

Living with drought prone landscapes

Spatial design interventions for a rain and dry seasons mitigation
system in Ryabega, Eastern Rwanda

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GLOSSARY

RAJISTHANI

Deir

Surface water

Wakar

Groundwater

Palar

Rainfall water

Khadin

Traditional water system from Rajasthan, Western India. Large earthen embankment, typically located on a slope or in a depression point to catch the rainwater. During dry seasons, it is a cultivated area that solely relies on soil moisture to irrigate the wheat, chickpeas and mustard crops.

Johad

Traditional water system feature from Rajasthan, Western India. Small earthen embankment to catch the rainwater runoff and store it for drinking water access.

KINYARWANDA

Amazi

Water

Amazi y'imvura

Rainfall water

Muraho

Hi

Mwaramutse

Good morning

Murakoze

Thank you

DESIGN TERMS

Dry season mitigation

System designed to still function during dry and warm climate conditons, so communities can prosper.

Rain season mitigation

System designed to collect and store rainwater for dry season resiliency and water circularity.

Resilience/Resilient

«*The quality of being able to return quickly to a previous good condition after problems*» (Cambridge Dictionary, 2024a).

In Landscape Architecture, it means the capacity to prosper and work with unexpected climates or conditions. A system that can adapt and be adapted to thrive on the long term.

Circularity

«*The fact of constantly returning to the same point or situation*» (Cambridge Dictionary, 2024b).

In the thesis, circularity also means the conservation of rainfall water in one area, locally sourced materials and activities generating local cycles.

Autonomy

« 1. *The right of an organization, country, or region to be independent and govern itself* 2. *The ability to make your own decisions without*

being controlled by anyone else» (Cambridge Dictionary, 2024c).

The thesis design works on a self-supporting system, enabling communities to make their own landscape and build their own water system without the help of governmental subsidies or investors.

Seasonal agricultural basin

Inspired by the Khadin traditional water system, it is an embankment made out of local stones to catch the rainwater runoff along the valley lines. Its area is cultivated during the long, dry season.

Reservoir

Made of stone embankment, it is a narrow-shaped basin based on water and humidity conservation that collects rainwater and is accessible during the dry season. It is located on the valley slopes.

Channel

A stormwater channel connected to the reservoirs. It follows the valley's contour lines to irrigate the surrounding crops during the dry season.

Tankaa

Shallow dug well originated in India. It collects the rainwater runoff and keeps dirt or big particles out thanks to a filter located at the inlet entrance.

ABSTRACT

Global warming exerts varied impacts across diverse regions worldwide, manifesting in distinct consequences such as floods, landslides, droughts, soil biodiversity loss, salinization, etc. Rwanda is one of these many cases.

Located in tropical Central Africa, the country mainly experiences landslides due to extreme and irregular precipitations. Nevertheless, global warming assumes disparate forms in the eastern region of the country.

In the plateau region inhabited by communities like the town of Ryabega, the predominant

challenge arises from recurrent droughts. These climatic disturbances significantly disrupt the agricultural cycle, upon which these communities heavily rely for food subsistence and livelihoods. The intensification of agricultural practices exacerbates this vulnerability, as deforestation, soil degradation, and the application of chemical fertilizers diminish landscape resilience.

By adapting an arid water system and implementing nature-based solutions, bioclimatic architecture and resilient landscape strategies, the project seeks to develop a rain and dry seasons mitigation system that connects communities back to their landscape and unique topography. Through water and humidity conservation, soil moisture and drinking water access, the project aspires to be locally sourced and built to ameliorate the town's water and economic autonomy as well as its vulnerability to global warming.

Furthermore, beyond its immediate scope, this graduation thesis serves as a catalyst for exploring new design possibilities applicable to the adjacent towns and landscapes.

RÉSUMÉ

Le réchauffement climatique impacte différemment multiple parties du monde, en se manifestant par des inondations, glissements de terrain, sécheresses, perte de biodiversité des sols, salinisation, etc. Le Rwanda en est l'un de ces nombreux cas.

Situé dans la région tropicale de l'Afrique centrale, le pays est principalement touché par des glissements de terrain dus à des précipitations extrêmes et irrégulières. Néanmoins, le réchauffement climatique prend des formes disparates dans l'est du pays.

Dans le plateau est, où vivent plusieurs communautés telles que la ville de Ryabega, les sécheresses longues et récurrentes sont l'une des problématiques principales. Ces événements climatiques perturbent considérablement le cycle agricole, auquel ces communautés dépendent fortement pour se

nourrir et subvenir aux besoins économiques du foyer. L'intensification des pratiques agricoles exacerbe cette vulnérabilité, car la déforestation, la dégradation des sols et l'utilisation de pesticides réduisent considérablement la capacité de résilience du paysage et du vivant.

En adaptant un système traditionnel fonctionnant en zone aride et en implémentant des théories telles que les «nature-based solutions», l'architecture bioclimatique et des stratégies paysagères résilientes, le projet cherche à développer un système de mitigation des saisons de pluie et de sécheresse en reconnectant les communautés au socle paysager et à son unique topographie.

Grâce à la conservation de l'eau et de l'humidité, à l'humidité du sol et à l'accès à l'eau potable, le projet, composé et construit avec des matériaux locaux, aspire à améliorer l'autonomie de la ville en eau et apports économiques, ainsi que sa vulnérabilité au changement climatique.

En outre, au-delà de son contexte actuel, ce travail de fin d'études aspire à ouvrir de nouveaux possibles pour les villes et paysages alentours.

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The Savannah plains of northern east Rwanda at
the natural state. Akagera National park location.
©Charlotte Delobbe

FRAMEWORK

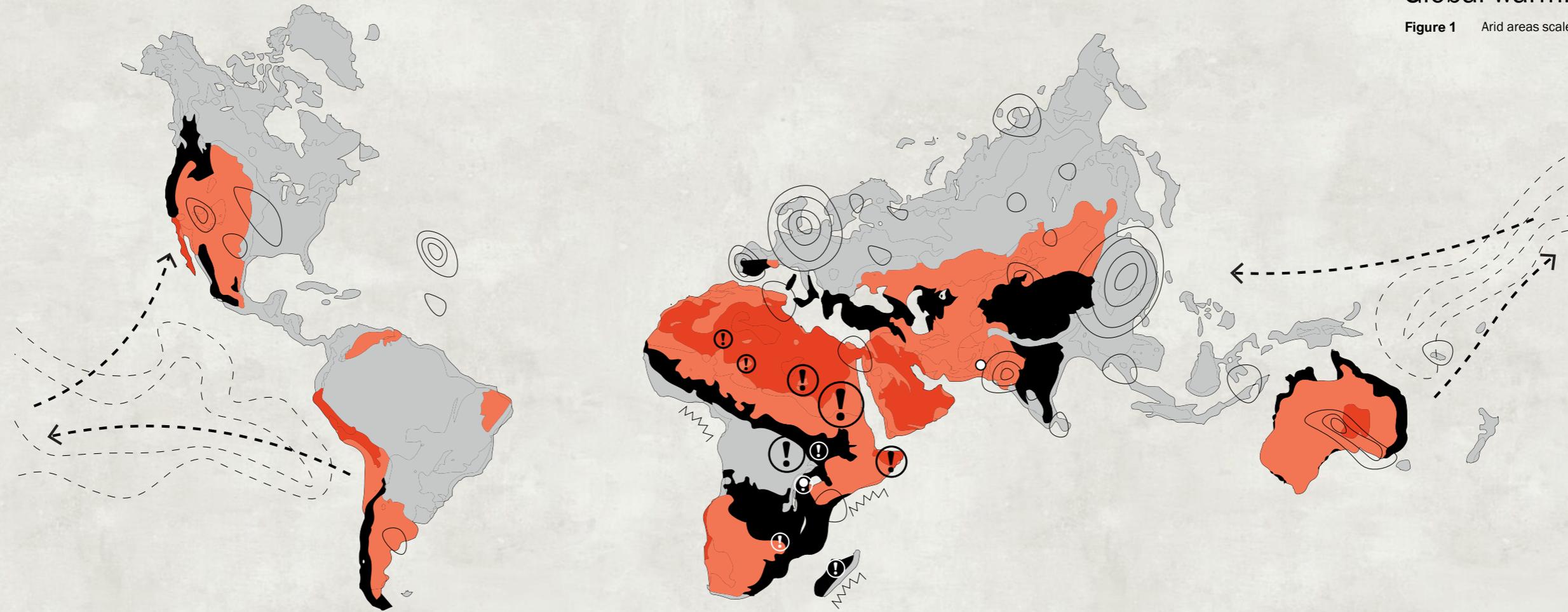
INTRODUCTION

Desertic and arid climates are all parts of millennia-long processes. These climates are characterized by low humidity and limited water availability, wherein the rate of water evaporation surpasses annual precipitation (Nunez, 2023). Variations in temperature exist among these climates, while the common characteristic lies in the prevalent dryness and infertility of the soil, decreasing water infiltration and predisposing areas to both floods and evaporation (World Atlas, 2019). While the terms desertification and aridification can be understood as natural processes, their current development has been related to human activities. In the case of desertification, most dry lands were considered worthless wastelands by the colonial's gaze, leading to damaging policies and activities when indigenous communities had been living and using the land sustainably (Davis, 2016) such as this research case study: the Jaisalmer farmers working with the traditional Khadin water system in India.

This thesis employs the term aridification to denote a temporal process leading to heightened occurrences of droughts, elevated temperatures,

Global warming manifesto

Figure 1 Arid areas scale



- Rwanda
- Khadin, India
- Deserts
- Arid areas
- Severe drought prone areas - process of aridification
- ⋯ El Nino
- - - La Nina
- ⊙ Human influenced heat events
- ⚡ Rising water levels
- ⚠ Lack of climate resiliency



While most emissions come from western and Asian countries, the consequences are located in other parts of the world that are highly vulnerable to climate change. Two main challenges arise: the increase in major drought events as well as the warming of the glacial Arctic circles, pressuring coasts with sea level rise.

The relevance between the research case study and the design location is that the former is located in an original arid area where people have learned to live with it. The latter, in Rwanda, is a tropical climate experiencing recurrent droughts in a year. Communities haven't developed resilient techniques yet and are the first impacted by such

and diminished soil fertility—attributes inherent to arid climates. Such events are nowadays more and more present as climates face the consequences of climate change, and more precisely, global warming. These extreme events are overstepping the “limits” of natural arid areas and occur in numerous regions globally where vulnerable communities confront their impact.

Rwanda, in particular, has encountered rising temperatures up to 1.5°C-2°C (REMA, 2011; MER, 2015), irregular rain seasons and prolonged dry seasons in its Eastern region. The country is particularly susceptible to the effects of global warming due to vulnerability in its landscape events (MER, 2015). However, numerous guidelines, strategies, and reports for climate change mitigation have been drafted as various ministries are aware of such challenges (Ministère des Terres, de l’Environnement, des Forêts, de l’Eau et des Mines, 2006; REMA, 2011; Benitez et al., 2020; Ministry of Environment, 2022).

Global warming not only has direct consequences, as enumerated earlier, but also rises indirect effects. Given that Rwandan agriculture relies solely on rainwater, constituting the primary source of both economy and sustenance, it is a national-scale issue.

In East Rwanda, two main solutions are offered to mitigate the water scarcity: pivots irrigation systems pumping from lakes and wetlands or local groundwater pumping stations. While they seem like a pertinent solution, they are unaffordable for local farmers nor are they long-term efficient and resilient to global warming’s consequences. The former could aggravate the droughts in wetlands, resulting in the drying up local flora and fauna’s water sources, while the latter relies on groundwater while rainwater is scarce and thus groundwater recharge. Furthermore, intensive agricultural practices leading to deforestation and the use of chemical fertilizers contribute to decreasing soil fertility and directly impacting the soil and subsoil over time.

Consequently, the perspective of Landscape Architecture in this research is highly pertinent to these challenges. The imperative for a resilient and climate-adaptive design emerges as crucial to addressing the human influenced aridification process before the situation reaches a critical juncture, jeopardizing agriculture, communities, and landscapes. It also strikes for a dry and rain seasons mitigation design and reconnecting people to their own landscape by spatial interventions.



Figure 2 Rwanda's location in Africa and design scales

Design location

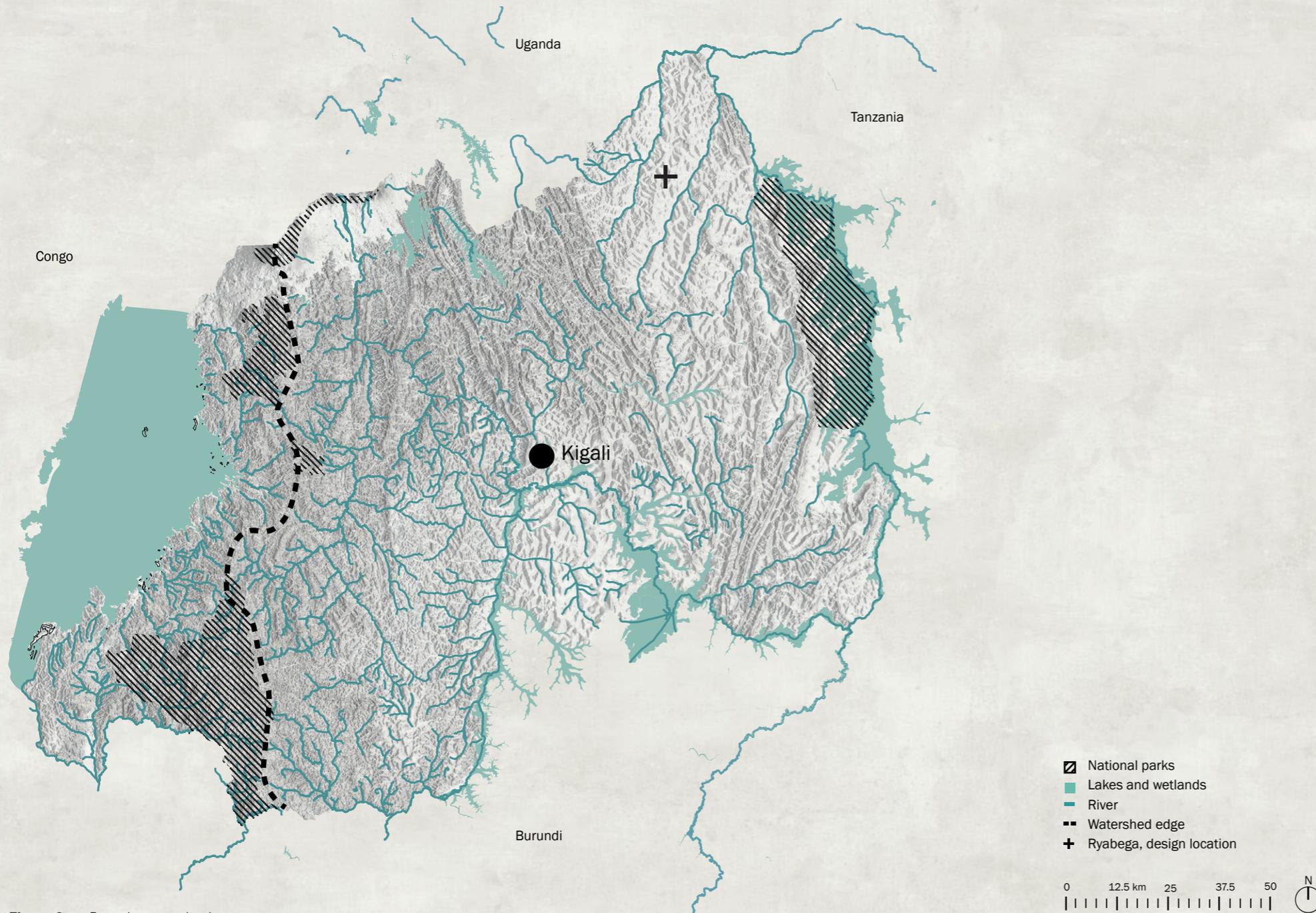


Figure 3 Rwandan water landscape

Rwanda is a densely populated landlocked country with a population of 14.5 millions inhabitants and a growth rate of 2.27% (Macrotrends, 2024). Its eastern and southern borders are defined by the Akagera River, at the beginning of the Nile watershed. It covers 67% of the country and delivers 90% of its water resource. In addition, the Congo watershed covers the western lands (REMA, n.d.)

Known as the “Land of a Thousand Hills”, Rwanda’s topography is unique and composed of a multitude of valleys and rivers engraving the landscape. Furthermore, numerous lakes and wetlands paint the country alongside 860 marshlands (Government of Rwanda, 2024). The major lake is located along the western border shared with Congo ; the lake Kivu.

Rwanda - Design location



Figure 4 Akagera National Park (WorldAtlas, n.d.)



Figure 5 Orange soil (Kawinda, n.d.)



Figure 6 Drought landscape (East Africa Monitor, n.d.)

Jaisalmer, India - Case study location



Figure 7 Jaisalmer (Inditales, n.d.)



Figure 8 Sandy and rocky soil (Gyaan, n.d.)



Figure 9 Khadin landscape (Narain & Kar, 2005)

Additionally, my intrigue in the topography of this nation, alongside a profound curiosity regarding the distinctive ochre soil, and the remarkable biodiversity it harbors, significantly shape the selection of my thesis site and my enthusiasm to engage with it.

However, the paradigm of a very lush landscape, tropical climate and drought events is indeed very paradoxical. Initially, the predominant impacts of global warming in this country appear to manifest primarily through phenomena such as landslides and torrential precipitation.

Consequently, these landscapes and their

associated communities struggle with recurrent environmental challenges for which they are ill-prepared, leaving them highly vulnerable.

As previously delineated, the focal point of this thesis lies on the Khadin traditional water system located in Jaisalmer, India.

The differences between the climate conditions of Rwanda and India are contrasting, if not in opposition.

Green and orange colors are painting both landscape in different ways. One is the mirror of the other.

Moreover, the substrate compositions diverge markedly, with Rwanda primarily comprising loam and clay-rich orange soil, its vibrant hue attributed to soil oxidation processes. On the other hand, Jaisalmer's terrain is typified by sandy, rocky desert soil.

The relevance between these two locations becomes more discernible upon a closer analysis of their climatic dynamics. Indeed, one region thrives amidst arid conditions, while the other undergoes a transition from a tropical climate to an aridification phase marked by elevated temperatures, diminished soil biodiversity, and recurrent drought events.

PROBLEM STATEMENT

In light of the challenges posed by the global warming phenomenon, the agricultural and economic infrastructure at large experiences significant repercussions. The Rwandan communities residing in the eastern region of the nation, owing to their tumultuous history, have undergone a process of emergency urbanization following the mass migration to Akagera National Park during and after the 1994 genocide. Rwanda is one of the most populated and dense country and following the return of the refugees, they resettled in the National Park, pressuring the natural ecosystem (Moran, 2019). Their interaction with the local landscape is characterized more by rapid and efficient urbanization than by harmonious symbiosis.

These dynamics have led to an excessive exploitation of landscape resources, manifested in deforestation for biomass and intensive

agricultural expansion, the intensified application of chemical fertilizers, and the burgeoning urbanization of both urban and rural settlements. The consequences on the landscape biodiversity are tremendous. *“Emissions from agriculture, forestry and fishery worldwide, nearly doubled over the last 50 years and could increase at 30% in 2050 mainly being driven by population growth.”* (Nahayo et al, 2016, p.1).

More than 80% of the country area is cultivated leading in a decreased forest cover of only 10% (Habiyaemye et al., 2011). Nowadays, Eucalyptus trees remain the main national specie as it covers 90% of the forested areas (Interview notes with Philippe Kwitonda, 2024) leading to a lack of biodiversity as well as ecosystems problems due to this problematic specie. Indeed, it is known to cause the drying up of water resources, erosion, low nutrients, and soil fertility (Dessie & Erkossa, 2011).

Consequently, the fabric of the landscape in eastern Rwanda, and more specifically in the town of Ryabega, lacks urban and landscape coherence owing to its conversion into a productive machine.

As a result, the social public spaces within the

Figure 10 People's stories on current challenges (FAO, 2018 ; InfoNile, 2022 ; The Howard G. Buffett Foundation, 2019)



townscape are not conceived in harmony with the natural topography of the region, but rather contradict its inherent contour lines. The town urban offers poor biodiversity and qualitative spaces while the residential areas are organized in a grid system made of large and long monotonous lines. Therefore, there is a lack of relationship between town and landscape as well as town and people. In other words, the “*art of relationship*” (Cullen, 1961, p.7) is not developed resulting in a lack of revelations, emotions, and enjoyment of the public spaces and surrounding landscapes.

Furthermore, the economic exploitation of land as a means of production has engendered numerous shortcomings concerning its capacity for adaptation and resilience in the face of global warming. The soil strata suffer degradation and loss of fertility, while surface soil becomes increasingly susceptible to aridity due to the depletion of biodiversity and vegetation. Furthermore, the extensive use of chemicals contaminates groundwater resources, natural springs, and rivers, exacerbating water scarcity, particularly during periods of drought.

The vulnerability to the impacts of global warming extends beyond the environmental realm to

profoundly affect local communities. Given their reliance on agriculture as a primary source of livelihood and food subsistence, farmers are acutely sensitive to the variability of seasonal precipitation patterns leading to water scarcity for both irrigation and drinking water use. This annual rhythm is destabilised by erratic and unpredictable rainfall spoiling harvests, while the prolonged and intensified dry seasons, renders soil unsuitable for sowing and cultivation (Interview notes with Emmanuel Hakizimfura and Suzan Nyirabahire, 2024; Interview notes with Eugenie Umutoza, 2024 ; InfoNile, 2022, FAO, 2018).

These problematics raise the pertinent question of analysing a system operating in an arid zone characterised by droughts, nutrient-poor soil, and a lack of water supply. The traditional Khadin water system in Rajasthan, India, exemplifies a viable solution by reintroducing the natural water cycle in an arid climate.

By analysing the territory and its topography, this system strategically harnesses rainfall runoff on slopes and within topographic depressions to harvest the slightest drop of rain. It is built from local materials and managed by local villagers.

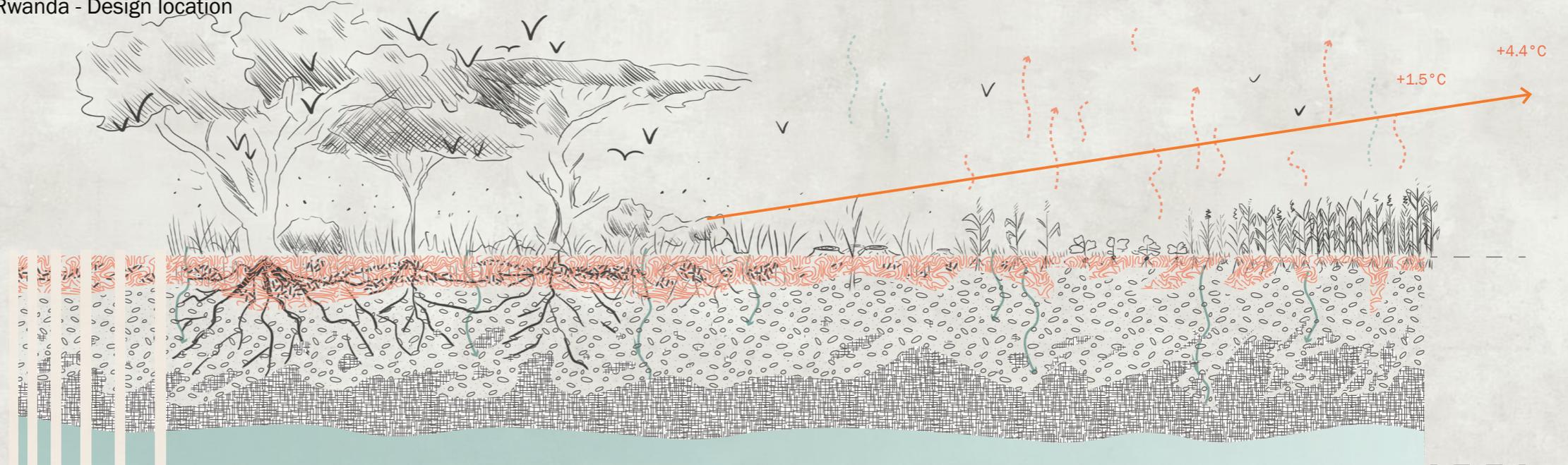
Rajasthan, India - Case study location



Figure 11 Khadin soil evolution

Figure 12 Rwanda soil evolution

Rwanda - Design location



Considering the impacts of global warming and the intensification of droughts, in what ways can the Khadin water system be a **resilient design tool** for tropical landscapes, the agriculture and the communities?

How can the design project enable communities towards town autonomy, resilient economy and water circularity ?

As the design assignment is located in a different culture, which methods can be employed in order to learn and understand how people use public spaces?

How can the design intervention evolve through seasons, years and time ?

METHODOLOGY

The process of aridification, a global phenomenon accelerated by anthropogenic activities such as carbon emissions and the greenhouse effect, is manifesting in various regions. The resultant droughts, elevated temperatures, and diminished precipitation pose significant challenges to communities lacking preparedness in adaptability, vulnerability, and resilience to face the consequences of global warming.

The primary methodology employed in this research is elaborated parallelly to the research topic. As highlighted earlier, communities residing in areas susceptible to aridification are yet to acquire the proper tools for addressing long-term water scarcity.

Therefore, an in-depth examination of a traditional arid water system is relevant, as the research aims to learn from water techniques and people's knowledge of water circularity in an

infertile soil, dry and hot climate. By collecting numerous papers on the khadin system and going through Indian news articles, the case study develops detailed and informative graphics, including maps, cross-sections, plans, circular water diagrams, image analyses depicting water and human presence, and details of the water infrastructure. This methodological approach is designed to acquire a better understanding of the Khadin system across various dimensions—ecological, hydrological, pedological, and anthropological—and to facilitate the application of its principles to the research project.

This traditional system is part of the methodology of the Circular Water Stories lab tutored by Inge Bobbink. The natural arid climate case study is selected for its contextual relevance to a transitional tropical climate undergoing the impacts of global warming, exhibiting characteristics akin to arid regions.

Consequently, the second facet of the research elaborates on regions facing the threat of aridification. While such areas are dispersed globally, the selection of Central Africa as the primary focus stems from a personal fascination with the distinctive orange soil prevalent in this

region as well as learning about new ecosystems and species.

Nevertheless, working in Central Africa raises several ethical concerns, given the historical implications of European colonization in delineating the borders of contemporary African countries and the forced colonial governance and its implemented politics.

Accordingly, decolonization theory plays an important role in the choice of the research location. Nowadays, numerous papers and articles have been written to decolonize the map (Rose-Redwood et al., 2020; Rose-Redwood, 2020; Oxfam, 2022). We can summarize them in the following points:

1. Highlighting existing knowledge and techniques
2. Naming places
3. Referring to their work
4. Going beyond the colonial gaze of cartography
5. Listening to people's voices
6. Designing with people

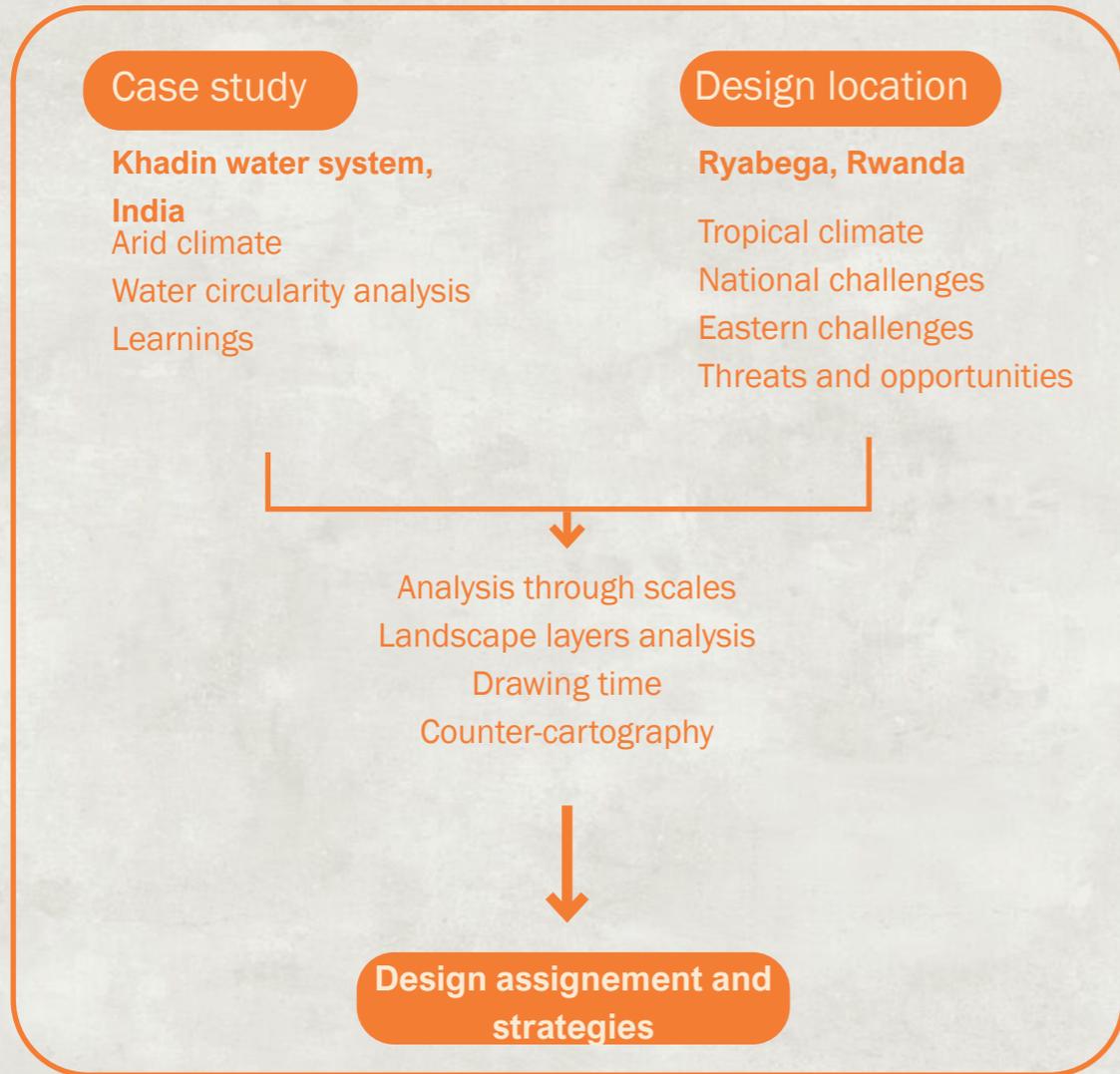
Given that this project aims to listen to people's stories, the research needed to easily reach out to locals and communities. As I grew up with a friend whose mother and family are from Rwanda,



Figure 13 African ethnicities before colonization (Deutinger, 2018)



Figure 14 Colonized borders



I started to contact them and ask for their stories and help in the research process. They were, and still are, very helpful in the deciding steps of this project and have become collaborators in shaping the trajectory of this graduation project in Rwanda.

Ultimately, to authentically represent and map the stories of local communities, the research analysis embraces approaches such as counter-cartography by Catalina Rey Hernandez and Keniko comics by Antonio Paoletti (2021). The former worked with the locals and drew the river maps with them. It unfolded several different viewpoints and helped her to reconsider her standpoint on how to map cartography. The map became a living retailing on people's experiences. The latter developed the method of storytelling through architectural comics. By drawing as objectively as possible and writing about the people's stories he collected, he immerses the reader in the design location. They can grasp a better understanding of the place, its dynamics, and spatial spaces.

Together, they aimed at raising awareness of local voices and capturing their perspectives and interactions with their landscapes.

Finally, the drawing time method learned during the flowscapes studio workshop habitates us to acknowledge the differences between the way space is used in Europe and how it is in the design location. The day cycle drawing underscores the processes that shaped the town informal social spaces.

In addition to the cartography methods, the analytical process unfolds in three distinct stages. Firstly, the traditional system analysis methodology is replicated to facilitate a comparative assessment of climates, soils, and locations. Subsequently, conventional tools and cartographic conventions are deconstructed, emphasizing ecosystem borders and the topography of East Rwanda, where the Savannah is situated, posing aridification challenges. Bibliography research focused on data found on the Ministry of Environment, RICA, RBIS, REMA websites, videos and farmers' interviews from the FAO and online articles and papers.

The second stage involves engagement with NGOs, organizations, climate activists, and governmental institutions through online meetings. Key individuals, such as Philippe

Kwitonda - the Minister of Environment and Director General of Land, Water and Forestry - and climate and feminist activist Ineza Umuhoza Grace, contribute valuable insights, enriching the understanding of East Rwanda landscape, its cultures, and its activities.

The third stage entails an on-site visit spanning from January 9th to January 20th 2024. During this period, multiple discussions with Philippe Kwitonda, John Kayumba and Gorette from the RAB Nyagatare Station, and agricultural organisations, provided an opportunity for learning about Rwandan environmental strategies, agriculture, and ecosystems. Additionally, a visit to the Rwandan Institute for Conservative Agriculture and the MASS design group's site allowed for an exploration on conservative agricultural practices, soil quality enhancement, and innovative design interventions in harmony with the surrounding wetlands.

On-site interviews have been held with two agronomists Geoffrey and Delphine from the Horeco cooperative and twelve farmers practicing three different types of agriculture or irrigation. The first group is a duo of rice farmers collecting the water from the Muvumba River, the second is

- ① Philippe Kwitonda - Minister of Environment
- ② Jean Mubirigi - Cousin of Aline Kavutse
- ③ Anselme - Cousin of Aline Kavutse
- ④ Richard Kabanda - RICA
- ⑤ Ferdinand - Rwandan Institute for Conservative Agriculture
- ⑥ Nelson - Akagera National Park guide
- ⑦ John - Nyagatare Rwandan Agriculture Board (RAB)
- ⑧ Gorette - Water management expert - Nyagatare RAB
- ⑨ Elder Umutoni - Translator
- ⑩ Geoffrey & Delphine - Horeco cooperative - Agronomists
- ⑪ Jean baptiste Niyiregera & Jean Paul Ndahimana - Rice farmers
- ⑫ Emmanuel Hakizimfura Emmanuel & Suzan Nyirabahire - Farmers
- ⑬ Eugenie Umuroza & seven women - Farmers
- ⑭ Andre Chuma - Soil scientist
- ⑮ Andre Gatete
- ⑯ Dr. Vicky Ruganzu
- ⑰ Dr. Jules Rutebuka
- ⑱ Dr. Desire Kagabo
- ⑲ Dr. Madeleine Nyiratuza
- ⑳ Dr. Sirikare, Frank Mutesa
- ㉑ Cyamweshi Rusanganwa

Rwanda Agriculture Board

In Belgium :

Aline Kavutse & Océane Palange - Friends

In the Netherlands :

Mona zum Felde - Defacto Urbanism

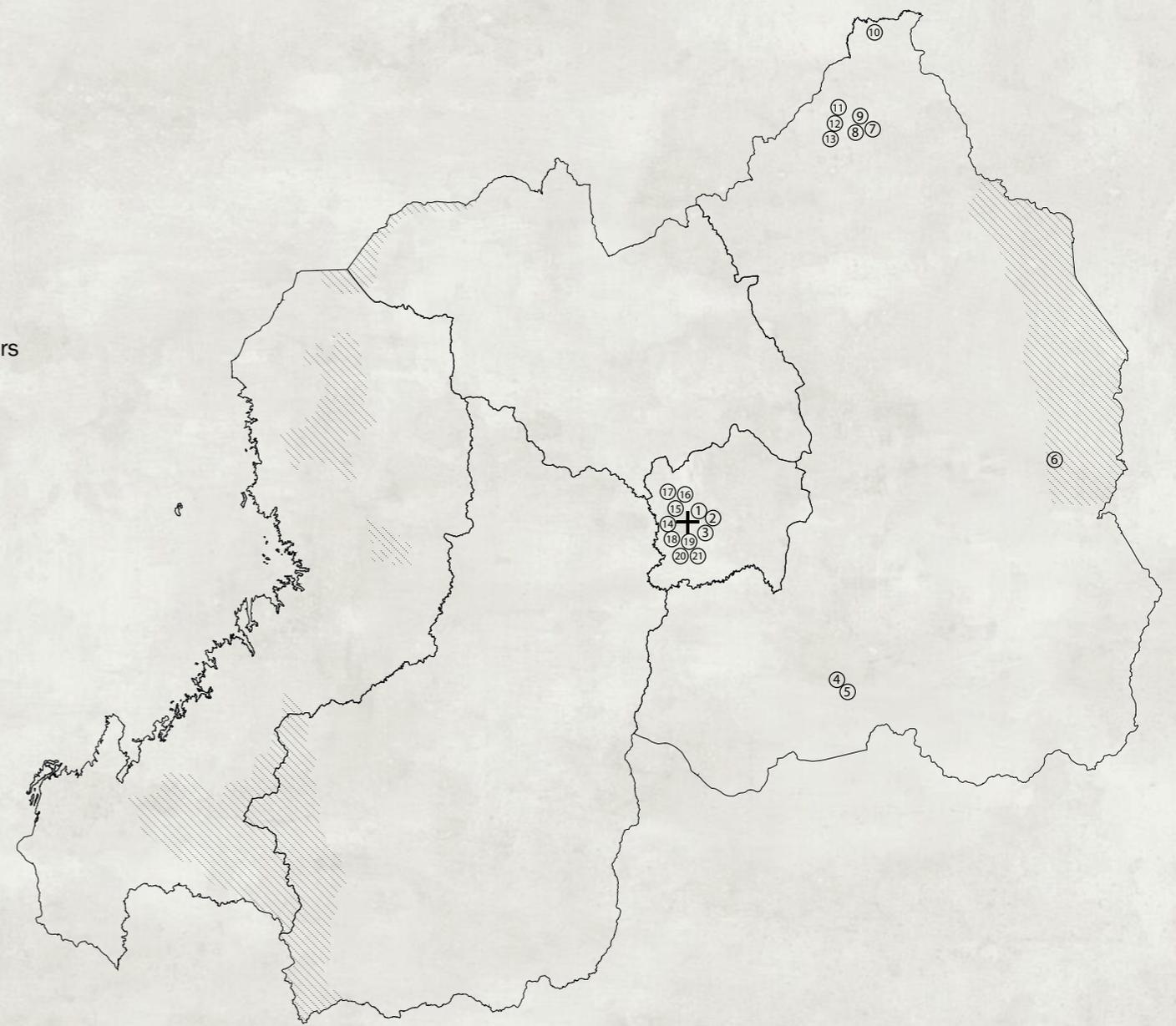


Figure 15 Interviews and contacts location

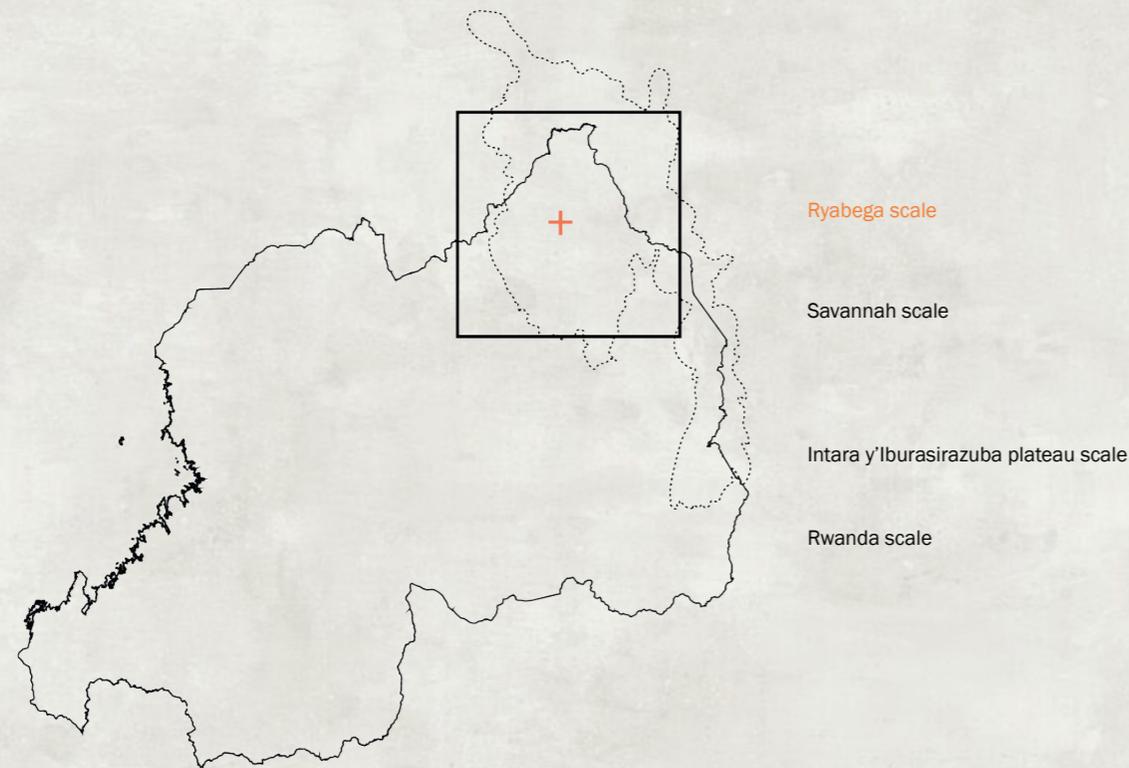


Figure 16 Scale method analysis

a group of eight young women working together and irrigating from the river via a long garden hose and the last group is a duo of husband-and-wife farmers working their land and relying on rainfed agriculture.

Finally, the reading itinerary of this thesis unfolds on four different scales.

First, the **Rwanda scale** elaborates on the climate and global warming consequences, multiple national challenges, that are very much relevant for the design location. Moreover, the main activity of the country revolve around the productive landscape. It plays an important role in the economy, employment, landscape shapes and both local and national food sources.

Secondly, **the Intara y'Iburasirazuba plateau scale** zooms in on the areas facing droughts challenges according to this thesis problem statement. This scale delves into the human threats and opportunities this unique landscape offers. As this chapter focuses on a first

understanding of people's stories, the counter-cartography method accompanies academic cartographies

Tertiary, the **Savannah scale** dives into the northern part of the plateau for its sub-arid typologies and flora, as well as a lack of water access. Like the arid climate case study, conditions of water scarcity are guiding this scale choice.

Lastly, the final scale is the design location: the town of **Ryabega**. It is organized in two parts. The former investigates the landscape and town processes and dynamics, and the latter delves into the design strategies implemented along with the design zoom-in.

APPLIED THEORIES

The theoretical framework of this study research is based on five primary axes; Bioclimatic-zones concept (1), Nature based-solutions for Landscape Resiliency (2), counter-cartography as a means for a decolonial theory application (3) and traditional arid water systems (4).

These theories are applied and thoroughly investigated to enrich the overall design.

Lastly, two others are directly implemented in the design master plan and zoom-in to address Rural transformation and «Townscape» theory.

Firstly, the **Bioclimatic-zones concept** in Landscape Architecture facilitates an adaptive site-planning strategy, particularly in regions characterized by hot climates such as arid or tropical environments. The fundamental objective of this theory is to strategically leverage elements such as heat control, wind patterns, and evaporation through meticulous planting and

landscape design interventions (Attia, 2009). This concept, widely recognized in Bioclimatic Architecture, involves harnessing and applying natural and local climate and environment characteristics (Widera, 2015). In architecture, this translates into daylight interior usage, natural ventilation design, interior native plants, natural air-cooling system like the Wind Towers, locally sourced materials and so forth (Widera, 2015). In the realm of Landscape design, this theory employs plant types and local vegetation strategically adapted to their site-specific conditions, contributing to the creation of micro-climatic oases in hot climates. Techniques such as vegetation layering and tree architecture play pivotal roles, fostering cool enclosed landscapes, filtration zones, and vertical or horizontal shade filters to ensure bioclimatic comfort (Attia, 2009; Adiguzel et al., 2019). Such initiatives are particularly pertinent in the context of global

warming adaptation (Widera, 2015).

Secondly, **nature-based solutions** are a well-established practice also in the specific context of Rwanda, as acknowledge during my meeting with Philippe Kwitonda and with the NBS for flood risk and resilience design by Defacto urbanism and Anne Loes Nillesen in Kigali. NBS aim to develop more traditional – and in this case – droughts resilience measures while enhancing spatial qualities of communities. They operationalize on an ecosystem approach by protecting, “enhancing, restoring, creating and designing new ecological networks characterized by multifunctionally and connectivity.” (Scott & Lennon in Scott et al., 2016, p.268). In the current graduation project, nature-based solutions are strategically employed as a tool to achieve **landscape resiliency**, representing a focal point in the research. Landscape resiliency theory, integral to this discussion, emphasizes flexibility and adaptability, grounded in an ecological design intention. It necessitates a conceptualization at multiscale levels to effectively address both regional and localized challenges (Masoud & Holland, 2021).

Furthermore, as mentioned in the methodology,

the application of **counter-cartography** serves as a methodological approach for addressing decolonial mapping. As learned during the conference by Catalina-Rey Hernández, this method empowers the representation of individuals’ unique stories and perspectives regarding their landscape. Their understanding is different than our own as we are outsiders to the studied environment.

Lastly, the case study methodology implies studying arid water system theories which revolve around drought-resiliency and water circularity. The landscapes values of the studied Traditional Khadin system in India rely on site-specific interventions to harvest the water runoff and reintroduce a new water cycle in desertic areas. The seasonal system is relying on soil moisture for irrigation, as well as humus and microbacterial activity for improved soil fertility.

Finally, in addition to the landscape theories, it is essential to look into **Rural transformation** literature as the design location is located in a poor and rural part of Rwanda. Such theory encompasses multiple aspects (Grinberg

Rabinowicz & Chinapah, 2015 ; UNDP Brasil, 2021) :

1. Increased income from diversifying activities
2. Connections to surrounding marketplaces
3. Community ownership: by the people, for the people
4. Empowering communities by empowering women
5. System and landscape resiliency
6. Economy sustainability

The creation of cooperatives also impacts tremendously, small rural communities through education, funding from NGO’s, mutual aid and cooperation.

Lastly, the spatial design zoom-in is inspired by the «**Townscape**» theory by Gordon Cullen (1961).

Such theory delves into the «*Art of relationship*» as another form of expression than architecture. It harnesses the faculty of sight, optics and serial vision to create a landscape experience in which the visitor feels emotions. The revelations and emotional impacts of «*existing view*» and «*emerging vision*» are instrumentalized to surprise and opposite conformity and monotony. Juxtaposition of views, colors and characters creates interacting spaces for collective benefit.

Native *Acacia* tree and wild baboons enclosed in
the Akagera National park.
©Charlotte Delobbe

RESEARCH

2

The first step of the research chapter dives into two scales: Rwanda and the eastern Intara y'Iburasirazuba plateau.

The former elaborates on the national challenges regarding climate and global warming, rapid urbanization, drinking water access and finally the productive landscape that shapes the hills and valleys of Rwanda.

The latter scale takes on the challenges the east of the country is currently facing, emphasizing the prevalent issue of recurrent drought occurrences and their ramifications.

RWANDA SCALES

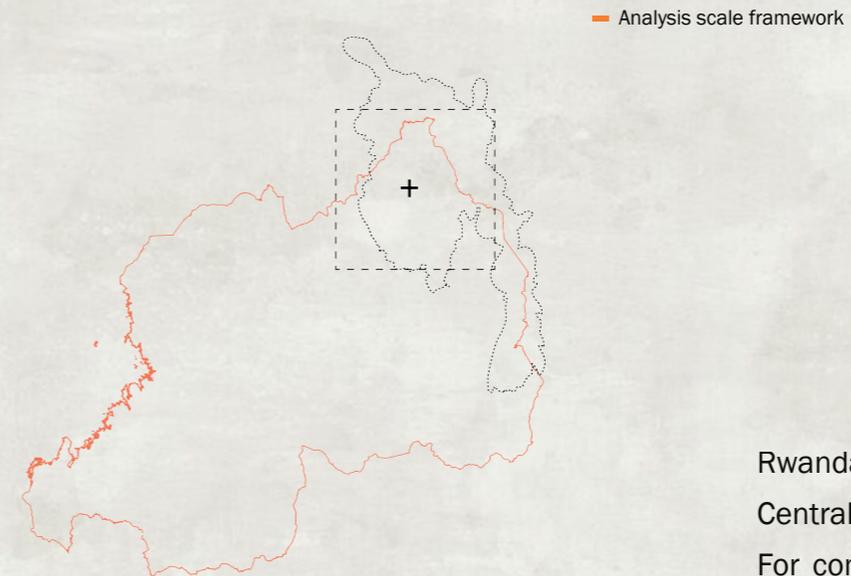


Figure 17 Rwanda scale key map

Rwanda is a small landlocked country in Central Africa with a land area of 26 338 km². For comparison, the Netherlands' surface area reaches 41 850 km² and Belgium's 30 688 km² (Wikipedia, 2024).

Located south of the Tropic of Capricorn, the country has five volcanoes, 23 lakes and multiple rivers and wetlands (Government of Rwanda, 2024). Its tropical climate means the year is punctuated by rain and dry seasons, rather than the four distinct ones experienced in Europe.

However, Rwanda's original climate is currently under threat of global warming, resulting in numerous irregularities and unexpected events such as droughts, floods, landslides, rainfall fluctuations and temperature increases (Republic of Rwanda, 2022)

Climate

Climate zone: Tropical

Climate & Weather Averages

High t°: 27.6 °C

Low t°: 11.57 °C

Mean t°: 19.1 °C

Precipitation: 1170 mm

Humidity:

Hottest Months: August and September

Coldest Month: July

Long dry season: December to February

Short dry season : June to August

Long rain season : September to December

Short rain season : February to May

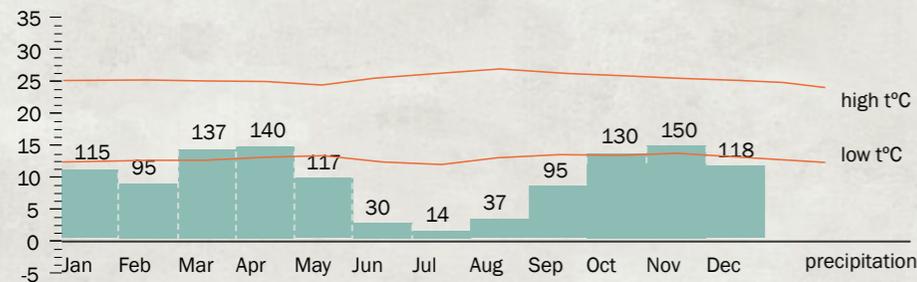


Figure 18 Annual precipitation and monthly average temperature

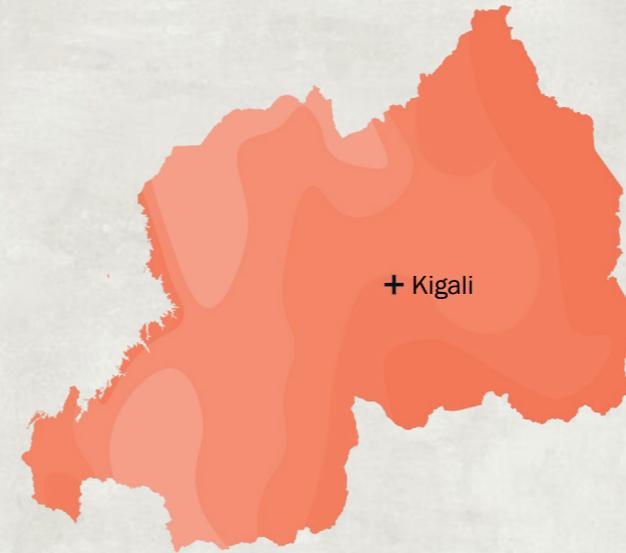
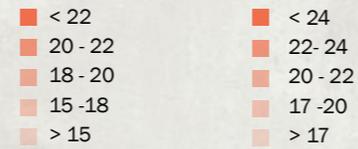


Figure 19 Average temperature (C°)

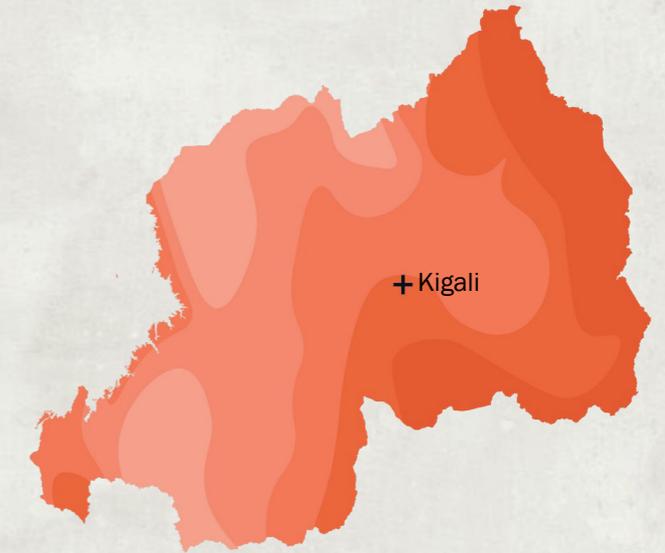


Figure 20 Higher annual temperatures - hypothesis map

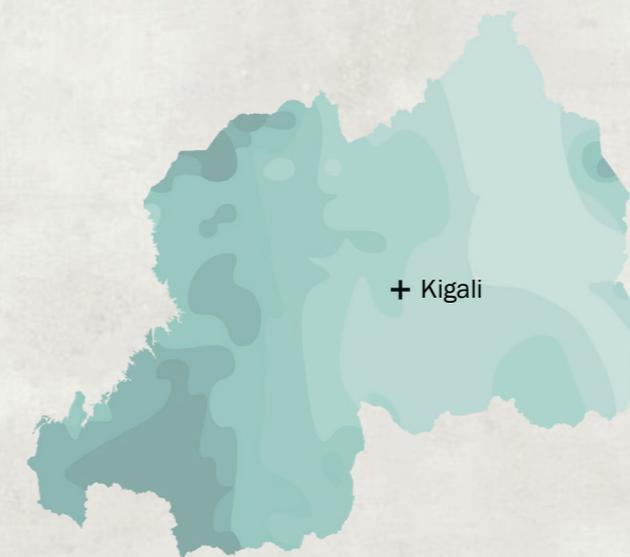


Figure 21 Average rainfall(mm)

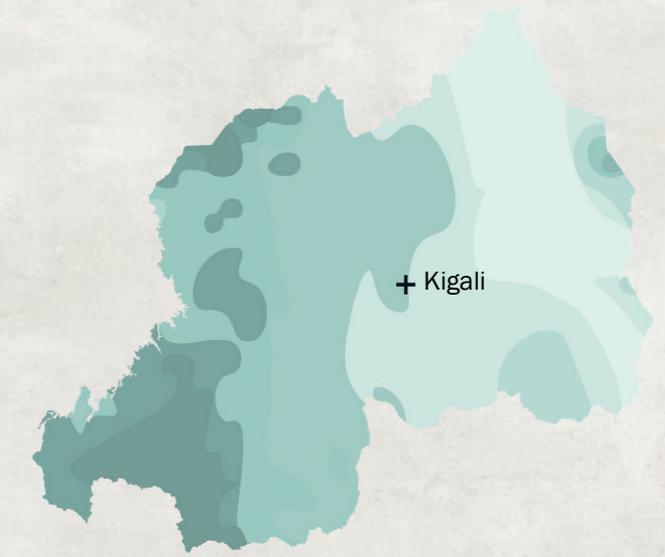


Figure 22 Extreme and irregular rainseasons - hypothesis map

National challenges

1. Rapid urbanization

Urban growth is nowadays an important topic, as around 90% of the population increase will take place in Asia and Africa by 2050 (United Nations, 2018 ; Nduwayezu, Manirakiza et al., 2021).

Since the 1994 genocide, in which Belgium's colonization and administration played a role by dividing the people through Darwinian theories (Republic of Rwanda, 2012), Rwanda has undergone a shift in its structure and urbanism. Indeed, the city of Kigali has been growing tremendously with the expansion of its boundaries and peripheral rural residents. Furthermore, current tendencies show high flows of migration attracted by the city's economy (Nduwayezu, Manirakiza et al., 2021).

The Rwanda Vision 2020 was drafted to tackle rapid urbanization alongside poverty, trade and low infrastructure development (Republic of Rwanda, 2012).

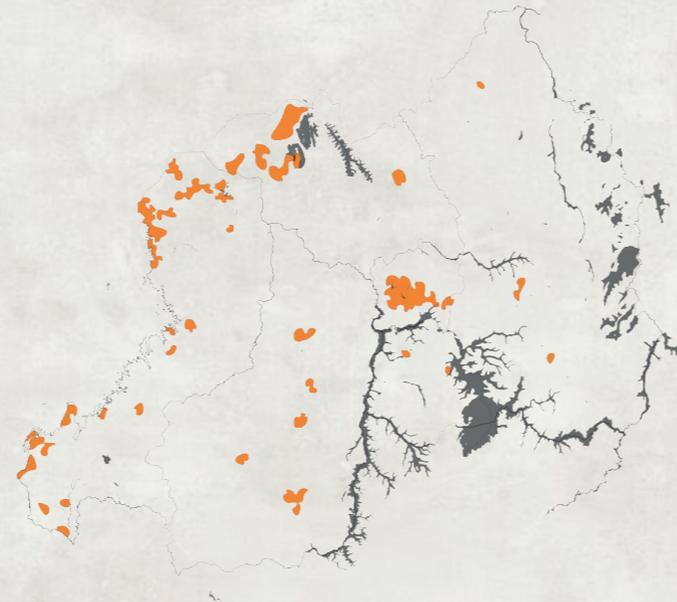


Figure 23 2002 (WorldBank Group, 2017)

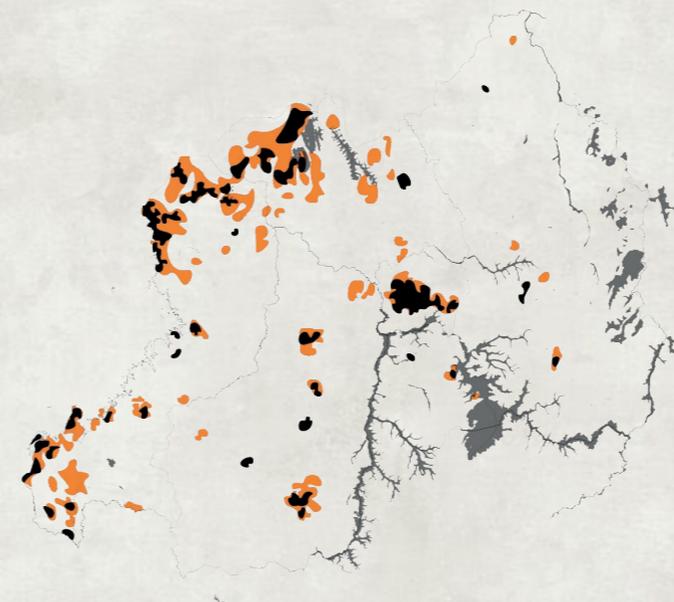


Figure 24 2015 (WorldBank Group, 2017)



Figure 25 2022

National challenges

2. Droughts and cities

The previous analysis elaborating on urbanization highlights two main aspects.

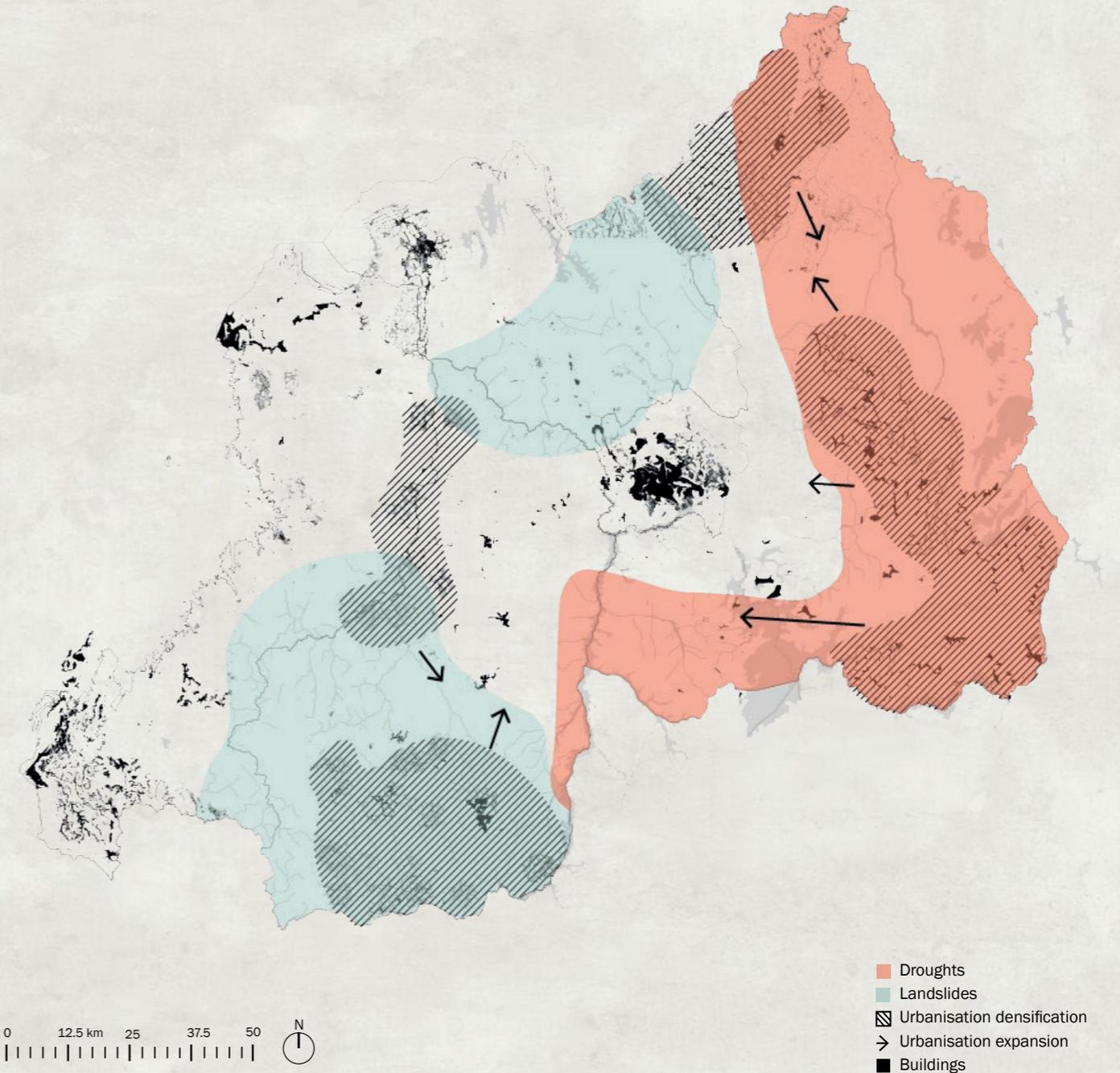
First, the urban expansion the country undergoes in the western and eastern parts of the country.

Second, the urban intensification of cities.

When juxtaposition these datas to the current global warming challenges this thesis works on, the analysis accentuates the importance of the climate adaptability and resilience of cities. Indeed, most developing areas are located in landslide-vulnerable areas or drought-prone areas (Mer, 2015).

It is an important parameter to take into account for future projects designed and located in these areas.

Figure 26 Cities global warming challenges



National challenges

3. Drinking water access

National water resources are under pressure from domestic and agricultural use.

As the deficit in drinking water is already in deficit, estimations shows the demand over the next ten years will double in the entire country (REMA, n.d.).

Tap drinking water is rare and a luxury, as more than 90% of the population doesn't have access (Broulard, 2021). In cities, most of the population can buy gallons at the local supermarket or store. However, it is more complicated in rural areas.

A few options include natural water sources, most of the time unsafe (Mukanyandwi et al., 2019), wells and public groundwater manual pumps (Sci Dev Net, 2013). However, as it was noticed during the on-site visit, there are few and quite scarce.

Governmental organizations such as INUMA aims to supply clean water in the 30 national districts by implementing Water Access kiosks (Magoum, 2020).

60 % <15 min distance
--> countryside

40 % 15 min distance

10 % tap drinking water

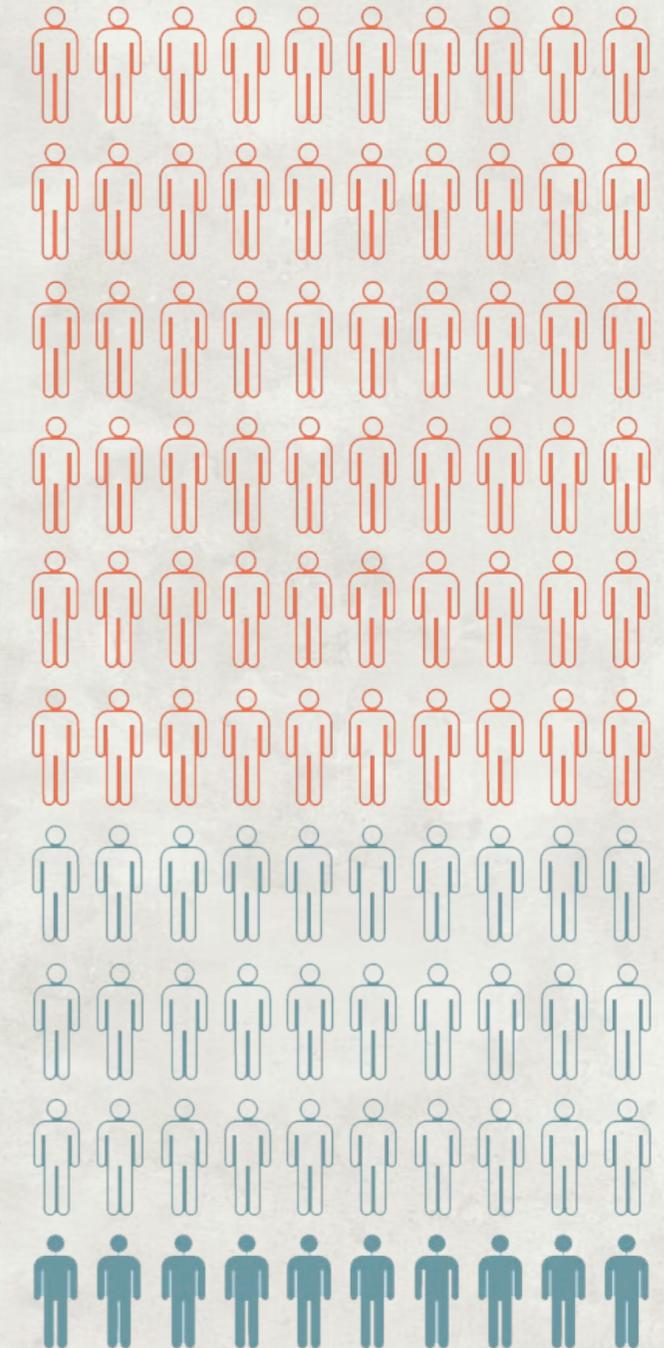


Figure 27 Drinking water access

PRODUCTIVE LANDSCAPES

The productive landscape of Rwanda has a tremendous importance for the country's economy, landscape and employment.

Indeed, it currently accounts for 33% of the Gross Domestic Product in 2012 (GDP) (Habiyaemye et al., 2011) and 24.9% in 2022 (Statista, 2024) by majorly exporting tea and coffee alongside other harvests (FAO, 2024). Other exports consist of minerals and services.

Moreover, the agriculture sector directly or indirectly employs 90% of the population (Mer, 2015). It is essential to people's livelihoods in order to afford basic needs and services, such as paying for their children's school (YouTube InfoNile, 2022).

Finally, agriculture is also celebrated throughout the country during the *Umuganura* or harvest day. It remains the largest festival to celebrate and motivate civilians on their achievements (Republic of Rwanda, 2024).

Shaping the landscape

Agriculture patterns

Rwanda is very hilly country with a fluctuating topography and the agriculture system had to adapt to such conditions.

As it covers around 80% of the country's surface area (Habiyaemye et al., 2011), it takes on numerous shapes and patterns, which paint the productive landscape in multiple ways.

Hilly agriculture consists of bocage or benching techniques to deal with steep slopes.

On the other hand, wetlands agriculture is located alongside and in the river bed.

These patterns shape the landscape and induce different spatial characteristics around which people build their residences.

Modern irrigation techniques result in major circular shapes, changing the landscape and urbanization lay out. Such projects can be found nearby the Nasho Lake, where people were relocated in poor spatial quality housing in order to implement those infrastructures (The Howard G. Buffett Foundation YouTube, 2019).

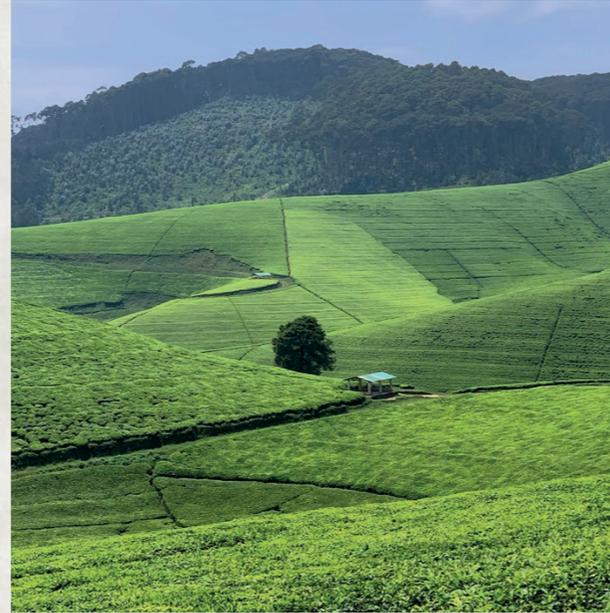


Figure 28 Hills agriculture (Logar, n.d.)



Figure 29 Hills bocage (The Economist, 2019)



Figure 30 Hills benching (Ntirengaya, n.d.)



Figure 31 River edge agriculture (FAO, n.d.)



Figure 32 Wetlands rice fields (L.M. Spencer, n.d.)



Figure 33 Pivot irrigation (RwandaAgri, n.d.)

Agriculture vulnerability to global warming

However, due to the high dependency of the population on agriculture, the country is also highly vulnerable whenever global warming impacts the sector.

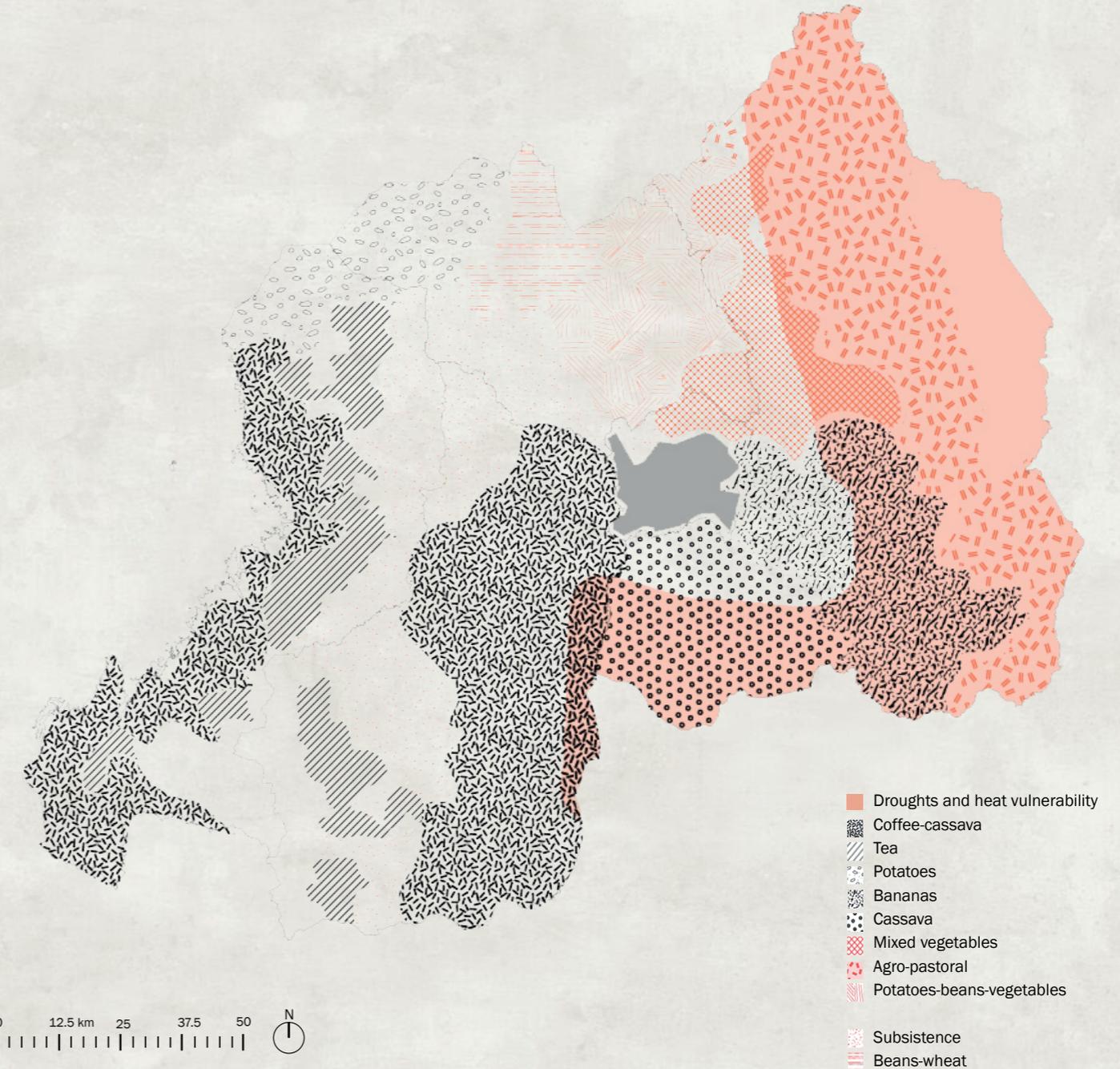
Crops are rain-fed, meaning they rely on the rain seasons to irrigate the fields. Because of a lack of rainfall and increased temperatures, the eastern part of the country struggles with hunger and lower income. Agriculture is usually a factor in poverty, especially in Rwanda, where most of the population lives below the USD1 poverty line, particularly women and rural populations (Mer, 2015).

Furthermore, the total dependency on agriculture destabilizes the whole system, resulting in a 1% GDP loss per year (Republic of Rwanda, 2022).

West Rwanda mainly cultivates coffee and tea, two of the main most profitable exports. Their location is due to the high precipitation in those

Agriculture represents 80% of the country surface area

Figure 34 Drought prone agriculture and heat-vulnerable crops



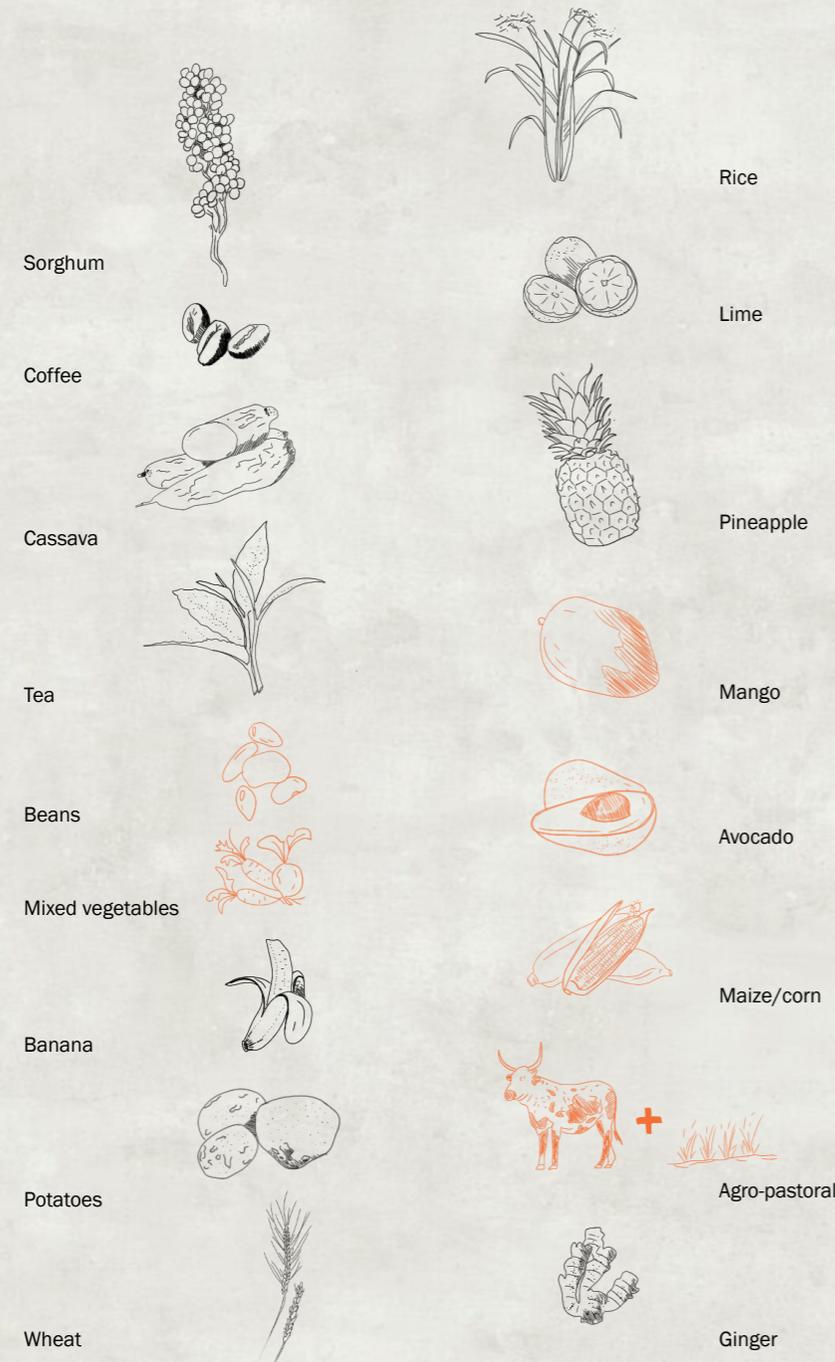


Figure 35 Plants vulnerability to increased temperatures

regions.

The central part of the country cultivates different plants like plantains, cassava, potatoes, maize and beans. Two of them; maize and beans, are highly vulnerable to global warming as they necessitate a lot of irrigation in order to grow.

Lastly, the eastern rural areas are still cultivating 30% of their crops for food subsistence (Interview notes with John Kayumba, 2024). Most crops are sown with maize, sorghum, bananas and vegetables, which are the main foods consumed. Some plants, like bananas and sorghum, are better suited to withstand the higher temperatures the region is experiencing (Mer, 2015).

These practices, along with cattle, make them highly vulnerable to droughts as they need high quantities of water. Only 5–10% of farmers have access to irrigation systems thanks to governmental subsidies (Interview notes with John Kayumba, 2024).

Furthermore, current practices such as intensive agriculture, the use of fertilizers, and the Crop Intensification Program (CIP) are pressuring the soil fertility of the fields.

Indeed, in order to cultivate most of the country's surface areas, the deforestation process degraded and weakened soil structures and resiliency. Nowadays, most forests are conserved in national parks or forest reserves (Rema, 2011b).

The CIP program revolves around decreasing agricultural loss from 40% to 20% and increasing national agricultural productivity and food security (Interview notes with John Kayumba, 2024). The crops' production aims to increase from 2T per hectare to 10T per hectare (Interview notes with Geoffrey & Delphine, 2024).

Rwanda scale conclusion

Rwanda economy and landscape exhibit considerable vulnerability to the impacts of global warming, stemming from factors such as intensive agricultural practices, deforestation, chemical usage, fertilizers, and rapid urbanization. This confluence of influences significantly affects the country's overall ecosystem and the livelihoods of its communities.

The occurrence of global warming-related events, such as landslides and droughts, is intricately linked to the region's topographical features. Particularly in regions characterized by hilly terrain, farmers and their agricultural practices face heightened vulnerability to extreme precipitation events, often resulting in substantial and calamitous landslides. Notably, the eastern part of Rwanda diverges from the country's famed «Land of a Thousand Hills» topography, instead featuring plateaus that offer distinct climatic conditions and biodiversity.

The eastern region naturally experiences lower levels of humidity, with annual rainfall ranging

from 633 to 938mm rainfall (Ngwijabagabo et al., 2023). Nevertheless, impacts of climate change have manifested in the form of severe and recurrent droughts, posing significant challenges to local communities, landscapes,

and agricultural activities. This concern is exacerbated by the inherent vulnerability of most agricultural practices and crops to rising temperatures and diminished precipitation levels.

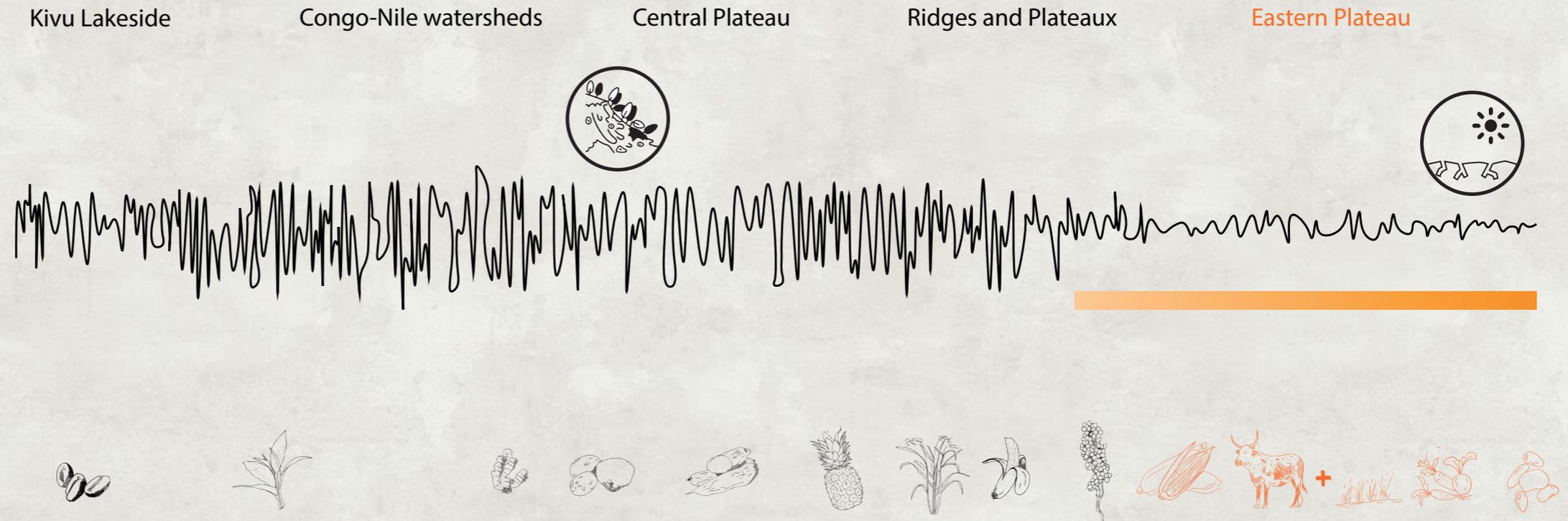


Figure 36 National topography relation to global warming events

Intara y'Iburasirazuba

PLATEAU SCALE

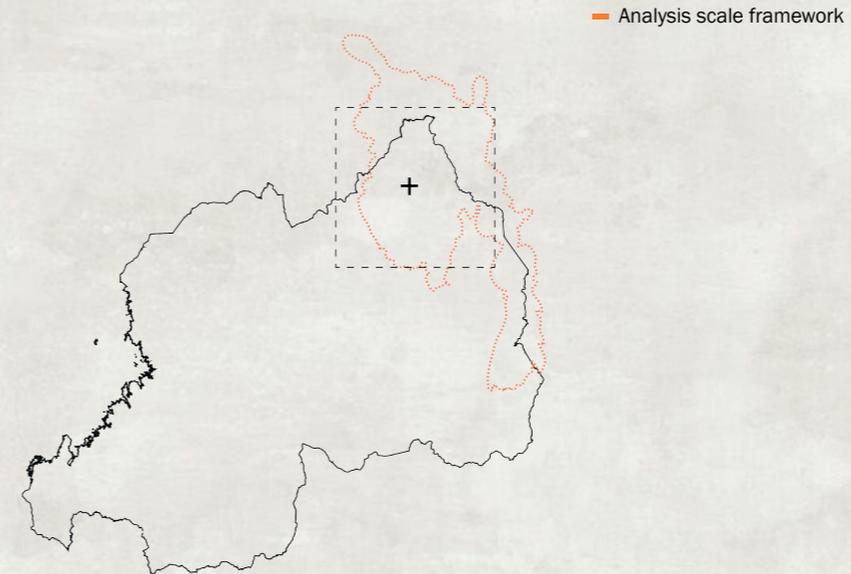


Figure 37 Plateau scale key map

This analysis scale delves into the Intara y'Iburasirazuba plateau scale.

Most drought challenges in Rwanda are related to this unique topography, which is also present in the central-eastern part of the country.

The eastern plateau shares its borders with Tanzania and Uganda. It is an extremely rich area in both wetland landscapes and flora, as well as in Central Africa's Savannah biodiversity.

The plateau scale chapter elaborates on the threats it faces as well as the opportunities this area has to offer.

1. Threats and opportunities

As highlighted within the framework of the national challenges' analysis, intensive agricultural practices, deforestation, and accelerated urban expansion manifest as prominent concerns across all geographical domains of the country, including the expansive Eastern Plateau.

Within the context of the Eastern Plateau, wherein the need for more agricultural income arises, the process of deforestation persists as an ongoing phenomenon. This practice exerts multifaceted repercussions upon the landscape, encompassing the loss of biodiversity, depletion of arboreal cover, diminution of natural bird habitats, and compromised climate resilience.

Most of the natural Savannah flora and fauna has witnessed a precipitous decline within the region, with much of its expanse now confined within the Akagera National Park, working for wetland preservation.

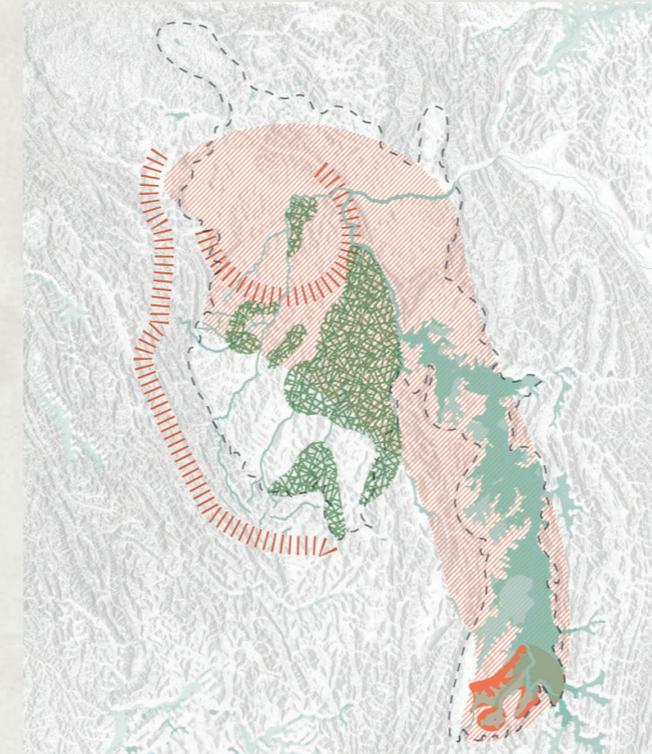


Figure 38 Threats map

- Lack of rainfall
- Threatened wetlands by intensive agriculture
- Water
- ▨ Urbanization pressure
- Deforestation process

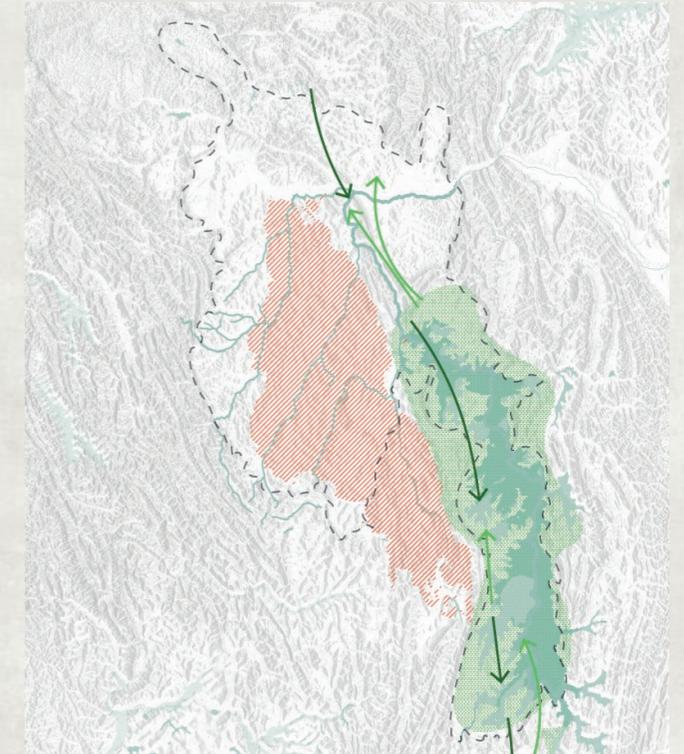


Figure 39 Opportunities map

- Rich sub arid savanna flora
- Bird nests
- Bird migration
- Water

2. Unique sub-arid landscape

in a tropical climate

In recent years, conservation has been able to safely guard the rich biodiversity of the plateau in the Akagera National Park. Since 1990 and after the genocide, the area has been under pressure from deforestation, and refugees and survivors of the genocide fleeing the cities to hide in the park (Fischer, 2011).

The plateau's biodiversity takes two different forms.

The south, full of beautiful wetlands, harbors a rich, humid tropical biodiversity and a high diversity of fish and birds. The habitat vegetation contains aquatic plants and high grasses such as papyrus reed, *Phragmites mauritanus*, *Typha domingensis* and *Polygonum pulchrum* (Fischer, 2011 ; ARCOS, 2021). Unfortunately, the southern wetlands are not protected by the National Park and are under the pressure of intensive agriculture, cattle grazing and urbanization (Fischer, 2011).

The northern part of the plateau is part of the Savannahs and steppes of Central Africa. Savannahs are typically "grass formation comprising a carpet of tall grasses measuring at least 80 cm in height at the end of the growing season, with flat leaves at the base or on the stubble, and herbaceous plants and grass of lesser size" (Letouzey, 1982 in Hiol, Kemeuze & Konsala, n.d., p.165).

That ecosystem contains rich sub-arid species that are adapted to drier conditions, low humidity and less rainfall (Vande weghe, JP & Vande weghe, GR, 2011). Tree and scrub species are *Acacia*, *Grevillia Striata*, *Pennisetum purpureum*, *Euphorbia candeladrum*, *Brachystegia*, *Markhamia*, *Callitris*, etc.

Worldwide savannahs are threatened by aridification and climate change, as well as by agricultural practices leading to biodiversity loss (Hiol, Kemeuze & Konsala, n.d.)



Figure 40 Rwandan Akagera Wetlands Landscape



Figure 41 Rwandan Savannah Landscape

3. Plateau stories

To summarize, the plateau's direct threats are deforestation and intensive agriculture.

Indeed, to palliate with the need of income and more production, deforestation is happening and pressuring the border of the Akagera national park.

Additionally, as aridification and droughts are impacting communities, agricultural practices and incomes are threatened and intensifying even more.

To face droughts and longer dry seasons, two main irrigation methods are implemented.

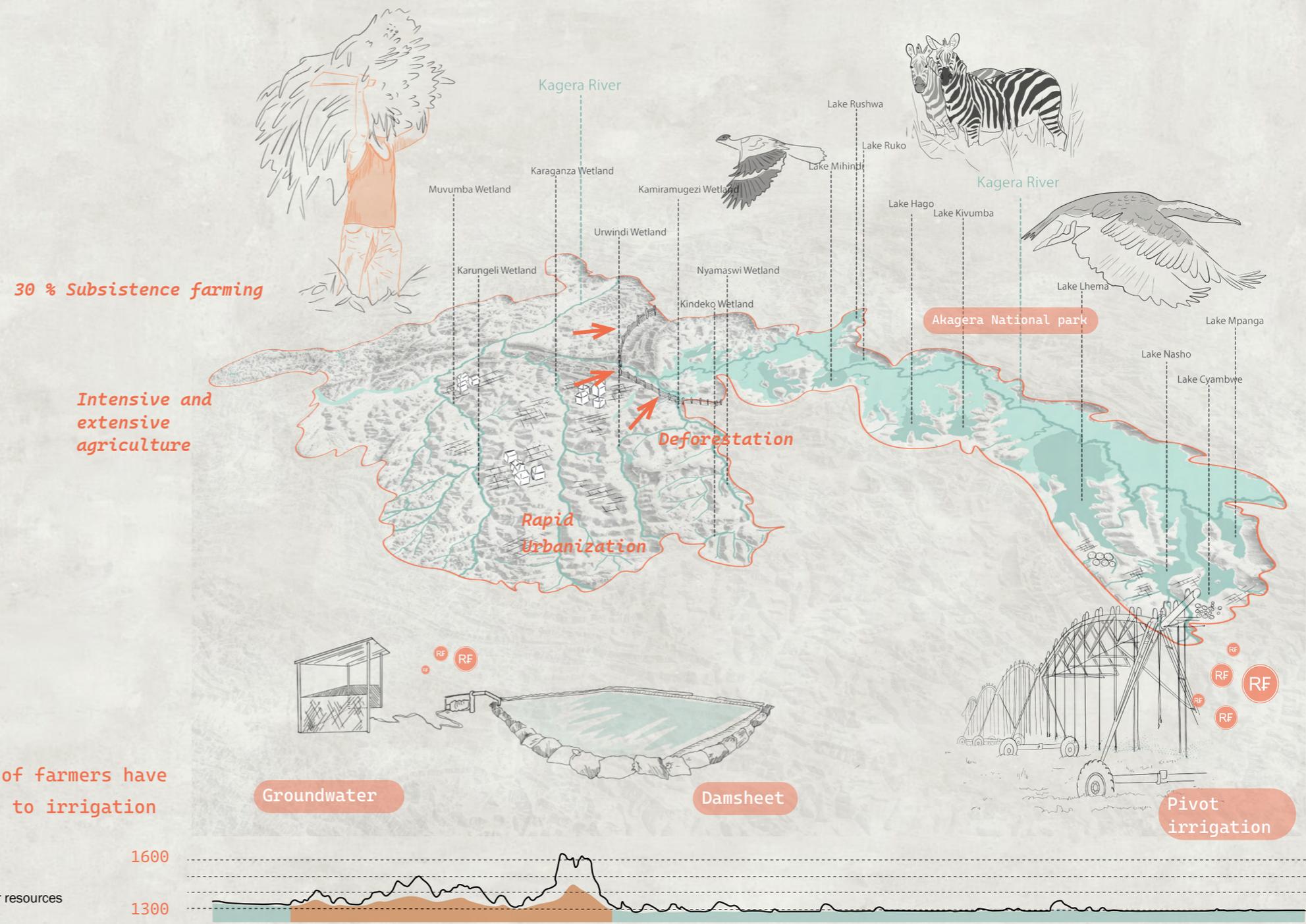
First, pivot irrigation systems pump water from the lakes, and secondly, groundwater pumps in the northern hills.

However, both rely on unreliable water sources during dry seasons and are worsening the situation by overconsuming them. Indeed, as groundwater resource potentials are already mid-to very low potential (REMA, n.d.), pumps are not a long-term solution, nor are they affordable.

Figure 42 Rwandan plateau stories

Figure 43 Plateau topography

■ Poor groundwater resources
■ Groundwater



Research

CONCLUSION

At both the regional and localized scales of Rwanda and the Plateau, multiple issues stemming from the intersecting dynamics of global warming and human activities have come to the fore. The consequential impacts on the landscape are profound, particularly exacerbated during periods of climatic vulnerability and resource scarcity.

Current urban, agricultural and irrigation practices need to be questioned and adapted to to mitigate adverse effects on landscape biodiversity and soil fertility.

Nowadays, the acquisition of knowledge on conservative agricultural techniques, mechanization, and irrigation infrastructure is restricted to farmers and cooperatives funded by governmental subsidies or external investments (Interview notes with John Kayumba, 2024).

Accordingly, a lack of knowledge on adaptive

agriculture and climate adaptability practices exists. In the context of this thesis addressing drought challenges on communities, landscapes and agriculture, the relevance of studying an arid water system is of importance.

Indeed, insights gleaned from locally built and sourced traditional water systems adept at navigating high temperatures and water scarcity hold considerable potential for ameliorating conditions within the northern sub-arid region of the eastern plateau.

Figure 44 Khadin landscape ©Rajendra Kumar



CASE STUDY



This third part of the thesis focuses on the case study and introduces the Traditional Indian Khadin Water System. Originating from the Jaisalmer District in Rajasthan, India, the Khadin works in arid areas characterized by high temperatures, sandy soil and water scarcity. It reintroduces the natural water cycle by a rain harvesting technique for agricultural purposes.

Context

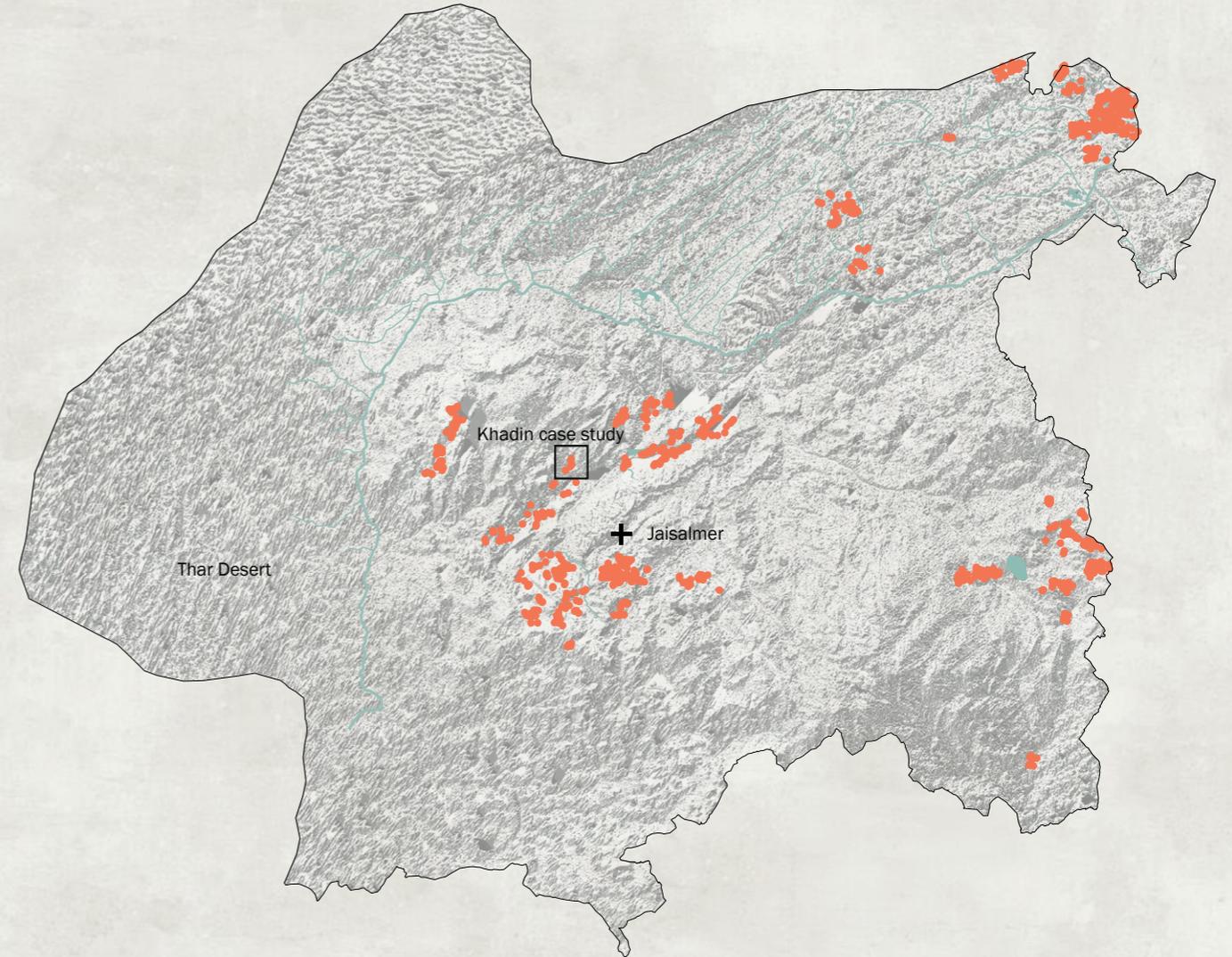
Location: Jaisalmer District, Rajasthan, India
Period: From the 15th century to nowadays
Function: Seasonal agriculture
Type: Water infiltration, wheat, chickpeas and mustard cultures
Area: 500 khadins - 12,140 ha
Components: Earthen embankment that catches the water run off in a natural depression. A nearby well collects the recharged groundwater for drinking purposes. Site-specific system.
Status: In use



Figure 45 Rajasthan location

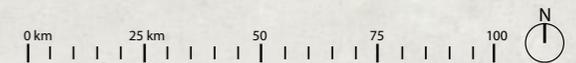


Figure 46 Jaisalmer District location



Canal
Water bodies
Khadins

Figure 47 Regional scale Jaisalmer District and the Khadins (non-exhaustive)



Human interactions

Wakar, Palar and Deir water are important denominations of water states. In order, they means : groundwater, rainfall and surface water. There are also many dugwells shapes and names depending on the size, ownership and location. For instance : a “kua” is an individual well, a “kohar” belongs to the community, “Sagar-ka-hua” is a 60 meters deep well, “Sajay-ka-hua” relies on the groundwater recharge of a watershed and many others names (Saxena, 2017). All these denominations inform us of the strong relationship people have with the different facets of water.

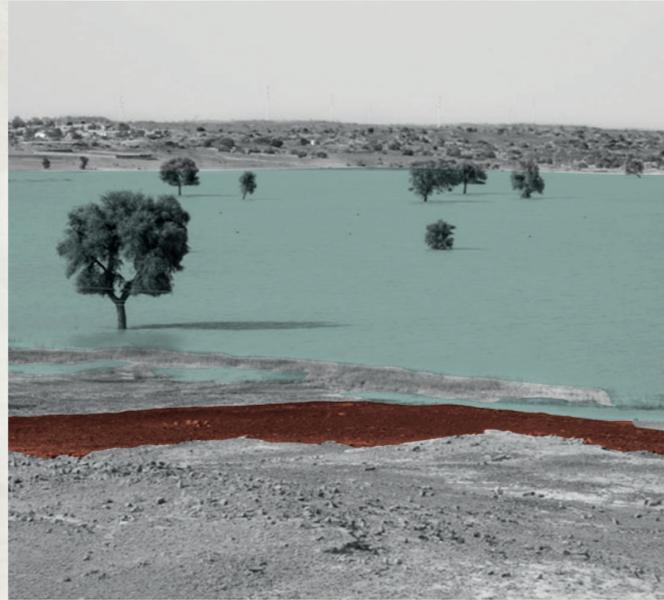


Figure 48 Khadin landscape after monsoon



Figure 49 Tool used to measure the khadin water height



Figure 50 A farmer showing around his field during the dry season



Figure 51 “Rabi” crop

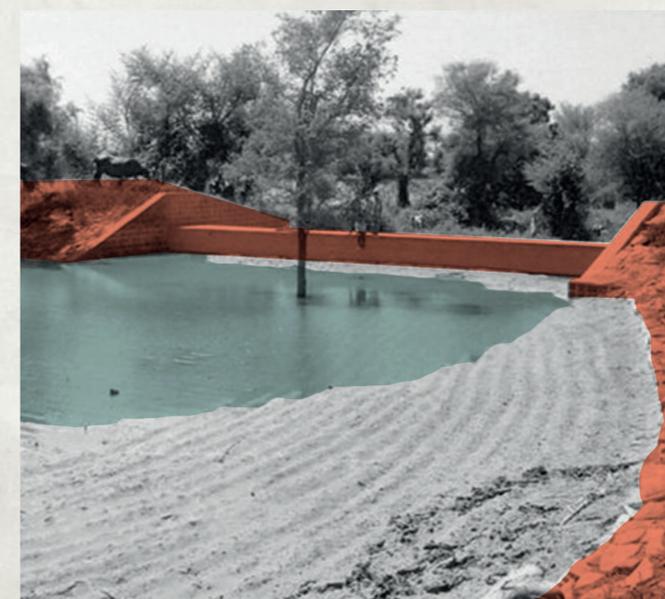


Figure 52 Khadin water work

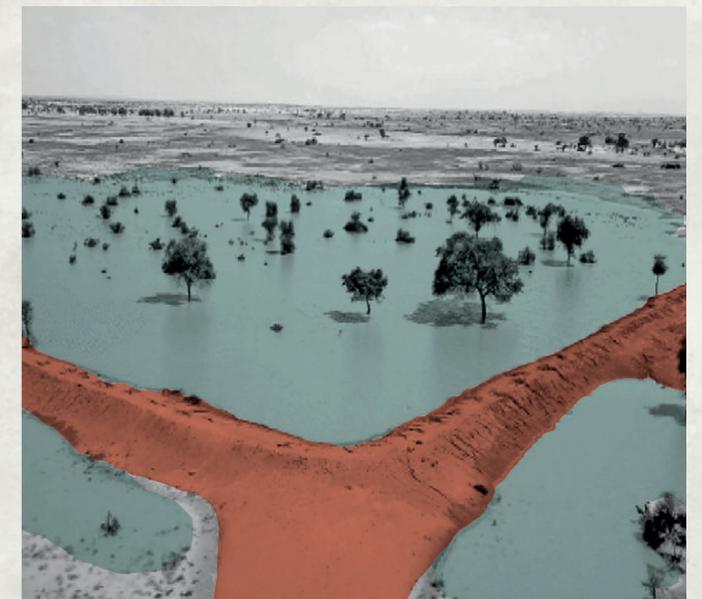


Figure 53 Khadin embankment

Climate

Climate zone: Arid zone
Sub-climate: Desertic type

Climate & Weather Averages

High t°: 33.09°C
Low t°: 23.72°C
Mean t°: 29.75°C
Precipitation: 3-70 mm
Humidity: 31.8%
Wind: 19.77 km
Pressure: 1.59 mb
Hottest Months: May
Coldest Month: January
Wettest Months: August
Windiest Months: July
Annual Rainfall: 16.5mm

The district of Jaisalmer is characterized by dunes or sand hills over 70% of its surface area (Kolarkar, Murthy & Singh, 1983). It includes the Thar Desert on its western part which covers 27.8 millions hectares in India (Saxena, 2017). Its climate is characterized by meagre rainfall of one rainseason and a long dry season which can reach high temperatures.

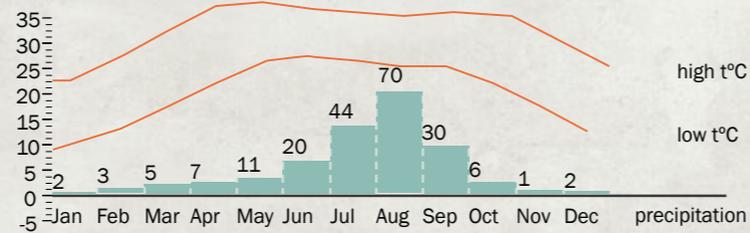


Figure 54 Annual precipitation and monthly average temperature

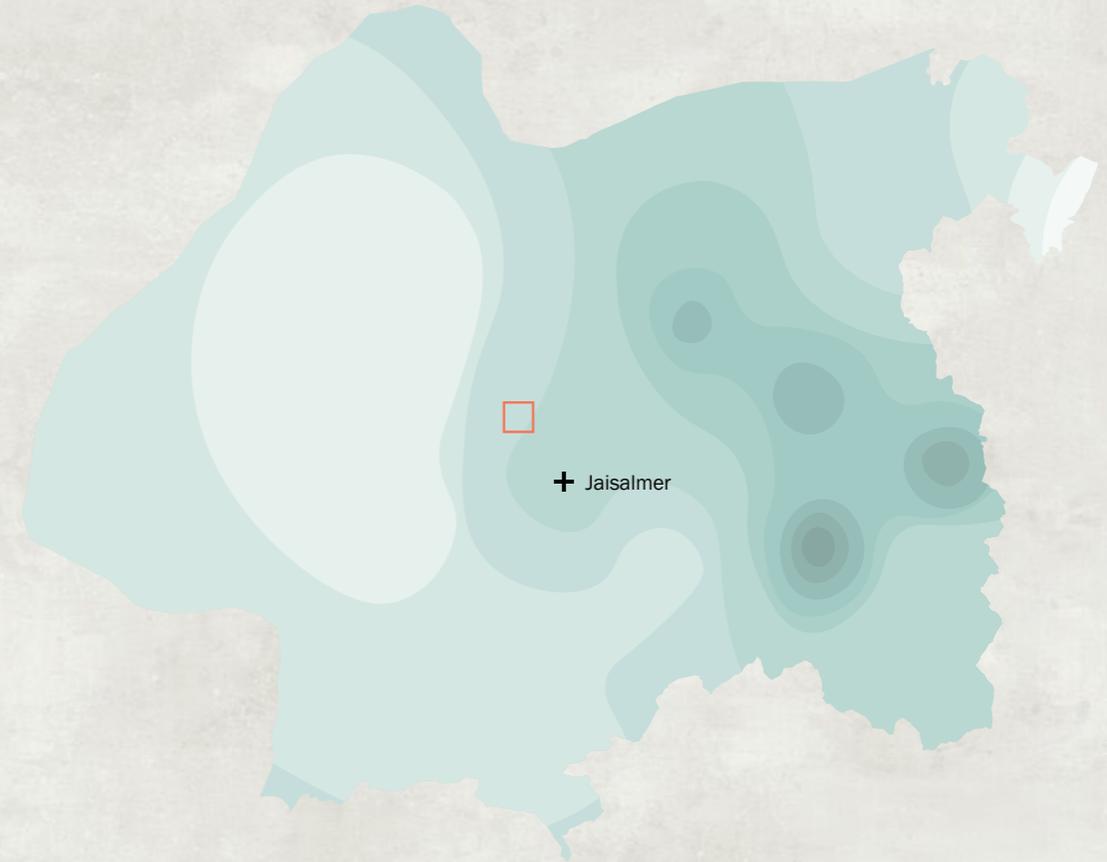
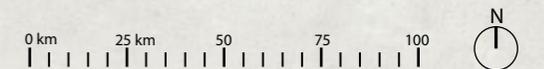


Figure 55 Average rainfall (mm)
 100 mm
 80 mm
 70 mm
 60 mm
 50 mm
 40 mm
 30 mm
 20 mm
 10 mm
 5 mm



Catchment Area

The Lanela khadins

The natural conditions of this area mean agriculture is precarious for local villages and irrigation limited by water scarcity (Saxena, 2017).

Therefore, systems must rely on “palar” water (rainfall) to design an optimal use of water.

Khadins are implemented in slopes and depression areas with suitable runoff capacity to collect and store “palar” water (Prasad & Mertia, 2004).

Its main characteristics are a large earthen embankment and a concrete wall with contains a spillway and sluice at its lowest level to let go of excess “deir” water (surface water) (Kolarkar, Murthy & Singh, 1983).

Khadins are located nearby villages as they serve as a agricultural practices to increase food

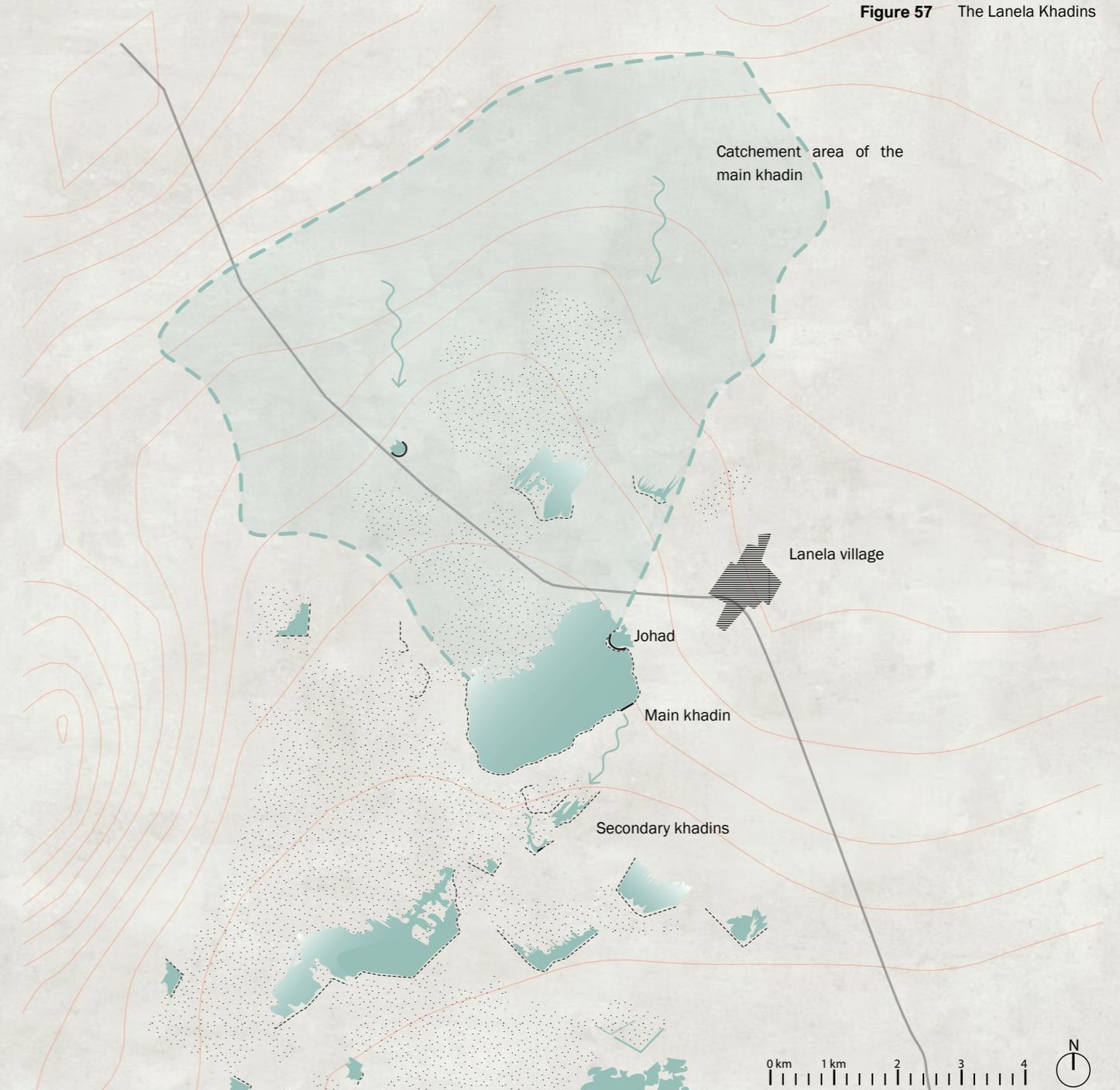
- Contour lines 5m
- Road
- ⋯ Earthen embankment
- Concrete wall
- Water
- ▨ Catchment area
- ▨ Crops
- ▨ Village



Figure 56 Kadin case study : The Lanela Khadins

source production. Shallow dug wells around khadins take advantage of the “wakar” water (groundwater) recharge to give access to drinking water (Kolarkar, Murthy & Singh, 1983). Thanks to its implementation, they have increased food production from 3-11% to 50-70% enabling farmers’s prosperity (Hussain, Husain & Arif, 2014).

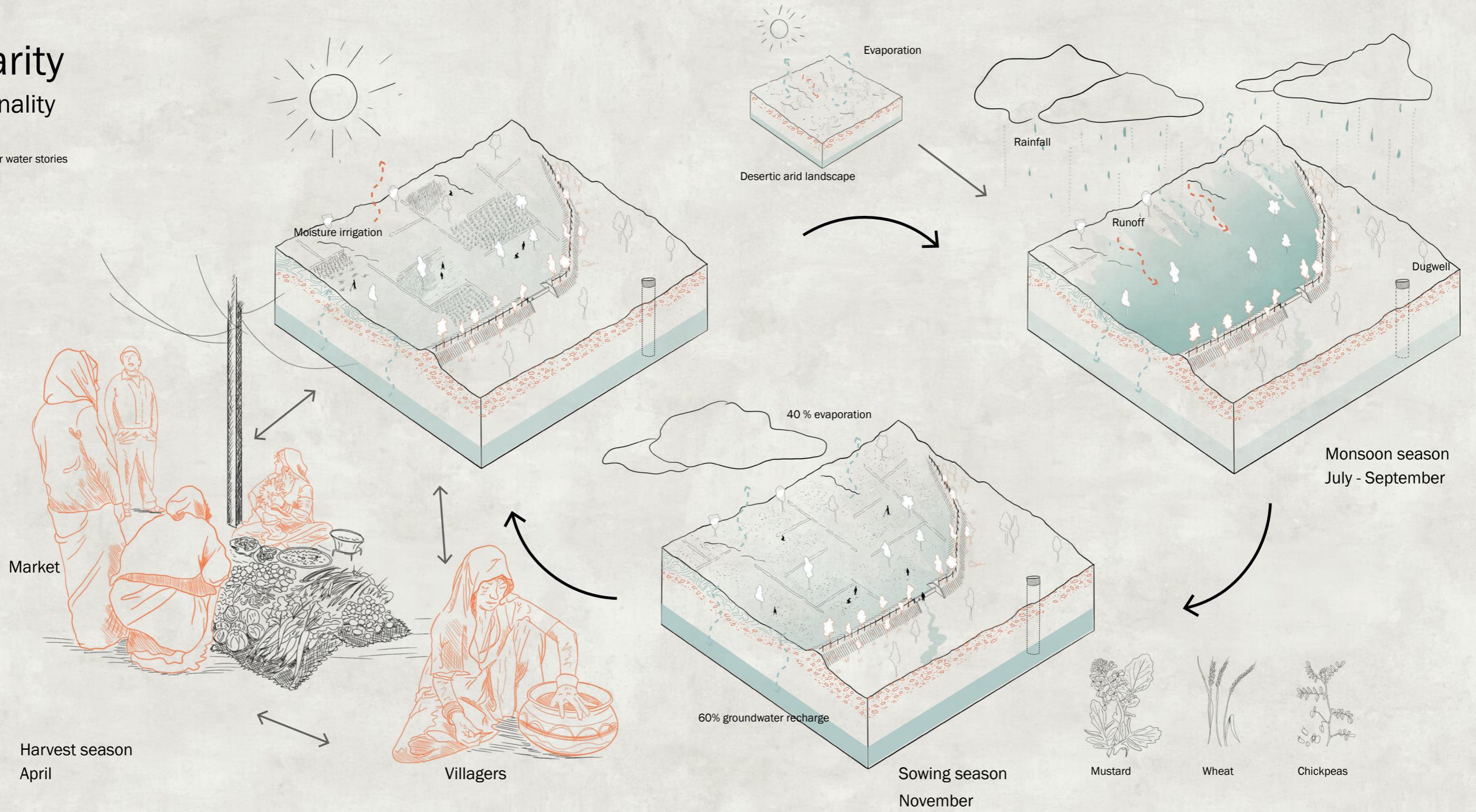
Figure 57 The Lanela Khadins



Circularity

And seasonality

Figure 58 Circular water stories



Circularity

And seasonality

The seasonal rhythms are dependent on the one rain season and an all-year-round dry season. As local groundwater does not suffice to sustain local crops and villages, the khadin collects as much water as possible.

Its embankment prevents soil deterioration (Kolarkar, Murthy & Singh, 1983) as it collects not only rainwater but fine sediments as well.

Over the years, the soil within the khadin develops a layer of humus, alluvium and loam which are advantageous for soil fertility. The moisture enables the development of chemical weathering and high microbial organisms (Kolarkar, Murthy & Singh, 1983; Prasad & Mertia, 2004). Therefore, khadins' soil water holding capacity is improved and varies from 200 to 250 mm per meter (Goyal, Singh & Gaur, 2018).

The caught water runoff accumulated during the rain season decreases by seepage and

percolation. The khadin helps to slow down evaporation by increasing infiltration capacities to recharge the groundwater and nearby wells. During the dry season, no chemical fertilizers or irrigation is therefore needed. People rely on natural moisture to till and weed the land by hand (Kolarkar, Murthy & Singh, 1983). The khadin helps increase crop productivity as well as the food production of the farmers (Prasad & Mertia, 2004).

The khadin is rhythmical by the rain season as it has been mentioned previously. During the harvest season, khadins connect communities. Households' shares are fixed and they sell the production at the local market. Sometime they use it as trade for services. For instance, marriage performances, woodwork for the fences, pottery, etc (Kisantak.in, 2023b)



Figure 59 Khadin concrete wall structure

The Khadin consists of a large earthen embankment and a concrete wall of a few meters. The wall functions as a sluice to let out of the excess debris water when the time to sow the crops comes.



Figure 60 Downstream khadin dugwell

Khadin water systems come with a dug well located downstream. It collects the wakar water, which was recharged thanks to the slow infiltration the basins enabled. Dug wells usually reach the groundwater and are different from tankaas, which collect the rainwater runoff in a shallow well.

Case study

CONCLUSION

Designed and implemented in desertic areas, the Traditional Khadin Water System is a remarkable intervention that catches every possible drop of water and reintroduces the water cycle. For centuries, arid areas and deserts have seen innovations by locals to thrive in these harsh environments. This report elaborates one of these chapters, a part of the cultural heritage of Jaisalmer, India.

Landscape values

The implementation of the Khadin is very site-specific, as it takes advantage of the topography and low points to catch palar (rainfall) water runoff. Its size and shape varies from relief to relief. It is, in a way, a reflection of the soil undulations and derives from the natural organic forms of the dunes.

The system works in the arid climate of Western India to reintroduce water infiltration, groundwater recharge, soil moisture and evaporation. It follows the pattern of the short rain season that lasts from July to September to offer water for agriculture during the year round dry season.

This new presence of water in the landscape attracts new types of vegetation on its edges, such as medicinal plants and low bushes, as well wild animals.

Architectural values

The first khadins from the 15th century were made of only local soil material to build the earthen embankment. Nowadays, we can notice the addition of a concrete wall with a sluice that functions as an outlet for excess water when the time for sowing comes.

Functionality values

The khadin is a seasonal system that collects Palar water to slow down its infiltration in a dry and hot climate. As the water infiltrates, it increases the groundwater levels and natural soil moisture, which will last for several months.

When the khadin is empty, its function becomes agricultural with the sowing of mustard, wheat and chickpeas. These plants take advantage of the soil moisture as a natural irrigation system.

Sustainability values

The main advantages of the Khadin is its ability to collect the meager average rainfall, which transforms the challenge of arid areas into a thriving environment. It relies on natural cycles and seasons, as well as topography, to offer villages a water source and an efficient agricultural system. Throughout the years, the khadin not only collects water but also accumulates sediments and moisture, which will develop into a rich and fertile soil composed of a humus layer, loam, and microbacterial activity.

Ethnographic and identity values

The khadin is deeply rooted in the village's activities and organization. Indeed, communities have distributed the land and organized themselves to maintain it. A family guards it from wild animals, another builds the fences, etc.

It is not only profitable from an economic standpoint but also from a social one too. Indeed, the harvested plants are sold, eaten and traded for pottery, marriage performances, woodwork and many more activities.

Lessons to learn

The key aspect of this traditional water system is the strategy behind it. Indeed, it has thrived in dry and hot conditions with low precipitation to develop working and advantageous agricultural practices. It shows a deep understanding of the topography, the soil type, the rain season pattern, and the water cycle.

We can learn from its ability to conserve humidity and soil moisture in arid conditions for future projects dealing with dry climates and droughts. It opens possibilities for global warming resilience, as many regions, worldwide, are experiencing such unpredictable events.

REFERENCES PROJECTS

These following projects are an inspiration to first develop adaptive agricultural and water system for circularity and autonomy. The RICA center has developed a greywater filtering system which pumps to water from the wetlands for irrigation and domestic use and filters it back to the source. Furthermore, the project by DELVA in the Netherlands works with woodland housing and afforestation. Even though this is a different climate, it showcases how intrinsically forests and housing can work together to create qualitative living conditions.

Lastly, both projects in Rwanda use locally sourced materials and traditional architectural techniques to offer climate-adaptive housing.

Rwandan Institute for Conservative
Agriculture (RICA)
Mass Design
2020- ...
Gashora, South Rwanda



Figure 61 Rica center (Baan, n.d.)

Figure 62 Roof collecting and filtering basin

Common Woods Amersfoort
DELVA
2023-...
Amersfoort, Netherlands

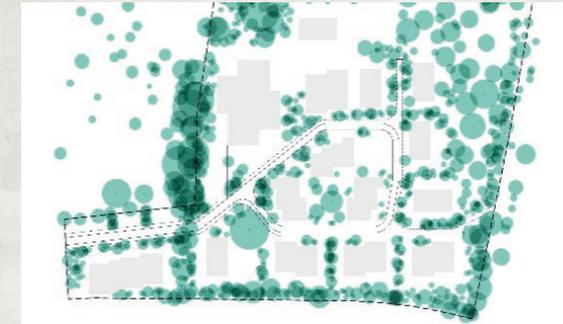


Figure 63 Living in the forest (DELVA, 2023)

Figure 64 Micro forest planting working alongside housing (DELVA, 2023)

Nyamata School hall
SAWA Architecture
2014
Nyamata, Rwanda



Figure 65 Traditional vernacular architecture (SAWA, 2014)

Figure 66 Natural materials and ventilation (SAWA, 2014)

Komera Leadership Center
BE_Design
2022
Komera, Rwanda

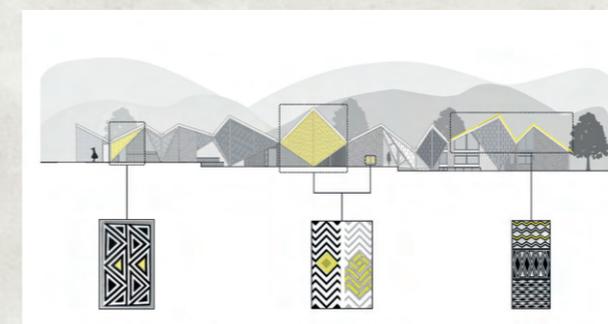


Figure 67 Local architecture and materials (Engels, n.d.)

Figure 68 Referencing local art in architecture (BE Design, 2022)

Savannah productive landscape

©Charlotte Delobbe

DESIGN ANALYSIS



Learning from the Case Study opens possibilities for working with dry seasons and aridification processes.

This fourth part of the graduation thesis delves into the inspiration and adaptation of the Khadin to the Rwandan landscape.

It is divided into four parts :

The learnings from the Traditional Water System analysis, the zoom-in onto the Northern sub-arid landscape of the Intara y'Iburasirazuba plateau, and finally, the design scale focusing on the town of Ryabega.

Lastly, references to projects from Rwanda and living with biodiversity will inspire this graduation project tremendously.

LEARNINGS FROM THE CASE STUDY

India and Rwanda are on opposite sides of the globe and have opposite landscape climates. Consequently, such a Traditional Water System adaptation needs to take several aspects into account.

Firstly, the soil characteristics. Indeed, the Khadin deals with sandy and rocky soil and quick infiltration, while the Savannah has loam and clay soil with a medium infiltration rate (9 to 13 mm/h).

Secondly, the case study has one rain season while Rwanda has two. Those seasons punctuate the yearly agriculture rhythm, meaning there are two sowing and harvesting seasons instead of one.

In tertiary, the landscape topography is immensely different, as the Lanela khadins are relying on one unique slope. Even though the plateau is less steep than the rest of the country, the topography is still very hilly and contains multiple complex slopes.

Lastly, the khadin system is independent from

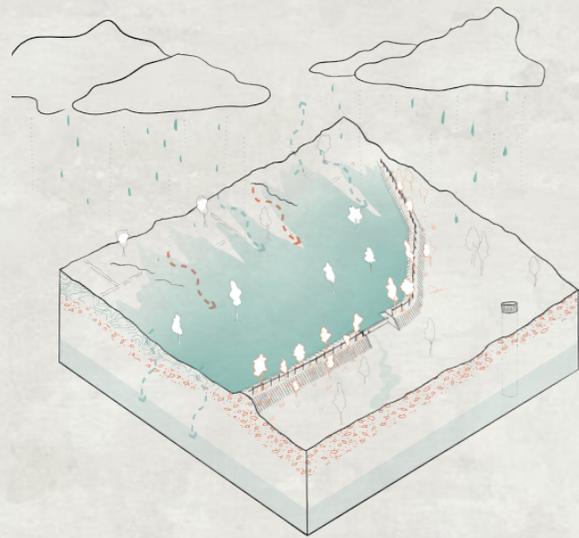


Figure 69 Khadin

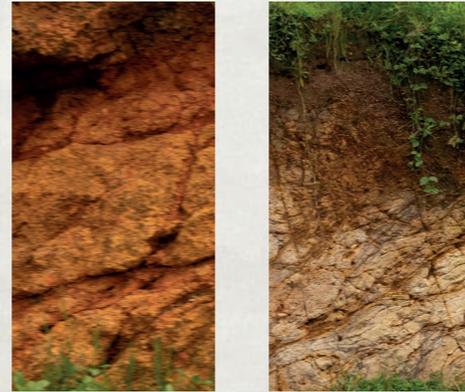


Figure 70 Savannah soil types

the local village. For circular and autonomous purposes, it is essential to connect such Khadin system to the design location's infrastructure. Especially as it is already equipped with roadside gutters and can potentially be connected to roof harvesting techniques.

Overall, the Khadin system is not enough on its own to be a potential tool for the design. There are multiple other water systems working with topography irrigation and contour lines for site-specific designs.

This thesis selects three different tools to adjust the case study to Rwandan conditions.

The **channel** is a shallow channel collecting, infiltrating and distributing rainwater. It usually goes alongside reeds and trees to filter the water and maintain a humid environment.

The second additional system, **the keyline design**, takes advantage of multiple depression points and contour lines to harvest and distribute water to the surroundings crops. It is a very interesting feature, as this replicates the Rwandan valley topography.

Lastly, the **tankaa** is a shallow Indian well that collects the water runoff and stores it underground. The inlet entrance contains a filter to keep sediments and waste out of the tank.

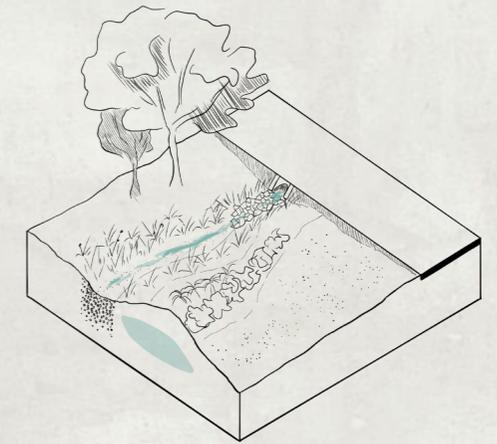


Figure 71 Channel

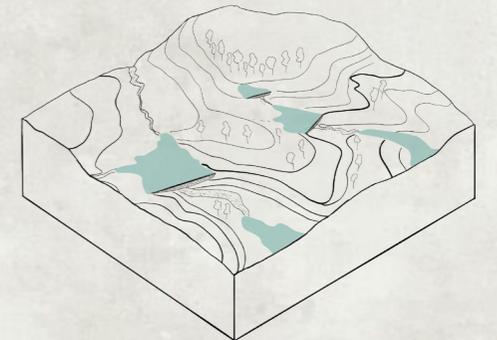


Figure 72 Keyline design

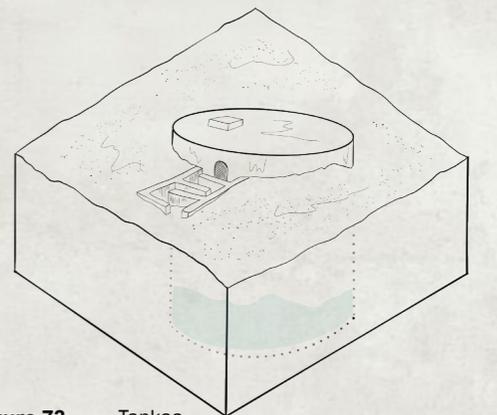


Figure 73 Tankaa

- *Soil fertility process
- *Soil moisture irrigation
- * Drought resilient
- *Site specific to topography and depression points
- *Excess water caught with the next khadin

SAVANNAH SCALE

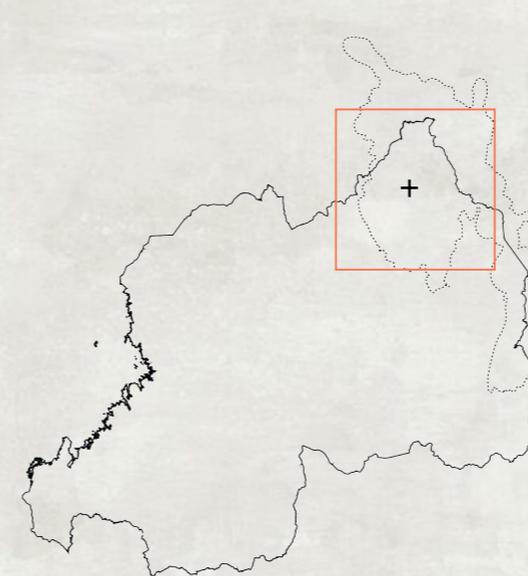


Figure 74 Savannah scale key map

— Analysis scale framework

The Savannah scale focuses on the northern part of the plateau to recreate the same conditions as the case study.

It consists of rainwater dependency, isolation from nearby water sources, and drier landscape conditions.

This area of Rwanda is crossed by three main rivers; Muvumba, Karanganza and Urwindi.

However, considering the hilly topography and the drying up of the river beds during the dry seasons, there is no accessible source of water for the surrounding towns and villages.

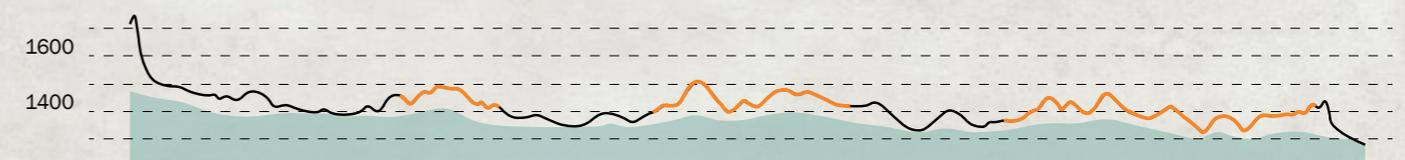


Figure 75 Savannah W-E section

— Difficult access to nearby water sources

Catchement potentials

Therefore, the catchement potential method relies on the same strategy developed in Rajasthan, India.

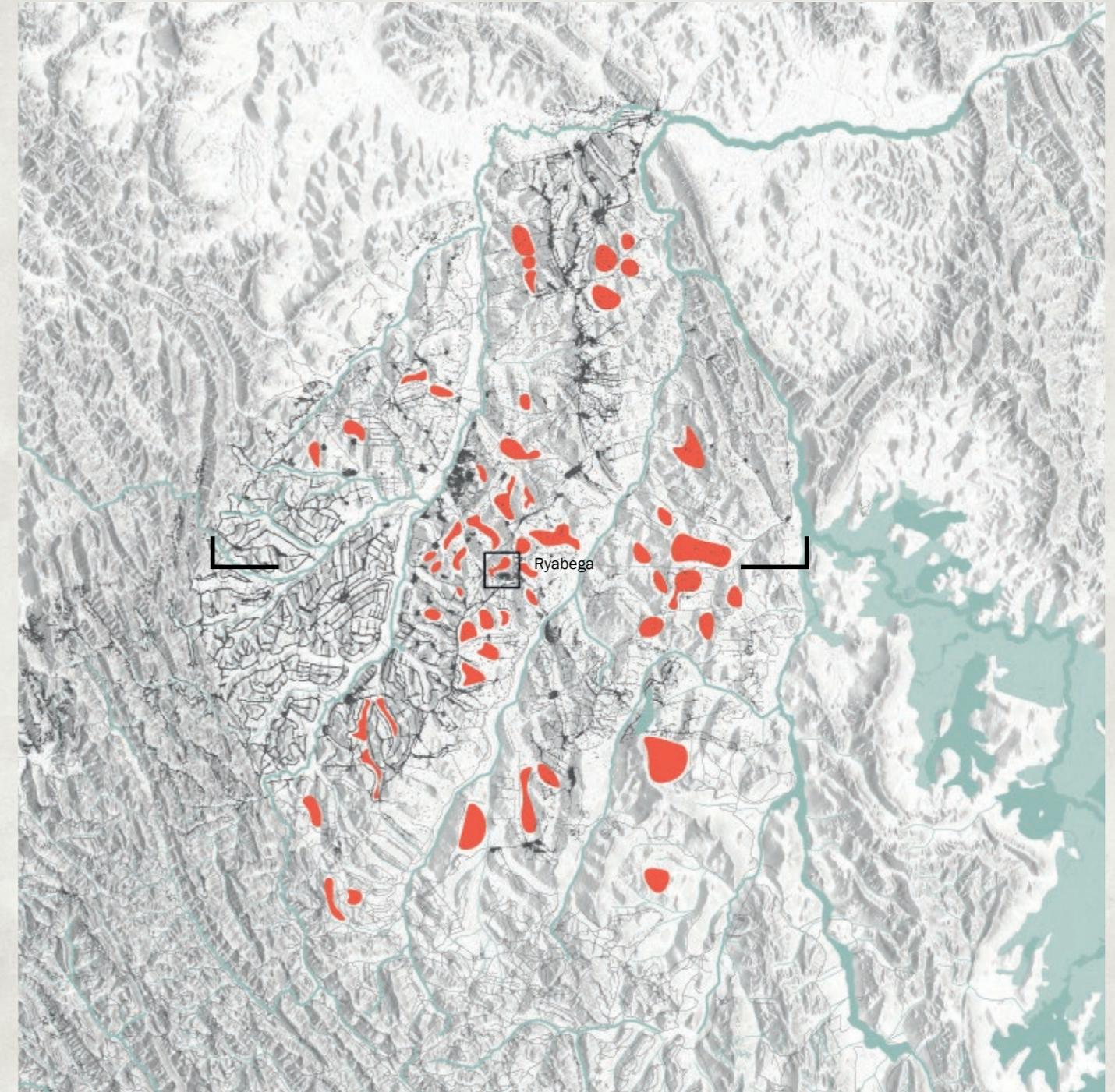
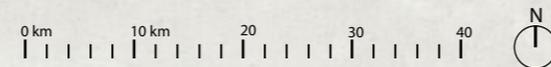
Topography is analysed to identify depression points and surrounding slopes that could host water harvesting embankments.

As indicated on the following map, there are multiple potentials located within this area. They are opportunities for surrounding towns to have access to their own water and irrigation systems. Together, they can form a large-scale system that can extend to other areas impacted by drought issues.

The following step of the thesis is to focus on one of these catchement potentials ; the town of Ryabega.

- Potential catchement area
- Buildings
- Roads
- Water

Figure 76 Savannah landscape



Catchement potentials

And governmental afforestation strategies

As stated previously, the Rwanda and Plateau scales are both highly impacted by deforestation because of wood fuel, urbanization and agriculture.

This area of the country has a poor forest cover density, ranging from very low (0-10%) to low (10-40%). It is the least forested in area and density of the country (Ministry of Environment, 2024 ; Interview notes with Philippe Kwitonda, 2024).

The woodland Savannah that characterized this area has severely reduced following the 1994 genocide and refugees taking root.

Government strategies are nowadays conscious and aware of the need to afforest and replant trees on a national scale. Regarding, the Savannah scale, the master plan focuses on agroforestry plantations. It intervenes in incorporating trees into the productive landscape alongside the crop and pasture edges. Implementing trees will

improve soil fertility and water quality, as well as provide shade and a steady source for biomass (Ministry of Natural Resources, 2014).

The species list incorporate *Acacia*, *Euphorbia*, *Grevillea*, *Ficus*, *Calliandra*, *Markhamia* and *Eucalyptus* (Interview notes with Philippe Kwitonda, 2024).

However, not all species are ideal, as, for instance, the *Eucalyptus* absorbs a high quantity of water, resulting in increased drought issues; the leaves do not deteriorate and seal the soil top layer (Kabir et al., 2023)

Therefore, this thesis can take into account the help of the government in replenishing the local biodiversity but must be aware of which species to implement as not all prone species are suited for such an environment and ecosystem.



Figure 77 Eucalyptus



Figure 78 Grevillea



Figure 79 Euphorbia

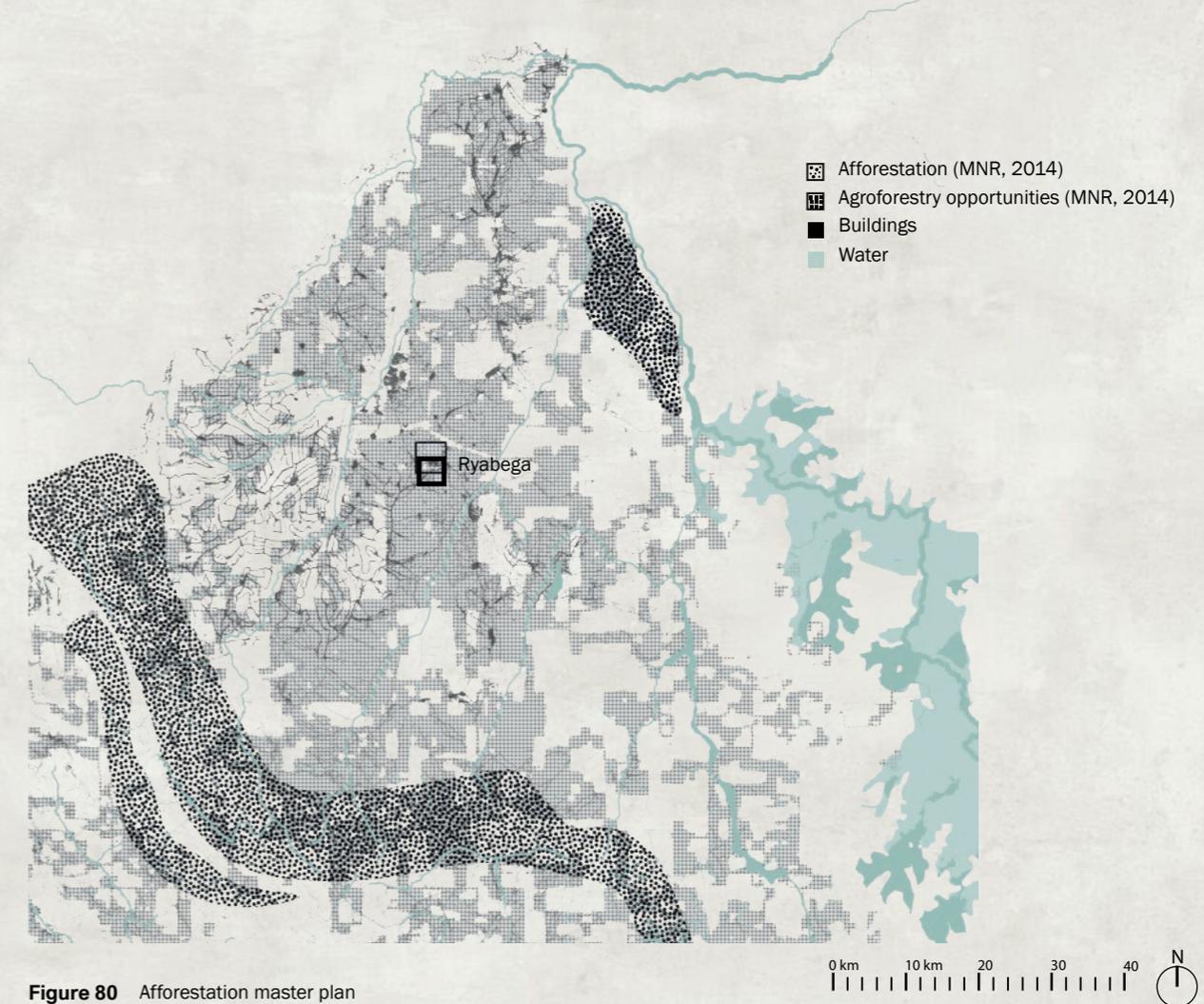


Figure 80 Afforestation master plan

RYABEGA SCALE



Figure 81 Ryabega scale key map

Now diving into the design location, this scale analyzes the town's history and dynamics that resulted in its creation.

Ryabega is one of the many towns located in the Savannah, and to design it, it is an opening to question the surroundings cities and villages as well.

This scale is rich in design opportunities to implement drought-tolerant water systems, as well as design spatial interventions that connect communities back to their landscape.

The analysis unfolds in two parts:

Firstly, the town history and urban expansion, and secondly, the daily activities held in the town center. Methods such as drawing time are used in order to understand the cultural differences in using and walking through space.

History

1. Ryabega urban creation

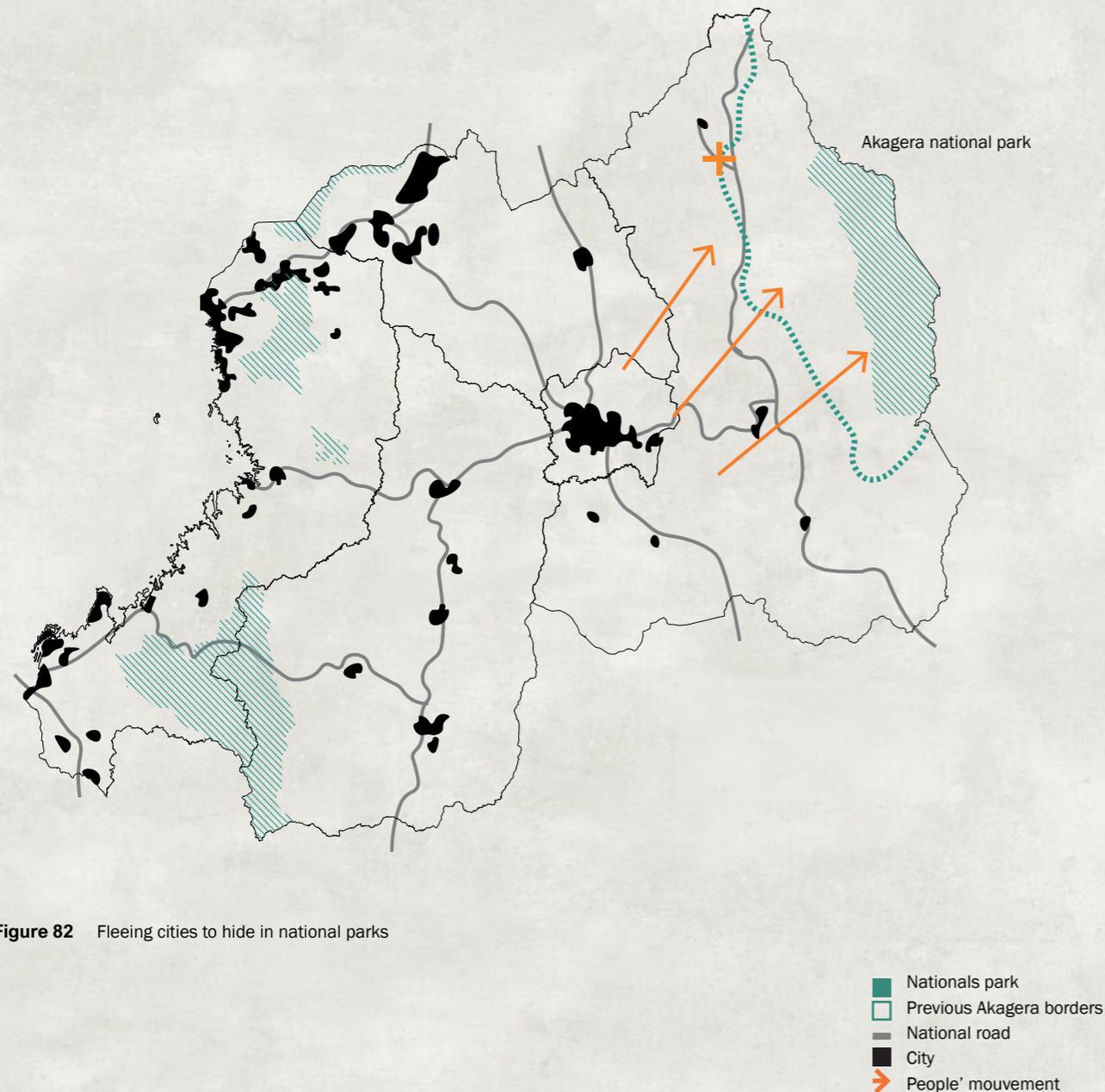


Figure 82 Fleeing cities to hide in national parks

As mentioned previously in the thesis, the Akagera National Park became a place of refuge during the 1994 Genocide.

This resulted in an urban boom in the eastern part of the country and led to the expansion of crops in most of the area.

Ryabega historical context is therefore deeply rooted in urban planning, resulting from needs and urgency.

The lay out revolves around vast grid and street patterns implemented over the landscape foundation rather than being site-specific.

Nevertheless, it is important to highlight that, as the town is new in the landscape, the community's relationship to the town's heritage is still building and therefore open to new adaptations and interventions.

History

2. Ryabega urban expansion

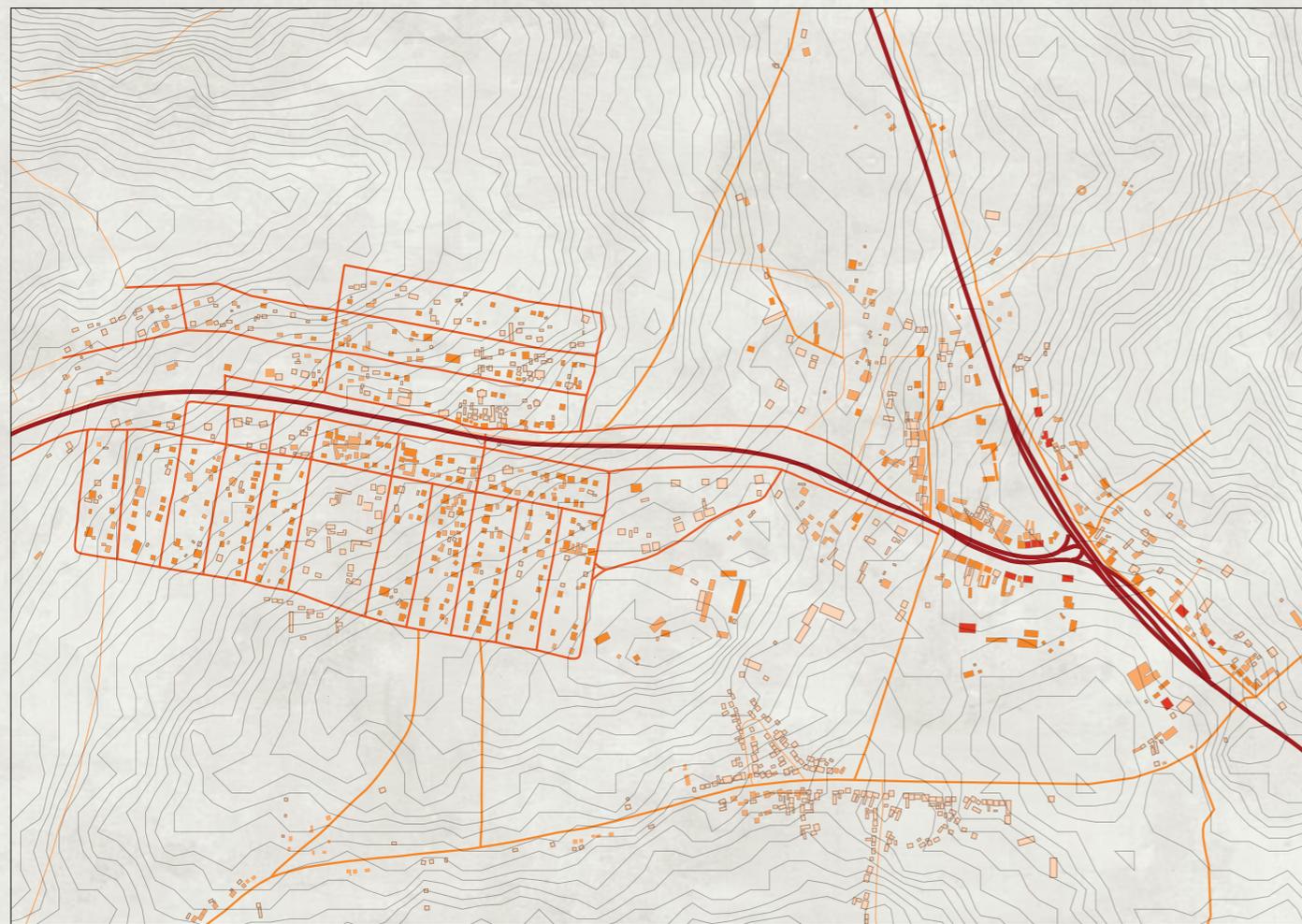
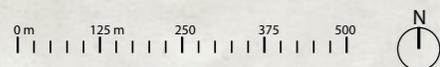


Figure 83 Urbanization development diagram

- Before 1984
- 1999
- Crops 1999-2004
- 2006
- 2011
- 2014 to now



The town consists of two typologies :

An original development alongside the main road

A street village and functional grid similar to a typical camp lay-out

Built before 1984, the main road has guided the town's location for efficiency reasons.

Therefore, the center first started to slowly develop around it.

However, the main shift happened in 1999, when the entire landscape surrounding Ryabega began to be cultivated for agriculture.

Western streets are drafted into an functional grid system, projected on the without site-specific planning, to host multiple houses and welcome the population new to the area.

These streets are designed on top of the landscape contour lines. The urban intention is related to this high need in housing and can be called «reacting planning urbanism».

This is an important opportunity to work on a design responding to rapid urbanization while still being cohesive and connecting the communities to the unique valley landscape.

Lastly, the major urban boom happened in 2006, and the town hasn't stopped intensifying since then.

History

3. Ryabega urban intensification



Figure 84 1985 (Google Earth)

Before the booming urbanization and deforestation processes that took place in Ryabega, we can notice how the landscape remained uninhabited and vegetated.

The road was the only sign of human presence.



Figure 85 June 2006, dry season (Google Earth)

While it slowly developed between, 1999 and 2004, the town's population growth explodes in 2006.

All surrounding lands are exploited by intensive agriculture.



Figure 86 October 2017, rain season (Google Earth)



Figure 87 August 2020, dry season (Google Earth)

4. Urban consequences on landscape biodiversity

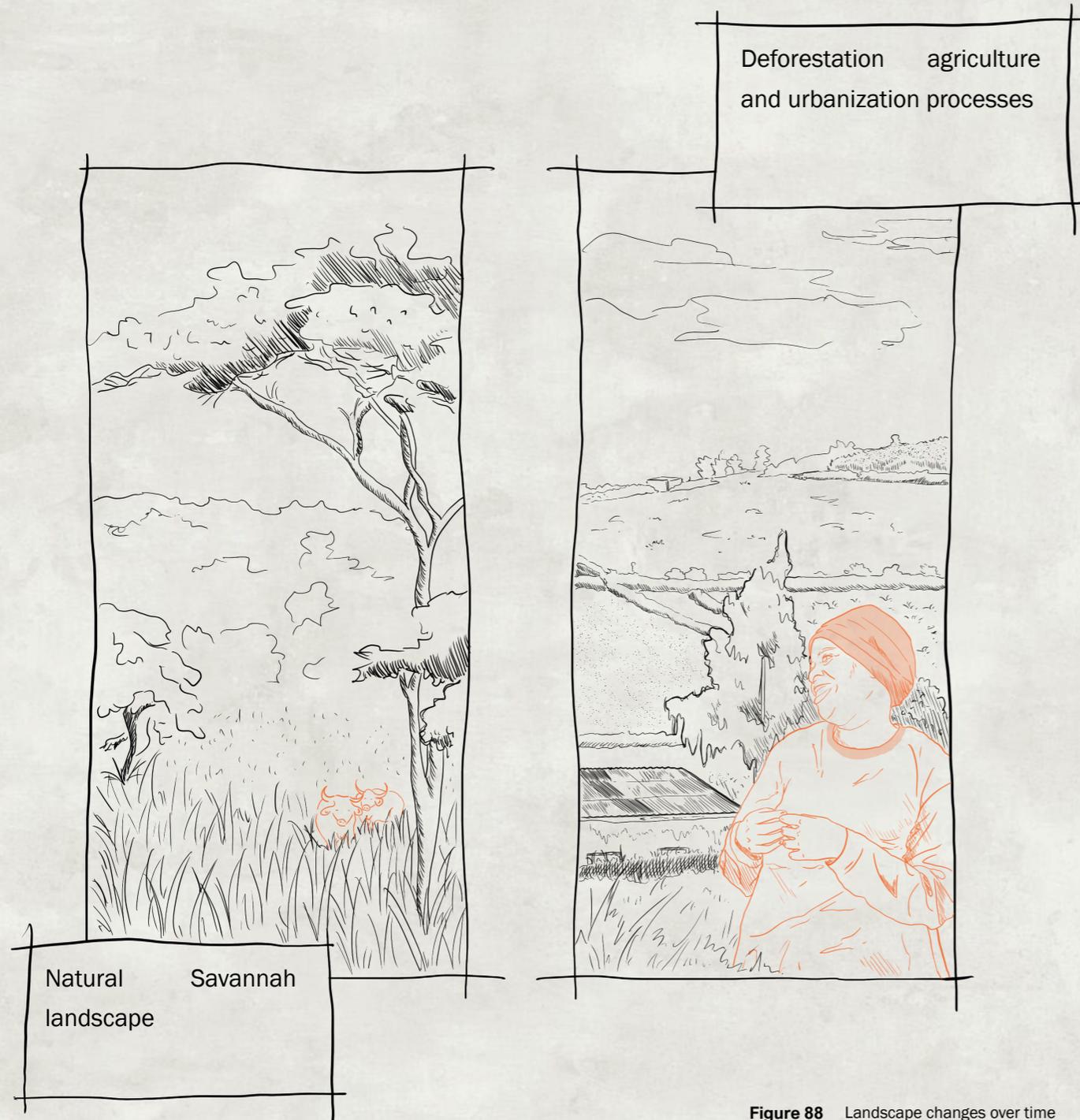


Figure 88 Landscape changes over time

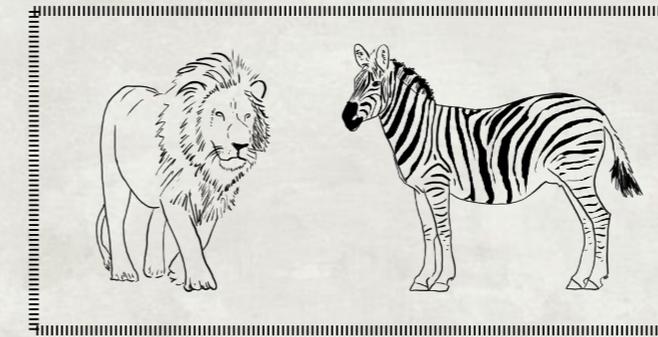


Figure 89 Enclosed mammals in the Akagera park

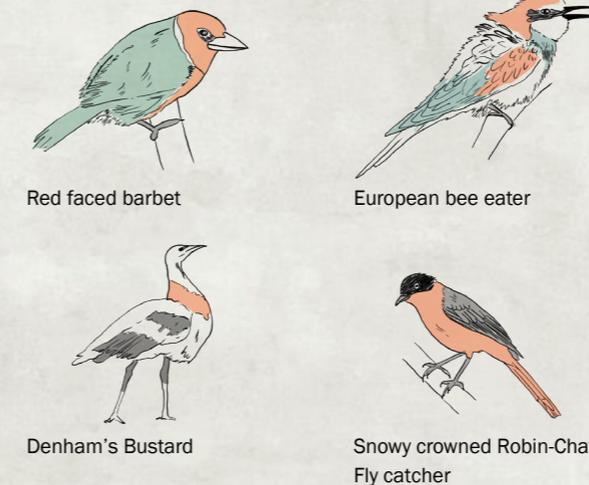


Figure 90 Endangered species

The implementation of Ryabega on the landscape induces major changes in biodiversity and habitats loss.

The territory remains separated into two opposite landscape ; the productive landscape and the conserved landscape of the Akagera National park.

Conflicts between humans and nature are amplified in this area, as most of it has been deforested and big mammals relocated.

This resulted in many endangered bird species as they lost their natural and reproductive habitats (Vande weghe, JP & Vande weghe, GR, 2011).

A day in Ryabega

Town

Eroded road sides



3



2



1

Commercial towncenter (Duhorannenayo, 2024)



10



4



5

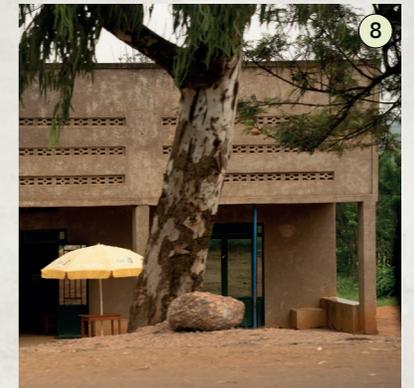
Vast built housing



6

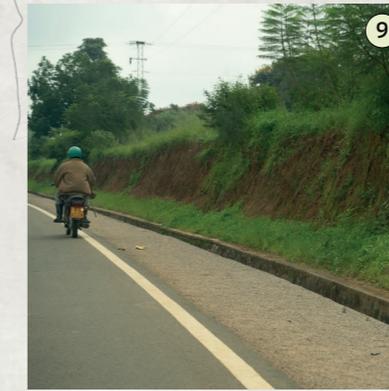


7



8

Narrow pedestrian lane



9



Figure 91 Town's promenade

Informal spaces

Ryabega public spaces have been man-made throughout daily flows and paths. This map draws them as they are visible from satellite images.

Created by people steps, these barren areas are informal spaces located nearby important town activities such as the commercial area, the bus station and marketplace. They are mostly reaction spaces rather than designated, designed spaces where people gather.



Figure 92 Commerce typology

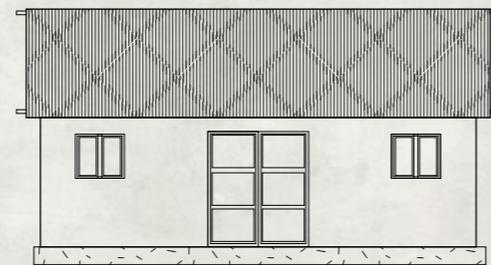


Figure 93 Residence typologies and other variations

- Main commercial area ①
- Bus station and stop ②
- Market place ? ③
- Small commercial area ④
- Football field ⑤
- Catholic church and angelic church ⑥
- School ⑦

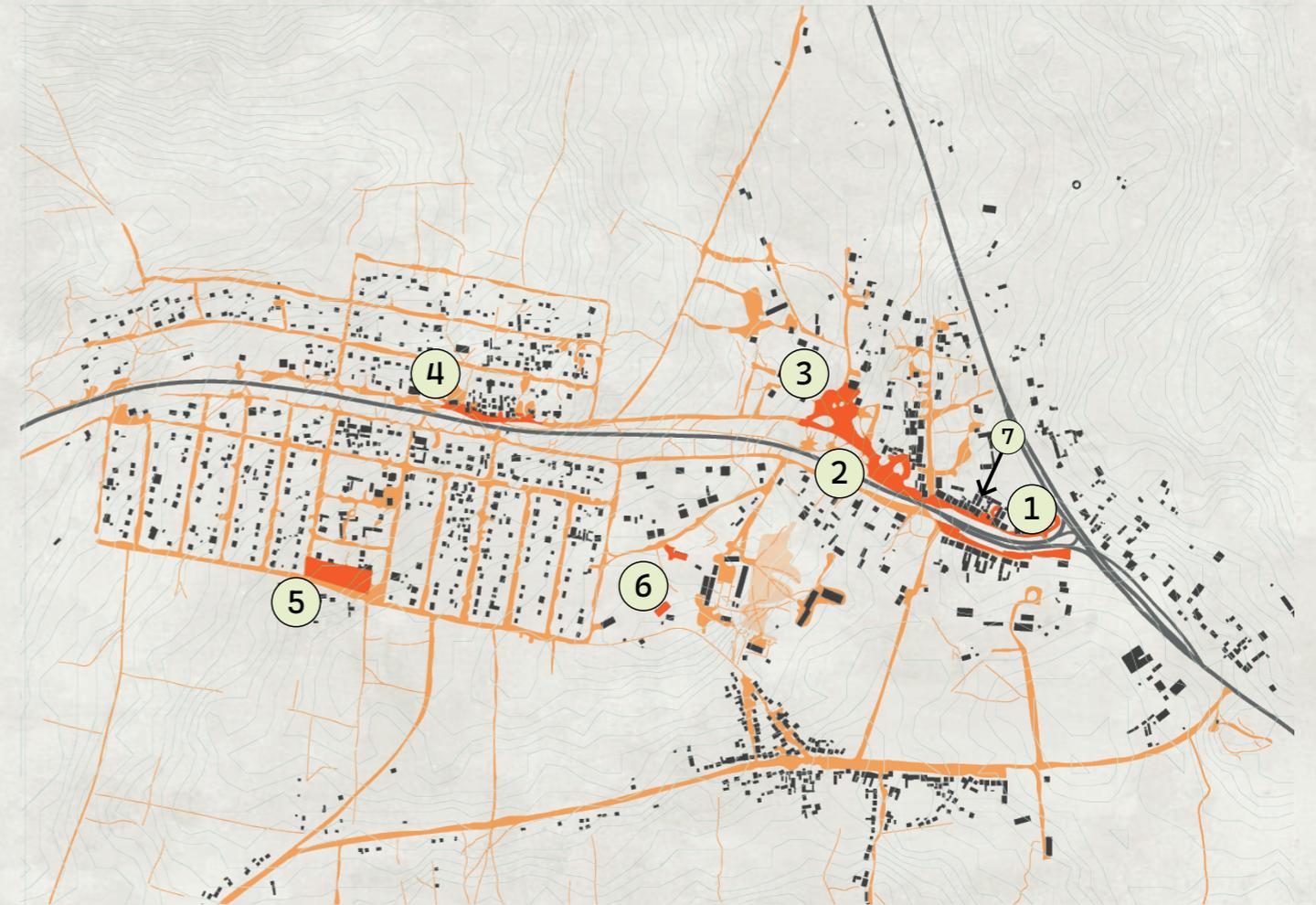
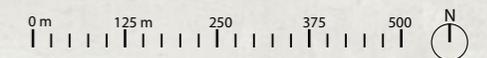


Figure 94 Social informal spaces

- Built road
- Buildings
- Self-created social spaces
- Main gathering spaces



Informal spaces

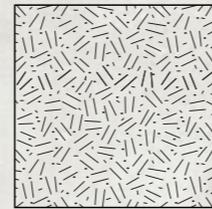
As well as the informal public spaces, Ryabega town's buildings and residences are self-built by the communities and households.

They are made of locally sourced materials, such as earth and wood.

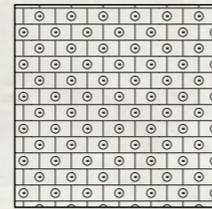
Earthen walls are also well known in arid climates, as they are an efficient material to regulate outside and inside temperatures.

This aspect of Rwandan rural areas is very interesting for future endeavors, as it means communities already have the knowledge and capacities to build their own water system and public spaces.

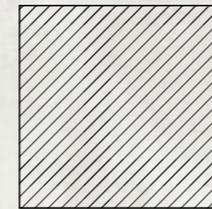
Figure 95 Materiality



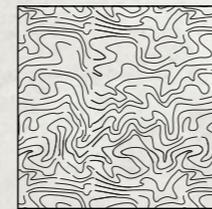
Rammed earth



Earth bricks



Metal sheet



Wood



Figure 96 People helping each other to build residences

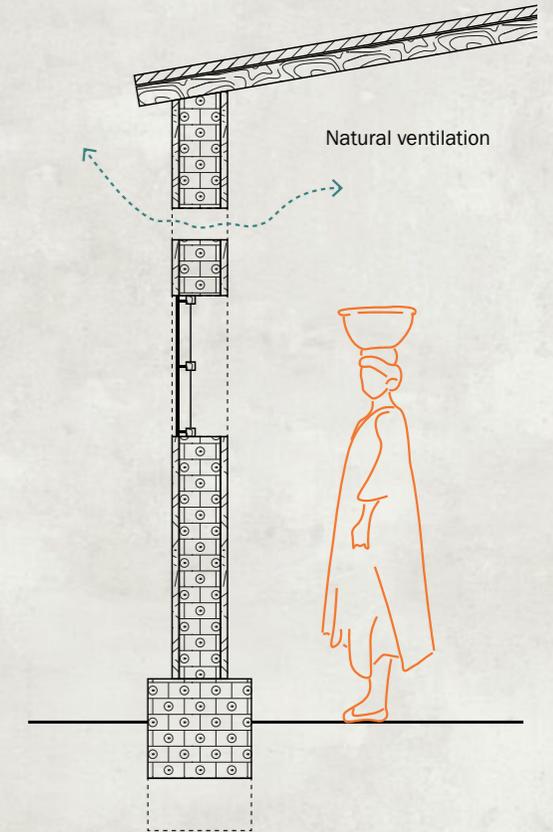


Figure 97 Residence principle section

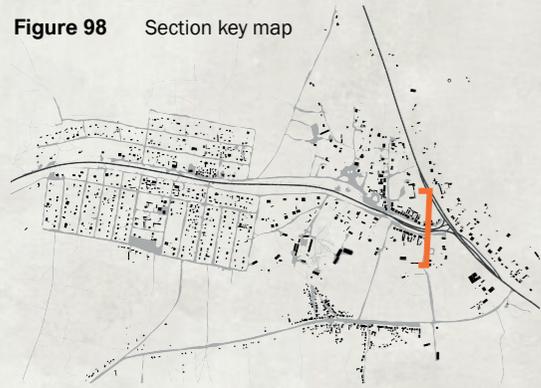
Informal spaces and activities

Upon closer look at how people experience these informal spaces, this day cycle section introduces the usage of space at different the temporal rhythms.

It focuses on the commercial area as it is highly animated and used by the locals.

This first section highlights the early hour at which people start their day and are on their way to tend to the agricultural crops. During this phase, the predominant function of the space revolves around facilitating transportation needs.

Figure 98 Section key map



The following section highlights the people occupation in the morning.

Farmers tend to their crops, while the town center is poorly animated.

Landscape and town endeavors are separate.

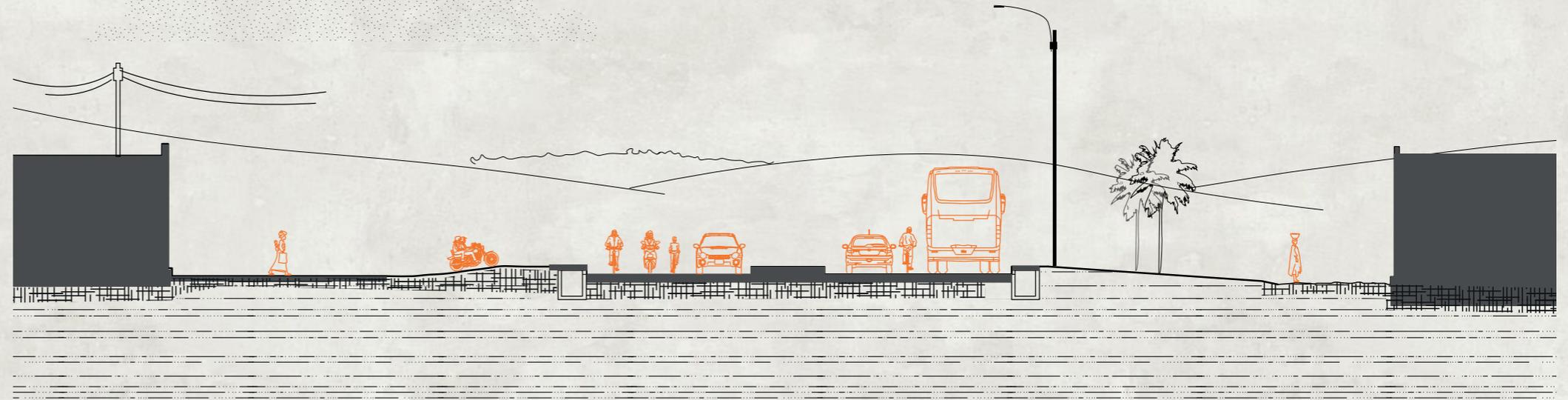


Figure 99 6:30 am

Figure 100 8:00 am



Informal spaces and activities

At midday, there is a tremendous concentration of flows and activities.

Farmers are traveling back from their fields carrying the harvest on their bikes, while other farmers are leading the cows and cattle to the dedicated grazing fields and pastures. In Rwanda, it is not allowed to let the animals graze on the roadsides.

Furthermore, it is during that time of the day that the poorly designed area is highlighted. Indeed, the road blocks and is in the way of the activities happening on both sides. Many users are utilizing the road as part of the social space as well.

Many people cross the road and are in conflict with the high traffic as so many different people are present. Bikes, pedestrians, buses, cars and animals are all making use of it.

Lastly, as the sun is high in the sky and temperatures are rising, we can notice how there is no biodiversity or public features offering shade and humidity. The existing palm trees serve as ornamentation.

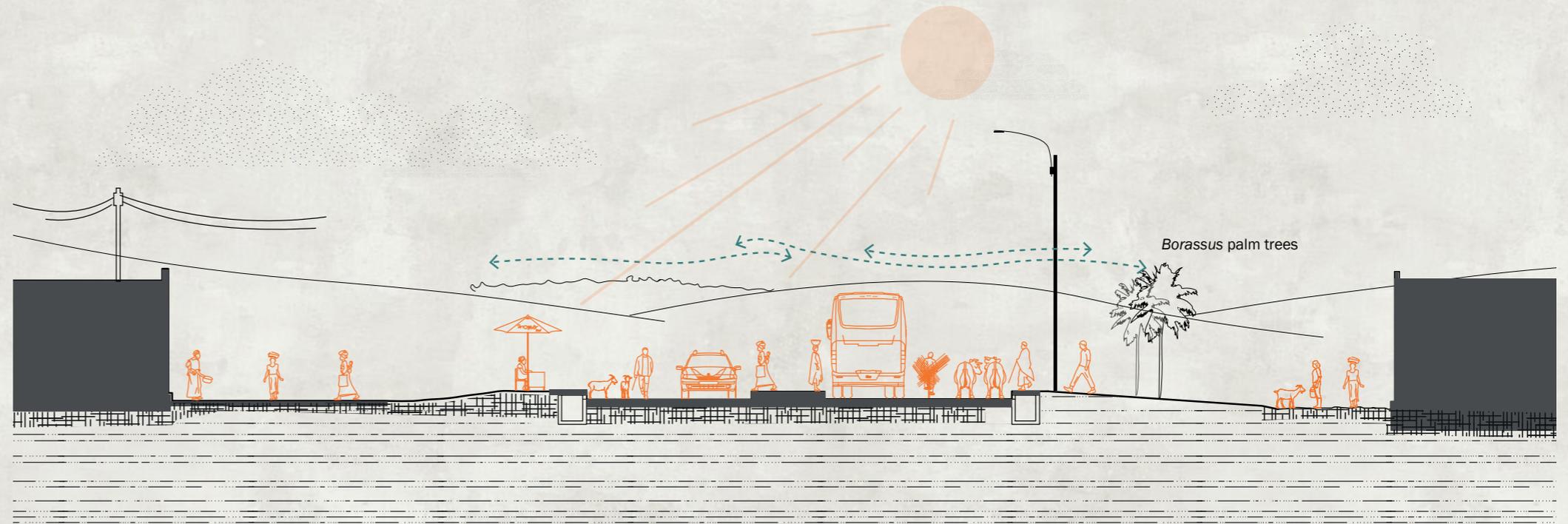


Figure 101 12:00 am

Informal spaces and activities

This fourth section showcases the end of the school day for the children.

They are walking on the road alongside buses and cars.

This is another aspect of how informal spaces are not currently offering areas suited to local activities.



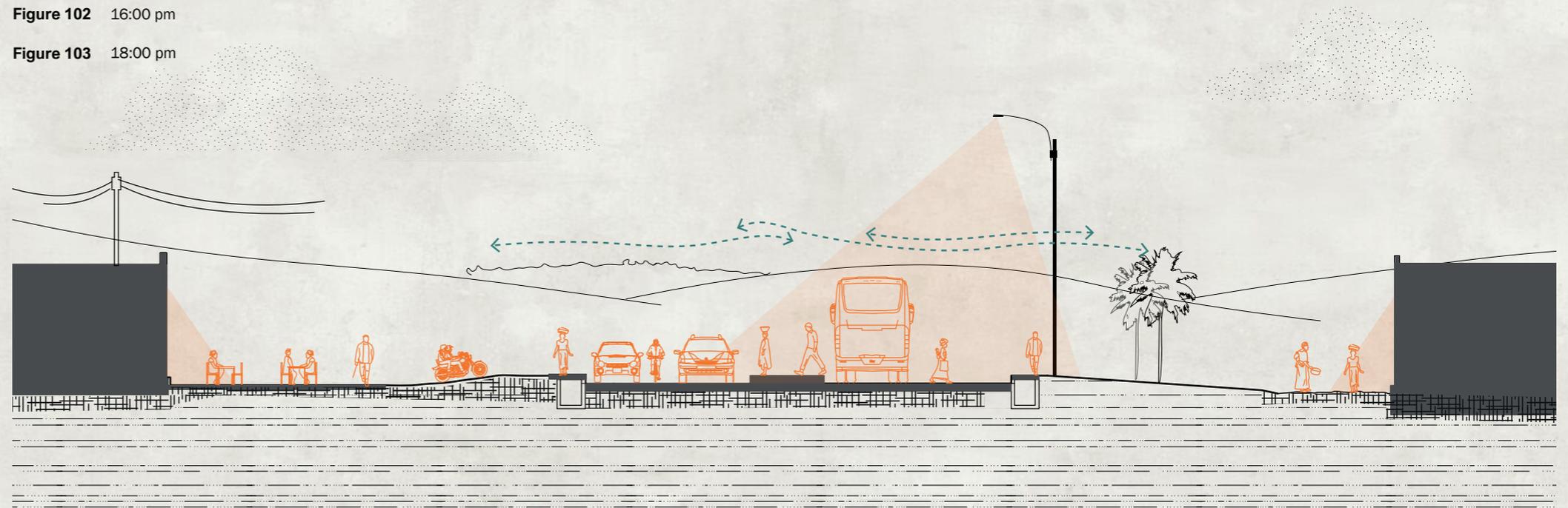
Figure 102 16:00 pm

Figure 103 18:00 pm

Lastly, similar to the activities at midday, the section illustrates how the road is part of the social space.

At 6 p.m., the day is already over and dark. During this time, many people are circulating in the town center. Others are laying out tables and chairs near the cafés to have a beer with their friends.

Temperatures are much more comfortable to be outside.



Design research

CONCLUSION

To conclude, the urban landscape of Ryabega town is characterized by emergency, pragmatic planning strategies, and extensive deforestation endeavors aimed at accommodating welcoming new households.

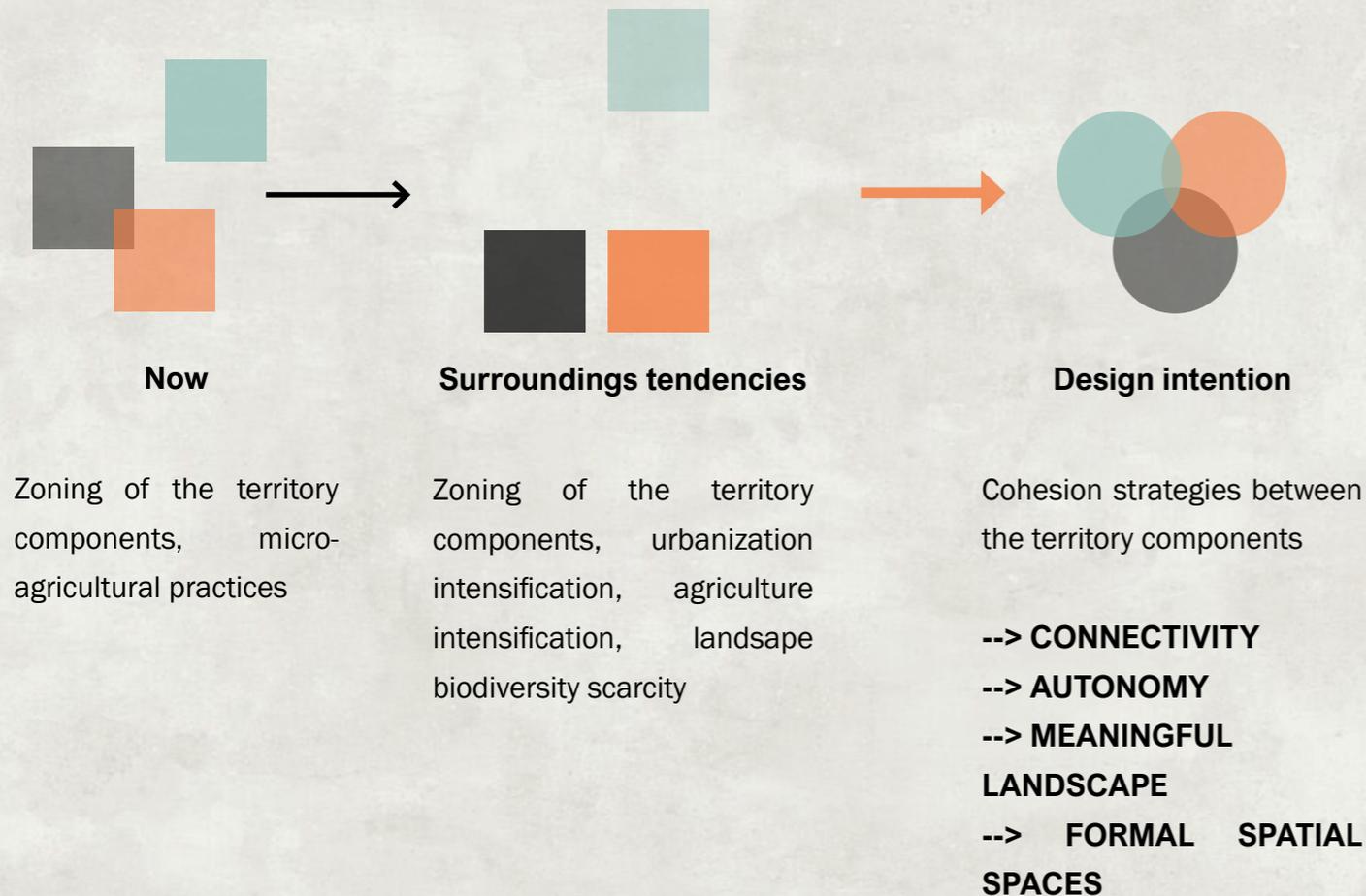
Self-built and informal spaces often proves incongruent with urban activities and the utilization of public spaces.

Nevertheless, there exists many opportunities to introduce meticulously designed spatial interventions that afford inhabitants a qualitatively enriching environment to circulate, gather, and rest.

In light of escalating climatic temperatures, the utilization of the town center becomes markedly challenging during daylight hours due to sun exposure. By leveraging local sub-arid biodiversity, the design hold the promise

of mitigating the town's vulnerability to global warming. Additionally, such interventions would also ameliorate people's comfort levels during daytime hours, thus fostering a more sustainable urban ecosystem.

Landscape intentions



■ Landscape
■ Agriculture
■ Urbanization

Hence, through the implementation of these interventions, the underlying objective of this thesis design resides in the harmonization of agriculture, landscape, and urbanization in order thereby composing a new connected and meaningful landscape layer.

It would intrinsically engage with both urban and landscape fabrics, fostering the reintegration of communities within their territory.



DESIGN INTERVENTIONS

This last part, before the design itself, delves into the different strategies that can be implemented at the design location. It serves as a catalog of opportunities one town can apply in order to increase climate adaptability and resilience, as well as offer formal design spaces to suit the town's activities.

FOREWORD



Figure 104 Catchement scale



Figure 105 Town scale

This «*Research through design*» part involves analysis and the elaboration of direct possible interventions. They will both be addressed simultaneously to draft efficient and cohesive design features.

The following pages will dive into topography, land use and spatial analysis to address the three components of the Rwandan landscape.

This analysis will address two scales: one focusing on the catchment topography and how the water flows within that area.

The second scale dives into the town scale to elaborate on three types of land use within Ryabega : green structures, agriculture and housing. Finally, spatial spaces will be analyzed to highlight design interventions and zoom-in potentials.

STRATEGIES

The following strategies and interventions are developed in order to, together, create a dry and rain season mitigation system.

Based on nature-based solutions, bioclimatic architecture and resilient landscape theories, they address four main aspects:

1. Water conservation
2. Soil moisture
3. Microclimate humidity
4. Drinking water access

By implementing tree covers, vegetation and specific design features, these interventions aim to create qualitative social spaces, social interaction, water circularity, town economic autonomy, resilient housing and drought temperature mitigation.

As the analysis uncovered, communities already have the knowledge to use local materials such as wood and earth to build their own households. All these interventions take into account feasibility and materiality so that they are easily set up and low cost.

Finally, regarding the planting of trees, the thesis counts on the government's already existing master plan to help facilitate communities in restructuring their rural and urban green structures.

Valley presentation

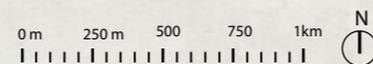
The topography of Ryabega is very hilly and engraved by centuries of rain run off.

Located on a higher point, the town overlooks the valley and offers beautiful perspectives on the surrounding hills.

Regarding this thesis research question, the complex topography is an advantage to multiple and maximize the number of rain-harvesting water systems.



Figure 106 Valley topography



Valley presentation



Figure 107 Viewpoint on the catchment area potential - end of the rain season



Figure 108 Catchment area potential

The catchment potential of Ryabega is located below the town's households.

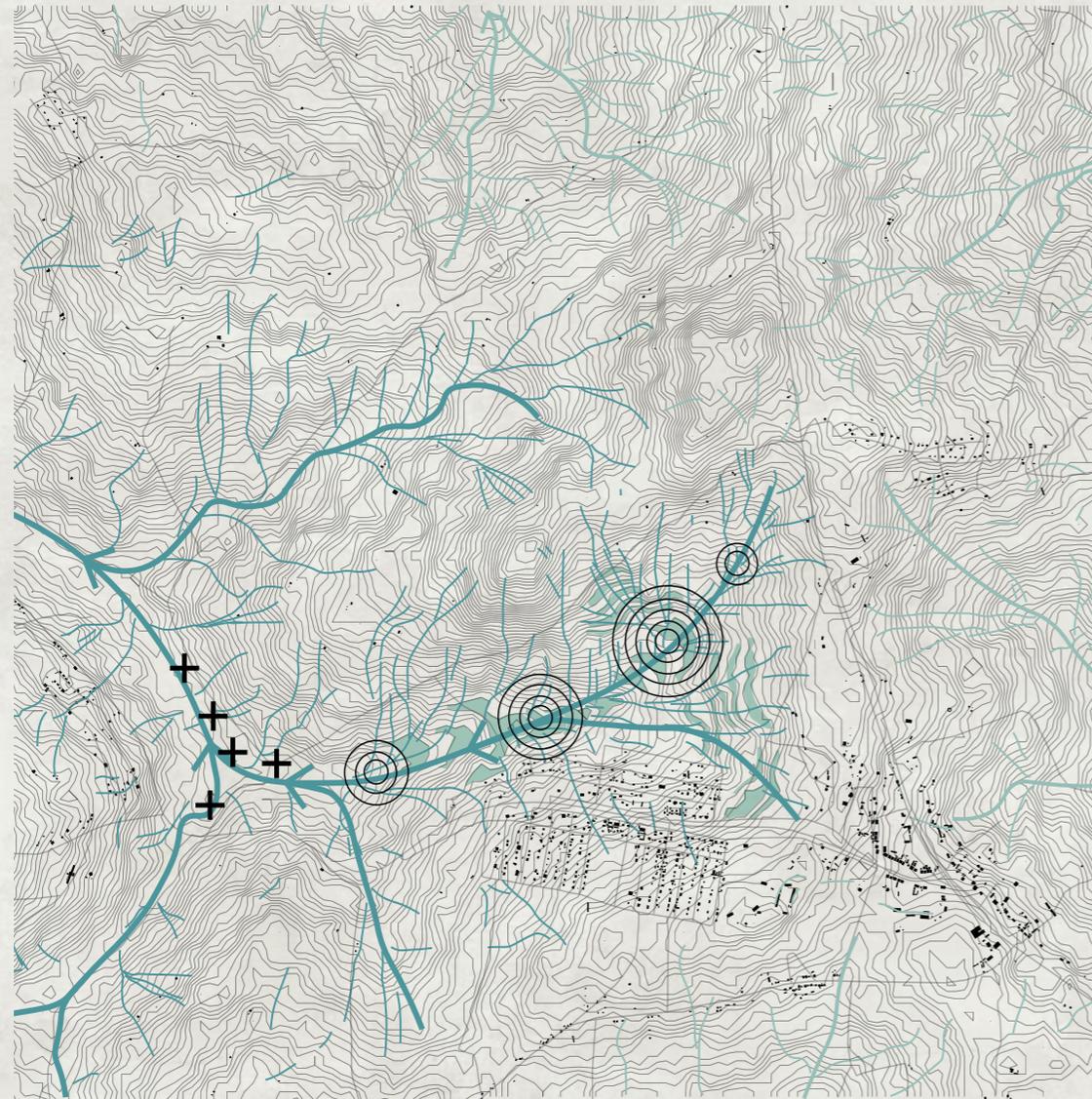
Merging slopes are creating a linear hollow depression point which guides to water down until it reaches the Muvumba River, a few kilometers away.

This first photo was taken on site right after the rain season in January. The landscape looks lush and humid during this time of the year.

At the foreground of the picture is actually one of the last natural areas of the site. Many trees and shrubs grow freely.

1. Topography analysis

Micro-topography and rain paths



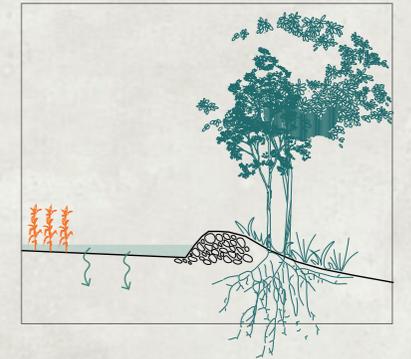
- Contour lines 2m
- Road
- Runoff paths for chosen catchment
- Other runoff paths
- ⊙ Concentration
- Buildings
- + Natural humid zone

The complex topography is gathering a lot of water in some punctual areas. The basins inspired by the traditional Khadin water system can be located in these high-concentration locations to harvest as much water as possible.

Furthermore, reservoirs basins can be located on the water runoff paths for two reasons: first, to collect and slow down the water runoff during intense precipitations, and second, to be able to distribute the irrigation water via the topography lines. Alongside a narrow shape, the implementation of trees and shrubs keeps the microclimate humid to reduce evaporation.

Lastly, connected to the reservoirs, the channel takes advantage of the topography to irrigate the crops above the agricultural basins and around the village.

⊙
Agricultural basins catching in the depression



—
Reservoirs along the rainpath



Channel : topography irrigation

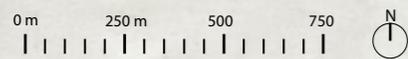


Figure 109 Rain runoff paths simulation

2. Land use analysis

a. Fragmented green structure

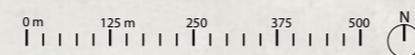


Figure 110 Fragmented green and strategy structure



Figure 111 Main road section

- Contour lines 2m
- Road
- Buildings
- ▨ Crops
- ▨ Grazing
- Vegetation
- + Commercial area
- 150m
- ▨ New green patch
- ▨ New green hedge



The current green structures have been fragmented by agriculture and urbanization. This first method relies on improving current tree lines along the main road. Tree cover and vegetation layers create shade for people to enjoy and increase soil quality and moisture.

Furthermore, agroforestry and hedge improvement can help facilitate soil fertility and natural moisture. Connecting the crops' vegetation to the infrastructure lines can be beneficial in terms of continuous foliage and increased habitats for the birds.

Lastly, increasing the presence of vegetation inside the private lands can increase the humidity levels around households and therefore ameliorate their living conditions.



① Tree line improvement along the main road



② Hedge line improvement along the crops



③ Residential green improvement in the plots

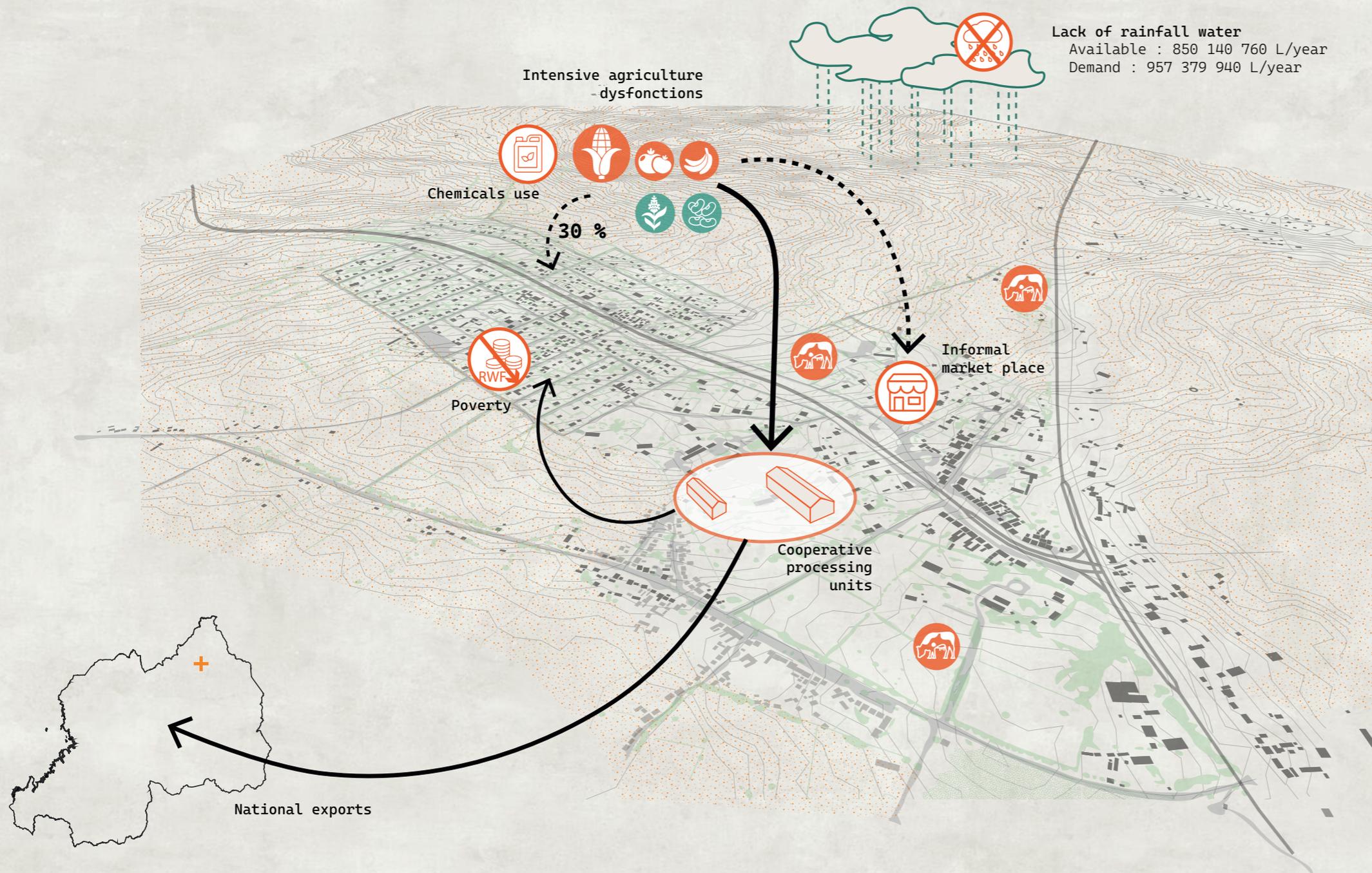


Figure 112 Current system challenges and problematics

2. Land use analysis

b. Intensive agriculture system

The current agricultural system raises numerous challenges and vulnerabilities.

First, the agriculture sector is an unstable source of income for households, and even more nowadays because of global warming vulnerability.

Indeed, the current rain-fed crops are relying on the long and short rain seasons for irrigation. This system raises concerns as irregular rainfall patterns and droughts increase.

Current water demand reaches 7883 m³/ha/year (Rwanda Agriculture and Animal Resources Development Board, 2020) which can be converted to 957 379 940 L/year for the design location area. Current rainfall of **750 mm** means there are 910 865 100 L/year of rainwater (a 5% difference), which already highlights the need for increased adaptability to a lack of rainwater.

This high water demand can be explained by the crop types. Indeed, maize and bananas have the highest water demand, along other crops (FAO, 2024b).

Maize: 500 - 800 mm

Banana: 1200 mm

Sorghum: 450 - 650 mm

Potato: 500 - 700 mm

Soybean: 450 - 700 mm

Bean: 300 - 500 mm

Tomato: 400 - 600 mm

Bell pepper: 600 - 900 mm

Cabbage: 380 - 500 mm

The range of crop types is **300 - 1200 mm** in water demand, a high number for this area.

Agriculture being main source of revenue in rural Rwanda, Crop intensification programs are developed to produce and earn more. However, intensive agriculture practices, chemicals are heavily used on soil structures, leading to soil degradation and loss of fertility.

Furthermore, as the population growth rate keeps rising, there is just not enough land for everyone. As crops are usually kept within families, they are divided between siblings, thus reducing their own owned crop surface throughout generations.

The cooperative system has been implemented to merge land cultivation in order to extensively plant the same crops and increase crop production. In the district, more 70% farmers are now part of a cooperative. Harvest is now sent to its infrastructure, where it is processed and exported across the country.

30% of crop harvests are still used for food subsistence or sold to local markets by the farmers themselves (Interview notes from John Kayumba ; from Geoffrey & Delphine, 2024)

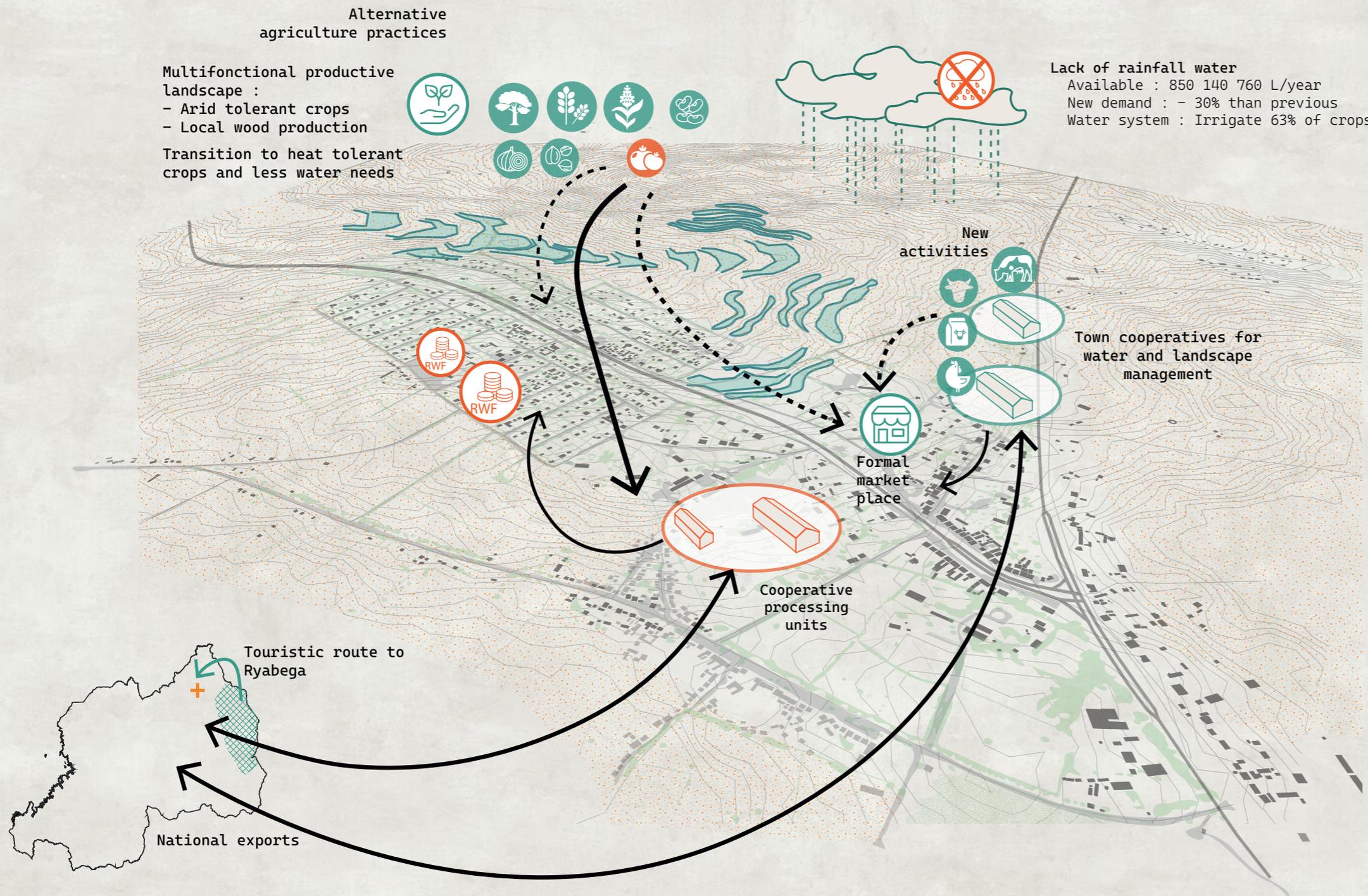


Figure 113a Adapted economic system

2. Land use analysis

b. Revised agriculture system

Even though the thesis cannot resolve all challenges regarding local economic issues, it still develops options and diversifies activities for communities, according to the rural transformation theory.

First, the diversification of income endeavors such as productive acacia forest for local construction and materials use, dairy farming, integrated poultry farming, integrated beef farms and so on. Such activities are already in the investment scope of the government and therefore can count on existing visions from the Rwanda Development Board.

Thirdly, the extension of the eco-touristic route throughout the Akagera National Park. Indeed, Ryabega is located 20 minutes away from the exit point of safaris, which attract many Rwandan and international tourists all year round. There is

potential to guide these travelers to stop by the design location for bird watching and boost the local economy of the town's cafés.

Regarding the agricultural system, alternative methods such as agroforestry, planned biodiversity interference, permaculture, soil conservation, crop rotation, manure and crop residue fertilization techniques, would help decrease the pressure on soil structures.

Moreover, adapted and new crop types are introduced to lower the water demand such as sorghum, wheat, chickpeas, beans, potatoes, tomatoes, cabbage, onions and groundnut. The current range of 300 - 1200 mm would decrease to **250 - 700 mm**.

The new water system, taking advantage of the topography and rain path patterns, would work as a mitigation system, so farmers do not solely rely on the rain seasons. It can enable water autonomy throughout dry spells for agriculture purposes, drinking water and domestic use.

The last chapter of this thesis will elaborate on such system.

Lastly, land ownership has been looked into as it

brings two main problems:

First, most lands are inherited and, throughout generations, divided between children. This results in a decrease in plots' hectares and, thus, the income the farmer will earn from working their land.

Second, following the genocide, people that fled east and settled there didn't register themselves due to a lack of legal basis. The Land Tenure Regularisation (LTR) programme was then drafted in the early 2000s. By 2012, in rural areas, there was still distrust from the public towards the government to handle titles deeds, taxes, etc (Centre for public impact, 2017). Consequently, it is not for certain that all the lands are officially owned by the farmers.

Therefore, the cooperatives' system can offer an overall management of the crops, crops rotation, productive forest and new activities.

Lands can be bought from the government and farmers and rented in order to implement a systemic organization. Through the cooperatives, there can be collaborations with the government's master plans and investment visions, with outside investors that are already interested in this region, and lastly, with NGO's to attract more funding and experts.

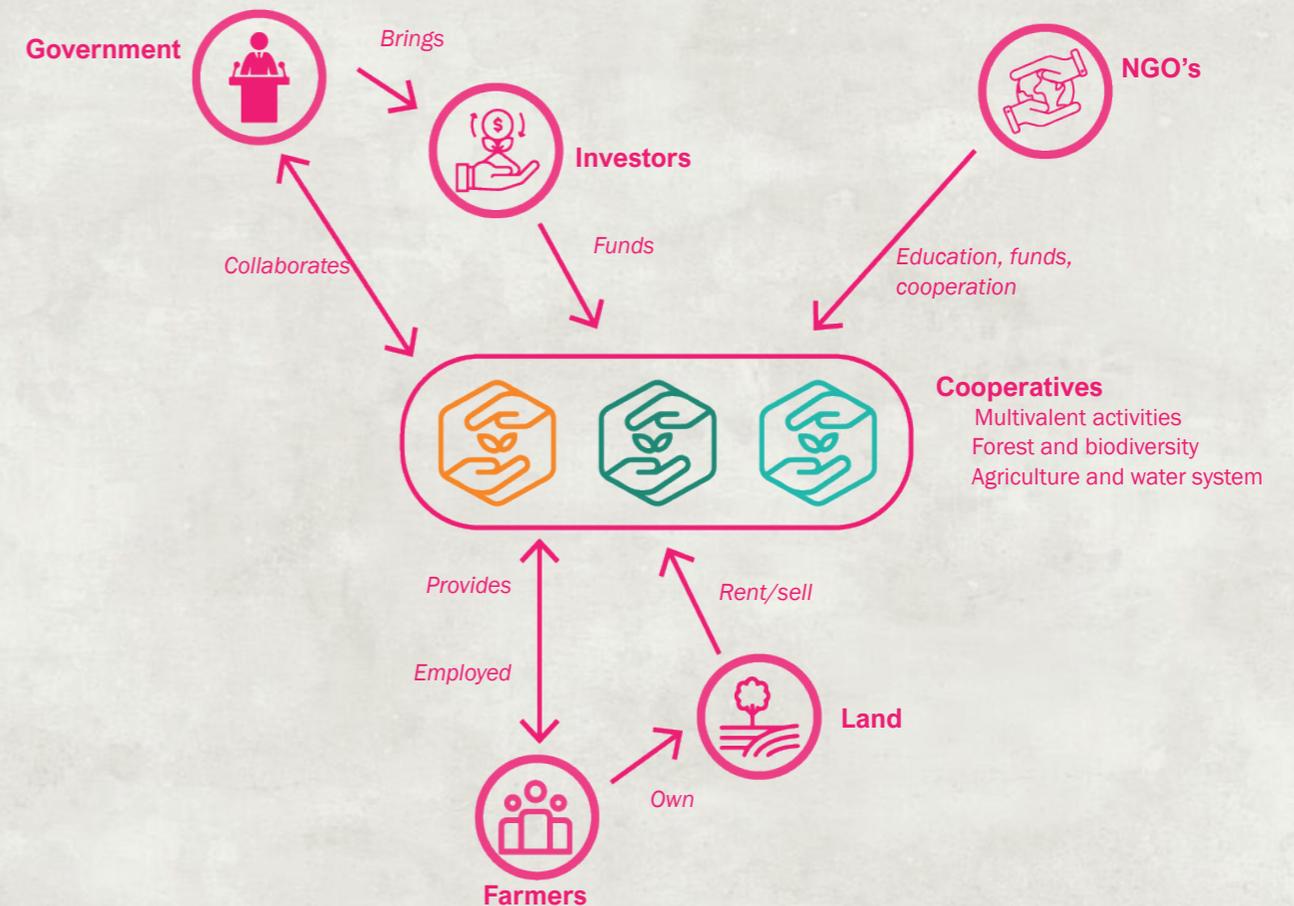
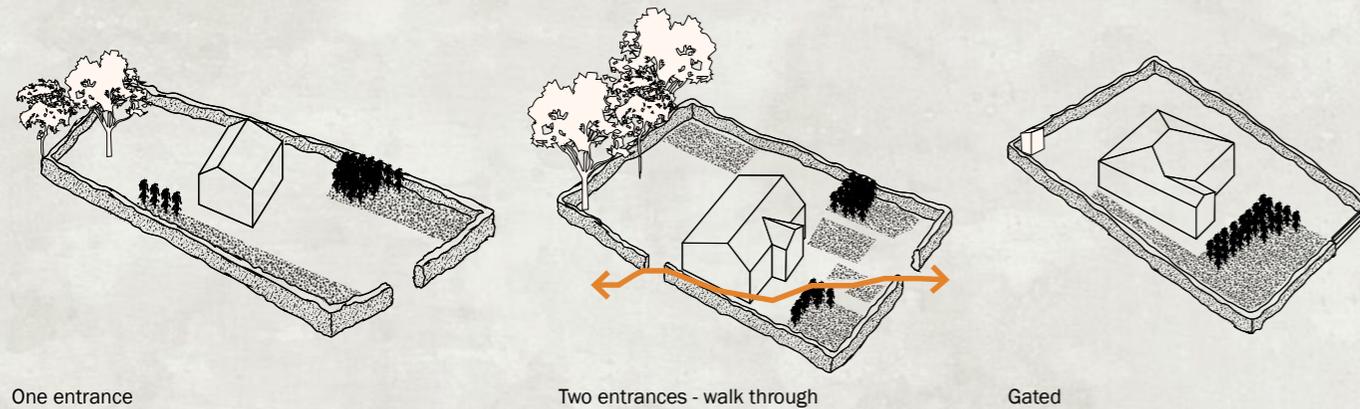


Figure 113b Systemic organization and land ownership

2. Land use analysis

c. Housing

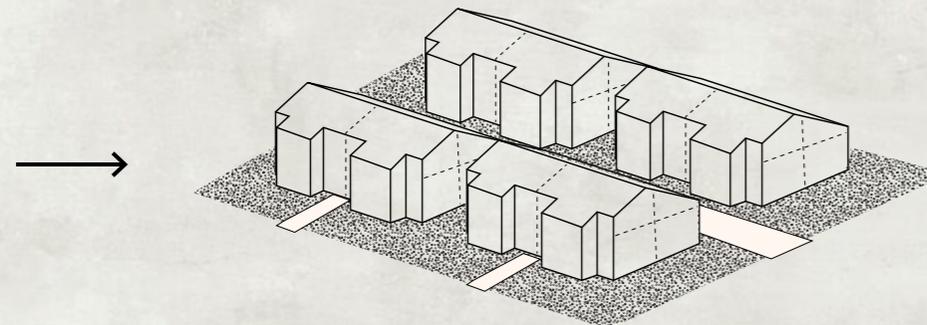


One entrance

Two entrances - walk through

Gated

Current living situation in Ryabega



«Imidugudu» units in Nyagatare - Town nextdoor
Efficiency over spatial quality and living quality

Surroundings tendencies

Figure 114 Living conditions

The last part of the land use analysis focuses on housing and housing tendencies designed by the government to deal with housing needs. These units are spatially poor as they do not offer any private space for the families. It is about efficiency. The new housing intervention focuses on qualitative living conditions, which juxtaposes the need of more units and the need of good living conditions with private gardens and humid microclimate vegetation around the houses.

Existing houses can be adapted in order to offer families their own drinking water access. Roof-harvesting systems can be connected to rain gardens, which will filtrate and guide it to the tank.

Shade, humidity preservation and reeds ameliorate the rain garden microclimate.

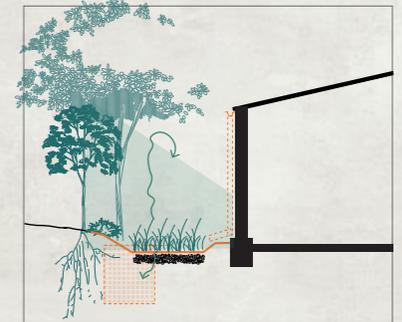
Lastly, most households have their own crops around their houses for food subsistence.

This intervention focuses on offering possibilities to conciliate drought-tolerant crops with private gardening by implementing a wooden structure. It is delivering shade and a more humid environment to facilitate good growing conditions.

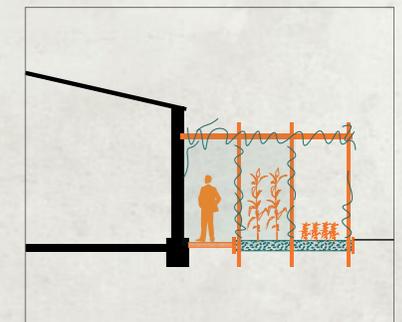
New housing
+ units variations
Bioclimatic
architecture



Private gardens and
rainwater tanks
Bioclimatic
architecture



Sheltered productive
garden



3. Spatial analysis

Public and social spaces

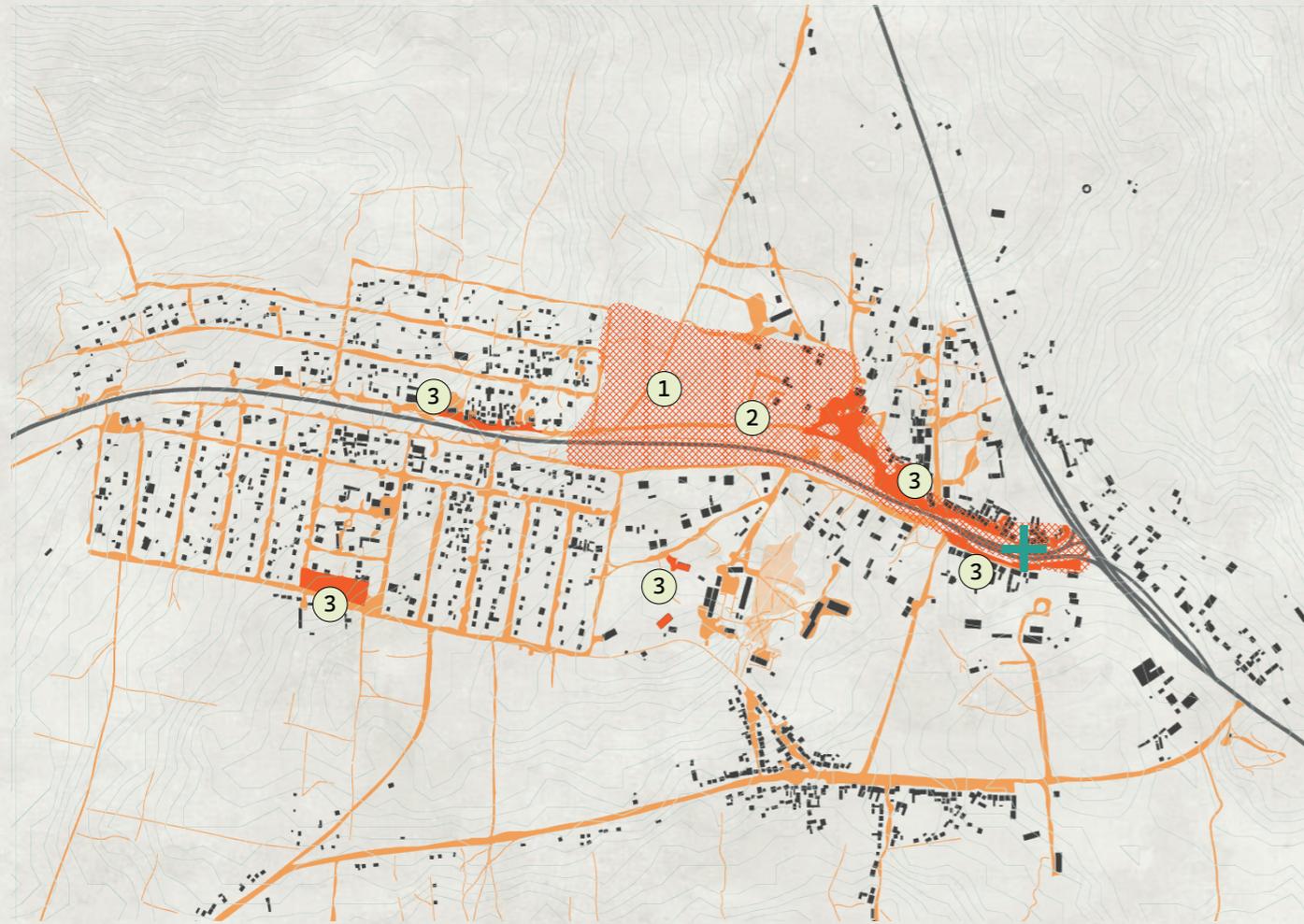
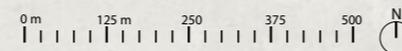


Figure 115 Social spaces opportunities

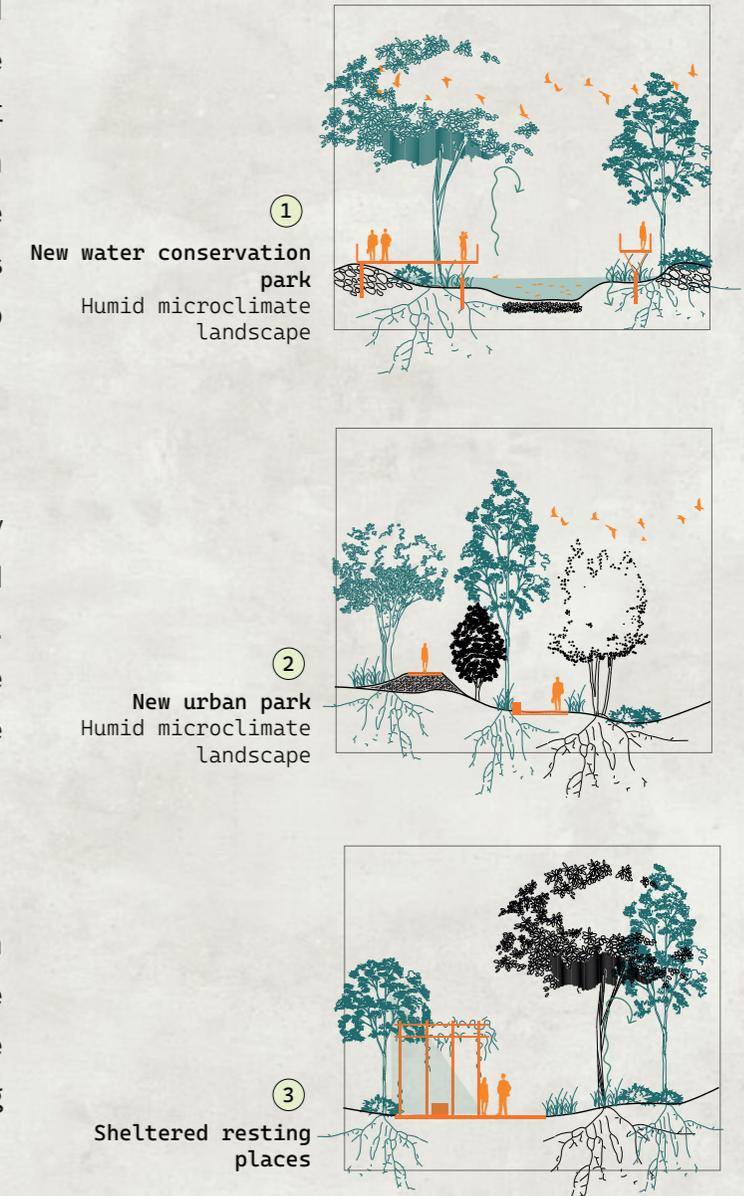
- Road
- Buildings
- Social spaces
- + Commercial area
- ⊠ New urban and landscape design potential



The residential area on the left and the commercial area on the right are separated spaces within the town's fabric. In this area, there is an important potential to develop connections and urban water conservation parks. Implementing large tree cover, vegetation layers and reeds creates a new humid ecosystem and ideal habitats to welcome back local endangered bird species.

Furthermore, as informal spaces currently constitute the town's layout, more designed and suitable gathering spaces can be implemented. They would offer recreative areas to experience the landscape topography as well as create social interaction.

Lastly, small interventions, such as wooden shelters, can be implemented throughout the town to offer multiple resting spaces to the inhabitants. Such spaces are also providing shade in times of increased temperatures.



3. Spatial analysis

Public and social spaces

■ Current used informal spaces
■ Potential design formal spaces



Figure 116 Large gathering space section



Figure 117 Commercial area section

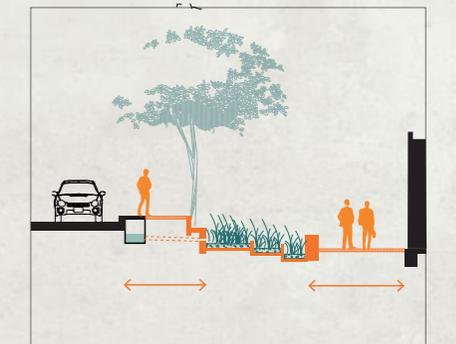
Large, informal market spaces can be transformed to better host local activities.

As this area will be more open to leave rooms for market stands, drought-resilient plants can be implemented as they won't necessitate shelter from sun exposure.

Lastly, biodiverse recreational features can be implemented on different road sides within the town to collect and filter the water coming from the gutters.



①
New market place
Drought resilient plants



②
New urban features
Collecting and filtering rainwater

3. Spatial analysis

Public and social spaces

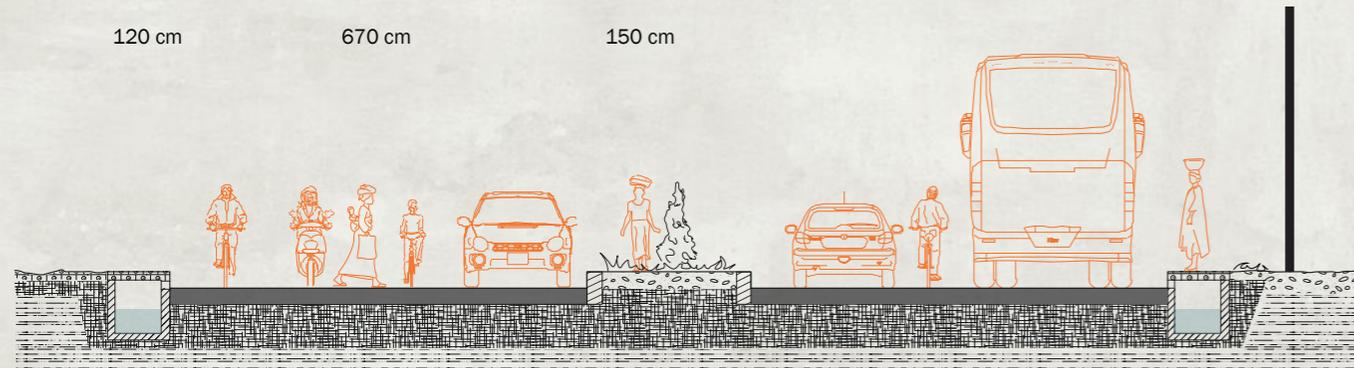


Figure 118 Primary network - main road in the commercial area

As the day cycle sections showed in Part 4, the main road is used as it is part of the social and public space. Therefore, the intervention can help mitigate the traffic needs and the activities held within that area.

It extends pedestrian spaces and creates biodiverse buffers in between roads.

New main road profile
Public space road
Urban biodiversity

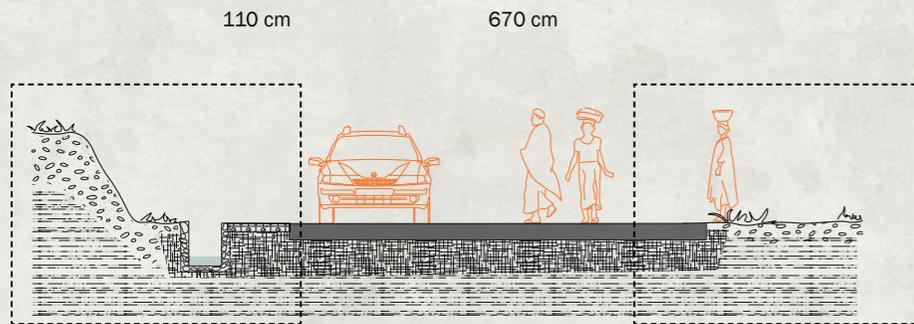
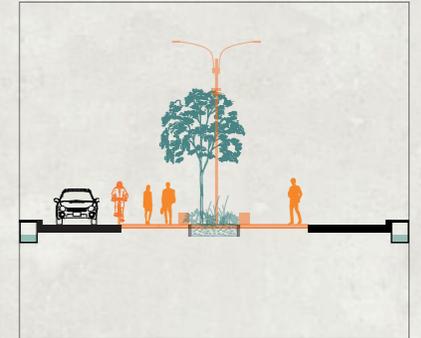
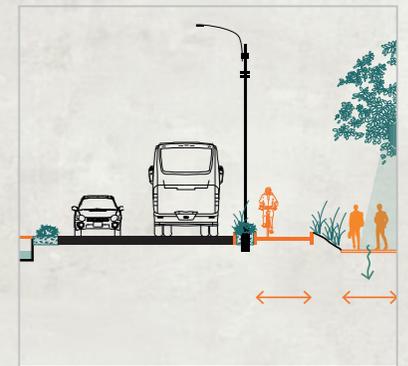


Figure 119 Main road outside the commercial area



New road profile
Filtering gutter and
room for users



Moreover, room for the multiple users can be created on the roadside in order to safely welcome them.

Adapted and new infrastructure, such as covering the gutters, helps reduce evaporation before the water reaches the reservoirs.

Paving the streets will also help guide the water towards the filtering gutters.

New street profile
Filtering gutter and
pavement

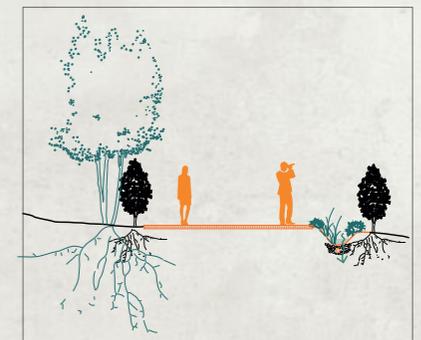


Figure 120 Secondary network - open soil street

Design analysis

CONCLUSION

The developed interventions present multiple potentials that can be implemented throughout the town. They are opening possibilities to be applied to other locations on the Savannah scale, given that the identified challenges are very common

Collectively, they work on reconciling spatial qualities with the imperative of agricultural climate adaptation.

Predominantly, urban centers have been conceived with a focus on efficiency and intensive agricultural practices, often at the expense of biodiversity preservation and spatial aesthetics.

Therefore, these interventions show the viability of meaningful impacts to mitigate global warming and rain and dry season, employing minimal means and locally sourced materials.

Anchored in principles of nature-based solutions, bioclimatic architecture, and resilient landscape paradigms, they are crafted in an adaptive and circular manner to ensure enduring efficacy over the long term.



- Potentials basins/reservoirs
- Spatial design intervention potential
- Existing social space
- Zoom-in intervention
- Rainwater runoff
- Rainwater concentration
- Public drinking water access
- Buildings
- Road
- Contour lines 2m
- 200m

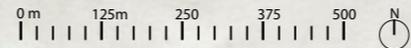
Figure 121 Landscape and urban potentials

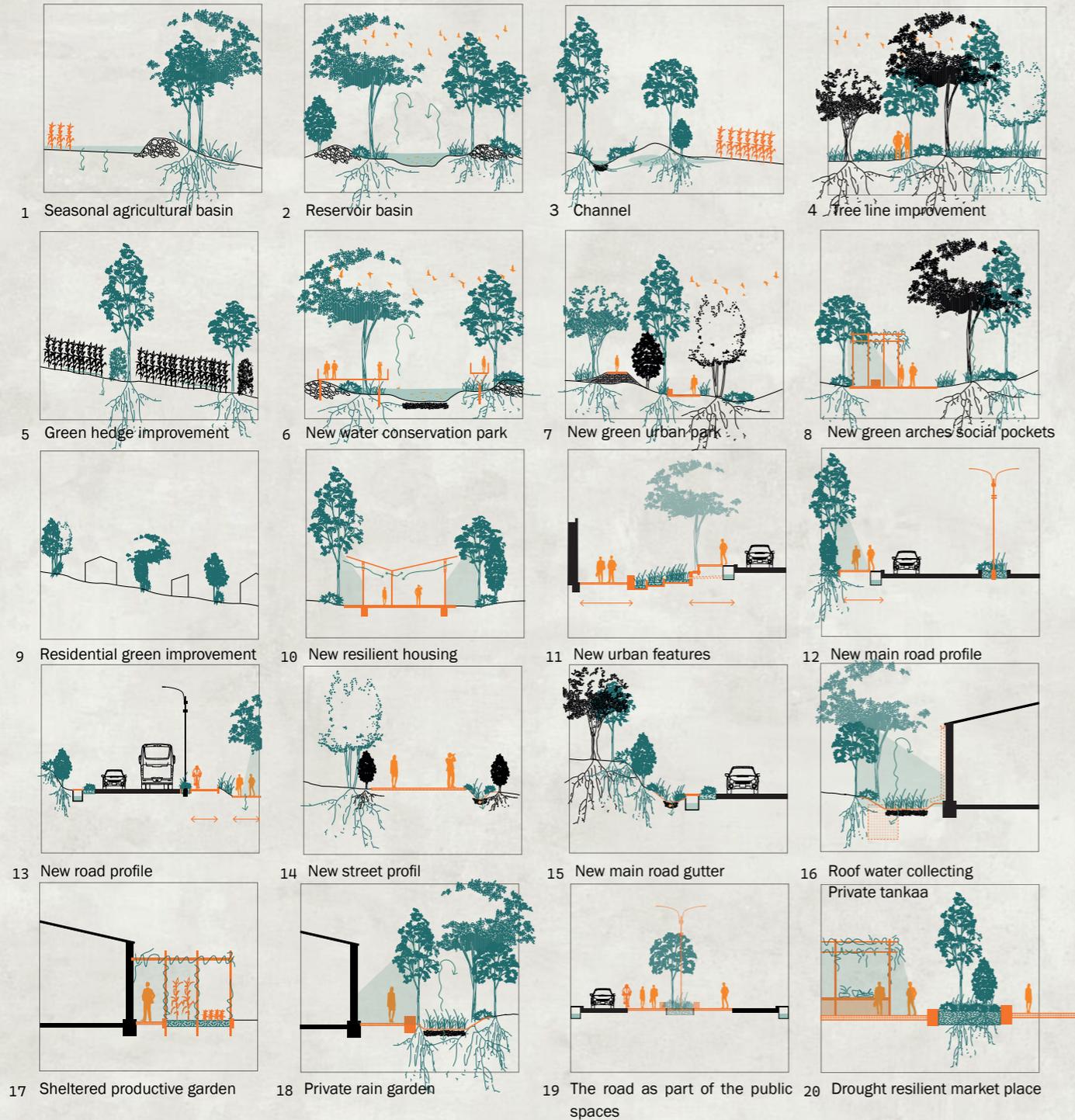
Simultaneously with the interventions catalog, analysis of the current layers of topography, land use and spatial spaces has unveiled multiple potentials within the landscape and urban fabric.

Such opportunities engage with the three landscape components developed in the design concept: landscape, agriculture and urbanization/housing.

Collectively, they offer a new foundation and connection with and on the landscape.

Regarding the following potential map, it highlights the prospective location of the water system reservoirs and agricultural basins based upon the underlying topographic foundation. Moreover, a large spatial design intervention connecting both sides of the town is poised to serve as a transitional zone from commercial to housing. It can engender multiple qualitative publicspaces, such as linear parks, marketplaces, urban and water conservation parks, and finally, new housing opportunities.





Interventions catalogue	Drought mechanism and rainseason mitigation				Location on topography				Landscape and living benefits												
	Humidity	Water conservation	Soil moisture	Drinking water	Village	Slope	Catchment slope	Catchement bottom	Biodiversity	Drought heat regulation	Recreation	Spatial quality	Social interaction	Private-public filter	Resilient housing	Village water autonomy	Economic activity	Accessibility	Locally sourced materials	Locally built intervention	
1	●	●	●	●					●	●	●					●	●	●	●	●	●
2	●	●	●	●					●	●	●	●	●			●	●	●	●	●	●
3	●	●	●	●					●	●	●	●	●	●	●	●	●	●	●	●	●
4	●	●	●	●					●	●	●	●	●	●	●	●	●	●	●	●	●
5	●	●	●	●					●	●	●	●	●	●	●	●	●	●	●	●	●
6	●	●	●	●					●	●	●	●	●	●	●	●	●	●	●	●	●
7	●	●	●	●					●	●	●	●	●	●	●	●	●	●	●	●	●
8	●	●	●	●					●	●	●	●	●	●	●	●	●	●	●	●	●
9	●	●	●	●					●	●	●	●	●	●	●	●	●	●	●	●	●
10	●	●	●	●					●	●	●	●	●	●	●	●	●	●	●	●	●
11	●	●	●	●					●	●	●	●	●	●	●	●	●	●	●	●	●
12	●	●	●	●					●	●	●	●	●	●	●	●	●	●	●	●	●
13	●	●	●	●					●	●	●	●	●	●	●	●	●	●	●	●	●
14	●	●	●	●					●	●	●	●	●	●	●	●	●	●	●	●	●
15	●	●	●	●					●	●	●	●	●	●	●	●	●	●	●	●	●
16	●	●	●	●					●	●	●	●	●	●	●	●	●	●	●	●	●
17	●	●	●	●					●	●	●	●	●	●	●	●	●	●	●	●	●
18	●	●	●	●					●	●	●	●	●	●	●	●	●	●	●	●	●
19	●	●	●	●					●	●	●	●	●	●	●	●	●	●	●	●	●
20	●	●	●	●					●	●	●	●	●	●	●	●	●	●	●	●	●

Figure 122 Interventions catalogue

Toolbox layout credits: Defacto Urbanism - Kigali



DESIGN LIVING WITH DROUGHTS



This last part of the thesis work finally dives into the design assignment and interventions implemented in the town of Ryabega.

The design applies the nature-based solutions, the bioclimatic architecture and resilient landscape theories on a detailed and human scale.

Working with the topography and climate adaptability, it aims to reconnect people to their landscape and to provide long-term solutions, so living with droughts is a possibility and not a vulnerability.

CONCEPT

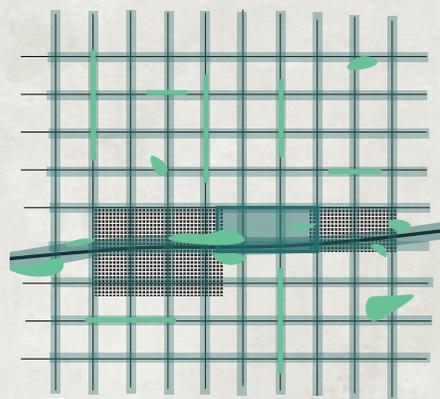
Focused on the three components - green structure, topography and social spaces - the conceptual framework seeks to reintegrate the existing situation with the surrounding landscape. Each layer is crafted to enhance existing conditions and anchor them to the landscape foundation.

First, the existing green infrastructure comprises fragmented woodlands and agricultural hedges. By enhancing agroforestry practices and integrating urban green spaces, the framework endeavors to establish a cohesive canopy, effectively functioning as green corridors and spaces across the area.

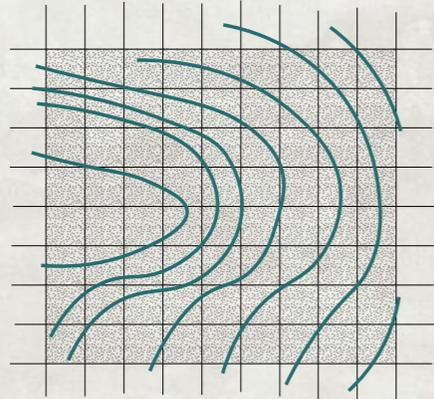
Second, detached from the topography foundation, the design aspires to harmonize with the natural contours of the land, thereby

reintegrating them into the broader landscape and urban framework.

Third, the current urban layout is characterized by a dichotomy between residential and commercial zones, resulting in a fragmented town structure. Consequently, there exists an opportunity to bridge them, fostering connectivity and transitional spaces within the urban fabric.



Fragmented to structured green



Water connections to the landscape



Social and urban connections

Figure 123 Concept steps

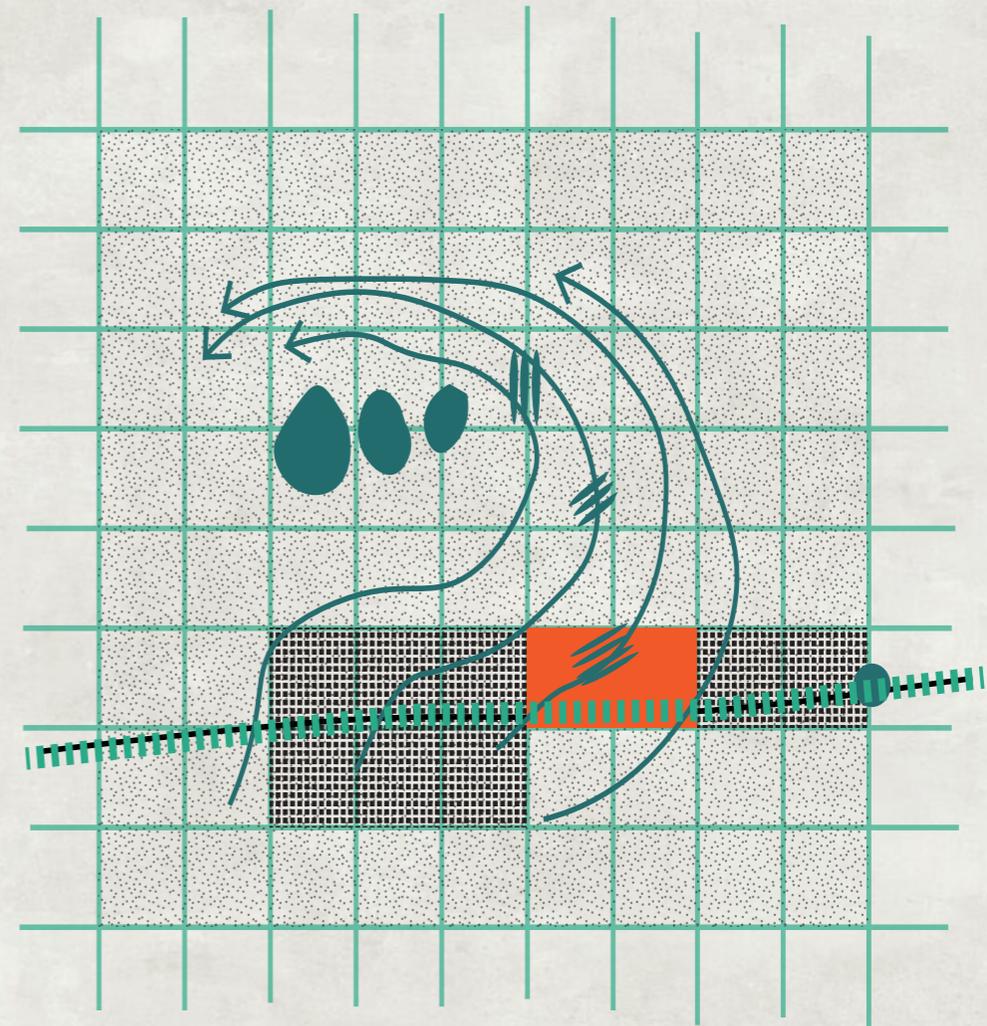
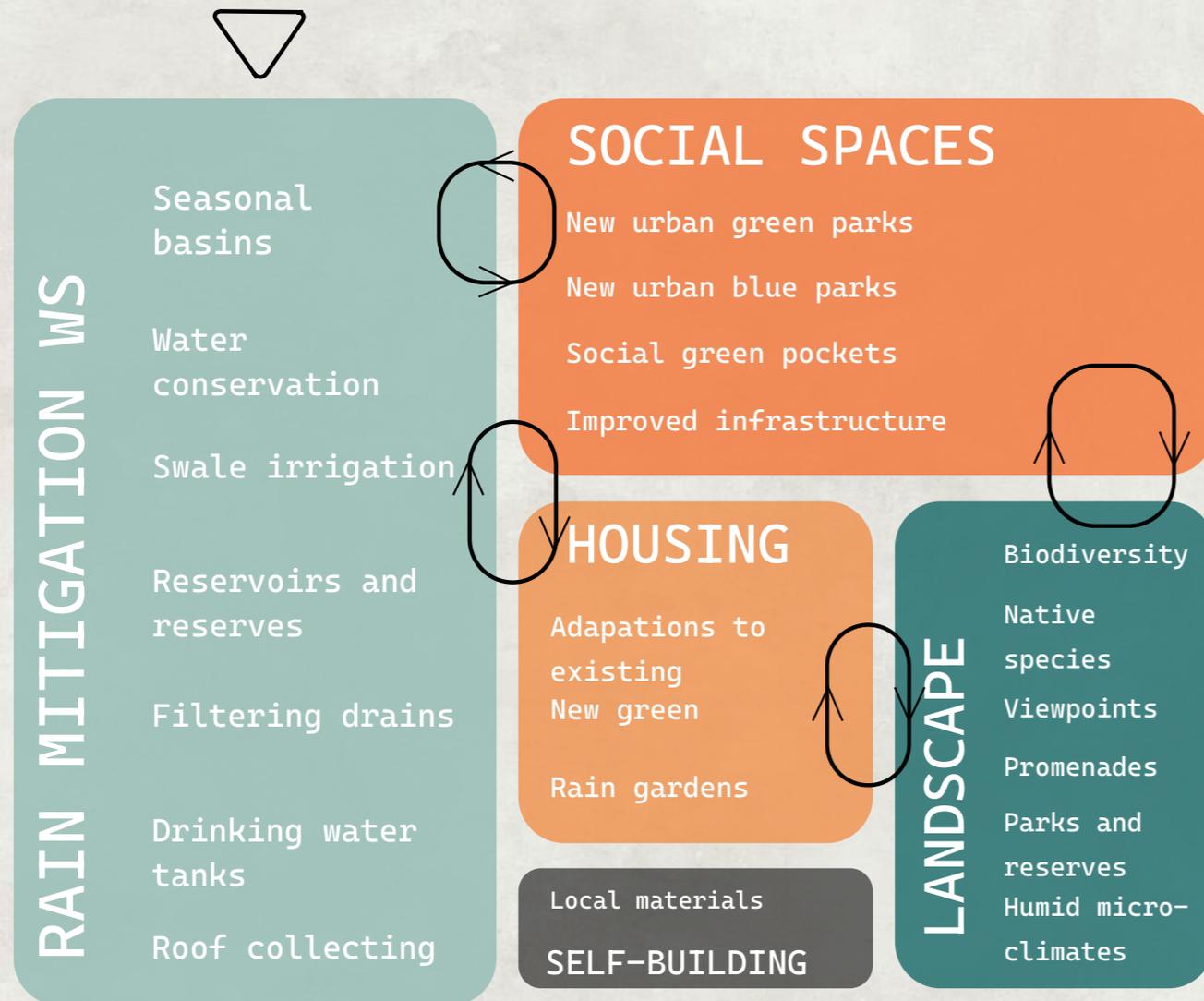


Figure 124 Concept diagram

Design program



the design initiative commenced with the implementation of a water management system intended to serve as both an urban catalyst and a landscape enhancer conducive to biodiversity and housing development.

Through the intensive analysis, results show the potential for integrating informal social spaces as part of the water system capillary, facilitating rainwater harvesting while concurrently designing qualitative social spaces.

One of the most important aspects relies on the selection of materials and techniques requisite for executing the design master plan. to utilize locally-sourced materials such as wood, rammed earth walls, earthen bricks and pavement.

This process thereby fosters self-sufficiency in building knowledge and resources within the community.

Figure 125 Program

MASTER PLAN

This chapter will delve into the master plan design and its components.

Building upon the preceding analysis and topography, it aims to integrate the productive landscape, biodiversity, and urban fabric to foster cohesion and a sense of place and identity within the community.

The yearly cycle will then be introduced to highlight the design responses to the climate fluctuations.

Finally, the thesis will zoom in on the urban transitional social spaces emphasized in the conceptual framework.

This last scale focuses on the human scale and human activities to meticulously designed formal, designed urban spaces.

Master plan

Strategies and program



- New urban green and water conservation park
- New green village : rain gardens, roof harvesting
- Seasonal agricultural basin
- Reservoir
- Reserves for bird habitats development, bird watching
- Productive forest
- New green structure
- Existing fragmented green structure
- New gutter system
- Swale, irrigation channel
- Linear raingarden channel
- Public drinking water access
- Contour lines 2m

Figure 126 Master plan

The water and urban master plan unfolds in five sequences.

Following the water flows, it starts from the town center and higher-altitude residential areas, They serve toprioritizing the establishment of new formal social spaces and green structures.

They serve to ameliorate water harvesting capabilities and foster humid microclimates, thereby mitigating heat susceptibility.

Second, the water infrastructure extends via channels, facilitating the flow of water throughout residential areas towards reservoirs while incorporating linear rain gardens.



Located nearby the town, the reservoirs store the water and collects the runoff aiming to maximize retention for both irrigation and domestic purposes.

Their design aligns with the objective of minimizing evaporation by narrowing their width and enhancing tree canopy coverage and the presence of humid plants.

Additionally, the reservoirs are connected to the landscape and crops via swales, which serve as conduits for distributing water and irrigating crops through topographical runoff.

Ultimately, the agricultural basins operate on a seasonal basis, functioning as repositories for rainwater infiltration. This design feature is instrumental in establishing a drought-resilient agricultural system viable during prolonged dry seasons. Basins and reservoirs cover 14% of current crops within the catchement area.

Master plan

Productive rural landscape



Figure 127 Irrigated agriculture with the water system

Figure 128 Afforestation and productive forests

Figure 129 Multivalent productive landscape

Figure 130 Housing development opportunities

The water system is composed of seasonal basins and reservoirs. The former covers 88 196,77 m² and the latter 21 234.9 m². With a 2m water level, the reservoirs can collect 31 852 350 L/year to irrigate the crops. Such water quantities signify that the system can only irrigate 63% of current crops.

This leaves 4 337 452 m² to diversify activities as developed previously in the revised agriculture system (p.171).

A productive forest can produce local wood for construction and such at a fast rate, as Acacia trees grow 1.8m per year.

Other types of productive landscape activities can be implemented alongside the main roads for connectivity advantages. This location choice is also supported by the fact that, as it is located on higher level, these lands cannot be irrigated by the developed water system.

Current urbanization tendencies show a 2.5% population growth rate. Instead of expanding the town's limits, there are still opportunities within the grid to welcome more housing development.

..... Catchment limits

Water system

Topographical harvesting



Figure 131 Key plan

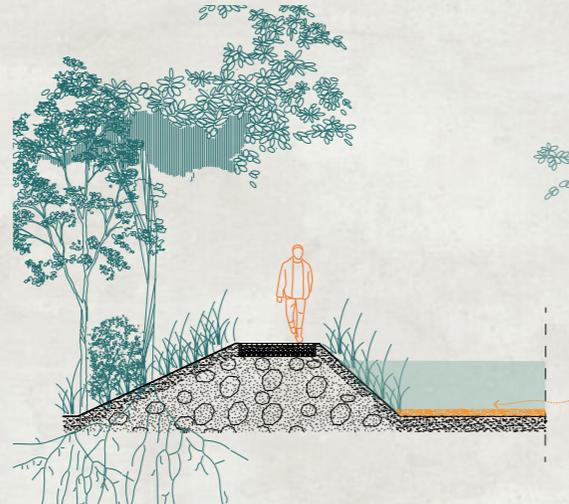


Figure 132 Agricultural basin detail

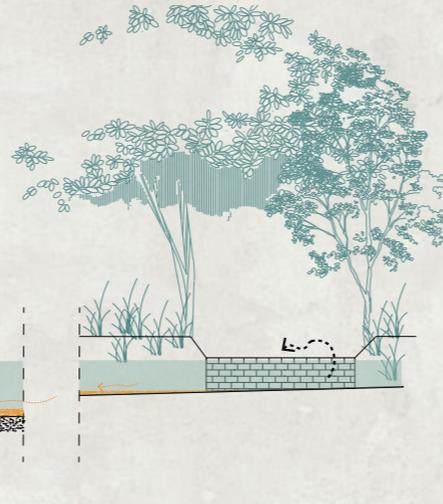


Figure 133 Overflow wall detail



Figure 134 Irrigation channel detail

Figure 135 Master plan agricultural section

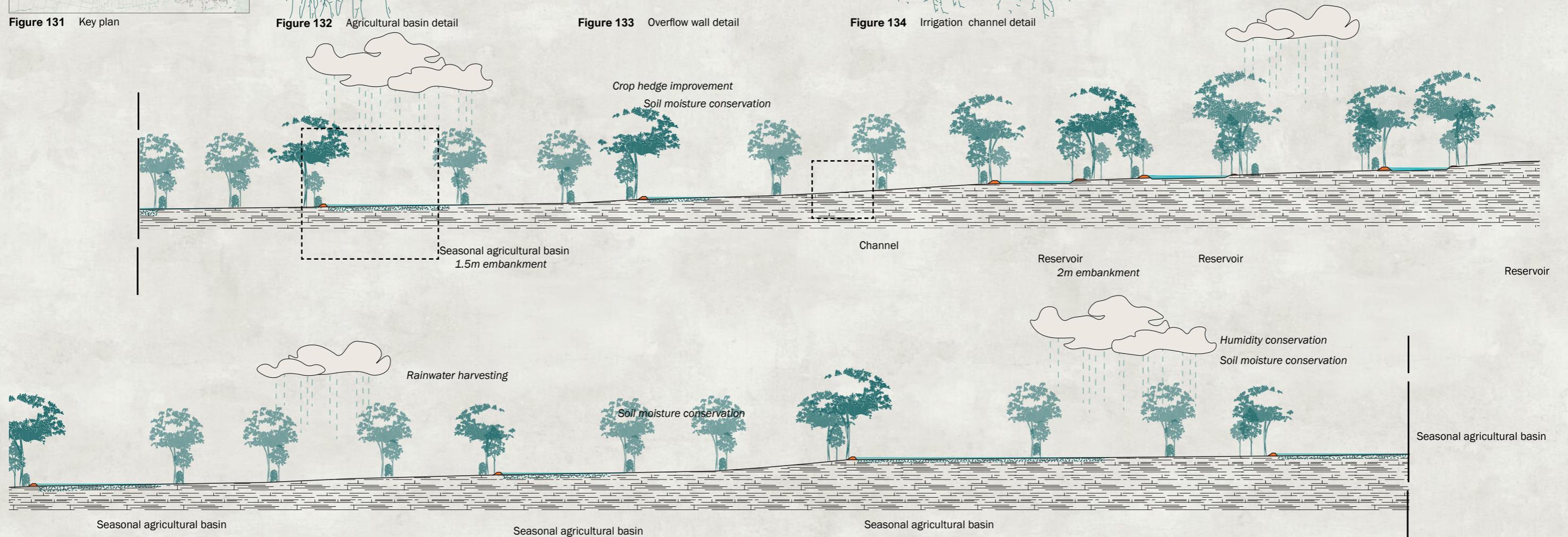


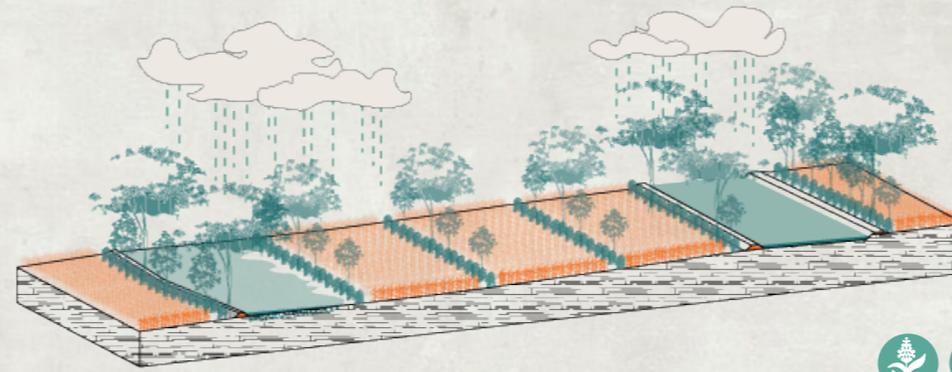


Figure 136 Water system landscape

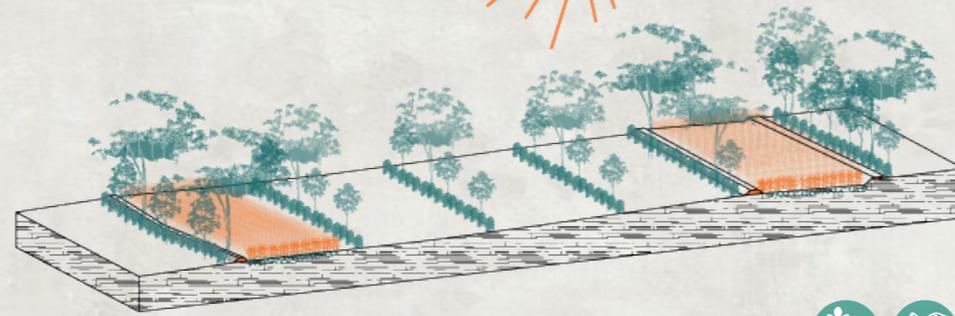
Seasonality

Rain and dry seasons mitigation

Long rain season
September - January
Growth - Rain irrigation

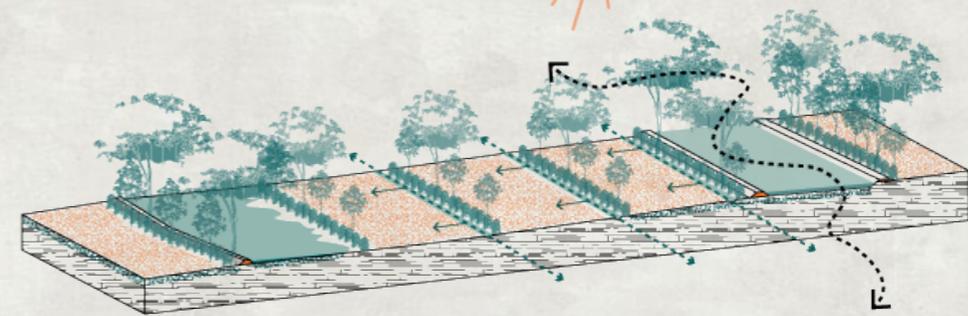



 Range : 400-700 mm

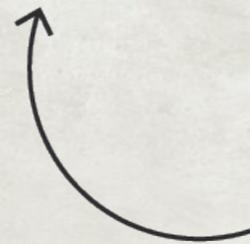



 Arid crop types

Long dry season
June - September
Growth - Seasonal basins irrigation



Short dry season
February - April
Sowing - Reservoirs and channel irrigation




 Range : 300-500 mm

Short rain season
March - June
Growth - Rain irrigation

Figure 137 Dry and rain seasons mitigation water system

Year cycle

Global warming mitigation

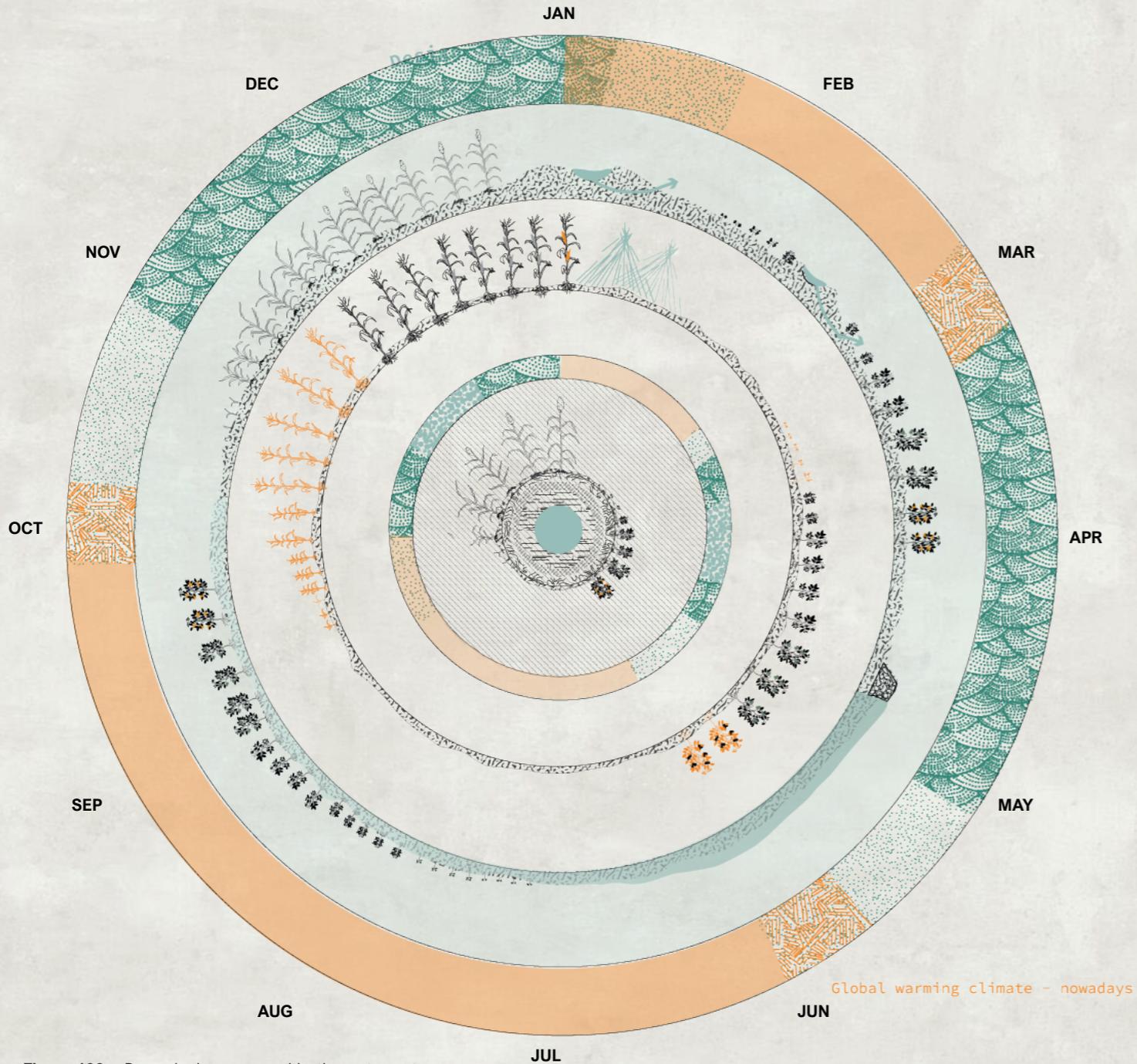


Figure 138 Dry and rain seasons mitigation water system

The usual agriculture system, which consists of two sowing seasons from September to January and March to June (Interview notes with John Kayumba, 2024) is currently vulnerable to climate changes.

Rain seasons are irregular and more intense, damaging the harvested crops (Jean-Baptiste Niyiregeka and Jean-Paul Ndajimana). To mitigate such a problem, the maize is placed in temporary shelters or cones to protect it from the rain (Interview notes with Geoffrey and Delphine from Horeco cooperative, 2024).

On the other hand, the dry seasons are hotter and expanding, resulting in farmers not being able to sow or in destroyed crops (Interview notes with Emmanuel Hakizimfura and Suzan Nyirabahire, 2024).

The dry and rain seasons mitigation water system aims to mitigate such problematics related to global warming.

The reservoirs and swales are in use during the short dry season in order to irrigate the crops, enabling farmers to sow the crops before the next rain season.

The seasonal agricultural basins, inspired by the Khadin case study, collects the water throughout the year to conserve soil moisture and recharge the groundwater. This humid environment is suitable for humus development and microbacterial activity, increasing the soil fertility and quality at the same time.

The utilization of the long dry season introduces a new sowing season, which is economically beneficial to the farmers.

RURAL DESIGN



Figure 139 Master plan



Figure 140 Design zoom-in

The design zoom-in focuses on the commercial area and transitional zone between commerce and residences.

This last scale introduces a sense of place by designing with the town's activities, flows and rituals so informal spaces can become formal, recreational and drought-tolerant.

Site and design composition

Components and layers



Figure 141 Urbanization and social spaces



Figure 142 Flows



Figure 143 Green

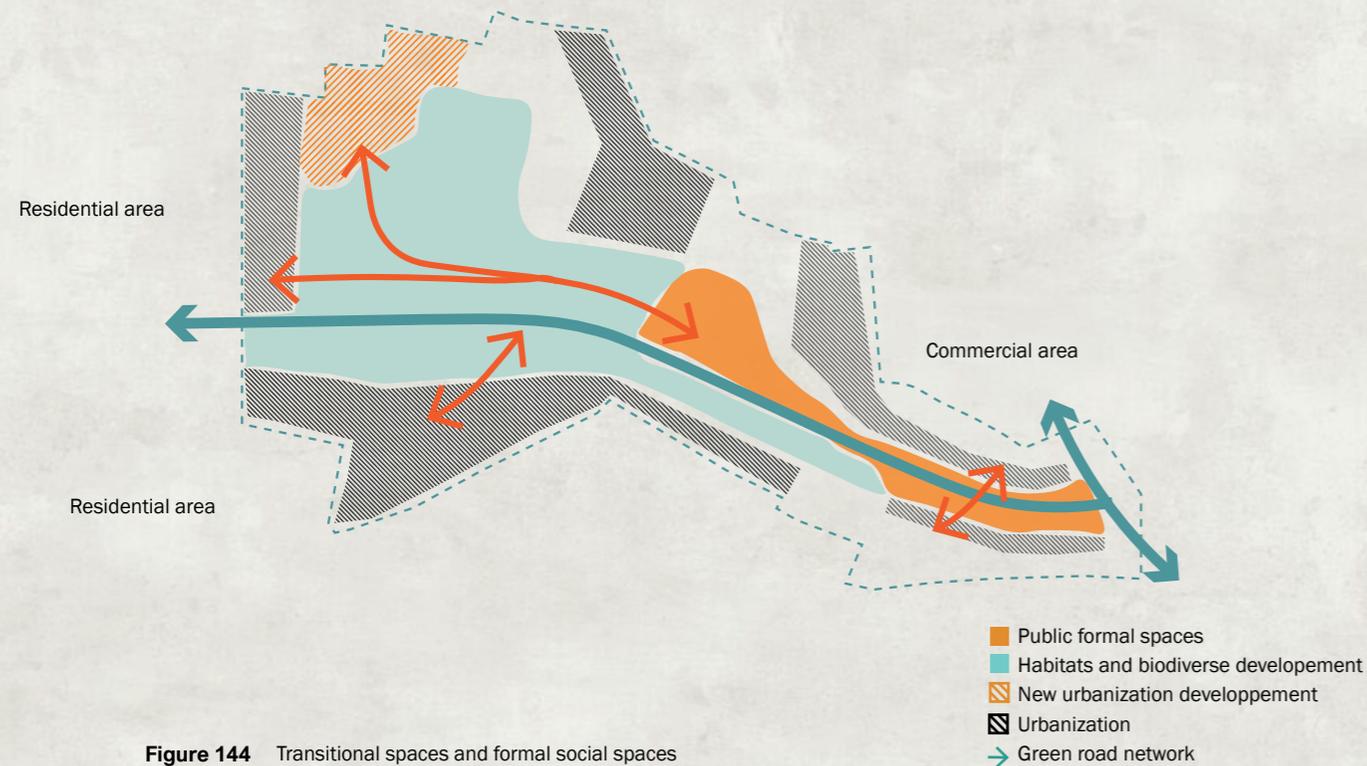


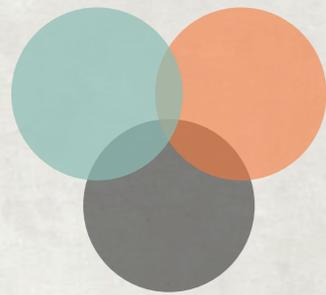
Figure 144 Transitional spaces and formal social spaces

The current situation revolves around urban spaces created as a reaction to the surroundings activities such as commerces, market places, and bus station. As mentioned throughout this thesis, urbanization and intensive agriculture resulted in deforestation and biodiversity loss. This site location has a lot of potential for biodiversity and ecosystem redevelopments in the many spaces of the town.

This design aims to reconnect the urban fabric, create transitions and experiences by designing qualitative urban spaces at a human scale. Furthermore, it strikes for a biodiverse green park implementation in order to offer recreational spaces for locals and tourists as well as new habitats for endangered bird species.

Designing to represent the landscape

Design zoom-in concept



TOWNSCAPE theory
Gordon Cullen

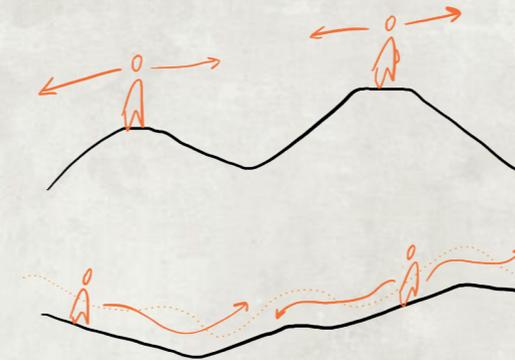
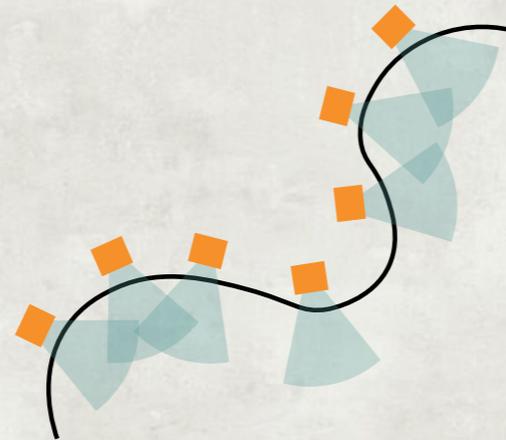


Figure 145 Thesis design concept

Figure 146 Village plan concept

Figure 147 Design experience concept

Connecting people and communities to the
landscape

Additionally to the map transitions and landscape connections, the design experience takes inspiration from the Townscape theory of Gordon Cullen (1961).

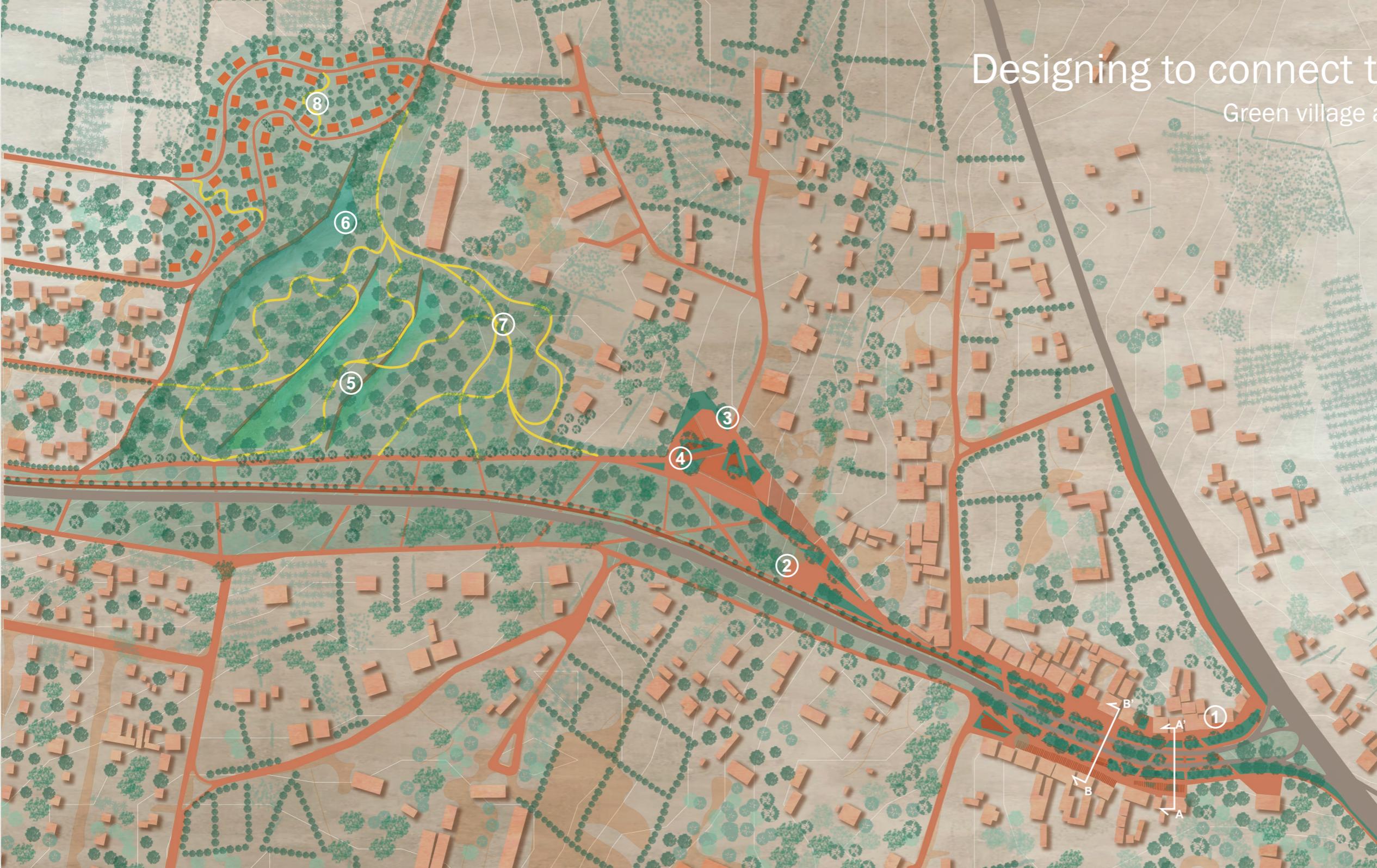
Curves, movement, and kinesthetics all refer back to the landscape topography and lines, unique to Rwanda.

Together, they create serial visions, surprises, fluidity, visual connections and perspectives to connect and immerse the visitor in the landscape.

Designing to connect to the landscape

Green village and urban blue/green park

Figure 148 Design Plan



- ① Linear public street park
- ② Bus station
- ③ Market place
- ④ Humid pocket resting places
- ⑤ Reserve and water conservation park
- ⑥ Reservoir
- ⑦ Kinesthetic promenade
- ⑧ New green village development

0m 35m 70 105 140 N

Designing to experience the landscape

Green village and urban blue/green park



Figure 149 Drought tolerant public space - Section AA'



Figure 150 The road as part of the public space - Section BB'

Developed in the commercial area, the design offers humid and shaded zones, so the locals can enjoy the center during high temperatures.

More room is offered to pedestrians in order to welcome the animation during peak town hours.

Lastly, filtering terraces are connected to the road gutters to collect and guide the multiplied public drinking water access tanks.

This section works on designing a unified public space in which the road has a part. As a lot of people cross the road to access the shops on the other side, room is created to host such dynamics. Furthermore, wooden pergolas can be added to the cafés' to create shaded terraces.



Figure 151 Key plan

Designing to experience the landscape

Green village and urban blue/green park



Figure 152 Market place - Section CC'

Figure 153 From residence to natural park - Section DD'



Larger spaces can be dedicated to larger public activities, such as the marketplace.

Some humid urban pockets with pergolas offer resting places and fresher temperatures in open areas.

Furthermore, a bicycle lane and a pedestrian lane are added on the side of the road to offer dedicated and safe areas to commute.

The water and habitat conservation park serves as a buffer between the animated areas and residences.

It redevelops the presence of green areas within the town as well as recreational activities with elevated paths and bird watching.



Figure 154 Promenade at the market place

Designing to live in the landscape

Microclimates ecology



Figure 155 Small wooden deck along the promenade for bird watching



Figure 156 Urban humid pocket and pergola

Bioclimatic architecture and microclimates are developed with the use of large foliage trees such as *Acacia*, *Brachystegia spiciformis* and *Markhamia*.

They create shade and help lower evaporation rate. Moreover, *Combretum molle* trees are advantageous for climate change mitigation as they help capture and store carbon in soils.

Furthermore, high grasses, typical Savannah flora, such as *Andropogon gerardii* offer cover for multiple birds and insects. They are also quite nutritious and help conserve water's moisture. Lastly, *Brachystegia spiciformis* is beneficial for the bees because of its nectar production, indirectly attracting bee-eater birds in the area.



Figure 157 Promenade in the reserve

Designing to live in the landscape

Microclimates ecology



The elevated paths create different perspectives on the landscape, as well as visual connections between the different visitors.

Figure 158 Building experiences with soil and earthen materials

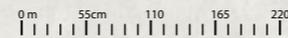


Figure 159 Resilient housing materials and simple techniques

New housing designs are built with rammed earth walls and simple wooden roof structures. The walls need to be elevated from the ground's humidity in order to conserve its properties. Foundations made out of local stones can be implemented.

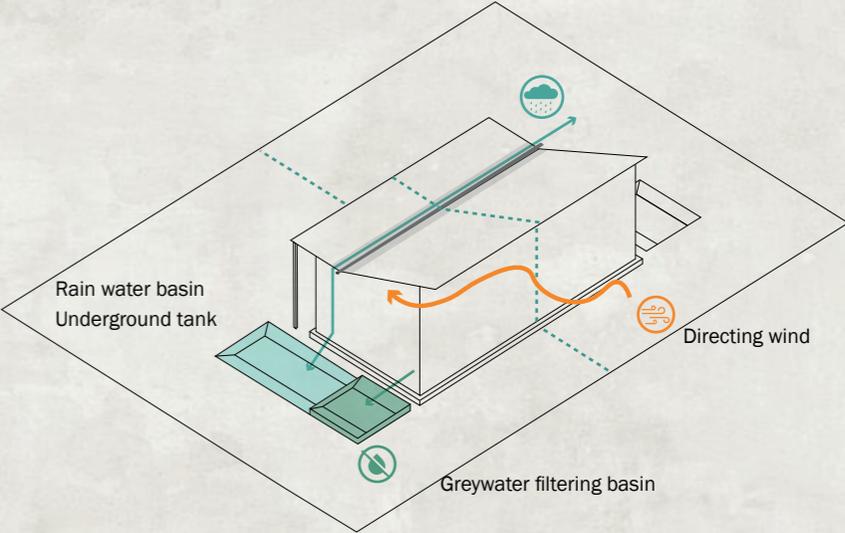
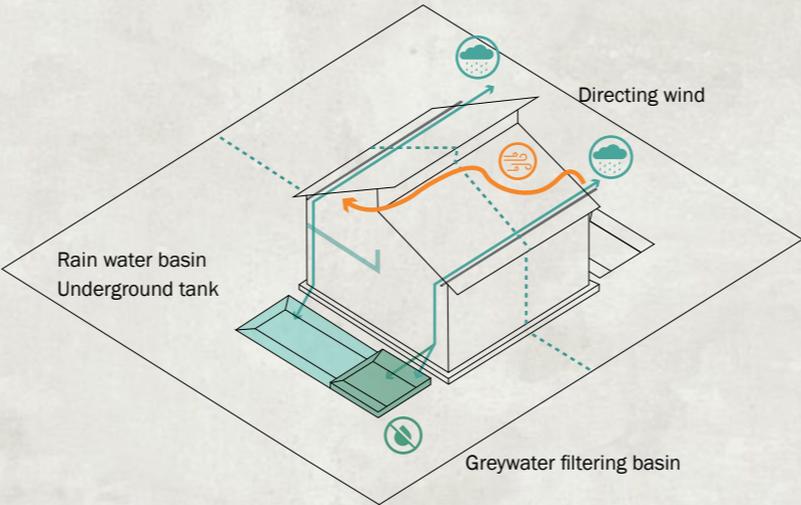
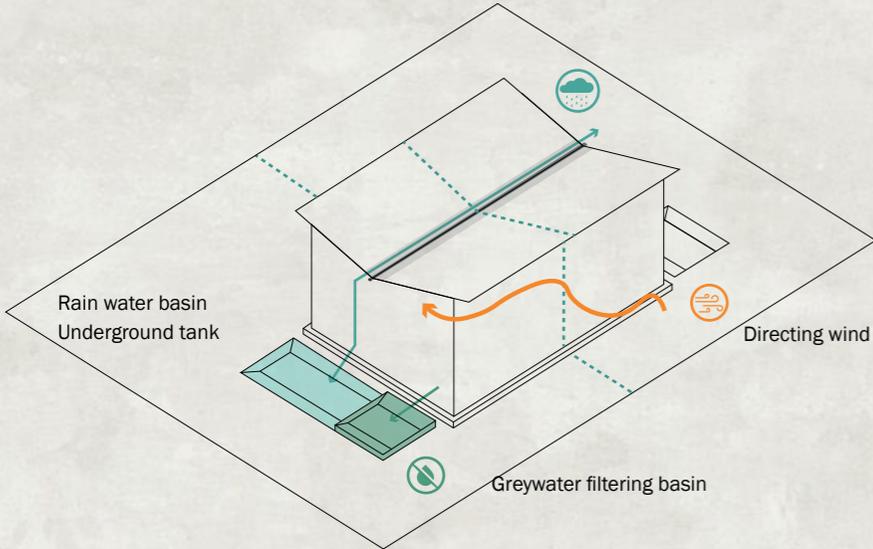
Furthermore, the roof is slightly longer to protect the rammed earth from intense rainfall. It also creates more shade alongside the facade.

Earthen bricks can be used to create natural ventilation openings and bring sunlight into the house.

Designing from the landscape

Housing autonomy and possibilities

Two-units houses - Rain and wind harvesting roof techniques



Bioclimatic architecture - Humidity conservation



Figure 160 Double slope roof



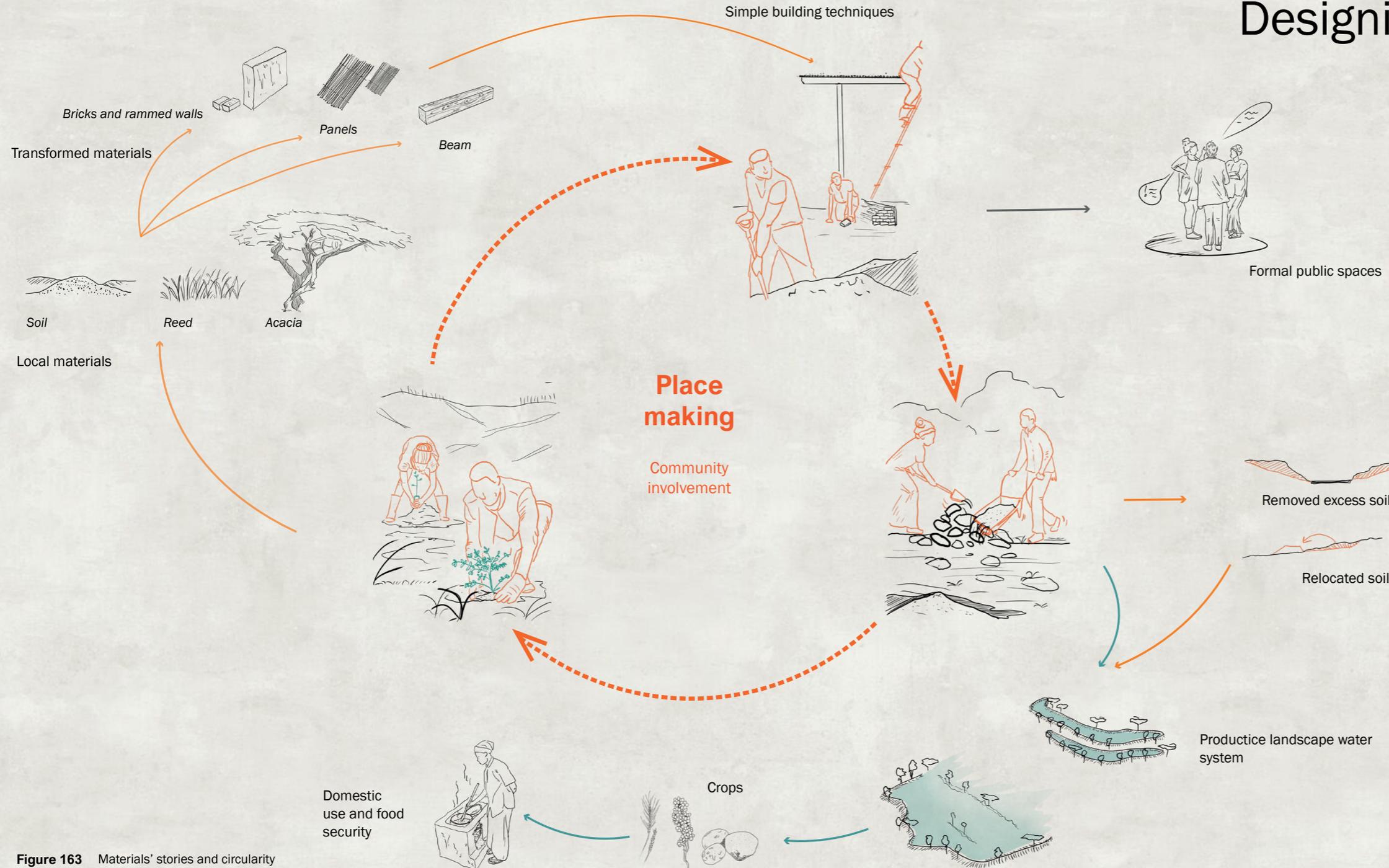
Figure 161 Two-level house



Figure 162 Private pergola roof

Designing from the landscape

Autonomy and circularity



The last facet of this thesis work is, in addition to the water cycle, the material circularity.

By favoring local resources, communities can build and implement the design interventions and water system with few means.

Soil can become earthen bricks and rammed earth walls.

Reed can be dried and weaved into panels and baskets.

Acacia trees are an important resource for wood construction such as beams, floors, furniture and so on.

The system involves the people as a starting point and a part of the process in order to reach autonomy, knowledge ownership and create a relationship between landscape and people.

Figure 163 Materials' stories and circularity

Plains of the Akagera National park

©Charlotte Delobbe

CONCLUSION

?

and irrigation practices to mitigate adverse effects on biodiversity and soil fertility. The lack of knowledge on adaptive agriculture and climate adaptability practices is highlighted, with the importance of studying arid water systems emphasized.

Considering the impacts of global warming and the intensification of droughts, in what ways can the Khadin water system be a resilient design tool for tropical landscapes, the agriculture and the communities?

The Khadin traditional water system is seen as a promising hypothesis for navigating water scarcity in the east of Rwanda. Insights and learnings from the case study have enabled and oriented the thesis analysis on five main points: the loam soil characteristics, the complex topography, the seasons, the agricultural rhythm, and existing infrastructure. Even though the case study offers pertinent insight on how to develop drought-resilient practices, it was not sufficient on its own.

Indeed, in the urban landscape of Ryabega town, emergency planning strategies were observed to accommodate new households, leading to contradictions between the informal public spaces laid out and the activities and uses they

held. However, opportunities exist to introduce well-designed spatial interventions that enhance the relationship of the town's urban fabric to the landscape foundation and mitigate the town's vulnerability to global warming.

These interventions, rooted in nature-based solutions and resilient landscape paradigms, aim to reconcile spatial qualities with agricultural climate adaptation imperatives. They also highlight the potential for similar interventions in other Savannah-scale locations facing common challenges. The thesis proposes various spatial design interventions, including water system reservoirs, agricultural basins, and transitional zones connecting commercial and housing areas, which can create qualitative public spaces to connect people back to their landscape and new housing opportunities.

How can the design project enable communities towards town autonomy, resilient economy and water circularity ?

The graduation thesis highlighted the instability of the agricultural sector in terms of food security and income for the farmers. Poverty remains an issue in rural areas, especially as agriculture is currently the only activity. To overcome such instabilities,

the design proposes different potentials that can be directly implemented. Furthermore, by encouraging the creation of cooperatives, not only for agriculture but also for biodiversity development and water management, it strikes for sustainable development and autonomy within the town. Such practices, along with resilient environmental solutions, are employed in other poor rural areas of the world, and the results are positive (Corrêa, 2019 ; Grinberg & Chinapah, 2015).

The contribution of this graduation thesis relates to the need for long-term and resilient designs in climate-vulnerable areas. The intervention catalog developed aims to offer diverse concrete actions that can be replicated in other drought-prone landscapes. One of their most important aspects is the use of local building knowledge and locally sourced materials such as earth and wood. Indeed, this thesis aims to provide accessible opportunities for communities to build their own landscape. Many vulnerable areas remain vulnerable because of the lack of subsidies and investments. This thesis shows that by multiplying simple interventions and involving the people - autonomy, water circularity and landscape resiliency can be achieved.

Despite the recognition of the need for climate change mitigation, progress remains sluggish, as evidenced by conferences, scientific seminars, and governmental assemblies (Toffelson, 2023). While the Paris agreements were to limit global warming to 1.5°C, that rate has been long reached in Rwanda. Indeed, past decades have witnessed a higher temperature increase up to 2°C between 1970 and 2009 (REMA, 2011; MER, 2015). The paradox between causes and consequences is not lost on us, as western countries, Russia and China have the highest carbon emissions (Statista, 2020) but most consequences are in South America, Africa and Southern Asia.

The thesis discusses the challenges faced by Rwanda and the Eastern Plateau due to global warming and human activities, leading to significant impacts on landscapes. It emphasizes the need to reassess current urban, agricultural,

REFLECTION

Water is omnipresent. It has shaped the world we know, carved landscapes, painted deltas and created life. It is essential to natural processes as its cycle is deeply rooted in climates, ecosystems, and the life it harbors. It has shaped us, and we have learned to shape it too. The interwoven narratives of water, nature, and humanity are all part of one story.

However, there are many stories to be told. Indeed, Water stories occur not only when it is present in the landscape, where we can see it and interact with it, but also when its absence and silence impact the many communities that rely on it.

In the context of drought-prone landscapes, the thesis has developed several methods to tackle water scarcity and enable communities to implement their own water systems themselves. As mentioned in the conclusion, it strikes for water circularity and autonomy.

Furthermore, the methods employed in the graduation thesis led to multiple discoveries and interesting design implications.

The primary objective of the thesis is to incorporate local biodiversity and locally sourced materials (NBS) into design interventions, drawing on community knowledge and engaging both people and the landscape. However, a significant limitation of this thesis is the insufficient understanding of local biodiversity, a known issue in Rwanda. Notably, architects such as Anne Loes Nillesen and Mona zum Felde from Defacto Urbanism, who have addressed Kigali's landslide challenges, have mentioned this issue. To address this limitation, the thesis explores two approaches: tree topologies and investigating the bioregion framework (One Earth, 2023). For instance, the Ryabega flora falls within the Victoria Basin & Albertine Rift Forests (AT12) and falls under the Victoria Basin Forest-Savannah ecoregion.

As the design assignment is located in a different culture, which methods can be employed in order to learn and understand how people use public spaces?

The Counter Cartography method did not yield the

thoroughness I had hoped for. Communication with people on-site, even with the assistance of a translator, proved challenging. Additionally, when discussing and mapping the community's understanding of their town or landscape, they frequently referenced governmental maps and Google Maps. This reliance might stem from the community's newness and its evolving relationship with the landscape, a factor that the design can leverage as a tool. This suggests that altering the urban fabric could be relatively straightforward, as it does not entail deep-rooted heritage.

Lastly, the drawingtime technique that highlighted the different activities in the town center throughout the day demonstrated interesting aspects of the informal spaces. It enriched my understanding of current space usage and how to design for people. By studying these spatial habits, the design aimed to shape formal and designed spaces suited to the community's needs, welcoming activities such as gathering,

resting, and circulation.

Scale continuum

This thesis employs a scale-based methodology. It examines the various challenges faced by Rwanda across different scales, ranging from the national level, through the eastern plateau and the Savannah, down to the town scale. As the analysis transitions from a broader scale to a local one, the design adopts a mirror approach. Indeed, it develops an intervention catalogue applicable to Ryabega which can also be replicable. By scaling back from Ryabega to the catchment potentials on the Savannah scale, these interventions and integrated water systems can significantly impact larger scales, contributing to the creation of cooperative landscapes and systems resilient to global warming.

Social and moral aspects

During my site visit, I learned that Rwandan farmers are receptive to change and willing to question their practices, considering current challenges. The design alternations on agriculture, coupled with the open-mindedness of locals, could serve as a starting point for further interventions and transformations within the town. Given the thesis's demonstration of the

benefits of reshaping the town center to enhance liveability and comfort during hot daytime temperatures, it is conceivable that the design could gain endorsement and support from the local community, particularly since it draws inspiration from the informal and unintentional shaping of Ryabega by its people.

Moreover, on a larger scale, the interview conducted with Philippe Kwitonda, the Rwandan minister of Environment, has raised a conversation about potential collaborations and government ambition and awareness of global warming. In this framework, the thesis work has included several parts of existing visions and investment reports by, on the one hand, counting on a collaboration with the afforestation master plan and, on the other hand, designing designated areas for landscape productivity and new activities.

Furthermore, I would like to mention that even though multiple green and ecological visions have been drafted on a national level, on a local scale, agricultural changes are more present. The current governmental interest in rural areas is still focused on agricultural intensification and production. Nevertheless, this thesis master plan demonstrates multiple opportunities to combine ecological and landscape benefits with economic

potentials.

Lastly, the political scope of the country is that of a constitutional republic with a dominant presidency. Paul Kagame has been president since 1994-2000, and the country's stability and security have been strongly enforced (United States, Department of State, 2023).

For tourism, it is said to be the safest country in Africa, and while on site, I noticed a strong presence of armed policemen and policewomen in many small towns.

In cities, houses are usually gated, and in the countryside, hedges surround private properties for intimacy as well. The design has responded to this last aspect by implementing trees and hedges to create intimate spaces.

How can the design intervention evolve through seasons, years and time ?

The starting point of this thesis is the vulnerability to global warming. The tropical climate of Rwanda and its communities are encountering new challenges and seasonal irregularities for which they are currently unprepared.

By studying and adapting an arid water system, the design has predicted increased temperatures and droughts in the many years to come. This system has been demonstrated to be effective in harsh conditions and can be relied upon in the

future.

Furthermore, by conserving humidity and reforestation, the landscape can rebuild its resilience to global warming. Especially as the selected plant species are drought-resistant and contribute to the creation of shaded environments. Fast-growing trees, such as *Acacia*, can rapidly establish and proliferate.

Additionally, adaptive agricultural practices, layered vegetation, and soil moisture generate the redevelopment of an humus layer and the activity of soil macrobacteria, which are essential for improving soil structure and restoring habitats.

Finally, each section in time involves new stakeholders. Indeed, this thesis relies on the communities as a starting point to build the

water system and on government collaborations for afforestation and tree planting.

Cooperative systems are implemented to diversify rural landscape activities, and such structures can attract the attention of international NGO's for funding and education on biodiversity, other agriculture techniques, etc.

Lastly, the landscape is a stakeholder, as it is active in acting on global warming resiliency and

creating recreational outdoors spaces for the town of Ryabega.

The 20–100 years section elaborates on the drought-tolerant vegetation and raises a last question. With global warming increasing to 4.4°C, there will come a time for crop and landscape adaptations and new questionings on the proposed design interventions.



Figure 164 Ryabega landscape and soil story - Now to 2 years

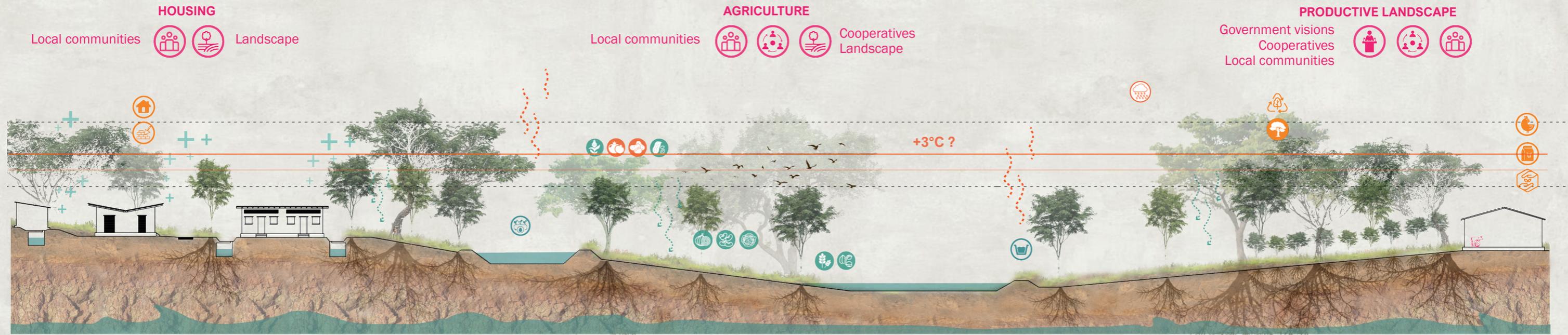


Figure 165 Ryabega landscape and soil story - 2 years to 10 years

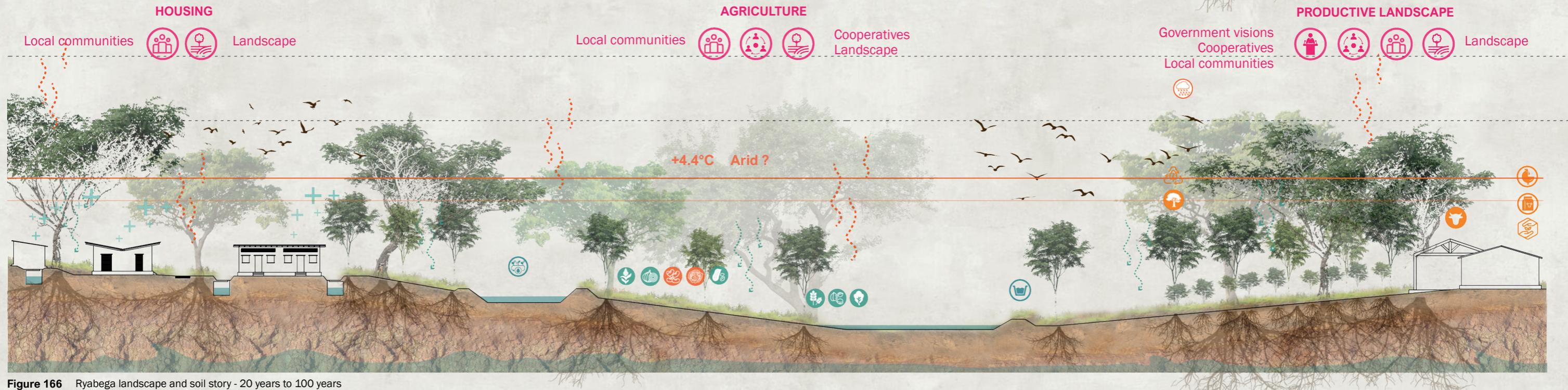


Figure 166 Ryabega landscape and soil story - 20 years to 100 years

Theoretical framework and thesis position

The design approach draws inspiration from Townscape principles (Cullen, 1961), aiming to reflect the natural landscape and create a dynamic topographical experience along the site's promenade.

Moreover, it presents alternatives to the current conventional urban grid layout, often inspired from the American landscape, which superimposes a rigid structure onto the landscape rather than harmonizing with it. As noted by Gordon Cullen (1961), grids tend to create a monotonous environment that fails to evoke strong emotional responses from visitors. However, residing within grid-based layouts does not exclude the development of a sense of place; inhabitants often adapt and personalize their surroundings by introducing elements such as pavements, fountains, planters, flowerbeds, and tree-lined avenues. Nonetheless, many of these interventions tend to conceal the underlying grid structure (Jackson, 1994).

Consequently, the design proposes novel urban typologies that are rooted in the natural landscape and its layers, aiming to enhance connectivity and foster a distinct sense of spatial and kinetic experience, inspired from the unique Rwandan topography.

In essence, all design methodologies converge on the objective of reestablishing and reimagining a meaningful landscape, aimed at creating a sense of place. To achieve this, the design meticulously examines existing flow patterns, which can be interpreted as spatial rituals. Rituals and recurring activities play a vital role in fostering a sense of place and community cohesion (Jackson, 1996).

Overall, this graduation project seeks to offer innovative solutions for climate-vulnerable towns while addressing the challenges posed by rapid urbanization, which often disregards the inherent layers and foundations of the landscape.

“The ability to read the landscape structure and the power of a landscape architectonic design to render the landscape lucid or legible as a structure and a force make it possible to position oneself in space and time. To experience a place as meaningful supports the understanding of oneself in his cultural and social context; landscape is as a mirror.” (Wit & Piccinini, n.d.,

p.2)

As an architecture designer and landscape architecture student, my studies have highlighted the significance of both spatial and social design considerations. Even though designs nowadays tend to emphasize responses to the climate change crisis, biodiversity conservation, and urban heat island effects, it is imperative not to lose sight of the ultimate beneficiaries of our designs. This includes acknowledging the physical networks, connections, and relationships between sites and landscapes, as well as the human interactions within these environments, so placelessness spaces can become places (Relph, 2008).

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Annex 1 - On-site questionnaire for the farmers, January 2024

My graduation project focuses on the droughts and lack of rainwater challenges the agriculture and ecosystem face. In the analysis process of my research, I would like to know more about your practices and the role agriculture plays in your daily life and community. Your answers would help a lot in the design process as I can then understand your stories, perspectives and needs and design a project that is useful for you and the landscape around you.

Agriculture practices

What types of plants and seeds do you cultivate?

What tools do you use?

Do you use machineries?

When do you plant the seeds? How many times a year?

When do you harvest the crops?

How many hectares do you own?

How many hectares is necessary to cultivate so you can make a profit?

How many days a week do you work in the field?

How many hours a day do you work in the field?

From whom did you learn to cultivate the land?

How many liters of water do you need to irrigate your crops?

What are the problems you encounter throughout the growing season?

Are you encountering problems with the local animals?

Do you cultivate for your family needs, or do you sell the crops production?

Animal husbandry

Do you have cows or goats?

Do you use the milk for your own needs, or do you sell it?

Do you grow your own animal's food? (Grains, hay, etc)

How many cows/goats/chickens do you own? Is it sufficient to support your family needs or do you need to buy from the market?

Economy

Are the agriculture crops privately own or do you rent them to the government or other institutions?

Did you inherit the land from your family or parents?

Did you buy the land?

Is your revenue from agriculture sufficient to support you and your family needs?

How much costs a groundwater pumping station? Is it expensive compared to your revenues?

Can you afford other types of irrigation?

Is there a local economy in the village? (For example: do you buy your clothes/tools/goods from other villagers?)

How many times a week is the market open?

Do you sell your crops production at the local market or to other places?

Do you sometimes trade?

Social

Do you live next to your crops or far? How far?

Does your family and children work with you?

What other activities do you like doing when you don't work?

How is the atmosphere in the town/village?

Can you ask your neighbours for help if needed?

Are there any types of social gatherings throughout the week/year?

What do you think of your village social spaces? Is there any space for gatherings?

Would you like to have more parks, squares?

Do people who are born in the town/village stay when they are adults? Or do they leave for the city or other places?

Have you noticed changes in the village dynamics? New settlements?

Environment

Have you notice a change in the climate throughout the years?

Is it getting hotter? Drier?

Are the rain seasons sufficient to irrigate your crops?

What are the consequences of water scarcity you have faced?

How many times a year are you short of water?

I would also like to have your perspective on the landscape. As I don't live in it, I only know it from maps or google views, so my perspective is very different than yours. How would you describe your landscape?

How would you draw it? How would you map it?

Annex 2 - Interview notes with Philippe Kwitonda, Wednesday 10th of January, 2024

Function: Minister

Field: Ministry of Environment Director General of Land, Water and Forestry

Email: pkwitonda@environment.gov.rw

Phone number: +250 788 666 014

Discussion in English and French

The minister is aware of the need of afforestation in the eastern part of the country.

It aims to implement different tree species and mainly *Acacia*, *Euphorbia*, *Calliandra*, *Ficus*, *Grevillea*, *Markhamia* and *Eucalyptus*.

Eucalyptus trees are 90% of rwandan forest

--> There is a need to diversify by promoting native species

Current governmental projects consist of plantation, agriculture, irrigation and landscape restoration.

There is a very low forest cover because the biomass is used for domestic purposes such as cooking. The government is working on discouraging citizens to use such resource.

It has been accepted by the population as it is something that is needed to be done.

Three types of wetlands.

- Protected
- For agriculture open use
- Conditional

On-site agriculture contact : John Kayumba from the Rwandan Agriculture Board (RAB) in Nyagatare.

Ecology is not well documented, not many studies. It is a gap in knowledge.

Landslides in the other parts of the country creating ditches and soil at its maximum water storage capacity.

Annex 3 - Ministry of Environment tree species list. Retrieved on the Wednesday 10th of January, 2024 from Philippe Kwitonda.

1. Eucalyptus
2. Grevillea
3. Cupressus
4. Markhamia/Umusave
5. Ficus/Umuvumu
6. Euphorbia/umuyenzi
7. Pinus
8. Cupressus
9. Acacia
10. Callitris
11. Casuarina
12. Polyscias
13. Podocarpus
14. Albizzia
15. Maesopsis
16. Calliandra
17. Leucaena
18. Senna
19. Sesbania
20. Tephrosia
21. Alnus
22. Mimosa
23. Melia
24. Jacaranda
25. Avocado
26. Papaya
27. Mango
28. Guava
29. Citrus
30. Cedrela
31. Coffea
32. Erythrina/Umuko
33. Tomato Trees

Annex 4 - Interview notes with John Kayumba, 16th-19th of January, 2024

Function: Station Manager

Field: Rwandan Agriculture Board (RAB), Nyagatare and Gatsibo districts

Email: /

Phone number: +250 788 480 078

Discussion in English

In the Nyagatare district (Ryabega is part of it), they have good acidic soil.

Subsidies programs from the government help to mitigate soil quality.

In Nyagatare, manure is managed by the farmers and they also use fertilizer to maintain the soil fertility.

CIP = Crop Intensification Program (starting in 2007)

Drafted in order to boost productivity.

It includes :

Land use conservation

consolidation (farmers sharing fields)

organization

soil fertility maintenance

The goal is to lower the crop loss from 40% to 20%.

It offers input on seed quality, post-harvest facilities.

Irrigation:

15% of subsidies from the government

Hillside irrigation is considered an expensive system and therefore, is difficult to implement.

Water resources:

1. Community infrastructures : dam

Sedimentation issues in the dam (excessive) that are blocking the outlets.

Problems of the spreading of diseases among the water sources. People can add tablets in the order to purify it.

The government advocates for damsheets so each farmer can have their water source and collect the rainwater for their cows.

2. Transport by truck to the farmers

There is a problem of evaporation in damsheets ponds.

Agriculture program:

20% of land for the livestock will become crop production fields

National target of 70% land consolidation via cooperatives, in Nyagatare (2022 objective).

The crop residue go to the livestock food. They are located in grazing fields and are not allowed to graze in open areas anymore.

Soy beans, maize, beans are planted along site agroforestry and high grasses to balance.

30% of farmers have livestock.

There is a national program to offer one cow per hectare in order to use the manure for crop fertilization. The new program will include five cows per hectare.

There is 0.4 cow/person nationally.

Fertility:

Decreasing

Mainly because of the land overconsumption (it depends on each farmer).

The farmers and communities can reach the RAB in case of issues.

There is a farmer promotor per village, trained by RAB to spread the knowledge on crop productivity. Farmer Field Schools (FFS) are also facilitated in order to train and select the best seeds to sow.

Agriculture rythm :

1. September to January

2. March to June

3. Late May to September

In Nyagatare, there are only the 1 and 2 seasons as it is not possible to utilize the crops during the long dry season.

The wetlands area dispose of 3 agricultural seasons.

In warmer areas, crop production speeds up.

Drought areas in Rwanda :

Bugasera

Kayanza

Ngoma

Kirehe

Gatsibo

Nyagatare

Soil: steep sandy soil causes landslides and high erosion

Local soil: loam soil + vegetation cover can resist erosion

Lowlands : floods

Annex 5 - Interview notes with Geoffrey and Delphine, Horeco Cooperative. January 16th, 2024

Function: Agronomists

Field: Horeco Cooperative, Nyagatare

Email: /

Phone number: /

Discussion in English

1086 farmers are part of the cooperative.

Geoffrey accompagnies the farmers in intensifying their crops production and teaches them agronomist techniques

Subsistence farming >< crop production

The cooperative owns 900 hectars and cultivates beans, maize, soy beans and vegetable.

It is a business which sells and exports the harvest to larger markets.

1 hec of maize = 7t of harvest

30% is kept for subsistence consumption.

CIP = Crop Intensification Program

National program from the Ministry of Agriculture

Farmers are organized in cooperatives

One crop per season --> crop rotation of cereales than vegetables

Use of IPM (Integrated pest management

chemical) to get rid of the insects on maize fields.

Fertilizers :

Alternation of deep roots and shallow roots plantations so crop residue feeds the next rotation.

Use of chemicals/synthetic substances

+ manure

+ compost

CIP goals is to decreased mixed and intercropping as it loses productivity. Monoculture practices are promoted (easy irrigation, weeding, rows).

Before CIP : 2t/hectare

During CIP : 10t/hectare

Utilization of machineries : tractors, rotivators, seeding

Farmers routine :

Agriculture from monday to saturday (sunday for church and boutiques)

Early start to cultivate and livestock/grazing in the afternoon.

Cooperatives exports:

The african market is the main potential buyer for vegetables and beans export to guarantee fresh products.

Local big markets are two days a week.

Irrigation :

Pivot, drip, dam, gravity

Pumps from the Muvumba River where electricity stations are located as well.

The water river is very muddy and needs to be decantated before use.

During dry seasons, the riverbed levels go down and dry up.

Seeding:

Subsidies from the gouvernement to improve the seeds quality and accées to better products.

DNP, NPK seeds

Crop fertility:

Diagnosis is made first to identify if there is a decrease in organic matter or a change of color (the brigher the orange, the better)

Soils are sent and tested in laboratories.

Worms cultivation are utilized to decompose organcic fertilizers.

Crop lost:

After harvesting, there are many problems due to the irregular rains.

Techniques to mitigate such issues are employed

- temporary shelters
- maize cones
- maize hanged upside down to accumulate the water at the bottom
- topling-sheets covers to shelter or dr the maize post harvesting).

Annex 6 - Interview notes with Jean Baptiste Niyiregeka and Jean Paul Ndahimana. January

Function: Farmers

Field: Rice fields

Email: /

Phone number: +250 725 226 472

+250 788 231 105

Discussion translated with the help of Elder, recommended by John Kayumba

Irrigation - hose connected to the Muvumba River pump.

Problematics:

The heavy rainfall destroys the rice crops.

Sickness of seed.

Increase in salts, destroying the crops.

Social:

Meeting with the shareholders to discuss current problems.

Held every tuesday.

Annex 7 - Interview notes with Eugenie Umutoza. January 17th, 2024

Function: Farmer with her seven friends

Field: Maize and vegetables fields

Email: /

Phone number: /

Discussion translated with the help of Elder, recommended by John Kayumba

Irrigation - hose connected to the Muvumba River pump.

Sowing:

Tomatoes - beans - maize - cabbage

Monocultures

After the harvest, they are sent to Kigali and local markets.

Problematics:

She and her friends have noticed the change in climate and temperatures.

There is too much sun in august which dries the fields and the soil.

Tools:

Batons to weed out the last of the maize crop residue. Preparing the soil for the tomatoes seeds.

Social:

The elders of the town/village meet and discuss salaries as well.

Annex 8 - Interview notes with Emmanuel Hakizimfura and Suzan Nyirabahire. January 17th,

Function: Farmers

Field: Maize and soy beans fields

Email: /

Phone number: /

Discussion translated with the help of Elder, recommended by John Kayumba

Irrigation - none

Problematics:

The irregular rain soils the maize in January.

They have to wait for enough rain to sow the next sowing season.

Sometimes, it comes, sometimes it doesn't.

If there is no rain in march, the crops are destroyed.

Last year, they experienced no rainfaill and irregular rains.

They plant the maize and in between the rows, the beans.



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