonal stream system acts as a key layer of analysis—starting from the upstream forested area near Menengai Crater, through the midstream peri-urban zone, and ending in the downstream agricultural land that drains into the Njoro River.

Based on this framework, the thesis proposes a series of spatial strategies aimed at guiding future urbanization and agricultural development in Nakuru's peri-urban areas by improving the local water system.

global societal challenges

2.3 Research Question

Research Objective: The main objective of this study is to develop a blue-green framework to balance water management and agricultural land scarcity issues faced by Nakuru in urban development, making Nakuru a more resilient city through nature-based solution.

Research Question:
What is a spatial strategy to guide urbanization and agriculture in peri-urban area of Nakuru by improving the local water system

Sub-Research Question:

ECOPOLIS	
s-RQ1 **The Responsible City:**	What integrated water system structures can connect seasonal streams, farmlands, and settlements to reduce surface runoff, enhance water retention, and prevent soil erosion?
s-RQ2 **The Living City:**	How can agricultural strategies be adapted to different soil types and spatial scales in Nakuru's peri-urban areas to promote sustainable land use?
s-RQ3: **The Participating City:**	How to connect and utilize the city's infrastructure and blue-green spaces to prepare for a high-density urban development?



Figure2.3-1, the Eastern Rift Valley, kenya, photo by author

CHAPTER **3**.
Research for Design

3.1 Water system
3.2 Agriculture Type
3.3 Soil Types
3.4 Water Management-Flood Risk
3.5 Population Density
3.6 Urbanization & Agriculture
3.7 Problem Statement
3.7.1 Problems caused by seasonal stream
3.7.2 Problem caused by urbanization


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3. Research for Design

3.1 Water system

Water System Nakuru's water system is shaped by its Rift Valley landscape, with various permanent and seasonal water bodies, including rivers, lakes, and streams, that are influenced by the county's unique topography and weather patterns.
The water system experiences significant seasonal variation due to bimodal rainfall (long and short rainy seasons). Lake Nakuru is a soda lake with a closed drainage system; water does not flow out into other rivers, making the lake sensitive to precipitation in the two rainy seasons (March–June and October–November) (Climate Vulnerability and Ecosystem Assessment for Nakuru County, 2022).

Spatial and Environmental Issues
Excessive abstraction of surface and groundwater for agricultural and urban needs places considerable stress on rivers, lakes, and aquifers. Rapid urbanization exacerbates these pressures by generating larger volumes of wastewater and pollutants, while fragmenting natural catchments. These factors collectively degrade water quality and promote processes such as eutrophication (Climate Vulnerability and Ecosystem Assessment for Nakuru County, 2022).

Summary The region's steep volcanic and crater slopes channel runoff into seasonal rivers, permanent streams, groundwater systems, and Lake Nakuru. During the rainy seasons, seasonal rivers and surface runoff dominate, whereas groundwater and springs play a more critical role in sustaining flows during the dry periods. Ultimately, the balance between water inputs and losses governs lake levels, water quality, and the health of the wider ecosystem.

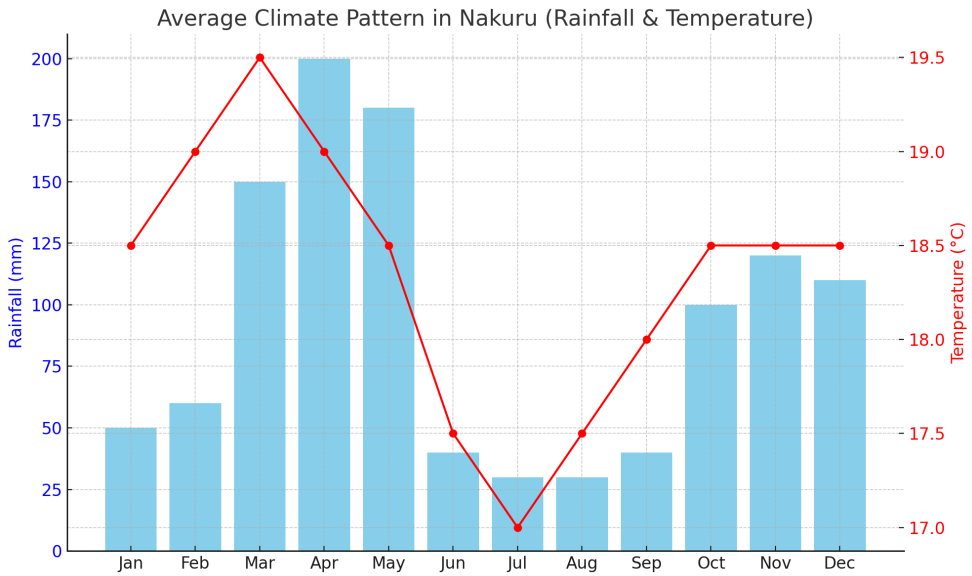


Figure3.1-1, Water system of Nakuru, drawing by author

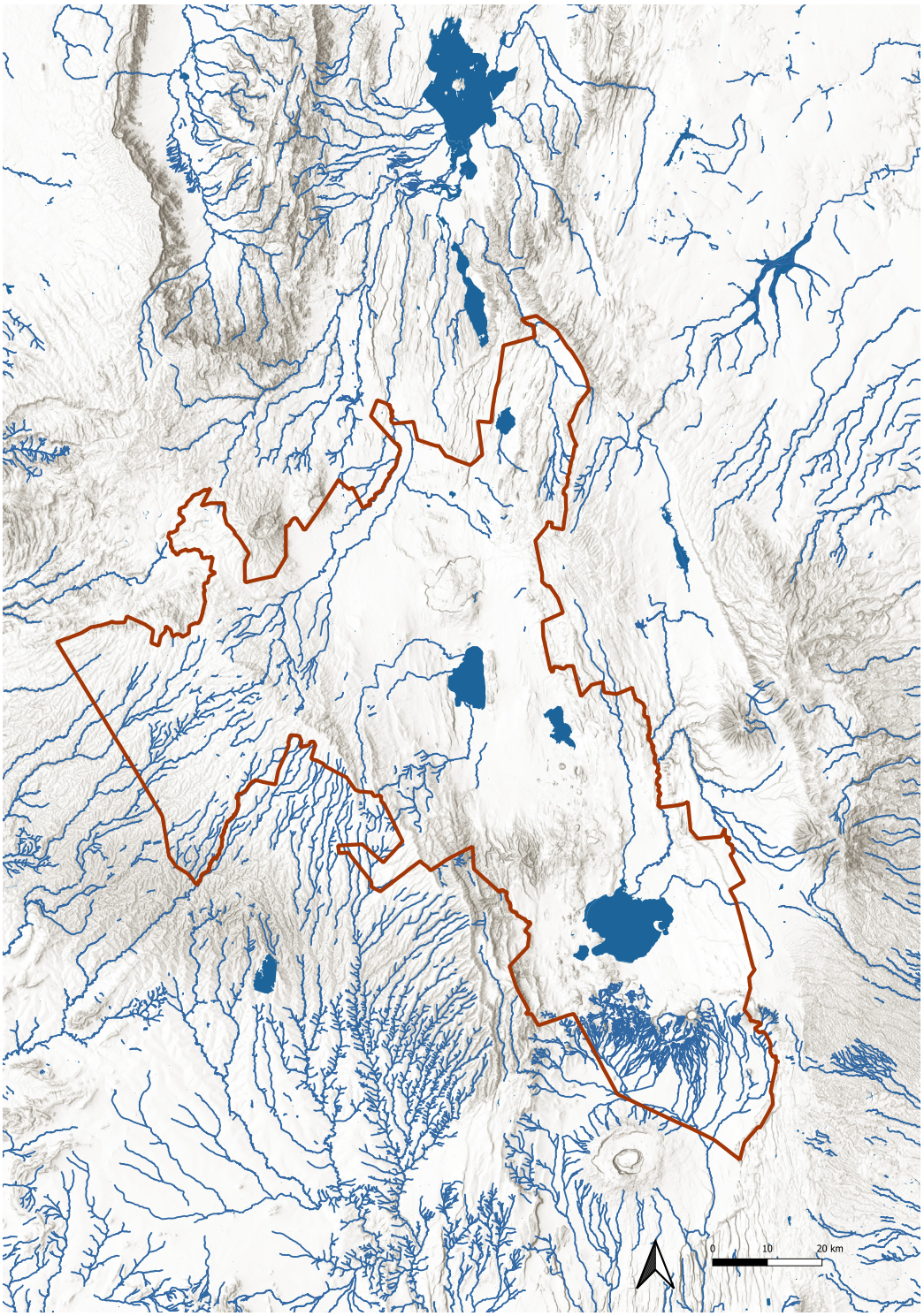


Figure3.1-2, Water system of Nakuru, drawing by author

3.2 Agriculture Types

Agriculture Types Nakuru's agricultural landscape is equally shaped by its climate and topography. Land-use surveys (Figure 3.2-2) reveal that most of the county is dominated by rainfed herbaceous crops, with only small portions allocated to irrigated farmland. The generally favorable climatic conditions have historically minimized the reliance on artificial irrigation. In addition, small areas of forest plantations are located on the southern slopes of the Menengai Crater. These forests play an important role in supporting the ecological system of Nakuru by functioning as water catchments and contributing to soil and water conservation.

Delincing Forest Plantation However, extensive deforestation has led to a marked reduction in forest plantation cover between 1930 and 1998, particularly in the southern parts of Nakuru and along the banks of the Njoro River. The main forested areas within the catchment basin include the Eastern Mau, Eburru, and Dundori forests. Among these, the Eastern Mau—part of the larger Mau Complex—serves as a critical national watershed and is the largest forest block, covering approximately 65,000 hectares. It consists of both plantation and indigenous forests, which have been progressively cleared over the past decade to accommodate human settlement (Ndetei, 2006).

Crop Types Nakuru County experiences a humid subtropical–temperate climate, with annual rainfall ranging from approximately 1,000 to 1,800 mm and mean temperatures between 10°C and 22°C, depending on altitude. These climatic conditions, combined with the county's fertile volcanic soils and extensive plateaus, create a favorable environment for diverse agricultural activities. Major crops include cereals such as wheat, maize, and barley, along with pyrethrum, potatoes, vegetables, and various fruits. In addition, livestock farming, particularly dairy cattle and sheep production, is a key component of the agricultural sector, further reflecting the county's strong dependence on its natural resources.

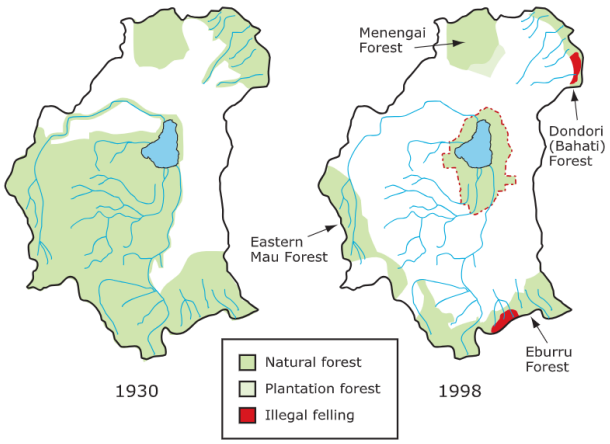


Figure3.2-1, Changes in Forest Cover in Lake Nakuru Basin,1930-1998, drawing from Ndetei, 2006

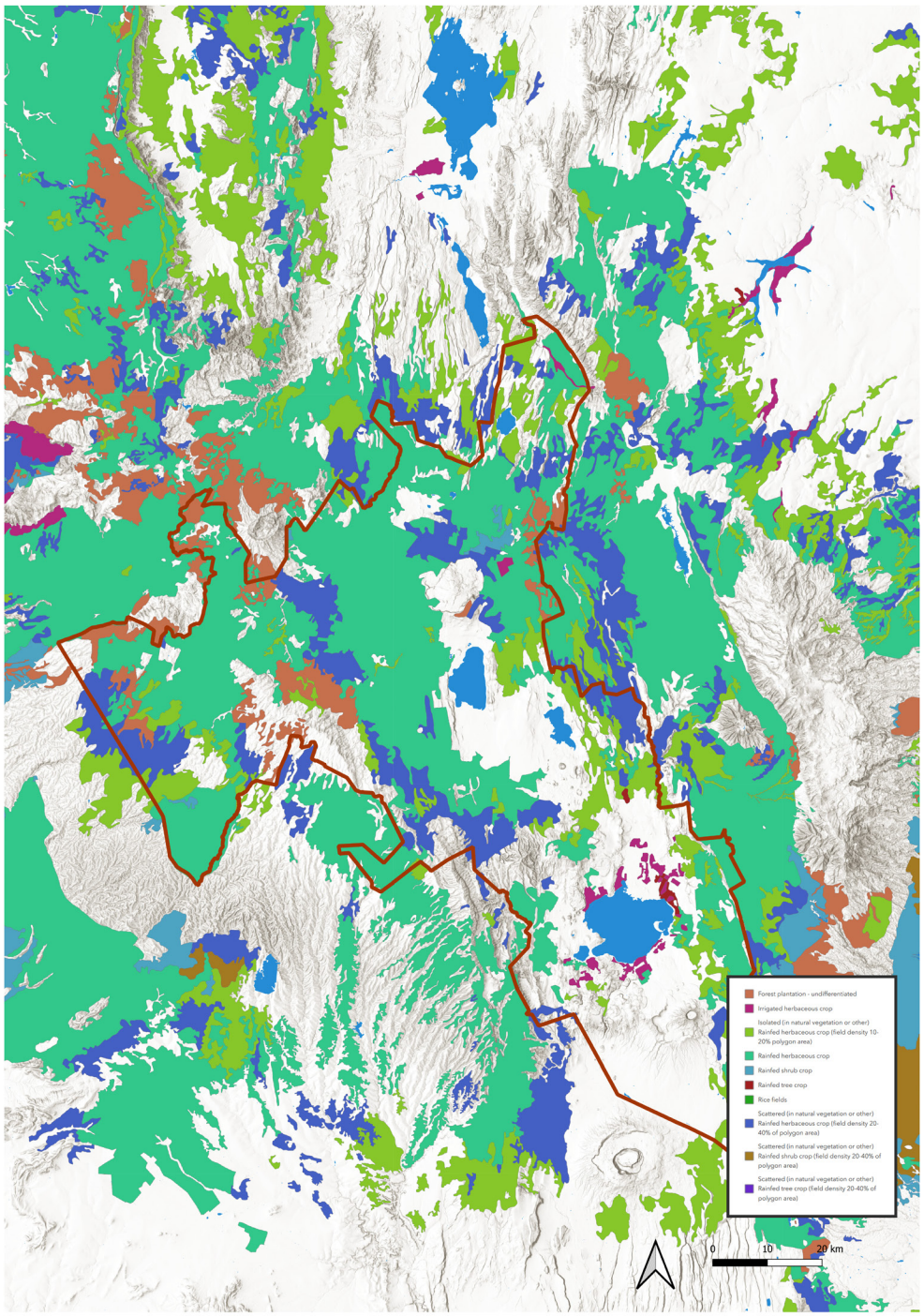


Figure3.2-2, Agriculture types of Nakuru, drawing by author, data from arcgis

3.3 Soil Types

The soils of Nakuru County are strongly shaped by its location within the East African Rift Valley and by past volcanic activity. The major identified soil and parent material units in the region include alluvial soils, lacustrine soils, sedimentary soils, and volcanic soils, each with distinct characteristics. Variations in soil fertility and permeability largely determine their agricultural potential.

The Menengai crater and its surrounding slopes are characterized by soils classified as Mi, Mt, and Ms, all of which exhibit relatively high natural fertility. These soils are primarily derived from pyroclastic materials, including ash, pumice, and scoria, deposited during the later eruptive phases of the Menengai volcano. Owing to their volcanic origin, the soils are generally loose, porous, and well-aerated, with favorable drainage properties. However, their loose texture also makes them highly vulnerable to erosion, particularly on the steep slopes of the Menengai volcanic complex. To ensure long-term soil productivity and ecological stability, the adoption of deep-rooted tree planting and soil conservation strategies—such as terracing, cover cropping, and agroforestry practices—is essential.

Meanwhile, much of the city is underlain by Qi soils (tuffs, lacustrine, and fluvial deposits). These soils illustrate the transitional nature of Nakuru's landscape, where volcanic processes intersect with fluvial and lacustrine dynamics. In terms of their physical properties, lacustrine-derived soils are typically clay-rich, with a high water-holding capacity but poor drainage (Jaetzold et al., 2006).

Owing to their distinct properties and ecological requirements, the soils near the Menengai Crater are particularly suitable for agroforestry. The deep-rooted trees play a crucial role in stabilizing the loose soil structure, thereby mitigating the risk of erosion. In contrast, the soils located between Lake Nakuru and the Menengai Crater are predominantly clayey, , making them more favorable for crop cultivation. However, this area requires careful land-use planning and ecological design to mitigate flooding risks and enhance ecosystem resilience during the rainy season.

Soil Units	Landscape/Origin	Fertility	Permeability
AI	Ancient alluvial plains	High	Moderate, influenced by land use practices
QI	Quaternary alluvial plains	High	Poor, prone to drought stress
Mt	Footslopes & terraces	High	Well-drained
MI	Volcanic uplands, moderate slope	Moderate–High	Good, suitable for irrigated farming
Ms	Volcanic mountains, steep slopes	Moderate	Good drainage, relatively high permeability

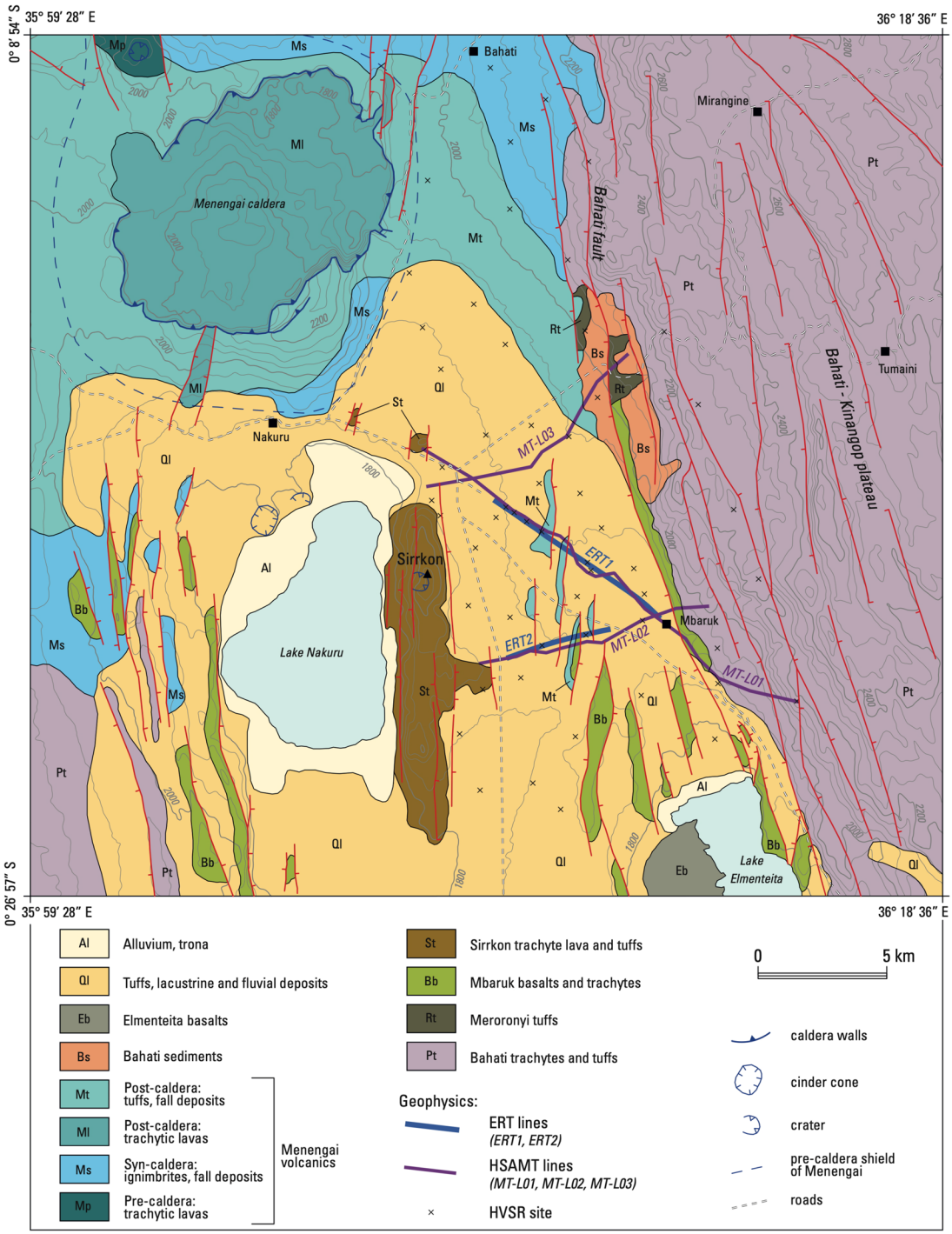


Figure3.2-2, Geological map of the Nakuru area, from Conti et al., 2021

3.4 Water Management- Flood risk

Nakuru's topography, water system, and soil structure have been profoundly reshaped by rapid urbanization. The hardening of land surfaces due to urban expansion has significantly reduced the ecosystem's capacity for self-regulation during the rainy season, resulting in frequent urban flooding. In periods of heavy rainfall, peri-urban areas such as Kiamunyi have historically acted as natural channels for surface runoff, mitigating the risk of flooding within the city.

Nevertheless, as urban development progressively encroaches upon these buffer areas, their effectiveness at mitigating floodwaters is increasingly undermined, heightening the risk that peri-urban districts may themselves become flood-prone. Accordingly, safeguarding functional surface runoff corridors and prioritizing investment in resilient water management infrastructure are now urgent imperatives for Nakuru's sustainable urban future.

Moreover, the absence of natural sub-surface drainage systems within the urban core exacerbates localized flooding. As illustrated in Figure 3.4-1, the Rhoda area is particularly vulnerable, facing the highest flood risk. The impacts of flooding extend beyond immediate infrastructural damage: polluted stormwater is washed directly into Lake Nakuru, degrading water quality and threatening the biodiversity of its unique ecosystem. At the same time, residents face disruptions to daily life, threats to property safety, and reduced mobility due to compromised transportation networks.

Ultimately, addressing flooding in Nakuru requires more than technical interventions—it calls for a rebalancing between urban growth, human settlements, and ecosystem protection. Such an integrated approach is essential for building long-term urban resilience while safeguarding the ecological integrity of Lake Nakuru and its surrounding landscapes.

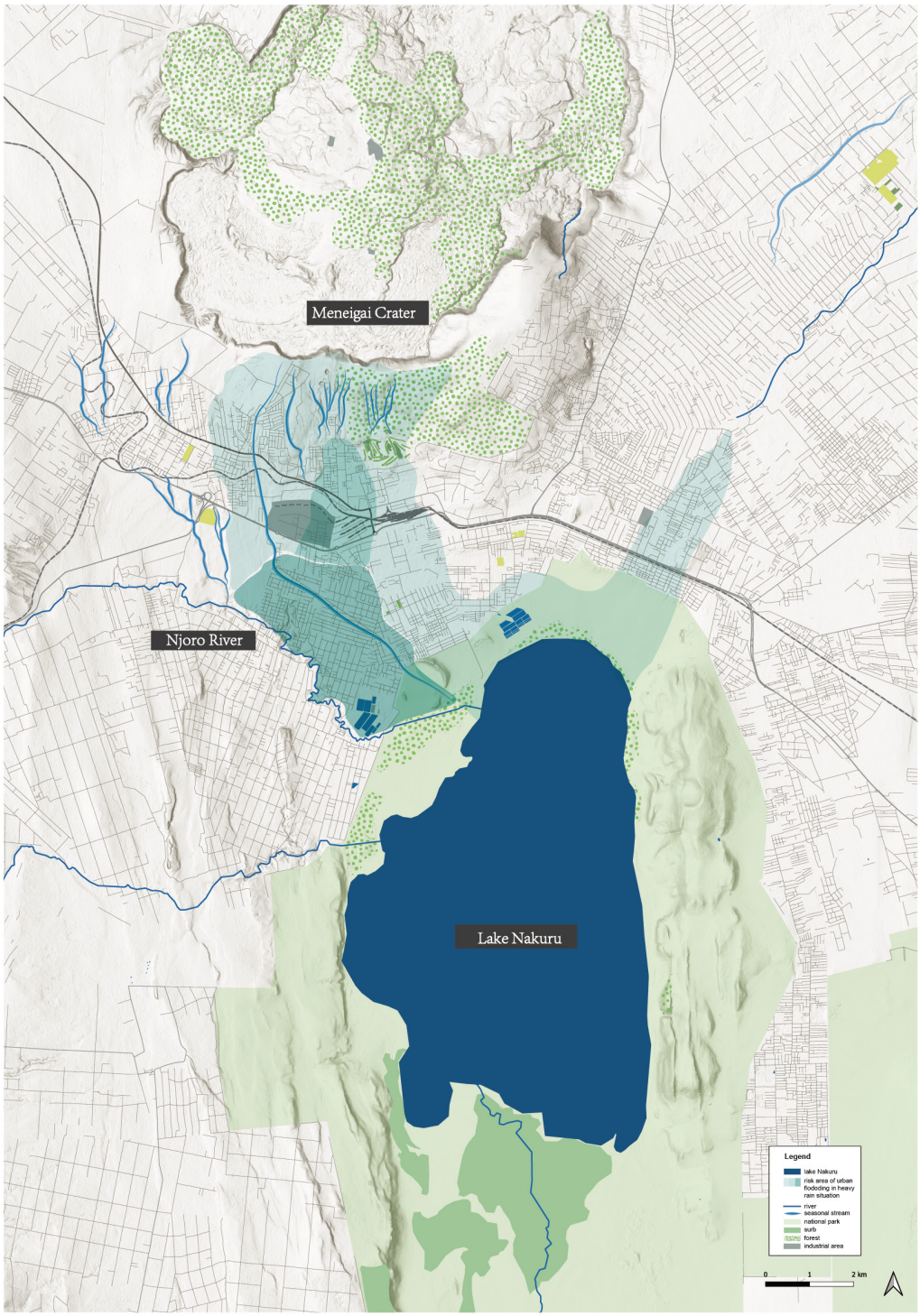


Figure3.4-1, Urban flooding area in heavy rain situation, drawing by author, rewrite from defacto

3.4 Water Management- Flood risk

In addition to the floods triggered by heavy rainfall, Nakuru is increasingly vulnerable to flooding driven by the expansion of Lake Nakuru and the Njoro River. As Figure 3.4-2, a comparison of Lake Nakuru's surface area across 1995, 2008, 2012, 2016, and 2024 clearly shows a consistent trend of expansion.

The rising lake level has had profound ecological consequences, particularly within Lake Nakuru National Park. One of the most notable impacts is the sharp decline in flamingo populations, which has diminished the lake's iconic pink shoreline. Between 2009 and 2022, the surface area of Lake Nakuru increased by 90.7%, while mean chlorophyll-a concentrations declined from over 400 mg m−3 to below 200 mg m−3 (Byrne et al., 2024). This reduction in primary productivity directly affected the food supply for flamingos, leading to their population decline.

Beyond ecological consequences, the continuous rise in lake level poses risks to both natural and urban environments. Without intervention, further expansion could inundate park grasslands and eventually encroach upon the city, threatening residential and commercial areas adjacent to the park's boundaries with permanent flooding.

Notably, Figure 3.4-2 also highlights the compounded flood risks when riverine and lake-driven inundation are considered alongside rainfall-induced flooding. The southern part of the Rhoda area emerges as a particularly high-risk zone, where multiple flood drivers converge, intensifying the potential for severe and recurrent inundation.

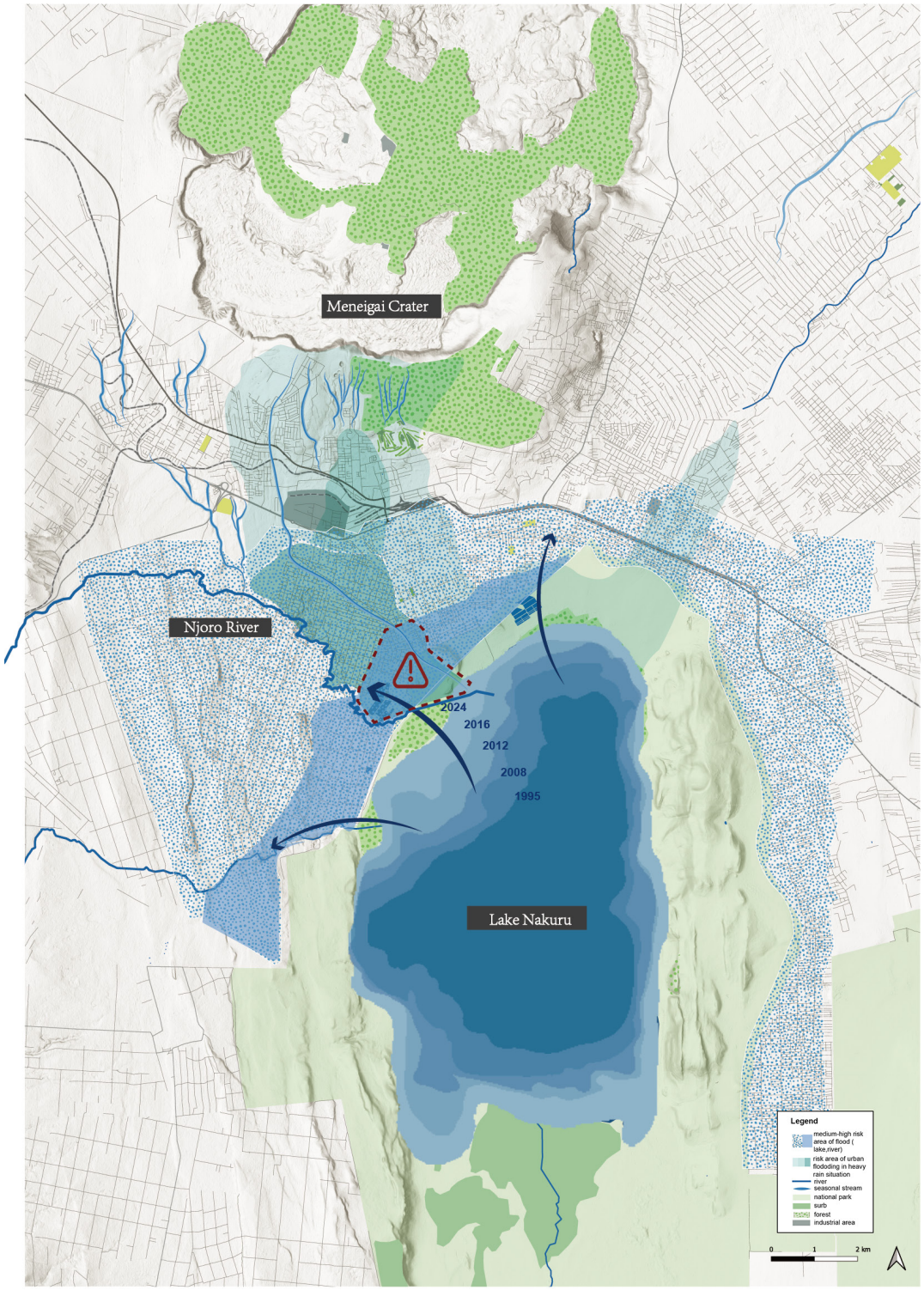


Figure3.4-2, risky flooding area from lake and river , drawing by author , rewrite from defacto together with the data from google map

3.5 Population Density

Nakuru has undergone rapid urbanization in recent years, marked by rising population density in the central urban core and along major transportation corridors.As figure3.5-1, high and medium-density populations overlap significantly with informal settlements. This spatial pattern highlights that a substantial share of residents outside the urban core or on the city's periphery secure housing through informal arrangements, leading to dense communities with inadequate infrastructure. In 2022, Nakuru's population was estimated at 686,630, growing at an annual rate of approximately 6.36%. By 2030, the population is projected to exceed one million, with around 35% of residents living in informal settlements (Tomorrowscities.org, 2022).

Informal settlements typically lack reliable infrastructure, including well-planned road networks, effective sewage and drainage systems, secure water and electricity supplies, and formalized land tenure. When these conditions intersect with rapid population growth, they significantly heighten environmental and social vulnerabilities.

When compared with the flood risk map, it becomes evident that Rhoda's high flood risk is closely tied to the infrastructural shortcomings of densely populated settlements. High-risk flood zones are not only characterized by large populations but also by a high concentration of informal housing. Infrastructure bottlenecks amplify the hazards associated with population density: during the rainy season, the absence of comprehensive drainage systems and effective solid waste management frequently results in waterlogging and sewage backflow. These conditions disrupt transportation, contaminate water sources, and increase public health risks, thereby deepening the vulnerability of communities already facing precarious living conditions.

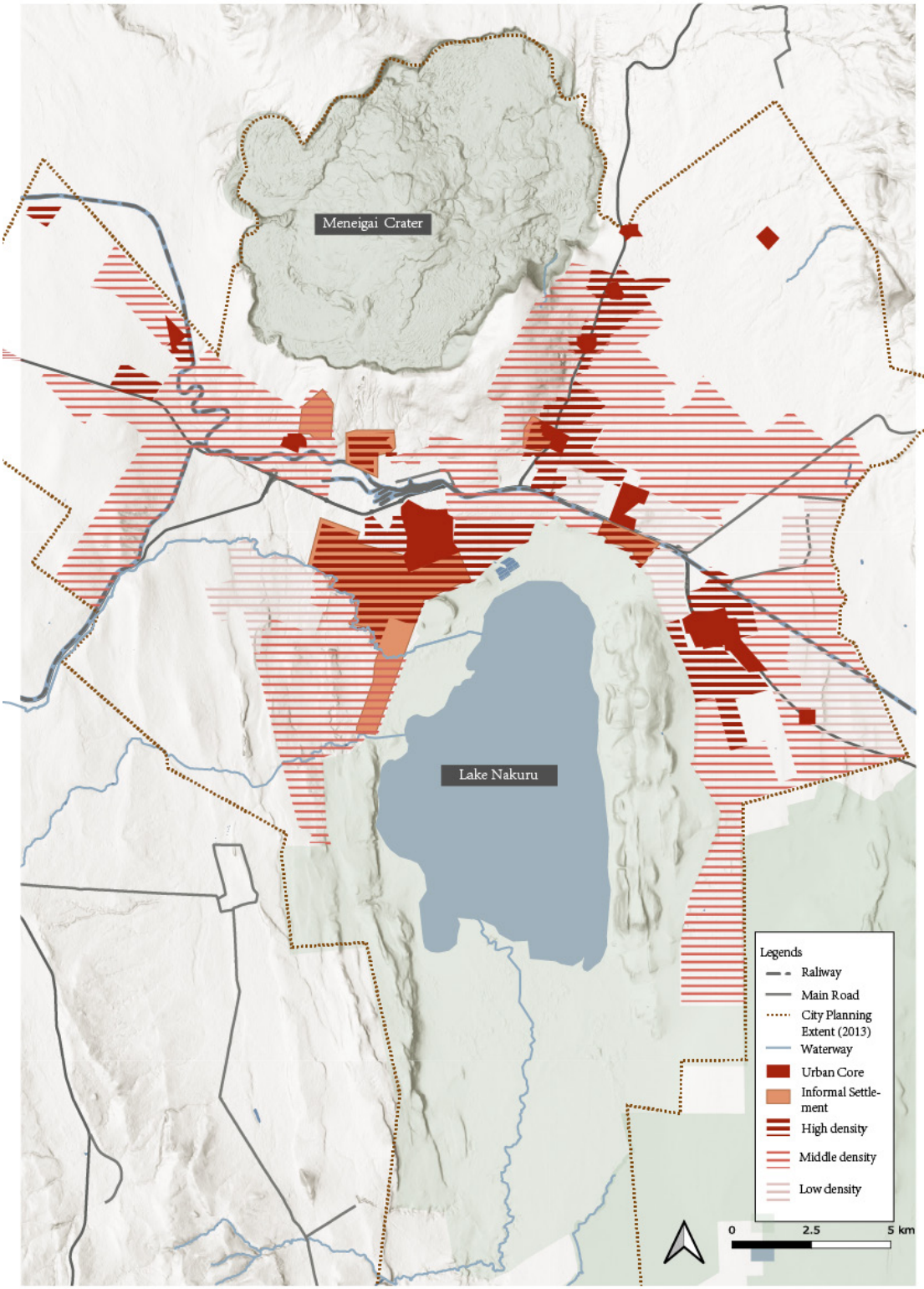


Figure3.5-1, Population Density Map ,
drawing by author,data from Nakuru County

3.6 Urbanization& Agriculture

As shown in Figure 3.2.2, urban expansion in Nakuru is concentrated along the boundary between agricultural zones and medium-density residential areas. The impact of urbanization on agricultural land is multi-layered and complex extending beyond the straightforward conversion of farmland into built-up areas. Instead, it is characterized by the simultaneous processes of replacement, fragmentation, and intensification (Willkomm, Follmann, & Dannenberg, 2020).

One of the most visible outcomes is the spatial fragmentation of farmland. Studies indicate that the average size of farmland patches declined from approximately 1.83 hectares in 2010 to 1.02 hectares in 2019, accompanied by a sharp rise in the number of small plots and a corresponding decline in large plots (Willkomm et al., 2021). This transformation is driven both by land sales and subdivision for urban development, as well as by farmers themselves subdividing land for the cultivation of high-value crops.

Kiamunyi, a peri-urban area within Nakuru's expansion zone, provides a representative example. Here, rising land values incentivize the subdivision and sale of inherited land. In this context, "replacement" occurs when agricultural land is sold and converted into residential estates, marking a clear shift in land use.Yet agriculture does not disappear entirely: small-scale farming or animal husbandry often persists within new housing areas.

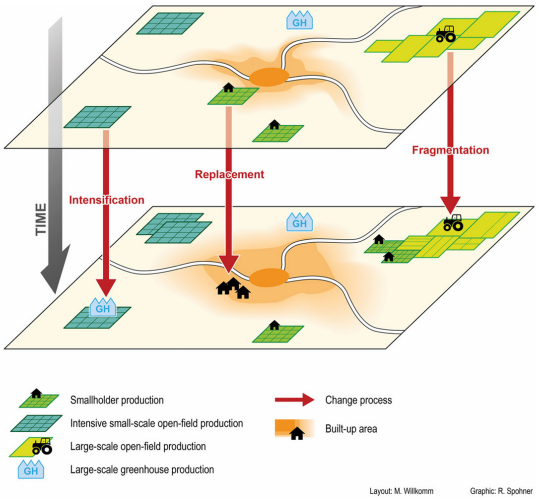


Figure3.6-1, Typical distributions of the four agricultural land use types and their dominating processes of replacement, fragmentation, and intensification , Willkomm, Follmann and Dannenberg, 2020

What changes is the scale and configuration of agricultural land, reflecting "fragmentation." Meanwhile, "intensification" refers to the adoption of more capital-intensive agricultural practices on smaller plots, as farmers seek to maximize returns on increasingly limited land resources.

The combined effects of fragmentation and replacement also have hydrological consequences. As farmland is subdivided and replaced by built-up surfaces, land hardening reduces natural infiltration pathways for seasonal runoff. Instead of being absorbed by soil, rainwater is increasingly converted into surface runoff, accelerating flow and amplifying downstream flood risks.

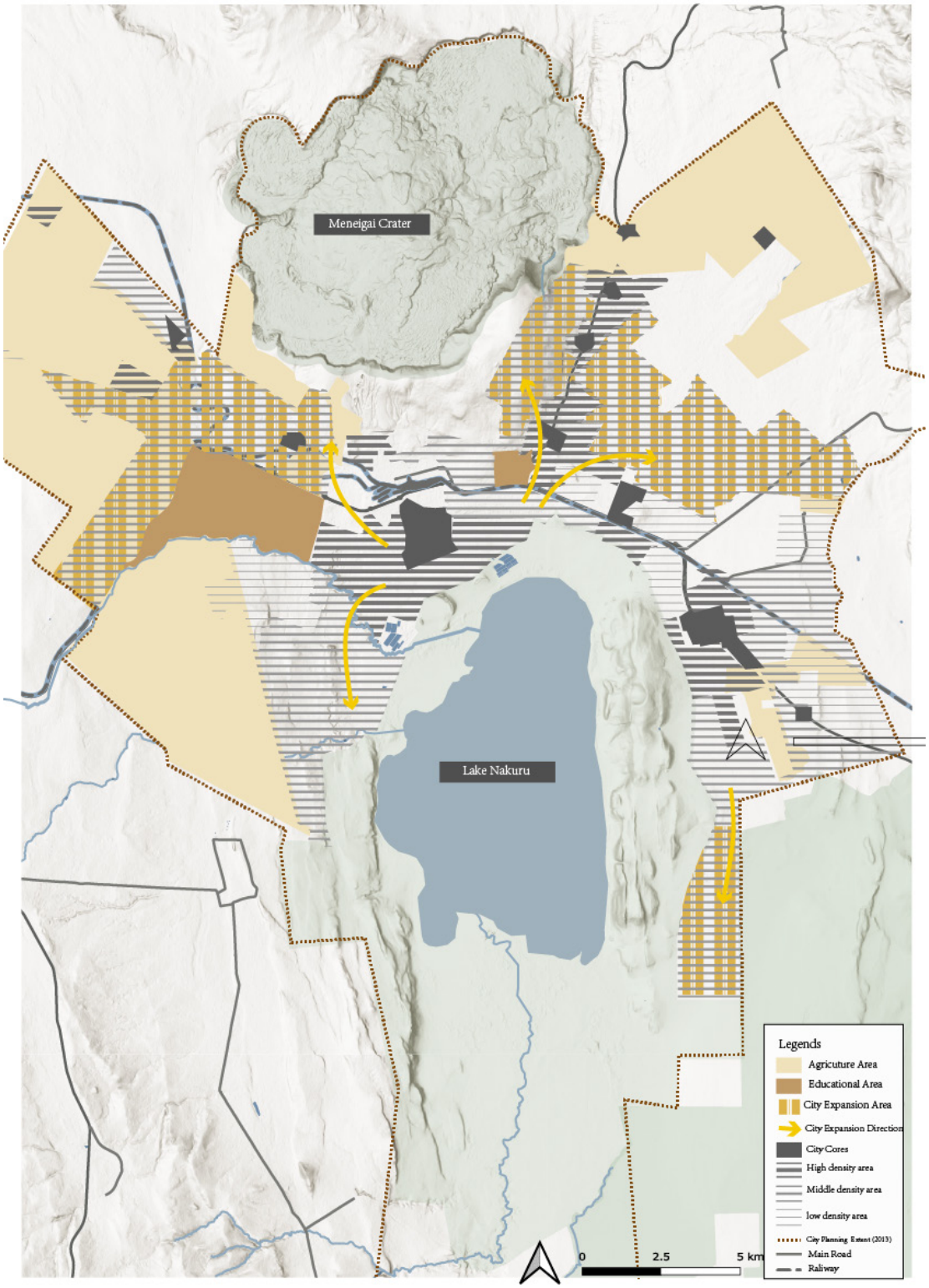


Figure3.6-2, relation between urbanization and agriculture, drawing by author

3.7 Problem Statement

3.7.1 Problem caused by seasonal stream

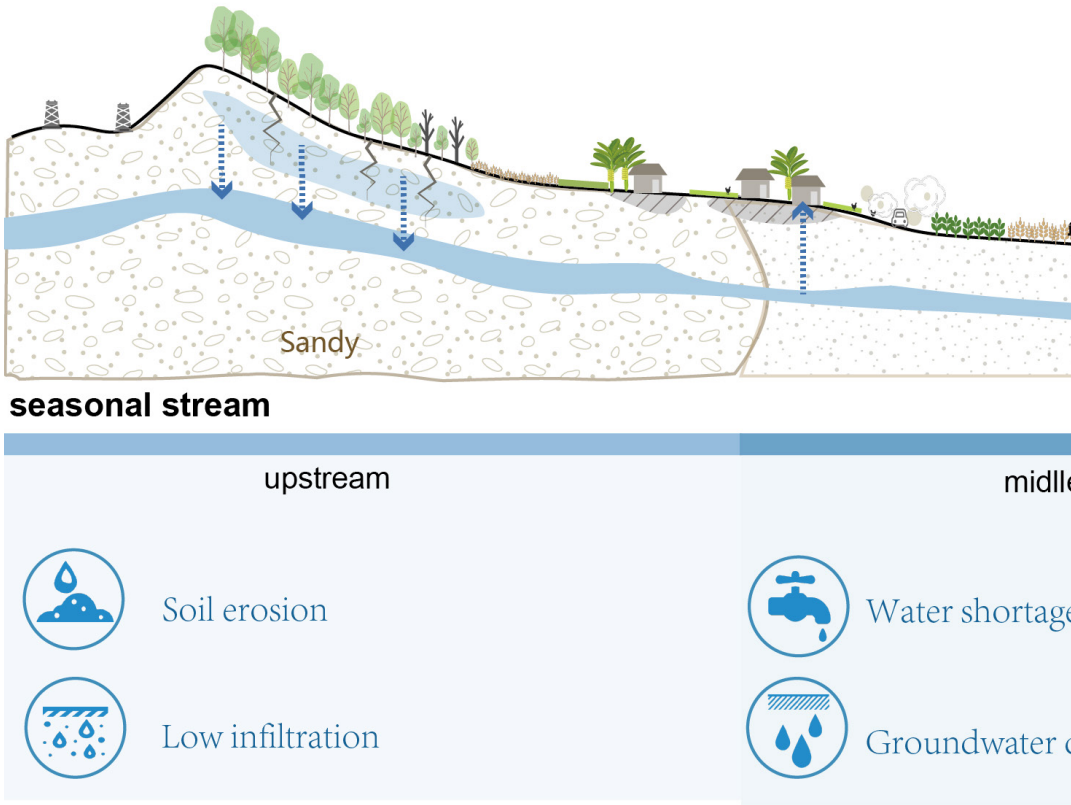
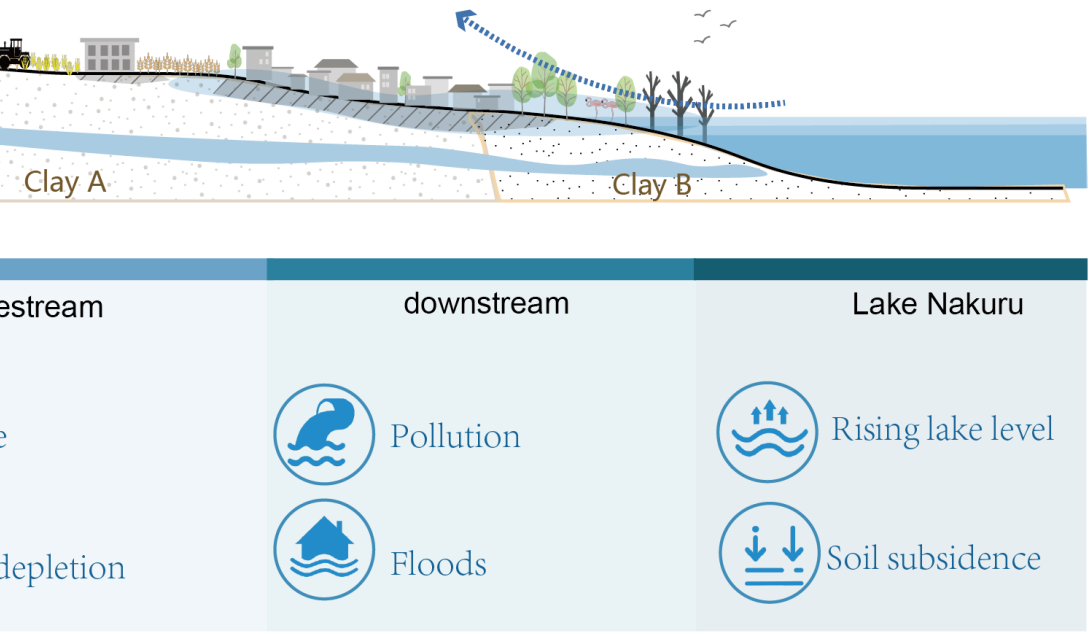


Figure3.7-1, problem statement drawing

Nakuru's problem statement can be framed through the interaction between seasonal streams and rapid urbanization. From a hydrological perspective, the city's cross-section can be divided into the upstream, midstream, and downstream reaches of the seasonal streams, as well as the receiving body, Lake Nakuru.

The upstream zone, characterized by sandy soils, has been significantly altered by farming and deforestation, which have reduced vegetation cover and triggered severe soil erosion. Moving into the midstream, which encompasses the peri-urban area, the impacts of urbanization become more evident. Agricultural irrigation and residential water demand have risen sharply. Excessive groundwater extraction, combined with the low permeability of clay soils, has limited aquifer recharge, resulting in both groundwater depletion and seasonal water shortages. The absence of a reliable piped water system further exacerbates the problem, forcing residents to spend substantial amounts of money on purchasing water.



from seasonal stream prespective ,
g by author

In the downstream zone, adjacent to the urban core, population density is high and industrial activities produce large quantities of sewage and solid waste. These are often discharged untreated into water channels, causing severe pollution. At the same time, the expansion of impervious urban surfaces, such as roads and buildings, has reduced the city's capacity to retain rainwater, heightening the risk of flooding. Polluted surface runoff, carrying sediments and contaminants, eventually flows into Lake Nakuru, contributing to rising water levels and soil subsidence.

Taken together, these dynamics demonstrate that flooding and lake expansion in Nakuru are not isolated phenomena but rather symptoms of a systemic imbalance in the urban–ecological nexus. The interactions between land use change, water demand, and inadequate infrastructure underscore the urgent need for integrated urban and environmental management.

3.7.2 Problem caused by urbanization

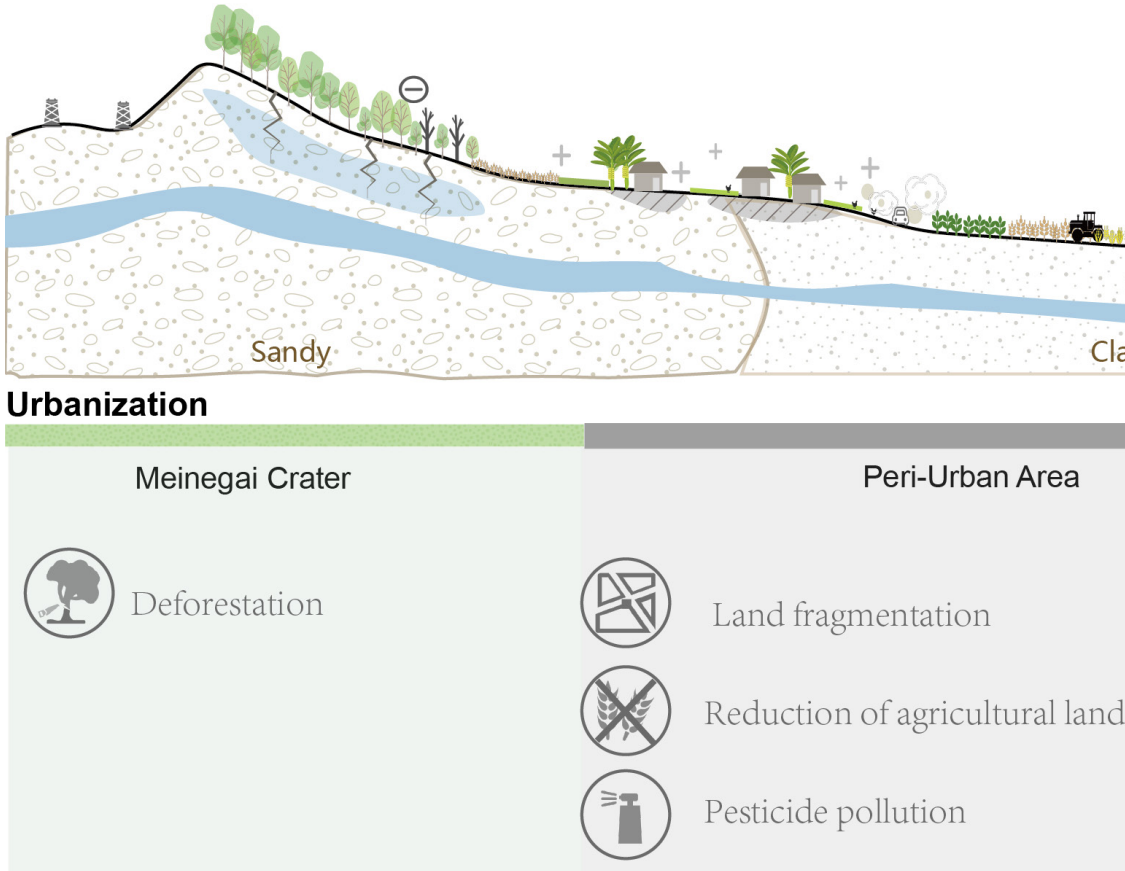
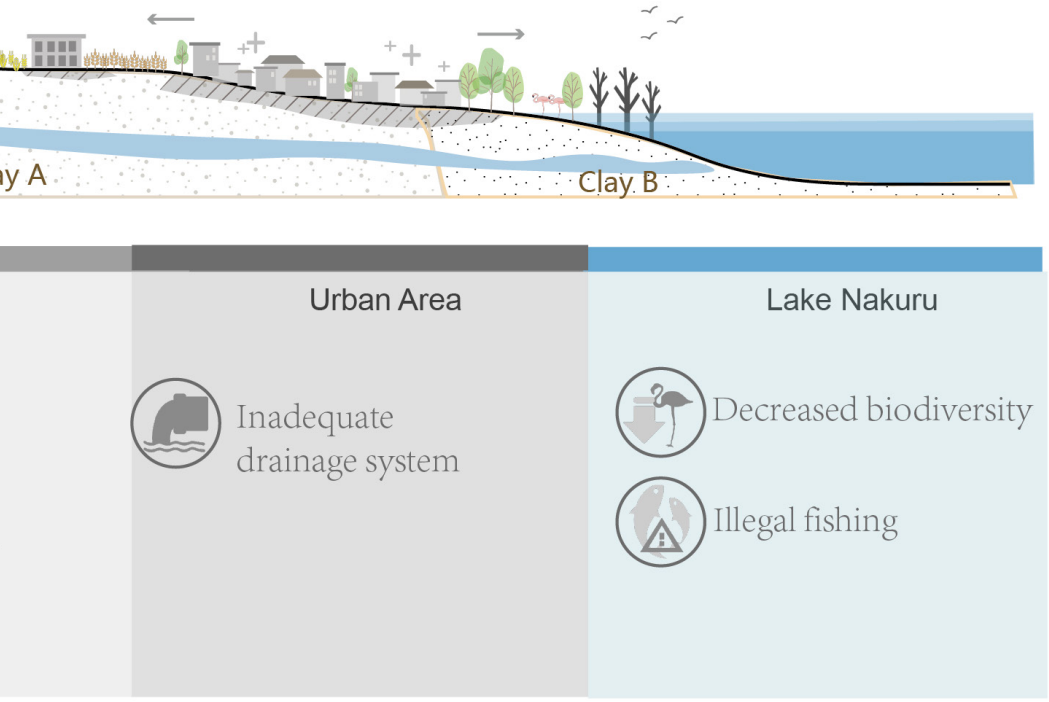


Figure3.7-2, problem statem
drawi

In addition to seasonal streams, urbanization itself is a major factor negatively affecting Nakuru's urban ecosystem. Based on the city's spatial structure and ecological framework, Nakuru can be divided into four key zones: Menengai Crater, the peri-urban area, the urban core, and Lake Nakuru.

The Menengai Crater area, an important geological and ecological landmark, has undergone extensive deforestation due to timber harvesting and agricultural expansion. This forest degradation has weakened the catchment's capacity to retain water, intensifying soil erosion and contributing to downstream water shortages. In the peri-urban zone, urban expansion and human settlement have fragmented land, reduced the availability of agricultural land and constraining traditional farming practices. To maintain productivity, farmers have increasingly relied on pesticides, creating risks of soil degradation and water contamination.



ent from Urbanization prespective ,
ng by author

The urban core is shaped by rapid population growth and insufficient infrastructure. Among the most pressing concerns is the inadequacy of drainage systems, which heightens vulnerability to flooding and waterlogging during the rainy season. Finally, Lake Nakuru, a protected wetland of international importance, has suffered ecological degradation. Fluctuating water levels and pollution have compromised its original alkaline water quality, leading to declines in bird and fish diversity. At the same time, illegal fishing by local residents entering the national park has further disrupted the lake's ecological balance.

In sum, urbanization in Nakuru is not merely a localized issue of land conversion. It represents a systemic and transregional environmental challenge, where deforestation, agricultural intensification, inadequate infrastructure, and ecological degradation interact to create cumulative pressures. These dynamics ultimately threaten both urban sustainability and the long-term resilience of the region's ecosystems.

CHAPTER 4.

Design Concept

4.1 Strategies

4.1.1 Create Partnerships among residents,Government and NGOs

4.1.2 Reconfigure the relationship between urban agriculture, water management systems and urban development

4.1.3 Government layer

4.1.4 NGOs&Residents Layer

4.1.5 NGOs&Government Layer

4.2 Vision,From Drainage to Sponge Urbanism


© xuejing

4.1.1
Create Partnerships among residents,Government and NGOs



Resid

NGOs

Information collection & Education

-Compile and organize knowledge and skills related to agriculture and rainwater harvesting.
-Share practical information, such as which crops thrive during the dry season and methods to reduce pesticide use.
-Educate residents about the benefits of agroforestry and how it differs from traditional farming practices.
-Host community events and advocate for the creation of a community environmental park.
-Develop a reward system to encourage knowledge sharing and participation.





Information sharing & Implementation

- Share local agriculture skills
- Practice learned rainwater harvesting strategies
- Participate in community garden development
- Understand the long-term benefits of agroforestry

ents

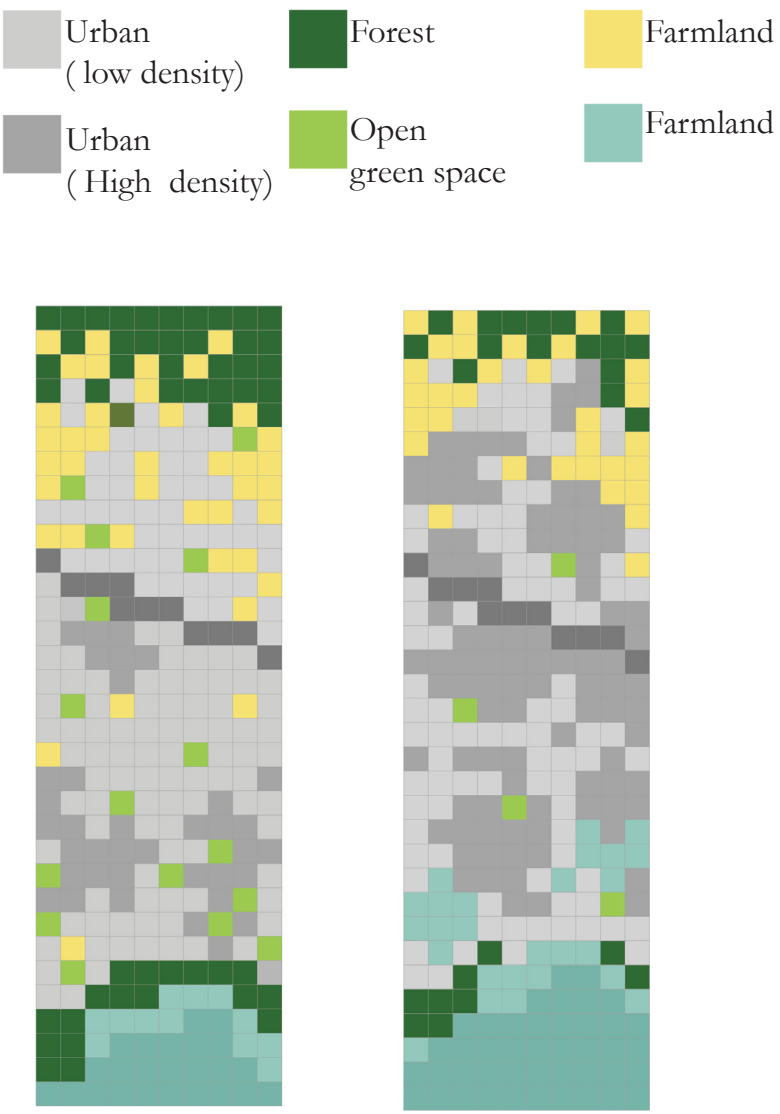
Government



Policymaking & Economic Support

- Maintaining a certain green space ratio in urban planning policies
- Providing financial support to encourage agroforestry and urban agriculture
- Incorporating a blue-green system framework into urban infrastructure

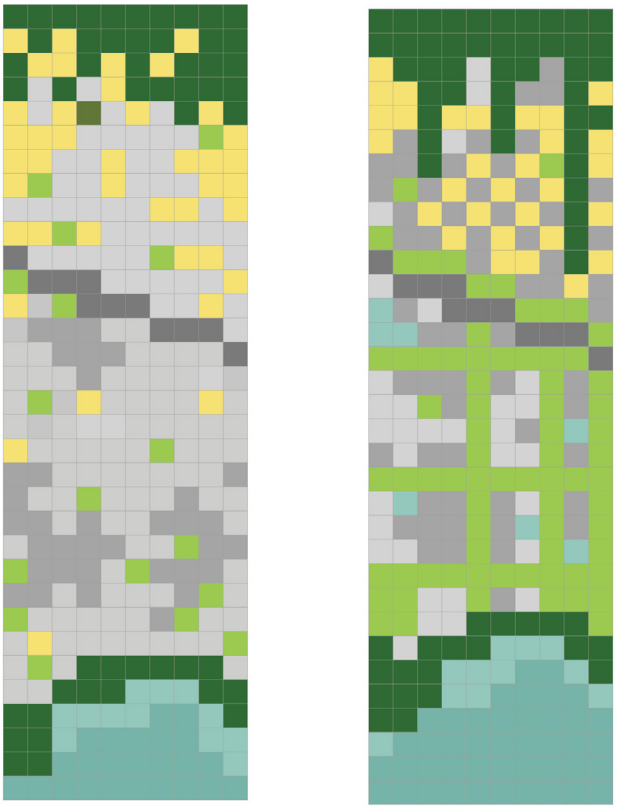
4.1.2
Reconfigure the relationship between urban agriculture, water management systems and urban development



Urbanization without intervention

In the absence of intervention, urban expansion is expected to further encroach upon agricultural land, which in turn will continue to replace surrounding forest ecosystems. The increasing construction density in the urban core will exacerbate land surface hardening, thereby reducing permeability and intensifying runoff. Concurrently, the rising lake water level poses a threat of inundation to parts of the urban area, resulting in the emergence of internal flooding.

Accordingly, the proposed intervention strategy seeks to establish a blue–green infrastructure framework that enables urban development within a resilient and adaptive spatial structure. The existing road network will be transformed into green corridors to intercept and regulate surface runoff directed toward the city center, while simultaneously mitigating the adverse impacts of climate change on the urban living environment. Furthermore, within the peri-urban zones, agricultural land will function as an ecological buffer that separates urban expansion from natural areas, thereby enhancing the city's overall flood resilience and environmental sustainability.

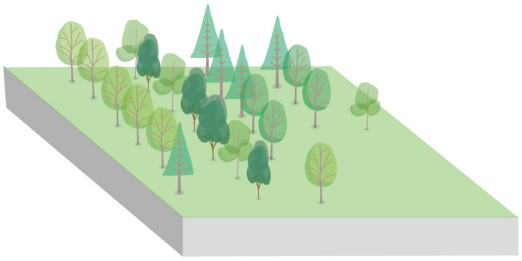


Urbanization with intervention

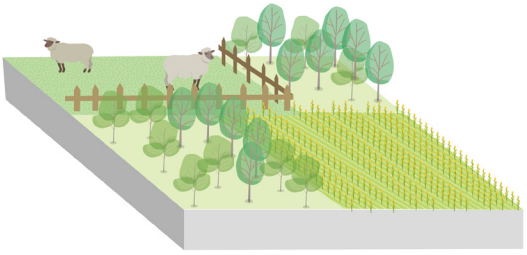
4.1.3 Government layer

Integrating water management and urban agriculture into the city's blue-green systems

Step 1: Increase rainwater infiltration

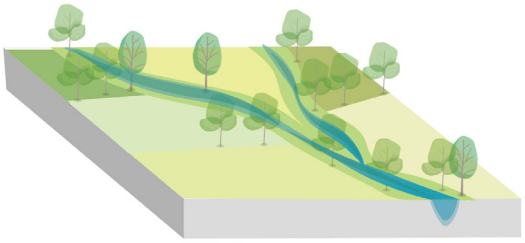


Agroforestry

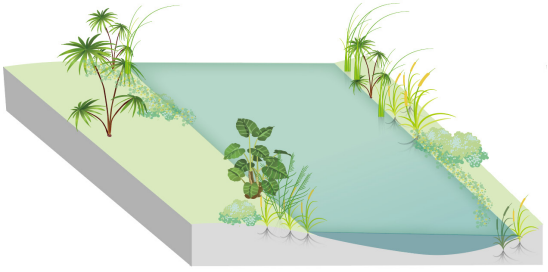


Mixed farming

Step 2: Maintaining rainwater harvesting systems

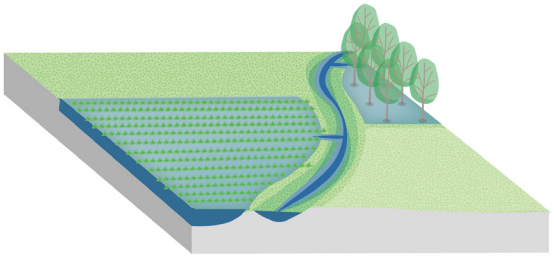


Maintenance of seasonal runoff

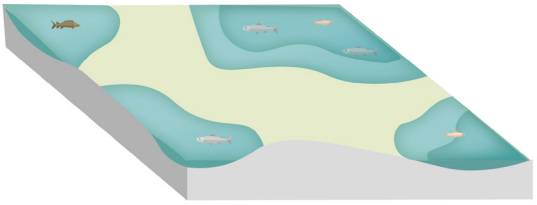


Bioswale

Step 3: Reusing rainwater



Wetland



Seasonal Fish Pond

The design strategy draws on the concept of the "Participating City" within the Ecopolis framework. From a macro-level perspective, the government plays a central role in shaping the city's spatial structure. Accordingly, the design strategy at the governmental scale emphasizes the integration of water management with economically productive green spaces, forming a cohesive blue – green infrastructure network.

In the Menengai Crater area, enhanced rainwater infiltration is designed to replenish local groundwater resources, contributing to long-term hydrological resilience. Within the urban space, the existing infrastructure will be adapted to function as a surface runoff collection network, optimizing stormwater management. The east – west arterial roads are planned to align perpendicular to the natural direction of surface runoff, enabling the captured rainwater to be utilized for linear community gardens situated along the streets.

During the rainy season, excess rainwater will be redirected and reused within the floodable wetlands of the Agricultural Hub, supporting wetland agriculture and aquaculture development. This integrated system not only mitigates flood risks but also enhances urban food production and ecological diversity.

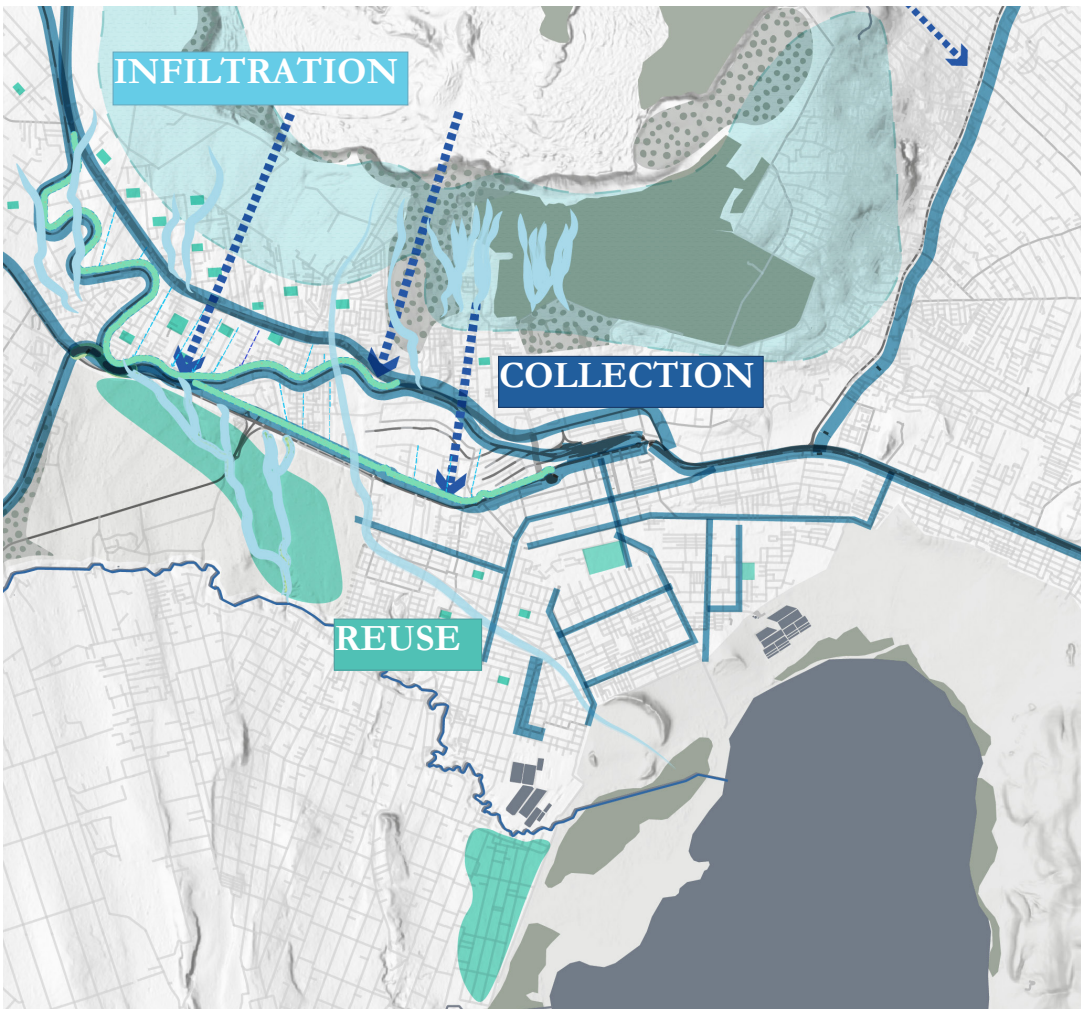


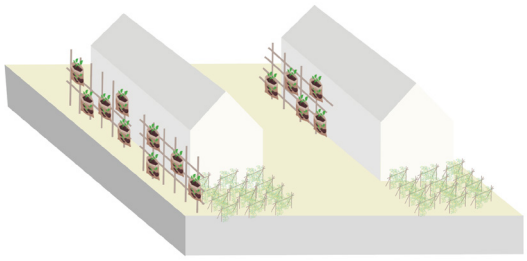
Figure4.1-1, Water Management Structure ,
drawing by author

4.1.4 NGOs&Residents Layer

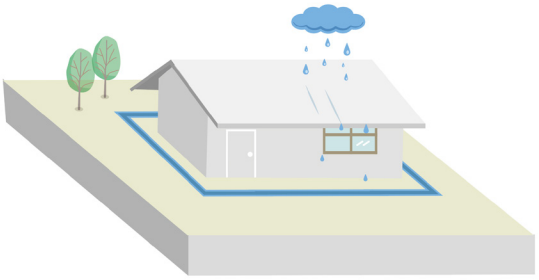
Provide a sustainable and resilient guideline for households to extend the rainy season and increase food production

Within the blue–green framework, household-level strategies such as rainwater harvesting and sustainable urban agriculture play a crucial role in extending the effective duration of the rainy season, generating additional income through cash crop cultivation, and reducing dependence on chemical fertilizers. When implemented at scale and adopted by individual households, these practices can significantly enhance the city's overall resilience and ecological sustainability.

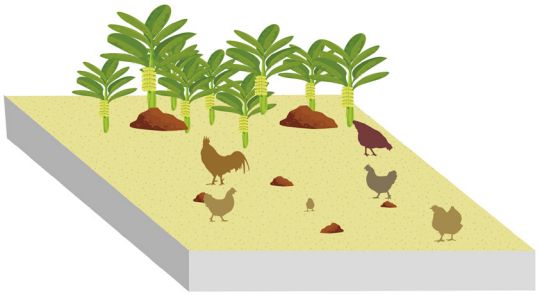
The successful realization of this process relies on collaborative governance between non-governmental organizations (NGOs) and local residents. NGOs serve as key facilitators by promoting vertical farming, educating communities about appropriate crop selection, the advantages of bio-manure, and techniques for rainwater harvesting and storage. Additionally, they organize community-based workshops and events to foster learning, knowledge exchange, and collective action. As residents develop a clearer understanding of the tangible benefits of these strategies, they are more likely to adopt and sustain them in daily practice, thereby reinforcing the city's adaptive capacity.



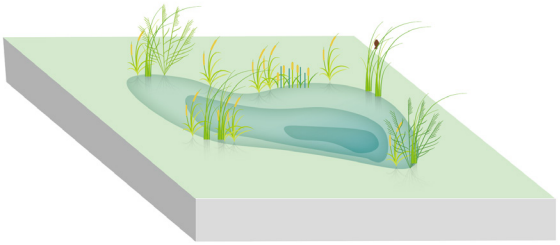
Vertical Farming



Rainwater Collection System



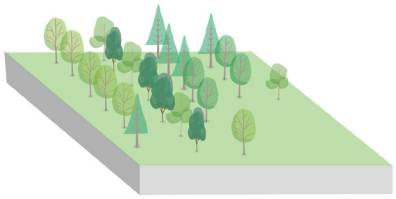
Poultry Manure Fertilizer



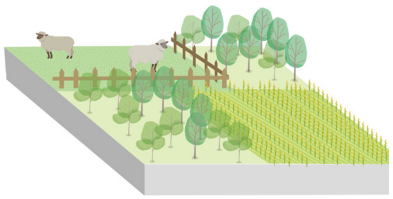
Retention Ponds

4.1.5 NGOs&Government Layer

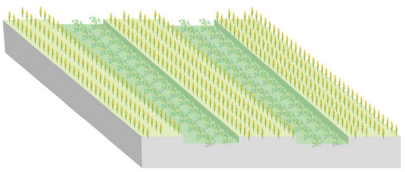
Develop native agroforestry and mixed farming strategies for Nakuru to improve agricultural returns



Agroforestry



Mixed farming



Intercropping

Certain areas are designated for agricultural production and agricultural education, serving as protective buffers that prevent further urban encroachment. While maintaining the existing green cover, it is essential to develop context-specific approaches that, under diverse soil and topographical conditions, can minimize soil erosion and topsoil loss, enhance long-term agricultural productivity, and improve water resource efficiency.

Broadly, the implementation of agroforestry, mixed farming, and intercropping systems offers effective strategies to address these challenges. At this stage, the government plays a crucial role by providing policy guidance and financial incentives, whereas non-governmental organizations (NGOs) contribute through technical support and community coordination. Their responsibilities include identifying tree and crop species suitable for integration into agroforestry and intercropping systems, facilitating land reallocation among farmers, and conducting regular monitoring and evaluation of agricultural land. Collectively, these measures reinforce the ecological stability and economic resilience of peri-urban agricultural zones.

4.2 Vision

From Drainage to Sponge Urbanism

Combining the previous analysis, Design Vision developed a new blue-green space plan based on the existing Nakuru water catchment structure, with the peri-urban area as the upper and middle reaches of the seasonal stream and the urban area as the downstream of the seasonal stream, aiming to lay a framework and prepare for future urban development.

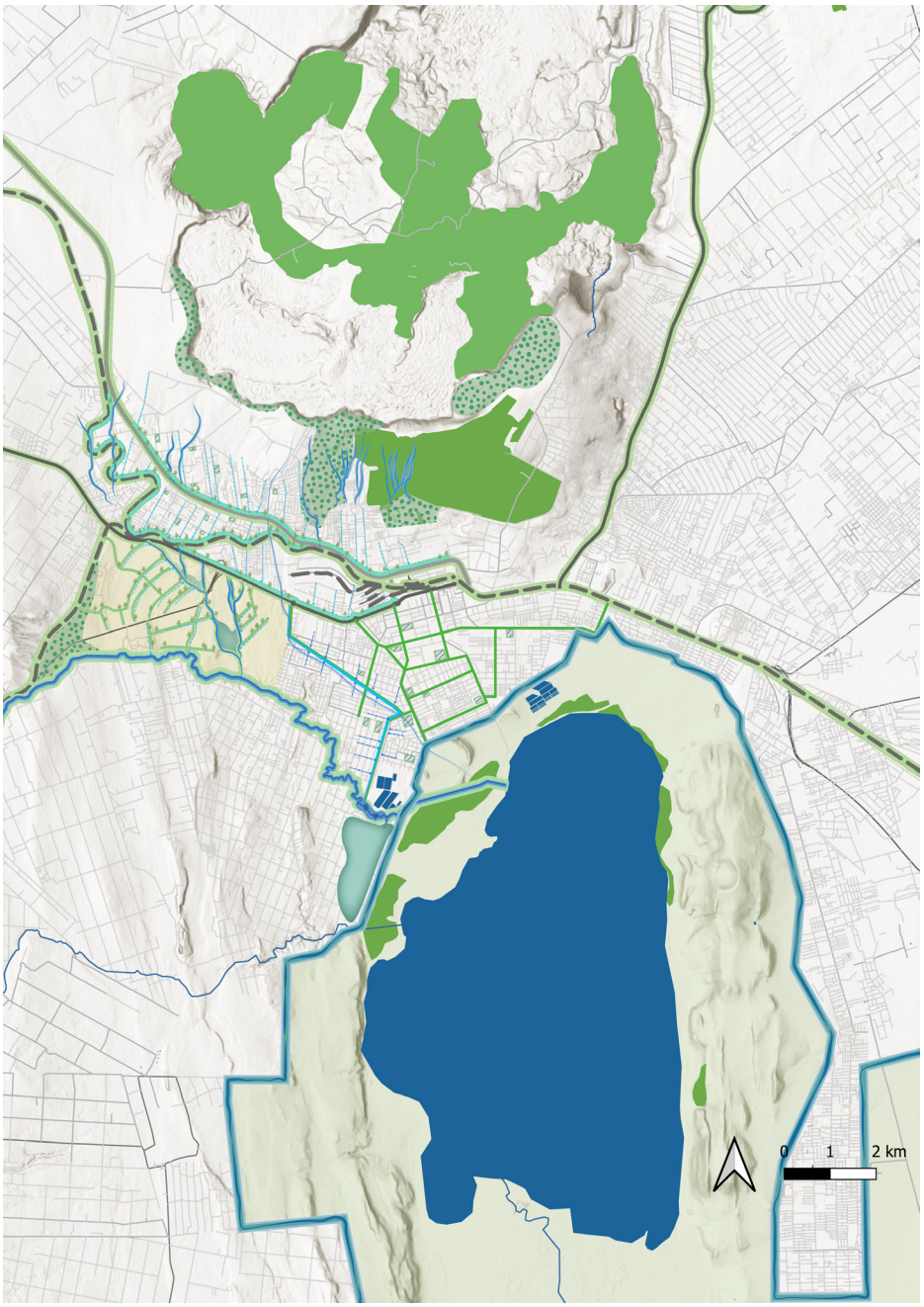
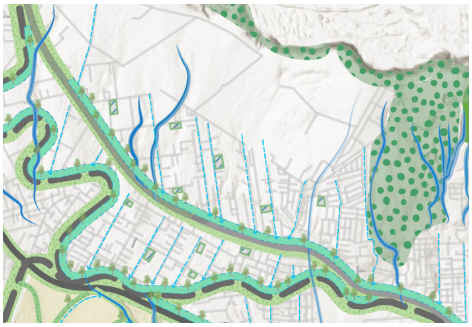
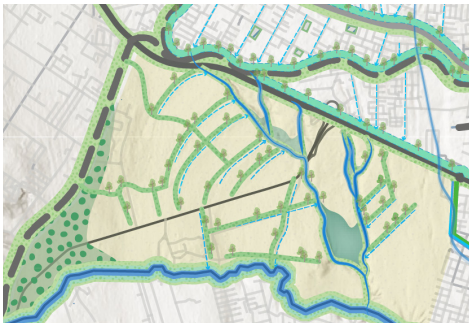


Figure4.1-1, vision , drawing by author



Kiamunyi Residential Area

The design of the area seeks to provide households with practical guidelines for sustainable rainwater harvesting and agricultural practices, while enhancing resilience through the creation of blue–green spaces that build upon the existing road network.



Kiamunyi Educational Agriculture Hub

Leveraging its natural seasonal runoff and its designation as educational land in the spatial plan, the Kiamunyi Agriculture Hub is designed to showcase diverse agricultural practices adapted to different soil conditions, while demonstrating strategies for integrating agriculture with water management.





City Core&Rhoda-Floodable Agriculture

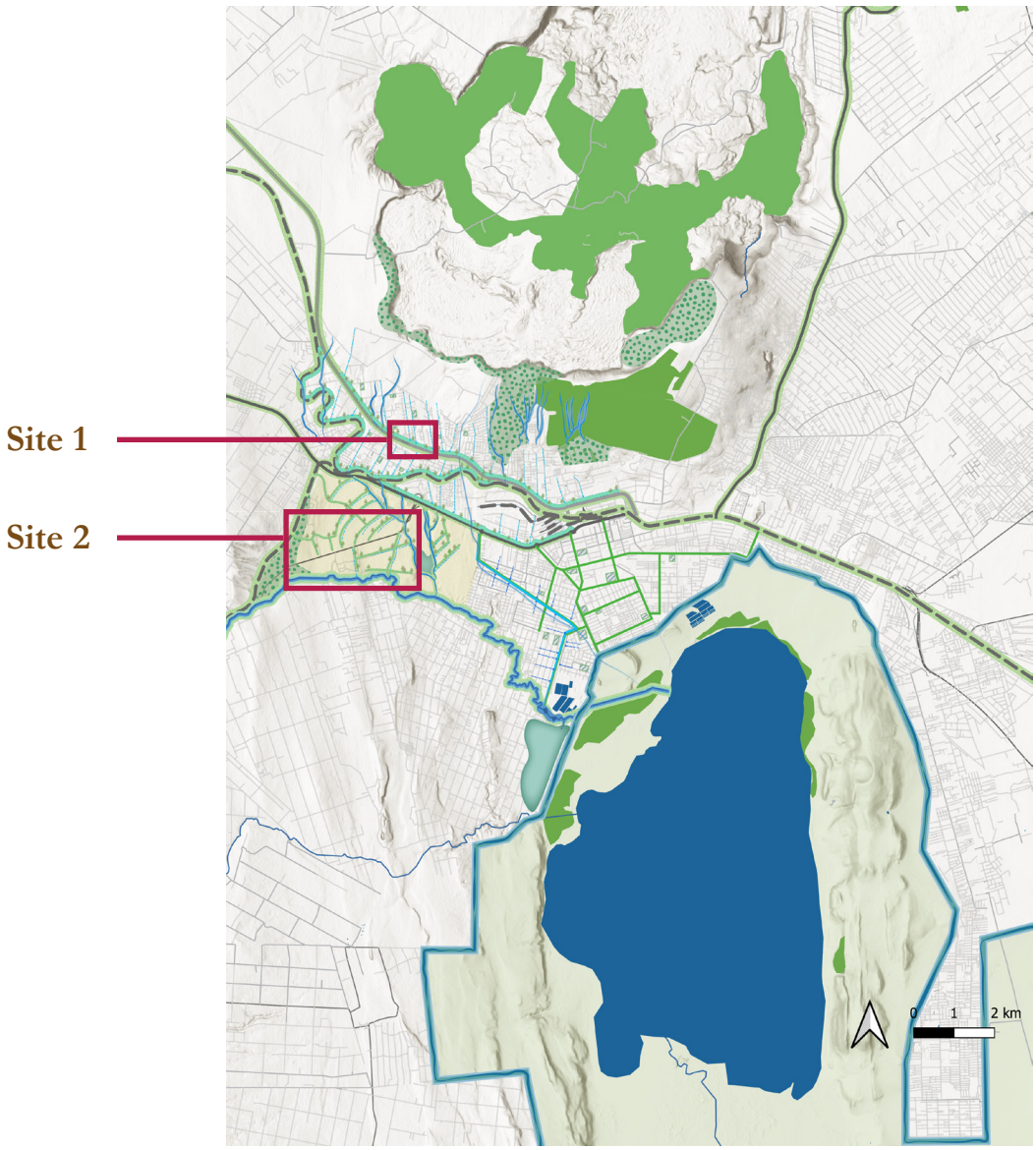
Flood-prone urban centers require a primary channel for flood discharge that not only directs excess water but also incorporates purification processes before the water is reused for flood-resilient agriculture. During the rainy season, floodwaters from the city can be diverted to the southern bank of the Nojoro River, where they are filtered and subsequently utilized for fish farming and farmland irrigation. As the rainy season ends and the waters recede, the runoff deposits silt and nutrient-rich sediments onto the wetlands. This natural process enhances soil fertility, thereby reducing dependence on chemical fertilizers and pesticides.

CHAPTER **5**.

Design for a sustainable "Paradise"

5.1 Site Selection
5.2 PILOT PROJECT 1:Kiamunyi Residential Area
5.2.1 Exsiting Situations
5.2.2 Design Concept for Kiamunyi residential area
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5.2.4 Site 1
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5.3 PILOT PROJECT 2:Kaptembwa Educational Agriculture Hub
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5.3.2 Design Concept
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5.3.6 Section
5.3.7 Scenarios


© xuejing


Site 1
Site 2
0
1
2 km

Educational Agriculture Hub

Site 1

Bioswale(Water Management)
Community farming park (Urban Farming)
House-hold guidelines （ Sustainable Agriculture)

Roadside community sponge park

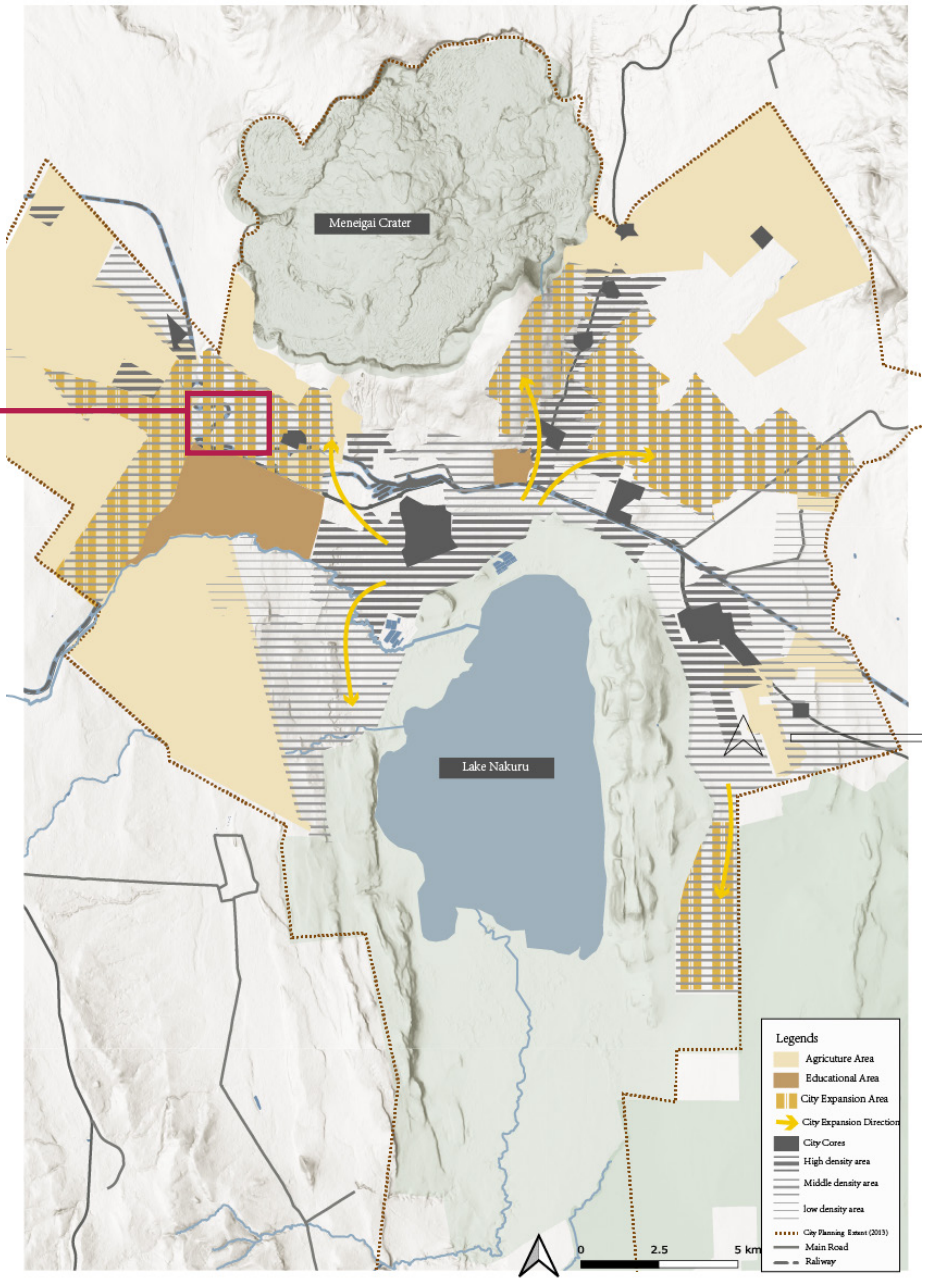
Site 2

Green corridor for seasonal stream (Water management)
Terrain + Ditch(Water management)
Floodable agriculture(Agroforestry)
Forestry+Livestock (Agroforestry)
Forestry+Agriculture (Agroforestry)

PILOT PROJECT 1

Kiamunyi Residential Area

Site 1



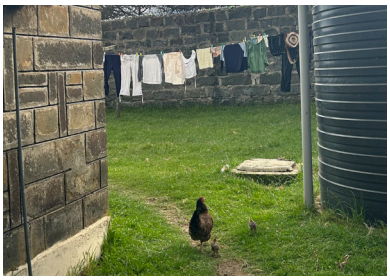





Figure5.1-1,2,3,4,Life styles in Kianmuyi residential area, photos by author



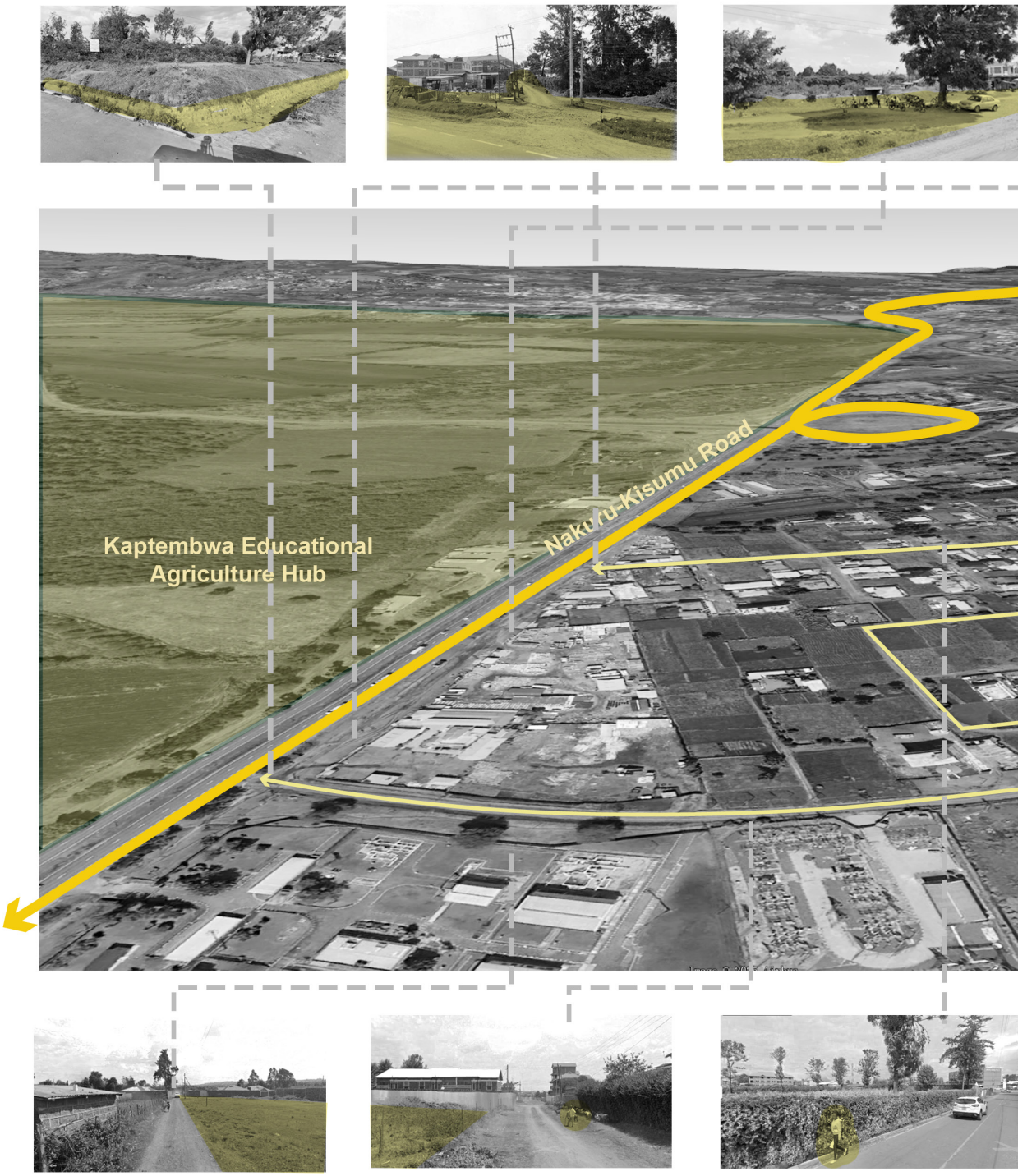



Figure5.1-5,6,7,8, Primary roads in Kianmuyi residential area, photos from google map

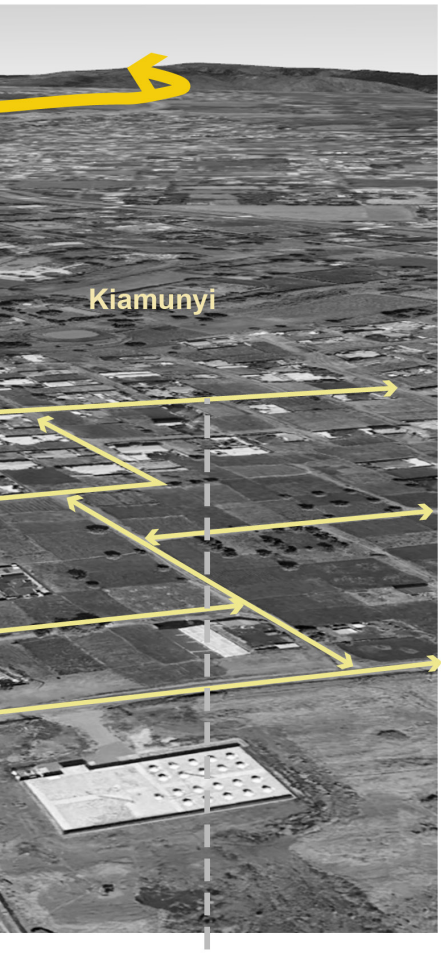
The Kiamunyi Agricultural Hub is situated in the peri-urban zone of Nakuru, an area currently characterized by relatively low-density development yet experiencing rapid urban expansion. Small- and medium-scale agriculture constitutes the dominant land use within Kiamunyi, with most cultivation occurring in plots adjacent to residential properties. This pattern indicates that Kiamunyi holds significant potential for future urbanization and spatial transformation.

Local residents engage in crop cultivation and poultry farming, producing a variety of agricultural goods throughout both the rainy and dry seasons. The area’s secondary road network consists mainly of unpaved dirt roads, while existing drainage infrastructure remains partial and fragmented, limiting its overall effectiveness in managing surface runoff and seasonal flooding.

5.2.1 Exisiting Situation





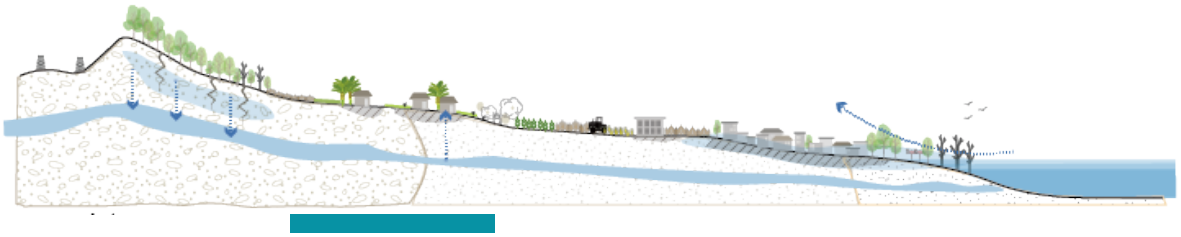




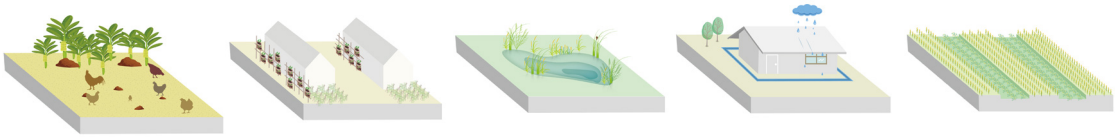
Kiamunyi is separated from the Kaptembwa agricultural hub by the Nakuru–Kisumu Road, a vital transportation artery connecting central and western Kenya. This road traverses key agricultural and trade zones, supporting domestic economic transport and serving as a crucial component of the East African regional trade corridor. Several secondary roads connect to it. Based on site observations, the Nakuru–Kisumu Road includes shaded rest areas and pedestrian walkways within green spaces, accompanied by drainage ditches along the roadside. However, while the primary and secondary roads are well connected for vehicular movement, their water management and green space systems remain unintegrated, with existing drainage channels ultimately directing runoff into the lower-lying Lake Nakuru.

Regarding the secondary roads, there are underutilized green spaces alongside the site, a lack of drainage infrastructure, and an absence of proper pedestrian walkways—resulting in low safety for pedestrians who must share lanes with motor vehicles.

5.2.2 Design Concept for Kiamunyi rrsidential area



Kiamunyi residential area



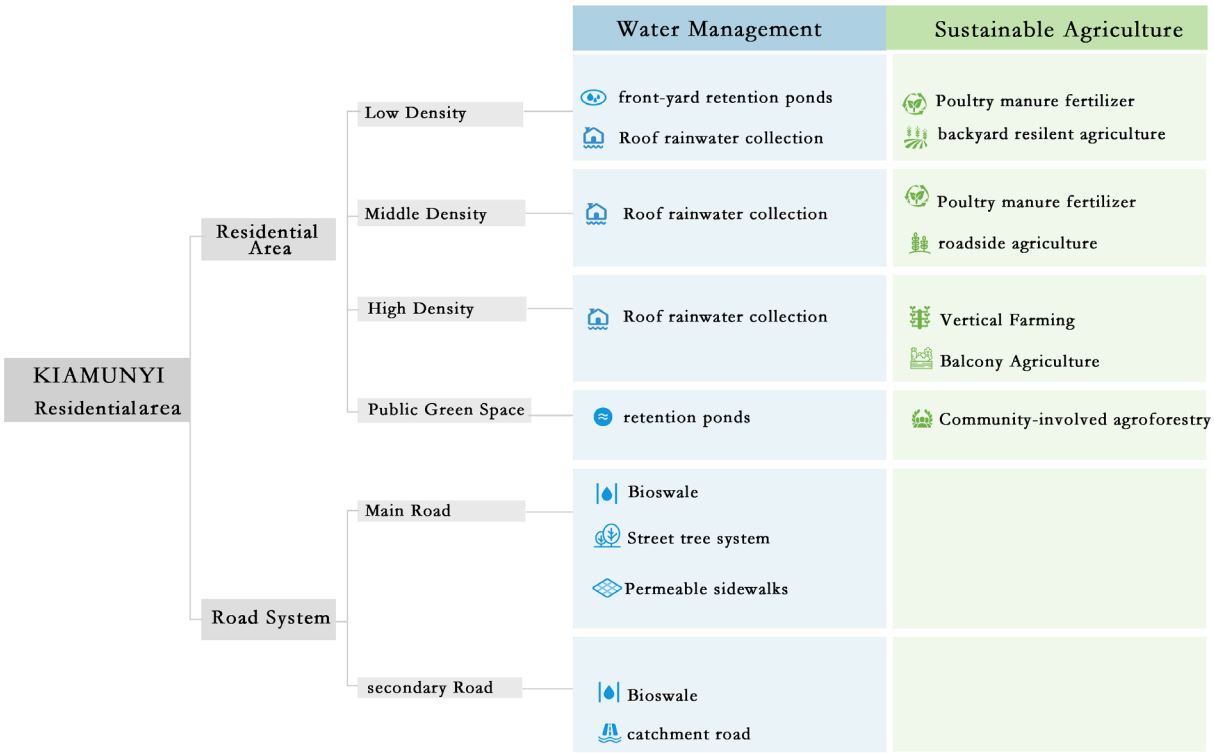


Figure5.1-1,design strategies for Kiamunyi residential area , drawing by author

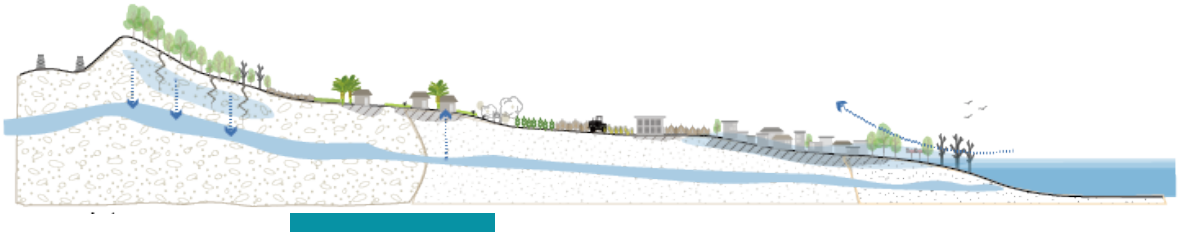
From a housing perspective, each settlement can be conceptualized as comprising a front yard, a house, and backyard agricultural space, with the relative proportions of these components varying by location. Situated in a peri-urban area, this region is experiencing increasing residential density and land fragmentation due to ongoing urbanization. Given the inevitability of this trend, the aim of this research and design is to provide guidelines for rainwater harvesting and sustainable agricultural practices.

Field investigations revealed that residents typically purchase clean water and store it in tanks for daily use. Additionally, most households engage in small-scale farming or poultry rearing within their yards. Based on these observations, this study proposes five key guidelines to support local residents in extending the rainy season and reducing reliance on chemical fertilizers and pesticides: vertical farming, rainwater harvesting, retention ponds, poultry manure fertilization, and intercropping using the push–pull method.

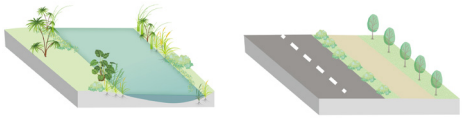
5.2.3 Design Concept for Road system



Figure5.2.3-1Pictures of the roads in Kiamunyi, photos from google map



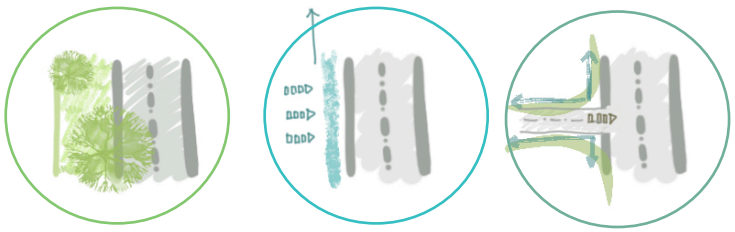
Kiamunyi Residential Area



Kiamunyi's primary road system runs east-west through the city, perpendicular to the seasonal stream, forming an effective water collection network, with the roads functioning like nets that capture rainwater. Secondary roads connect to the primary roads, creating a drainage system that leverages the existing infrastructure. Unlike the current urban system, which directs all rainwater from Kiamunyi to the lake, this design seeks to repurpose the primary road network to recycle rainwater, establishing a rain-fed agricultural community park.

Field observations indicate that local residents already use the green strips along roads for walking and rest, and that numerous secondary roads intersect with primary roads within Nakuru's infrastructure. Consequently, developing green spaces for recreation alongside a comprehensive, nature-based drainage system represents the ecological framework necessary for this site.

Therefore, the design concept starts from three perspectives: blue, green, and connection, aiming to combine different functions to collect and reuse rainwater for community agriculture.



Green + **Blue** = **Connection**

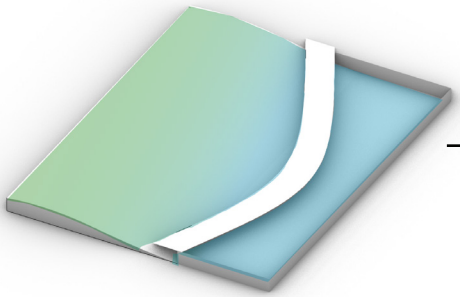
recreational space
community park
agriculture

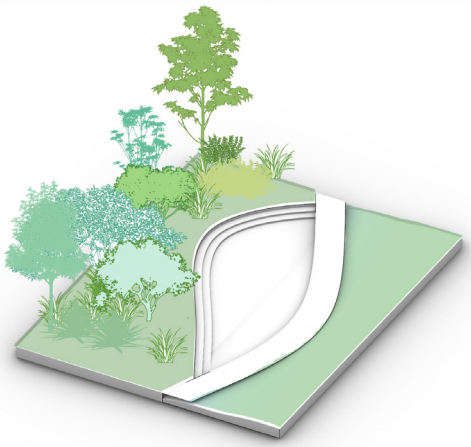
collection
reuse surface runoff

5.2.3 Design Concept for Road system

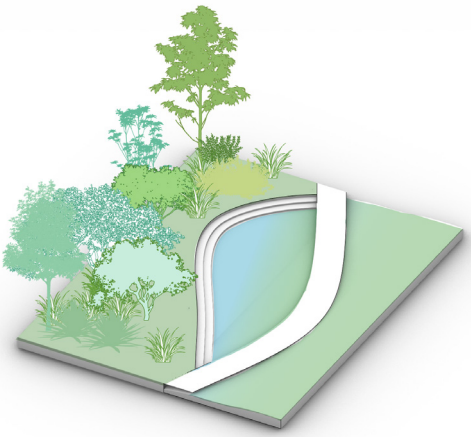
water management
+ recreational functions

landform only made for
water management

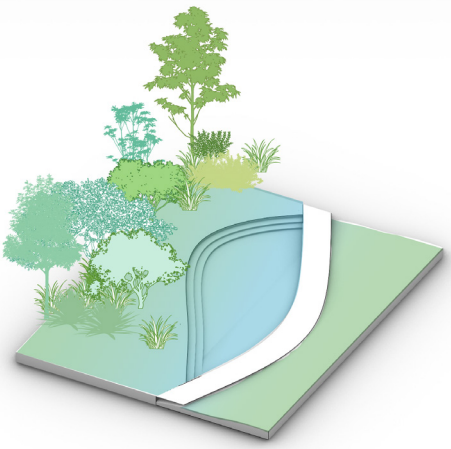




Dry season



Rain Season
50%



Rain Season
100%

In the design of green spaces along urban roads, the focus extends beyond conventional linear pedestrian systems and green corridors. It also explores how the spaces adjacent to secondary roads can be transformed into functional sponge landscapes that simultaneously serve ecological and social purposes. Unlike terrain designs that simply retain or store stormwater during the rainy season, the proposed open green space design seeks to integrate community engagement, social interaction, and environmental education into the spatial framework. These spaces not only contribute to water management but also respond to community needs, strengthen the relationship between NGOs and residents, and provide venues for collective activities and knowledge exchange.

To achieve this, a community "threater"—an open, adaptable public space—was designed based on a rain-resilient topography. This structure serves as a multi-functional platform where residents can share agricultural practices, participate in seasonal events, and cultivate a sense of community ownership. During the dry season or periods of low rainfall, the thrower functions as an active social and educational hub. However, during the rainy season, the designed terrain allows the space to absorb and temporarily store floodwater, thereby reducing surface runoff and alleviating localized flooding. In this way, the design merges hydrological performance with social utility, creating a hybrid infrastructure that embodies both ecological resilience and community vitality.

5.2.4 Site 1 : Kiamuny Residential Area

Guideline for Household level

By integrating these five guidelines, urbanization can attain a certain degree of household-level sustainability. Even at higher residential densities, strategies such as vertical farming and rainwater harvesting remain feasible. Nonetheless, urban development requires clear limits and regulatory frameworks, with the existing road network providing a solid foundation for planning and structuring future growth.

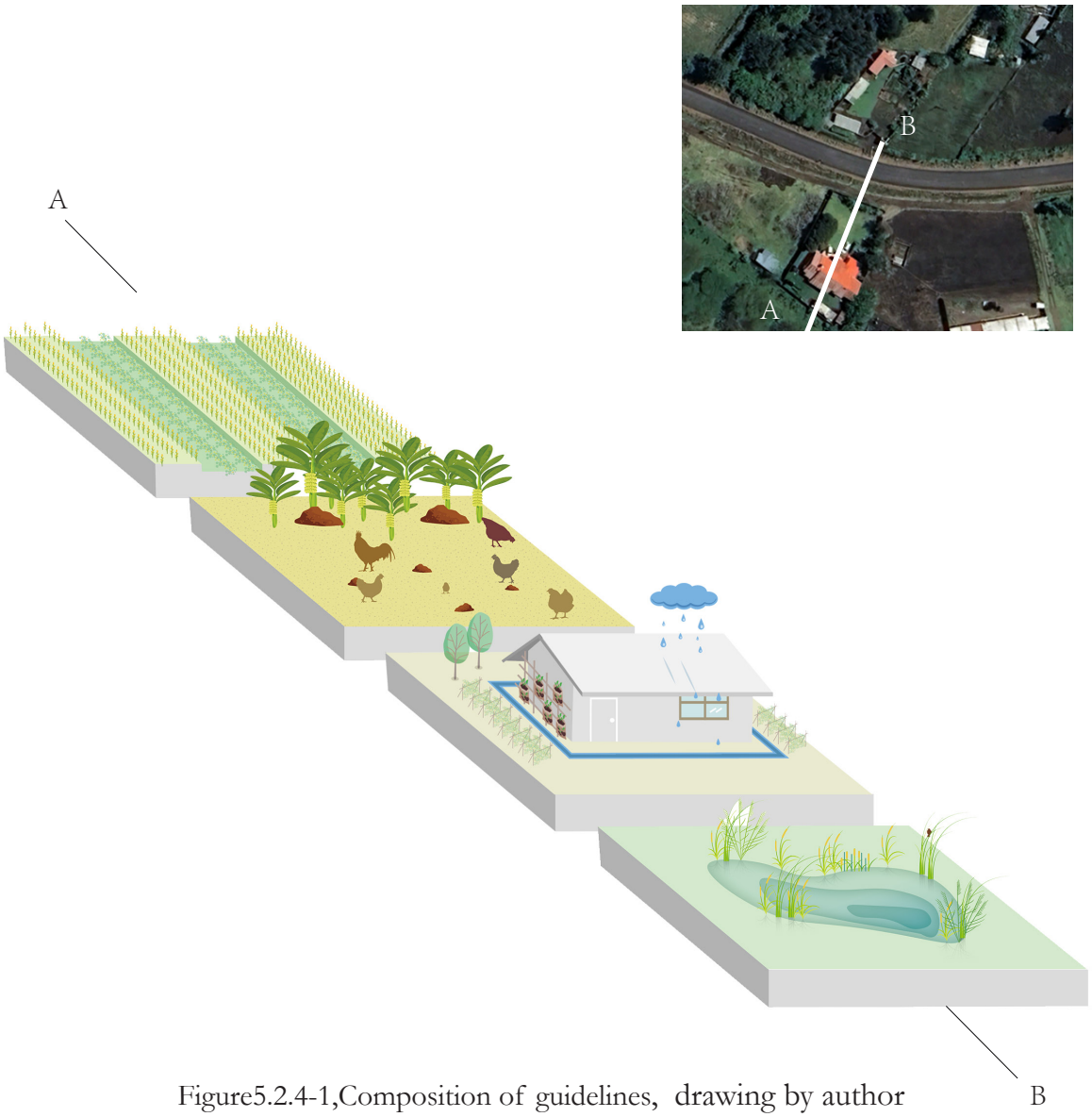


Figure5.2.4-1,Composition of guidelines, drawing by author

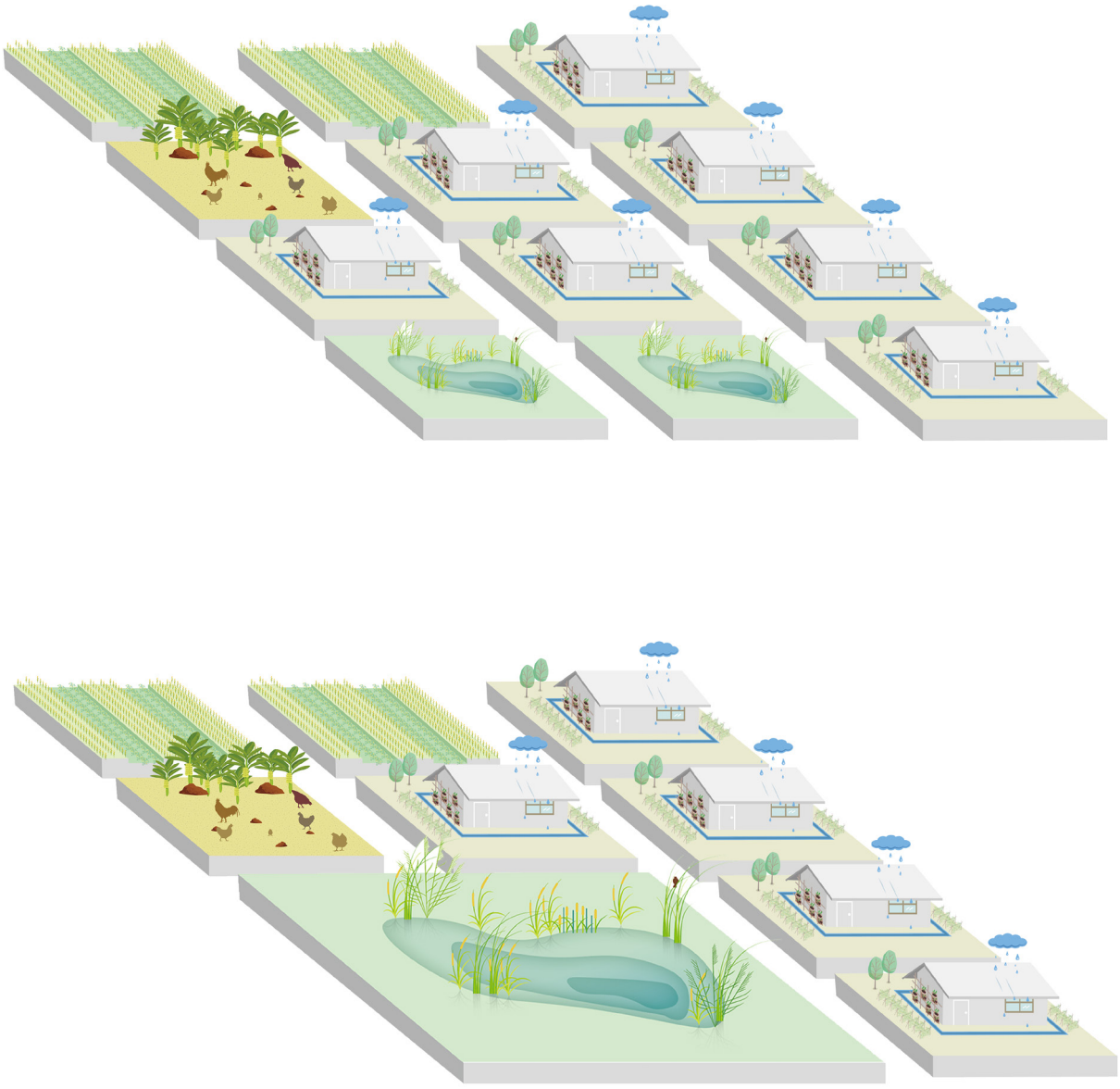


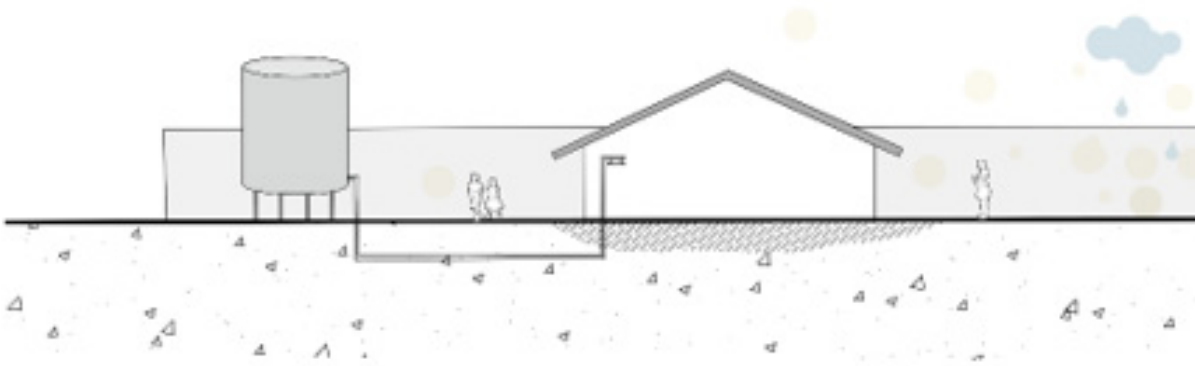
Figure5.2.4-2,Trend of urbanzition, drawing by author

5.2.4 Site 1 : Kiamuny Residential Area

Section of Household level

In the current condition (top diagram), most surfaces between residential areas and roads are paved, causing rainwater to flow directly across the surface into nearby drainage ditches or roads. Although limited drainage infrastructure exists, it is fragmented and inefficient, leading to insufficient infiltration and increased surface runoff during heavy rainfall. The lack of vegetation and terrain variation weakens the site's ability to regulate stormwater and recharge groundwater.

BEFORE



BEFORE

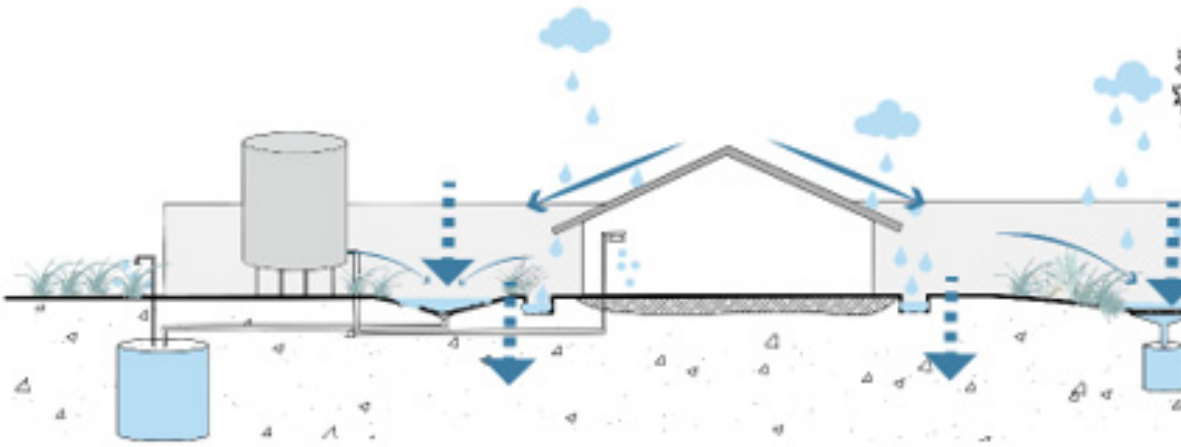
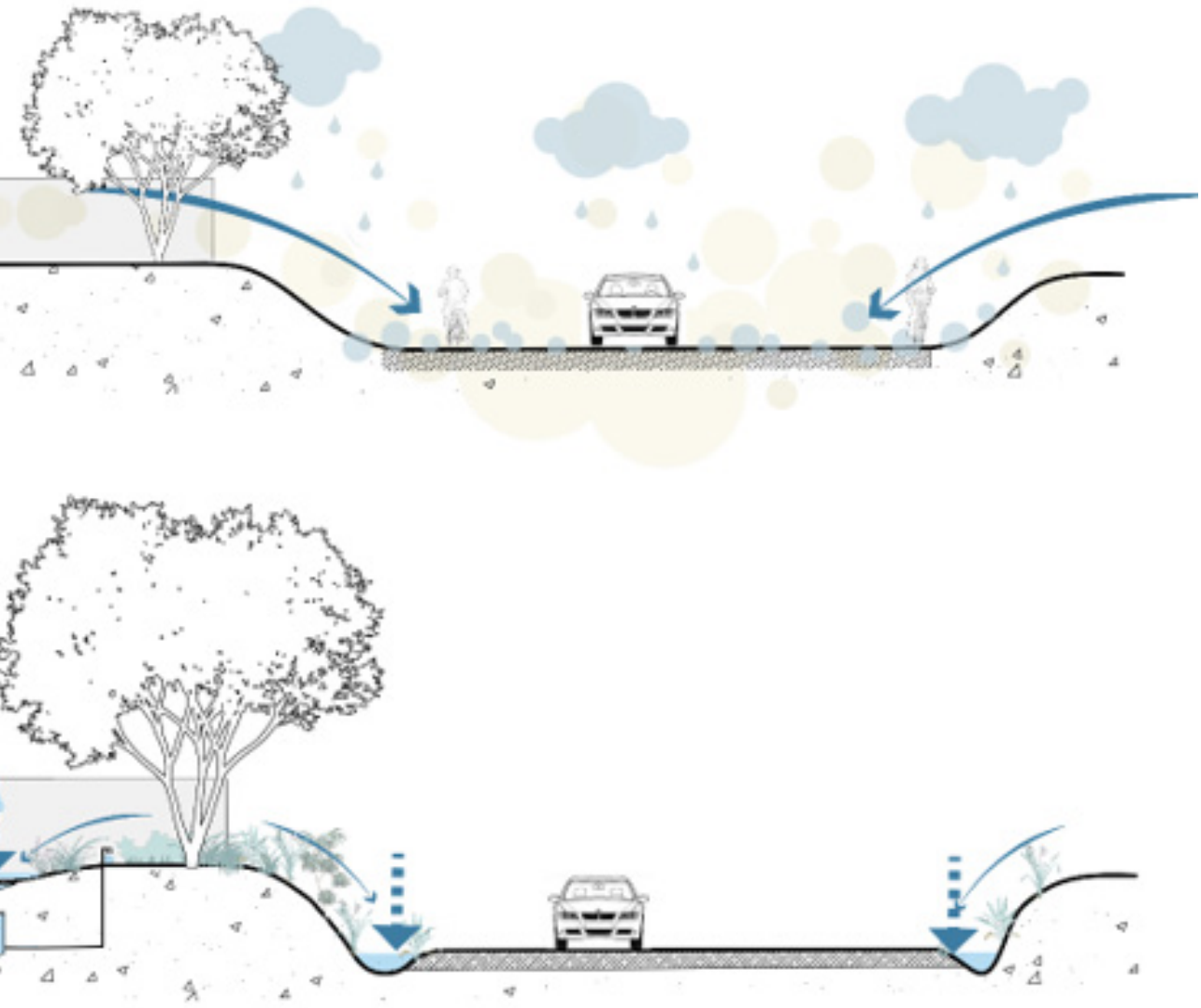


Figure5.2.4-3,"Before" and "After
autho

In the proposed condition (bottom diagram), the design introduces a network of rain gardens, vegetated swales, and sunken green spaces between houses and roads. Rainwater from roofs, courtyards, and roads is directed into these sponge spaces and temporary storage tanks, where it is gradually filtered, infiltrated, and reused. This system enables a cyclical process of collection–detention–infiltration–reuse, reducing flood risk and enhancing groundwater recharge.



r" the guidelines, drawing by
or

5.2.5 Site 2 : Road Systerm

Plan





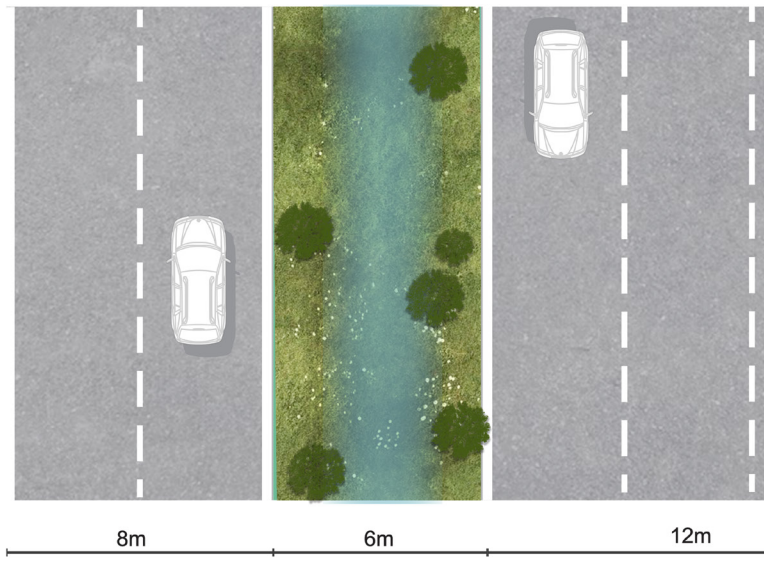
The design not only emphasizes the connectivity of blue-green spaces along the roadside but also enhances the walkability and experiential quality of the pedestrian system. By integrating shaded pathways, permeable pavements, and visually engaging planting layouts, the design encourages daily use by residents and visitors. Moreover, the improved accessibility and spatial continuity of green areas significantly increase the utilization and social value of urban open spaces, transforming them from passive landscape buffers into active public spaces that support recreation, education, and community interaction.

5.2.5 Site 2 : Road Systerm

Primary Road

Community agricultural gardens are established along the roadside, making use of collected rainwater for irrigation. These gardens not only enhance the efficient use of rainwater resources but also foster community engagement, strengthen local food production, and enrich urban biodiversity. The accompanying sections illustrate how subtle topographical adjustments and stratified vegetation systems collaboratively create a sponge-like landscape—one capable of absorbing, storing, and recycling water while preserving the functionality of the roadway.

Overall, this design approach seeks to integrate water management with social and ecological objectives, enhancing both the city’s environmental resilience and the quality of urban life.



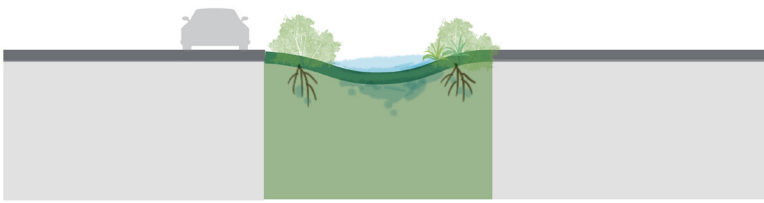
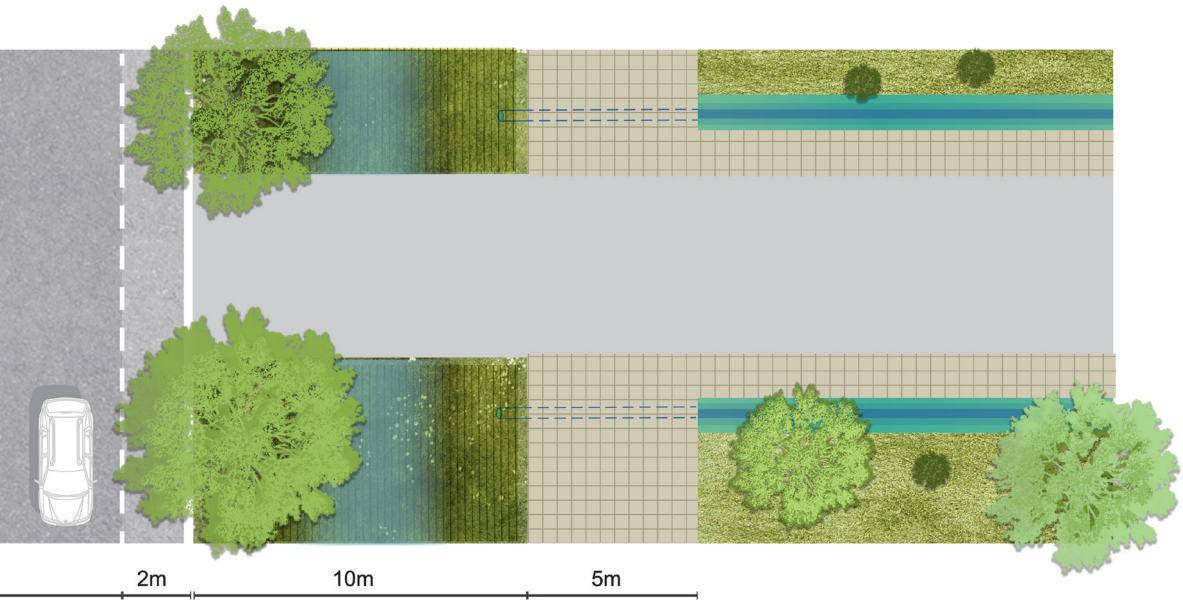
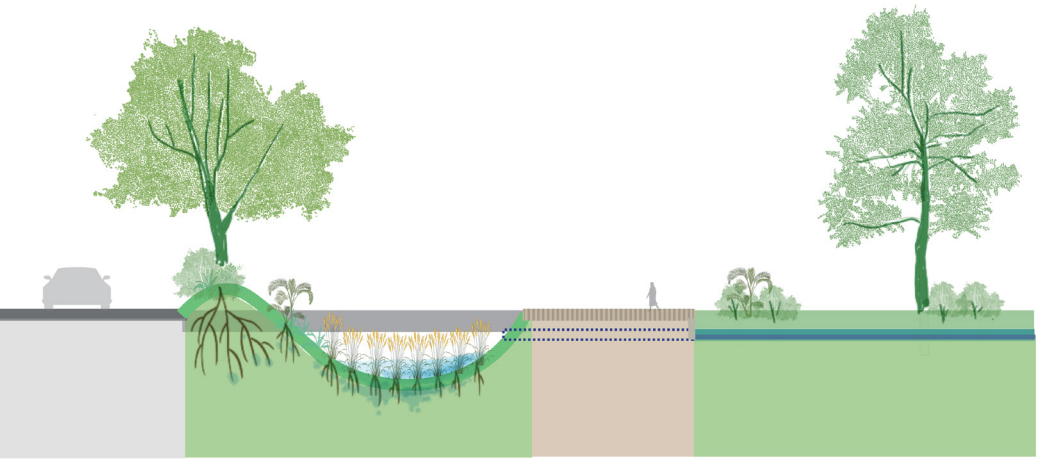


Figure5.2.5-1, Sect

community agriculture garden

Water catchment system





tion of a Primary Road

5.2.5 Site 2 : Road Systerm

Secondary Road

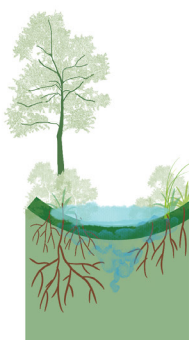
The proposed design for this secondary road section demonstrates how stormwater management and community activity spaces can be seamlessly integrated into everyday urban infrastructure. The approach transforms the roadside into a multifunctional blue-green corridor, combining bioswales with a “sponge theater” to address both ecological and social needs.

On the left side of the section, bioswales run along both sides of the carriageway. These vegetated channels capture and filter surface runoff from the road, promoting infiltration, sediment filtration, and groundwater recharge. Deep-rooted plants stabilize the soil and enhance the ecological performance of the roadside while preserving the road’s drainage capacity.

On the right side, the design transitions into a “sponge theater”, a sunken public space shaped by rain-resilient topography. This space serves dual purposes: during dry periods, it functions as a community gathering and recreational area; during rainy periods, it temporarily stores stormwater, allowing gradual infiltration. Layered vegetation improves biodiversity and provides shade, while permeable pavements enhance comfort for users and reduce surface runoff.

This design illustrates how urban infrastructure can be both functional and socially engaging, turning stormwater management into an opportunity for ecological enhancement and community activation.





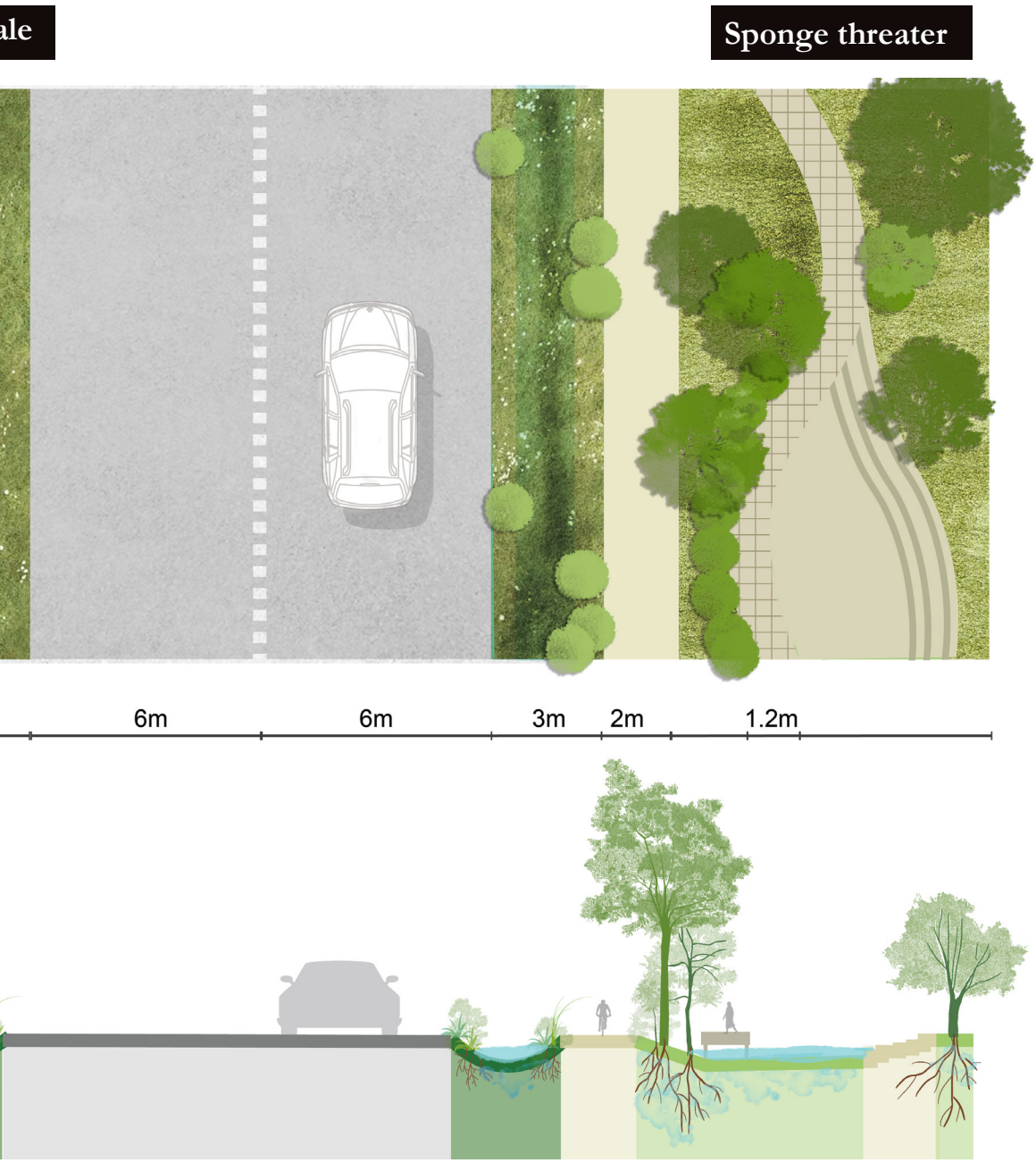
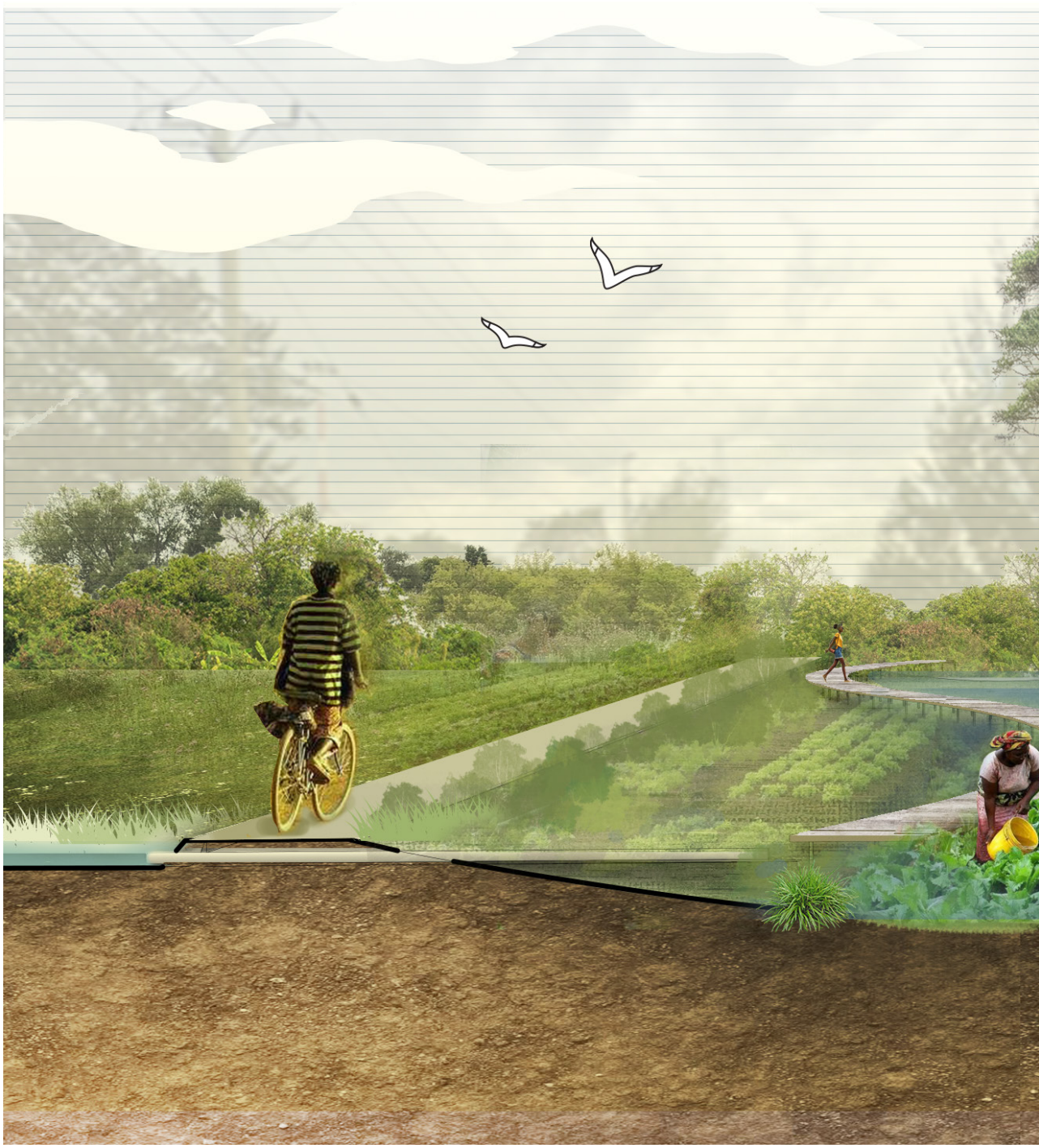


Figure5.2.5-2 , Section of a Secondary Road

5.2.6 Site 2 : Scenario

Community envolved agriculture park



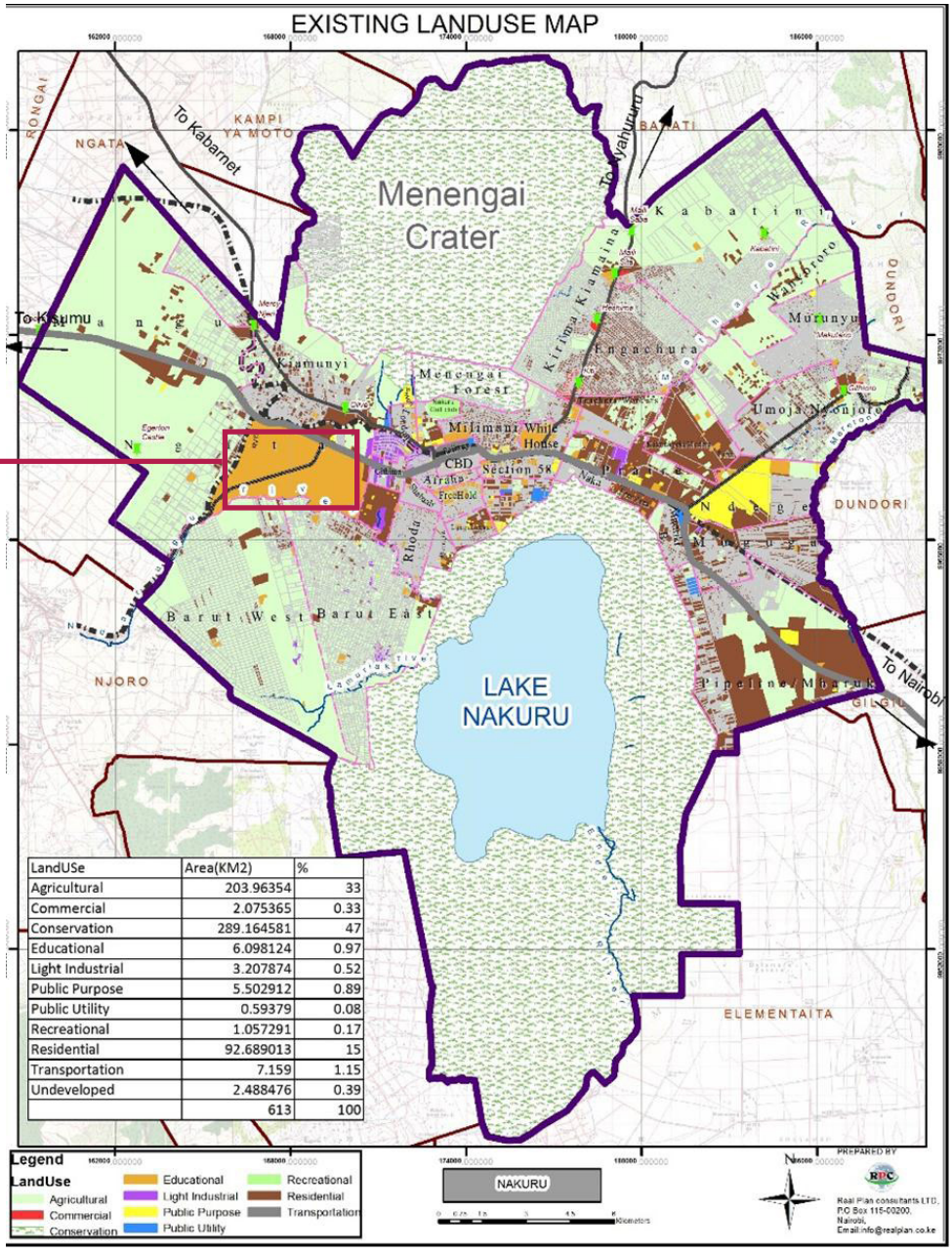


PILOT PROJECT 2

Kaptembwa Educational Agriculture Hub

Water management integrated Agroforestry solution

Site 2



LandUSe	Area(KM2)	%
Agricultural	203.96354	33
Commercial	2.075365	0.33
Conservation	289.164581	47
Educational	6.098124	0.97
Light Industrial	3.207874	0.52
Public Purpose	5.502912	0.89
Public Utility	0.59379	0.08
Recreational	1.057291	0.17
Residential	92.689013	15
Transportation	7.159	1.15
Undeveloped	2.488476	0.39
	613	100

Figure5.2-1 , Exsiting Landuse Map, from County Government of Nakuru

Pilot Project 2 is located between urban and peri-urban Nakuru. According to Nakuru County's existing land-use plan, this area is currently designated for educational purposes; however, future industrial planning envisions its transition toward agricultural–industrial expansion.

Unlike other large-scale agricultural lands, this site is owned by the Rift Valley Institute of Science and Technology, making it an ideal location for demonstrating sustainable agricultural practices. The project is expected to increase crop yields, reduce dependence on pesticides and chemical fertilizers, and serve as a replicable model for other areas in the region.

Furthermore, the project integrates agriculture with water management, establishing a blue–green spatial framework that promotes sustainable regional agricultural development. The site also functions as part of the sponge city strategy, helping to alleviate flooding during the rainy season and mitigate the rising water levels of Lake Nakuru on a county-wide scale.

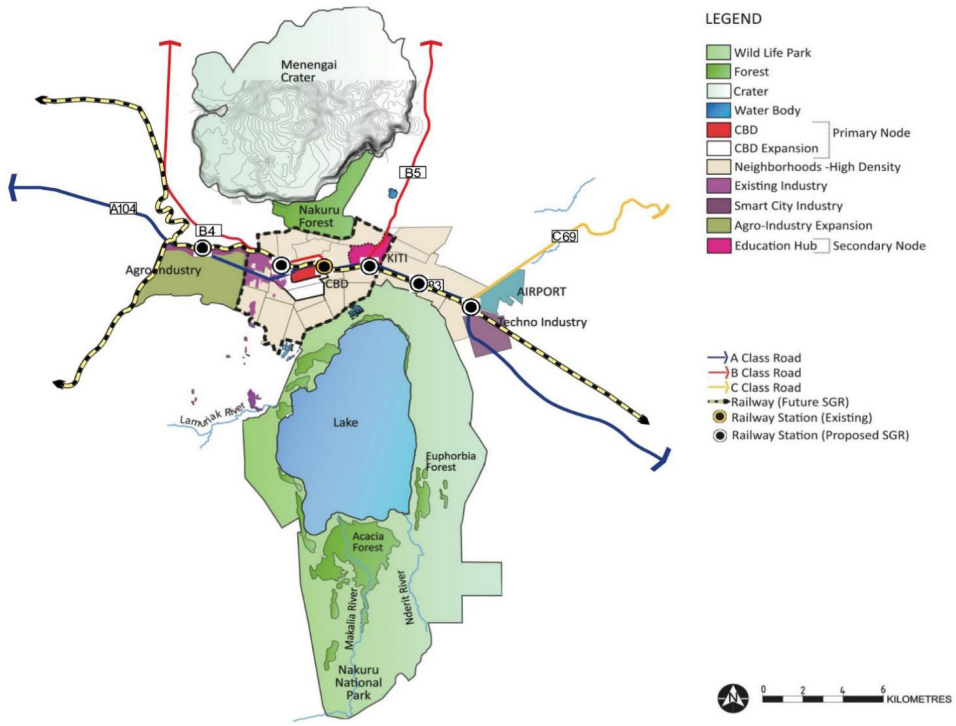


Figure5.2-2 , Industry Planning Map, from County Government of Nakuru

5.3.1 Existing Situation



Figure5.2-3 ,: A series of photos to show current situation of Kaptembwa Agricultural Hub

The Kaptembwa Agricultural Hub currently comprises farmland and forested areas mainly along seasonal runoff channels(figure 5.2.3).

This seasonal runoff originates from the higher ground of Kiamunyi, flows through Kaptembwa, and ultimately drains into the Njoro River(figure 5.2-4), which subsequently flows into Lake Nakuru. The runoff not only shapes the local topography (figure 5.2.5)but also provides a critical water source for plant growth.Satellite images show that forests are mainly distributed around seasonal streams in low-lying areas.

The design objective of this pilot project is to optimize the use of rainy-season water resources and develop diverse and sustainable agricultural, forestry, and livestock systems, tailored to the site's varied soil conditions. Unlike the clay soils in the eastern portion, the western area features sandy soils with a loose structure and good drainage, making it particularly suitable for tree cultivation. The integrated application of multiple agricultural types is intended to restore soil fertility while also functioning as an educational and demonstration project.

Based on the site's soil characteristics, topography, and existing land-use patterns, this study proposes a design concept to guide sustainable development.

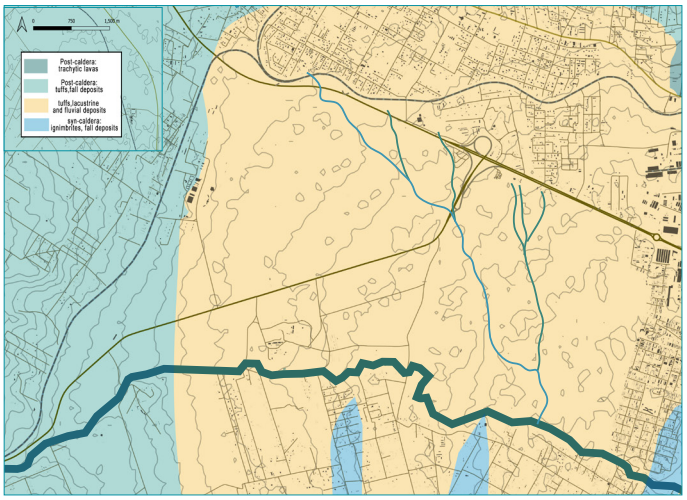


Figure5.2-4 ,:Soil Types of Kaptembwa Agricultural Hub

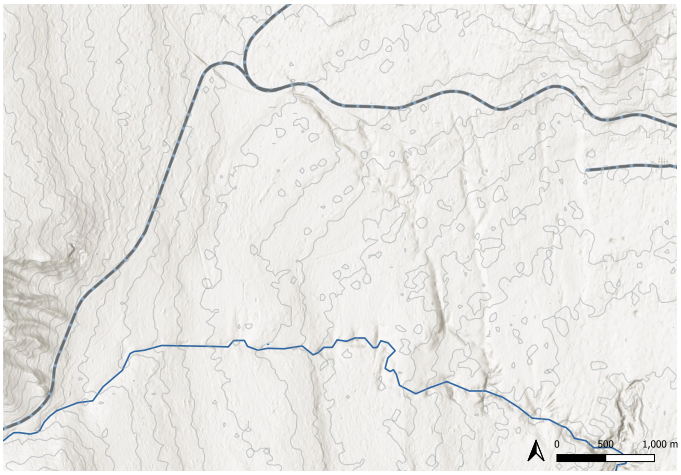


Figure5.2-5 ,:Landform of Kaptembwa Agricultural Hub

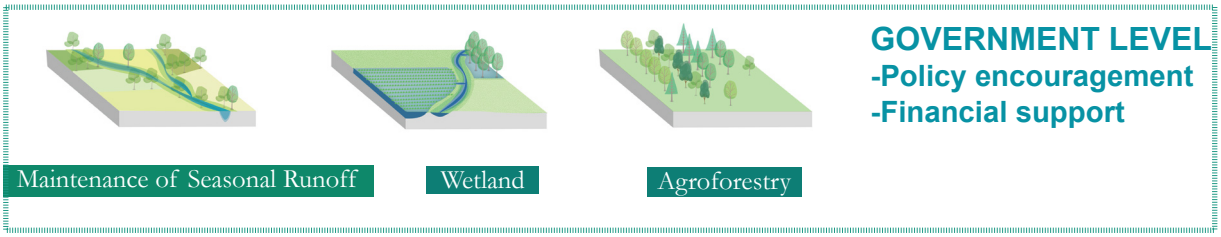


Figure5.2-6 ,:Satellite Image of Kaptembwa Agricultural Hub from google map

5.3.2 Design Concept



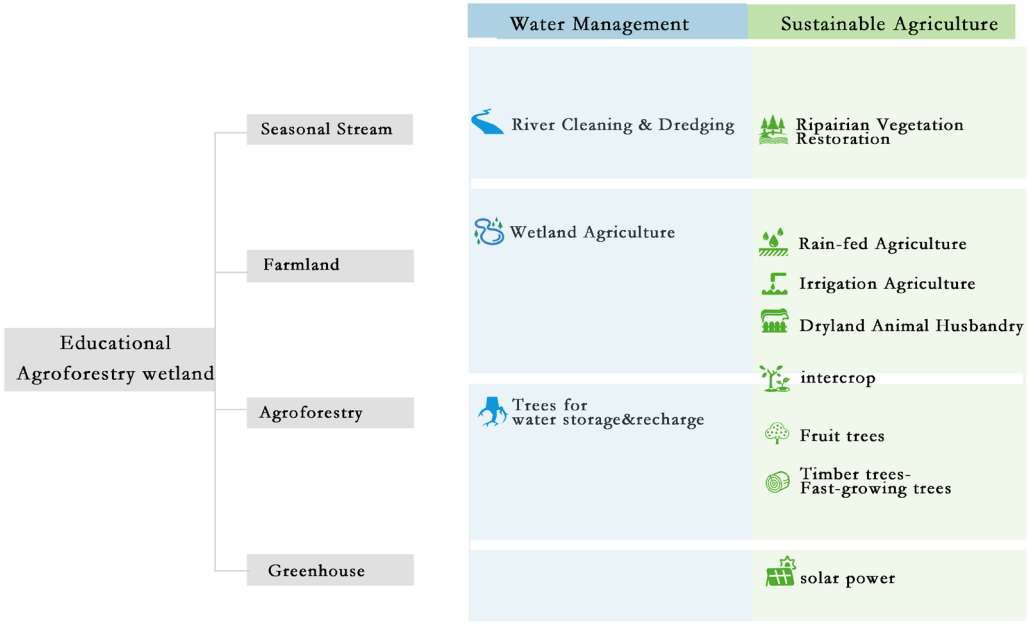
Kaptembwa Agriculture Hub



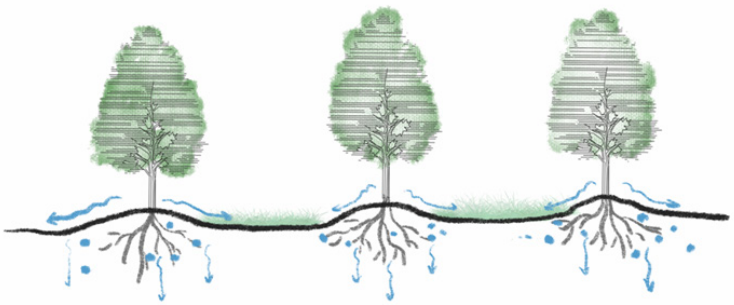
The Kaptembwa Agriculture Hub is located midstream in a peri-urban area along a seasonal stream. Although designed for educational purposes under Nakuru County's planning framework, the site also functions as a buffer against urban expansion.

The design concept leverages seasonal runoff management, floodable wetlands, mixed agriculture, and intercropping strategies, including agroforestry and greenhouses. The proposed design strategy is closely integrated with stakeholder engagement approaches. Specifically, the government provides policy support for large-scale spatial planning, including maintenance of positive runoff patterns and wetland development, as well as financial support for agroforestry initiatives. NGOs primarily contribute knowledge and educational resources, such as guidance on which crops can be intercropped with trees and best practices for implementing mixed farming systems.Building upon the foundational blue–green framework, this approach incorporates a more diverse intercropping system, including integration between forestry and agriculture, which helps reduce topsoil erosion and optimize nutrient use at varying soil depths.

In addition, a "push–pull" strategy intersperses pest-attracting and pest-repelling plants, thereby reducing pesticide application and limiting surface runoff pollution. Furthermore, waterwise layered intercropping alternates deep-rooted, high-water-demand crops with shallow-rooted crops, effectively maximizing limited water resources and enhancing crop yields. Consequently, the first step in implementing this design concept is to determine the construction of the blue–green framework.



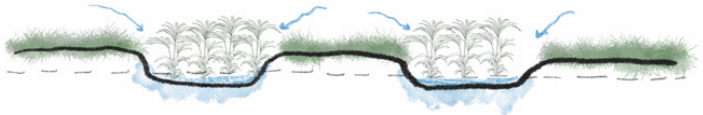
1.intercrop: An agricultural system enhances biodiversity and resource use efficiency by growing two or more crops together in the same field.



2.Push-pull: An agricultural system integrates pest management and soil fertility improvement through companion crops.



3. Waterwise Layered Intercropping : A backyard farming method uses small-scale elevation differences to guide water flow and match crops with varying moisture needs.



5.3.3 Building Blue-Green Structure

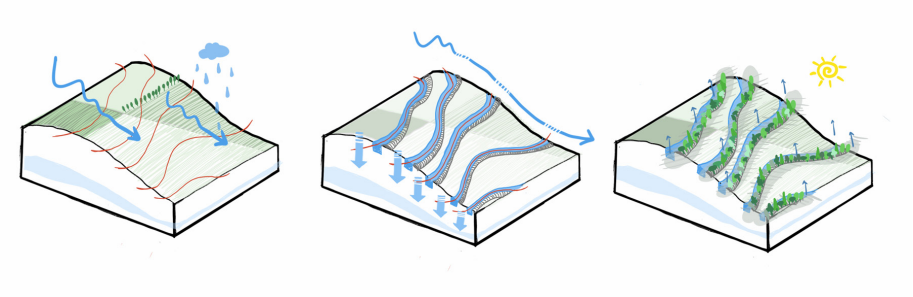


Figure5.2-2 ,the process of building blue-greenn structure ， drawing by author

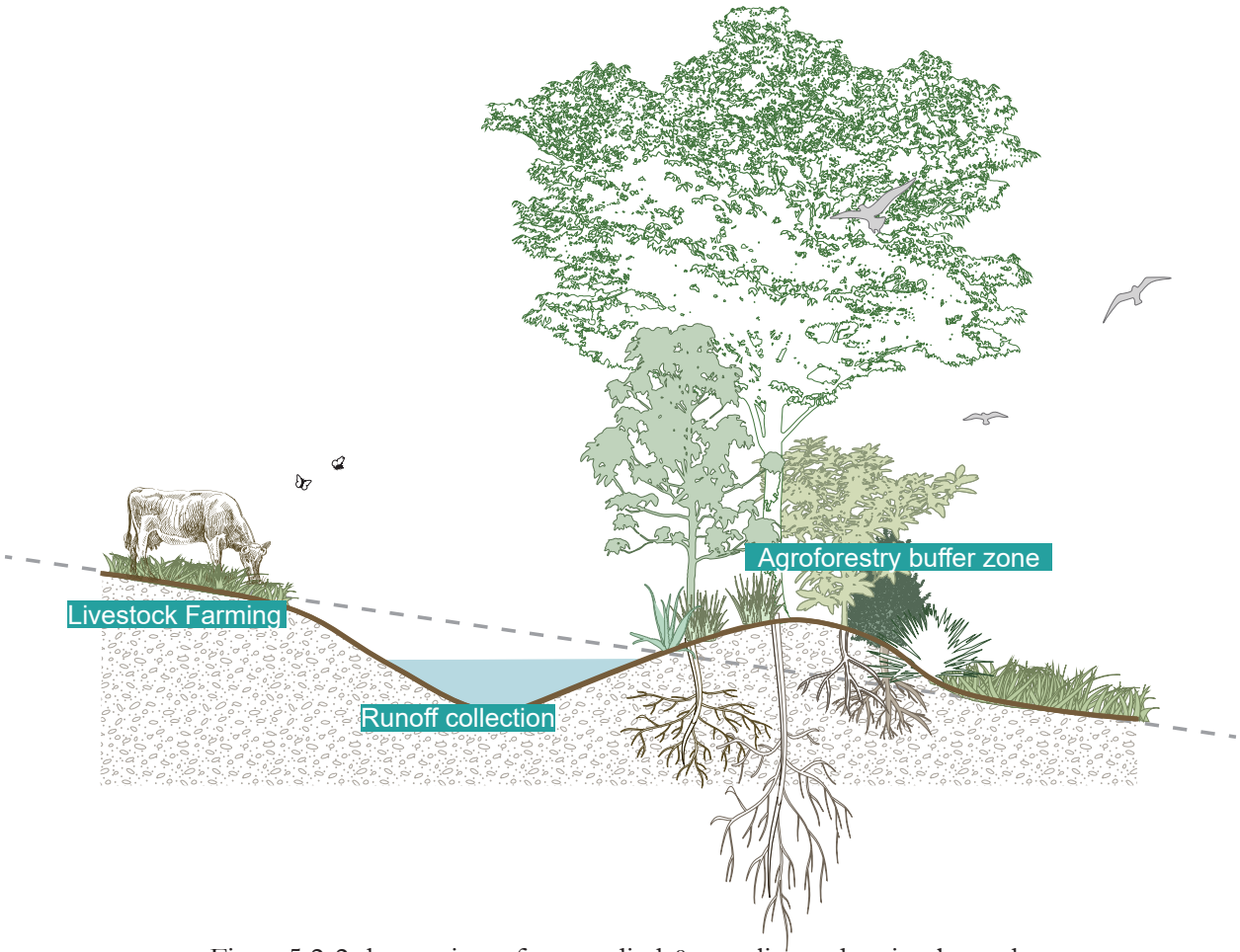


Figure5.2-2 the section of water ditch& tree line ， drawing by author

Based on the existing farmland pattern and contour lines, water ditches are designed along the contours to slow surface runoff and collect rainwater. Furthermore, these ditches are connected to seasonal streams and wetlands, helping to reduce flood peaks during the rainy season and mitigate extreme flooding events, such as 50-year or 100-year floods.

Beyond water management, from an ecological perspective, the water stored in the ditches can serve as a drinking source for livestock and support the growth of shrubs and herbs, thereby enhancing local biodiversity. In addition, the root systems of trees within the agroforestry zones help stabilize the terrain and reduce soil erosion.



Figure5.2-4 , Blue-green structure for Kaptembwa Agriculture hub , drawing by author

Strategies

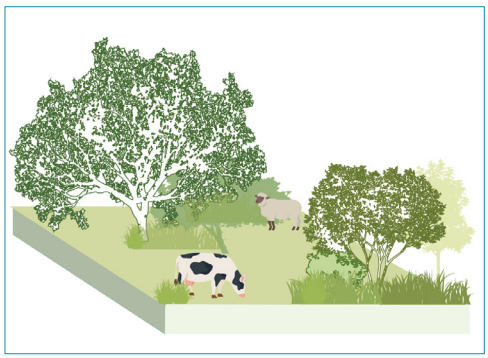
5.3.4 Agroforestry & Crop rotation

Agroforestry is a sustainable land-use system that integrates trees or shrubs with crops, pastures, or livestock. By utilizing land in multiple layers, agroforestry enhances productivity while delivering a range of ecological and environmental benefits, such as maintaining soil fertility, preventing soil erosion, enhancing biodiversity, and regulating the water cycle. There are several typical agroforestry configurations, each offering distinct advantages.



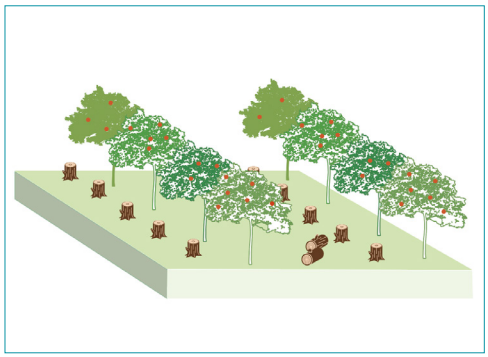
Silvoarable

Silvoarable systems, also called alley cropping, involve planting woody plants at intervals among annual or perennial crops. These systems enable the simultaneous production of timber, fruits, and crops, while improving land-use efficiency, reducing soil erosion, and diversifying agricultural risk.



Silvopastoral

Silvopastoral systems combine trees and shrubs with pasture and livestock. In these systems, grassprovides fodder, while trees offer shade, windbreaks, and supplementary feed. This arrangement improves animal welfare, increases carbon sequestration, and helps maintain soil health.



Timber–Tree Intercropping

Timber–tree intercropping is an agroforestry practice that involves growing timber species together with fruit trees, leguminous trees, or other high-value trees on the same land. This system aims to optimize land use, enhance ecological stability, and generate both short-term and long-term economic benefits.

In the long term, crop rotation enhances soil fertility and leads to higher agricultural returns. **In the first phase,** fast-growing timber species are intercropped with high-value crops. These species can produce substantial timber yields within a relatively short period. **In the second phase,** following timber harvesting, livestock farming serves as an effective approach to restore soil fertility, as animal manure enriches the topsoil with nitrogen. **In the third phase,** existing trees continue to mature, while crops are cultivated among them. Certain species, such as Faidherbia albida, shed their leaves during the rainy season, thereby creating favorable light conditions for short crops. Additionally, tree root systems help reduce soil erosion and improve soil stability.

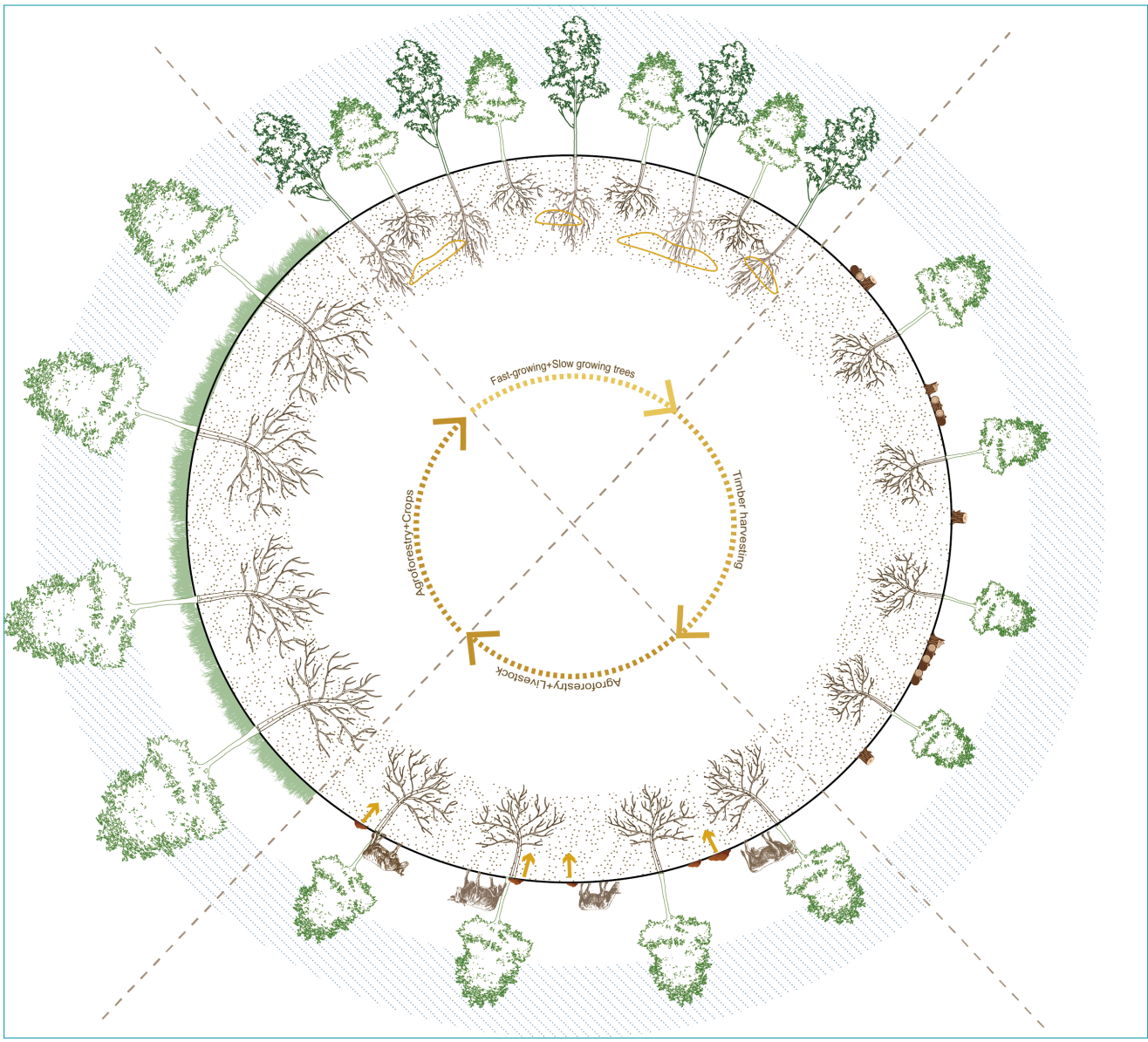
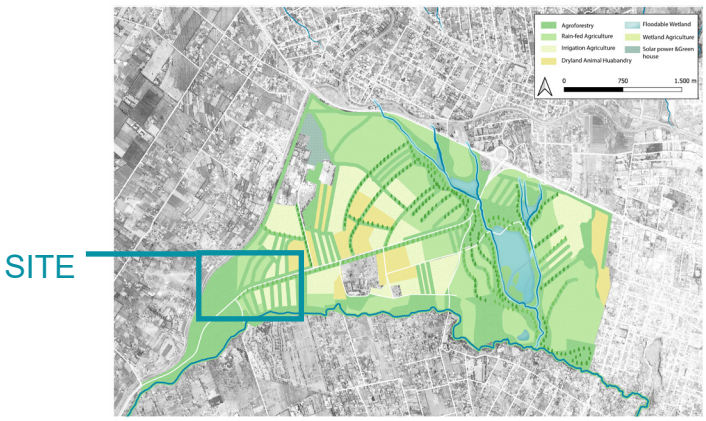


Figure5.2-4 , Blue-green structure for Kiamunyi Agriculture hub , drawing by author

5.3.5 Plan

Agroforestry at Sandy Area

Building on previous desig
zones, agroforestry areas,
properties and rainfall patt
This plan focuses on the p
Hub. Following the conte
introduced to facilitate inte
Greenhouses are also inc
opportunities for the comm
Overall, this design help
Combined with cross-secti



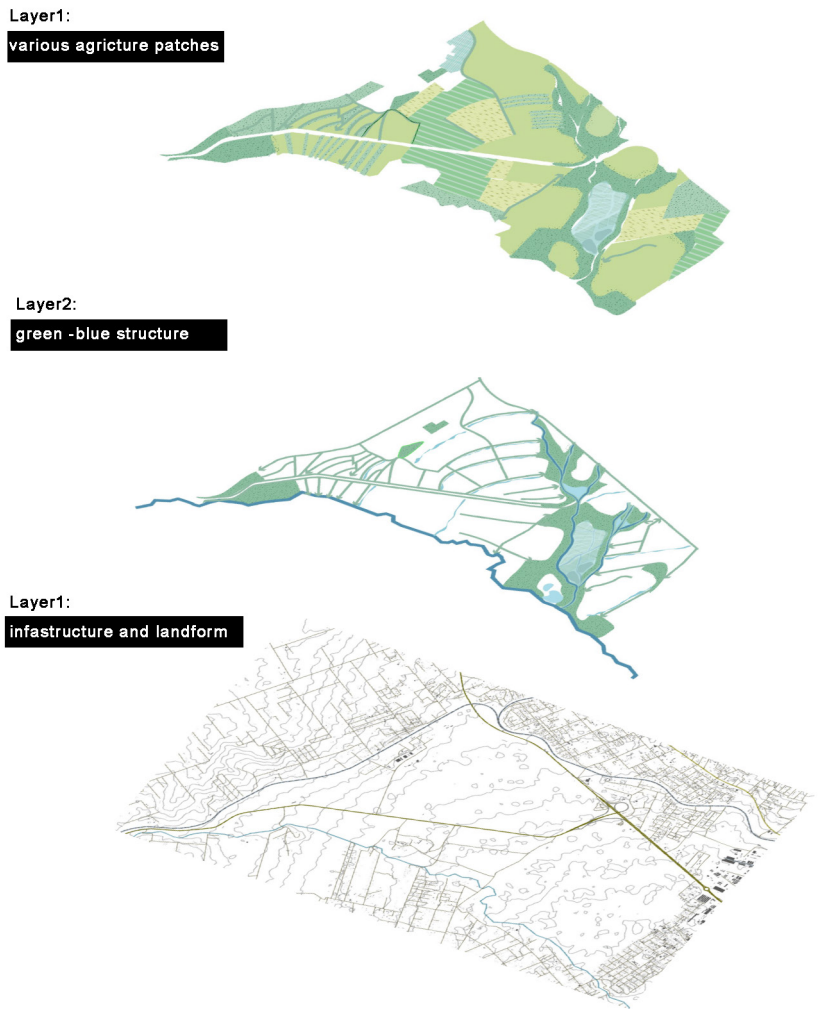




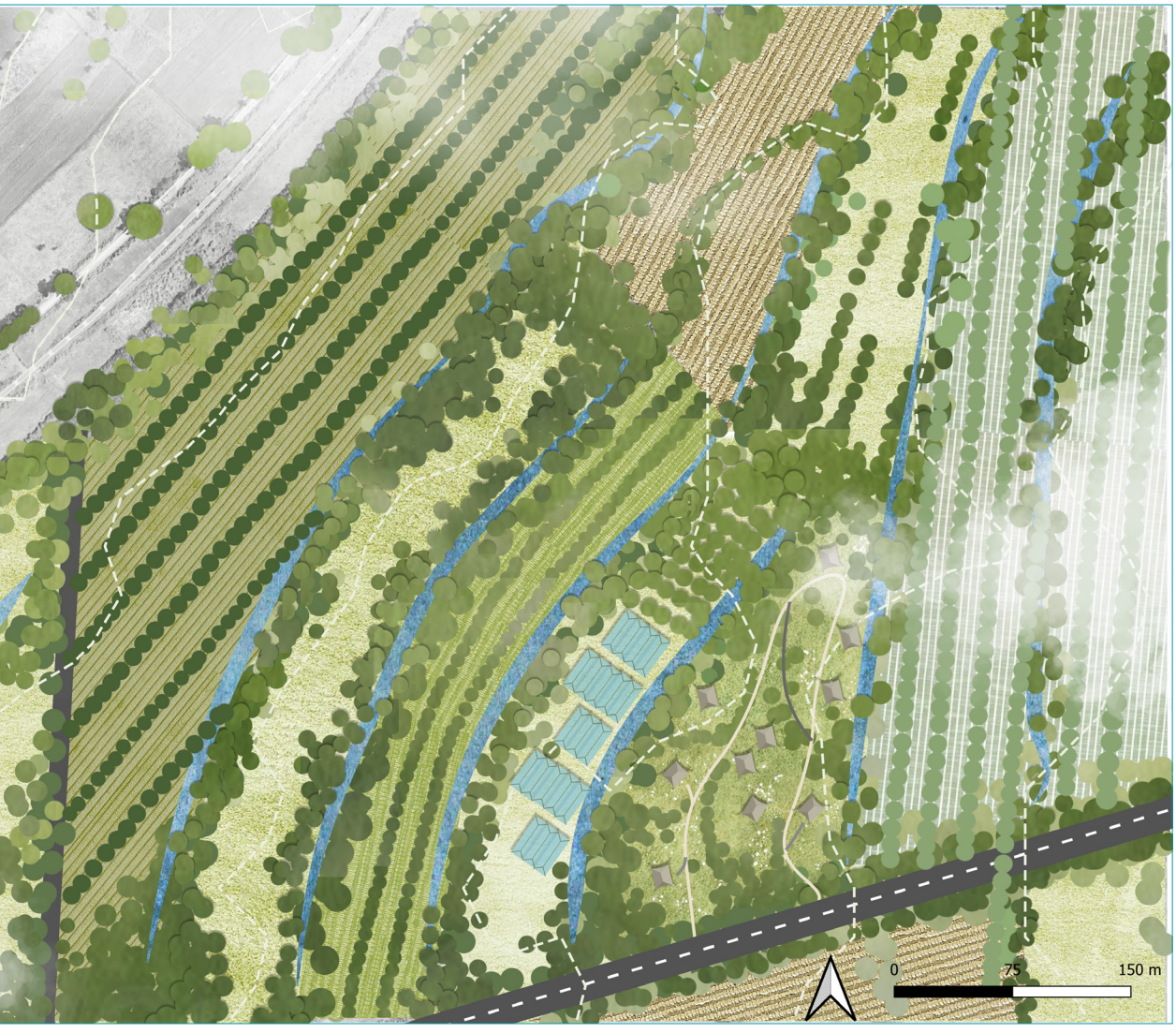
Figure5.2-3 , Layers of design, drawing by author

gn concepts and strategies, the site is organized into floodable wetlands, wetland agriculture and dryland animal husbandry zones along the seasonal streams, based on variations in soil terns.

predominantly sandy soil area located in the southwestern part of the Kaptembwa Agriculture our lines and existing farmland patterns, water channels and linear tree buffer zones are ercropping, animal husbandry, and forestry practices.

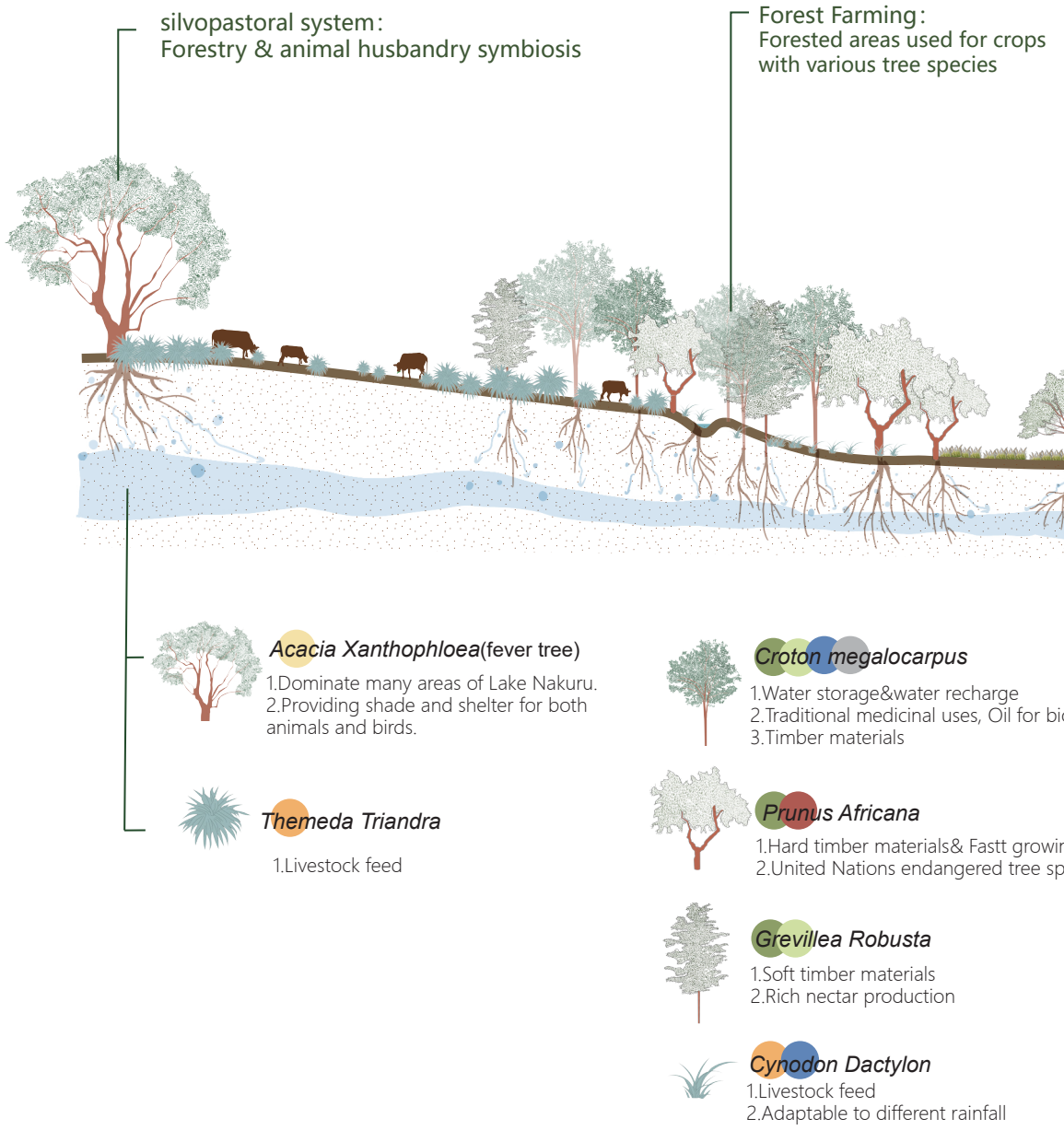
corporated to create campsite areas, generating additional income and new agricultural munity.

s slow surface runoff and optimize water resource utilization during the rainy season. ional analysis, the study will further identify appropriate tree species suitable for the area.

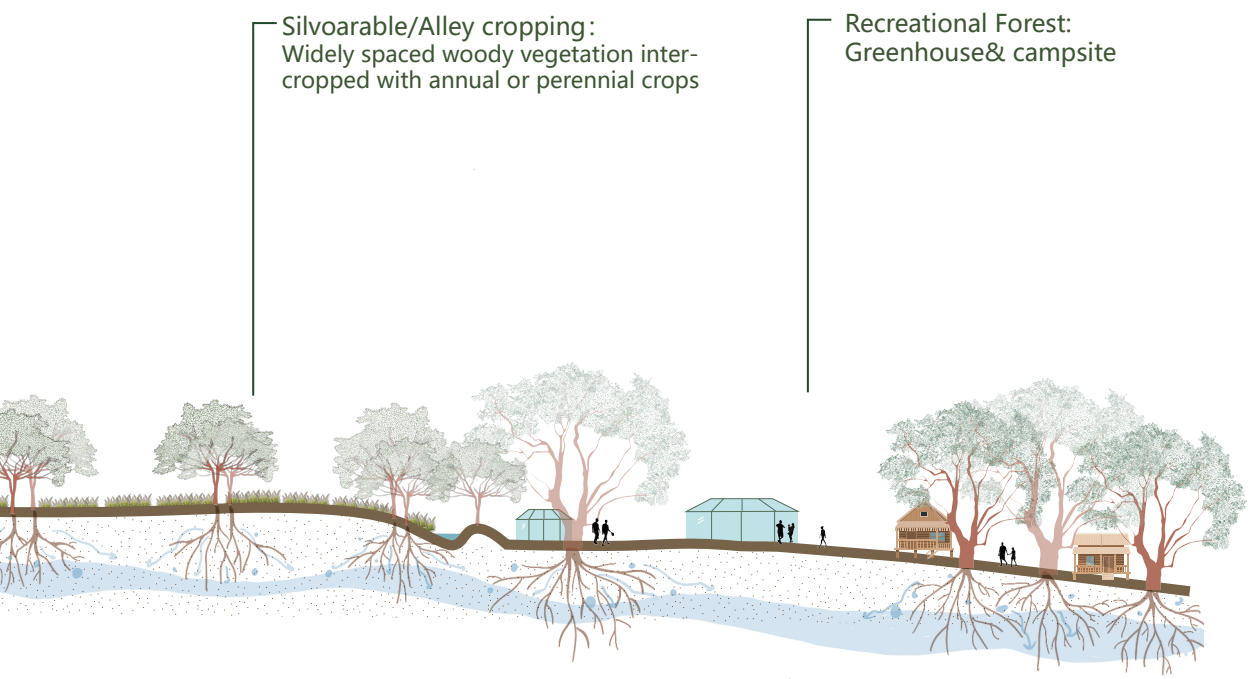


5.3.6 Section
Selected Tree Species for Agroforestry

The silvopastoral system refers to the integration of forestry and livestock production. In this type of system, *Acacia xanthophloea* provides shade and shelter for animals, while *Themeda triandra* is cultivated under the trees as forage for livestock.The upper layer of **the forest farming system** consists of *Croton megalocarpus, Prunus africana*, and *Grevillea robusta*, all valuable timber species. Moreover, the conservation of *Prunus africana*—a UN-listed endangered species—adds significant educational and ecological value to the system.



Silvoarable/Alley cropping uses *Faidherbia albida* as the main tree species, mainly because The trees shed their leaves during the rainy season so they don't compete with crops for sunlight. In addition, this species provides multiple economic benefits beyond its ecological functions. **The Recreational Forest** area includes campsites and greenhouses. The dominant tree species in this zone is Acacia xanthophloea, which is also the characteristic and native species of the Nakuru region, can provide shade for humann activities.



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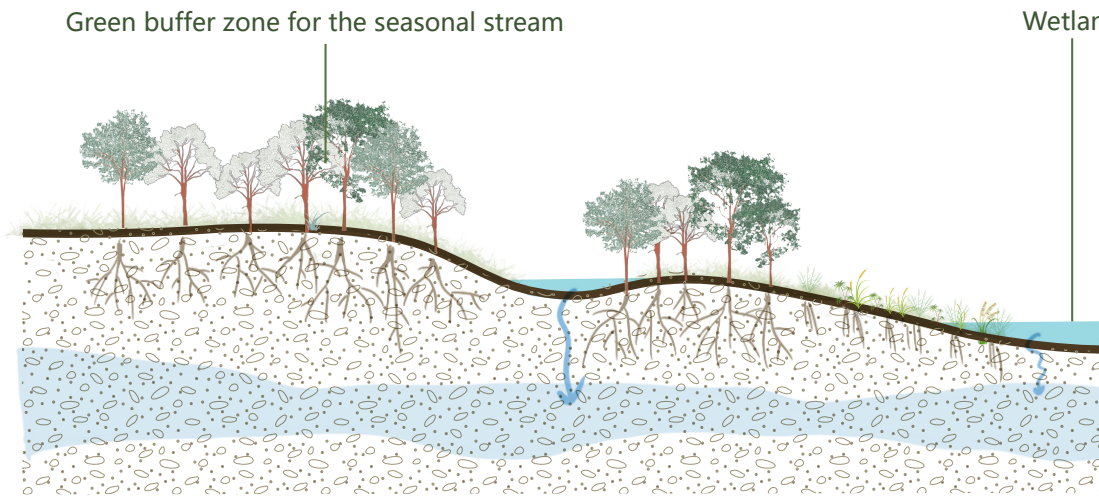
Faidherbia albida

1.Perfect Agroforestry tree:The trees shed their leaves during the rainy season so they don't compete with crops for sunlight.
2.Flowers provide honey at the end of the rainy season
3.Livestock feed
4.Timber materials
5.Wood ash is used in making soap and as a dehairing and tanning agent for hides and skins
6.Medicinal value

Acacia Xanthophloea(fever tree)

1.Dominate many areas of Lake Nakuru.
2.Providing shade and shelter for both animals and birds.

5.3.6 Section
Selected Tree Species for Wetland





Albizia Gummifera

1.The largest specimens grow in wet or seasonally wet forest and closed woodland but they also thrive in some woodland areas with a notable dry season



Moringa oleifera

1.Treatment of wastewater
2.Oil & fruit



Croton megalocarpus

1.Water storage&water recharge
2.Traditional medicinal uses, Oil for biofuel or biodiesel
3.Timber materials



Cynodon Dactyl

1.Livestock feed
2.Adaptable to diffe



Cyperus papyru

1.Deep roots
2.Bird habitat frien



Typha domingen

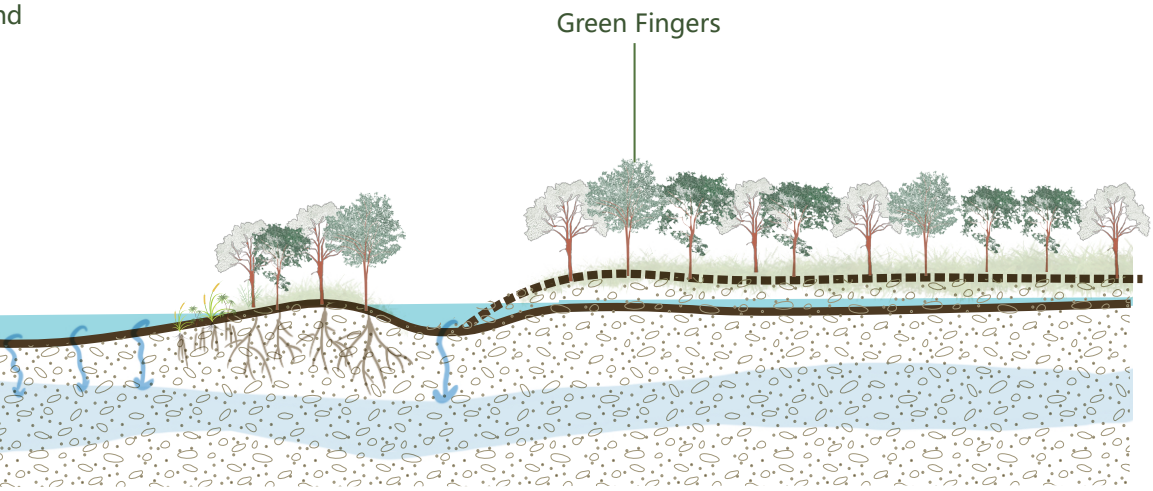
1.Deep roots



Phragmites mau

1. important for ri
erosion

nd



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s

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ver bank and control

Chloris gayana

1.Deep roots, good for controlling the soil erosion
2.Good drought resistance and good salt tolerance

Panicum maximum

1.Treatment of wastewater
2.Oil & fruit

5.3.7 Scenarios
the view of agroforestry land





Refelction

Lessons Learned

• Understanding the landscape as an integrated system

Throughout this project, I have come to understand the landscape not merely as a physical backdrop but as a dynamic, interconnected system where natural processes, human activity, and urban development interact constantly. The terrain, hydrology, and ecological networks in Nakuru, particularly the role of seasonal streams and the catchment from Menengai Crater to Lake Nakuru, demonstrated how deeply nature shapes spatial form and functionality. Nature, when respected and integrated into planning, is not just a constraint but a valuable framework and a low-cost, self-regulating system. Designing with nature rather than against it fosters a more resilient, adaptable, and sustainable urban future.

• Balancing local tradition with strategic innovation

Living and agricultural practices in Nakuru's peri-urban areas reflect deep knowledge of seasonal change, water needs, and land management. While these practices are often fragmented or under pressure from urbanization, they offer meaningful insights into land use flexibility, water harvesting, and food security. Through interviews, mapping, and observation, I realized that combining traditional ecological knowledge and feedback from local people with contemporary spatial strategies, such as agroforestry , bioswales and various crops for dry and rain season can yield solutions that are both innovative and locally grounded.

• Design is political and participatory

Water-related problems in Nakuru are not just technical, they are deeply social. Access to water, the placement of drainage systems, or the expansion of paved areas all reflect power structures and socio-economic priorities. This project reinforced that useful design is not just about spatial logic, but about governance, stakeholder engagement, and equity. Participating in workshops and incorporating stakeholder interviews challenged me to think beyond the design from plan.

Research and Design as an Iterative Process

Initially, my research focused on broad ecological systems and typologies of runoff and land use. However, as I zoomed in the design, it became clear that small spatial changes,such as how a seasonal stream meets farmland,had implications at both micro and regional scales. This required me to return to earlier assumptions and refine the research. For example, studying how rainwater could be stored at the household level and connect it with the bioswale system led me to reconsider watershed-scale strategies for reducing flood risk.

Each design proposal raised new research questions, and each research insight reshaped design priorities to look forward and back. Particularly, the seasonal stream network became a key element, influencing how I defined spatial strategies at county, urban, and site scales. This back-and-forth between analysis and intervention helped build a more coherent and layered system of solutions.

Limitation& future reaserch

Before the field trip, the research initially focused on Nakuru's urban area, particularly the CBD and Lake Nakuru, due to the abundance of existing literature available on these locations. The original design intention was to explore strategies for restoring the large flamingo populations in Lake Nakuru. However, after visiting the site and speaking with local stakeholders, it became clear that most residents did not view flamingo conservation as a priority, as they do not directly benefit from tourism.

In addition, compared to other areas of Nakuru, the urban zone is already highly developed. If landscape strategies are to effectively address ecological and environmental issues, the peri-urban area should become the primary focus, as it represents the direction of future urban growth. Unlike in the urban core, rainwater in peri-urban areas can form visible seasonal streams during the rainy season instead of becoming scattered runoff. These seasonal streams are often rich in vegetation and offer opportunities for ecological interventions that require minimal infrastructure.

As a result, the design direction shifted toward exploring how to manage and utilize surface runoff within the peri-urban landscape. This shift allows local residents to benefit more directly from the design outcomes, such as increased access to water sources, with relatively low levels of external intervention.

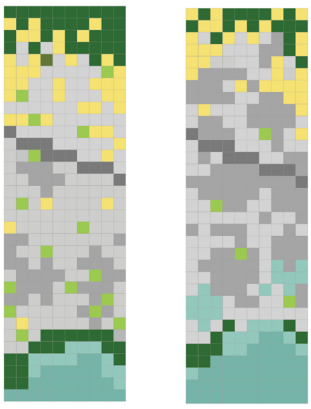
In future research, it will be essential to begin with detailed on-site investigation and direct engagement with local communities to understand their real needs. Furthermore, increased participation from local farmers, planners, and residents will strengthen the practicality of the project and support the development of solutions that are both adaptable and rooted in local experience.

Conclusion

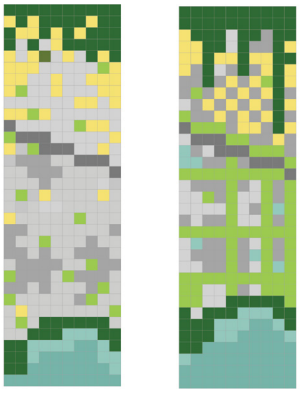
What integrated water system structures can connect seasonal streams, farmlands, and settlements to reduce surface runoff, enhance water retention, and prevent soil erosion?

Before addressing this question, it is essential to clarify that the various components of an ecosystem do not exist independently but are interrelated and mutually influential. Water management extends beyond conventional underground drainage systems to include buffer zones that are functionally and spatially integrated with green spaces. The term green space encompasses not only urban parks but also forests, farmlands, street greenbelts, and backyard agricultural plots. Compared to impermeable urban surfaces, open green areas can slow surface runoff, enhance rainwater infiltration, and consequently replenish groundwater resources, thereby serving as natural buffers during flood events.

Effective water management must therefore be site-specific, responding to the particular form, soil conditions, and topographical characteristics of each green space. For instance, integrating water management strategies with linear roadside green spaces can create interconnected blue–green networks that improve hydrological connectivity. Similarly, combining water management with forest areas, characterized by well-drained soils, extensive root systems, and water-tolerant vegetation, can strengthen the city's ecological resilience. However, as emphasized above, no element within an ecosystem functions in isolation; hence, water management should be conceived as an integrative system that operates across farmland, forest, and urban green space interfaces.



Urbanization without intervention



Urbanization with intervention

How to connect and utilize the city's infrastructure and blue-green spaces to prepare for a high-density urban development?

During urban development, land use patterns often undergo substantial transformation within a relatively short period—sometimes within just a decade. Residential expansion may encroach upon farmland, while farmland, in turn, replaces forested areas. Throughout this process, roads play a stabilizing role, as their transportation function helps anchor land use patterns along and around these corridors.

Therefore, road design and planning must take into account not only present needs but also the city’s long-term development trajectory—envisioning conditions 50 or even 100 years into the future. Integrating blue–green infrastructure as a key supporting component of road systems can enhance both ecological and social resilience.

Based on the road’s alignment, topographical conditions, and adjacent land uses, street-associated green spaces can be diversified into street tree corridors, pocket parks, and community gardens. These spaces not only improve the urban microclimate and social vitality but also perform essential water management functions. For instance, community gardens can utilize harvested rainwater for irrigation, reducing dependency on municipal water systems.

By linking these blue–green elements with existing infrastructure, the city can form a sustainable and adaptive network that supports biodiversity, mitigates urban flooding, and strengthens resilience to climate change—thereby ensuring that high-density urban development proceeds in a more balanced and ecologically integrated manner.

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