
DAR

AFRICAN YO

The African Youth Development

Working towards Youth Developme

P.O. BOX 16464.
DAR-ES-SALAAM. TANZANIA.

TEL: 07

Email: africanyouth

TEL: 076

VIG 33

VIG 33

Bajaji tour: fuzzy streetcape DAR



Acknowledgment

Ten months of Master Thesis lie behind us and we are proud to stand the mental challenge of keep going and going and going… Through this time we have learned a lot about ourselves, each other, team work, Dar es Salaam and all the different topics directly related to our graduation topic. We are very grateful for the academic support of our mentors Frank van der Hoeven and Frits van Loon and external advisor Nathalie Jean-Baptiste, for the financial support for the fieldtrip from the Faculty of Architecture and the Built Environment, the University funds, the Department of Urbanism and the EFL stichting, for the institutional support during our fieldtrip at Ardhi University, for our laptops for not breaking down during the last phase before the final submission. We also want to thank our friends and families who did not get the attention they deserve and still dealt with our mood swings without complaining. We are excited to start the next chapter of our lives with daylight and weekends, a Master degree and lots of experiences richer than a year ago.

TU Delft BK Bouwkunde

Urbanism

TU Delft | Universiteitsfonds

EFL STICHTING



Abstract

The biggest city of Tanzania, Dar es Salaam, faces increasing flood risk, causing frequent sickness, loss of life, and widespread damage to property. Dar es Salaam is one of the fastest growing cities in the world. More than 70% of the residents live in informal settlements. Many of them are located in flood prone areas like river valleys and floodplains, which flood annually. Because of their limited coping capacity, residents are not able to recover from the impacts of this flooding. Due to the change of precipitation patterns, the flood risk is likely to increase in the future, putting even more people and assets at risk during more frequent and intense floods. This graduation project seeks to answer the main research question: How can urban form and landscape help to mitigate the effects of floods on citizens in Dar es Salaam, Tanzania?

For areas with a high density of buildings, multifunctional courtyards are proposed. The existing building structure is strategically densified, and filled with new buildings to shape courtyards. Inside, a variety of interventions reduce the water run-off into the river valley, treat waste water and generate income via urban agriculture and aquaponic systems. For the river valley the construction of “chinampas” is being proposed, which creates a high retention capacity for storm water while enabling agricultural activities and connectivity across the river valley throughout the wet and dry seasons. At the edges of the valley, different interventions are located in order to reduce and clean run-off water before entering the valley. The combination of spatial interventions to reduce the flood risk with urban agriculture reduces the impacts and increases the ability of residents to deal with future hazards.

The design proposals are supported by a implementation strategy and complimenting policies which reduce pollution, steer future urban development and introduce new renting models to host a higher diversity of lifestyles with different economic abilities.

Keywords: Africa, Tanzania, informal settlement, flood design, urban agriculture, climate change, sustainability



Content

p.10 - Introduction
analytical framework / methodology / research question / timeline

p.18 - General analysis
global perspective / main problems / problem statement / design goal

p.28 - Problem analysis: rapid urbanisation
(in)formality / growth / urban development / typologies

p.36 - Problem analysis: water
river basin / water system / flooding

p.46 - Problem analysis: no coping capacity
reaction chain / negative housing cycle / negative water cycle

p.56 - Location selection
flood risk / transferability / proximity

p.60 - Location analysis
social institution / infrastructure and connectivity / flood risk / landscape / river basin

p.78 - Plant analysis
trees / fruit and vegetable / fish / plants / wetland plants

p.92 - Beke-Marleen Hörmann
introduction / analysis / concept / courtyard system / courtyard design

p.144 - Mona zum Felde
introduction / analysis / intervention / chinampa design

p.196 - Implementation strategy
river basin strategy / strategic masterplan / timeline / stakeholders / policies / cable car

p.212 - Reflection
design interaction / design reflection / individual reflection

p.222 - Academic frame
conclusion / relevance / ethical issues / motivation / theoretical framework / abstracts

p.230 - Bibliography
table of maps / table of figures

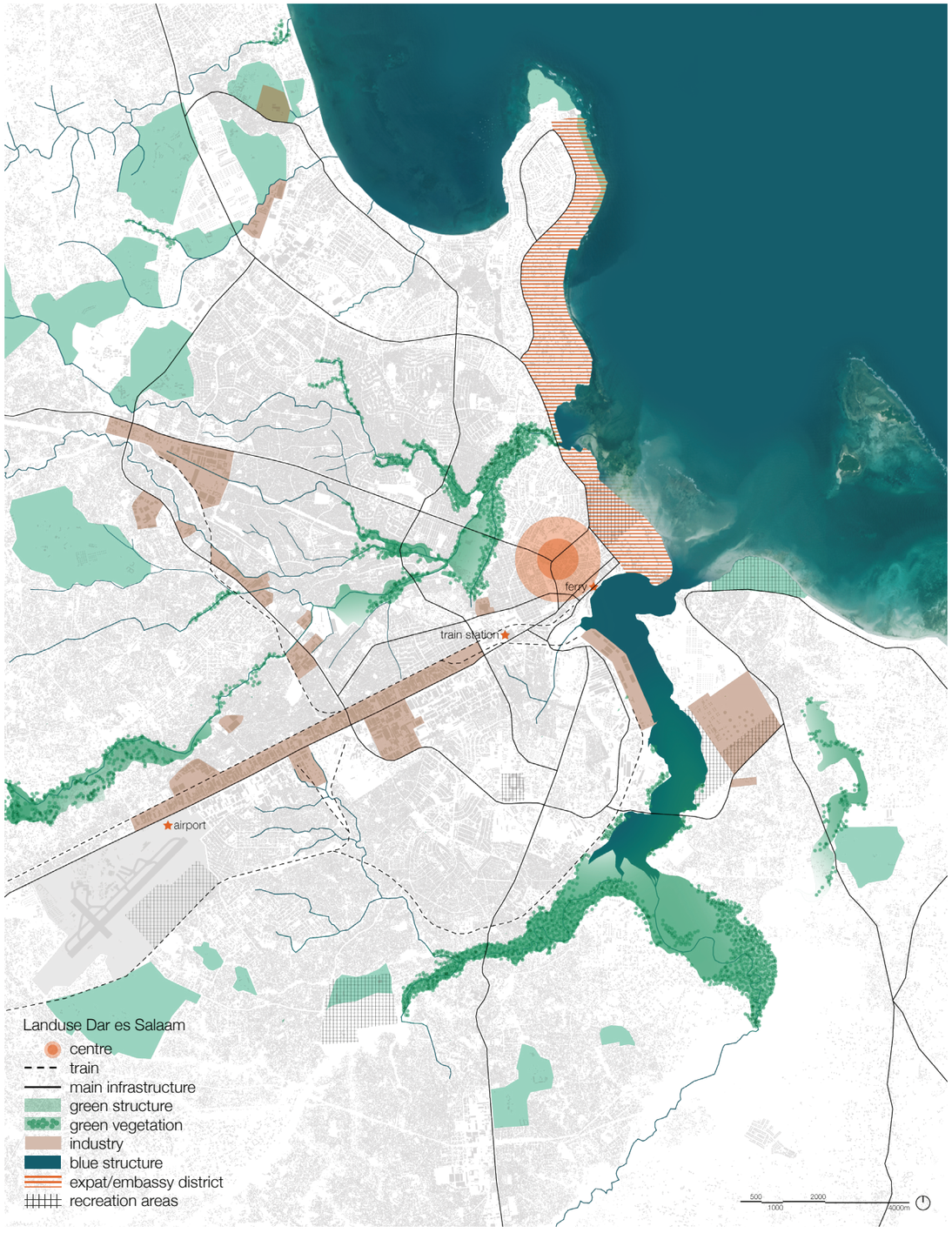
p.236 - Annex
spatial analysis / vulnerability / theory papers





Introduction

analytical framework / methodology
/ research question / timeline



Dar es Salaam is the biggest city of Tanzania and one of the fastest growing cities in the world. This rapid and unplanned urbanisation results in informal settlements and urban sprawl. At the same time, the city is highly vulnerable to the effects of climate change, such as sea level rise, temperature rise and changes in precipitation patterns. The trends of rapid unplanned urban growth and climate change amplify each other, which increases the occurrence and intensity of floods. These hazards have a huge impact on the physical, social, ecological and economic environment of citizens and therefore on their health and well-being.

While climate change is the main cause of more frequent and more intense rainfall, the consequences of unplanned urbanization massively amplify the impact of these historically large floods. Over time, people moved close to flood zones such as river valleys, which periodically flood. This brings many people and their properties at risk. The infrastructure of the city does not have the capacity to deal with stormwater. The lack of sewage and waste collection increase the problem and also cause a high level of pollution. The latter is problematic, because residents come in contact with polluted water and in some cases even use it as source for drinking water, which has implications for their health.

This graduation project aims to present urban design solutions which reduce the flood risk and create coping capacities for local residents. Hence the main research question is formulated as follows: “How can urban form and landscape help to mitigate the effects of floods on citizens in Dar es Salaam, Tanzania?”

This report is structured according to our analytical framework (see p. 16). The general analysis is being concluded with the problem statement and the formulation of a design goal. The steps from the problem analysis until the location analysis provide necessary information and knowledge for the design phase. After the explanation of the individual design proposals, a common masterplan and timeline show a possible strategy for the implementation of the designs.

The city of Dar es Salaam is divided into five administrative districts, namely the old districts Kinondoni, Ilala and Temeke and the recently added districts Ubungo and Kigamboni (Mhagama, 2016). Each of these districts is further subdivided into wards and sub-wards, locally called Mtaas (Pauleit et al., 2015, p. 13). The land use map (see p. 12) shows the central and most dense area of the city of Dar es Salaam. It gives a brief overview of the cities’ main structure, important areas and points for orientation.

The city centre is also the historic starting point of the city. Starting as a fishing village in the 19th century, a new city was built by an arab sultan in the 1860s. In the late 1880s the city became a German colony until it was taken over by the British empire during World War II. The city only became independent in 1961 (World Travel Guide, 2018).

The expat area stretching from the city center towards the peninsula along the coastline is the location of many embassies and international organisations and companies. The international and domestic airport of Dar es Salaam is located in the west of the city and is connected with the city center by an industrial corridor along main infrastructure. There are many rivers and creeks throughout the city, which is also guiding the green structure of the city.

analytical framework

To structure the research and design of this project, an analytical framework (see p. 16) has been developed. The framework contains several steps, starting with a general analysis describing the problem fields addressed by this thesis. After defining the problem statement and design goal, it continues with a problem analysis. With the input of the analysis, the common intervention location has been selected. The process results in the production of two individual designs as well as a common implementation strategy, which is based on the finding of the previous analyses of the common intervention location and the individual design locations.

All parts of the analytical framework are linked to applied methods as well as to sub-research questions which will be (partially) answered. A description of the methods and an overview of the research questions can be found on the following pages.

The basic structure of the analytical framework is linear, however different parts of the framework influence or give input to other elements in a non-linear way. Some steps of the process happen simultaneously and after every new finding or newly appearing question, previous findings will be revised.

This organization of this report is based on the structure of the analytical framework, in order to build up the story of Dar es Salaam and its problems. This report contains all the steps until the selection of location.

methodology

The different methods have been linked to steps in the analytical framework and different research questions (see p. 15), in order to gain knowledge, inspiration and create a design focus. These methods are further explained in the following paragraphs.

Literature research

The sub-research questions 1, 3, 4 and 5 can be (partially) answered by reviewing different kinds of literature. In the initial phase of the project, web research has been conducted in order to get an overview of relevant discussions, activities and new related to the research topics. A scientific basis has been developed based on publication of previous research about climate change and flood risk, problems and solutions. Reports about current projects, research and policies were used to deepen the understanding of the local problems in Dar es Salaam and get an overview about activities in the past, present and future.

Mapping

To get a better understanding of the local spatial situation in Dar es Salaam, and to answer the sub-research questions 2 and 3, mapping will be used as a method. Areas at risk for floods will be mapped based on information from literature about climate change for sub-research question 3.

The first part is based on inventory mapping, to summarize current (spatial) conditions and. This is followed by conclusion mapping, combining the information from other sources with those of the inventory mapping. This will indicate correlations and systems, leading to certain conditions or outcomes. The third mapping method is explorative mapping. This will mainly be used during the design phase in order to test ideas and detect new findings. This mapping method is strongly related to the method of research by design.

Site Visit

A site visit will respond to sub-research questions 2, 3, 4 and 7 and will also help to get a better understanding of the place. During the site visit, photographing, sketching, mapping and taking notes will be part of the process and the documentation of observations and findings.

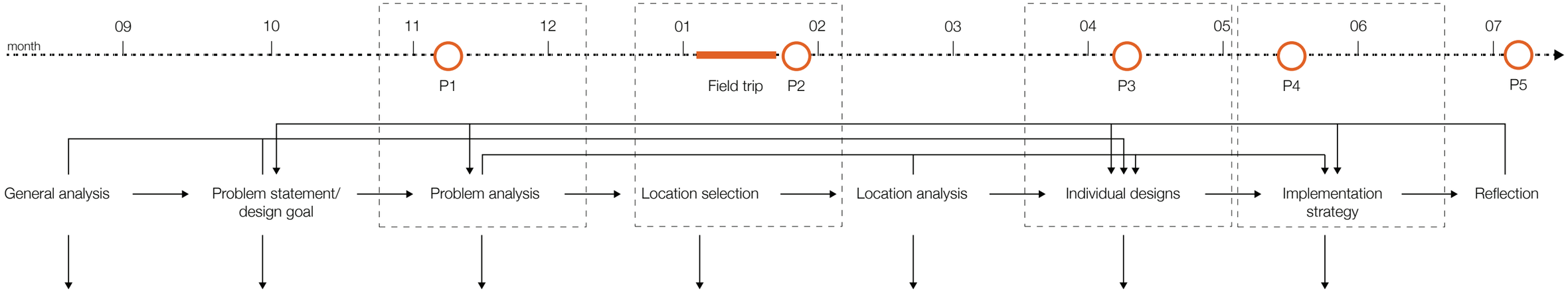
Research by Design

To find possible answers to sub-research question 5, 6, 7 and 8, research by design is an important method to test possibilities and explore other options and ideas simultaneously. This will also help to understand impacts and possible outcomes of design interventions.

research question

Main research question:
How can the urban form and landscape help to mitigate the effects of floods on citizens in Dar es Salaam, Tanzania?

Sub research questions:
1. What are the main causes for floods in DAR?
2. Which areas are the most at risk for flood events and what is their dominant urban form?
3. What are the consequences and effects of floods on the population of DAR?
4. What is the local urban form and human behaviour and how do they currently deal with flood risk?
5. How can we mitigate the effects of floods on existing urban form and their citizens by improving landscape and building local resources?
6. How can the existing urban form be integrated in flood risk adaptation?
7. How can a shift in human behaviour contribute to create coping capacity and adapt to changing climate conditions?
8. What are the benefits of the spatial transformation for local residents?



Method:
Literature research
Mapping

Research question:

1. What are the main causes for floods in DAR?
3. What are the consequences and effects of floods on the population of DAR?

Method:
Literature research
Mapping

Method:
Literature research
Mapping
Site Visit

Research question:

1. What are the main causes for floods in DAR?
2. Which areas are the most at risk for flood events and what is their dominant urban form?
3. What are the consequences and effects of floods on the population of DAR?
4. What is the local urban form and human behaviour and how do they currently deal with flood risk?

Method:
Mapping
Site Visit

Method:
Literature research
Mapping
Site visit
Research by design
Interview

Research question:

2. Which areas are the most at risk for flood events and what is their dominant urban form?
3. What are the consequences and effects of floods on the population of DAR?
4. What is the local urban form and human behaviour and how do they currently deal with flood risk?

Method:
Case study
Site visit
Research by design

Research question:

5. How can we mitigate the effects of floods on existing urban form and their citizens by improving landscape and building local resources?
6. How can the existing urban form be integrated in flood risk adaptation?
7. How can a shift in human behaviour contribute to create coping capacity and adapt to changing climate conditions?
8. What are the benefits of the spatial transformation for local residents?

Method:
Research by design

Research question:

8. What are the benefits of the spatial transformation for local residents?

Fig. 01: Analytical Framework & time planning. Own drawing.





General analysis

global perspective / main problems
/ problem statement / design goal



Changing Climate Conditions

Changes in climate have always been part of the lifecycle of the earth and are to some extend natural (UNISDR, 2009). There have always been warmer or colder, dryer or wetter periods. However, what scientists are widely discussing in the past decades is the speed and the extent of change, which is caused by human activity like urbanisation, deforestation, greenhouses gases and intervening in ecological systems (Gasparini et al., n.d.). “Climate Change” itself became a term based on this fast and extreme changes and the consequences for the planet resulting from them.

The effects of climate change are diverse and include among others changes in temperature, precipitation patterns and extreme weather events. These consequences will occur in the short-term, like “increasing frequency and severity of extreme weather events” (Pauleit et al., 2015, p. 18), and the long-term, like “sea level rise, falling groundwater tables and increasing desertification” (Pauleit et al., 2015, p. 18). Countries in Africa will be affected the most by climate change (see Fig. 02). Coastal zone areas, where most big African cities are located, are exposed to multiple hazards (see Fig. 03) which will be exacerbated by climate change (Pauleit et al, 2015).

East Africa will mainly face three effects of climate change, which are closely linked to each other. First, rising temperatures will cause a rise of sea level, which raises the risk of flooding in low lying coastal zones, where the majority of inhabitants are located. Second, an increase in rain intensity and frequency will cause more floods around rivers and in urbanized areas with inadequate water discharge. Third, an increase in temperature and an increase of heat waves will intensify the urban heat island effect, although heat waves are a bigger problem in the inland than in coastal areas (Gasparini et al., n.d.; Pauleit et al., 2015; Sudmeier-Rieux et al. 2017).

Division Global North/South

The Cambridge Dictionary (2017), defines developing countries as countries with “little industrial and economic activity” and “low incomes”. When talking about these countries, the term *global south* is often used, which is based on the model of a north-south division described by Brandt in 1980. In the report ‘*north-south: a program for survival*’, Brandt states that there is a geographical division, in which the global north is affiliated with wealthy and developed countries, while the south is mostly affiliated with countries which are underdeveloped and suffer from poverty (Rigg, 2007, p. 3).

The African continent consists of 54 countries of which all are classified as developing countries and more than half of them even belong to the group of the least developed countries of the world (United Nations, 2017).

African countries are facing a broad range of social, ecological and economic challenges. Currently 40% of the African population lives in cities, but this number will rise in the future due to the ongoing rural-urban migration. Therefore, the cities keep growing, mostly in the form of urban sprawl, which leads to more pollution and loss of biodiversity. The growth of the urban areas happens at such a high rate that makes it impossible for the economy to keep up. Local governments are unable to enforce zoning plans or provide infrastructure and services for new neighborhoods, whic are mostly informal (Pauleit et al, 2015).

Tanzania is rated as one of the least developed countries of the world (United Nations, 2017). Like many other developing countries, it has to deal with “economic and social development limitations” (Mirza, 2003, p. 236) as well as the “world’s highest urbanisation rates” (Niang et al., 2014, p. 1224). The restricted economic abilities of the country negatively influence the investment capacity for “social protection and climate change”, while the effects of climate change are the highest on the African continent (see Fig. 04) (United Nations, 2017, p. 5).

The latter is particularly a problem, with the increase of hazard events caused by climate change. This exposes a high number of people and economic activities to risks and increases the existing problems mentioned above. This could set back the country even further, when effects of climate change, like sea level rise and extreme weather events, continue to damage social and physical infrastructures of the country without the establishment of sufficient coping mechanisms (Pauleit et al., 2015).

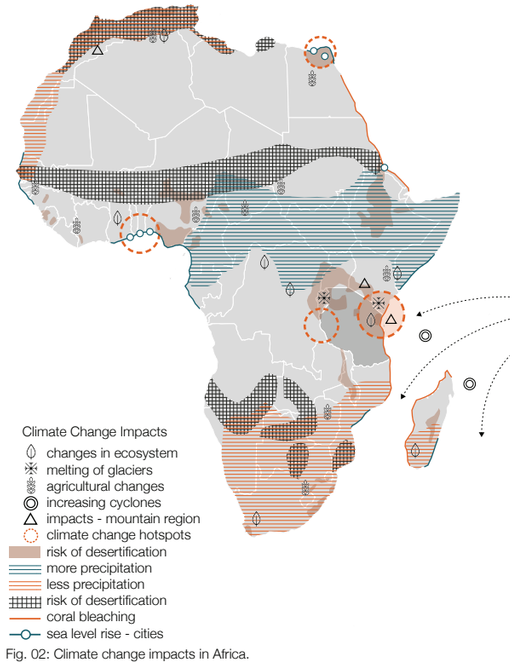


Fig. 02: Climate change impacts in Africa.

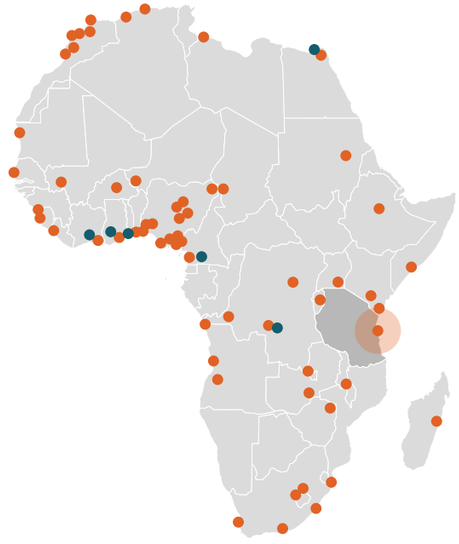


Fig. 03: African cities exposed to hazards.

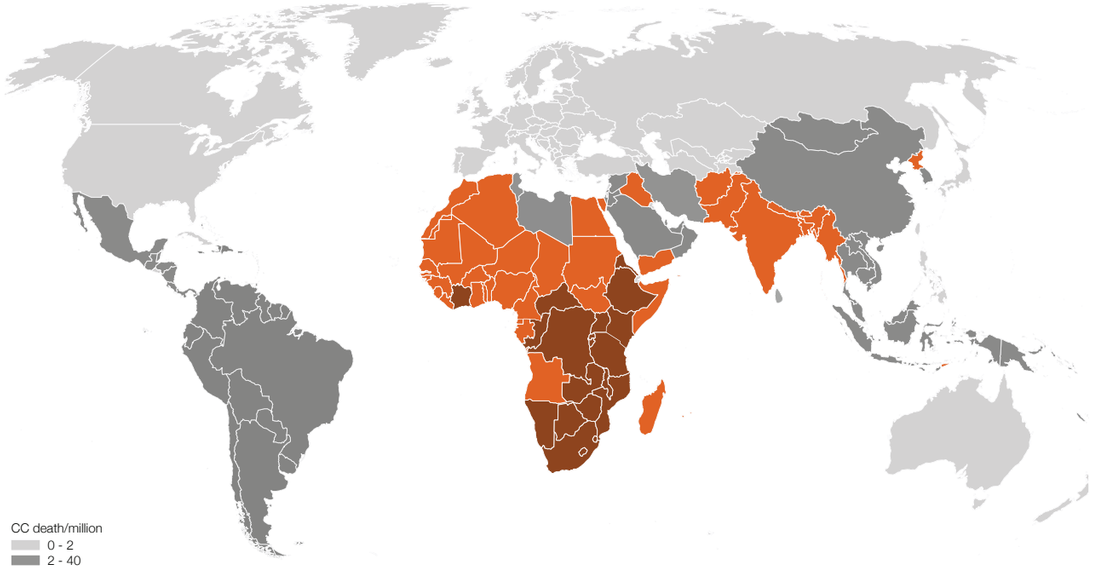


Fig. 04: Climate Change related deaths worldwide.

Rapid Urbanisation

With more than 4,5 million inhabitants Dar es Salaam is the biggest city and economic capital of Tanzania (Auswärtiges Amt, 2017). It is located in the east of the country on the coast of the Indian ocean. Tanzania is one of the least developed countries in the world with a low urbanisation rate of about 40% (United Nations, 2017). The ongoing strong rural-urban migration, catalyzed by climate change impacts in rural areas, results in a rapid and unplanned urbanisation and makes Dar es Salaam with an urbanisation rate of 6,6% (UN-Habitat, 2014, p. 150) one of the fastest growing cities in the world (Pauleit et al., 2015, p. 13; UN-Habitat, 2014; World Bank, 2017a).

While the city is growing rapidly, the economic growth as well as the urban management are unable to keep up with the same speed. This leads to a number of problematic consequences for the city, its urban form and its population. New inhabitants create a continuously rising demand for housing and services, which the city is not able to provide in the necessary speed or at a cost that is accessible for the people in need. Development projects of the government only address the needs of wealthier population groups (Niang et al., 2014; UN-Habitat, 2014). As a result, those migrants who are not able to afford provided housing, which is the majority, settle in informal areas which are located in high risk areas. These areas, which houses 70% of Dar es Salaam's residents, are more prone to hazards, lack infrastructure and services and the quality of housing is extremely low (John, Kombe & Mayunga, 2012). Simultaneously, the rate of un- and underemployment in informal settlements is with 75% extremely high (John, Kombe & Mayunga, 2012), because new job opportunities cannot be created at the same speed as new migrants are moving to the city (Pauleit et al., 2015).

Water

Worldwide, floods, which are hazards resulting from nature and human activities, are the most frequent disasters. Effects from climate change, like sea level rise and increased precipitation, as well as consequences of the ongoing urbanisation, like the deterioration of the natural water flow, water run-off and sealed surfaces preventing seeping of water, will increase the risk of flooding. Not only will the occurrence and intensity of floods increase in the future, but also the damage caused by floods because of the severity of floods and the rising number of people living in flood prone areas (Gasparini, DiDuocco & Bruyas Amra, n.d., p. 8; Pauleit et al., 2015; Sudmeier-Rieux et al., 2017).

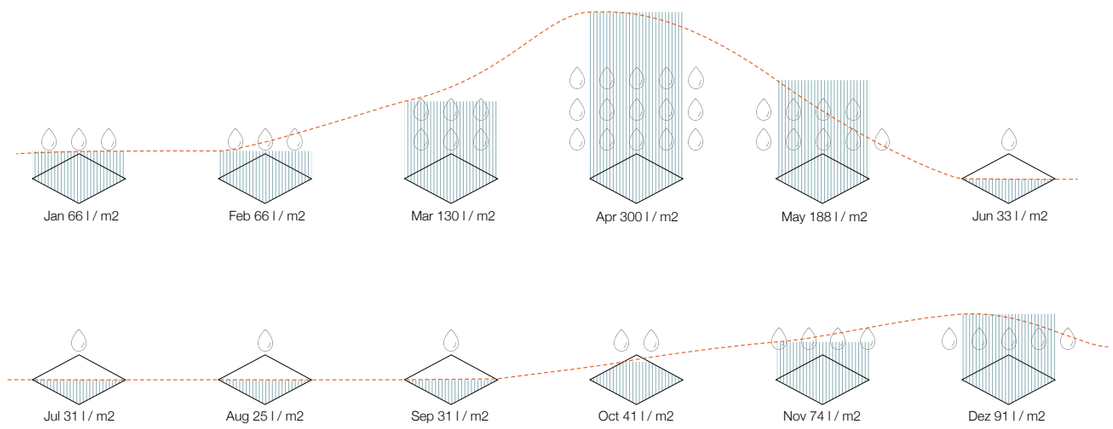


Fig. 05: Monthly rainfall Dar es Salaam. Own drawing.

Also in Dar es Salaam, water is a sensitive issue in different aspects. Mostly during the two rain seasons, the big one between March and May and the small one between November and December (see Fig. 05), the city is regularly hit by floods. Depending on their severity, they destroy livelihoods and bring residents in danger. During an extreme flood in 2011 several people even died (Pauleit et al., 2015, p. 19). There are different factors which contribute to an increase of flood intensity and occurrence as well as to an increasing impact of floods.

One factor is the impact of changing climate conditions. Precipitation is currently the main cause for floods in Dar es Salaam. Future climate projections show an increase in precipitation patterns, which will increase the occurrence and intensity of floods even more (Gasparini et al., n.d.; Pauleit et al., 2015). But also sea level rise and strong winds from the ocean contribute to a higher flood risk (Pauleit et al., 2015; UN-Habitat, 2014).

Another factor contributing to the increased risk of flooding is the ongoing urbanisation process, besides the contribution to climate change as mentioned above. The increase of sealed surfaces due to urbanisation, results in an increase run-off towards the river valleys, as there are no surfaces to intake or spaces to temporarily store water. At the same, people move further towards - and even into - the river valleys into informal settlements, because the city is not able to provide affordable housing in the required speed and amount. Conclusively, residents are occupying spaces which are by nature supposed to flood. This reduces the space for stormwater and puts more people and assets at risk. People settling in these flood prone areas are usually the poorest of the urban community. These people do not have the necessary coping capacities to face and deal with floods, which increases the danger and the impact (Gasparini et al., n.d.).

A secondary consequence of the rapid and informal urbanisation is the lack of infrastructure and services. The water and sewage network is not comprehensive in Dar es Salaam. Almost half of the households do not have access to piped drinking water, which means that they have to use open and publicly accessible sources. At the same time only 10 percent of households are equipped with a sanitation connection, which is why most of the wastewater is directed unfiltered into open water. This aggravates pollution of soil and water bodies which are used as drinking water sources for people without access to piped water, dangerously increasing the risk of diseases and epidemics and bringing human health at risk (Niang et al., 2014, p. 1222; Pauleit et al., 2015, p. 82-86; UN-Habitat, 2014, p. 168).

The availability and accessibility of clean drinking water in Dar es Salaam is unstable and insufficient and can further be jeopardized by heat waves and drought periods. These occur primarily in the hinterland of Tanzania, but also occasionally in coastal zones and urban areas. Dar es Salaam is not only affected by local droughts, but also by the droughts in the hinterland. Insufficient water flows compromises the hydroelectric electricity production, which feeds the urban electricity network. A water shortage in the rural areas threatens local and regional food supplies and can result in a greater rural-urban (climate) migration, bringing even more people to Dar es Salaam (Gasparini et al., n.d.; Niang et al., 2014, p. 1225; Pauleit et al., 2015; UN-Habitat, 2014).

No Coping Capacity

Coping Capacity is defined as "the ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters." (UNISDR, 2009). Together with fragility and exposure it dictates the vulnerability of an area or community (Gasparini et al., n.d., p. 19), which is defined as "the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard" (UNISDR, 2009). If the exposure and fragility is high, while there are no coping capacities, then the vulnerability is high. This means in return that when exposure and fragility are low but there are many coping capacities, then the vulnerability is low. This indicates the impact of a hazard. Even a mild hazard can have a dramatic impact in a highly vulnerable area, while an area with low vulnerability can easily cope with it and the daily life is only slightly interrupted (Pauleit et al., 2015, p. 26).

EXPOSURE + FRAGILITY + NO COPING CAPACITY

= VULNERABILITY



Dar es Salaam is the biggest and fastest growing city in Tanzania, one of the least developed countries of the world. Like other countries on the African continent, Tanzania experiences negative effects of the changing climate conditions, like rising sea level, heat waves and especially changes in precipitation patterns, resulting in more frequent and more extreme floods in coastal areas and droughts in the hinterland of the country.

At the same time, the city of Dar es Salaam faces several additional problems. Rapid urbanisation processes confronts the city with a big amount of new inhabitants which the government is not able to accommodate formally. As a consequence, new residents settle in informal settlements, mostly located in high risk areas prone to flooding. They don't have access to infrastructure, services or formal jobs.

Influenced by the changing climate, rapid urbanisation and the lack of infrastructure, problems related to water are rising as well. The occurrence and intensity of floods becomes more extreme while more people live in high risk areas. These risk areas are mostly occupied by informal settlements, which do not have access to infrastructure or services, which is why sewage water is directed unfiltered and untreated into open water bodies, together with high amounts of solid waste. As a consequence, water and soil, which are also used for drinking water and urban agriculture, are highly polluted. While coastal areas around Dar es Salaam mostly face problems related to too much or dirty water, the hinterland of Tanzania will also face more heat waves and associated drought periods in the future, leading to electricity shortages and increase the rural-urban migration.

While a rising number of residents in Dar es Salaam are exposed to hazards, they lack necessary coping capacities. Therefore, they are not able to deal with or recover from such impacts, which makes them extremely vulnerable.

design goal ◀

The design aims to show potentials for a possible transformation of the intervention area for the coming 30 years, which reduces the flood risk and creates coping capacities for local residents. This shall trigger a discussion between local stakeholders and planners to implement proposed interventions in a balanced approach between top-down and bottom-up.

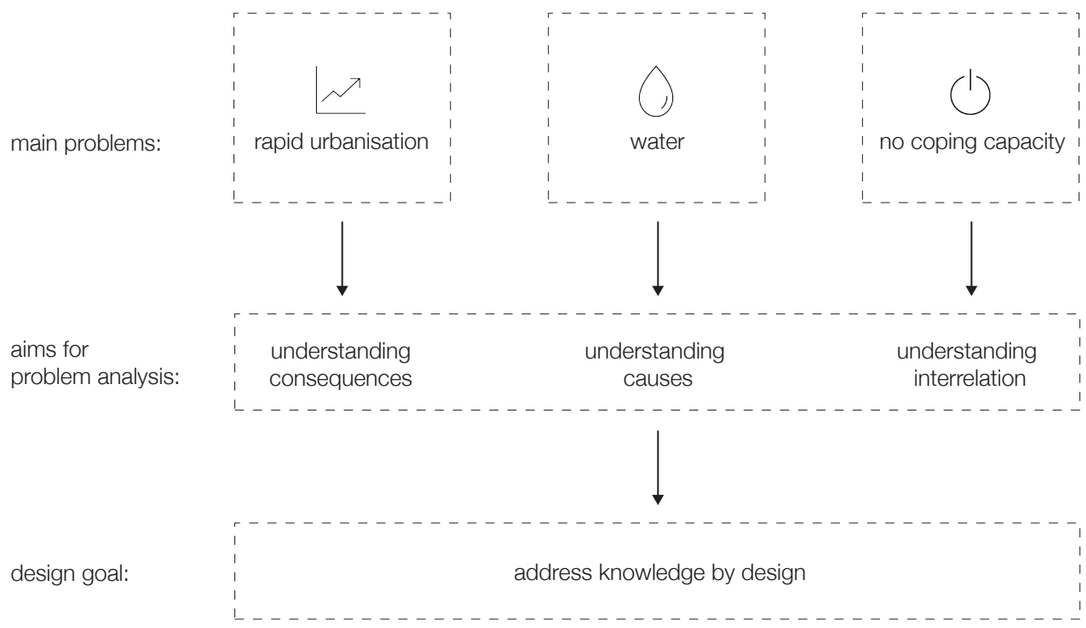


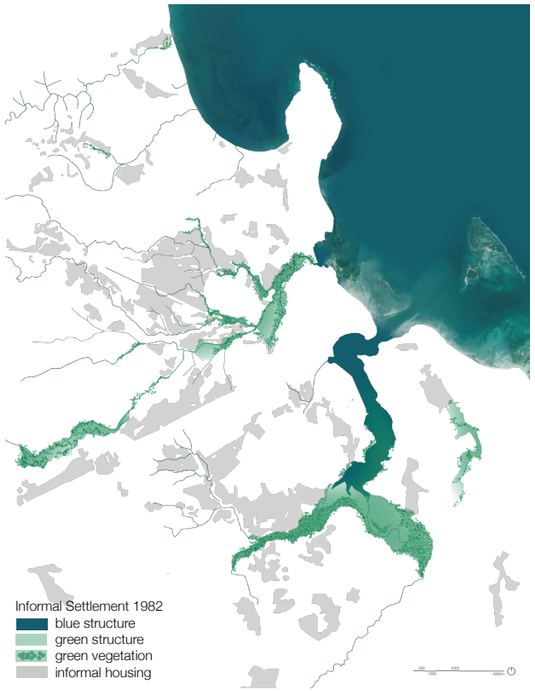
Fig. 06: Relationship between main problems and aims. Own drawing.

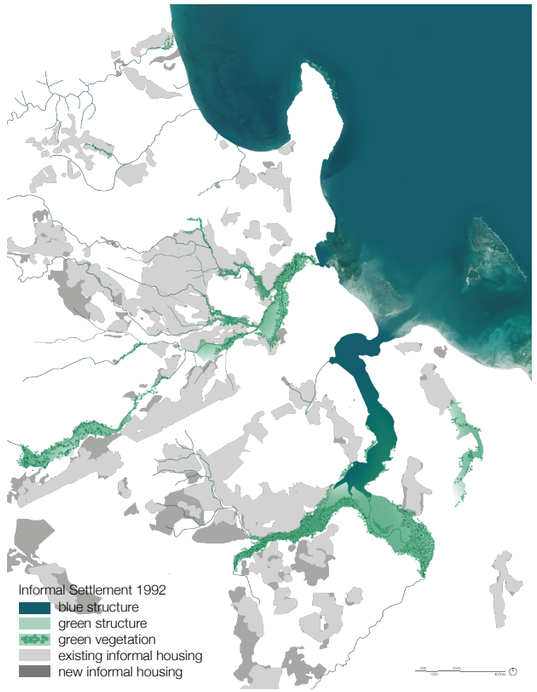


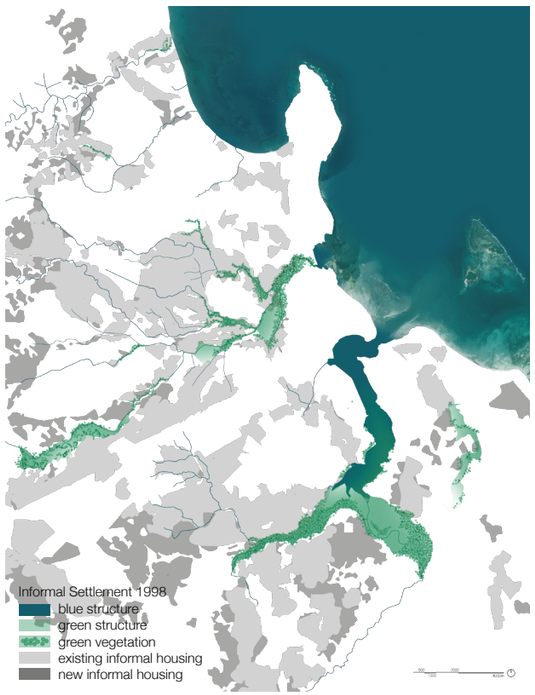


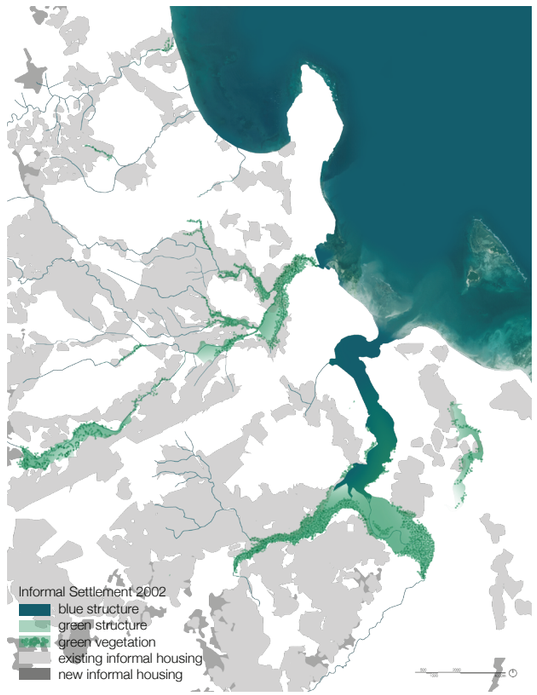
Problem analysis: rapid urbanisation

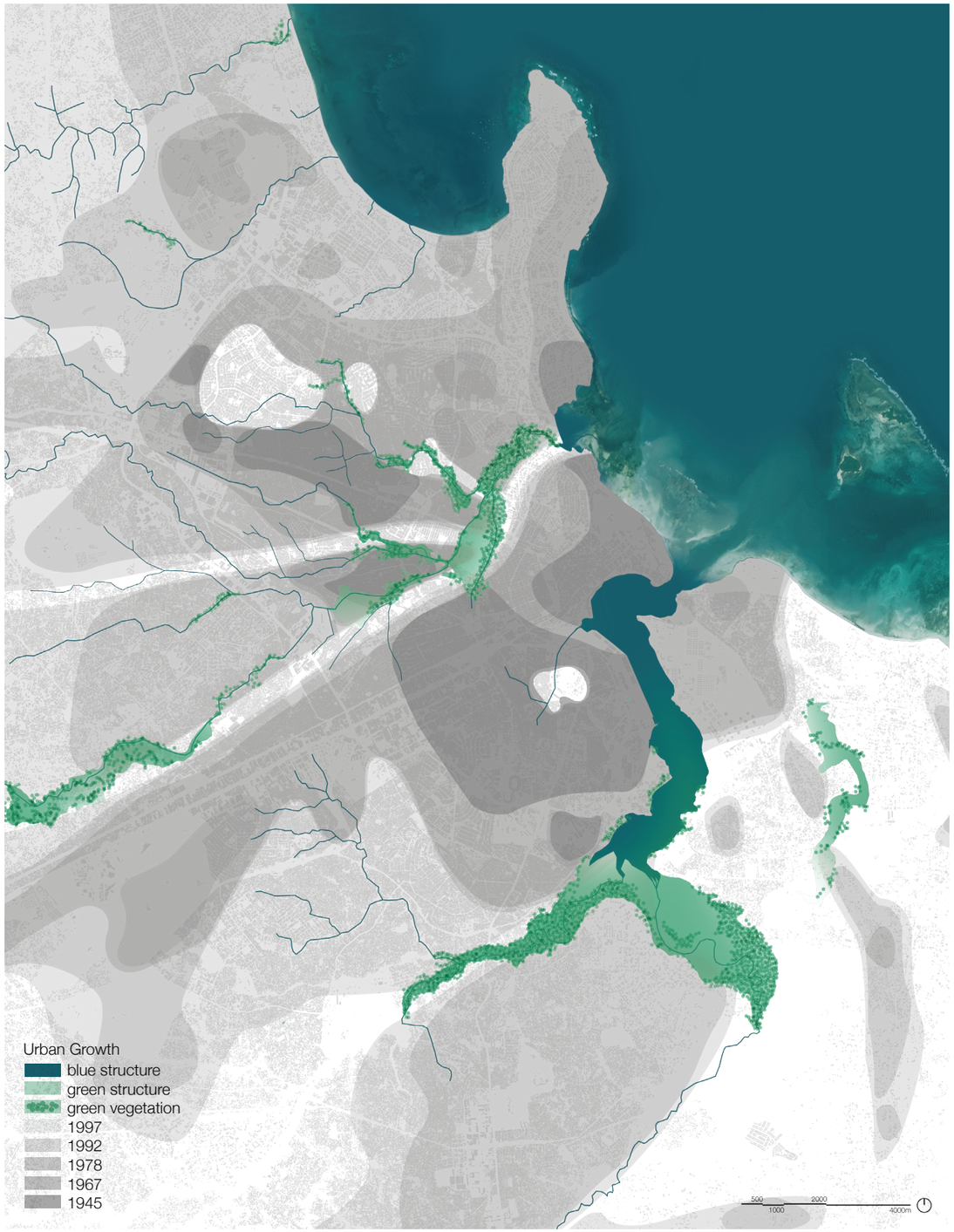
(in)formality / growth
/ urban development / typologies


Informal Settlement 1982
blue structure
green structure
green vegetation
informal housing


Informal Settlement 1992
blue structure
green structure
green vegetation
existing informal housing
new informal housing


Informal Settlement 1998
blue structure
green structure
green vegetation
existing informal housing
new informal housing

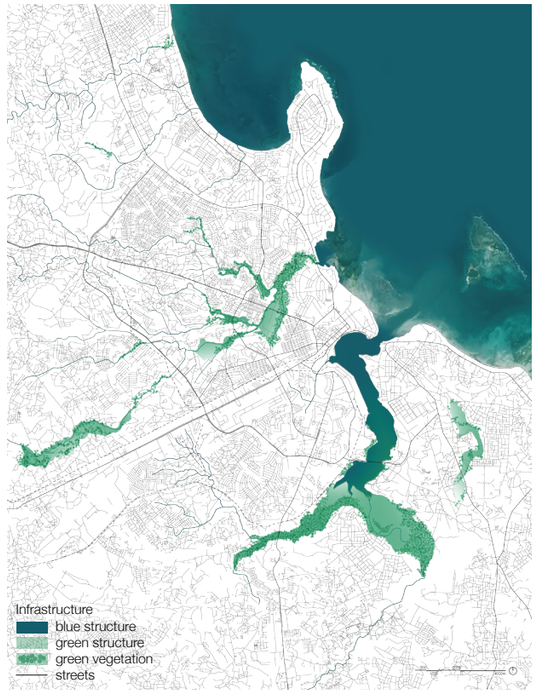

Informal Settlement 2002
blue structure
green structure
green vegetation
existing informal housing
new informal housing

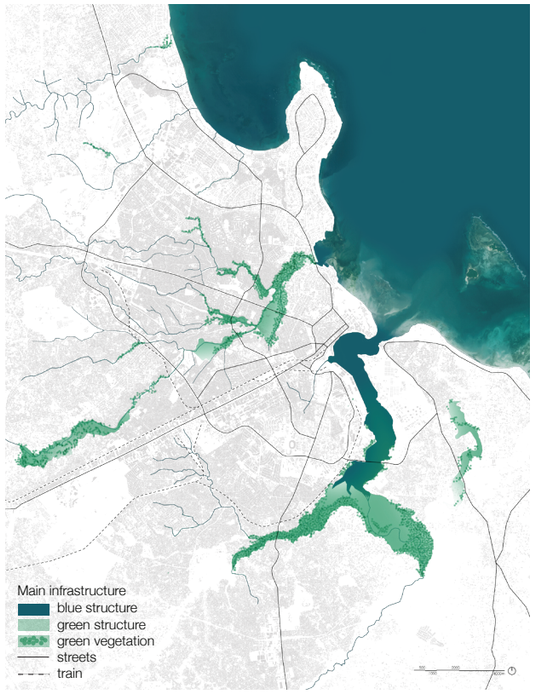

Urban Growth
blue structure
green structure
green vegetation
1997
1992
1978
1967
1945
500
1000
2000
4000m

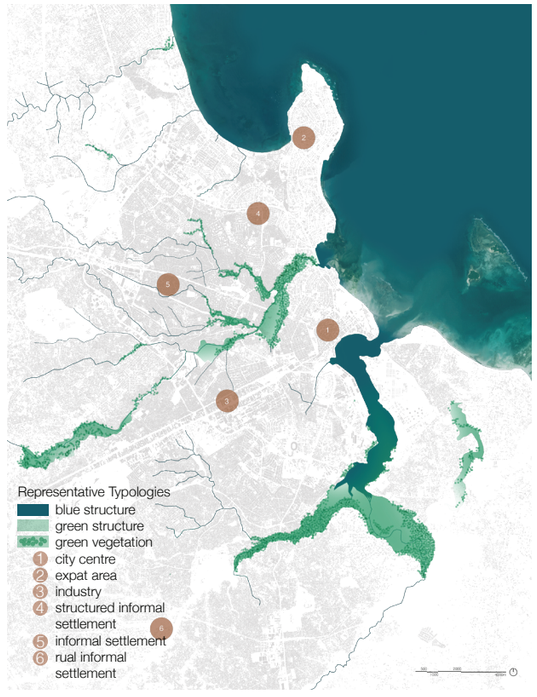
Dar es Salaam has its origin in the coastal area and expanded over time away from the coast (see p. 31). Earlier settlements were located in safe distance to river valleys and were therefore safe from flooding. Only with the rapid urbanisation and the rising demand for space in central areas, especially during the last 20 years, the city started sprawling at the outskirts and people moved closer and closer towards the rivers within the city. These new settlements are mostly informal (see p. 30). The planning system of the city was unable to keep up with the speed of growth and therefore could not provide sufficient affordable living areas. Furthermore, the proximity to the city center, which provides jobs, facilities and services, attracted new residents to settle in informal settlements in the flood areas of the river valleys, because they were unoccupied and therefore affordable.
The government tries to reduce the pressure of spatial demands in the city by developing six satellite cities around Dar es Salaam. These developments are being criticised, because they only focus on the highest market segment and do not provide space affordable housing (UN-Habitat, 2014, p. 150).
The road network of Dar es Salaam is irregular in form and density. In the city center and on the peninsula, the road structure is very regular, following a grid. The area north-west of the center is extremely dense, while there are much fewer roads in the south. The road network also contains different hierarchies. There are a few main radial streets leading from the center out of the city. They main roads who connect there radial streets with each other shape a ring road around the central area of the city. There are only very view bridges who cross the rivers which are running through the city, creating bottlenecks for traffic.
Dar es Salaam is characterised by a very diverse urban form. Six different typologies have been identified, which are the most dominant throughout the city. The areas highlighted in the map (see p. 33) are representative for these typologies. They are categorised according to the arrangement of buildings, building heights and form, infrastructure and surface structure.

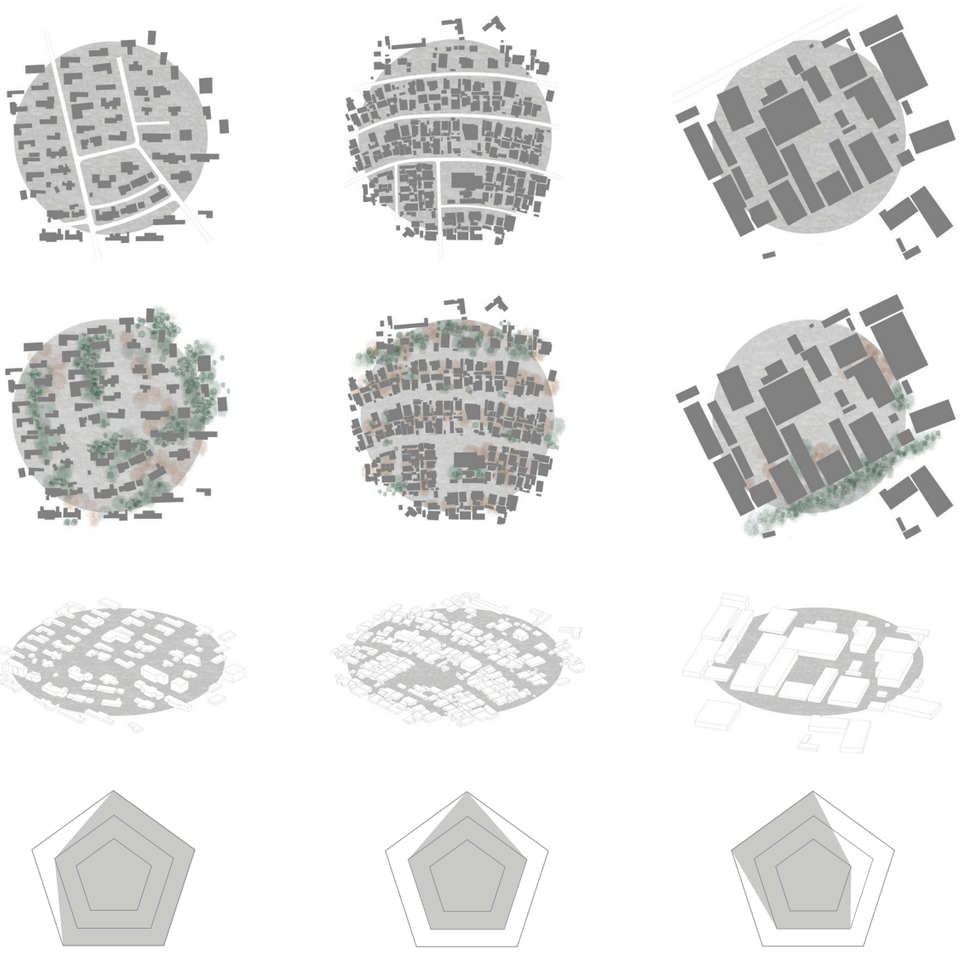
The first typology is the ‘city center’, named after its location. It is organised in a grid structures which directs the development of building blocks. This area is very dense and has mostly multiple story buildings. The second typology is the ‘expat area’, mostly present on the peninsula. A wide grid structure divides big private properties with single houses with mostly one to three stories on it and a lot of private green. Third is ‘industry’, characterised by big scale structures with a large footprint. The in-between areas are very functional to serve the industrial needs and infrastructure is adjusted to transport by cars and trucks.

The ‘structured informal settlement’ contains much smaller buildings which are mostly one or two stories high. Road structures are readable and access the first row of houses, though behind this first row, buildings start to be arranged in a less structured way. Because this typology is informal, it does not provide formal services and infrastructures like water, electricity and sewage. The ‘informal settlements’ became more and more dominant in the last decades within the city. They are much more difficult to read because they do not provide a road network. The single story buildings have a large footprint and are mainly accessible by foot. No formal infrastructure and services can be found in these areas as well as very little green spaces. The ‘rural informal settlement’ is comparable to the previous typology, with the difference that the building footprint is much smaller and therefore the green and unbuilt surfaces are much more dominant. This typology shapes the majority of the outskirts of the city.





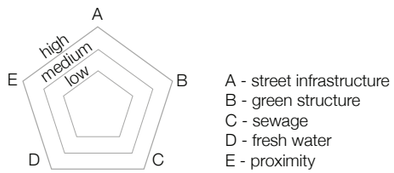




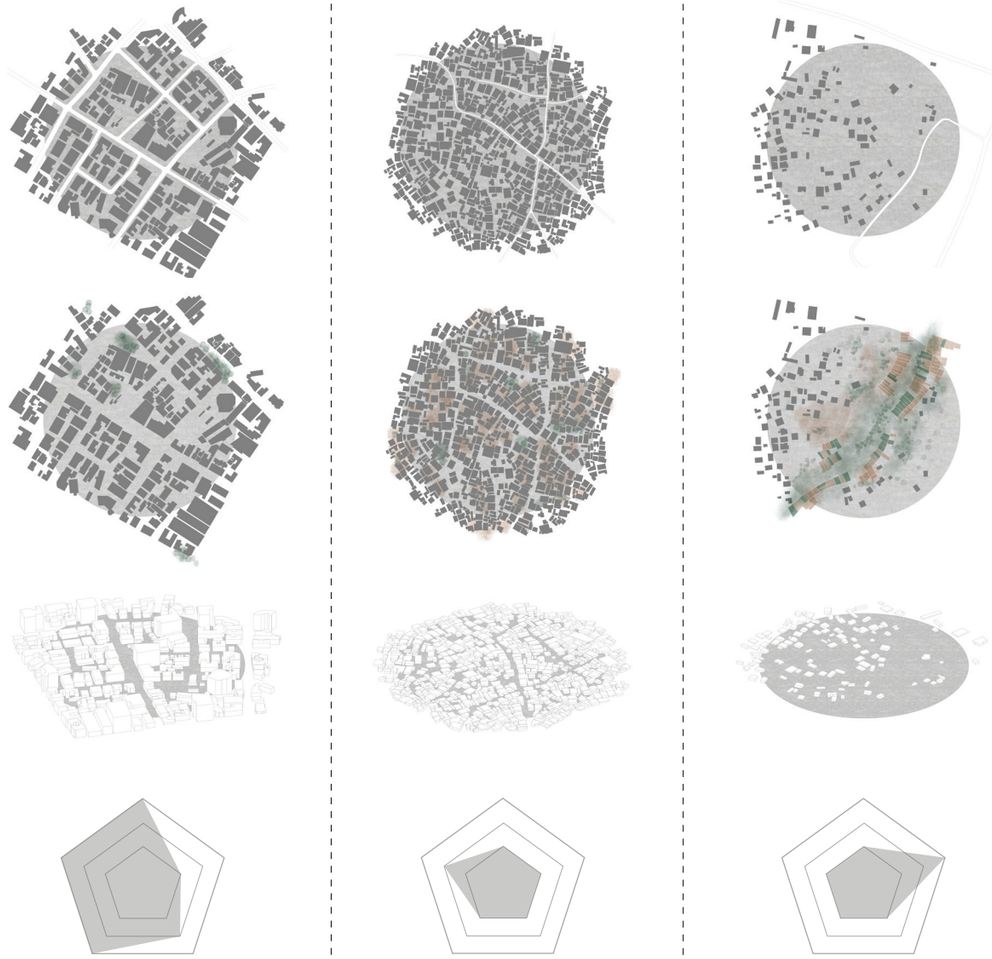
1. expat

2. planned
informal settlement

3. industry



A - street infrastructure
B - green structure
C - sewage
D - fresh water
E - proximity



4. city centre

5. informal settlement

6. rural
informal settlement

Conclusion:
the typology evaluation shows the lack of infrastructure, green structure, sewage, fresh water and proximity in the informal settlement. Further analysis will focus particularly on informal structures and will be guiding for further steps.





Problem analysis: water

river basin / water system
/ flooding

Dar es Salaam is located in the Wami Ruvu River Basin, which is extending westwards from the coast in the east. Different landscapes are present within the basin (see p. 241). They withhold important functions for the water system, like storage or purification, but their capacities are decreasing due to environmental threads and other pressures (Saha et al., 2014).

The Lower Ruvu Basin and the Coastal Basin are the two sub-catchments, which serve as main freshwater sources for Dar es Salaam (see p. 39). In the Lower Ruvu Basin, freshwater is directly retrieved from the Ruvu river. In the Coastal Basin, water is extracted from the groundwater of the coastal aquifer and form the surface water of local rivers in the city. The main functions who require the extracted freshwater are industry, housing and agriculture (IIED, 2017).

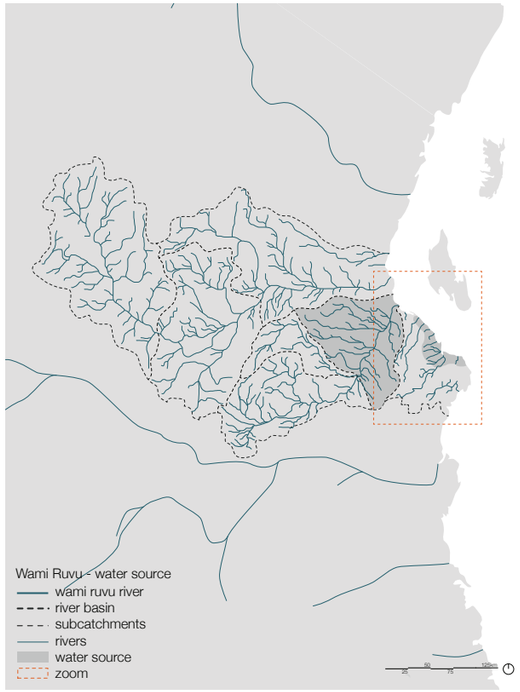
The water system is faced with several severe environmental threats (see p. 39), compromising the accessibility of freshwater and the health of the inhabitants. Rivers and groundwater are being polluted by sewage discharge and waste, the quality of the groundwater is further compromised by saline intrusion from the coast. There is a shortage in water supply from the Ruvu river during droughts and also in general, because of the exhaustion of water resources (IIED, 2017).

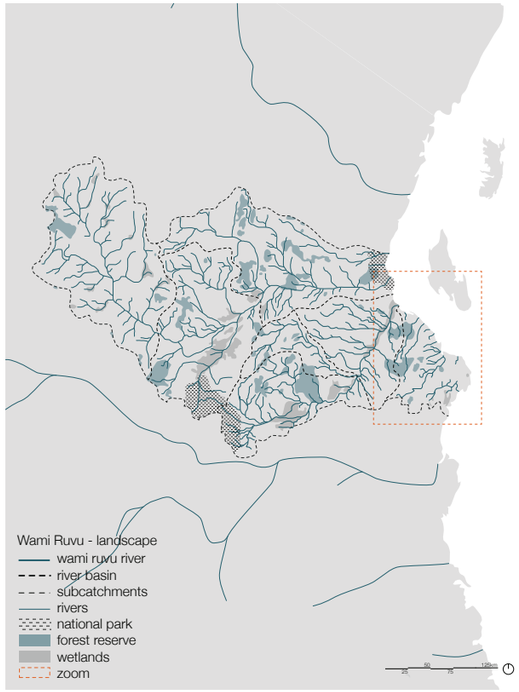
The water network in Dar es Salaam is insufficient. Local rivers and creeks form the main drainage system in big parts of the city, because the artificial sewage and drainage network is not comprehensive and of low quality. The network is already at its capacity limits during dry season. During rainy periods, the network is not able to cope with that, since there are no capacities for storm water whatsoever (Ramani Huria, 2016).

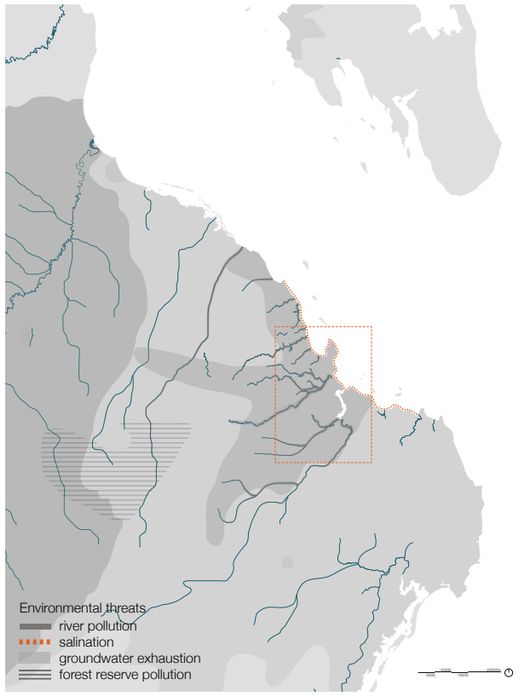
The rivers and creeks do not only function as drainage but are also the structuring elements of green spaces, which follow the water courses (see p. 40). This means in return that not only water and soil are being polluted by untreated sewage, but also the very limited green areas of the city strongly decrease in quality. This has a negative impact on the health of residents and the environmental services which are available.

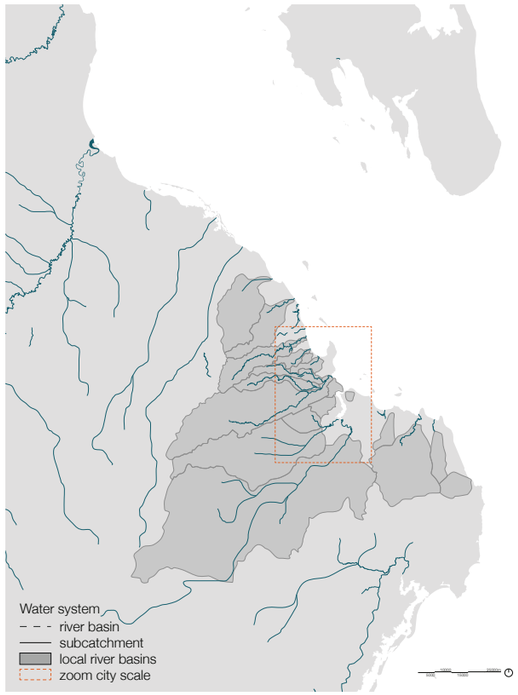
Because of the insufficiency of the water system in combination with the changes of precipitation patterns, many areas in the city of Dar es Salaam are at risk for flooding. Many of these risk areas are occupied by informal settlements (see p. 41), because these areas were unplanned, empty and cheap and close to the city centre with its economic activities.

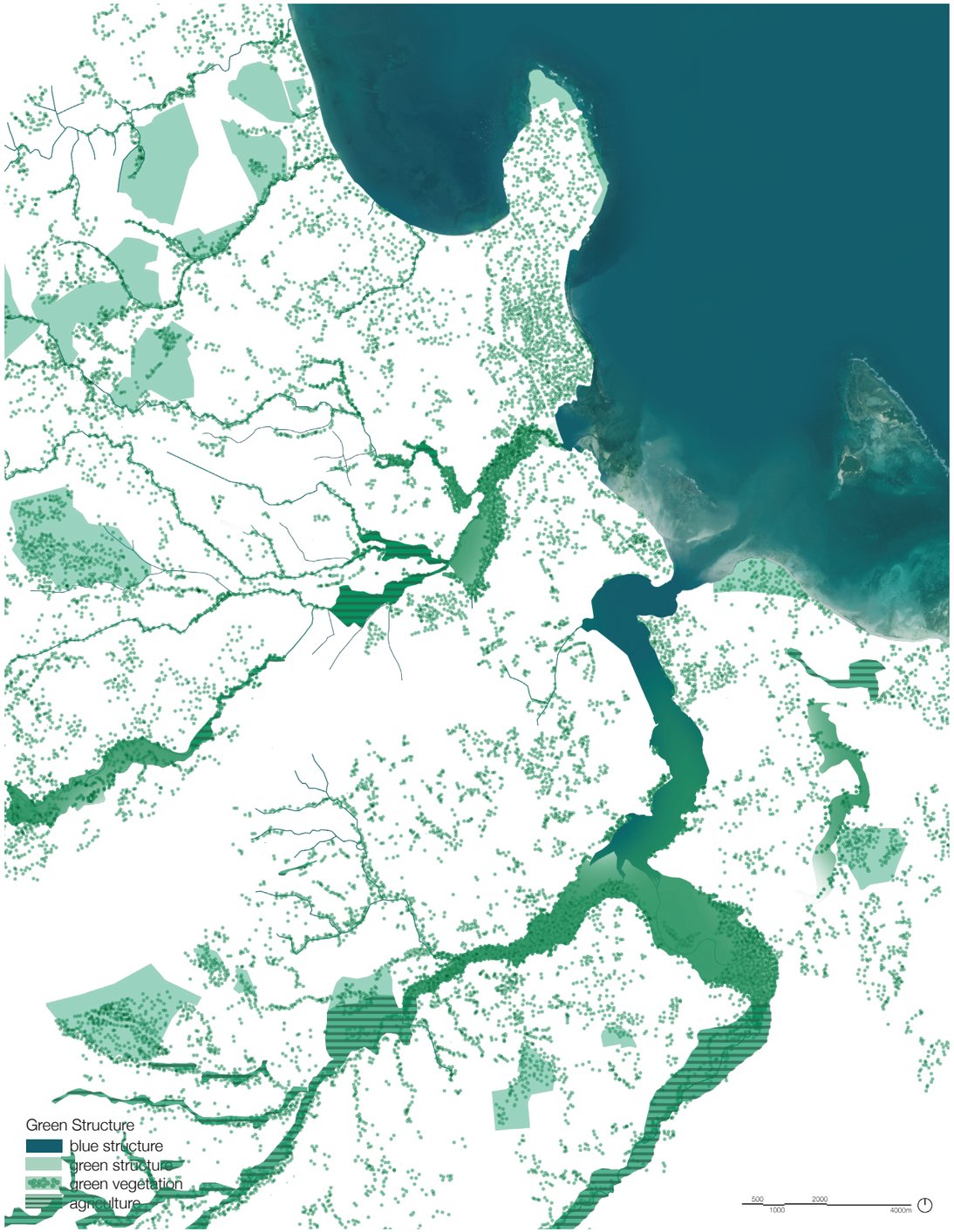
To get a better understanding of the extend and implications of floods in the informal settlements, the community based mapping project ‘Ramani Huria’ has conducted a sorrow analysis of the risks by ward (Ramani Huria, 2016). The summary (see p. 45) highlights the wards which are the most at risk regarding its total number of inhabitants, number of houses, institutional building or percentage of total area at risk of flooding. This supports the spatial flood risk analysis, showing that the wards who are located around or next to a river are at risk the most.

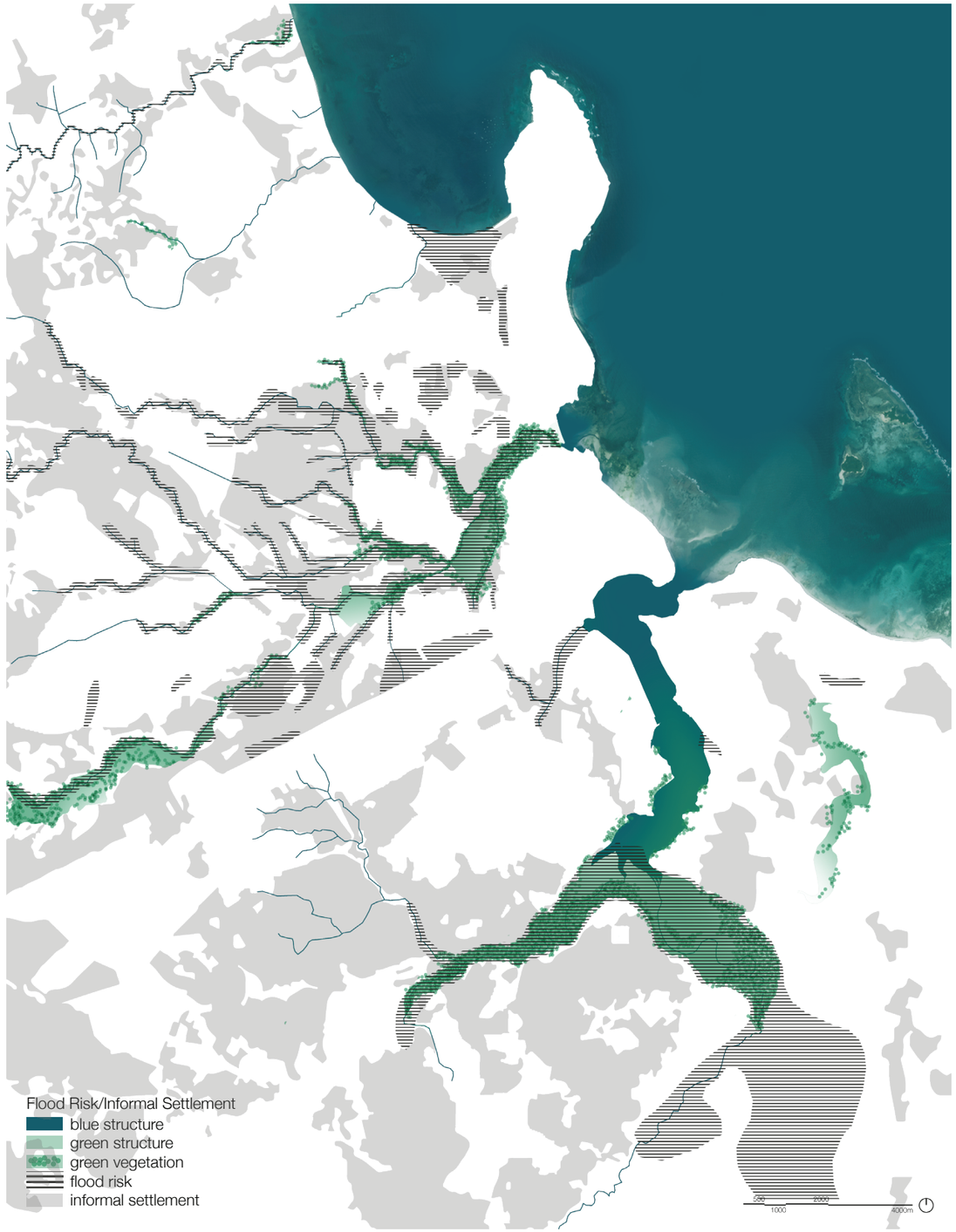


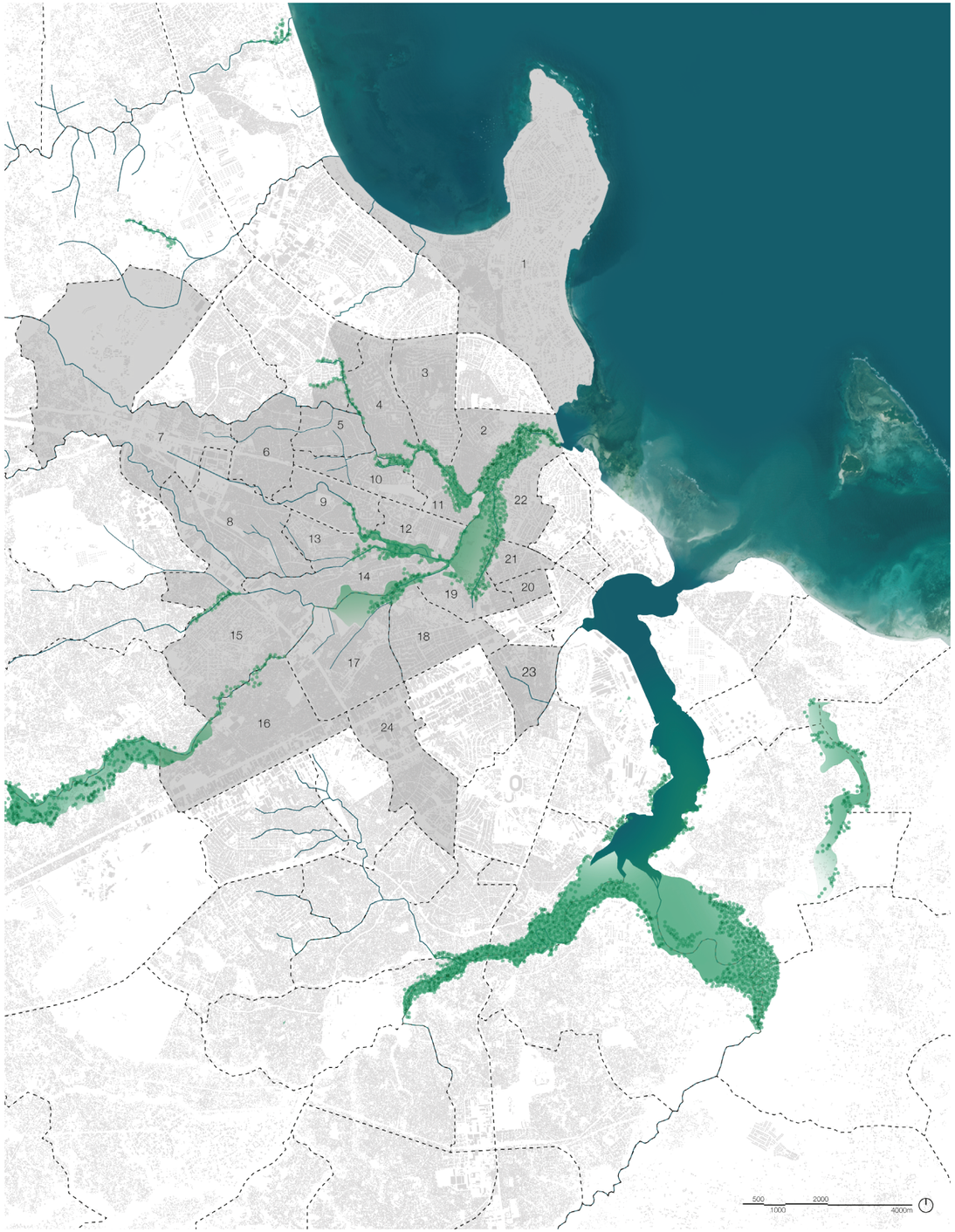







Green Structure
blue structure
green structure
green vegetation
agriculture
500
1000
2000
4000m


Flood Risk/Informal Settlement
blue structure
green structure
green vegetation
flood risk
informal settlement
500
1000
2000
4000m



1. Msasani
- 9%
- 48.920
- 8.020
- 2.578
  - 27

2. Hananasif
- 31%
- 37.115
- 6.528
- 1.272
  - 1

3. Mwanan yamala
- 23%
- 50.560
- 9.914
- 2.863
  - 21

4. Makumbusho
- 35%
- 68.093
- 7.848
- 3.053
  - 19

5. Tandale
- 30%
- 54.781
- 9.504
- 1.948
  - 12

6. Manzese
- 17%
- 70.507
- 9.504
- 1.948
  - 12

7. Ubungo
- 6%
- 56.015
- 9.282
- 1.102
  - 12

8. Mabibo
- 13%
- 85.735
- 16.349
- 1.519
  - 2

9. Makurumla
- 18%
- 63.352
- 8.043
- 1.669
  - 1

10. Ndugumbi
- 13%
- 36.841
- 5.242
- 1.137
  - 0

11. Magomeni
- 45%
- 24.400
- 4.273
- 1.744
  - 0

12. Mzimuni
- 27%
- 21.486
- 4.021
- 959
  - 1

13. Mburahati
- 33%
- 34.123
- 5.753
- 1.997
  - 1

14. Kigogo
- 48%
- 57.613
- 8.869
- 4.450
  - 4

15. Tabata
- 18%
- 74.742
- 11.485
- 2.324
  - 2

16. Vingunguti
- 27%
- 106.946
- 15.080
- 5.321
  - 26

17. Buguruni
- 20%
- 70.585
- 12.315
- 2.937
  - 10

18. Ilala
- 45%
- 31.083
- 4.544
- 2.513
  - 38

19. Michikichini
- 49%
- 25.510
- 3.551
- 1.374
  - 8

20. Kariakoo

21. Jangwani

22. Upanga Magharibi

flood most
often in center

23. Keko
- 17%
- 35.163
- 4.575
- 961
  - 0

24. Temeke
- 4%
- 26.047
- 4.246
- 323
  - 2

Dar es Salaam wards
- most vulnerable numbers
- area at risk
- number of inhabitants
- number of houses
- number of houses at risk
- schools/hospitals at risk





Problem analysis: no coping capacity

reaction chain / negative housing cycle
/ negative water cycle



Having coping capacity is important to be able to deal with flood events or other hazards. The cycle (see Fig. 07) shows, why residents of informal settlements are not able to build coping capacity and are therefore much more vulnerable in case of a flood.

The many people coming to Dar es Salaam as a consequence of the rapid urbanisation are often poor and the city itself has only limited institutional capacities, which is why it can not provide adequate affordable housing for the new residents. As a consequence, the new residents settle in informal settlements, which are often located in flood risk areas because these are unoccupied and therefore cheap (Pauleit et al., 2015; Sudmeier-Rieux et al., 2017).

The informal settlements are not equipped with infrastructure or services as well as no formal economy to provide jobs and income. Because these elements are not regulated, the area gets very fragile when it comes to external impacts or disruptions. Because of the high unemployment rate in informal settlements, residents create their own sources of income within the informal economy, mostly taking place inside or within the direct surroundings of their houses (John, Kombe & Mayunga, 2012). This means in return that in case of a hazard, not only their houses are exposed but also their place of work to generate income, which leaves the residents with nothing.

The consequences of the lack of infrastructure is two folded. On the one hand it reduces the coping capacities of the area in case of a hazard, for example for evacuation or receiving help (John, Kombe & Mayunga, 2012). On the other hand it causes pollution of water and soil by unfiltered sewage run-off into open waters or waste dump, which causes the destruction of ecosystems. This compromises the coping capacity of the existing ecosystem which could otherwise help to reduce the impact (Gasparini et al., n.d.; Hassan, Schules & Ash, 2005; Pauleit et al., 2015, p. 27).

This leads to a very high vulnerability in the social, physical and ecosystem dimension (see p. 242 for more information). This overlap of vulnerabilities causes a disruption of daily lives, including economic activities, and damages or even destroys infrastructure and homes in areas where people do not have the capacity to cope with it (Pauleit et al., 2015; Mirza, 2003; Sudmeier-Rieux et al. 2017).

The negative housing and water cycles (see p. 53-54) do not only show the consequences which lead to the next, but also explain how knowledge and behaviour have an influence on these processes.

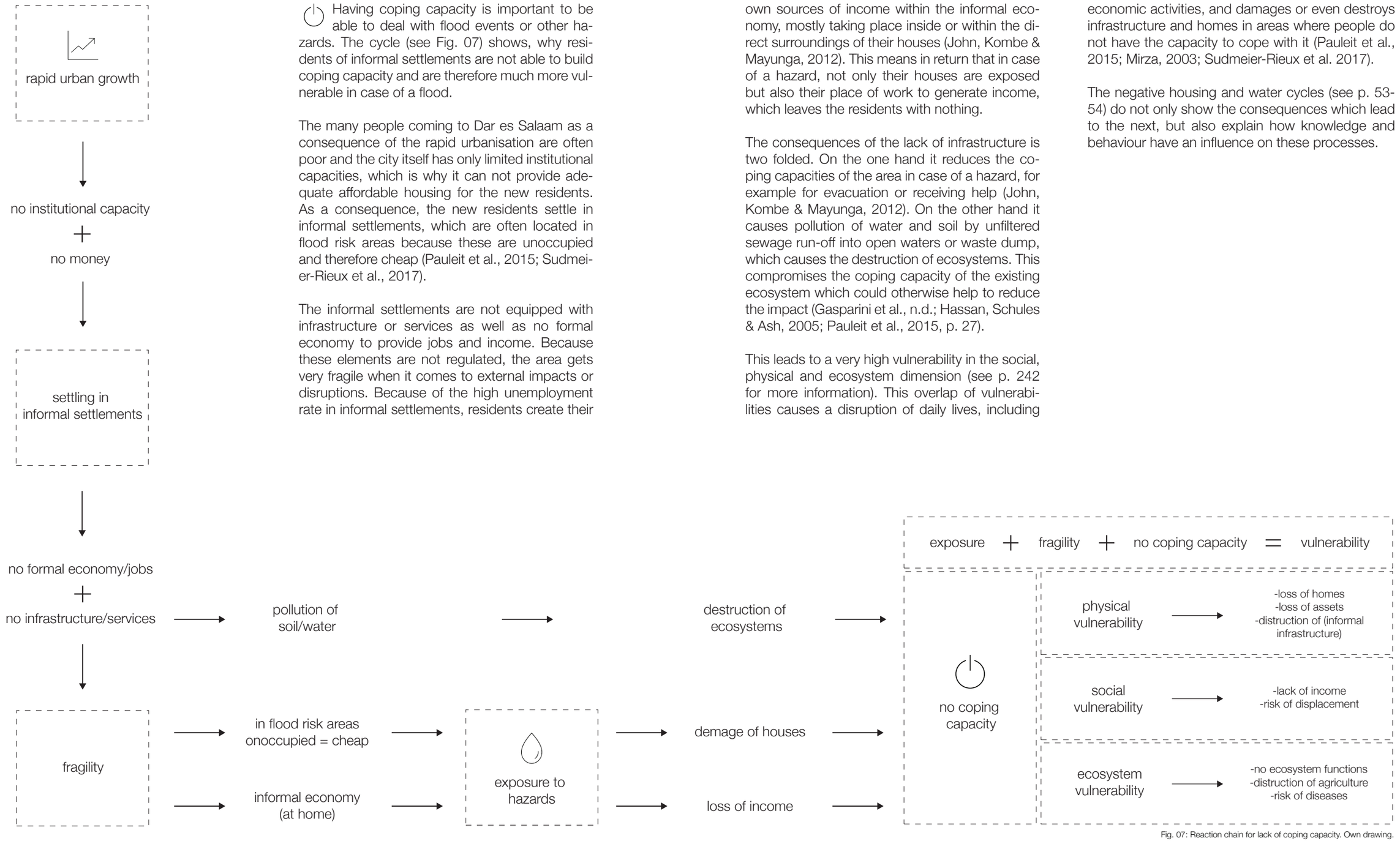


Fig. 07: Reaction chain for lack of coping capacity. Own drawing.



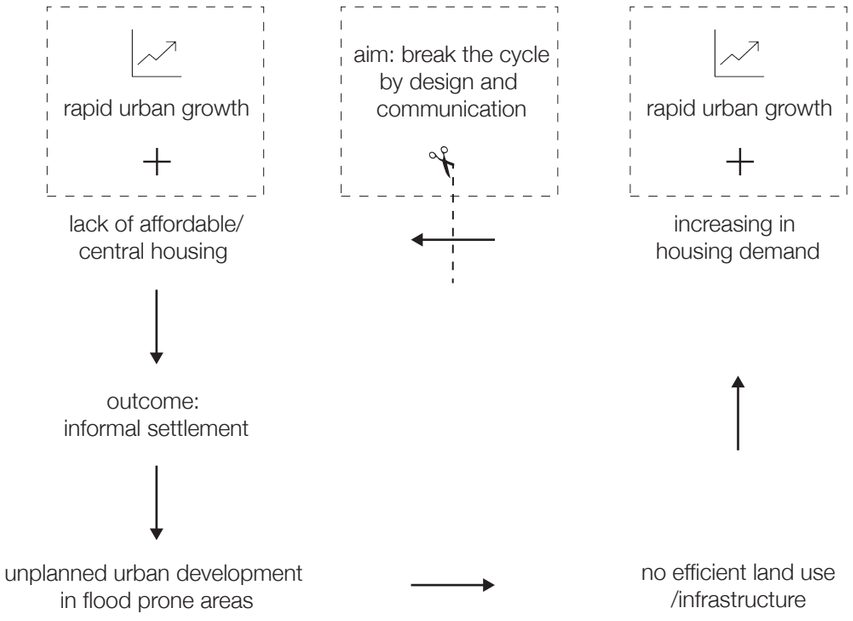


Fig. 08: Negative water and housing cycle. Own drawing.

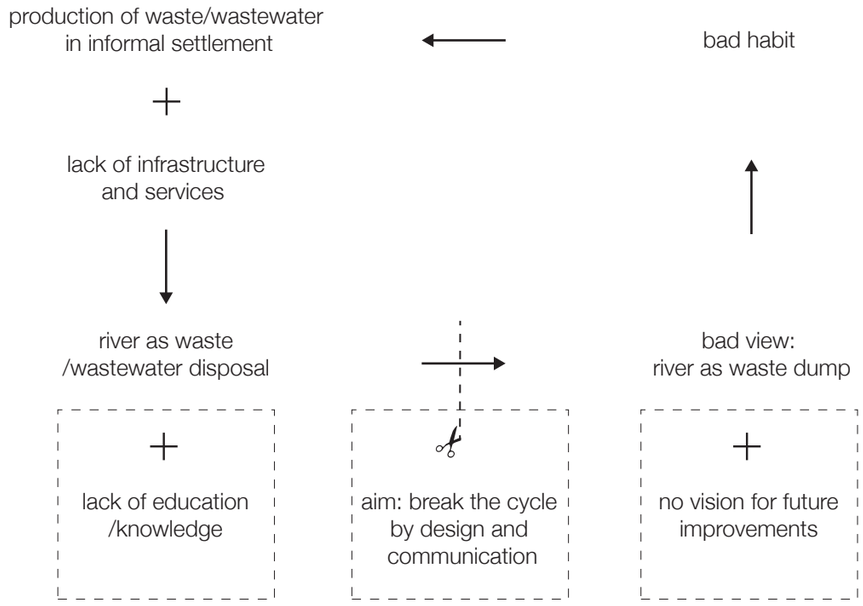


Fig. 09: Negative water and housing cycle. Own drawing.







Location selection

flood risk / transferability
/ proximity

Selection
In order to select the common intervention location within the city, three criteria have been used. This area will be used to show how a set of interventions can transform an area while addressing the main problems (see p. 24). Within this common intervention location, two individual design locations will be selected to show the possibilities and spatial implications of interventions on the local scale.

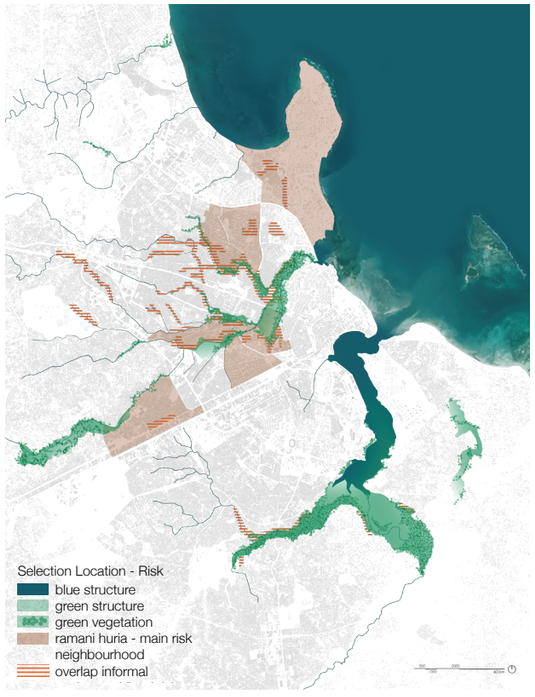
1. Risk
The first step to select the common intervention location is an assessment of the flood risk. The maps of flood risk and informal settlements (see p. 41) have been overlaid to identify areas with a high vulnerability and therefore the highest urgency to intervene. The overlapping areas are then combined with the wards which are the most at risk according to the Ramani Huria mapping project (see p. 44).

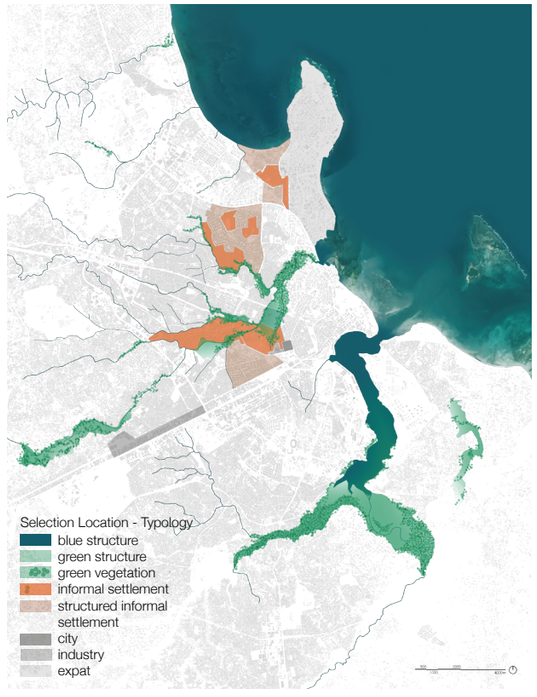
2. Urban Typology for transferability in the city
In a second step, the identified risk areas were categorised according to their urban typology. This way the diversity of typologies (see p. 34) within the urban fabric, which have been discovered before, is brought into relation to the flood risk. Since there are several typologies within the flood risk areas, it is important to address more than one of them, to achieve a level of transferability within the city and make it easier to integrate it into an urban framework. Risk areas which are located in one of the two most occurring typologies in this context will be taken into the smaller selection.

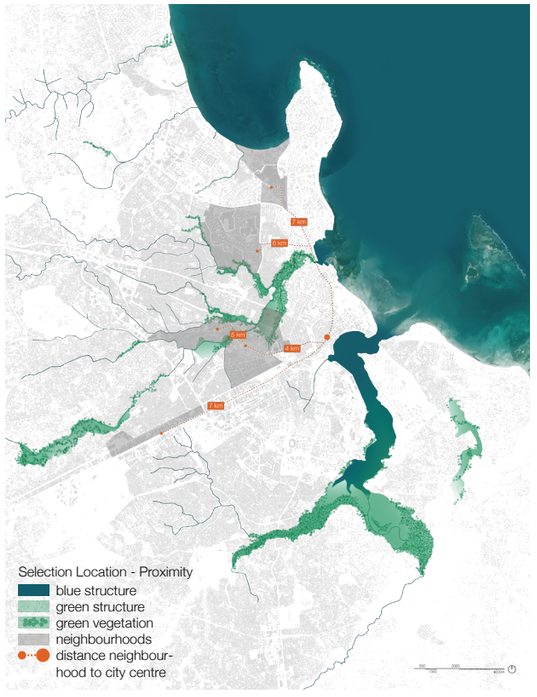
3. Proximity
The third and last criterion to narrow down the common intervention location is the proximity to services and jobs but also to important political, social and international institutions, which are mostly available in the city centre. This is important, because it helps residents to acquire necessary tools and resources and creates some kind of visibility, which is important for the project to be visible as a test case within the city where other actors can learn from for future projects.

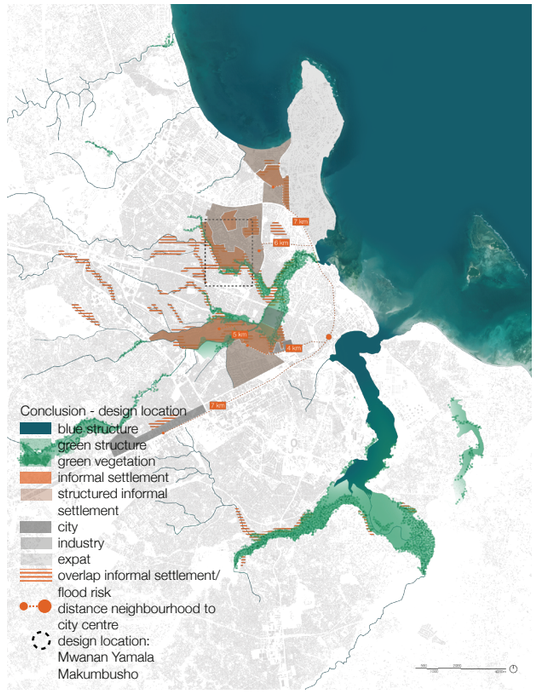
The proximity has been measured in kilometres based on the network of primary and secondary roads (see p. 33). They connect different areas for motorised vehicles like cars and busses, which are the main connectors between wards as the distances are too long to walk. Time would have been a better indicator for proximity, however the traffic conditions change so much depending on time and day, it would not give a clear impression.

Conclusion
As a conclusion of these three steps, the highlighted area has been identified as an appropriate test case. The flood risk is very high, it contains two different typologies and is relatively close to the city center. It is not the closest area to the city centre, but for the final decision, practical reasons have been taken into account, like the distance to Ardhi University and the location of the accommodation during the fieldwork.







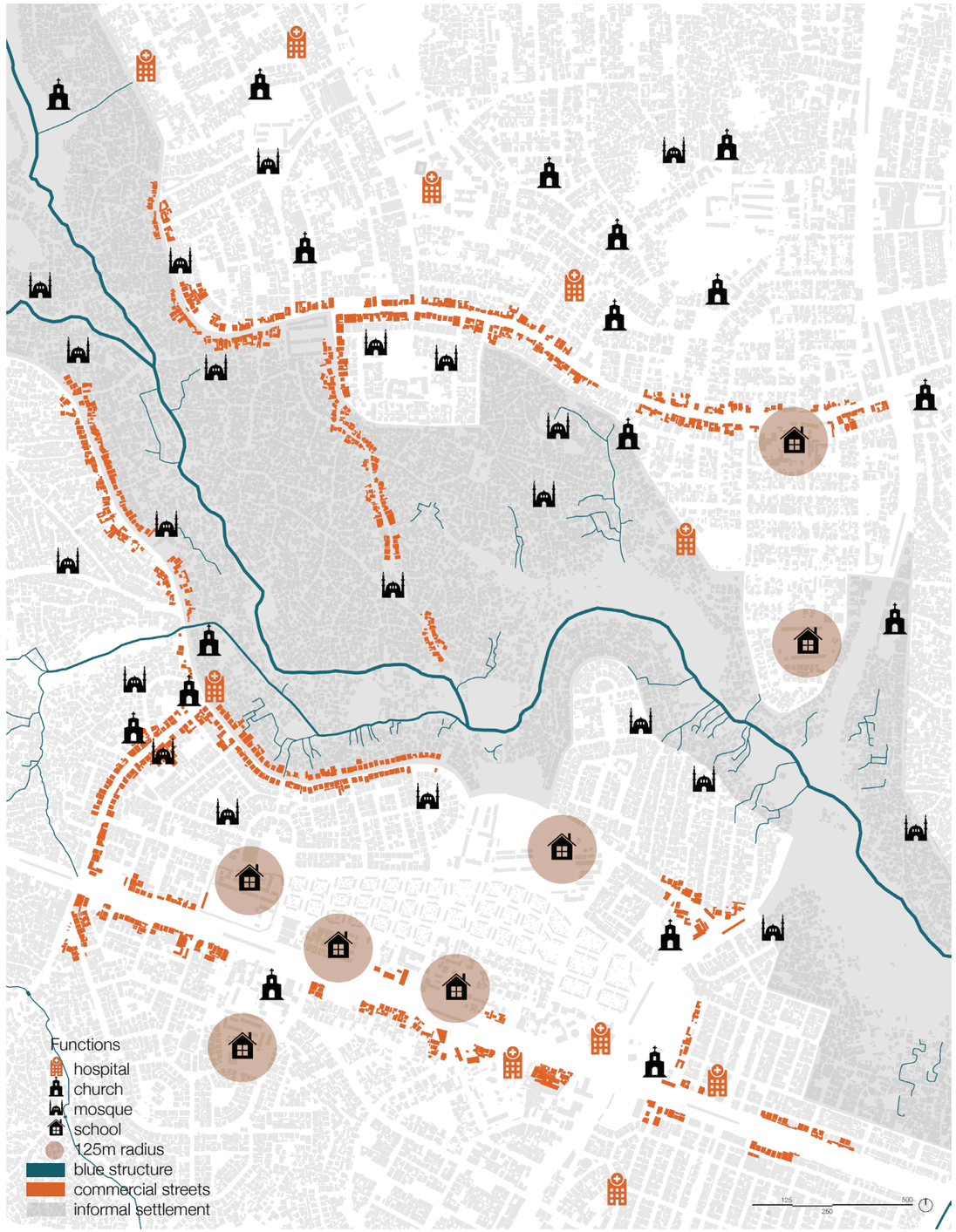


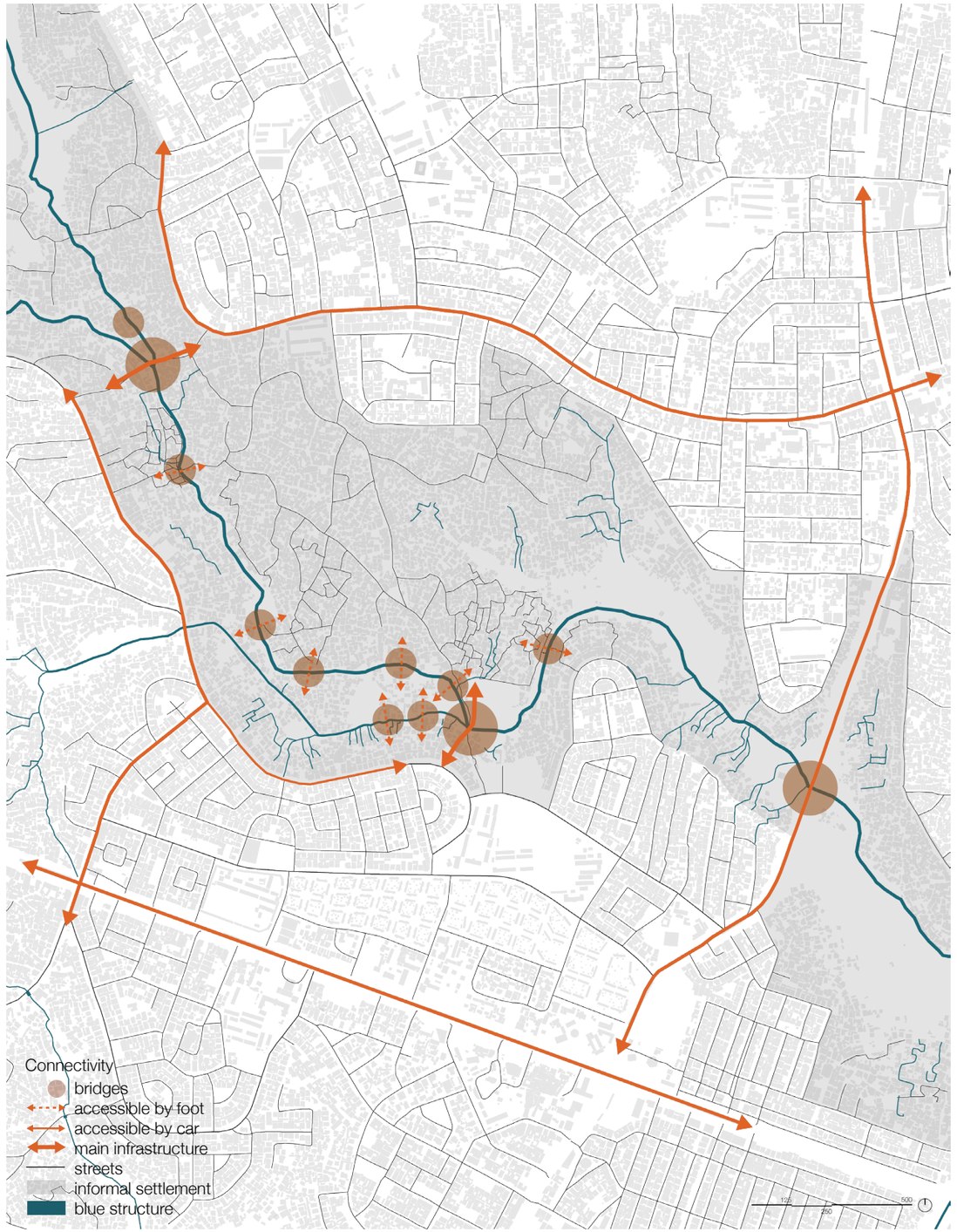




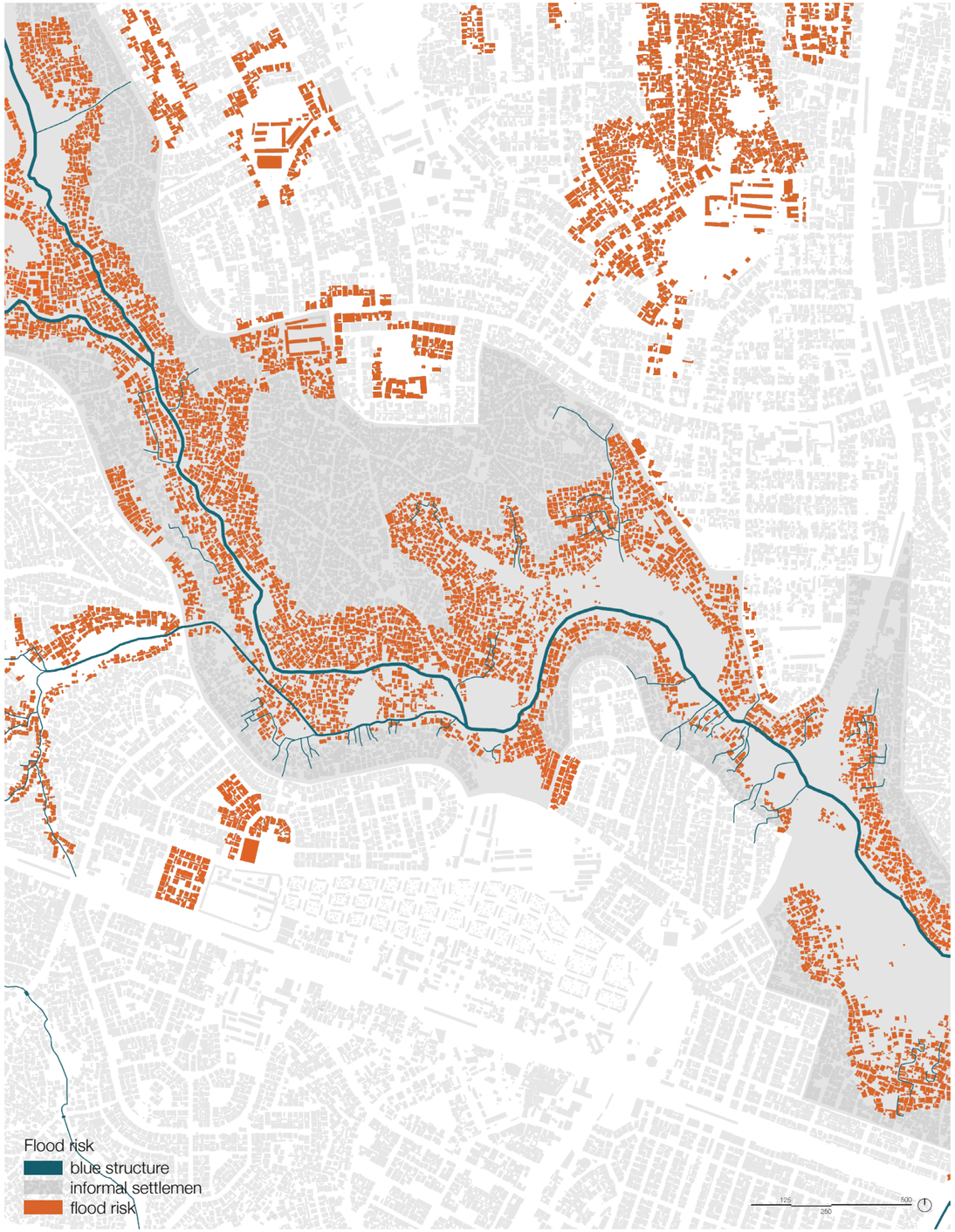
Location analysis

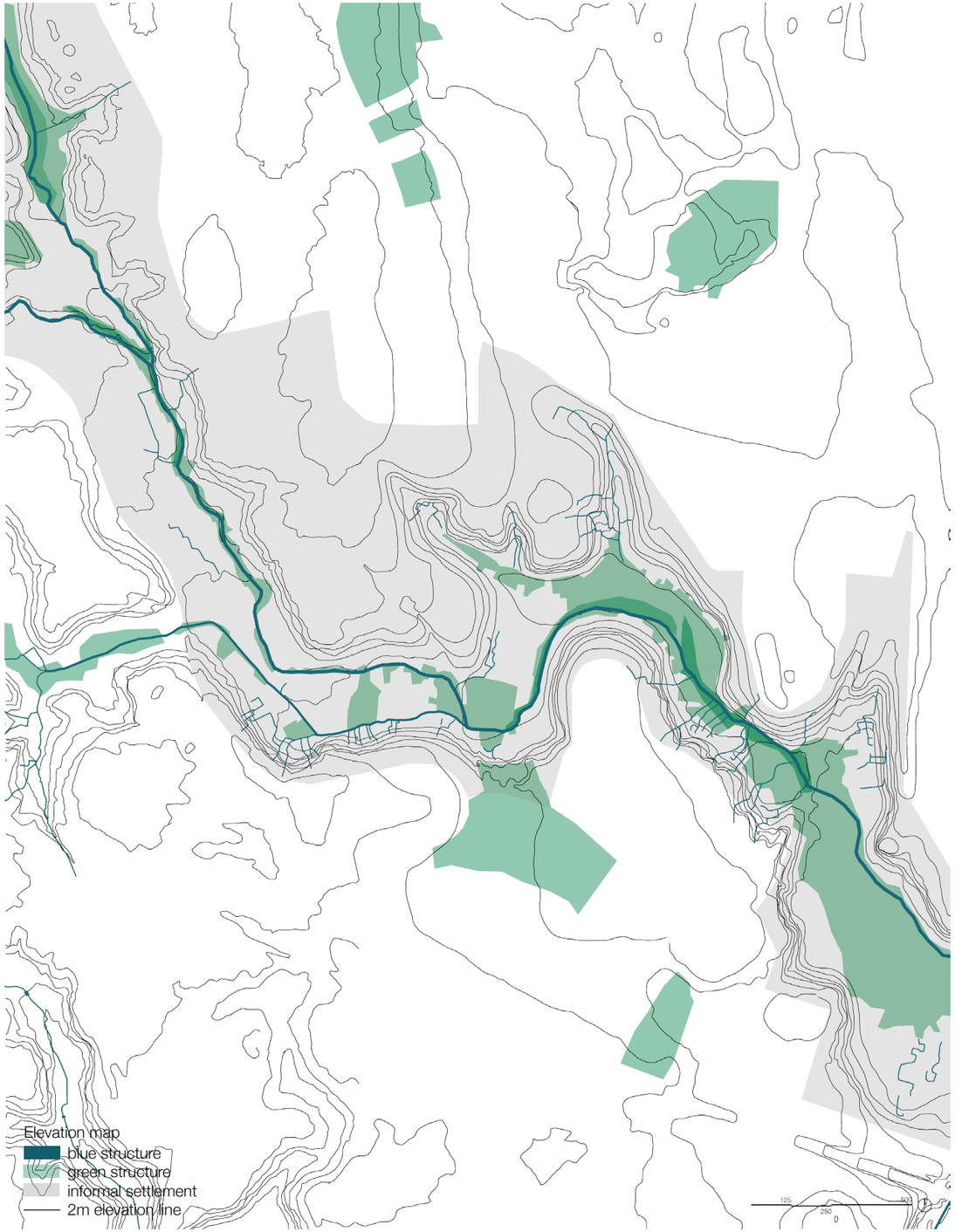
social institution / infrastructure and connectivity
/ flood risk / landscape / river basin

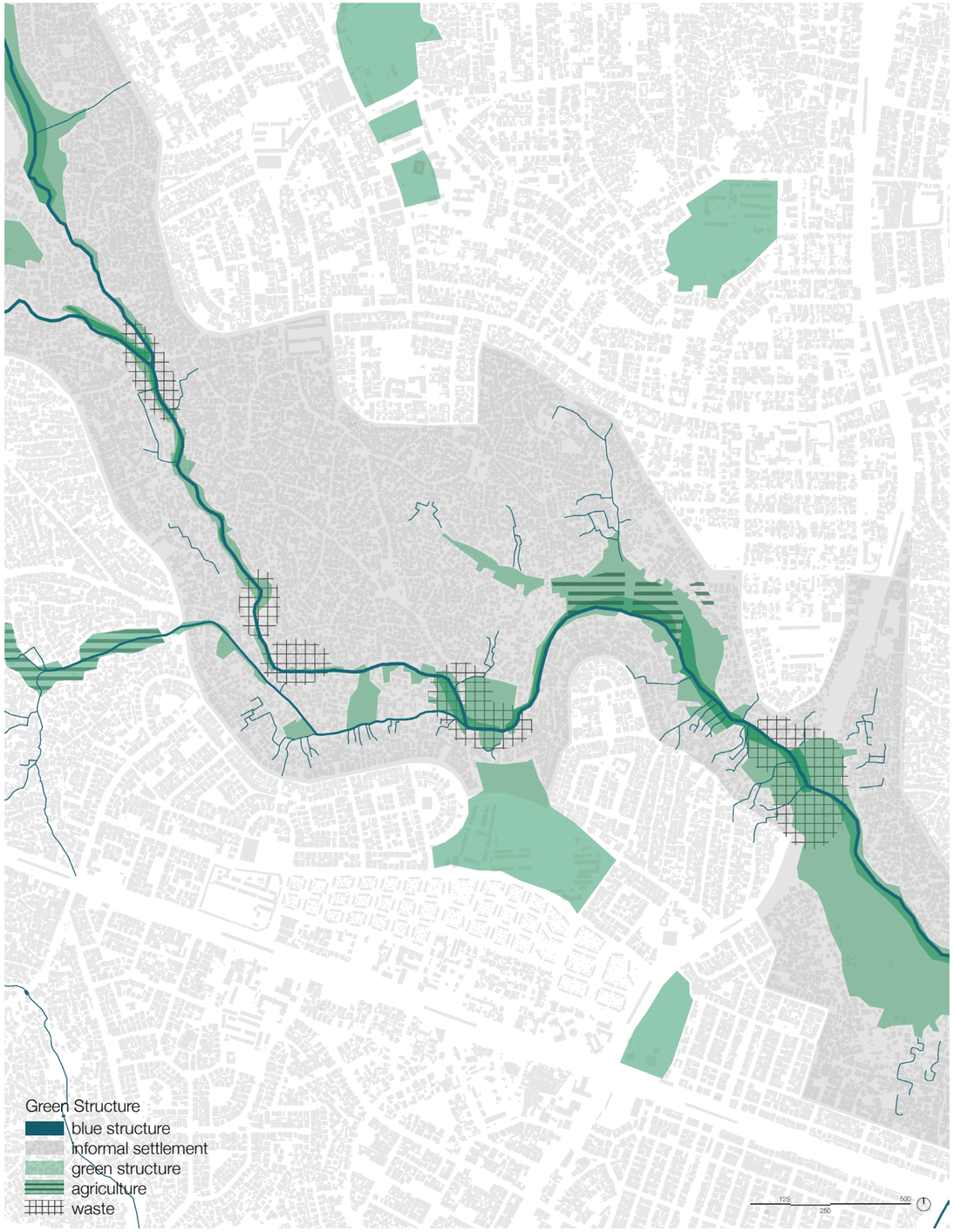

Functions
hospital
church
mosque
school
125m radius
blue structure
commercial streets
informal settlement
125
250
500


Connectivity
bridges
accessible by foot
accessible by car
main infrastructure
streets
informal settlement
blue structure
125
250
500




Flood risk
blue structure
informal settlemen
flood risk
125
250
500


Elevation map
blue structure
green structure
informal settlement
2m elevation line
125
250
500
0



The final decision about the extends of the common intervention location has not been based on the wards, like it has been the case in the previous steps, but based on the spatial specifications of the area.

Based on this, the common intervention location includes both sides of the Ng'ombe river and extends towards secondary roads around it to be able to connect to them. As a consequences, the borders of five different wards are being crossed, namely Makumbusho, Mwananyamala, Tangle, Ndugumbi and Magomeni. This will be a difficulty for the implementation but is necessary to be able to make comprehensive design decisions.

The area is dominated by informal settlements but also contains structured informal settlements at the edges. The one story buildings are constructed very close to each other, of poor quality and in bad condition. Marks of previous floods are visible on the walls, showing their impact and extend. While the area is dominated by housing, small scale informal economic activities can be found in between, for example in form of little shops or local food and coffee production. Several churches and mosques are located within the area, while (formal) educational and medical facilities can only be found outside the area.

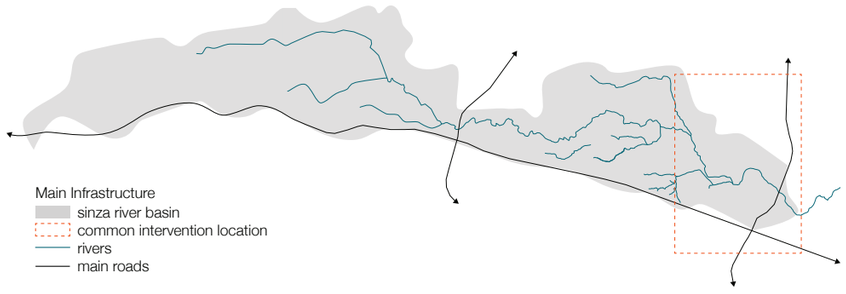
The common intervention location is surrounded by roads of different hierarchies. A main road is running east of the area, also accommodating the Bus Rapid Transit (BRT) line. On the other sides of the area are tertiary roads, of which those north and south of the area are used by local busses. Despite the existing connections around the area, the connectivity through the area and across the river is very poor. Only very few roads are accessible by car and the bridges are of very poor quality, damaged or broken, not accessible during or after heavy rainfalls or not existed at all.

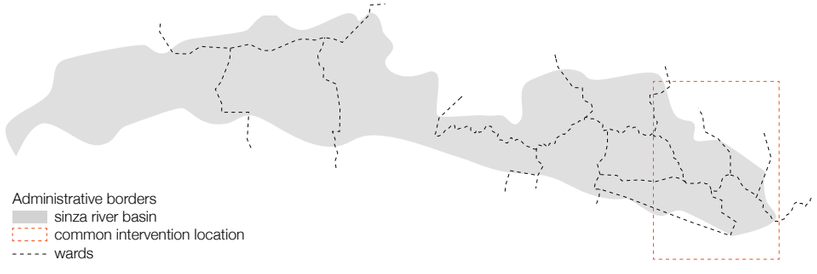
Within the area are no sewage or drainage systems. As a consequences, waste- and stormwater are being flushed unfiltered into the Ng'ombe river and its adjacent creeks, accelerated by the heights differences, polluting the water and soils of the surrounding green areas. Not only wastewater is pollution the river valley, but also solid waste is accumulating in the river and green areas, brought there by residents or with the last rainfall, since there is no waste collection.

The green areas around the river are of different depth and form. Where the river valley is wider and still unoccupied, urban agriculture activities can be traced, though they are located in areas prone to flooding and pollution.

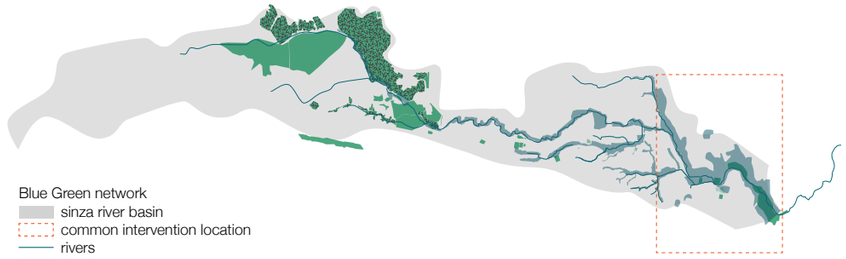

Buildings density
sinza river basin
common intervention location
buildings

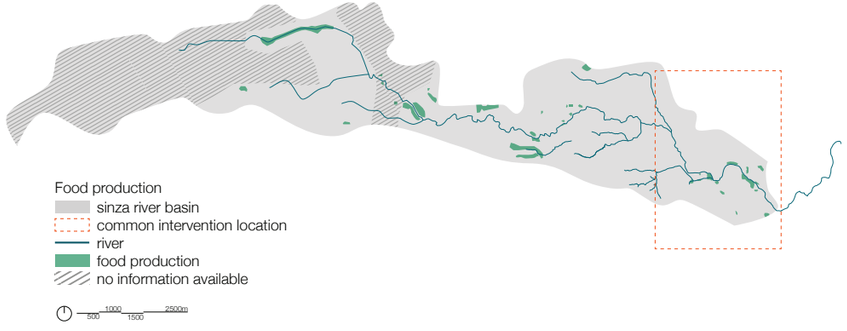

Informal Settlements
sinza river basin
common intervention location
informal settlements


Main Infrastructure
sinza river basin
common intervention location
rivers
main roads


Administrative borders
sinza river basin
common intervention location
wards


Functions
sinza river basin
common intervention location
industry
commercial
education


Blue Green network
sinza river basin
common intervention location
rivers
flood areas
meadow/bushland
forest
cemetery


Food production
sinza river basin
common intervention location
river
food production
no information available
500
1000
1500
2500m

In order to understand the role of the river in the area, it is necessary to understand the entire river basin and impacts on the environment further upstream.

The project area is located in the most eastern part of the Sinza River Basin. Along the southern edge of the basin, the Morogoro Road runs from the country side in the west towards the city centre in the east as one of the main connections. In the north-south direction, two main roads are crossing the basin. The Sam Nujoma Road is cutting through the middle of the basin while the Kawawa Road runs along the eastern edge of the basin through the project area.

The Ng'ombe river is the main river of the basin, fed by several creeks and small canals. East of the area the Ng'ombe river joins the Msimbazi river, which is connected to the Indian ocean. The areas around the rivers and creeks are prone to flooding, though there are more areas at risk in the east than in the west. In the western part of the basin, close to the origin of the river, are extensive green areas, consisting of grassland and forests.

The basin is very urban, with a lot of built up areas. The density regarding the footprint as well as the building heights is the highest in the eastern part, which is closest to the city center, and decreases towards the west where it fades out into urban sprawl.

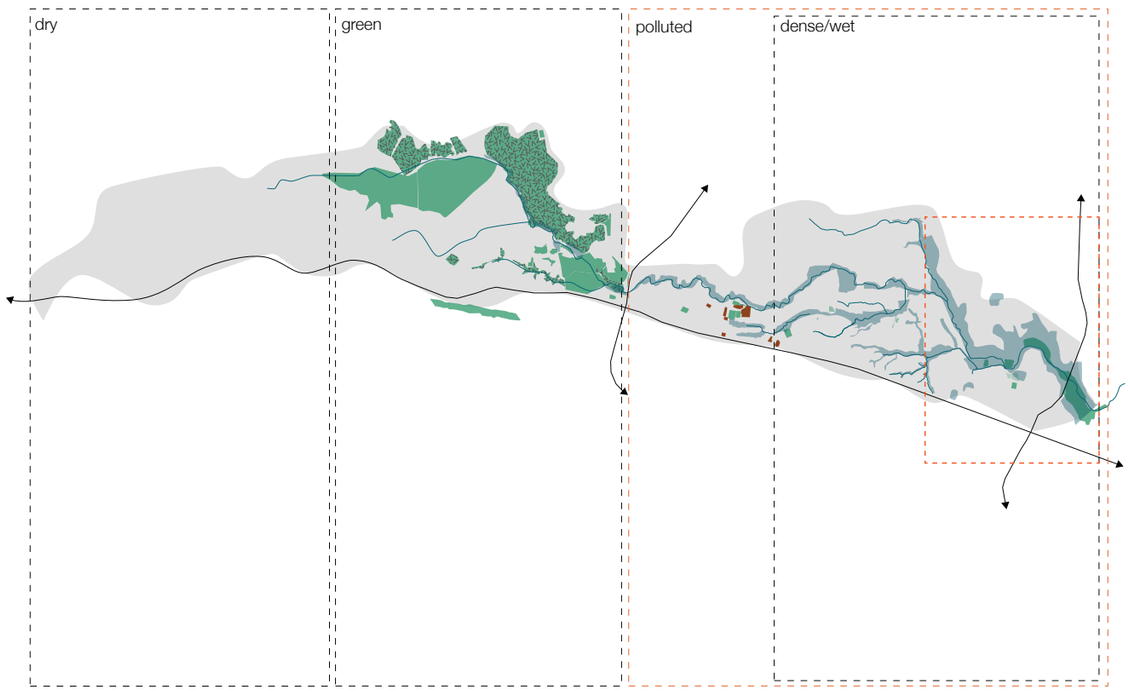
Most of the built up areas consist of informal settlements. This has consequences on the availability of services and infrastructure and for the enforcement of policies. An additional challenge is the juridical division of the basin by many administrative borders.

The area is dominated by housing. Many educational institutions of different levels are located within the denser part of the area. Only in the centre of the basin, a few industrial and commercial areas are located. For the pollution of the Ng'ombe river, this means that the pollution is mainly caused by households. South of that industrial area are more and bigger industrial areas, but they discharge their waste water into the Msimbazi river and therefore do not affect the Ng'ombe river.

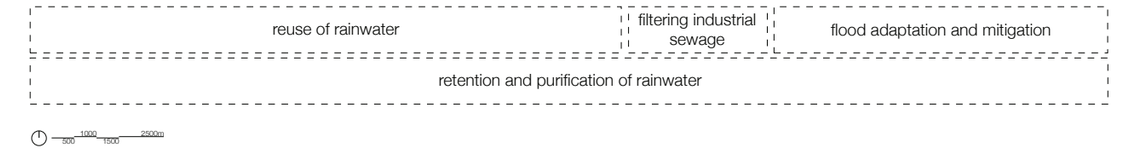
To address the water problem already on this scale, several actions can be considered:

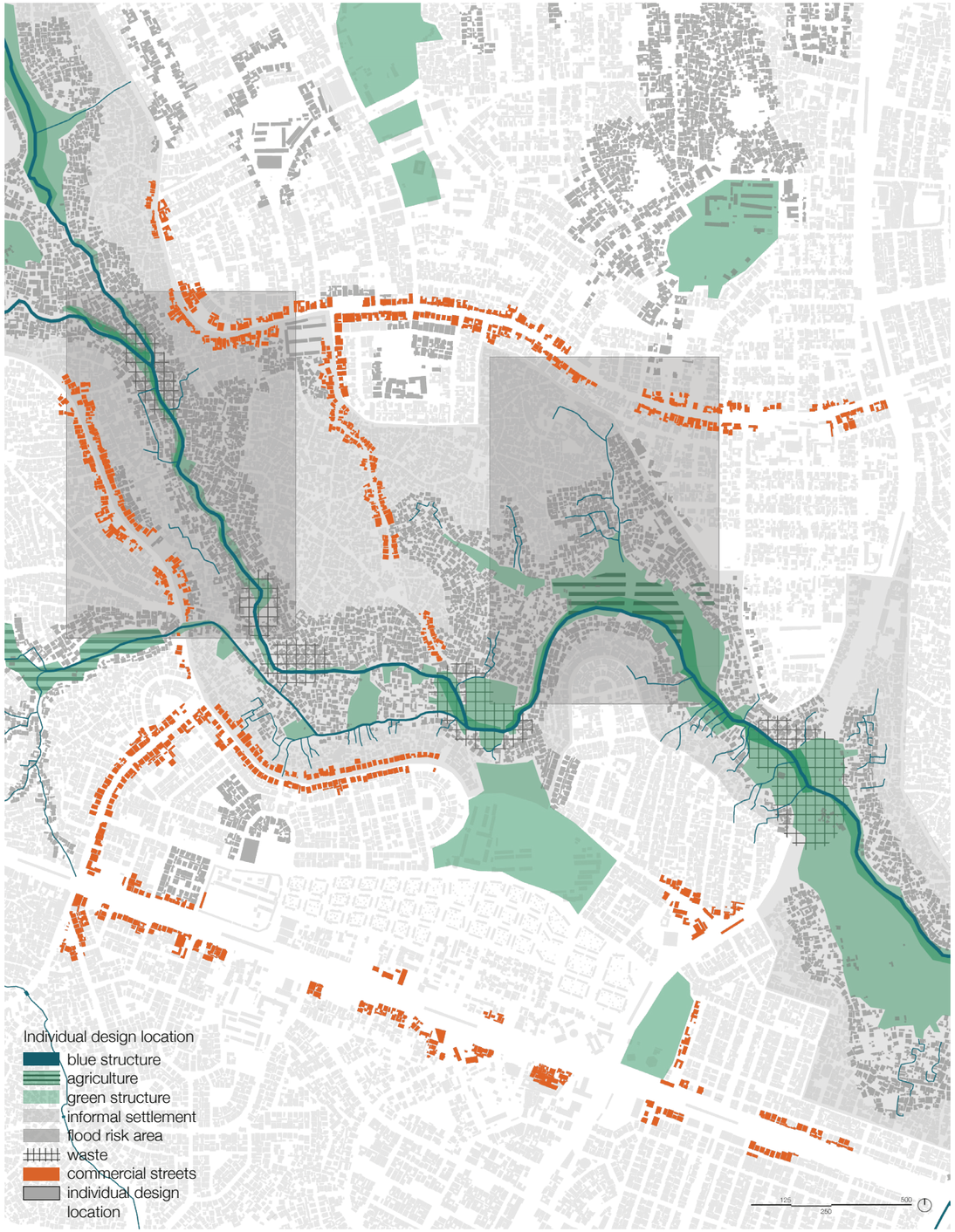
- Policy for waste water filtering of the two factories in the area
- Water retention areas upstream
- Buffer zone along the whole stretch of the river
- Water purification of blackwater in form of constructed wetlands as proposed in the design
- Cable car for transportation of waste.
- Building line to give more space to the river
- Densification of housing around commercial areas to relocate residents away from the streams

conclusion:

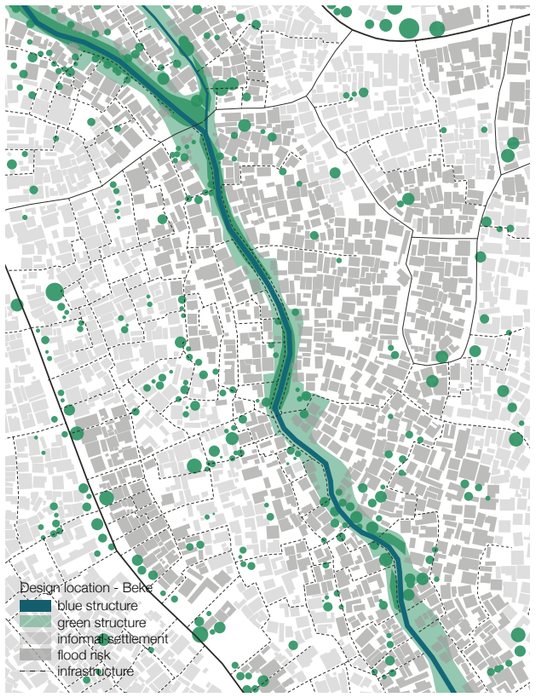


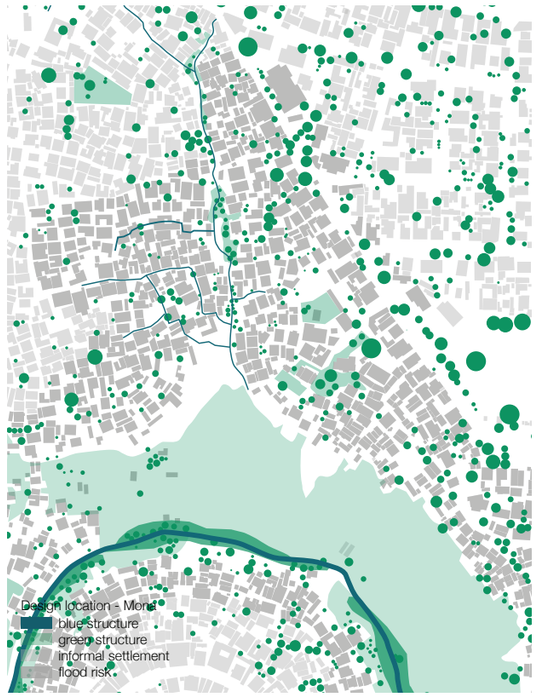
approach:

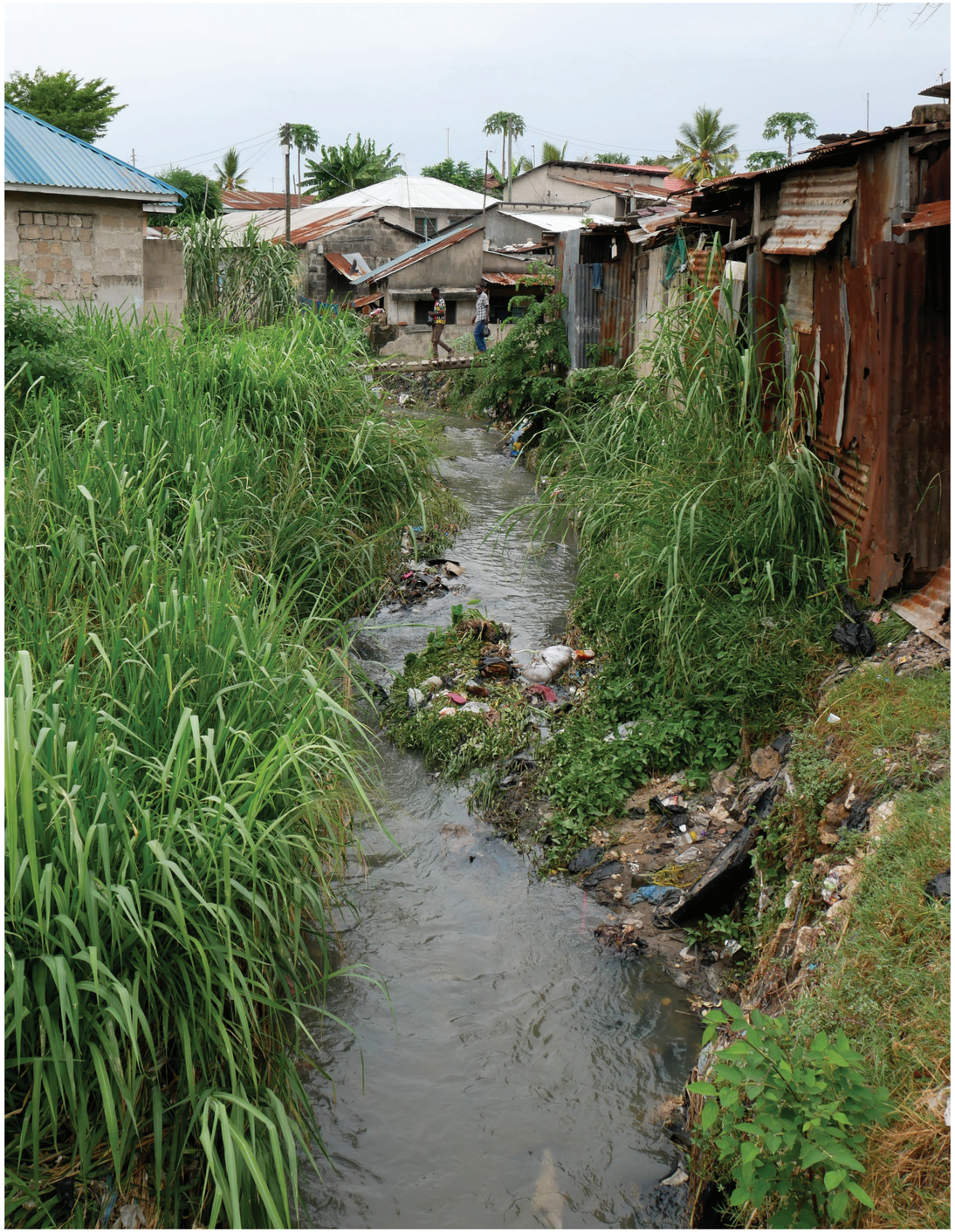




To address the diversity of the place, two individual design locations with different characteristics were selected. The area in the west is very dense, has high height differences and buildings are constructed all the way down to the river. The area in the east is much less dense and contains a very wide open area of the river valley.









Plant analysis

trees / fruit and vegetable / fish
/ plants / wetland plants



Sycamore fig
Ficus sycomorus

Character:
tree,
25m height,
rounded crown,
large leafs,
no flower

Fruit:
4cm round figs,
eaten by birds and monkeys,
water from cooked barkis taken for stomachache



Small beadbean
Maerua triphylla ssp.Johannis

Character:
small tree,
4-6m height,
shrub with a round crown,
evergreen,
small white flowers in a head

Fruit:
edible fruits (cooked),
flowers attract bees/butterflies,
roots used for snakebites/cures headache



Tamarind
Tamarindus indica

Character:
large tree,
30m height,
dense crown,
yellow flowers with red veins

Fruit:
edible sour fruit,
used for flavouring,
overripe fruit used to clean metals,
roots used for cough and fever



Mango
Mangifera indica

Character:
tree,
10-15m height,
densely leafed tree,
rounded crown,
evergreen,
small creamy flowers

Fruit:
green/red fruit,
yellow when ripe,
edible fruits,
leafs are used as fodder and manure



Giant diospyros
Diospyros abyssinica

Character:
tree,
9-30m height,
mushroom-shaped crown,
glossy lanceshaped dark-green leafs,
small white flowers in clusters

Fruit:
red/yellow (black when ripe) fruit,
eaten by birds



Forest rothmannia
Rothmannia urcelliformis

Character:
tree,
9m height,
evergreen tree,
dark-green glossy leafs,
trumpet-shaped creamy/white flowers

Fruit:
brown-black egg-shaped fruit up to 6cm long,
bark is used for treating malaria



Desert date
Balanites aegyptiaca

Character:
tree,
6-10m height,
evergreen tree,
rounded crown with thorny branches,
oval grey-green leafs,
yellow-green flower clusters,

Fruit:
yellow-green clusters - 5cm,
bitter-sweet flesh,
fruits and leaves are browsed by goats



Cycad
Encephalartos hildebrandtii

Character:
6m height,
nonbranched palm tree without stem

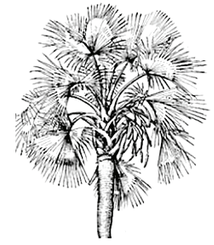
Fruit:
yellow cylindrical up to 60cm in the centre of rosette,
seed-covering/ starchy pith of the stem are edible



Cape fig
Ficus sur

Character:
tree with rounded crown,
25m height,
broadly oval large leafs

Fruit:
rounded figs in heavy clusters up to 3cm,
orange to red when ripe,
ripe figs are edible,
bark used for stomachache and diarrhoea,
water from cooked roots is taken for coughing



African fan palm
Borassus aethiopum

Character:
tall palm tree,
25m height

Fruit:
large orange round fruit about 15cm long,
edible fruit, leafs are used as material for weaving















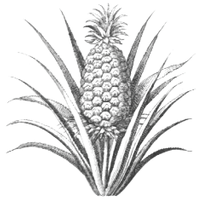












Pineapple
Ananas comosus

Character:
harvest once a year
leaves grow in large rosettes,
flowers arising from the heart of the rosette

Fruit:
edible oval fruit in the middle of plant,
used as anti-in-flammatory,
roots used for diarrhea



Banana
Musa sapientum

Character:
harvest once to twice a year
grow in variety of soils (60cm deep),
largest herba-ceous flowering plant, good in compost area

Fruit:
edible fruit,
appears in large hanging cluster,
harvest in green colour,



African spinach
Spinaciae hades

Character:
growing all year,
harvest after max 45 days,
up to 30cm height,
flowering stem,

Vegetable:
edible leaves,



Tomatos
Solanum lycopersium

Character:
growing all year,
harvest after 90 days,
height up to 180cm,
flowers are 1–2 cm yellow,
grow as a series of branching stems,
flowers appear on the apical meristem

Vegetable:
edible fruit,
yellow, red or green



Amaranth
Amarantus

Character:
growing all year,
leafy greens,
likes moistured/rich soil,
cope with heat and dry conditions,
height 5-15cm,
nutritious leaf/grain,
broad leafed and moderately tall,
round or lance shaped,
flowers big tassles or tiny globes,

Grain:
edible grain

E P E A A

dry soil · wet soil · edible · E reduces erosion · P cleans polluted soil/water · A aquaponics system



Sweet Potato
Ipomoea batatas

Character:
growing all year,
harvest after three to four month,
sensitive to cold water,
lush vines cover the ground,
crop good for sandy soil,
ready to harvest when leaves turn yellow

Vegetable:
10-20cm sweet potatos



Cassava
Manihot esculenta

Character:
height 15-30cm,
harvest after 14 month,
flesh is chalk-white/yellow

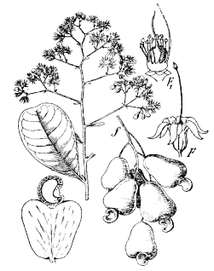
Vegetable:
root is long and tapered,
15 to 30cm,
cassava leaves have a lot of protein



Maize
Zea mays subsp. mays

Character:
height about 3m,
growing about 60 to 100 days,
moistured soil needed,
leaves arranged spirally on the stem

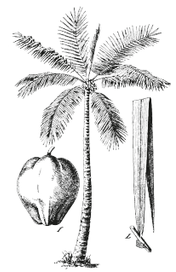
Grain:
edible yellow corn,
starch is used in various products such as cosmetics or medicin



Cashew
Amacardium occidentale

Character:
tree,
height about 14m,
evergreen,
pale green flowers,
fruit ribes within two month

Fruit:
Fruit turns pink and nut grey then harvest time,
edible nut



Coconut
Cocos nucifera

Character:
large palm tree,
height up to 30m,
leaves 4-6m,
one coconut tree can yield about 30-75 coconuts per year,
female and male flowers,

Fruit:
includes edicle coconut water,
mesocarp is composed of a fiber,
used in several products such as cosmetics and medicin

E E

dry soil · wet soil · edible · E reduces erosion · P cleans polluted soil/water · A aquaponics system



Papaya
Carica papaya

Character:
small/sparsely branched plant, height between 5-10m,
flowers apart in 5 pieces and highly dimorphic

Fruit:
edible fruit, harvest after colour break, 9-14 month after planting,
fruit often dema-ged by flies/birds



Rice
Oryza glaberrima

Character:
height about 90cm,
growing around five month,
grown in different environments,
growing in drought prone, favors medium depth; waterlogged, submergence, and flood prone

Seeds:
seed harvest once to twice a year,



Chives
Allium schoeno-prasum

Character:
herb,
growing time two to three weeks,
harvest 3-4 times per year,
round/purple chive flower

Herb:
edible chive leaves,
contains vitamin A and C



Cucumbers
Cucumis sativus

Character:
a fruit used as a vegetable,
50-70 days growing time,
well drained,
need 8-9 hours sun light per day,
possible for vertical gardens

Fruit:
edible green fruit, contains 95% water,



Borlotti beans
Phaseolus vulgaris

Character:
vegetable, grow about 25cm high,
need well drained soil,
full sun light, 90-120 days growing time,
sensitive to cool weather,
grow in vines

Vegetable:
edible, red/green pods, contains magnesium and iron

P | A | A | A

dry soil | wet soil | edible | E reduces erosion | P cleans polluted soil/water | A aquaponics system



Basil
Ocimum kilimand-scharicum

Character:
herb,
45cm height,
need to be well drained,
need 8-9 hours sun light per day,
grows in two to three weeks

Herb:
edible leaves,
contains vitamin A and C



Mint
Mentha

Character:
herb,
13-18m different species,
30-60cm height,
well drained, need sun light,
10-15 day growing time

Herb:
edible leaves,
contains vitamin A and C



Perch
Percinae

Character:
edible after 9-16 month
adaptable to different conditions
temperatures between 50-70 F degree
eat bugs and craps



Bass
Morone saxatilis

Character:
edible after 12-18 month
sensitive on conditions
temperatures between 75-85 F degree
daily monitoring required



Catfish
Siluriformes

Character:
edible after 5-10 month
very fast growing
quick conversion ratio
sensitive to water temperatures and water quality
degree need to be around 80 F degree
eat various of plants, bugs and small fish
high in vitamin D

A | A | A | S A | S A

dry soil | wet soil | edible | E reduces erosion | P cleans polluted soil/water | A aquaponics system | S sensitive



Nile tilapia
Oreochromis niloticus

Character:
edible after 6-9 month
origin Nile river in Egypt
oldest farmed fish
adapt to environment
can stand less ideal water conditions
water need to be between 55-80 F degree

Goldfish
Carassius auratus

Character:
not edible
ideal temperature between 68-75 F degree
adapting to many water conditions
goldfish are shy fish and require plant cover
goldfish produce a lot of nutrients because of size
not edible

Common carp
Cyprinus carpio

Character:
edible
like to eat insects and crustaceans
native from europe and asia
ideal temperature 73–86 F degree

Trout
Perca fluviatilis

Character:
edible after 12-16 month
contains a lot of protein and omega
water need to be between 50-60 F degree
requires pristine water and high dissolved oxygen
less plant choice for aquaponic

Barramundi
Lates calcarifer

Character:
edible after 12 month
popular in commercial aquaculture
aggressive to smaller fish
temperatures between 78-83 F degree
saltwater and freshwater system

A | A | A | S A | A



Papaya
Carica papaya

Character:
small/sparsely branched plant, height between 5-10m,
flowers apart in 5 pieces and highly dimorphic

Fruit:
edible fruit, harvest after colour break, 9-14 month after planting,
fruit often damaged by flies/birds

Banana
Musa sapientum

Character:
harvest once to twice a year
grow in variety of soils (60cm deep), largest herbaceous flowering plant, good in compost area

Fruit:
edible fruit, appears in large hanging cluster, harvest in green colour,

Olives
Olea europae

Character:
evergreen shrub or tree, grows up to 15 m tall

Fruit:
edible fruit, olives are harvested in autumn

Safsaf willow
Salix mucronata

Character:
evergreen willow tree, grows along river banks, up to 15m tall, open crown

Tana River poplar
Populus ilicifolia

Character:
evergreen tree, growing along river banks, up to 30m tall, diameter trunk 1,5m red listed

P | P E | E P | E

dry soil | wet soil | edible | E reduces erosion | P cleans polluted soil/water | A aquaponics system | S sensitive



Arrowhead
Saggitaria latifolia

Character:
perennial plant with arrow shaped leaves, growing in wetlands, 30-60cm tall stems



Reed canary grass
Phalaris arundino-cea

Character:
tall perennial bunchgrass, common in wetlands, 0,5-2m tall



Water Hyacinth
Eichhornia crassipes

Character:
perennial aquatic plant, floating, fast growing up to 0,3m tall, purple flower, can be invasive



Broad-leaved cattail
Typha latifolia

Character:
perennial plant with brown flower spike at the top, growing in wetlands, 90-270cm tall



Reed
Phragmites communis

Character:
perennial grass, common in wetlands, 2-4m tall







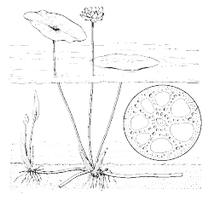




Water Spinache
Ipomoea aquatica

Character:
semi-aquatic perennial plant, hollow stem, arrow shaped leaves, vines up to 2,70m long

Vegetable:
edible stem and leaves



Indian Lotus
Nelumbo nucifera

Character:
perennial plant, growing in moist soils and water, up to 1m diameter, ornamental plant



Chillie plant
Capsicum annuum

Character:
evergreen perennial plant, growing upright up to 1m

Fruit:
edible flowers, fruit, leaves



Elephant grass
Pennisetum purpureum

Character:
perennial grass, growing in diverse soil conditions, up to 4m tall, narrow leaves growing up to 1m long



Vetiver grass
Chrysopogon zizanioides

Character:
tropical grass, 2-5m tall, extensive root system, growing mostly in moist soils

Product:
roots as fiber material











Soybeans
Glycine max

Character:
annual plant, legume family, up to 2m tall, hairy on leaves and stem

Vegetable:
edible vegetable

Vegetable:
edible seeds



Lablab (hyacint beans)
Lablab purpureus

Character:
perennial climber, legume family, up to 2m tall, purple seeds, blooms pink,prefers moist soils



Cowpeas
Vigna unguiculata

Character:
legume family, short and bushy (20cm) or tall and climbing (2m), peduncles 20-50cm long holding seed pots, diverse soil conditions

Vegetable:
edible seeds



Wheat
Triticum aestivum

Character:
annual plant, 1,5m tall, prefers moist soils

Grain:
edible cereal crop



Velvet beans
Mucuna pruriens

Character:
annual climber, legume family, vines up to 15m long, hairy leaves, itches with contact, prefers moist soils

Vegetable:
edible seeds

dry soil | wet soil | edible | E reduces erosion | P cleans polluted soil/water | A aquaponics system



Sisal
Agave sisalana

Character:
perennial plant, thick fleshy leaves, short trunk, leaves 0,6-1,2m long and 10-20cm wide, prefers dry soil

Product:
leaves as fibre material



Onion
Allium cepa

Character:
biennial plant, 15 to 45cm tall, flat long leaves, prefers dry soil

Vegetable:
edible vegetable



Sugarcane
Saccharum officinarum

Character:
large perennial grass, thick culms 2-3m tall, prefers dry soil

Vegetable:
edible juice, stems for fibre material

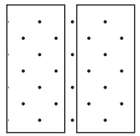
dry soil | wet soil | edible | E reduces erosion | P cleans polluted soil/water | A aquaponics system



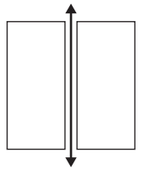


Beke-Marleen Hörmann

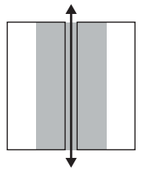
introduction / analysis / concept
/ courtyard system / courtyard design



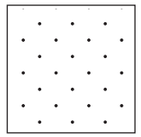
site consists of two neighbourhoods:
tandale/makumbusho



river in between called Ng'ombe



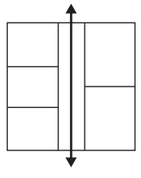
about 50% is flood risk area



site is about 500 000m^2



in one swahili house live 4-5 families



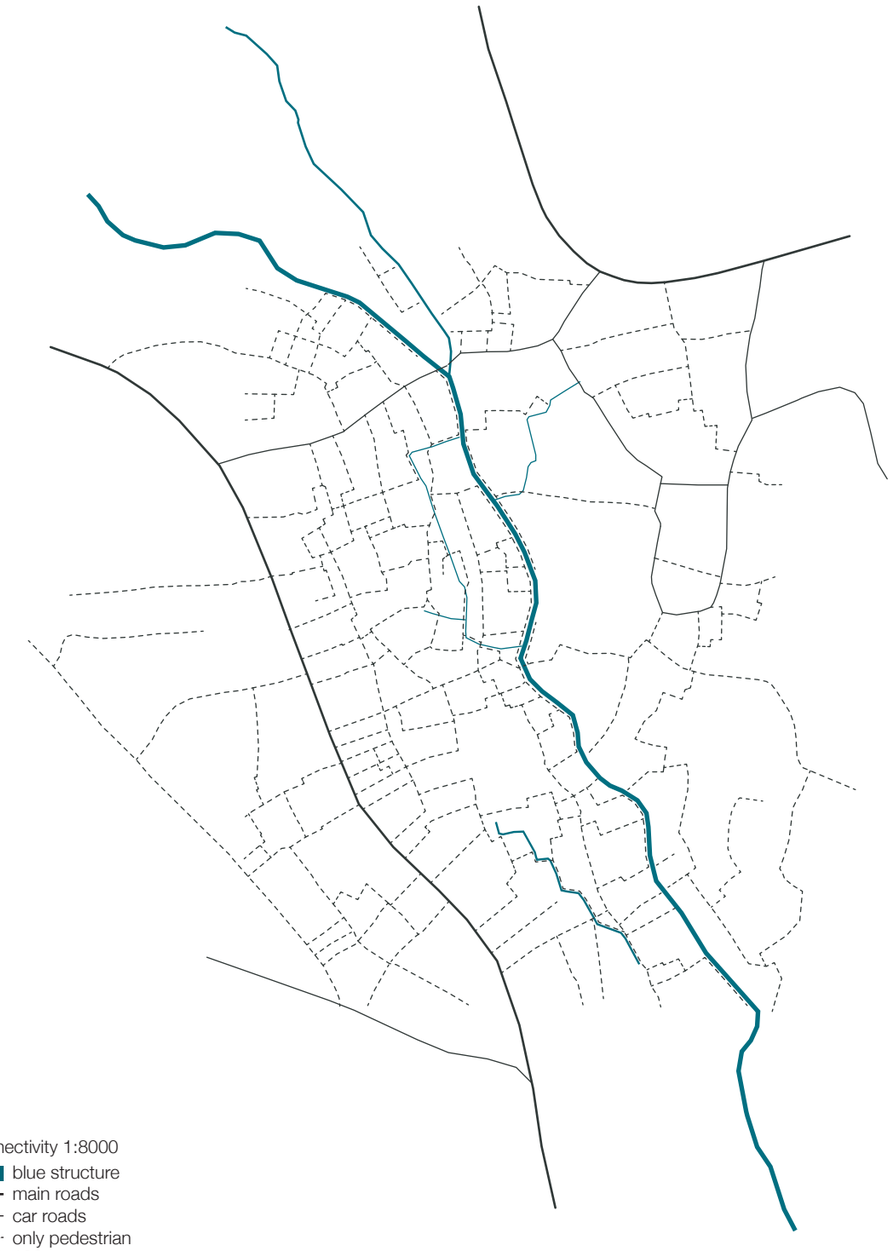
typical swahili floor plan with
common hall way





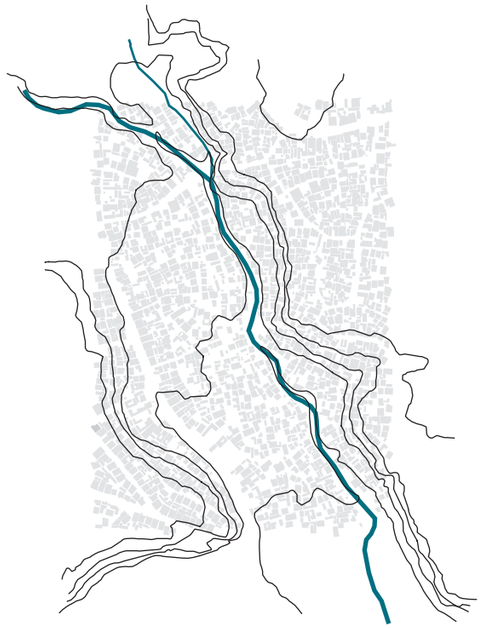
Infrastructure 1:8000
- blue structure
- main roads
- car roads
- only pedestrian
- existing grid

beke-marleen hörmann



Connectivity 1:8000
- blue structure
- main roads
- car roads
- only pedestrian
- 100m radius
- connected
- missing connection


pesa
ORYX



Elevation map 1:15000
blue structure
2m elevation line



Green structure 1:15000
blue structure
green structure
flood risk



Low - high flood level 1:15000
blue structure
main roads
car roads
flood risk



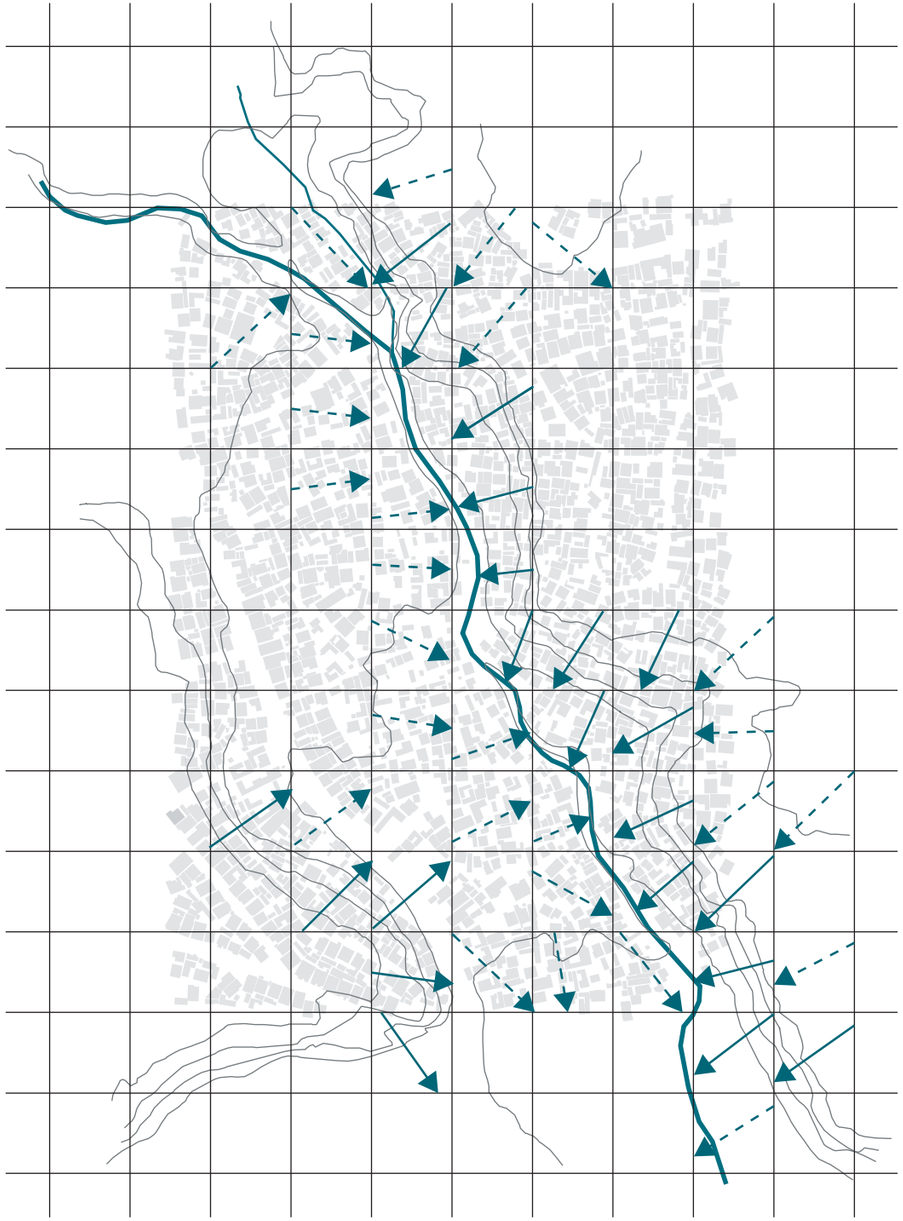
Water/landscape
Almost 90% of the surface is covered by roofs which means that rain water run-off is uncoordinated. The lack of green space is intensifying the problem because water can't infiltrate (see p. 100). The analysis Water flow (see p. 102) shows clearly how water spreads through the neighbourhood and brings local communities into danger. The east side of the river has a steep landscape, whereas the west side is flatter. This irregularity effects the run-off water flow and the urban structure on different height levels.
Besides, rain water increases the height level of the river which means that water floods in other parts of the neighbourhood (see p. 100-101). Particularly in the wet season the flood water spreads out into the neighbourhood. The closer people settle next to the river, the more likely they are effected by floods.

Infrastructure
The elevation of the landscape formed the existing infrastructure and settlement of the neighbourhood. There are just a few roads accessible by car – in the far west following the direction of the river and in the north connecting the area with the city of Dar es Salaam. The river N'Gombe creates a barrier between the west- and east. Only two connecting bridges are functioning which shows the lack of connectivity within the neighbourhood (see p. 97).
However, the west side of the river with an existing urban grid shows a more developed infrastructure network than the east side (see p. 96). Groceries and mosques are accessible in all parts of the neighbourhood, whereas fresh water sources are limited and exist just on the west side of the river.

Urban settlement
As mentioned above the urban settlement is influenced by the existing urban grid in the west- and by the elevation on the east site of the river. The area is very dense in two dimensions which means houses are mostly one-story high. There are opportunities to collect and manage water from the roofs of the buildings. The life cycle of the buildings in Dar es Salaam is short and is highly affected by the extreme weather event. A Swahili house in an informal settlement last around four years. Therefore, there is vacant land which gives opportunity to introduce new typologies and densify into the third dimension (see p. 103).



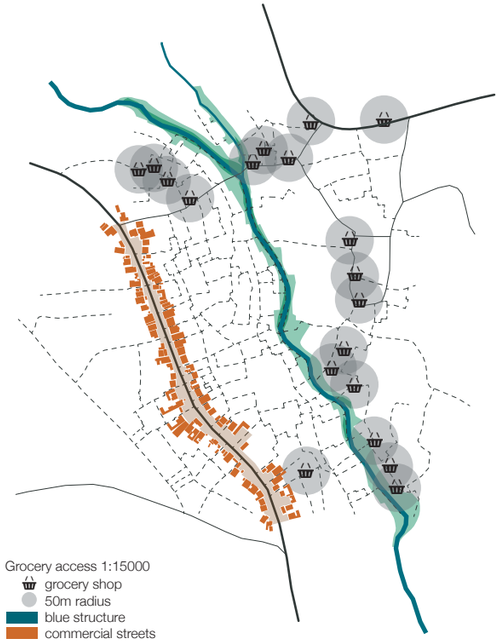




Water flow
- 100m grid
- 2m elevation line
- slow water flow
- fast water flow



Vacant land 1:15000
- blue structure
- green structure
- vacant land



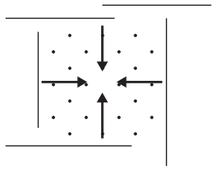
Grocery access 1:15000
- grocery shop
- 50m radius
- blue structure
- commercial streets
- main shopping streets



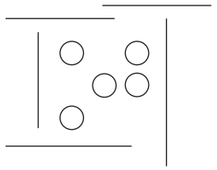
Water access 1:15000
- toilets
- fresh water
- 50m radius
- blue structure
- commercial streets
- no fresh water access



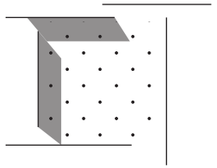
Religious institutes 1:15000
- mosque
- 50m radius
- blue structure
- commercial streets



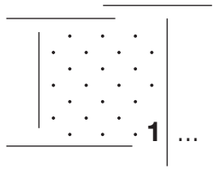
arabic/muslim courtyard culture



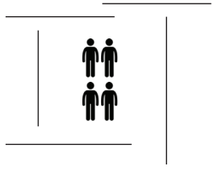
small scale intervention



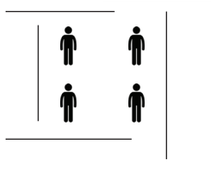
good climate - shade/green space



implementation by units

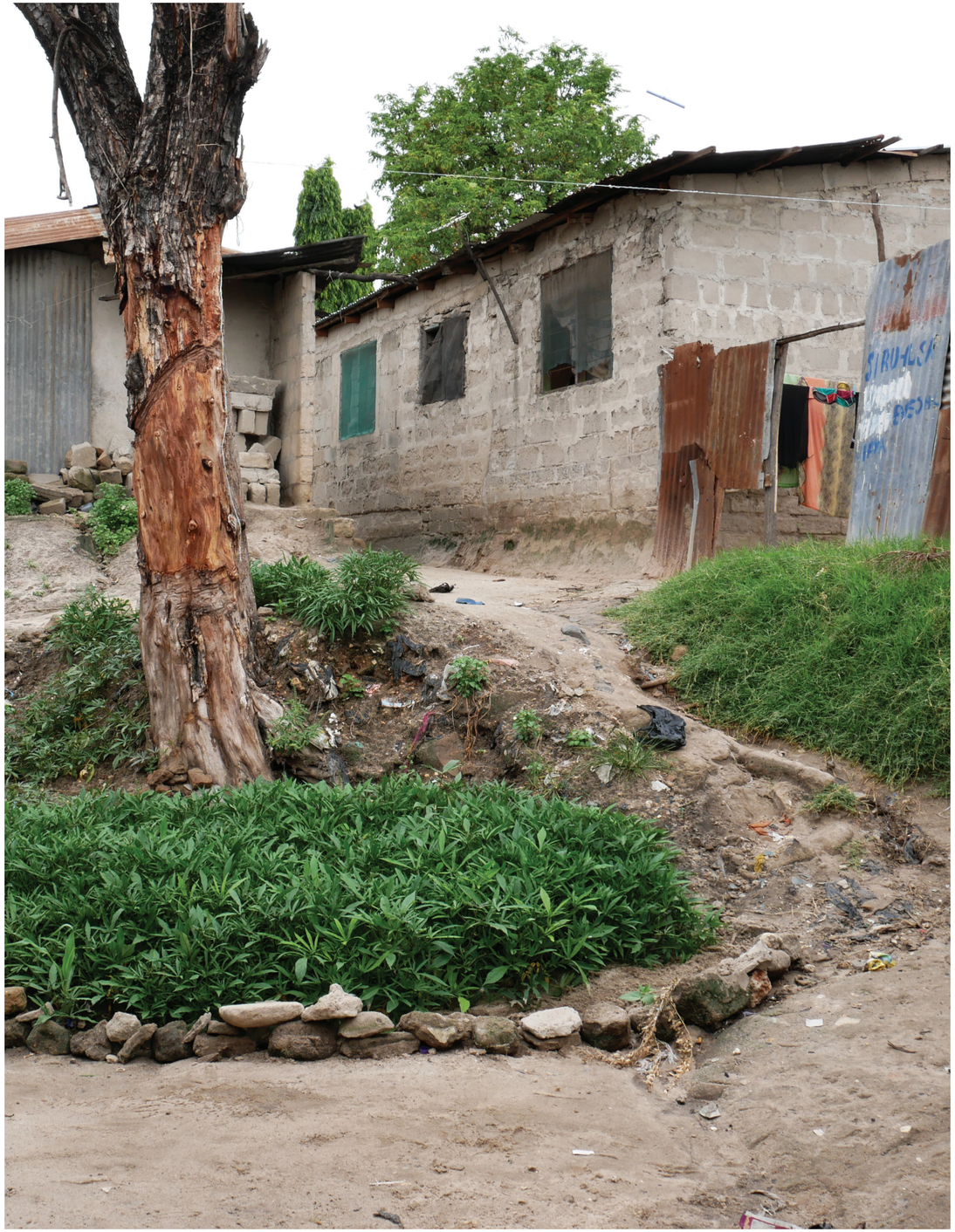


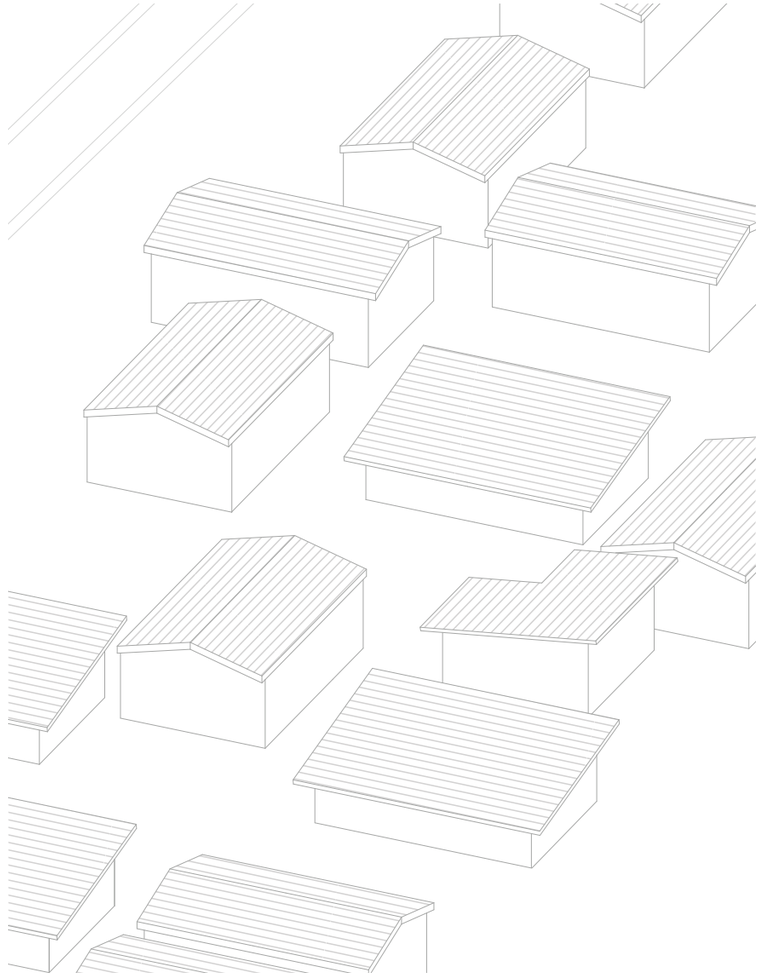
don‘t have to move



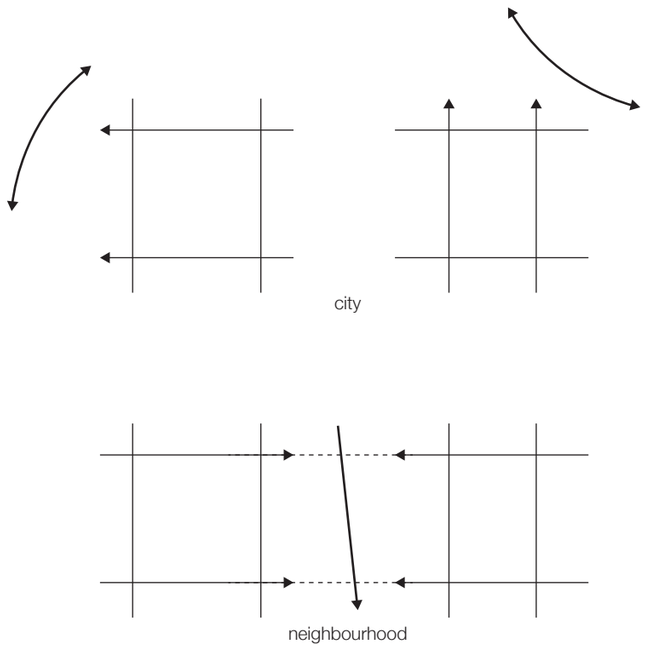
community based units







current situation -



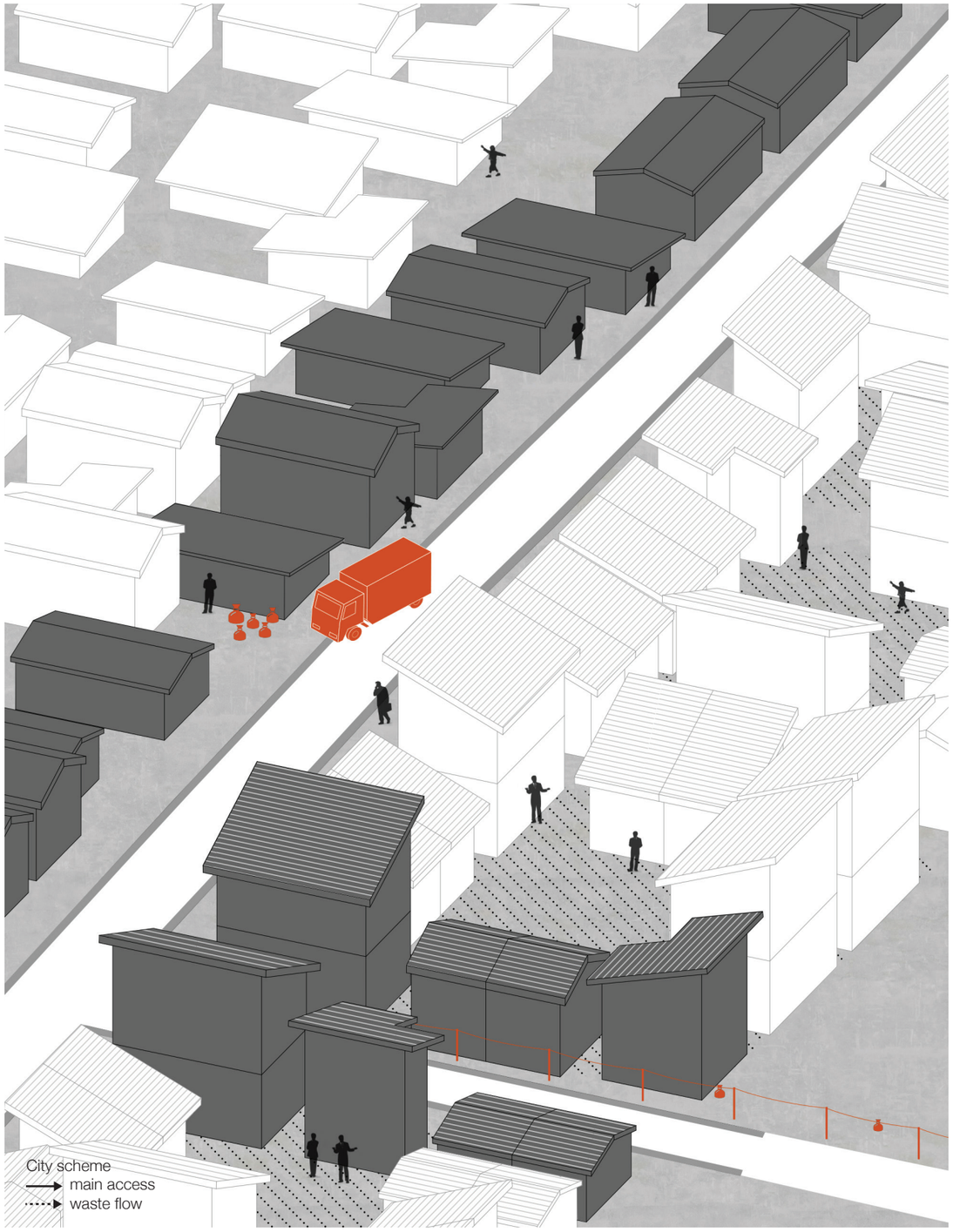
The field work in Dar es Salaam showed that most of the local life takes place outside the crowded house. The spaces in between and in front of each house are used for growing plants and laundry (see p. 105). Outside space plays an important role in a Swahili life. The analysis supported this observation and showed a clear structure of how people move and use their neighbourhood (see p. 96-97). The result is a courtyard structure framed by the urban block connecting east-and west of the neighbourhood and on a big scale connecting the city. This observation of existing urban grid and infrastructure has been a guiding while developing the concept of the courtyard.

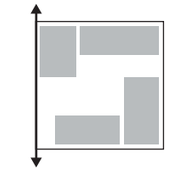
The courtyard concept addresses several urban layers whereas the (1) courtyard layer is the heart of the project as the name already indicates. The urban layers such as (2) urban block, (3) neighbourhood and (4) city are complementing but play a secondary role.

In the (1) courtyard mostly water related interventions take place but also the problem rapid urbanisation, no coping capacity and waste are being addressed (see p. 116). The idea is to keep water- and waste flow in a small-scale cycle. That means collecting water via the roofs of the buildings. New typologies for buildings will make it easier to collect water but also offer more space for the fast-growing population. Once water is collected, it will be stored and re-used for local urban farming in an aquaponics system. Brown- and blackwater as well as organic waste can be directly treated in the biogas reactor to generate a sustainable source for cooking and heating. The green courtyard provides a natural way where water can infiltrate and evaporate but also space for chickens and composting.

However, in peak seasons it is possible that the courtyard system cannot cope with the entire volume of rain water. In that case, each courtyard is connected to the bigger (2) urban block (see p. 114). From there water can flow off via ditches. All courtyards are accessible via smaller paths. The (3) neighbourhood layer connects the leftover rain water with the local river Ng'ombe where it finally can flow outside the neighbourhood. Besides, it connects the east- and west side of the river with pedestrians walk ways and connects the cable car for waste management to the bigger infrastructure of the city (see p. 112).
The (4) city layer provides the main access into the neighbourhood and from there back into the city of Dar es Salaam. From here the council can collect waste from collection points and can access the neighbourhood with bigger vehicles (see p. 110).

In summary, the courtyard concept persists of four urban layers whereas the courtyard plays the most important role. Water- and waste management is primarily treated on this scale which keeps the cycle small and semi-closed. This provides several advantages such as community based courtyard management, local urban farming as additional income and sustainable biogas production. The actual physical intervention is completed at unit level, with makes the implementation easier to scale and carry out in phases.

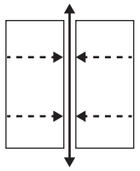




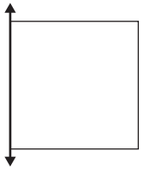
urban block connected to
city infrastructure



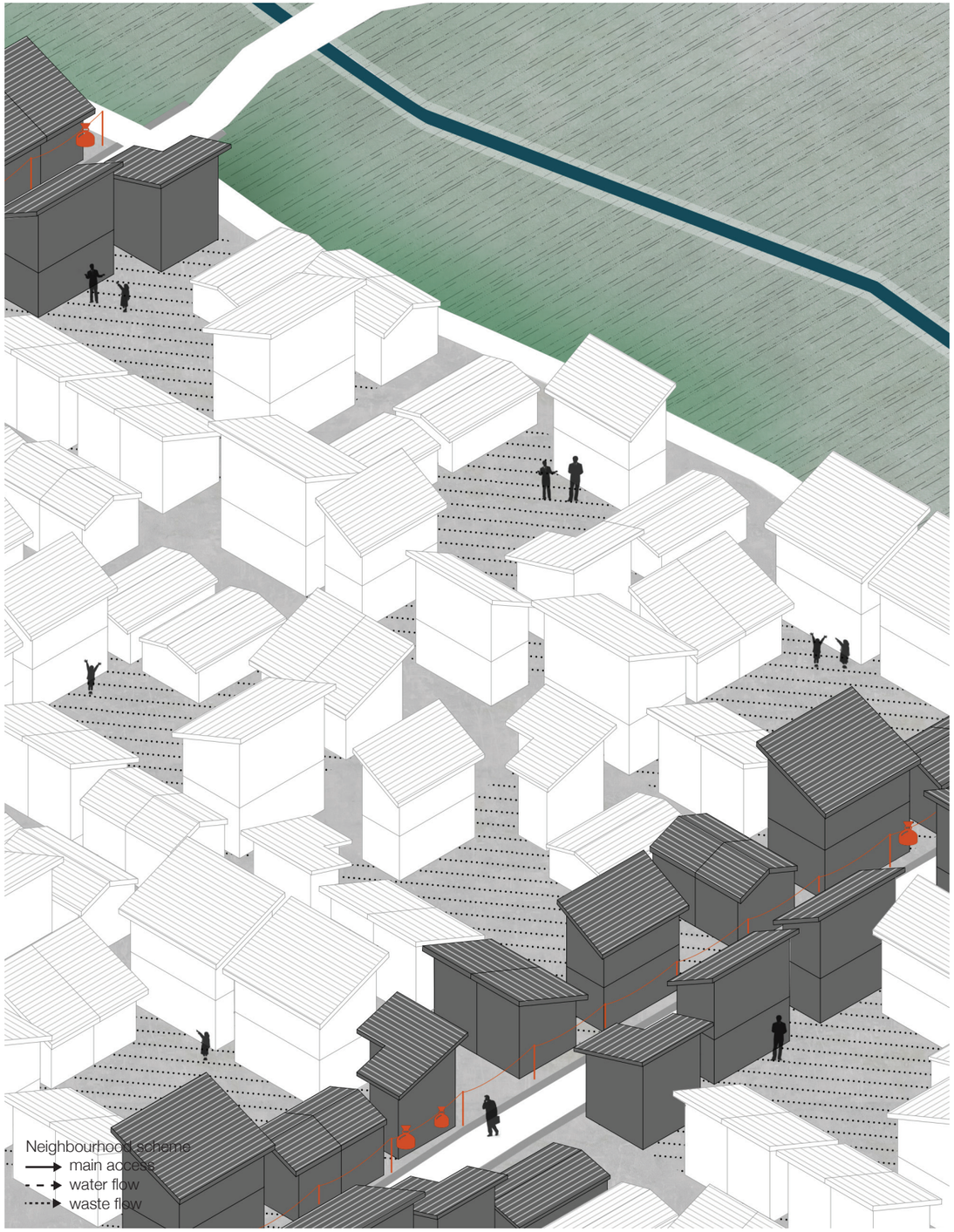
waste management -
collection points

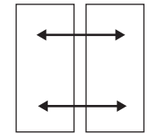


water ditches
connecting the river

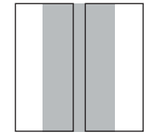


main city
infrastructure access





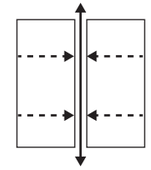
connecting east-and
west side of the river



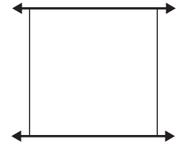
green buffer zone
for the river



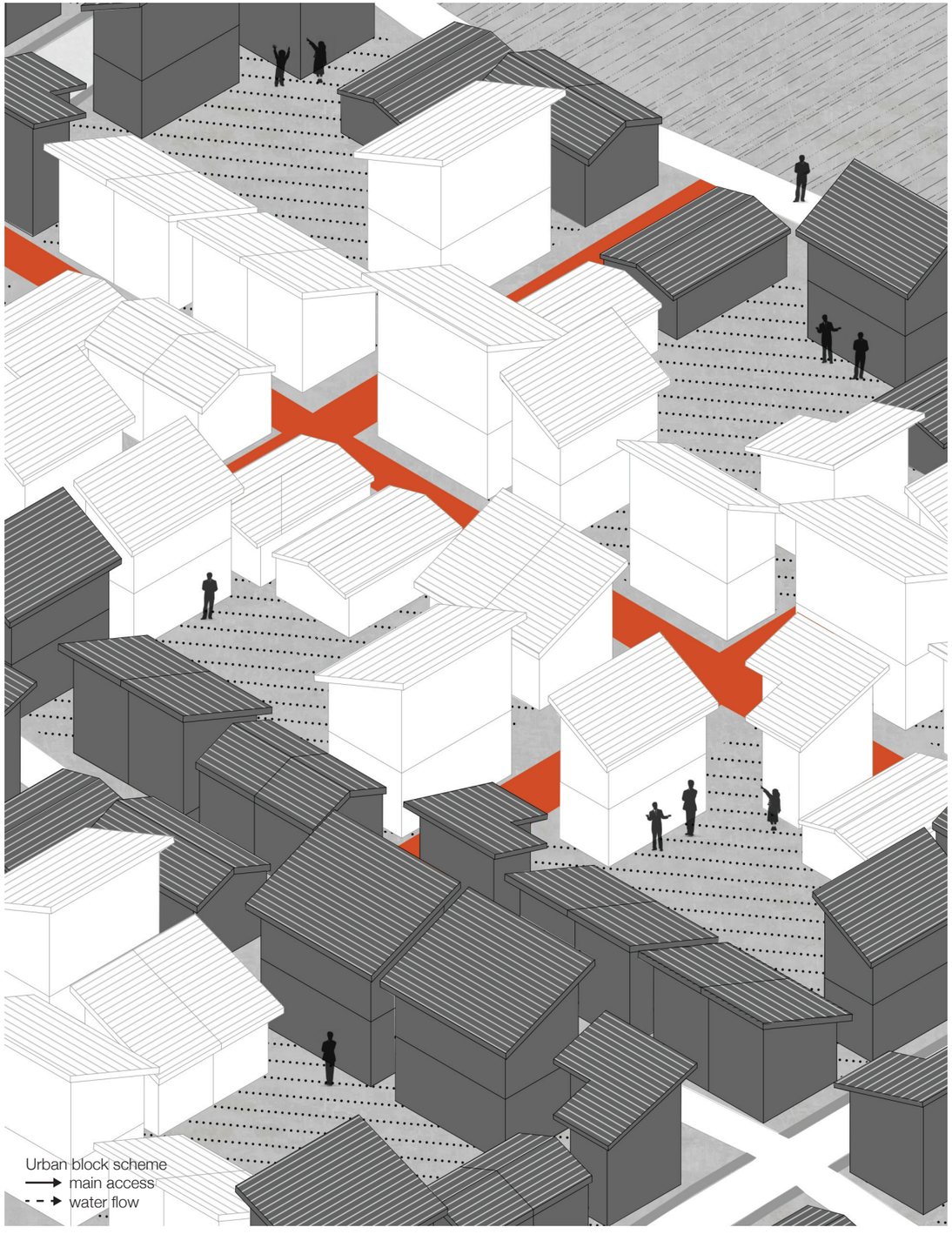
waste management



water ditches
connecting the river

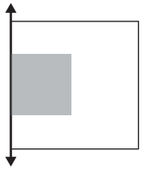


main infrastructure access

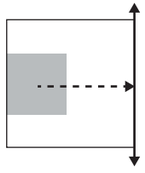




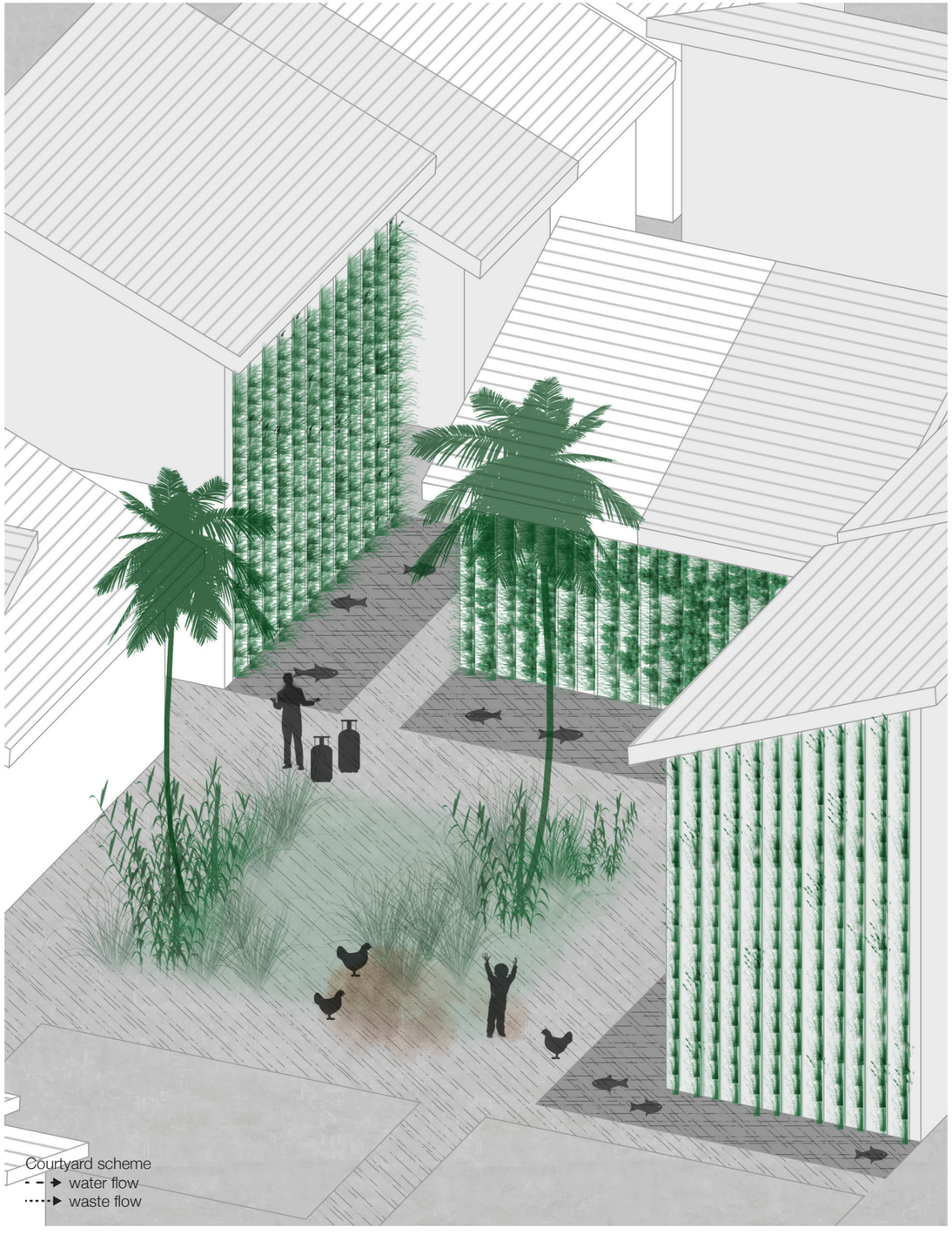
enhance natural urban block

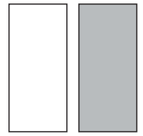


each courtyard is connected
to infrastructure



courtyard releases left-over
rain water to bigger infrastructure

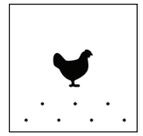




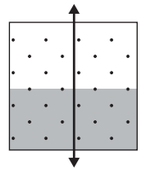
new housing typologies
(see page 118)



urban agriculture -
aquaponics system



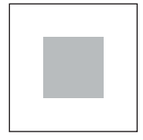
chickens and composting



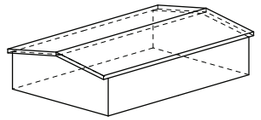
evaporation and infiltration



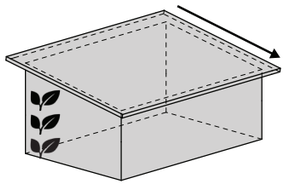
biogas generation



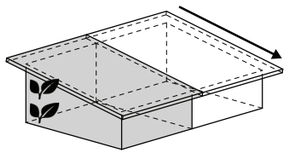
green courtyard for
fruit and vegetables



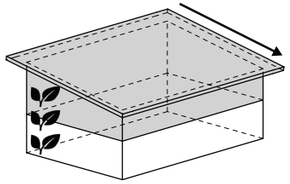
25% strategic removal of
old houses/reducing built surface



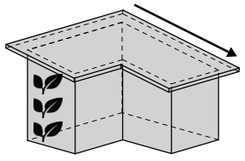
20% new housing /guiding and
manageing run-off rain water /using
facade for aquaponics



strategic housing expansion /guiding
and manageing run-off rain water
/using facade for aquaponics



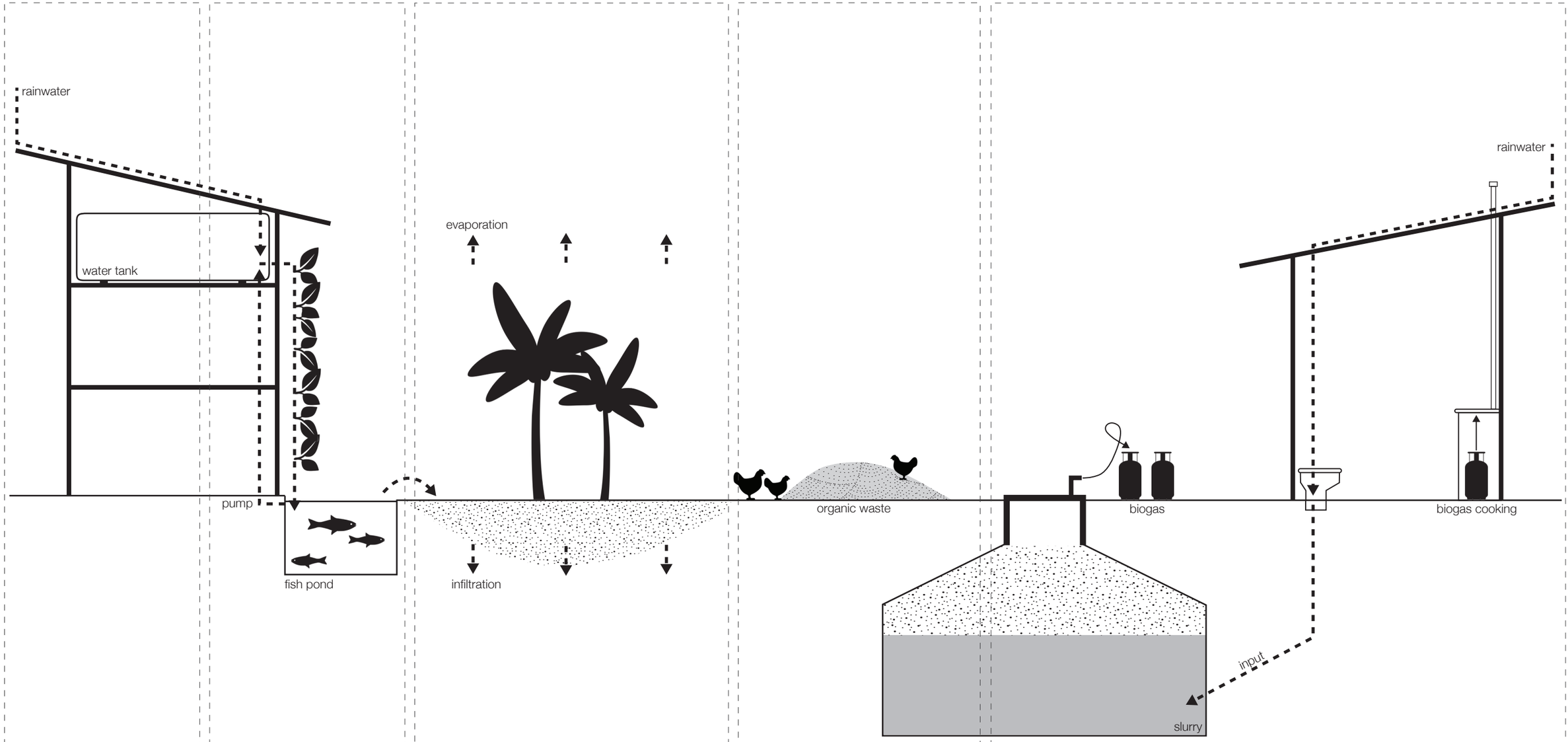
densifying in height
/reducing built surface /guiding and
manageing run-off rain water /using
facade for aquaponics



enhancing courtyard
structure /guiding and manageing
run-off rain water /using facade for
aquaponics



beke-marleen hörmann



rainwater collection
(see p. 122)

aquaponic system
(see p. 123)

natural system
(see p. 122)

composting/chickens
(see p. 124)

sanitation biogas system
(see p. 125)

Rainwater collection
The roof of the buildings plays the most important role because it is guiding the water into different directions – either into the courtyard or into the bigger system of neighbourhood where it then flows into the river.
The green courtyard has similar infiltration to the natural landscape of Tanzania and can infiltrate almost 50% and evaporate 40% of the rain water. That means just 10% of the water runs off and need to be guided into the river. The native landscape will be supported by rainfall which means native fauna and flora will improve over time (Watson & Adams, 2011).
The chart below shows an indication of landscape infiltration:

	rain water	green space
∅ courtyard	25% deep infiltration 25% shallow infiltartion 40% evaporation 10% run off	380 m²

However, most of the rainwater (about 55%) in the dense urban space will be collected via the roof of the buildings surrounding the courtyard and will be stored in a water tank. Only 10% infiltrates and 30% evaporates of the rain water. Most of it gets used for cooling the house, flushing toilets, watering the aquaponics system or washing laundry (Watson & Adams, 2011).
The chart below shows an indication of infiltration and water use in dense urban areas:

	rain water	urban space
∅ courtyard	5% deep infiltration 10% shallow infiltartion 30% evaporation 55% run off	2000 m²

	55% run off water	urban space
∅ courtyard	5% toilet 15% aquaponic 20% fish pond 5% laundry	2000 m²

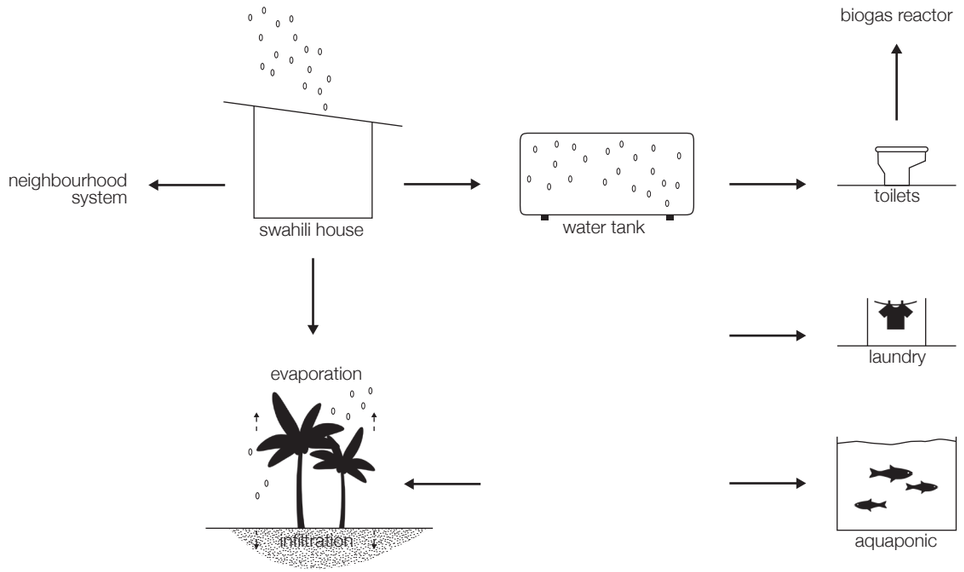


Fig. 10: Rainwater collection. Own drawing.

Aquaponics system
An aquaponics system combines aquaculture (raising fish) and hydroponics (non-soil growing plants). The fish manure supply organic nutrients for plants, and plant naturally filter the water for the fish - a sustainable eco system (The Aquaponic Source, 2018).

Water will be collected from the roof of the building and stored in a water tank which is connected to the aquaponics system of the courtyard. The aquaponics system will be vertically installed on the façade of buildings. Plants are stacked on top of each other, water flows through from the top down to the bottom of the system and supplies water for the roots. This has a cooling effect for the inside of the house and is useful for areas where soil is polluted as plants can grow off the ground. To keep the water in the loop a pump will move the water back into the water tank in dry seasons. In wet seasons, left-over water will be released from the fish pond into the green courtyard where it can now naturally infiltrate and evaporate (The Aquaponic Source, 2018).

Particularly leafy plants such as salads and spinach but also tomatoes are growing well in a vertical aquaponics system. The advantage of such a system is that you keep water in a loop in the wet and dry season of the year. Depending on the kind of crop, vegetables can be harvested after one month (Nelson and Pade, n.d.).
The following chart gives an indication of how much lettuce and tomatoes can be harvested per courtyard:

	3.8 kg	1 m²	1 year
∅ courtyard max. capacity	957.5 kg	250 m²	1 year
	18.4 kg	250 m²	1 week
	2.6 kg	250 m²	1 day

	10.2 kg	1 m²	1 year
∅ courtyard max. capacity	2550 kg	250 m²	1 year
	49 kg	250 m²	1 week
	7 kg	250 m²	1 day

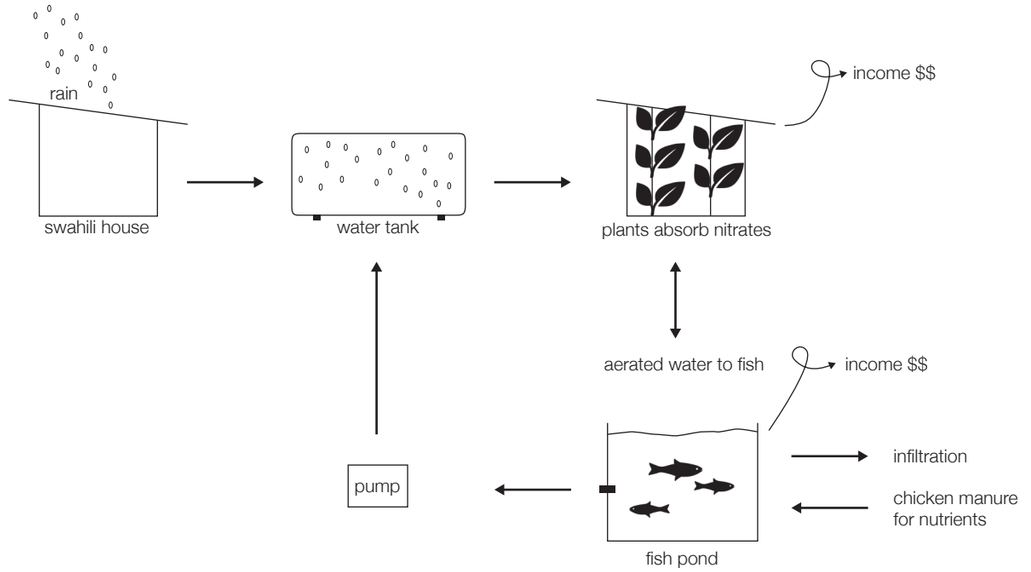


Fig. 11: Aquaponics system. Own drawing.

There are different kind of fish which can be used in an aquaponics system in Dar es Salaam such as Nile Tilpia. As the name indicates this fish is an African sweet water fish and lives in 27-30 C degree water. The growing time is about 28 weeks until it weighs approximately 500-700 grams. In addition, the Nile Tilpia likes to eat insects which, lowers the risk of mosquito borne diseases (Uponics, n.d.).

The following diagram gives an indication of how much Nile Tilpia can be farmed per courtyard:

	50 kg	1 m³	1 year
∅ courtyard	5000 kg	100 m³	1 year
max. capacity	96.2 kg	100 m³	1 week
	13.7 kg	100 m³	1 day

The Nile Tilpa is just one example of fish which is suitable, vertical aquaponics system. To find more suitable fish please see fish analysis page 85.

Composting
The green courtyard offers space for composting and keeping chickens. The human waste such as organic household waste can be collected and composted. The nutrients and beneficial soil bacteria's from the compost can be used as fertilizer for growing new crops. Those once can be harvested and eaten - a sustainable ecological cycle.
Additional, the compost offers a perfect environment for chickens. Leftover food gets picked by the chicken and the chicken manure enriches the composting process (Tilley et al., 2014).
The chart shows how many chicken can be hold in one courtyard and how many eggs they produce per day. Chickens can be eaten after 1-1.5 years.

	1 chicken	2 m²	0.5 egg/day
∅ courtyard	190	380 m²	96 egg/day
max. capacity	190	380 m²	126 chickens/ years
optimum	50	380 m²	25 egg/day

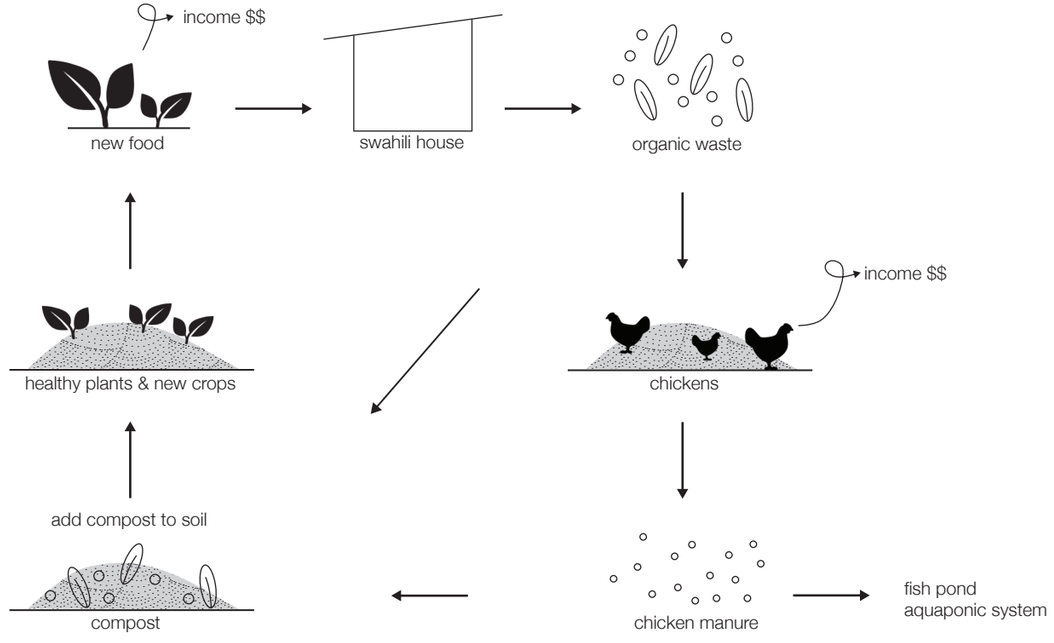


Fig. 12: Composting. Own drawing.

Biogas reactor
The inner of the courtyard offers appropriate space for a biogas reactor which produces on one hand (1) digested slurry which can be used as fertilizer and on the other hand (2) biogas which can be used for energy. Biogas is a combination of methane, carbon dioxide and other trace gases which can be used for electricity, cooking and heating (Energypedia, 2016).

The input of the biogas reactor includes blackwater, faecal sludge, brownwater, faeces, excreta and organic waste. In the case of the courtyard it will be mostly used for black- and brownwater (Tilley et al., 2014).

Due to the small land requirement, the production of renewable energy, conservation of nutrients, moderate costs and the long service life. The system need to be emptied every 10 years depending on the construction (Tilley et al., 2014).
The reactor is installed underneath the ground in the centre of each courtyard. This reduces the impacts of smell, bacteria in the neighbourhood and therefore mitigating many health risks. Every toilet of the one courtyard is directly connected with the reactor via pipes.

Another advantage is the hot climate in Dar es Salaam. The biogas reactor doesn't work under 15C degree and produces biogas faster above 25 C degree. The retention time of the biogas reactor is about 40-100 days (Tilley et al., 2014).

The biogas reactor can be brick constructed domes or a pre-made tanks. Once gas gets removed from the reactor, new slurry flows back in. The retention time is about 15 days under warm weather conditions. The size of the tank varies from 1000 litre for a single family up to 100 000 litres for public use (Tilley et al., 2014).
The following chart gives an indication of the capacity and size of a biogas reactor:

	1 person	1.2-1.6 m³	40-100 days
∅ courtyard	160	192 m³	40-100 days
max. capacity			

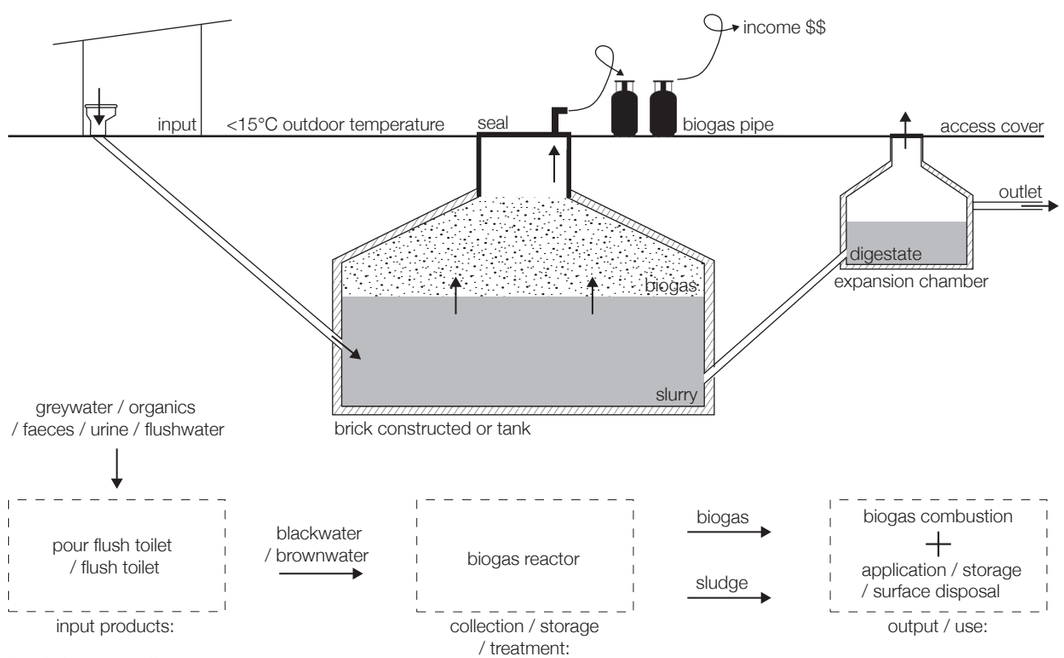


Fig. 13: Biogas reactor. Own drawing.

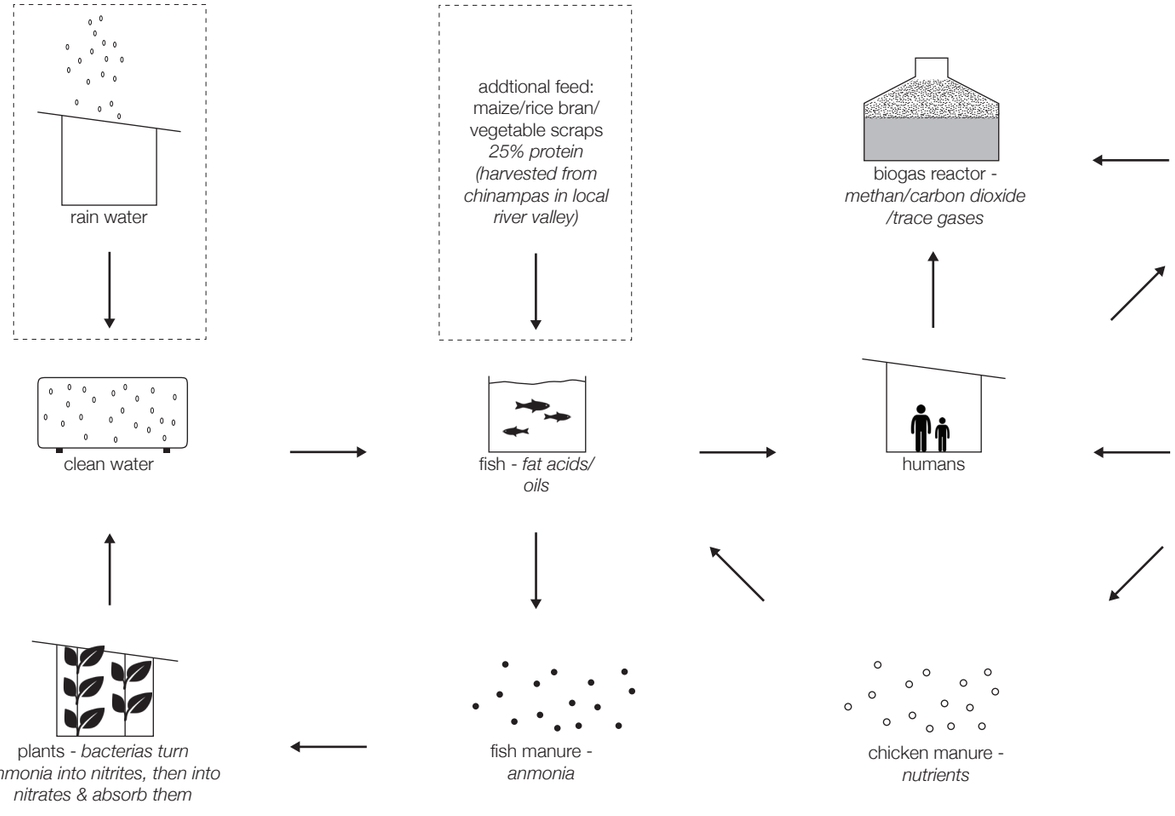


Fig. 14: Agriculture cycle. Own drawing.

The agriculture cycle shows how the different systems, within the closed cycle, complement each other. The agriculture cycle is not dependent on rain throughout the year – it functions in wet and dry seasons. The aquaponics system and natural infiltration/evaporation are the most important systems of the green courtyard for water management and have the most significant impact.
The weather conditions in Dar es Salaam are extremely diverse, but this does not compromise the functioning of the courtyard system.
Aquaponics farming is about 20 times more water efficient than traditional farming systems and can therefor bridge the dry season in Dar es Salaam which last from June to September (see p. 24) (Love, Uhl & Genello, 2015). It functions up to 280 days without additional water input. At the same time, the system has a very high water retention capacity which reduces run-off during the rain seasons.
The following chart gives an approximate indication of the water loss of an aquaponics system:

	10 litre	1 m²	1 week
∅ courtyard	2500 litre	250 m²	1 week
max. capacity of fish pond 100m³ (rain water tank not included)	357 litre	250 m²	1 day
	100m³ / 357 litre = 280 days		

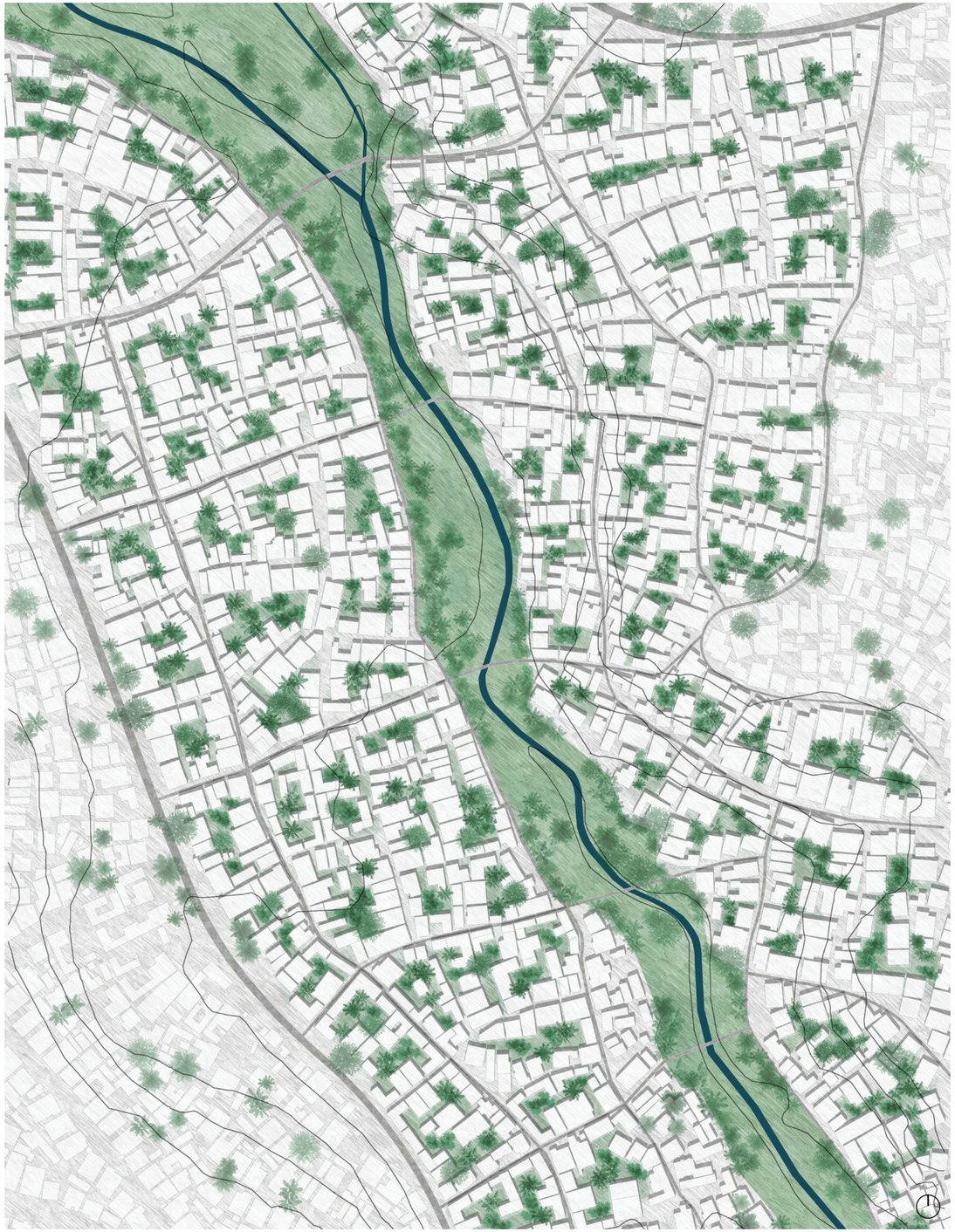
The agriculture system does not just include the aquaponics system and the natural infiltration/ evaporation for water management - it also includes composting and chicken farming for essential protein- and nutrient supply.

The humans are in the centre of the diagram because they are connected to each system. Human organic household waste brings nutrients and beneficial bacteria into the agriculture cycle which is used as fertiliser for growing crops and feeding chickens. The eggs and the chickens can be eaten by humans and are an important protein source. Chicken manure brings nutrients into the fish pond of the aquaponics system, whereas the fish bring important fatty acids and oils into the human diet. Fish manure functions as fertiliser for the aquaponics plants. Those filter the water and release it cleaned back into the fish pond. In that way water can stay in the loop and be recycled for long periods without new additional input.

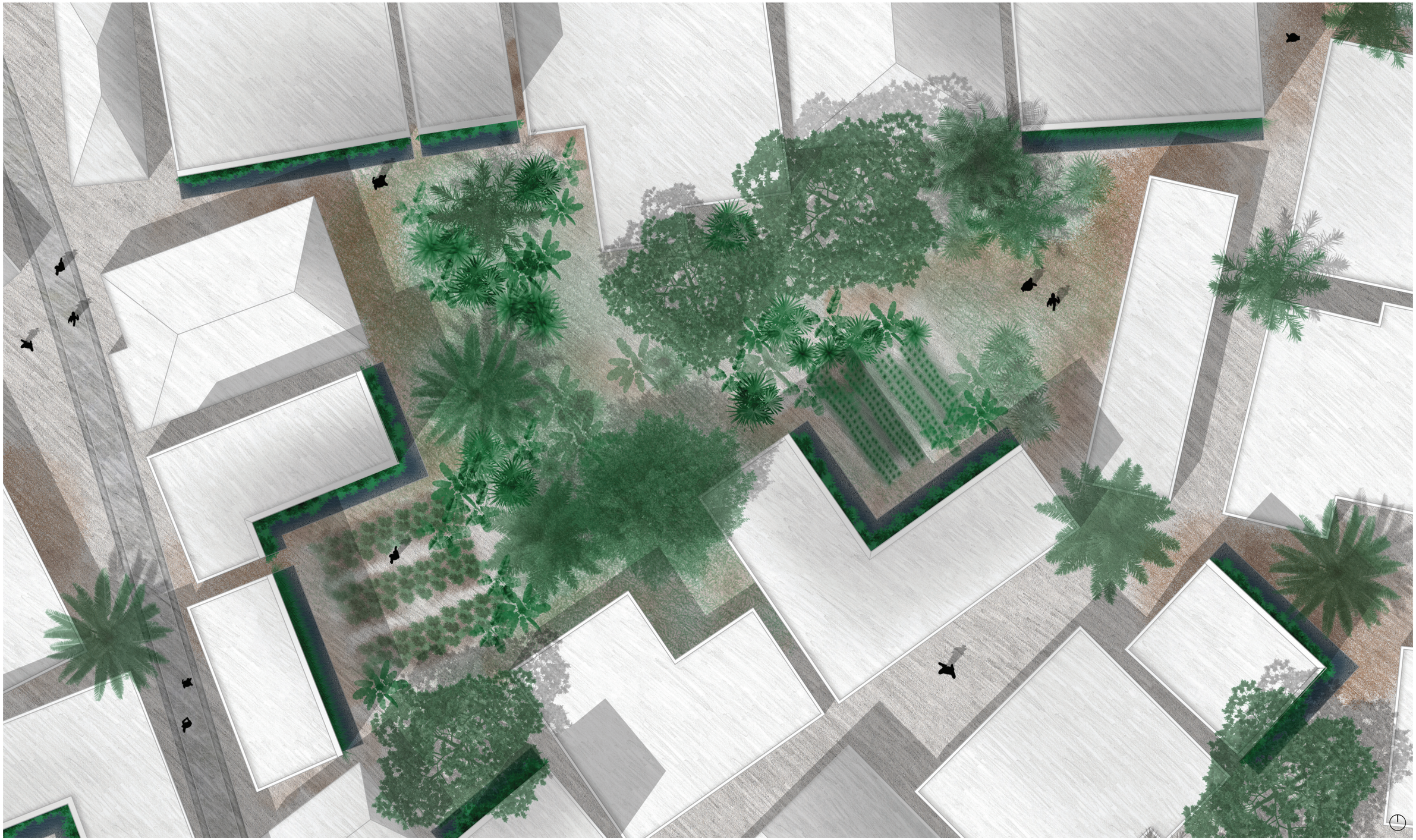
The field trip in Dar es Salaam showed the highly polluted environment due to untreated waste water. The systems mentioned above can treat organic household waste but can not treat any waste water. Therefore, an additional sewage system need to be implemented into the agriculture cycle.
Human blackwater, brownwater and organic waste can be treated in the biogas reactor of each courtyard which generate carbon dioxide, methane and trace gases. These can be used for electricity, cooking and heating (Tilley et al., 2014).

Even though the agriculture system provides different nutrients and proteins, the system is not an entirely closed cycle. Some inputs are required: Chickens and fish need about 25% extra feed consisting of vegetable scraps, maize or rice bran to provide the right number of vitamins and protein (Backyard chicken coops, 2018). The extra feed can be harvested from the Chiampa's in the local river valley.

site plan 1:5000



beke-marleen hörmann



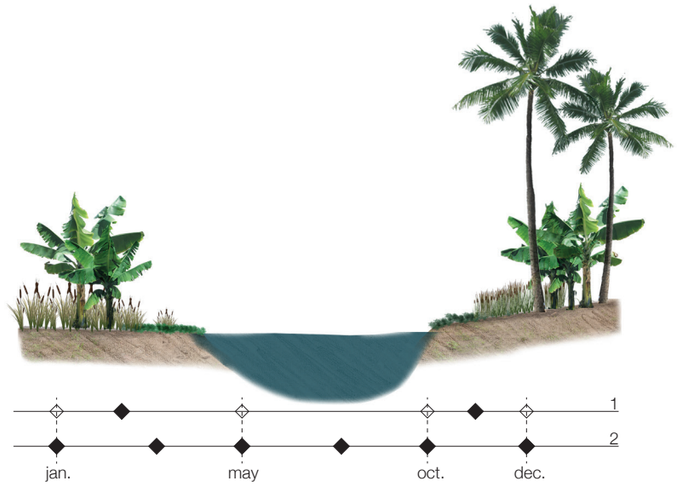
beke-marleen hörmann



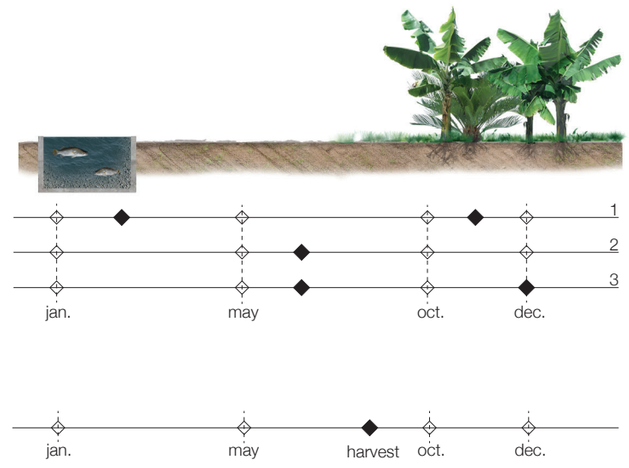
cross section east side 1:200



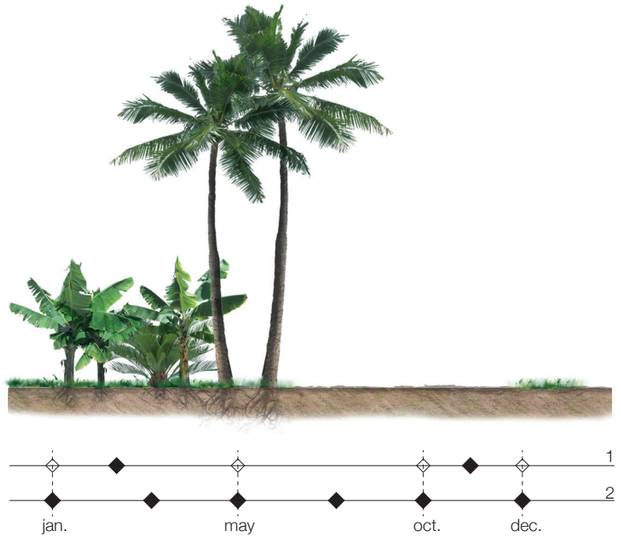
Green river buffer zone:
1 musa sapientum / 2 cocos nucifera / typha latifolia / phragmites communis / eichhornia crassipes / saggitaria latifolia



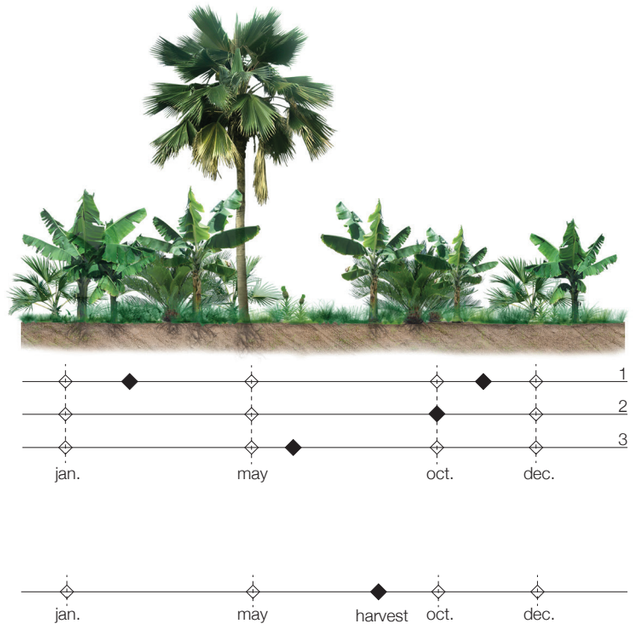
Courtyard fishpond:
1 musa sapientum / encephalartos hildebrandtii
fish: 2 percinae / 3 oreochromis niloticus



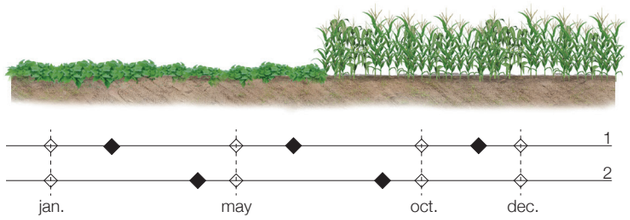
Courtyard surface:
1 musa sapientum / 2 cocos nucifera / encephalartos hildebrandtii



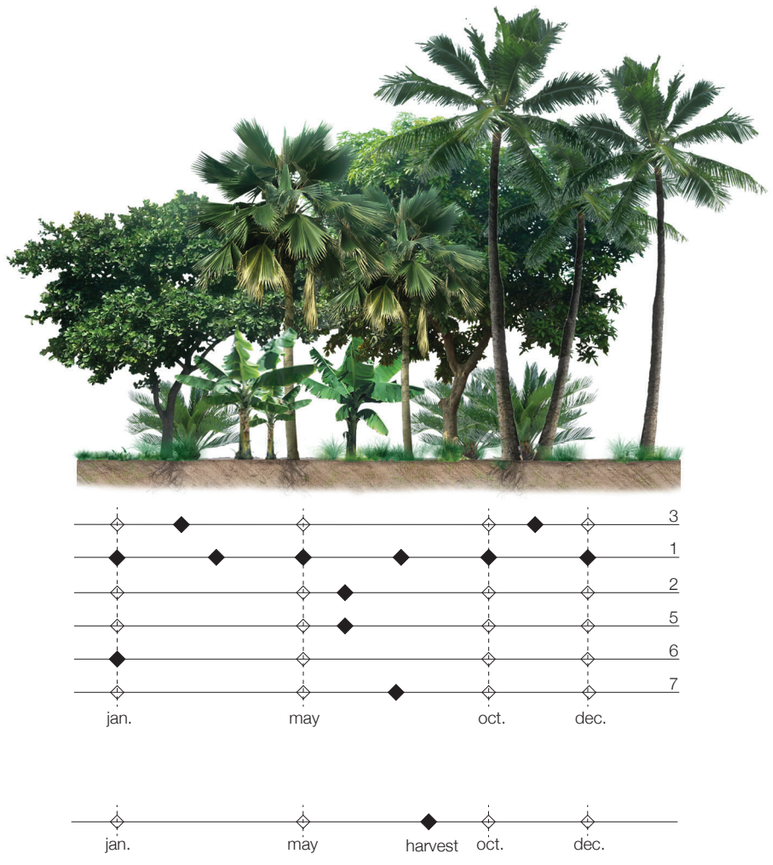
Courtyard bushes:
1 musa sapientum / encephalartos hildebrandtii / typha latifolia/ phragmites communis / 2 ananas comosus / 3 carica papaya



Courtyard agriculture field:
1 ipomoea batatas / 2 zea mays subsp. mays



Courtyard trees:
1 cocos nucifera / 2 carica papaya / 3 musa sapientum / 4 encephalartos hildebrandtii / 5 tamarindus indica / 6 mangifera indica / 7 ficus sycomorus



beke-marleen hörmann



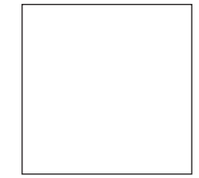




Mona zum Felde

introduction / analysis / intervention
/ chinampa design





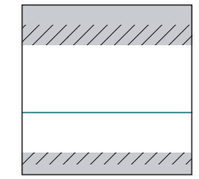
total area: 500.000m²



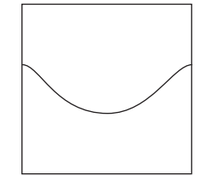
river valley:105.000m²



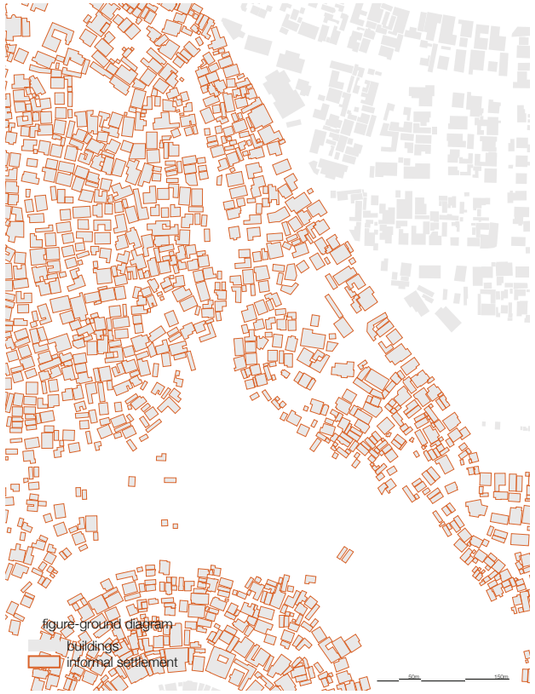
built up area: 35%

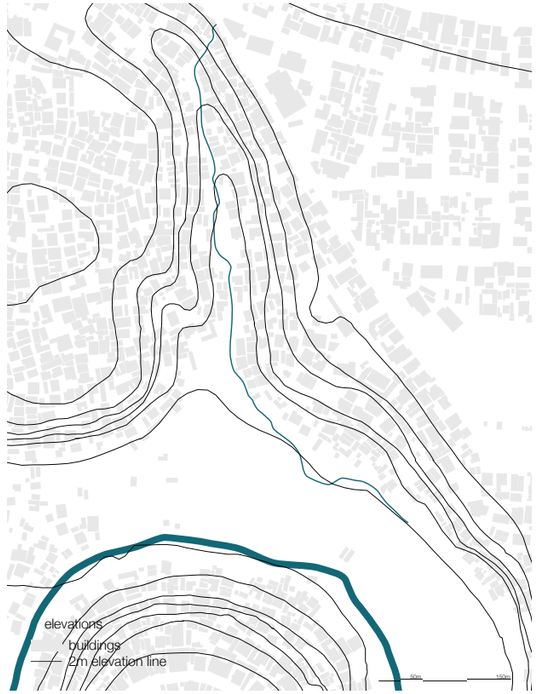


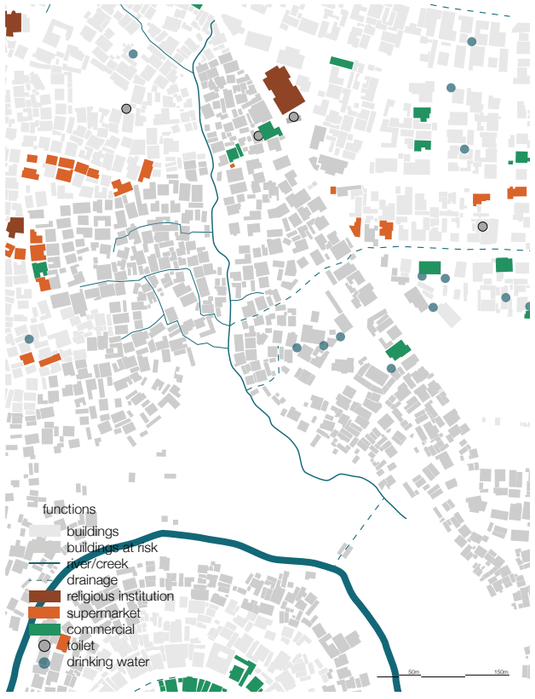
flood risk buildings: 50%

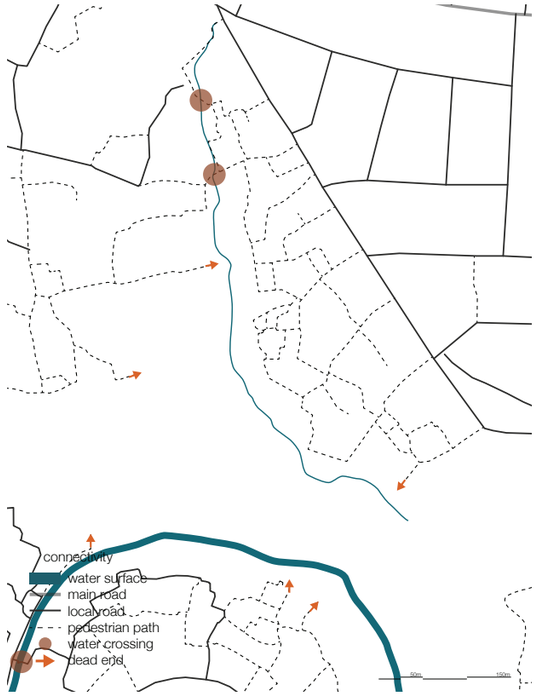


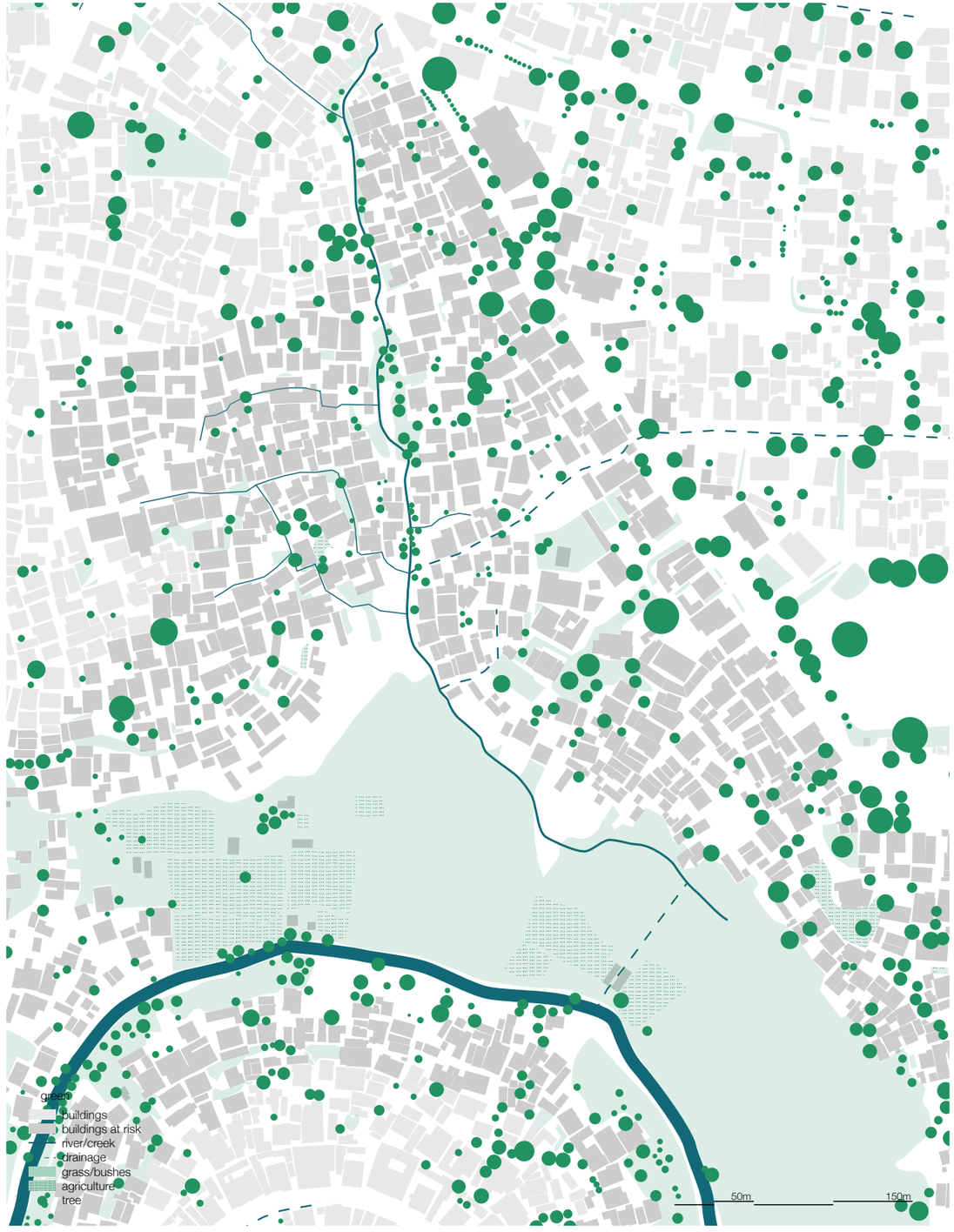
total height difference: 12m

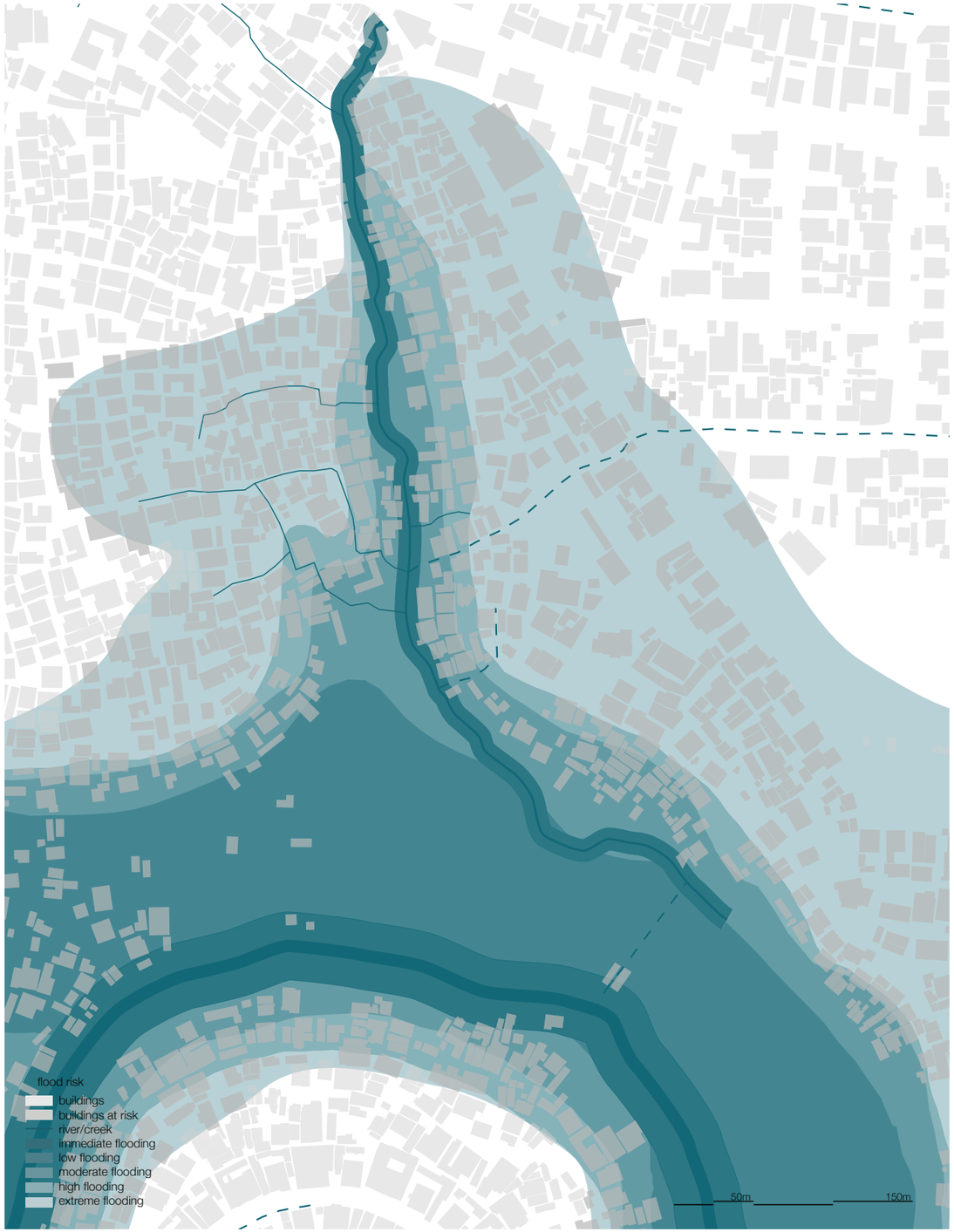

figure-ground diagram
buildings
informal settlement
50m
150m


elevations
buildings
2m elevation line
50m
150m


functions
buildings
buildings at risk
river/creek
drainage
religious institution
supermarket
commercial
toilet
drinking water
50m
150m


connectivity
water surface
main road
local road
pedestrian path
water crossing
dead end
50m
150m


green
buildings
buildings at risk
river/creek
drainage
grass/bushes
agriculture
tree
50m
150m



The individual design area is located in the east of the common intervention area. The areas north and south of the Ng'ombe river, characterised by big heights differences, mostly consist of informal settlements. Only a small part of the individual design area includes planned informal settlements. Buildings are not only located in high areas which are safe from flooding, but also in lower areas close to the river. As a consequence, more than half of the buildings are at risk for flooding, primarily those located in low situated areas.

The area is dominated by housing, of which most is for rent (observation field work). In between the residential areas are clusters with commercial or social functions, like supermarkets, bars, churches and mosques.

The physical infrastructure is very poor in the whole area, though big differences can be seen between the planned informal settlement and the informal settlement. In the planned informal settlement a clear road structure is present. The roads are not paved and only few roads provide a basic drainage system, which is not sufficient for the amount of storm water occurring during rain seasons. Overflowing storm water is mixed with untreated blackwater and together discharged into the river, causing pollution of soil and water (observation field work). The majority of the informal settlement is only accessible for pedestrians. Just few roads located in higher areas are also accessible for cars. The unpaved roads and footpaths are in bad condition and its majority is not accessible during rainfall. Since there is no drainage system of any kind, the mixture of storm water and untreated blackwater is running via footpaths towards the river valley, making connections inaccessible and causing pollution. The existing connections are not continuous with the river and its valley as major barrier, which currently cannot be crossed within the design area. Existing bridges east and west of the area are far away and exceed walking distance.

The distribution of green spaces varies within the area. The density of trees is decreasing towards the western part of the area. The green are of the floodplain is partially used for agricultural activities. These areas are not safe from flooding and carry a big health risk due to the pollution of the river water and soil. Furthermore, due to rainfall throughout most of the year, the soil is extremely muddy so that it is not possible to walk there. Despite the available spatial potential on existing green patches and unbuilt spaces between buildings, there is little urban agriculture activity in higher areas.



In order to identify elements to address with the design, a SWOT analysis of the individual design area has been conducted. This SWOT analysis is based on the spatial analysis as well as personal observations during the field work.

Strength

- central location within the city
- existing neighbourhood communities
- informal economic activities
- large “natural” / unbuilt area
- urban agriculture activities
- many plants/trees

Weaknesses

- pollution of water & soil
- solid waste pollution
- erosion
- weak governance
- ownership issues
- flood areas occupied
- no connection across river
- illegal housing

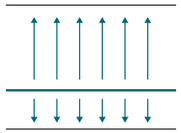
Opportunities

- existing infrastructure to link to
- space for adaptation
- ecology based transformation
- densification of built area to accommodate relocated/new residents
- self production/self sufficiency
- local circular economy
- educational institutions for knowledge exchange

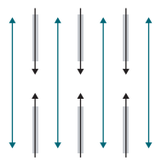
Threats

- high market developments
- difficult enforcement of free river valley without governance
- risk of gentrification and displacement of residents
- pollution from factories & industries

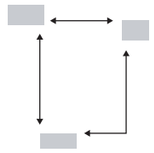
spatial
chinampa
concept



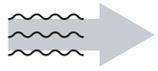
space for water



combine water & human adaptation



connect economic clusters

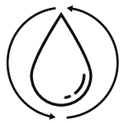


steer movement of water

functional
chinampa
concept



retain water



clean water



reuse water



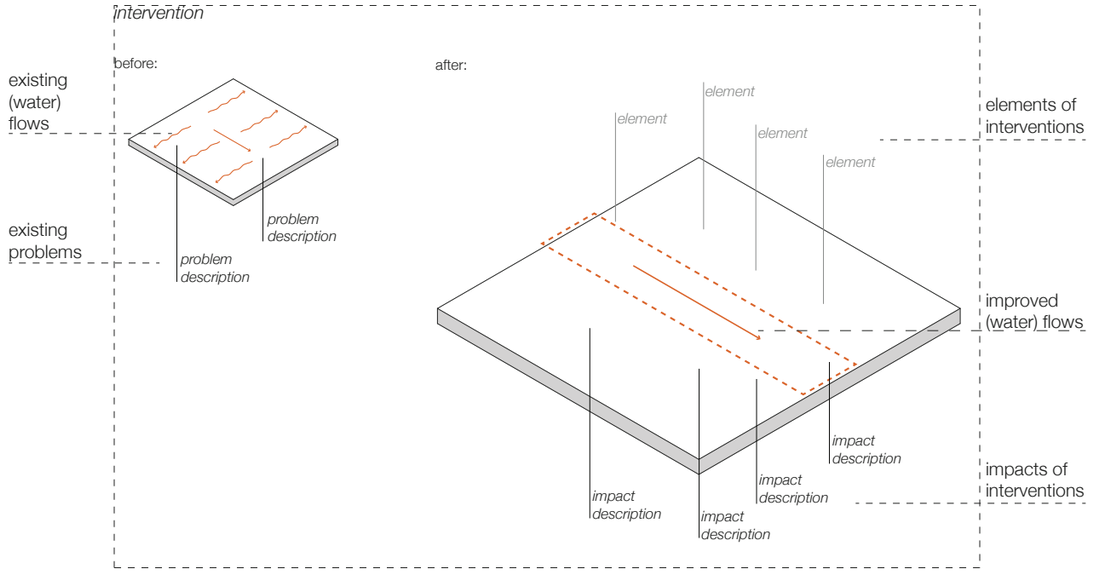
build capacity

The concept of chinampas for the river valley has a spatial and a functional component which are strongly related to each other. Chinampas create a high retention capacity for storm water while enabling sustainable agricultural production in the flood plain. The canals between the elevated fields give space to the water in an organised way. To connect economic clusters across the river valley with each other, the function of strategically located chinampas change from agriculture to connection.

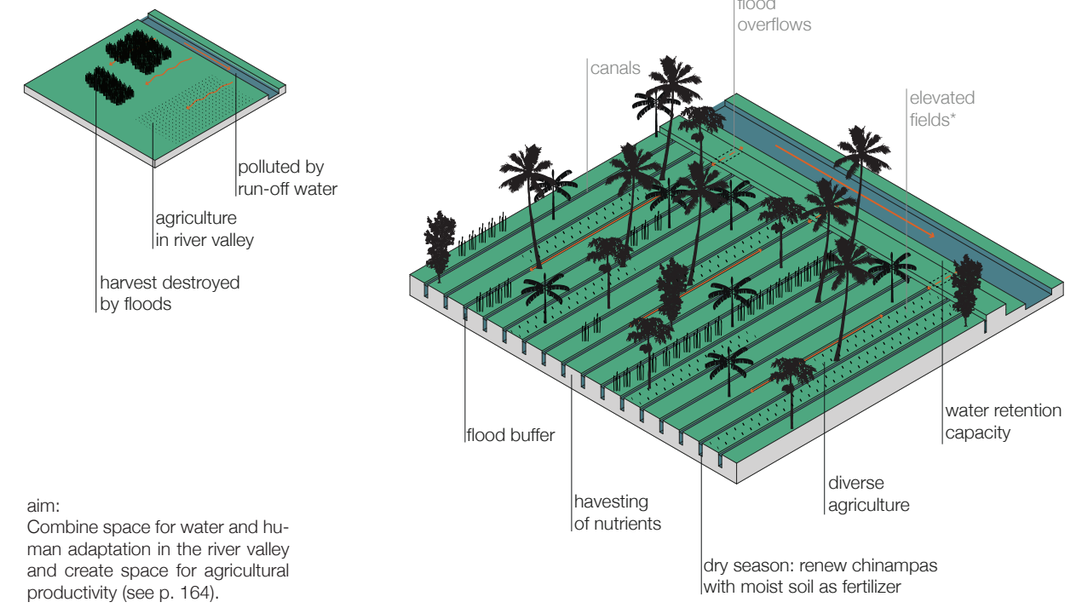
The canals retain the water, make use of it for irrigation of crops and harvest nutrients. The combination of spatial interventions to reduce the flood risk with urban agriculture enables residents to build capacity to deal with future hazards.

Other interventions are located along the river and at the edges of the river valley to contribute to the functions of chinampas, creating a clean, safe, productive and sustainable environment.

interventions - legend

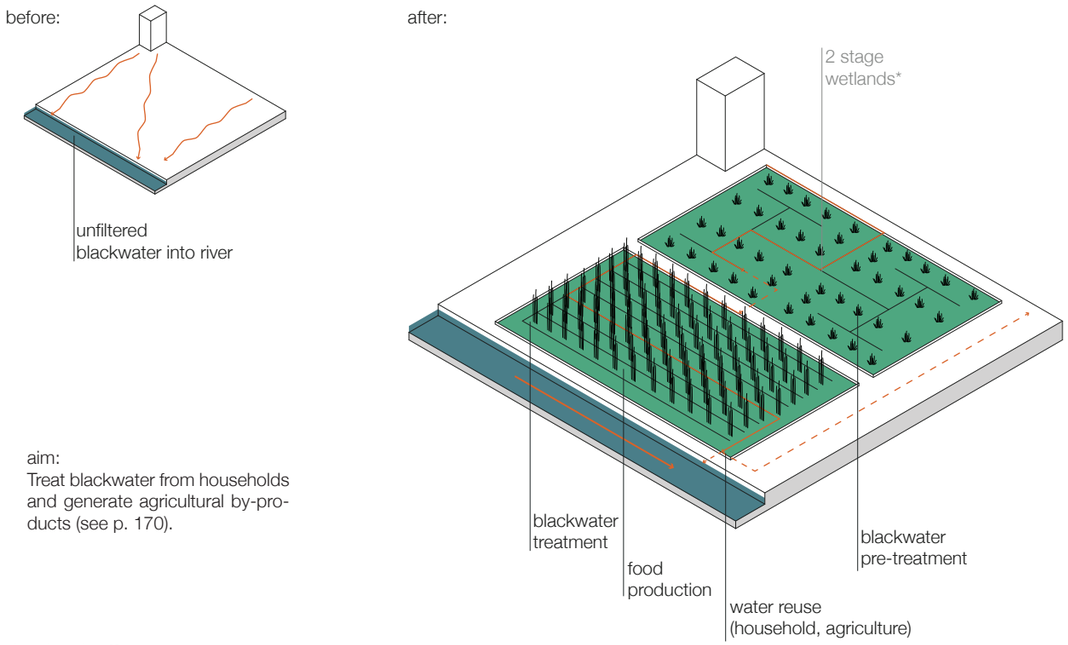


chinampas



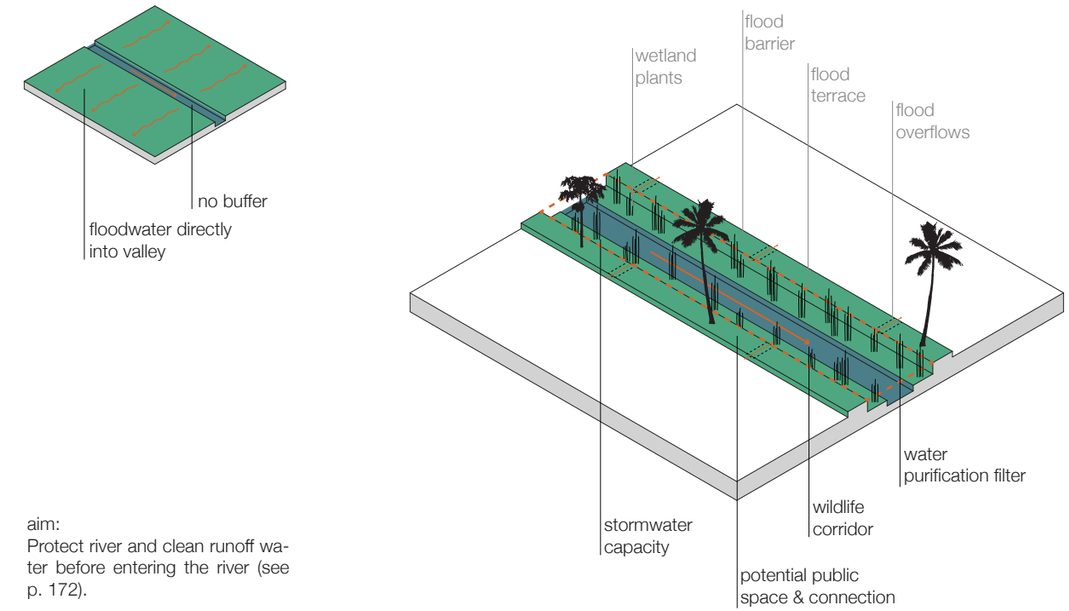
aim:
Combine space for water and human adaptation in the river valley and create space for agricultural productivity (see p. 164).

constructed wetland



aim:
Treat blackwater from households and generate agricultural by-products (see p. 170).

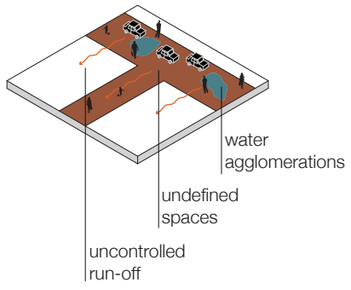
riverine buffer zone



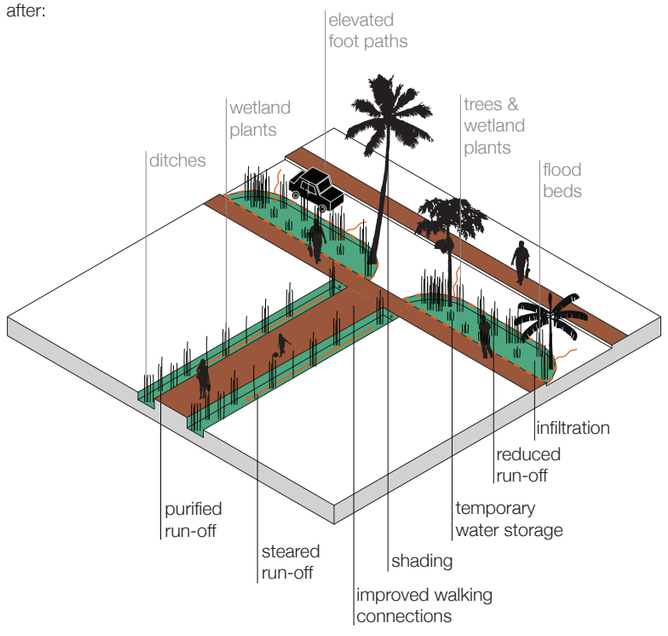
aim:
Protect river and clean runoff water before entering the river (see p. 172).

retention areas and ditches

before:



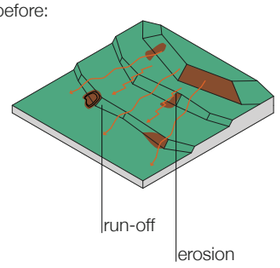
after:



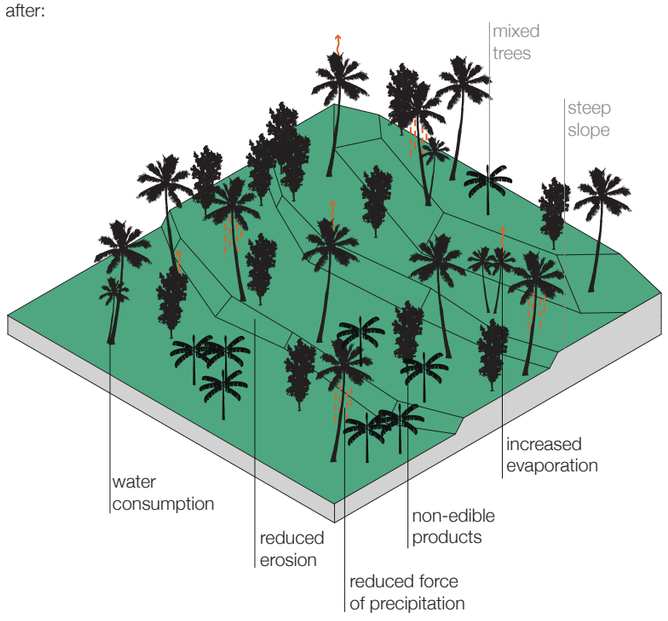
aim:
Soak up and temporarily store captured storm water (see p. 172).

urban forestry

before:



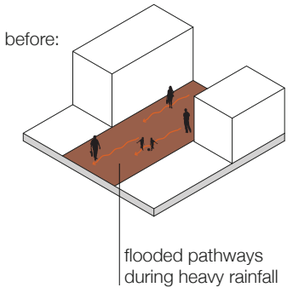
after:



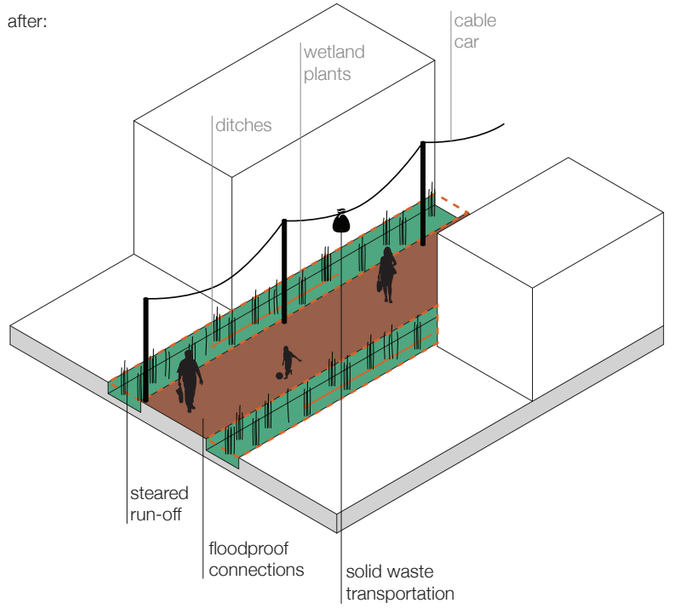
aim:
Reduce erosion and runoff and produce non-edible products (see p. 172).

connections - neighbourhood

before:



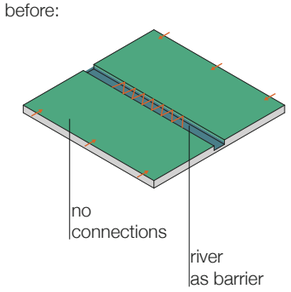
after:



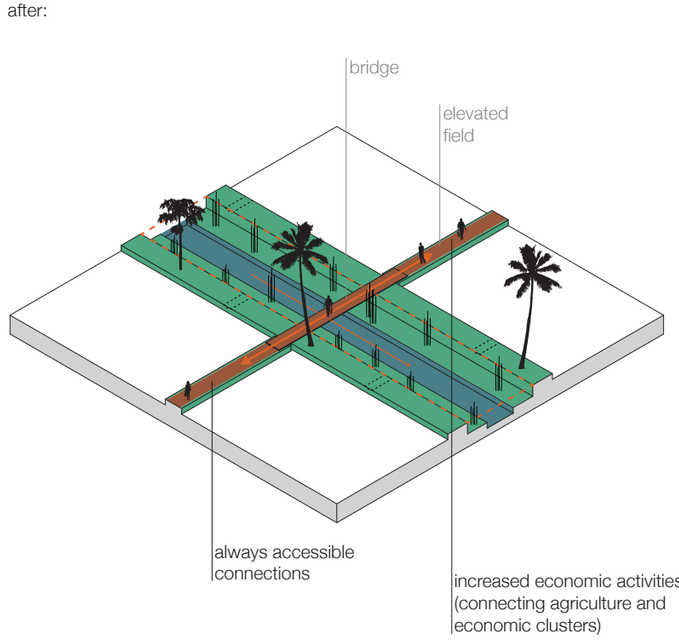
aim:
Improve and add connections which are accessible around the year (see p. 172).

connections - river valley

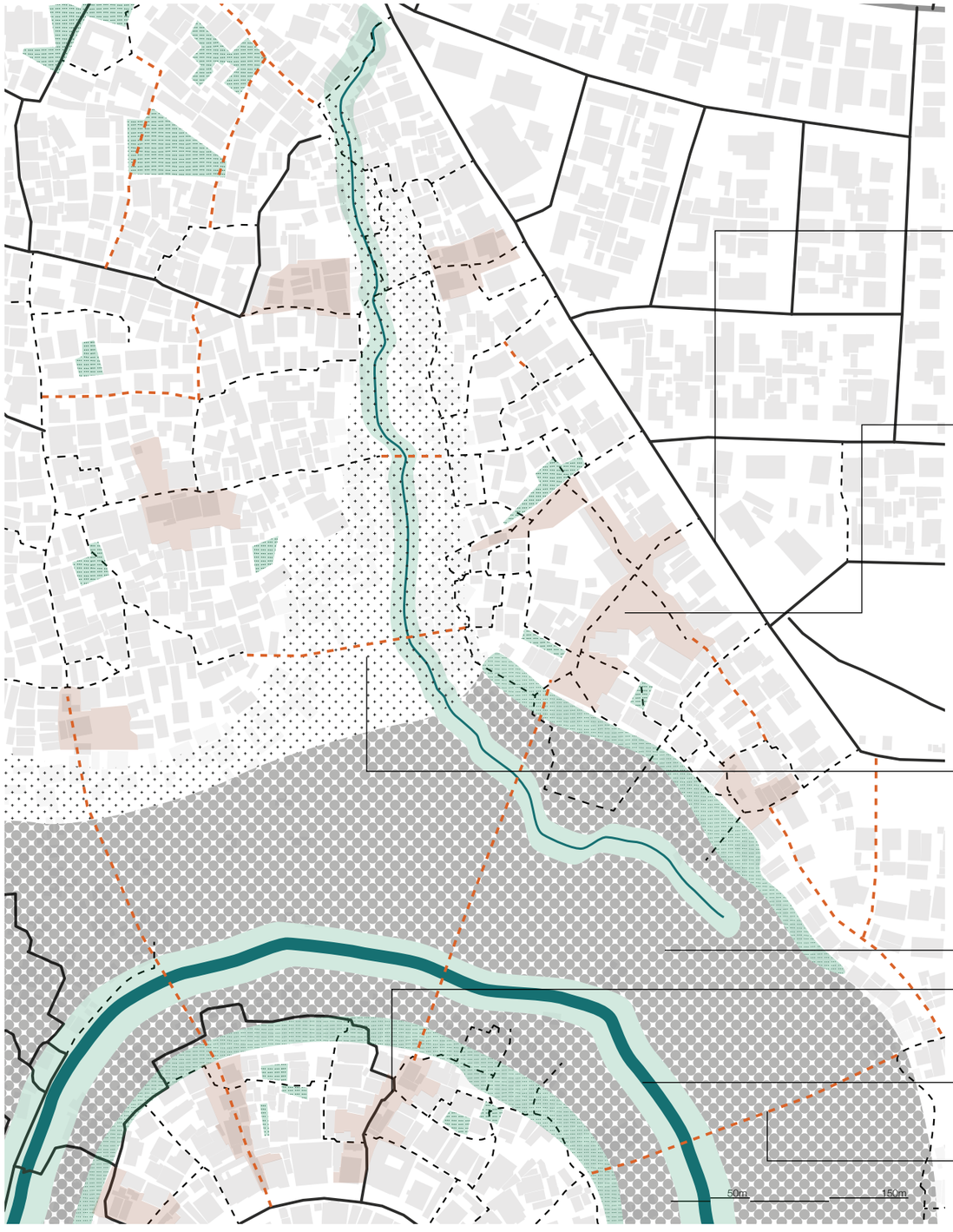
before:

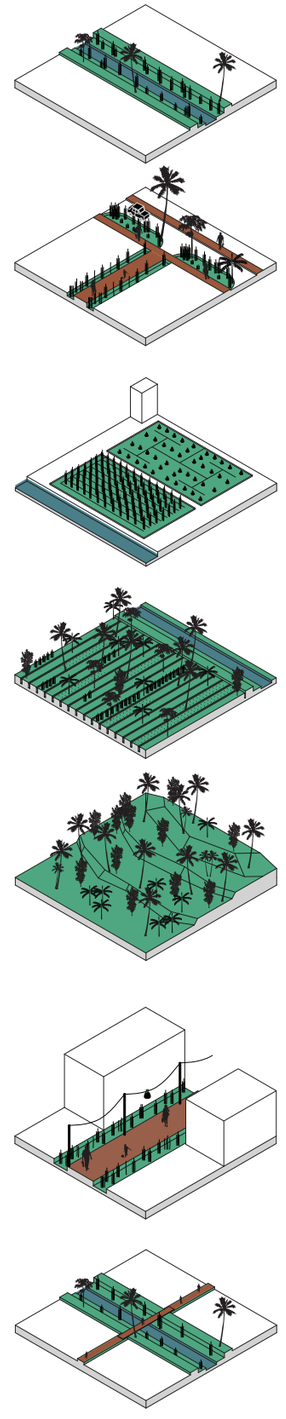


after:



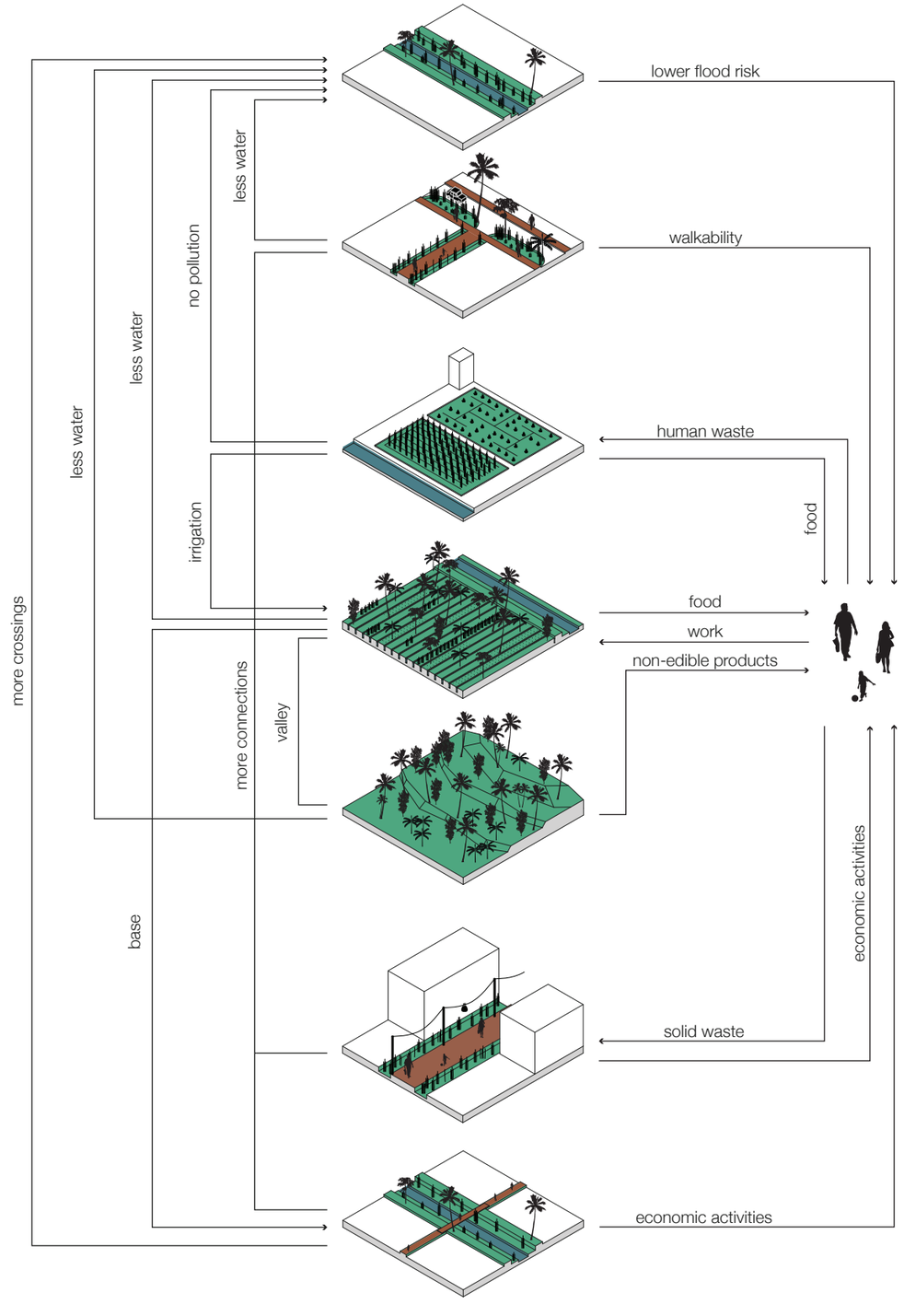
aim:
Add connections across the river valley to connect clusters of economic activity (see p. 172).





160 - chinampa system

161 - chinampa system


lower flood risk
walkability
human waste
food
food
work
non-edible products
economic activities
solid waste
economic activities
less water
less water
no pollution
less water
irrigation
more crossings
more connections
valley
base

Chinampas
Agricultural activities are part of the current setting of the river valley. However, due to their location on low areas close to the river they are highly vulnerable to flooding. In case of flooding (parts of) the harvest might be destroyed and the polluted water also pollutes soil and plants for consumption, which carries health risks.

To create flood proof agricultural areas while maintaining the water retention capacity of the river valley, chinampas are proposed as a new structure. Chinampas, also known as floating gardens, are a traditional way of agricultural production invented by the Aztec in Mexico. They created long narrow islands in lakes by digging out the soil of the lakes and piling it up, supporting the edges by a structure of wood and fibre and stabilising the soil by planting trees with extensive roots (see Fig. 16). This created a system of fields and canals. Every year the sediments of the canals are moved onto the fields on the one hand as natural fertilizer, on the other hand to renew the fields. This way of agriculture is very productive, because the water from the canals keeps the soil moist. Maize and legumes grow extremely well in these conditions but also a diversity of other plants (Moss, 2010).

This approach can also be adapted to the case of Dar es Salaam to create space for agriculture in a sustainable way. During the dry seasons, chinampas can be constructed field by field (see Fig. 15), making use of the local work force of unemployed residents. During the rain seasons the canals between the fields will fill up with water, indirectly irrigating the fields from below which increases the productivity of agricultural activities. That way, the flood water will not be a threat to the agricultural production in the valley but rather an accelerator.

Assuming that the whole designated area is filled with chinampas (see p. 160), the canals will have to be dug out to 50cm below the current ground level (see Fig. 18). Together with the 12,5cm of piled up soil on top of the field, this can accommodate storm water during the peak of the big rain season in April, without flooding the fields. On strategic locations, chinampas will have to be higher, for example for connections, which in return created deeper canals for extra water storage capacity. The variety of canal depth creates a hierarchy which influences the flow of the water.

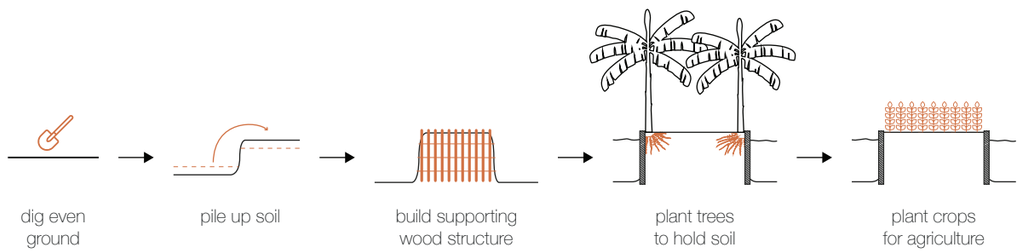


Fig. 15: Construction steps of chinampas. Own drawing.

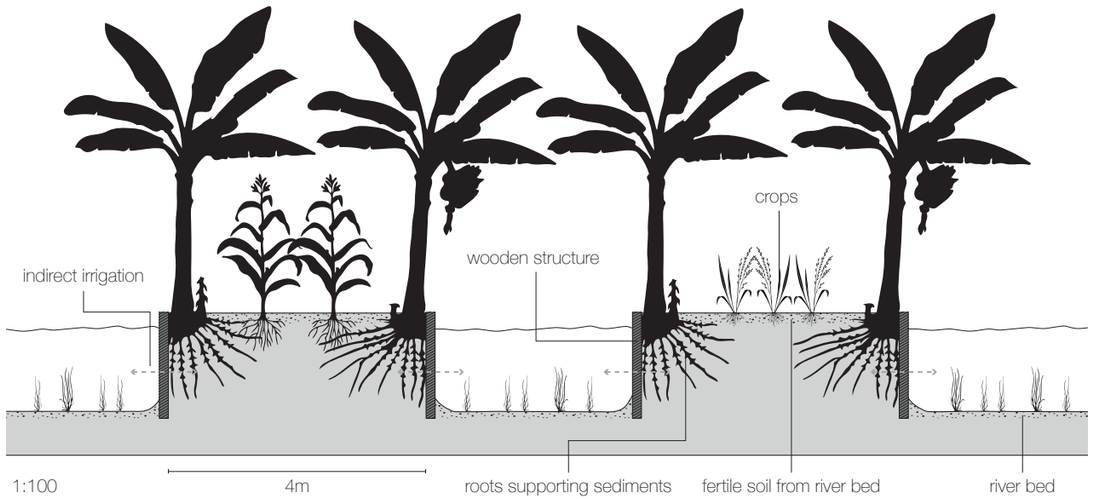


Fig. 16: Section of traditional chinampas. Own drawing.

The deeper canals are located along the chinampas designated for connections (see Fig. 19), since these have to be higher than those for agricultural production, as well as at the end of the intervention area. This means that deeper canals are also at the edges towards the neighbourhoods and along the riverine buffer zone. An additional deeper canal is located in the middle of the intervention area where chinampas are divided to enhance the natural water flow towards the Indian ocean.

As a consequence of the hierarchy of the canal system, the water flow is influenced as well (see Fig. 20). The deeper canals are the primary areas to flood and only after they are filled up to the level of the lower canals, these are filling with water as well. The run-off water from the neighbourhoods as well as the treated wastewater from the constructed wetlands are directed to the inlet of the deeper canals. Overflows between the riverine buffer zone and the canals are located at the deeper canals next to the connections. Here, the water can flow into both directions, either releasing pressure of the river or the canal system.

Traditionally, chinampas were accessed and worked by boat (Moss, 2010). This is not possible in the case of Dar es Salaam due to two reasons. First, the canals will not be deep enough and second, the water level will vary too much throughout the year (see Fig. 17). Instead, the accessibility will be organised with a network of wooden bridges. As a result, the chinampas have to be constructed from the edges of the river valley towards the river, otherwise those closer to the river would not be possible to reach in case of flooding.

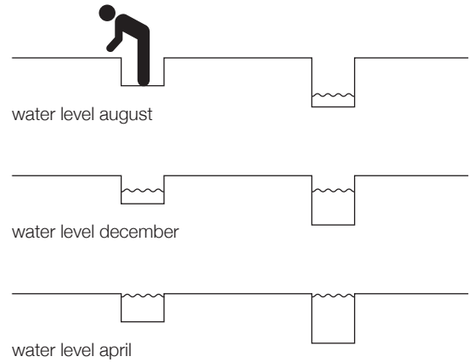


Fig. 17: Varying waterlevel in canals. Own drawing.

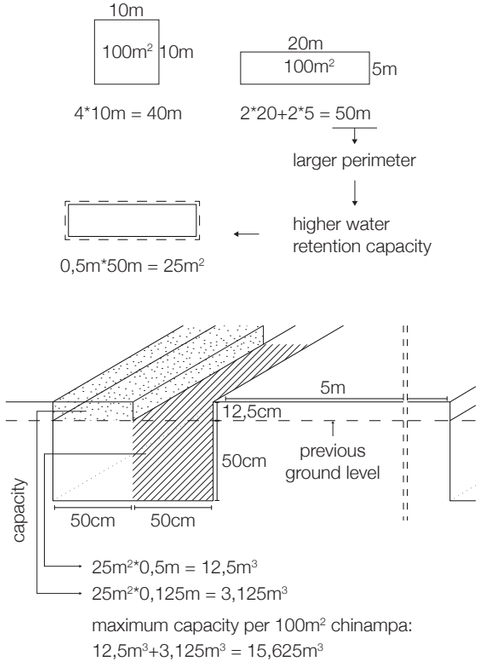


Fig. 18: Dimension and capacity of chinampas. Own drawing.

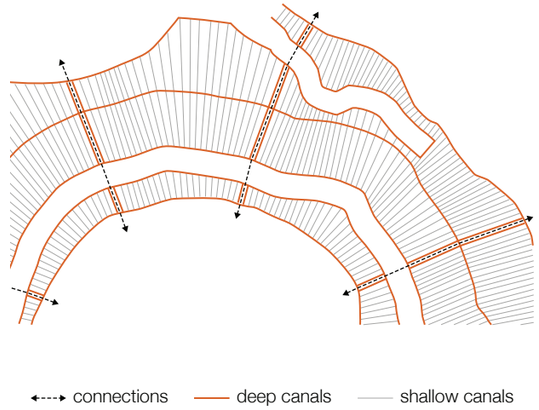


Fig. 19: Canal depths. Own drawing.

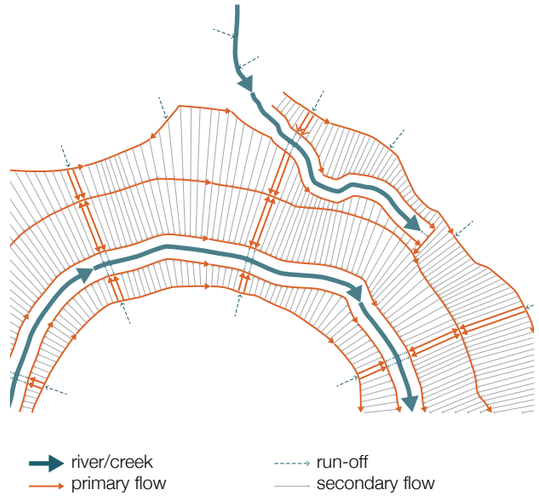


Fig. 20: Flow direction and hierarchy. Own drawing.

Local agricultural production can have a substantial contribution to the livelihood of the residents and to the local ecology.

Fig. 21 shows the spatial requirements for different kinds of crops to self-sustain a person as well as the contribution of chinampas to the food demand of the neighbourhood. Given that all chinampas are used for agricultural production to its full capacity, they can fully sustain 1,12% of the residents with a vegetarian diet, including goat-milk and eggs from chicken. This number increases when people do not plant their own wheat but buy flour or bred, because the production of wheat requires a lot of space. If only vegetables were grown on the chinampas, the demand for vegetables of more than 11% of the residents could be covered. This is a potential for local residents to either cut their costs on food supply or use it as a product for trade. The spatial requirements are based on one or two harvest cycles per year, depending on the crop. With the good growing conditions created by the chinampas, the productivity can potentially be increased to three cycles per year for some plants, meaning an even higher outcome per m^2. Not included in the calculations are food production on fields inside the neighbourhood, on 2nd stage wetlands and fruit and nut trees all over the area, but they also have the potential for a substantial contribution to the food demand of the neighbourhood.

The plant analysis (p. 80ff.) shows a number of edible and non-edible plants which can grow on chinampas. Especially legumes, like different kinds of beans, are growing very well in the conditions provided by chinampas. Goats and chicken can be integrated for their milk and eggs, diversifying the diet of the residents. Space for food production for the animals is not included, but a big part can be covered by agricultural by-products (Pötz, Bleuzé & Sjauw En Wa, 2012).

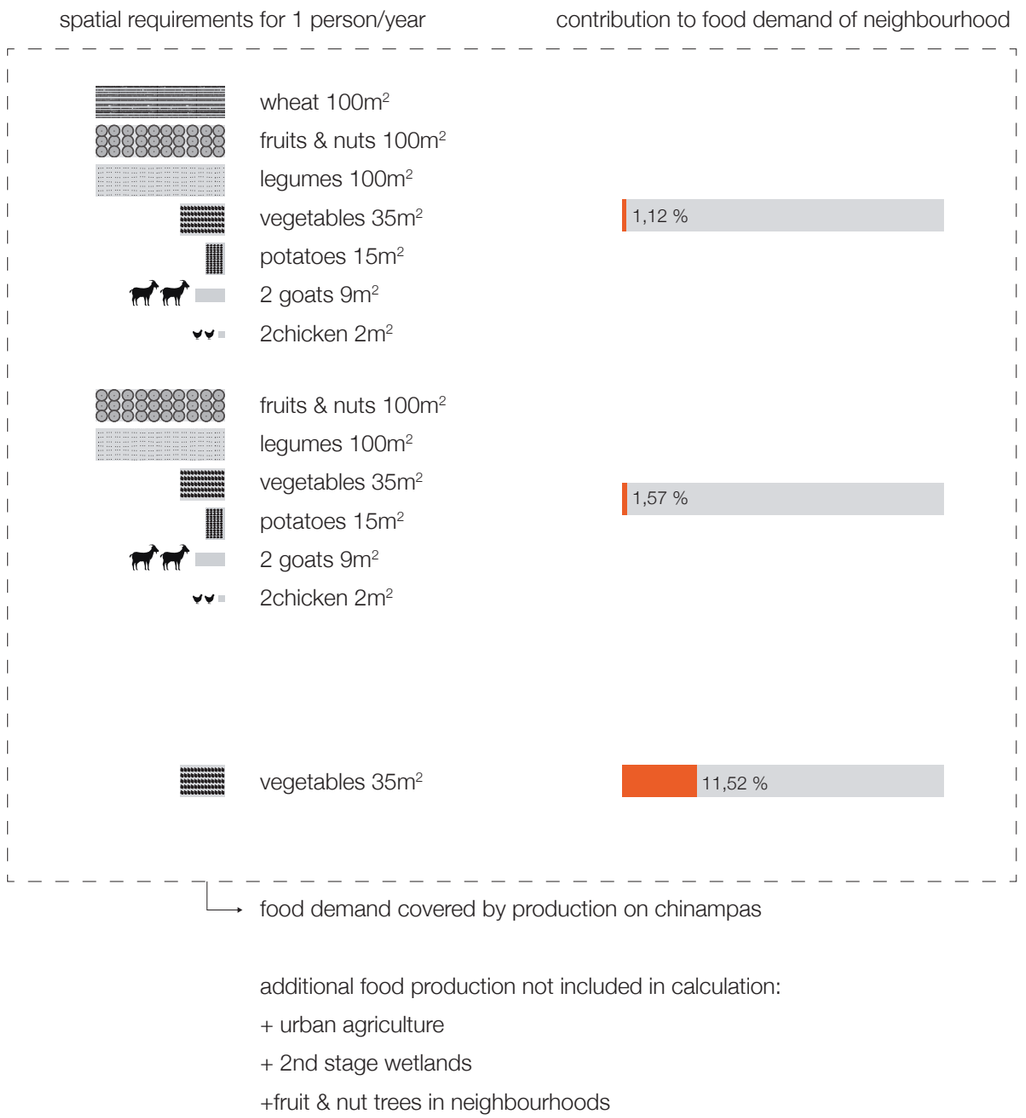


Fig. 21: Food production capacity. Own drawing.

Constructed Wetlands

Treating wastewater in the area is vitally important. Currently, residents use pit latrines, which are not connected to any kind of sewage system. Due to the difficult accessibility and the low economic abilities of the residents, these pit latrines are not emptied on a regular basis. As a consequence, the content of the pit latrines is flushed into the rivers during rainfall, causing pollution of rivers and soil. This increases the health risk of the residents who can come in contact with contaminated soils or water, consume it directly or indirectly when they use it for irrigation of agricultural areas (John, Kombe & Mayunga, 2012; field work observations).

Because of the informality and the lack of infrastructure of the place, a centralised system for wastewater collection and treatment is not appropriate. Therefore, Decentralised Wastewater Systems (DEWATS) are required (Tilley et al., 2014).

The proposed solution for the individual design location if the so called “French system”, which is a two-stage vertical flow constructed wetland (see Fig. 22). The costs for construction and the maintenance intensity are comparably low and no pre-treatment of wastewater is required, which are important factors in the area (Molle et al., 2005).

In the French system, the untreated wastewater from households is being directed into the first stage of the system. Here, sludge is being filtered and nutrients are removed. At the end of this process, the pre-treated wastewater is then further directed towards the second stage of the system. Here, the remaining nutrients are being removed. After the second process, the water is freed from polluting substances and can be reused, for example for irrigation of plants or flushing toilets, or can be released into open water bodies. Electricity is required to distribute the water evenly before each stage of the wetland. This can be covered by solar energy or by transforming the locally produces biogas to electricity (Energypedia, 2016).

Depending on the climate conditions this process can be faster or slower, though the high temperature in Dar es Salaam is likely to accelerate the process. To have a sufficient capacity for the treatment process, about 2m2 wetland are required per PE. To maintain this capacity, the sludge accumulating in the first stage has to be removed every 10-15 years. Also, the flow has to be continuous and he wetland plants healthy (Molle et al., 2005). An overview of applicable plants can be used in the plant analysis.

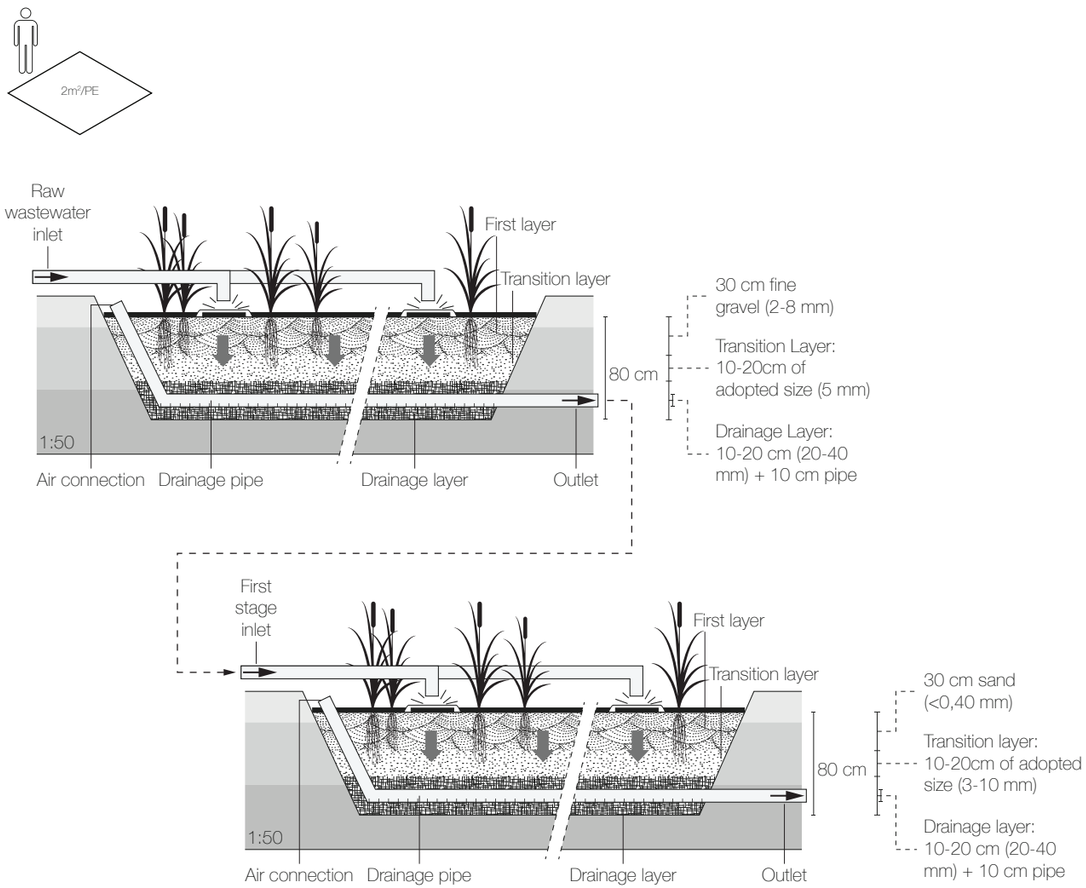


Fig. 22: French System: two-stage vertical flow constructed wetland. Own drawing.

Besides the treatment of wastewater, wetlands can have several co-benefits. The choice of plants has a big impact on the visual appearance and can contribute to a higher quality of public spaces around it. Edible products can be harvested for self-supply or trade. Wetlands are also habitats to different animals, contributing to a higher biodiversity, positively impacting the availability of ecosystem services in the long term.

Alternatively, a septic tank (see Fig. 23) could replace the first stage wetland to pre-treat the wastewater, before it is directed into the second stage wetland for further nutrition harvesting. While this alternative is less space consuming, it is very expensive to construct, need constant maintenance and has to be emptied much more often (Tilley et al., 2014).

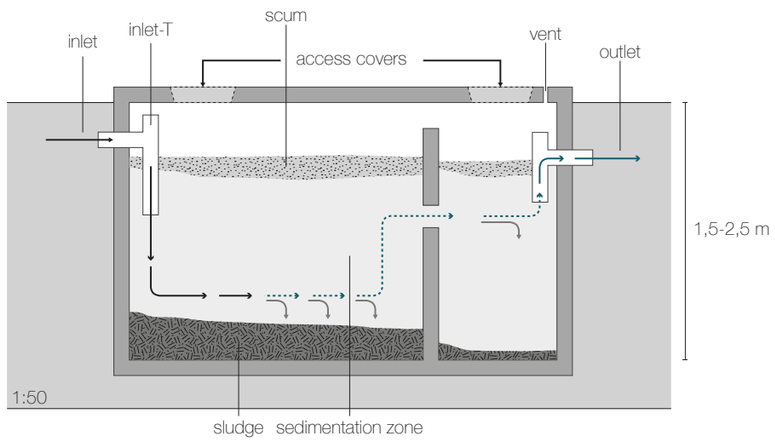


Fig. 23: Septic tank. Own drawing.

Riverine buffer zone
Along the course of the river and bigger creeks stretch riverine buffer zone to protect natural characteristics of the river and filter runoff water before entering the water body. If established continuously over a long stretch of the river, it has the potential to become a corridor for wildlife (Watson & Adams, 2011) and could connect the green valley with the green areas west of the basin.

The typical width of such a buffer zone is around 30m on each side of the river, creating a 60m wide corridor. However, the with depends on local regulations and zoning plans, conditions of the surrounding and local assessment (Watson & Adams, 2011, p. 119f.). The width of the riverine buffer zone in the design proposal is reduced to 20m on each side of the river and 10m each side along the bigger stream. The establishment of retention areas and purification zones uphill and the chinampas, which harvest nutrients out of the water, reduce the need to purify the water. Also, by reducing the width of the buffer zone, the spatial capacity for economic activities like agriculture and forestry is higher.

Interventions upstream as well as in the neighbourhoods, like the opening of surfaces and the implementation of retention areas, reduce the runoff of storm water. That way the amount of water ending up in the river is smaller and arrives there later, so the rivers capacity to discharge water is not overwhelmed by flash floods anymore.

To reduce the flood risk, the riverine buffer zone has a lower terrace close to the river, to create additional water retention capacity for short periods of rainfall.

Urban Forestry
To prevent erosion at the slopes towards the river valley, which is one of the consequences of storm water run-off, urban forests will be planted. Trees have many important functions for the natural environment and water management. They absorb water from the soil and evaporate it back into the atmosphere, reduce the force of precipitation on the ground because water is only dripping though the leaves, which in combination with the root system reduces erosion. These natural processes of (urban) forests reduce runoff, improve water and soil quality and create shade (Watson & Adams, 2011).

Besides the benefit of reduced erosion and improved water management, it is also a way to generate economic activities where the incline of the slope is not appropriate for agricultural purposes without the construction of terraces. Furthermore, the production of non-edible products can start immediately without taking pollution of soil and water into consideration.

Retention area
Retention areas capture runoff water from roofs and impervious surfaces to soak it up or temporarily store it. They are filled with trees, shrubs, flowers and grasses which can survive strongly changing conditions, regarding temperature, salinity or moist. The bed is ideally filled with sand or gravel to increase the storage capacity (Watson & Adams, 2011, p. 113).

In the design, retention areas are incorporated into the road layout in form of speed control islands. The current dimensions existing roads are generous, considering that most residents are walking and not so much space for cars is required. The addition of plants into roads improves the quality of public space by creating shade and reducing the urban temperature. It also makes the adjacent areas more accessible, because roads are not flooded anymore.

Connections
Existing connections will be improved with green ditches to divide the space for people and water. This will prevent the connections from flooding to be accessible around the year. The open surface of the ditches and the addition of wetland plants will reduce runoff water by infiltration and treat water before entering the river valley.

New connections will be added across the river valley to connect clusters of economic activities and social institutions. By reducing the commuting time for residents, this will stimulate economic activities and social interaction. The connections through the valley will be built on chinampas, which will be connected by wooden bridges.

The main focus group for all connections are pedestrians, but cycling should be made possible as much as possible.



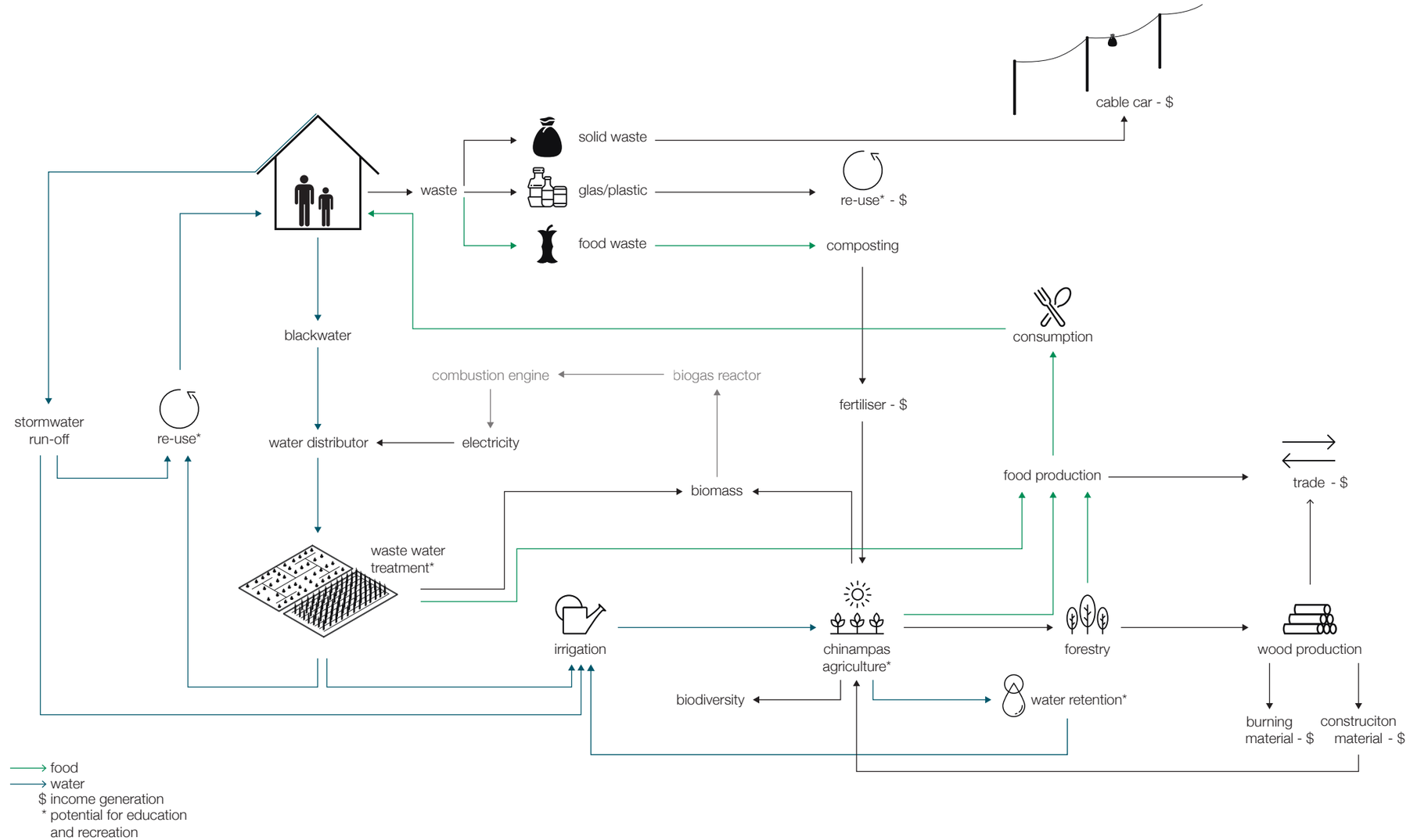


Fig. 24: Local circularity of flows and products. Own drawing.

The functions of the different interventions can be combined to a decentralised circular system of water, food and other products and flows (Fig. 24).

The water, which is currently treated as an unwanted threat, becomes an important source for irrigation of agriculture and to be re-used in households. Similar to that, waste, which is now an unwanted output which is dumped all over the neighbourhoods, becomes valuable for composting and re-use.

Because the new value of waste and the treatment of water, soil and water are free from pollutants, which increases the potential of agricultural activities. Agricultural production of edible and non-edible products can be used for self-supply or for trade. Biomass, a by-product of agricultural production, can be used for energy production in local biogas reactors.

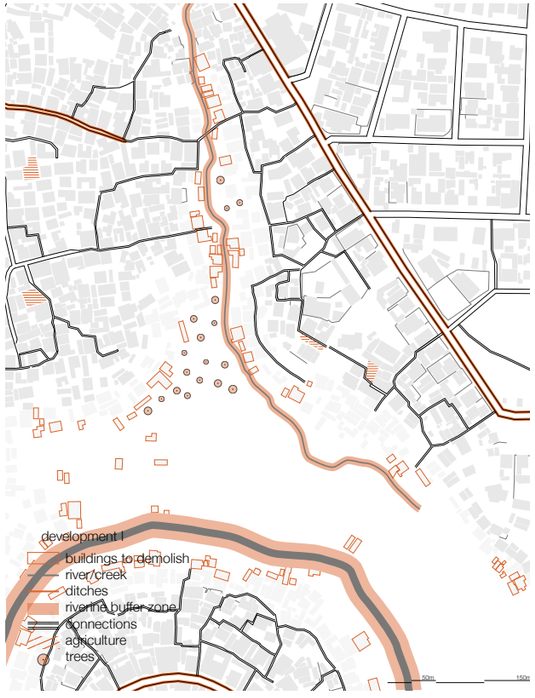
The local production of (agricultural) products and energy and the re-use of water are resource efficient, because little to know transport is required.

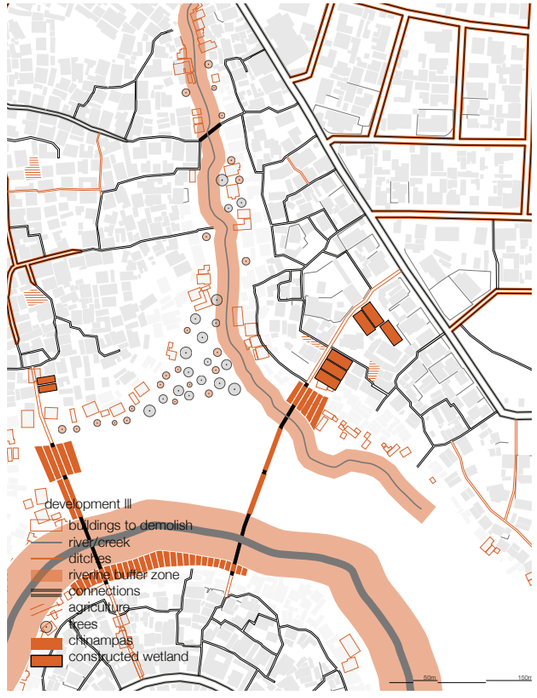
The multiplicity of connections between different interventions builds capacity and makes local communities more independent from external factors and centralised systems. This enables them to adapt to changes and recover more easily from hazards.

mona zum felde

The implementation of interventions can happen simultaneously and in different locations. Although chinampas are the key element of the design, their implementation can only start later. They have to be developed from the edges of the valley towards the river in order to be accessible by the proposed bridge system. Before this can happen, some of the buildings who are at extreme risk for flooding, have to be demolished first (see policy p. 208).

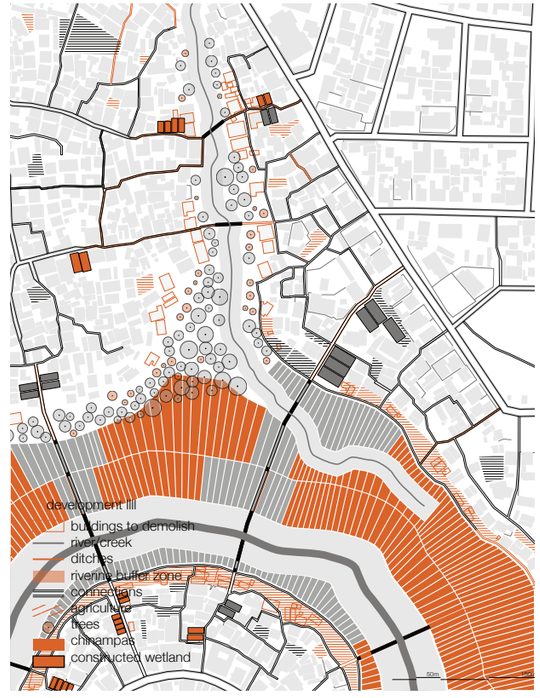
The planting of trees on steeper slopes should start as soon as possible, first in unbuilt areas and later at the location of demolished buildings, to grow building materials for the construction of chinampas as well as for buildings. Also other interventions, like the riverine buffer zone ditches and constructed wetlands can already start before the construction of chinampas. That way, storm water is already guided out of the residential areas and water is treated before entering the river. After the first chinampas at the edge of the valley have been constructed, the strategic chinampas for connectivity have to be implemented, in order to connect economic clusters and stimulate activity. Over the years, the interventions will be added in all the designated locations to complete the system.



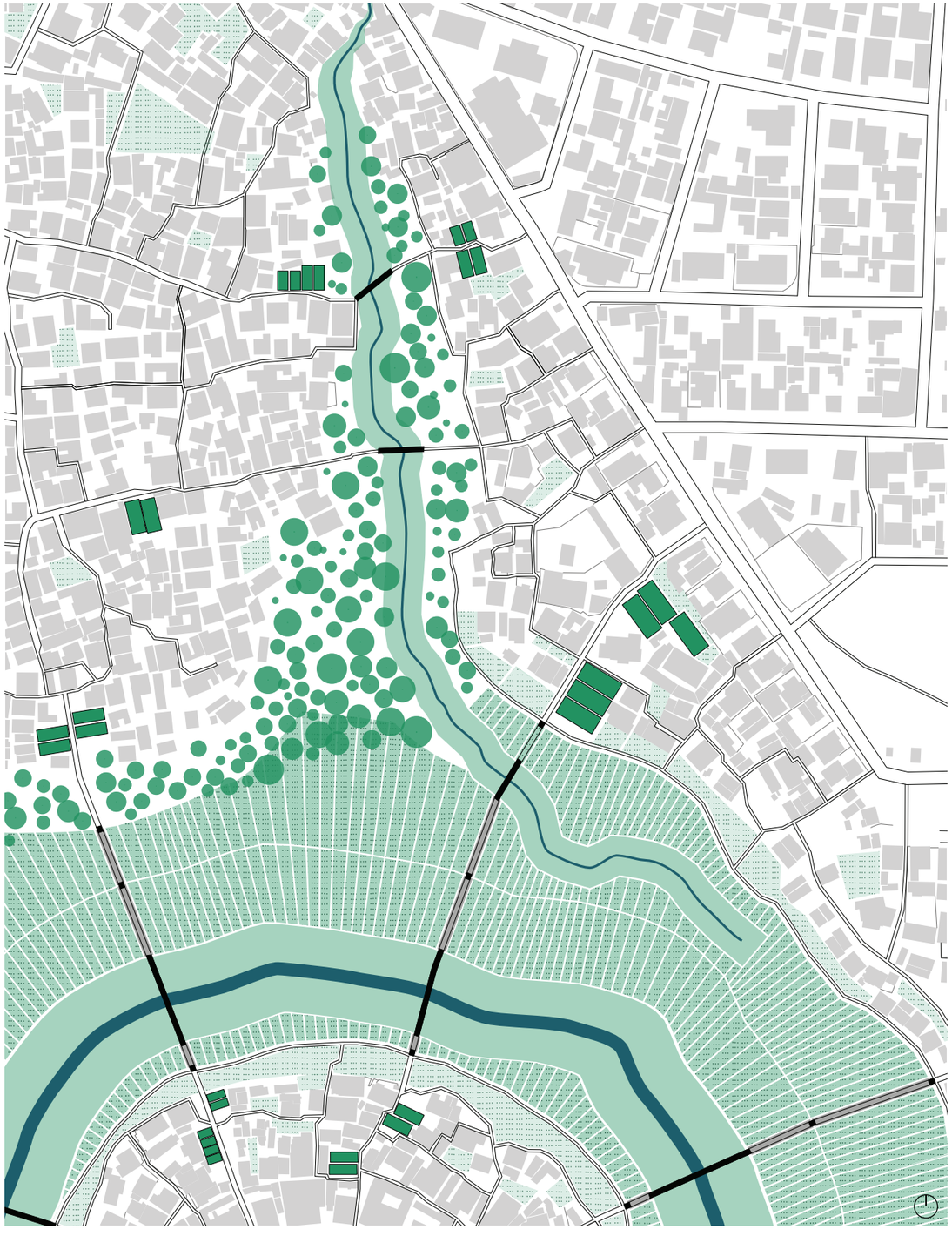


176 - chinampa design





177 - chinampa design



The design combines all interventions to transform the area into an accessible, productive, clean and flood proof area.

The river and big creek are surrounded by a riverine buffer zone, the rest of the river valley is filled with chinampas. The arrangement and orientation of the chinampas enables a water flow both from the river as well as outside the neighbourhoods. The main outlets from both directions are located at the canals next to the connections, since these are deeper and therefore have a higher retention capacity and can flood first without flooding the whole area. This lets the other canals dry out during the dry season with only occasional or short-term rainfall, to reduce smell and mosquito breeding of muddy soil and increases the accessibility of the chinampas, because people can walk inside the canals.

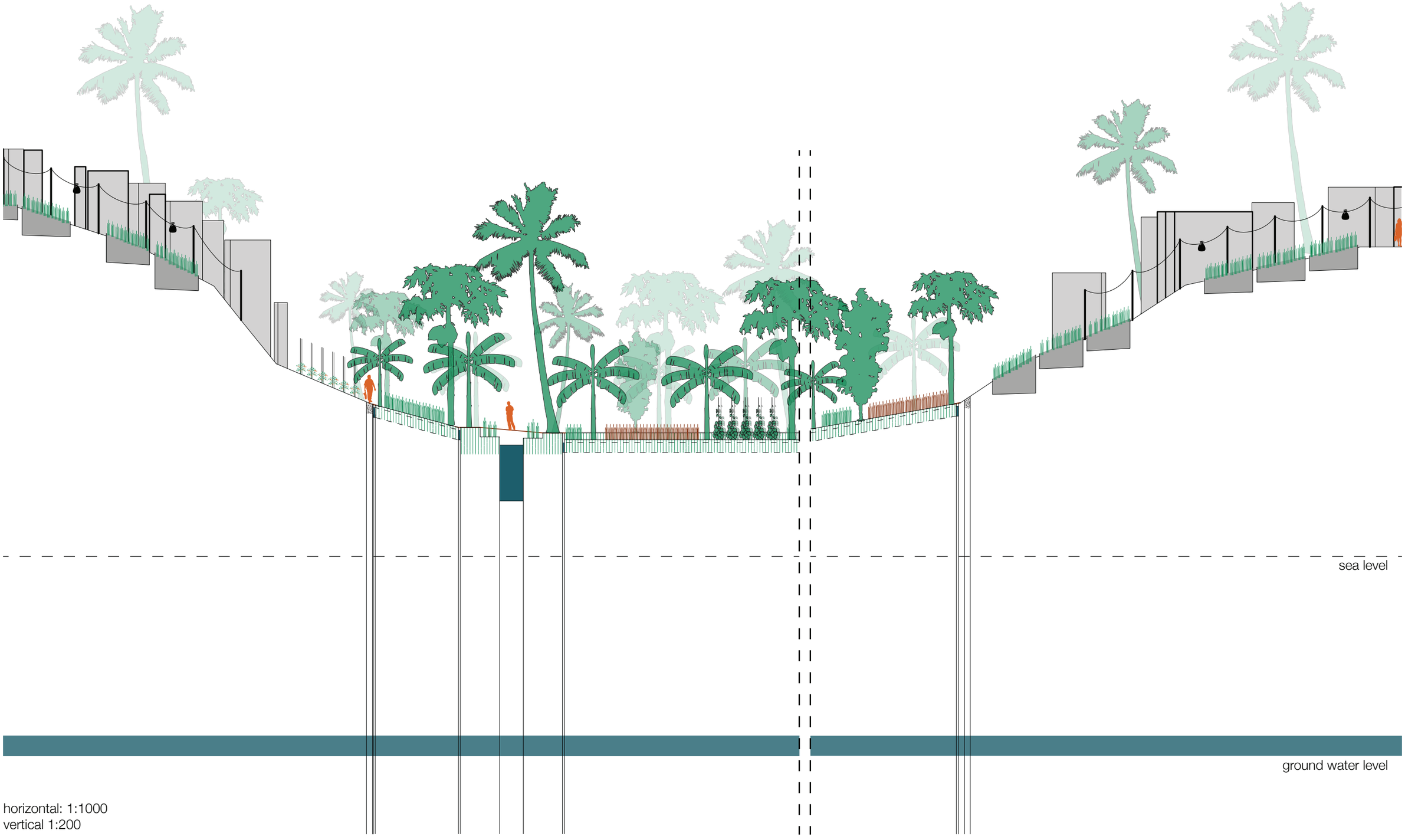
Agricultural fields and forests follow the edges of the river valley before the building line starts. Constructed wetlands are located inside the neighbourhoods and their outlets connected to ditches, which steer storm water and treated waste water towards the valley.

Storm water is captured in local retention areas along the roads and steered into the valley via ditches, which makes roads and footpaths accessible throughout the year. The new connections across the river valley stimulate economic activities. People can trade with the products produced in the river valley.

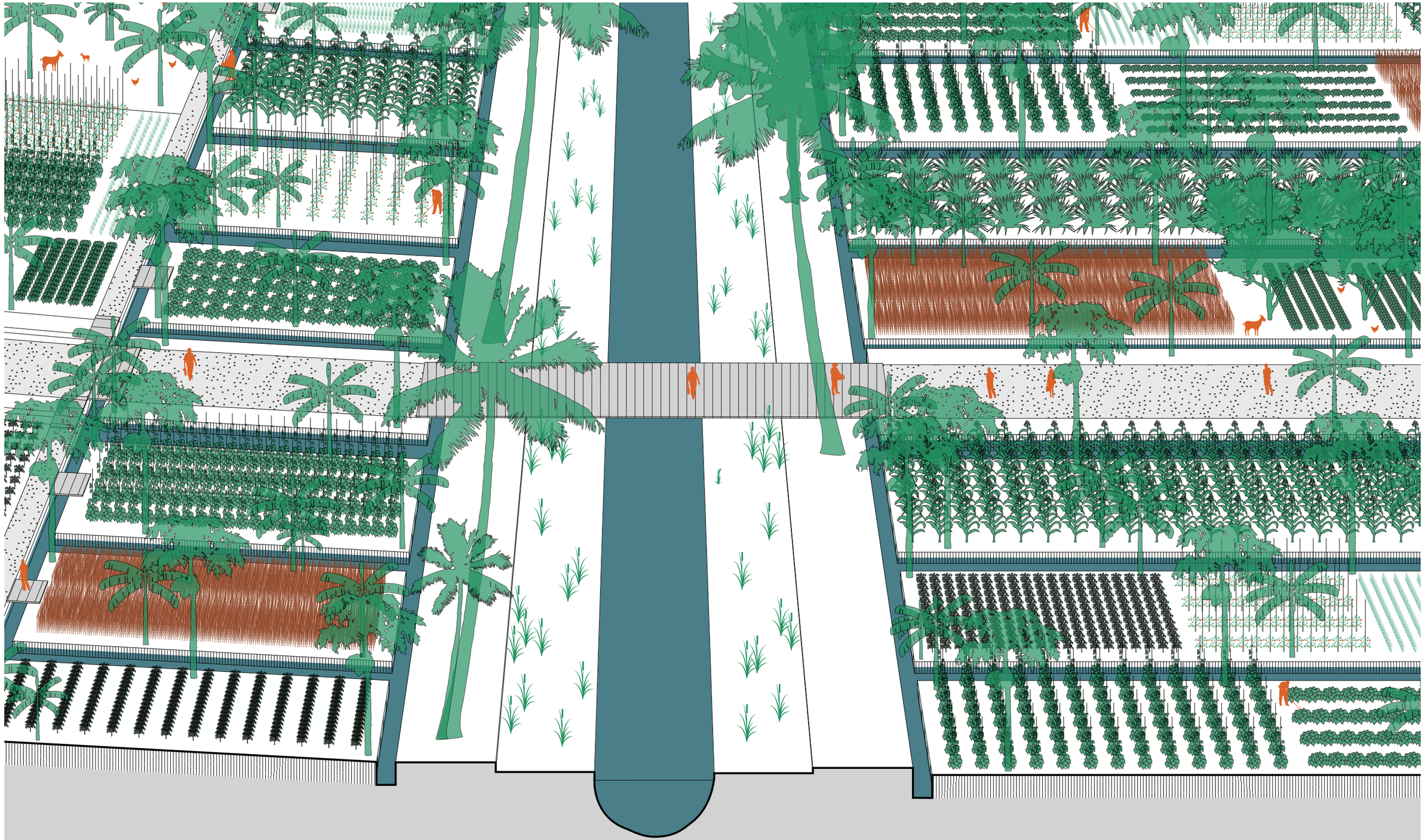
The flood risk is being reduced due to increased infiltration, more retention capacity and guided flow of storm water.

mona zum felde

▶ south-north section



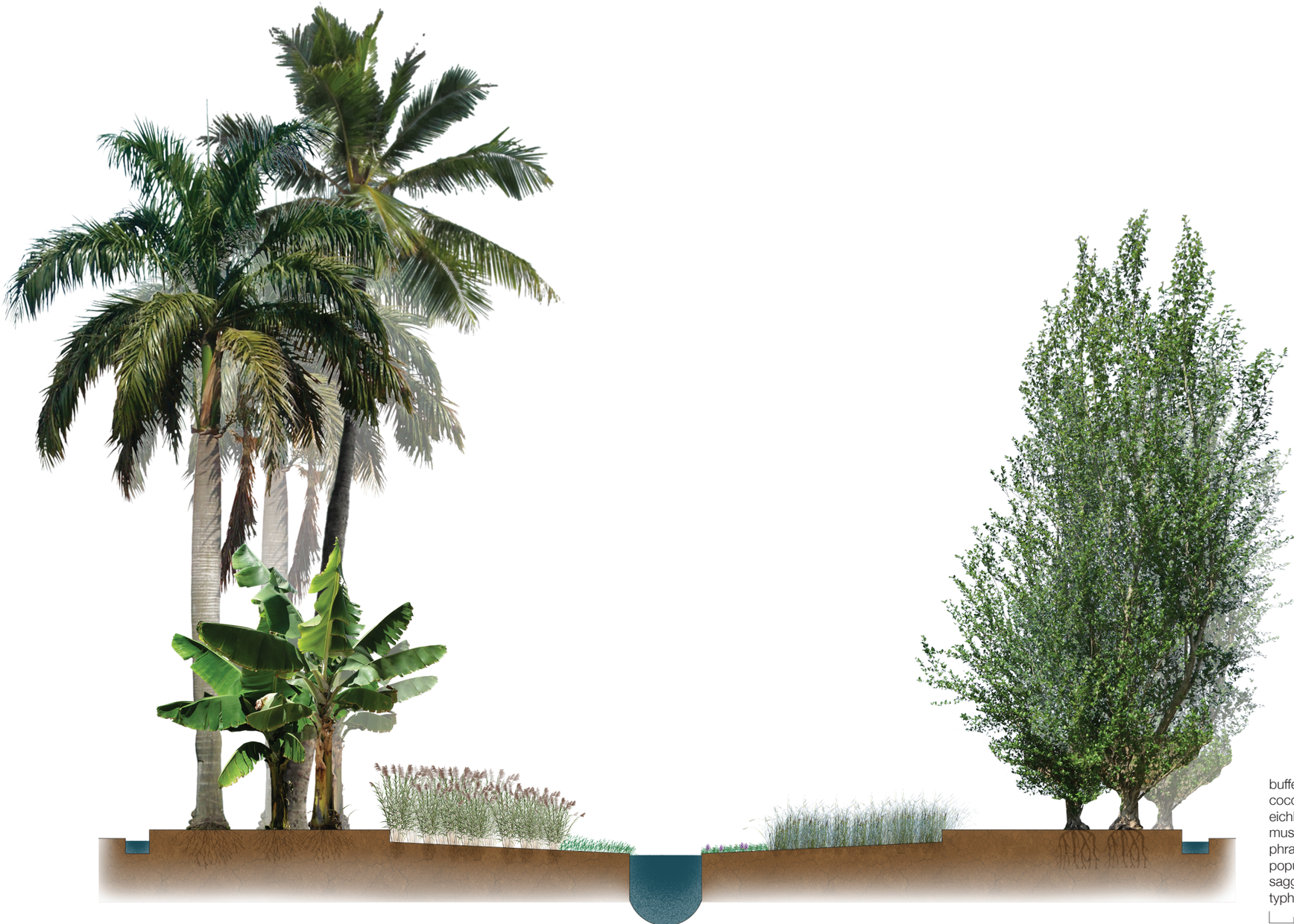
horizontal: 1:1000
vertical 1:200



mona zum felde



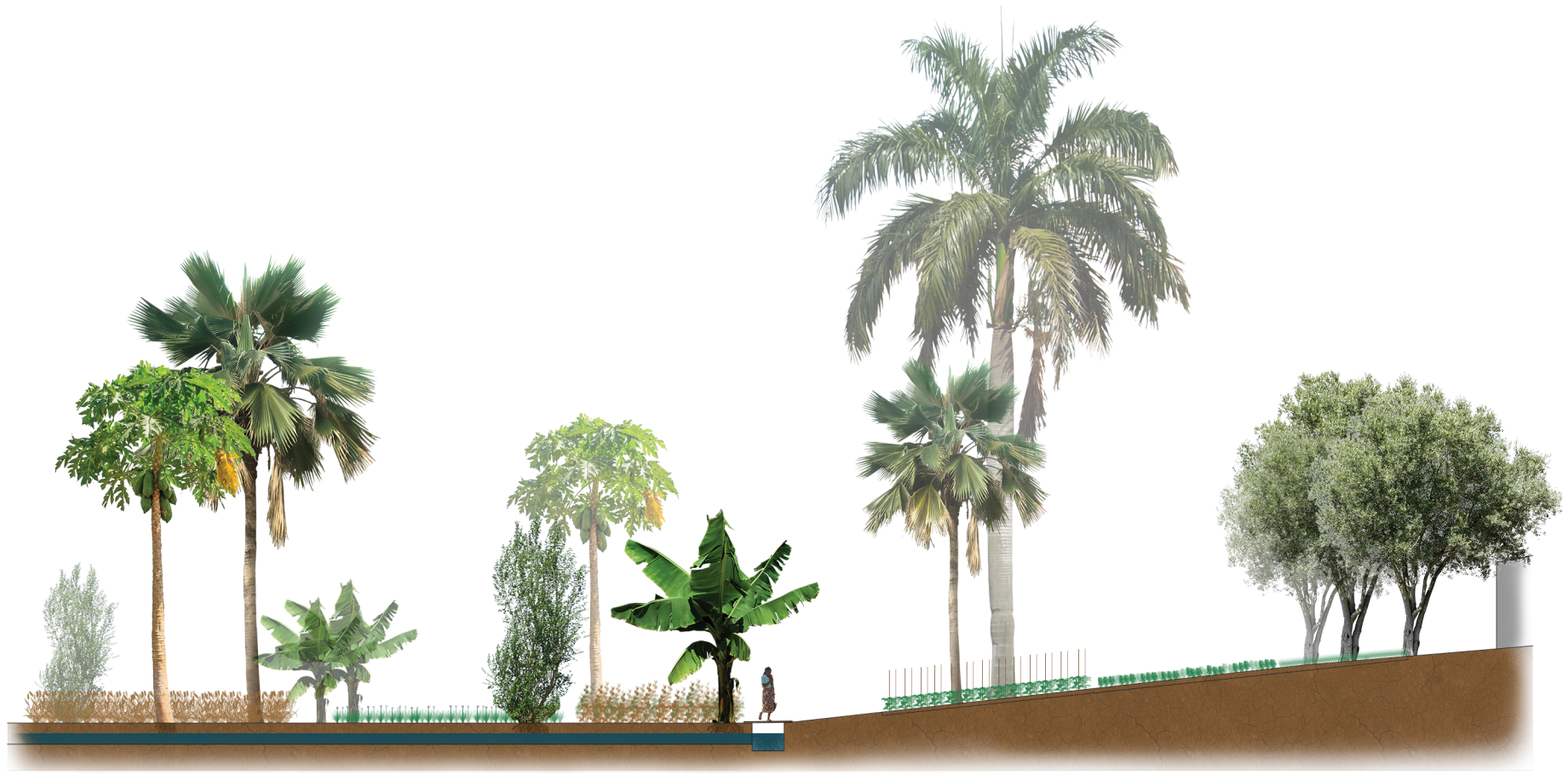
mona zum felde



buffer zone:
cocos nucifera
eichhornia crassipes
musa sapientum
phragmites communis
populus ilicifolia
saggitaria latifolia
typha latifolia

1m 5m

mona zum felde



chinampa to agriculture:
allium cepa
carica papaya
cocos nucifera
glycine max
musa sapientum
olea europaea
salix mucronata
solanum lycopersium
triticum aestivum
vigna unguiculata

1m 5m

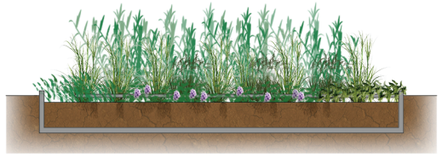


wetland 1st stage:
chrysopogon zizanioides
pennisetum purpureum
phragmites communis
saggitaria latifolia
typha latifolia

1m 5m

wetland 2nd stage:
capsicum annuum
eichhornia crassipes
ipomoea aquatica
nelumbo nucifera
pennisetum purpureum
phalaris arundinocea

1m 5m





chinampa connection
to ditches:
cocos nucifera
phalaris arundinocea
phragmites communis
saggitaria latifolia
salix mucronata

1m 5m

road with retention area:
carica papaya
chrysopogon zizanioides
cocos nucifera
musa sapientum
pennisetum purpureum
saggitaria latifolia

1m 5m



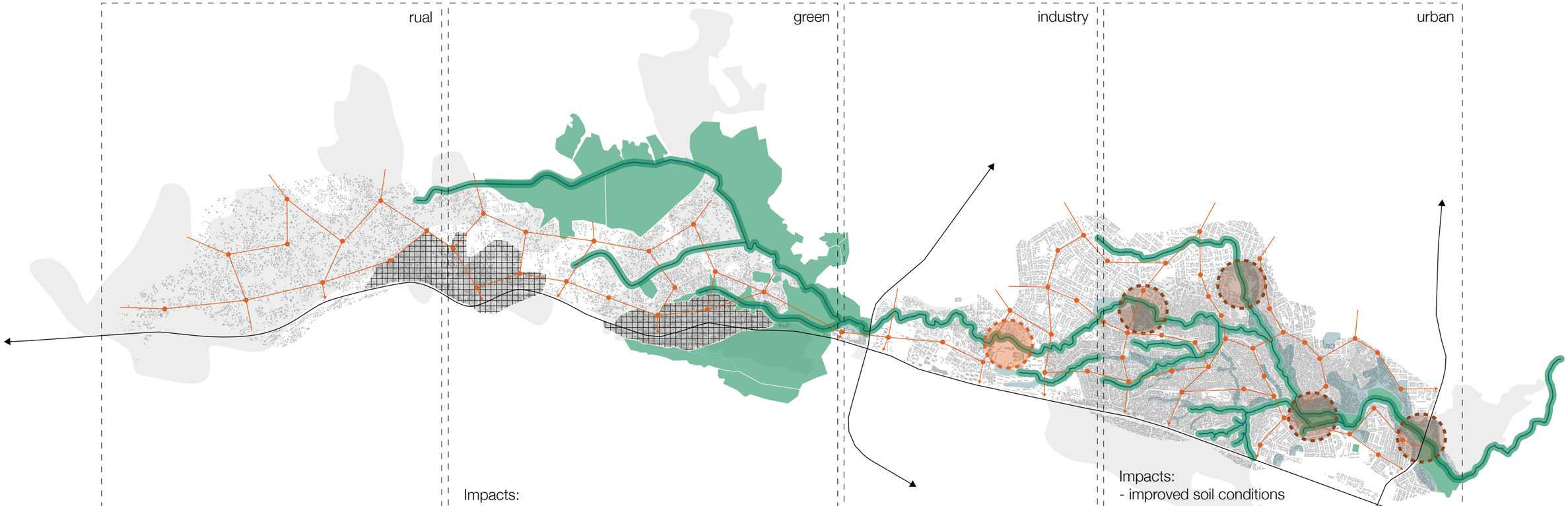






Implementation strategy

river basin strategy / strategic masterplan / timeline / stakeholders / policies / cable car



Impacts:
- improved soil conditions
- reduced run-off
- reduced pollution by waste
- reduced blocking by waste

Interventions:
- restriction of urban sprawl
- keep infiltration capacity
- densification around sub-centre (courtyard system)
- maintain main infrastructure
- waste network

Problems addressed:

Impacts:
- improved soil conditions
- increased biodiversity
- natural water purification
- more river space
- reduced run-off
- reduced pollution by waste
- reduced blocking by waste

Interventions:
- keep infiltration capacity
- increase food production (courtyard system, chinampa system)
- relocation in 500m zone
- riverine buffer zone
- protection of green areas
- densification around sub-centre (courtyard system)
- maintain main infrastructure
- waste network

Problems addressed:

Impacts:
- industrial water purification
- more river space
- reduced run-off
- reduced pollution by waste
- reduced blocking by waste

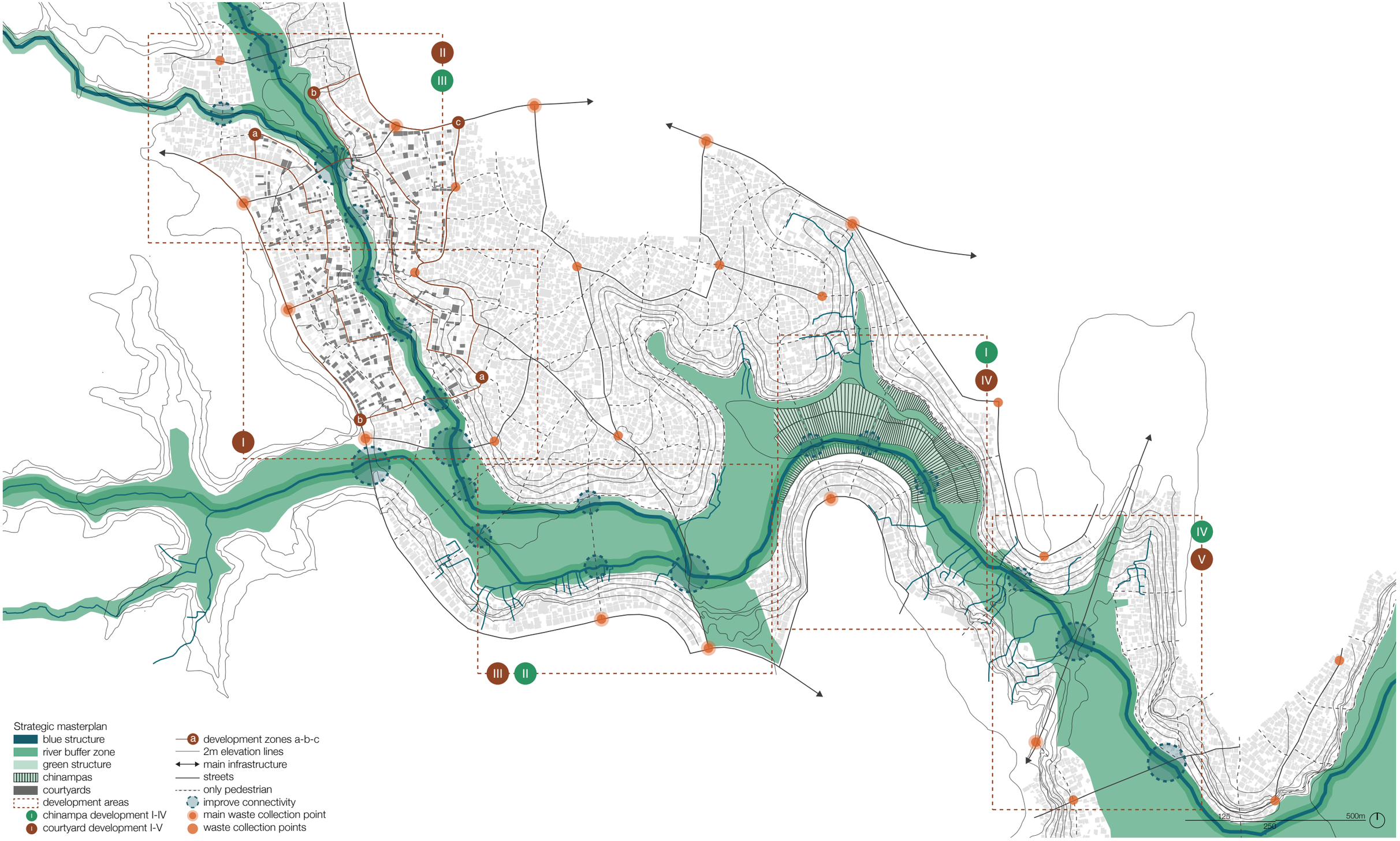
Interventions:
- relocation in 500m zone
- waste water treatment plant for industry
- riverine buffer zone
- maintain main infrastructure
- waste network

Problems addressed:

Impacts:
- improved soil conditions
- increased biodiversity
- natural water purification
- more river space
- reduced run-off
- reduced pollution by waste
- reduced blocking by waste

Interventions:
- increase food production (courtyard system, chinampa system)
- increase water retention capacity (courtyard system, chinampa system)
- relocation in 500m zone
- riverine buffer zone
- densification (courtyard system)
- conflict/risk zone - awareness campaign, early warning system, evacuation plan
- maintain main infrastructure
- waste network

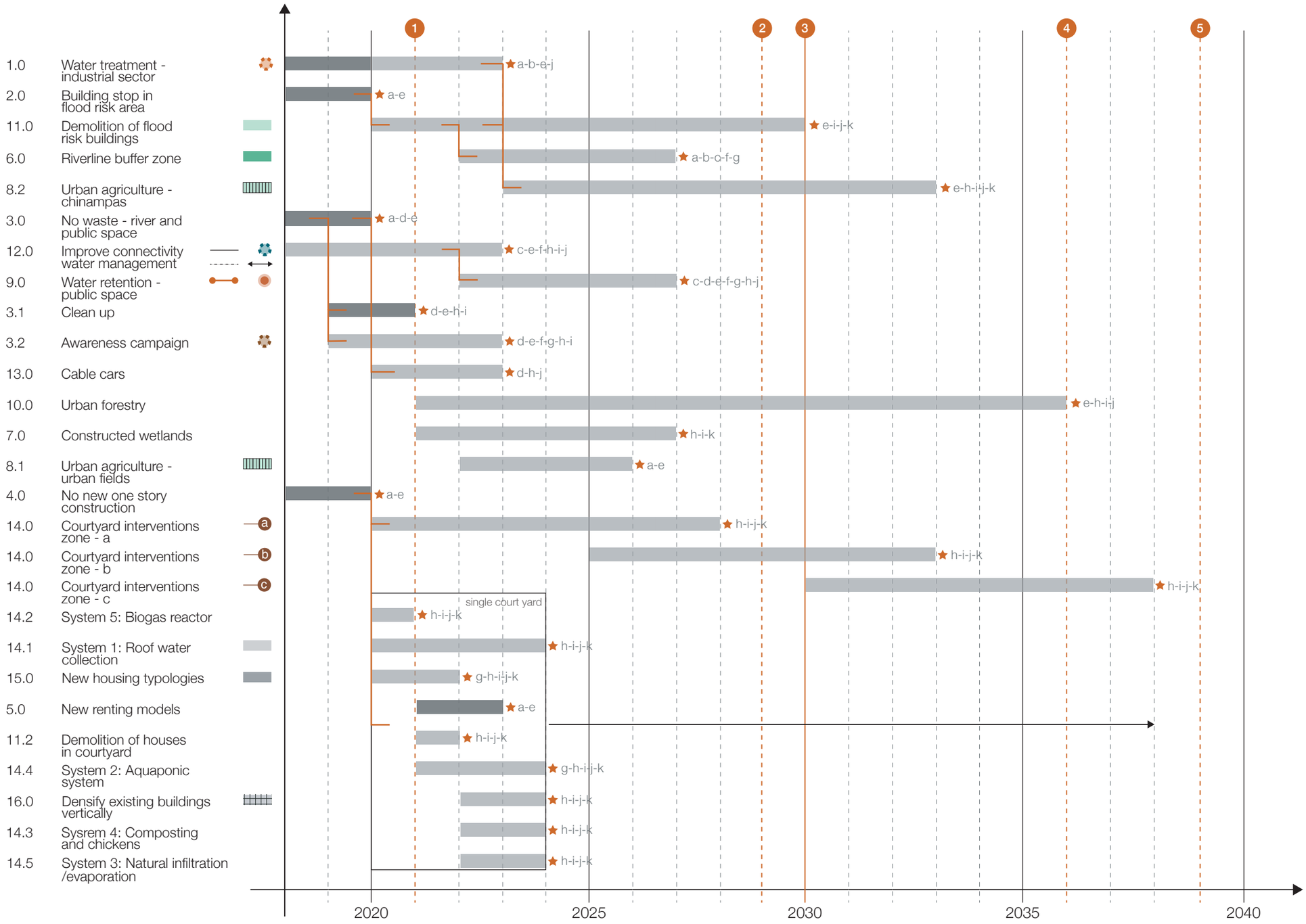
Problems addressed:



Strategic masterplan

- blue structure
- river buffer zone
- green structure
- chinampas
- courtyards
- development areas
- chinampa development I-IV
- courtyard development I-V
- development zones a-b-c
- 2m elevation lines
- main infrastructure
- streets
- only pedestrian
- improve connectivity
- main waste collection point
- waste collection points

timeline



★ Stakeholder:

a - National Government Tanzania /President office
b - City council Dar es Salaam
c - District council Kinondoni
d - Ward councils Makumbusho, Mwananyamala, Tangle, Ndugumbi, Magomeni
e - Sub-wards/Mtaas
f - DAWASA & DAWASCO
g - Ardhi University
h - NGO's
i - Residents
j - Private companies
k - Property owners

Milestones

1. Clean surface
2. No people living in high risk areas
3. Coping with small rain season
4. Coping with big rain season
5. Formalisation of the informal settlement

Timeline policies/interventions

policies
intervention

Problems addressed:

The timeline indicates the period of implementation and interventions. After the implementation follows a continous process of operation, maintanance and renewal.

The timeline is linked to the strategic masterplan and sinza river basin strategy (see previous pages).

Sinza river basin strategy
The identified problems are mainly addressed by the two design proposals. However, the analysis has shown that the problems are not only locally produced but are connected to processes on the bigger scale. This makes it necessary to relate the design proposals to the bigger scale of the Sinza river basin as well as to policies in order to create certain preconditions which accommodate the design interventions and make them function effectively.

By changing conditions in the whole river basin, especially further upstream, negative impacts can be reduced or even be prevented, which has positive effects on the intervention area. The biggest impact can be made regarding pollution and storm water run-off. By the protection and extension of green areas and open surfaces, the capacity for water retention and infiltration can be increased, which prevents big amounts of water from flowing down into the more dense areas. A continuous riverine buffer zone along the whole river and the bigger creeks can contribute to this, reduce bottleneck effects along the river and has the positive side-effect of an increased biodiversity.

A continuous waste management network and wastewater treatment installations for industries and households tackle the issue of water pollution. This prevents waste and wastewater from entering the river. Minor pollutants can be treated by wetland plants in the buffer zone to continuously purify the water before entering the ocean.

Two locations are highlighted for vertical densification to accommodate future urban growth, based on existing commercial functions and infrastructure. These areas do not have the capacity to accommodate the full expected growth but has to be understood as starting point for further developments in a compact way, as it is proposed in the courtyard system, to reduce land consumption of urban sprawl.

Despite all spatial interventions on different scales, some conflict/risk areas will remain due to their critical characteristics, like low elevations or a bottleneck for the river. These areas need additional measures like awareness campaigns, early warning systems and evacuation plans to prepare the residents and that way reduce the impact on them in case of a flood hazard.

Strategic masterplan
The strategic masterplan of the common intervention location shows the impact of the two systems in relation to their context and their connection by the common interventions.

The riverine buffer zone connects the systems along the river and the connectivity is improved within the housing areas and across the river in strategic locations. The waste management network makes use of the improved connectivity to transport the waste to the waste transportation system of the city.

For both systems, the direction of future development is indicated. The courtyard system has its starting point in the individual design location and is from there developing downstream. The chinampa system has its starting point in the individual design location and is then further developing according to the biggest spatial capacities within the river valley, always developing from the edges towards the river.



Marufuku kutupa taka hapa - Do not leave your waste here!

The timeline shows the required implementation periods of policies and interventions and their timewise relationships over the next 20 years. Policies usually take around two years to be adopted (N. Jean-Baptiste, personal communication, March 28, 2018) which is why they have to start immediately, as they are part of the preconditions of many interventions. The indicated periods for the implementation of interventions relate to the final implementation in the whole common intervention location. This means in return, that parts of the systems can already function locally at an earlier point in time. Not included in the time indication is the continuous operation and maintenance of the interventions which follows after the implementation. For each policy and intervention, relevant stakeholders are indicated, which will be explained further on the following pages.

Over time, five milestones have been defined to focus the implementation phase and measure the impact. After three years the surface should be clean from solid waste. After ten years, no people should live in high risk areas in the river valley. Regarding the resilience to flooding, the midterm aim is to be able to cope with small rain seasons and in the long term with big rain seasons. In the end of the 20 year period, the informal settlements should become formal neighbourhoods of the city, since the implementation of the interventions and policies give them a more formal and safe form and function.

▶ stakeholder relation

The timeline indicates the stakeholders related to each intervention and policy, which can be in planning and preparation, realisation and construction, operation or for maintenance. The process involves governmental and non-governmental institutions as well as residents and property owners.

Policies are adopted on national level while their implementation mainly takes place under the supervision of the sub-wards. Infrastructure and services are responsibilities of the councils of the city, the districts and wards, depending on their impact of the network. To implement physical interventions, private companies are necessary as partners to finance developments.

In Dar es Salaam, DAWASA and DAWASCO are the responsible institutions for issues regarding water and sanitation, however the regular and immense flood issues of Dar es Salaam are also part of the agenda of the president's office because of their huge impact on people and economy.

NGO`s, regardless their focus, mostly work closely together with the sub-wards and also involve the local communities in their projects. Ardhi University can contribute knowledge to all levels and partners and student projects have the potential to contribute to the implementation of small scale interventions in a collaboration with residents (N. Jean-Baptiste, personal communication, March 28, 2018; R. Rolvink, personal communication, May 17, 2018).

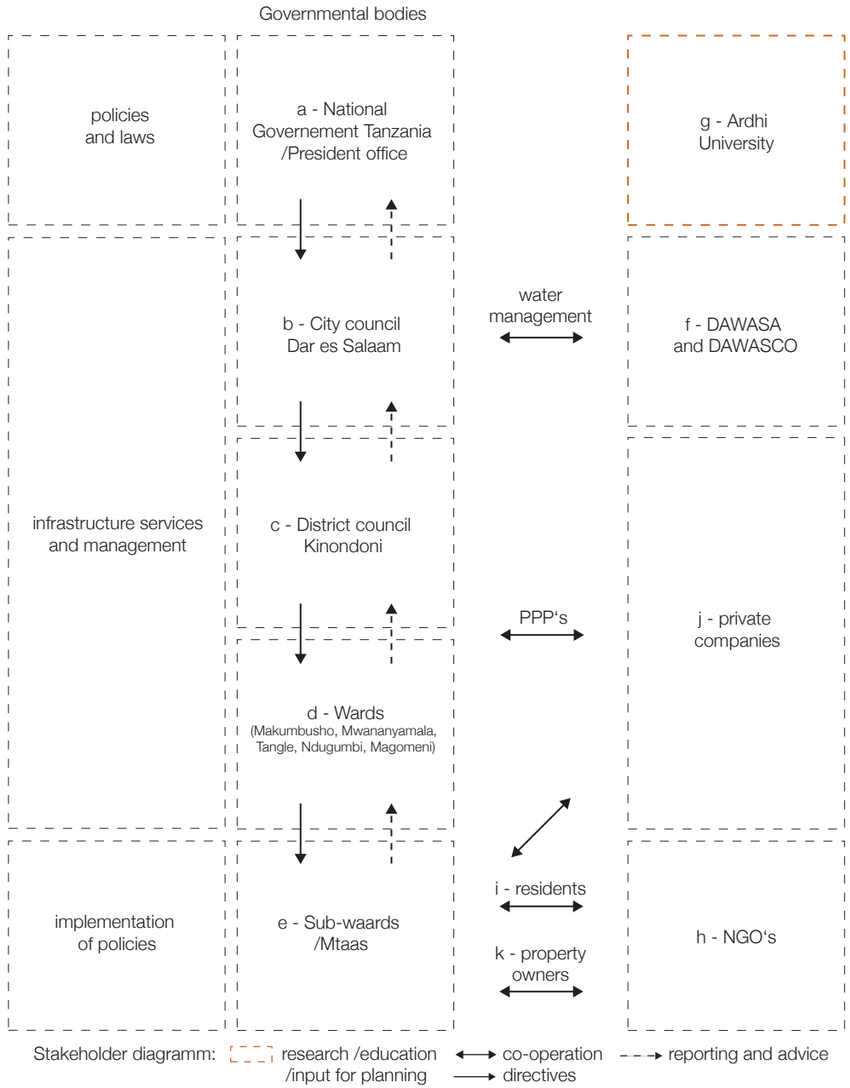


Fig. 25: Stakeholder relation. Own drawing.

To create the necessary preconditions, a set of policies has been formulated. These policies should be implemented at least on the scale of the local river basin but preferably on the scale of the whole region, because even without the design they can have a positive effect on the urban landscape and the water management of the city to some extent. The timeline shows how the design interventions are linked to the proposed policies while the spatial implications and locations are shown on the Sinza river basin strategy and the strategic masterplan (see previous pages).

1. Water treatment by industrial sector
Content: Companies of the industrial sector are obliged to filter and treat their own waste water, to free it from metals and other harmful and polluting substances, before discharging it into the river and other water bodies. Within a period of three years, factories have to add missing treatment facilities and get it running. Companies who discharge untreated wastewater after this period will be fined.

Aim: This policies aims to prevent heavy pollution of the river, for example by metals, which cannot be treated once discharged into the river. This is an important precondition in order to make agriculture possible and safe for consumption in the river valley.

2. Building stop in flood risk area
Content: Within the high risk area of the river valley it is prohibited to construct new buildings or reconstruct or repair existing buildings. If water gets inside the house more than twice a year it is considered uninhabitable. In this case it is not allowed to inhabit this building or rent it out. If a building is declared uninhabitable, it has to be demolished within three years. If the owner of the building does not remove the building within this period, everything within the footprint of the building, including construction materials for re-use and the ground it stands on, goes to the authority of the ward to benefit the community.

Aim: The aim of this policy is to prevent buildings being located in the high risk areas of the river valley to give space to the river on the one hand and protect inhabitants on the other hand.

3. No waste in river & public space
Content: It is prohibited to dump waste of any kind in the river or in public spaces. Waste has to be brought to designated waste collection points for further transport and treatment. Biological household waste can alternatively be used for biogas reactors or be composted to create fertilizer for urban agriculture. To ensure that no pollutants affect soil or river, the treatment of biological waste has to take place in a location safe from flooding or other flood protection measures have to take place.

3.1 Key action: clean-up
A initial clean-up will free the area from existing waste pollution before the area can be transformed.
3.2 Key action: awareness campaign
An awareness campaign is necessary to inform residents about potentials a clean river provides and to educate them on how to reduce, re-use and treat waste in a sustainable way.

Aim: This policy aims to reduce pollution of water and soil by solid waste and waste water to create a more healthy environment which is safe for the production of edible products. Reduced pollution by solid waste also reduces the sealed surface cover and therefore enhances infiltration and also reduces accumulation of waste in the river which prevents waste from blocking the water flow towards the ocean.

4. No New One-Story-Constructions
Content: New constructions of one story buildings are prohibited. All new buildings have to have at least two inhabitable stories to increase the housing capacity per square meter ground floor area.

Aim: The aim of this policy is to restrict urban sprawl into the river valley and increase urban density. This increases the housing capacity on less land to keep as much surface open as possible to reduce run-off of rainwater.

5. New Renting Models
Content: All land- or building owners who rent out (parts of) their properties have to apply newly proposed renting models. The different renting models (see next page) have in common, that they protect renters from being kicked out arbitrarily by the landlord after a short period of time. Longer renting contracts make renters take better care of the condition of the buildings and related land, which increases the lifecycle of the buildings.

The calculation of the lowest rent is based on the fact, that tenants should not spend more than 30% of their monthly income on rent (Dixon, 2017). In Dar es Salaam, 50% of the residents of informal settlements have an income of 1$ per day (John, Kombe & Mayunga, 2012), which means about 30$ per month. 9$ are 30% of the monthly income, which is then the rental price. The proposed prices are rough estimations which have to be re-evaluated based on the income of the residents of the informal settlements. It is necessary to ensure that current residents will be able to afford to stay within their neighbourhoods to protect their social capacities. The renting prices mentioned above are per room per month. Besides the re-evaluation of the prices, it is also necessary to think about appropriate units to define, e.g. per room or per m2. These policies are not the main delivery for this project. Therefore, they have to be understood as rough ideas. Before implementing them, it is necessary to develop these initial ideas further, combine them with tools to enforce them and link them to responsible and involved stakeholders.

Aim: The aim of this policy is a diversification of housing typologies and motivate landlords to construct multiple-story buildings. Furthermore, they promote urban agriculture and creates ownership for agricultural areas. Longer renting periods to protect residents also generates an interest in maintaining their living environment, improving the overall quality of the neighbourhood.

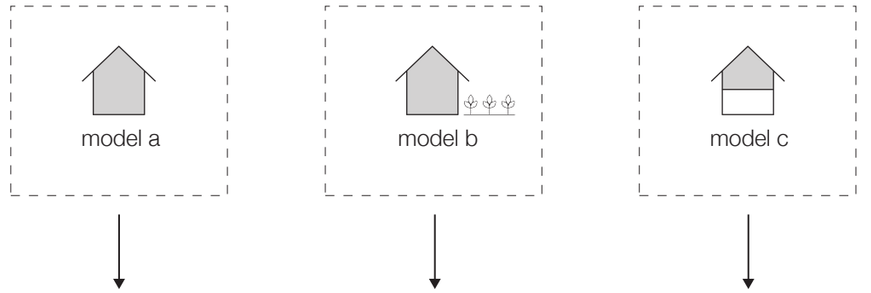


Fig. 26: Renting models. Own drawing.

To achieve a waste free area, it is vitally important to introduce a waste transportation network. Waste can't be treated completely inside the area and conventional transportation systems by truck do not work in informal settlements, due to the lack of infrastructure and space inside the neighbourhoods.

Therefore, a network of small scale low budget cable cars is being proposed to organise waste collection for the least accessible and steep neighbourhoods to local roads. From there, waste can be transported by bajajis to main roads, where it connects to the conventional and existing waste transportation network of the city. Cables cars, also known as aerial ropeways or aerial trams, have been chosen as the most appropriate means of waste transportation, because they can bridge height differences and do not depend on space on the ground floor.

Cable cars have a long history in cargo transport which goes back to the middle age. It was a crucial means of transportation in mining, where big height differences have to be bypassed. Cable cars lost attention as means of transportation with the extensive development of railway and road transport (De Decker, 2011). In more recent history, cable cars regained attention for the transportation of both cargo and people. Their energy efficiency and low cost requirements for implementation, operation and maintenance make it a good alternative, especially in areas which are difficult to access by land, are very dense or have big height differences. These systems are applicable in different scales and qualities, depending on what has to be transported (Grabar, 2013).

Different examples show, that cable cars, even in a very basic form, can have a big impact for the transportation of goods, especially in areas which are not easily to cross on the ground. A gondola made of a simple metal and wood structure are used in Spain to transport bananas (see Fig. 27) across terraced fields. In Switzerland, cable cars are used to transport goods through the mountains (see Fig. 28) and also illustrate, how the gondola can be adjusted according to the requirements of the goods, like in Fig. 29 with containers for milk. Without much investments, cable cars can also be used to transport people. In rural areas in Nepal for ecample, cable cars, locally known as 'tuin' are used to cross rivers (see Fig. 30). People are pulled manually across the river in a trolley which is hanging on a wire (Appropedia, 2012).

Depending on the purpose and the scale of the cable car, costs and technical skills for implementation, operation and maintenance can vary a lot. In the case of Dar es Salaam, the main purpose of the cable car is the transportation of solid waste out of the informal settlements. The cable car can also be extended to transport products and goods in and out the area. Although the proposal focuses on a small scale system which can be implemented and operated by the local communities, it is possible to implement a bigger system for the whole city and not only focus on waste and goods, but also extend it as part of the public transport network of the city.



Fig. 27: Cable car banana transport in Gomera, Spain.



Fig. 28: Cable car goods transport in Switzerland.



Fig. 29: Cable car milk transport in Isental, Switzerland.



Fig. 30: 'tuin' to cross rivers in Nepal.





Reflection

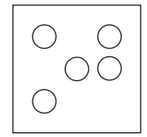
design interaction / design reflection
/ individual reflection



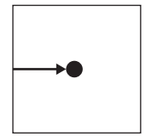
courtyard design



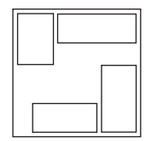
urban



small scale intervention/
implementation

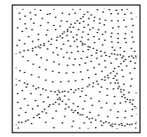


short term intervention/
implementation

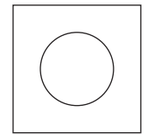


old structure

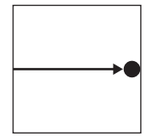
chinampa design



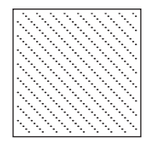
landscape



big scale intervention/
implementation



long term intervention/
implementation



new structure

The aim of the design proposals was to address the five main problems, namely rapid urbanisation, water, no coping capacity, connectivity and waste, which were identified during the analysis.

As it can be seen in the first diagram, the courtyard system has its main focus on the first three problems, which are strongly addressed by the design proposal. The reorganisation of urban blocks and the addition of new typologies strongly address rapid urbanisation by introducing a vertical densification. A multiplicity of interventions, like the orientation of roofs, aquaponic systems or renaturation of surfaces address the issue of water management by improving the flow of water as well as infiltration and retention capacities. The addition of functions to generate income, like aquaponic and urban farming, as well as the improved spatial conditions improve the coping capacity of the residents.

Although there is not a specific design strategy to address the waste issue, it is secondarily addressed by other interventions. Self-production and the use of local products reduces the appearance of waste and strategies like composting reduces the amount of household waste. Other materials like bottles or paper can be re-used in the production and storage of own products.

The problem of connectivity is not directly addressed. However, the negative of the newly shaped blocks create a more readable and connected public space, which accessibility during rainfall is improved by the implementation of ditches to steer the water out of the area.

The second diagram shows, that rapid urbanisation is not directly addressed by the chinampa system, since its main focuses lies on the landscape. The problems of water and no coping capacity are the most addressed by the chinampa system, mainly by interventions which address both issues simultaneously. Chinampas give space to water in the river valley while maintaining dry areas for agricultural purposes, constructed wetlands treat blackwater from households to keep the river clean for agricultural production and ditches and retention areas steer the flow of water and improve the infiltration and retention capacity. These areas can be planted with edible plants to add economic value to them. Forestry areas reduce erosion to prevent blocking of the river and also improve infiltration and evaporation to reduce run-off.

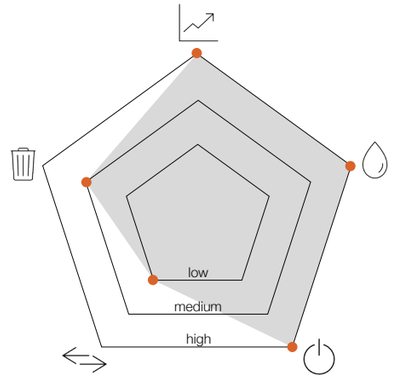
Like the courtyard system also the chinampa system does not provide specific design strategies addressing waste but addresses it secondarily within other interventions in the same way.

The connectivity in the area is addressed by new and improved connections which are also accessible during heavy rainfall. Especially the new connections across the chinampas through the river valley contribute to a better connectivity and an improved accessibility of bigger infrastructure and public transport.

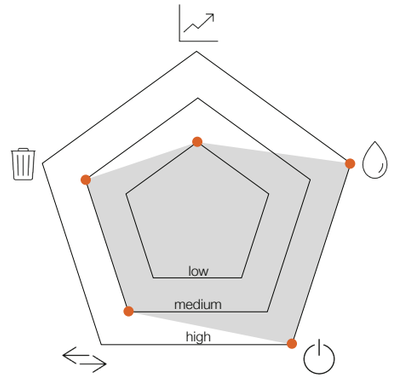
The third diagram overlapping the reflection of the two design proposals show, that the main focus lay on the three main problems identified in the initial problem analysis. However, the other two problems identified during the location analysis are also addressed secondarily.

It is important to note, that this reflection only covers the design proposals. These are supported by the proposed policies and the strategic plan for the river basin, which further address all of the five identified problems.

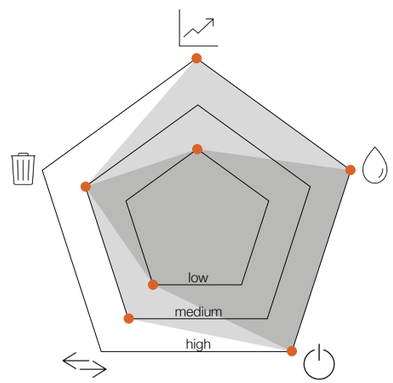
courtyard design



chinampa design



overlap



Relation of the project to the Design of the Urban Fabric studio

The studio Design by the Urban Fabric focuses on the physical structure of the urban environment. Design is used as a tool to understand how to improve socio-cultural structures, explore ecological approaches and/or integrate new technologies in the current and future urban structure. Working with form, materialisation, scales and density are one of the core elements used in this research group and we applied these elements in our joint graduation project.
Having my bachelor degree in Architecture I have always been interested in the way a single building relates to its complex urban structure. It has always been important to me to work at multiple scales and this requires interdisciplinary collaboration. This is why I chose to complete my Masters in the Urbanism track.
Our joint graduation project explores these multi scale and interdisciplinary processes of the river N'Gombe as it runs through the city of Dar es Salaam. We aimed to create design solutions that mitigate the impacts of N'Gombe river floods on local citizens. The flood risk problem has socio-cultural drivers; poverty, migration and lack of planning. To solve this, we propose a landscape architectural/urban design solution. An interdisciplinary approach is needed to both understand the drivers of the problem and design a solution. In this sense, the Design of the Urban Fabric studio gave us a great starting point to develop our graduation project and enough flexibility to integrate a landscape architectural approach.

Reflection on methodology and working process

The Design of the Urban Fabric studio works with various of methods which we applied during the graduation project. Some of these methods, used in the research studio, explore the relation between research by design, fieldwork, interaction with professionals and using tools such as problem mapping and drawing. These methods proved to be very helpful in developing our graduation project and helped us to become more concrete choosing a project location, interventions and gave us insights of possible design solutions.
Mapping – Until now I have not had the chance to work in Africa. These spatial structures and the tropical landscapes were completely new for me. The method mapping proved to be helpful in the beginning of the project to get an understanding of the spatial urban structure and the interaction between landscape and informal settlement in Dar es Salaam.

Field work – The visit in Dar es Salaam gave us a better understanding of the living conditions of urban poor. We could see for ourselves the interaction between building style, cheap building materials and the dramatic weather conditions. These areas lack fresh water, sanitation and waste management. These areas also miss connectivity within informal structures and they also lack links to the city as a whole. The field work confirmed our analysis and research in many aspects and also helped us refine our problem statement and analysis.

Interaction with professionals – Personal interaction with a local researcher from Dar es Salaam provided us with research documents from Institute of Human Settlements Studies at Ardhi University. The meeting and documents gave us insights of processes and needs of governance from different perspectives that deepened our understanding of the socio-economic aspects of the city. Furthermore, the workshop organized by students working in African context has helped to understand the conflict between research and practise – in our case the conflict of research and design proposal.

Research by design – This approach proved to be very helpful during the phase of designing the courtyard. First, we researched different methods to deal with water and enhance urban agriculture. Second, we used this knowledge and brought it into a new spatial order. More specifically, aquaponics was a familiar system to me. However, through the research I went through a process of thinking which gave me new insights of how to implement the aquaponics in a new spatial context.

In summary, the various methods offered by Design by the Urban Fabric studio proved to be very helpful and crucial to get an understanding of the African context, forming the project and the designing interventions. These methods in cooperation with my practical/pragmatic mind improved the development of the project in a good pace but also helped in decision making of how to proceed further.

Reflection on the proposal
The proposed plan includes a strategic masterplan and a strategic timeline for incorporating the individual designs. The design comprised of an urban layer with new buildings typologies, an infrastructure layer suggesting new waste management and improved connectivity and an urban landscape layer proposing new forms of urban agriculture and flood buffer zones. Thinking of the context of a developing country it would be interesting to see to which extent the design of the courtyard is feasible. The design proposes small scale, bottom up interventions which can be done by an individual group and is therefore easy to implement. Societal value of the courtyard will increase once people understand the economic and environmental benefits of the design.
The challenge will be to change the mind-set of the locals in the first place. More in detail, the change of how they perceive and treat their environment in order to maintain the design. These are socio-cultural aspects which are difficult to include and to prospect. It also rises ethical questions to which extent behaviour can and should be changed.
However, I believe that the issue of dealing with informal settlements in flood risk areas is a topic which is relevant in many parts of the world. The interventions suggested in the courtyard proposal are easily transferrable to other places in the world, whereas the spatial structure of informal settlements can differ - and need to be adjusted individually.

Uncertainty
Working in the African context means working with uncertainties. Uncertainty of information flow during the research phase. Uncertainty of travelling to an African city and not being able to make a detailed plan of the trip. Uncertainty about the feasibility of the project and capability of locals living in informal settlements. All in all, uncertainty has been the biggest challenge of the graduation project but also the biggest joy. Particularly during the research phase, we came across a lot of questions we couldn't answer because the information simply didn't exist. Therefore, the research phase and information search has been challenging and an intense time. Our own intuition, case studies and interactions with professionals helped us to continue our work and fulfil the missing gaps.
However, I took advantage of this uncertainty. The uncertainty and the lack of governmental planning in a developing country gave me a lot of design opportunities to change and improve the area. Imagination is less restricted and creativity is more challenged.

Reflection on team work
Working as team was extremely helpful in all stages of the project. We were able to complement each other and have discussions about the project with a person who was the same engaged with the project. The interaction of a team partner is crucial because it gives you the opportunity to reflect and remark critically. This improved our project but also enhanced our way of thinking. Besides this, the team work gave our project and ourselves more security and self-confidence because project decisions have been discussed by two critical minds instead of just one.

Conclusion
To conclude, this project can be used as a pilot project or a test case on how to approach flood risk problems in informal settlements in an African context. A shift from big urban designs towards small scale interventions in enhance building style and culture. The projects include not just flood risk mitigation strategies but also opportunities to use local resources and support the local economy.
The project can trigger conversation of how to intervene in a developing country and can raise protests and doubts of existing and future projects.

Scientific and societal relevance

This research and design project addresses the high flood risk and lack of coping capacity that results from rapid urbanisation in local communities in Dar es Salaam. These problems do not only occur in Tanzania, but in most cities in the global south. This makes it a relevant case to explore potential solutions to protect and empower residents, which could be transferred to other contexts as well.

Reflection on the design proposal
My design proposal shows an alternative way of using the landscape, which gives space to the river and to human adaptation equally and does not compromise the needs of one another. By modelling the landscape with different interventions, it is possible to build capacities to deal with flooding and to generate income at the same time.

Different levels of skills and decision-making authorities are required in order to implement the different interventions. The riverine buffer zone for example requires a high-level authority to decide on the implementation. The longer the stretch of this zone, the more effective it is. The constructed wetlands can be implemented by the local authority but requires advanced technical knowledge and skills for construction and maintenance. Other elements, such as community gardens or chinampas can - once authorised by the responsible body – be implemented in a bottom-up approach, with local knowledge and work force.

In the current state of the individual design area, flood management and protection are not addressed and people lack the opportunities to build capacities to deal with hazards. Since nothing is currently in place to deal with these issues, every small implementation will already have a positive effect on the area. However, the proposed system only functions to its full capacity once all the interventions have been implemented in the entire area. This is a clear weakness of the proposal. Its full implementation requires a lot of time, decision-making, agreement of all stakeholders and funding.

The individual design is supported by our joint policies, which allow for a setting that enables the implementation of joint- and individual interventions. In the long term, the implementation of the proposed policies and interventions can lead to a formalisation of the area, because they improve the safety, accessibility and condition of the area. While this should be desired by the government, it also carries the risk of gentrification. This makes it especially important to protect current residents and give them the opportunity to stay in the area and grow with it in economic terms.

My role as urbanist
As an urbanist, I have to fulfil a wide variety of different functions, some which can be controversial and difficult to bring into balance. I have to be an advisor with my expert knowledge on urban form and function and have to show the potentials of possible developments. At the same time, my role as urbanist is also to be a holistic expert. Someone who knows a bit about various different topics which are linked to the urban fabric. Therefore, one of the roles is also that of a mediator between different specialists and experts to combine the different opinions, expertise and ideas into a combined approach. Besides mediating between experts, mediating between stakeholders with different interests and different levels of influence is also an essential task. Combining these influences makes it very challenging to find a compromise between the different partners, without compromising the aims of the profession.

Based on this understanding of the urbanists' role, it can be judged positively that we work in an unknown context in this project. We were unbiased and not hindered in our thinking-process by things that may not seem possible for locals, allowing us to think of new ideas and opportunities. Still, to create a realistic proposal, it is important to combine external knowledge with local knowledge and research. Here, the role of the mediator became more dominant, to find the right balance between these three elements and to relate it to local stakeholders and governance.

Due to the limited economic and social resources in low income countries, development in the global south requires, to some extent, external funding. As a consequence, urbanists from donor countries/organisations become active in those countries that are in need. The funds should

not be used so much to construct, but rather to create new local knowledge (which is also part of capacity building), bridging it to the existing local knowledge and empowering local communities that way. This can be an opportunity to create local decentralised systems, which make communities more independent from externalities. This can especially help to empower the urban poor.

Creating opportunities for the urban poor brings another balancing act with it, namely, when the rights and needs of individuals opposes those of the community. It might, for example, be necessary to demolish houses and replace residents for the safety of the entire neighbourhood. In such a case, it is especially important to weigh up the options in each individual case and to find adequate alternatives for those individuals who have to be compromised. In case of a necessary displacement, this would mean ensuring housing with comparable standards have to be considered: not only in terms of the construction of the buildings, but also the social and economic infrastructure, distance to facilities and jobs and the distance to their neighbours and social networks.

The relationship between research-design
In the initial stage of the project, a general study of the location and its challenges was necessary to identify focus areas and to prioritise between the multiplicity of challenges. The following design steps brought up more (specific) questions, which in return were explained and justified by further research. This continuous back and forth between research and design enabled us to create a proposal with functioning systems, regarding the elements which were taken in consideration.

Due to the location, there was limited availability of information about certain topics. In these cases, we were forced to make educated estimations based on other examples, conversations with experts and local stakeholders or on our observations during the field work.

Since this project is an academic project with a limited timeframe, certain topics had to be excluded. One topic we did not include, partially due to the lack of accessible information, was landownership. We chose our common intervention area based on spatial characteristics and not on municipal borders or ownership borders for example. Though this opened-up possibilities for the design, it also makes it more difficult to implement because it requires the agreement of many different landlords, NGO's, ward leaders and other higher governmental bodies and institutions. This is something that would have to be analysed and managed thoroughly to build up a precise implementation strategy.





Academic frame

conclusion / relevance / ethical issues
/ motivation / theoretical framework / abstracts

To focus the research and design of this graduation project, a main research question has been formulated in the beginning of the process as follows: “How can the urban form and landscape help to mitigate the effects of floods on citizens in Dar es Salaam, Tanzania?”. Additionally, a series of sub-research questions has been formulated as well, to gain necessary information and knowledge to answer the main research question. While the answers to these questions can be found in the different findings, conclusions and products throughout the report, this chapter will summarise the answers to the different questions to conclude the findings of the project, which are based on the research, design and observations from the field work.

Sub research questions:
1. What are the main causes for floods in DAR?
The main causes of floods in Dar es Salaam are extreme precipitation patterns, rapid urbanisation and a lack of water management within the city. Rising water levels during the two rain seasons have always been part of the reality in Dar es Salaam. However, due to the rapid urbanisation, people started to settle in floodplains and river valleys, reducing the required space for the natural water flow and putting assets and lives at risk. Due to the increased level of urbanisation, there is less permeable ground for water to seep in, which increases the run-off of storm water which is flowing into the river. The lack of infrastructure for water and waste management, especially within the informal settlements of the city, blackwater and solid waste are carried into the river by storm water, causing pollution and blockages of the water flow, which prevents storm water to be discharged into the Indian ocean. Additionally, changing climate conditions affect precipitation patterns, which will make seasonal peaks of rainfall even more severe in the future.

2. Which areas are the most at risk for flood events and what is their dominant urban form?
Flooding occurs in different locations all over the city, however those areas around the rivers and creeks are the most at risk for flooding, since these areas are lower and have to cope with run-off water from higher located areas. The neighbourhoods in these areas mostly consist of informal settlements as a consequence of the lack of affordable housing areas for urban poor in areas which are safe from flooding but within reach of the city centre with its facilities and job opportunities.

3. What are the consequences and effects of floods on the population of DAR?
Residents of Dar es Salaam, in particular those living in areas with the highest risk for flooding, are strongly affected by floods in physical, economic and social terms. Houses are being damaged or destroyed and neighbourhoods are being isolated when insufficient connections cannot cope with the amount of water anymore. This takes away the economic abilities of residents, because they either cannot reach their place of work anymore or because they had economic activities at their homes which are damaged, destroyed or cannot be reached by customers. In addition, floods carry a high health risk due to heavy pollution and mosquito breeding.

4. What is the local urban form and human behaviour and how do they currently deal with flood risk?
The informal settlements of Dar es Salaam are formed by one story buildings made of brick and tin roofs, which are constructed close to each other. There is no clear structure in the placement of the buildings, but they are adjusted to the conditions of the landscape. Daily life activities of the residents, like cooking, laundry or informal economic activities, mostly takes place outside their houses, on the porch or the street. Due to the lack of infrastructure, there is no structural approach to deal with floods. Occasionally residents try to make defence walls of stones or solid waste like car tires or block the bottom of their entrance doors in an attempt to keep the water out. Since these efforts are not implemented continuously, they have little to no effect once the water level is rising and the flow of the water is speeding up.

5. How can we mitigate the effects of floods on existing urban form and their citizens by improving landscape and building local resources?
To mitigate the effects of floods it is important to note, that a set of interventions are required to have sufficient impact. At the same time, it is necessary to consider the whole river basin and already apply landscape interventions upstream to reduce floods and mitigate effects downstream.
One of the reasons for floods are the spatial consequences of rapid urbanisation, which compromise the landscape capacities to deal with high amounts of water. Therefore, it is necessary to bring back the landscapes capacity. Surfaces have to be opened up to increase infiltration and evaporation and surfaces have to be models strategically to create retention areas, both to reduce the amount of run-off water during rainfall to reduce the amount of water in the river. Furthermore, ditches have to be integrated into the urban landscape to steer the run-off water which cannot be dealt with locally into the river valley to reduce negative impacts on buildings, infrastructure and spaces for economic activities. For the river valley itself, it is important to give space to water again, as it is the valleys original purpose. Chinampas are a sustainable way to accommodate large amount of water while contributing to the economic coping capacity of the residents with the provision of agricultural areas.

6. How can the existing urban form be integrated in flood risk adaptation?
The strategies for mitigation named above also contribute to flood risk adaptation, as mitigation and adaptation go hand in hand and complement one another. However, it is important to integrate the existing urban form and the residents livelihood. With the transformation of existing urban blocks, proposed as part of the courtyard system, the basic structure of the urban form will be maintained and not every building has to be touched. Additional functions incorporated into the new block structure retain, store and reuse water and open surfaces between blocks and buildings can be used more efficiently for water management and agricultural production without changing the urban tissue.

7. How can a shift in human behaviour contribute to create coping capacity and adapt to changing climate conditions?
Human influences like urbanisation and waste disposal have a major impact on the current conditions and have therefore the potential to also affect it in a positive way. One important factor is the perception of the river as a valuable resource and not as a waste disposal and a threat, like it is currently the case. If residents change their behaviour about waste disposal and help to keep river and soil clean, flood risk can be reduced because the water flow is not blocked by solid waste anymore. Also the local treatment of blackwater by the residents positively affect the coping capacity, because unpolluted water is a big resource for urban agriculture and other economic activities.
Regarding the urban form, residents and especially landlords have to understand the negative impact of the construction of houses in the river valley for the urban and natural environment. The construction of multi-story buildings has the potential to reduce the urban footprint, create a multiplicity of housing typologies and additional income generation per square meter ground floor.

8. What are the benefits of the spatial transformation for local residents?
The spatial transformation of landscape and urban form do not only benefit the urban and natural environment and the adaptation to changing climate conditions, but also the residents directly benefit from it. First, the residents will face much less risk from flooding, securing their living and working environment. Second, added functions like urban farming and aquaponics as well as improved connections strengthen the economic coping capacity of the residents in case of a hazard, because there are more sustainable and diverse possibilities of income generation. Third, transformed neighbourhoods become more independent from external factors and centralised systems, because of the many functions integrated in the systems and the high level of circularity. The latter carries potentials especially for informal settlements to improve their environment and living standards.

The findings of the sub-research question helped to answer the main research question: “How can the urban form and landscape help to mitigate the effects of floods on citizens in Dar es Salaam, Tanzania?”
The complementing systems of courtyards and chinampas, which transform the landscape as well as the built environment, reduce the occurrence of floods as well as their effects by steering, reusing and retaining storm water where it appears. Less water will end up in the river valley and the flow of the water is not disturbed anymore by buildings or waste accumulations and can be discharged into the Indian ocean. The residents have to face less and less extreme floods which keeps their houses more safe and additional functions to generate income increases the coping capacity to deal with floods in case they appear.

Societal Relevance
Like most developing countries, Tanzania has to deal with limitations regarding economic and social capacities. At the same time, the country is hit by extreme weather events like floods and droughts. Not only do these events have an effect on the physical structures of cities/regions but also on their communities and inhabitants. Physical damages to cities can compromise the health and safety of people, like destroyed buildings, falling trees or broken water supply systems. Physical impacts can also damage the human body, for example by heat, or secondary effects of physical damages like lack of drinking water, faster and more frequent spreading of disease epidemics (Pauleit et al., 2015; Sudmeier-Rieux et al. 2017). By designing solutions to mitigate the negative effects on communities in Dar es Salaam, this study can contribute to a more healthy and safe urban society.

Poor communities are often hit harder by these events, because they live in more vulnerable locations due to economic abilities and have less capacities to cope with damages. Therefore, designing solutions which are affordable and replicable, can help poor communities not only in Dar es Salaam but also in other parts of the world.

Scientific Relevance
One effect of climate change is the change of appearance of extreme weather events, like droughts, heat waves or storms. These events will most likely occur more frequently and more severely in the future, depending on the climate conditions of the area (UN-Habitat, 2014). While a lot of research has been conducted to reveal the damage that might happen in the future caused by these events, there is still a lack of well developed solutions to prepare residents and communities, make them more resilient to hazards and to mitigate the cause before such an event strikes. This study can contribute to the latter by designing solutions for flood problems in Dar es Salaam.
Besides the studies on climate change, the United Nations have defined 17 Sustainable Development Goals (SDG`s) to promote sustainable development worldwide. While these goals set a clear aim what each of these shall achieve, there is not much done yet about their implementation.



Fig. 31: Sustainable Development Goals addressed within this project.

This study will address the SDG´s (Fig. 31) and can therefore contribute new ideas on how to implement them also in other locations (United Nations, 2015).

Possible Ethical Issues: Altruism
Altruism stands for the “principle or practice of unselfish concern for or devotion” to the well-being of others (Dictionary.com, 2017). Altruism is often understood in relation to international development work. Are development workers really concerned of the welfare of others or does their devotion to difficult causes come from selfish reasons? The concern of why students study a developing country also raises the question of what impact they can have?

As already described above the urgency of Dar Es Salaam is one of the driving factors why this projects is interesting. The challenge of solving problems but also to learn about a developing city is an attractive reason to work on a project in a developing country. Besides, a development project stimulates curiosity and expands knowledge and experience.

Concerning the second question; one of the possible impacts of a development project could be to connect Tanzanians with best practices from western countries. Western students can provide new ideas of thinking in order to solve problems such as adapting to climate change in urban areas.

These two questions/answers of why to work in a developing country but also what impact western students can have arises a lot of moral questions. Often developing projects are driven by a balance of self interest and selfless concern towards others. However, it is questionable if pure altruism really exists and to what extent western students are aware of their self interest when dealing with people from a third world country.

Motivation
Climate change is a global problem and one of the topics of today’s present. Researchers often discuss the environmental impacts of global warming such as rising sea level, glaciers melting or more frequent hazards (Mirza, 2003; Sudmeier-Rieux et. al., 2017). But what does climate change mean to human health and how can humans adapt to it? One of these questions we would like to explore in a (1) developing country such as Tanzania. There is a (2) urgent demand for support because of limited investment capacity, lack of governmental tools and little resources. We would like to get challenged by the (3) uncertain local situation in Tanzania but also the lack of information and accessibility of such a place.

(1) Developing country - Tanzania is a developing country with limited resources and tools in governance and planning. The government does not yet have the means to implement plans and many projects are based on or funded by development aid (Mirza, 2003). At the same time, governance is trying to solve problems in the short term because of the urgency of the situation. Long term solutions are being delayed. The weakness of the government but also the lack of investment capacity is causing the population big risks (Field, 2014, p. 1226).

However, developing countries are not the only ones facing problems and risks. Western countries are also affected by it. Migration caused by climate change will increase in the upcoming years and will challenge our cities. African citizens will have to move because their home country won’t be livable anymore (GIZ, n.d.; UN-Environment, 2017).
(2) Urgency - Dar es Salaam is hit by severe floodings on a regular basis, mainly caused by heavy rain, which destroys livelihoods and puts residents in danger. The quality and quantity of drinking water is decreasing, which has a negative impact on human health. Diseases such as malaria, dengue fever or cholera are quickly spread (Pauleit et al., 2015, p. 216-219).

Another indicator of the urgent situation in Tanzania shows the life expectancy. In average people die approximately fifteen years earlier than in a western country. This is also caused by the impacts of climate change such as diseases mentioned above (World Bank, 2017b).

(3) Personal motivation - Dealing with uncertainty describes our personal motivation the best. We would like to get challenged by uncertainty. This includes to force ourselves to get in contact with organizations and institutes but also to reach out to local people to get an understanding of the city. At the same time, we hope that one or two of our ideas can help or offer insights to the Tanzanian urban planners.

Another personal motivation is to move from theory to practical intervention. Particularly in development projects the link between theory and action is important in order to mitigate the effects of climate change. Planning aspects but also design interventions are closely related when we talk about climate adaptation. Therefore the physical implementation is crucial (Dhar & Khirfan, 2016).

Climate Change Adaptation and Mitigation
The climate is changing and has a huge impact on the planet, urban and rural areas and human beings. In order to be able to deal with them in the future, it is necessary to adapt to future events and at the same time mitigate them to reduce negative consequences. Adaptation is “The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects” (UNISDR, 2009, p. 4), while Mitigation is defined as “the lessening or limitation of the adverse impacts of hazards and related disasters” (UNISDR, 2009, p. 19).
One element of adaptation is Disaster Risk Reduction, which is “the concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters” (UNISDR, 2009, p. 10f.).

The impacts of climate change on human health in Africa – adaptation/mitigation strategies - Beke-Marleen Hörmann
(For full text, see p. 244)

Abstract - Climate change is estimated to indirectly kill 250 000 people globally between 2030 and

2050. Developing countries such as Tanzania, are increasingly affected. The changes in climate are particularly noticeable on a local scale in African cities, even though the causes of climate change need to be addressed globally. Physical health impacts, vulnerable housing and thermal stress are just a few negative impacts people experience. This paper aims to show that for African cities, adaptation strategies are more relevant than mitigation strategies. Adaptation is widely understood as adjusting to the conditions to cope with climate change, whereas mitigation addresses the root causes of climate change. In the case of Dar es Salaam, Tanzania adaptation plays a more important role than mitigation. This is because cities in Africa are very vulnerable to climate change, however people living in these cities do not contribute significantly to global greenhouse emissions. This paper reviews practical greenhouse adaptation and mitigation project examples from Dar es Salaam and discusses the methods for comparing one strategy with another. Urban planners need to define what their values and goals are, and from there they can use tools such as cost/benefit analysis to compare one strategy with another. Local and regional scale planning projects have the most efficient impact, in terms of the number of human lives saved.

Sustainability of Flood Protection - A comparison of approaches for flood protection with regards to sustainability - Mona zum Felde
(For full text, see p. 252)

Abstract - Floods are the most frequent causes for disasters in the world, destroying livelihoods, economies and communities. Influenced by urbanization and climate change, the frequency and intensity of floods is most likely to increase in the future. At the same time, more and more people live in flood risk areas. These developments make flood protection more important than ever to protect urbanized areas and mitigate the effects of flooding. This paper gives an overview of three different approaches for flood protection, namely the structural, the non-structural and the ecology-based approach, and assess these with regards to their sustainability. The conclusion is, that non-structural and ecology-based measures are more sustainable. Nevertheless, they have to be combined with structural approaches in certain conditions, in order to provide sufficient flood protection in the future. This is important, because floods themselves are unsustainable as they interrupt the continuity of the flow of other systems.

Resilience

Due to climate change, extreme weather events will be inevitable in the future. Therefore, it is necessary to make cities and communities more resilient as one way of coping with them. Resilience is defined as “the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard” (UNISDR, 2009, p. 24).

Capacity Development

Developing countries like Tanzania are lacking capacities to deal with hazard events on the one hand and to initiate developments on the other. Therefore, it is vitally important to not only develop urban areas but also to develop capacities. Capacity does not necessarily mean financial abilities, but all kinds of resources that can help a community to cope with hazards, like “infrastructure, […] societal coping abilities, human knowledge […] [and]social relationships” (UNISDR, 2009, p.5).

Developing capacities means to build a diversity of capacities in the short term and maintaining them in the long term (UNISDR, 2009, p.5), to make local communities more independent and empower them for future developments to transform their communities and their environments. Capacity development bridges the gap between external and local knowledge, which in return benefits long-term success and sustainable development (UNDP, 2009).

It is therefore necessary to maintain existing community and neighbourhood structures, create awareness within the residents and collaborate with local stakeholders to share knowledge and expertise.



Bibliography

table of maps / table of figures

Appropedia (2012). *Aerial Ropeways in Nepal.* Retrieved from: http://www.appropedia.org/Aerial_Ropeways_in_Nepal.

Auswärtiges Amt (2017). *Tansania.* Retrieved from: http://www.auswaertiges-amt.de/DE/Aussenpolitik/Laender/Laenderinfos/01-Laender/Tansania.html?nnm=383178.

Backyard chicken coops (2018). *Give your chicken a protein kick.* Retrieved from: https://www.backyardchickencoops.com.au/give-your-chickens-a-protein-kick.

Cambridge Dictionary (2017). *Developing Country.* Retrieved from: http://dictionary.cambridge.org/dictionary/english/developing-country.

De Decker, K. (2011, January 26th). *Aerial ropeways: automatic cargo transport for a bargain.* Retrieved from: http://www.lowtechmagazine.com/2011/01/aerial-ropeways-automatic-cargo-transport.html.

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) (n.d.). *Risikobewertung und -management zur Anpassung an den Klimawandel.* Retrieved from: https://www.giz.de/projektdaten/projects.action?request_locale=en_EN&pn=201397579.

Dhar, T. K., & Khirfan, L. (2016). Climate change adaptation in the urban planning and design research: missing links and research agenda. *Journal of Environmental Planning and Management,* 60(4), 602-627. doi :10.1080/09640568.2016.1178107.

Dictionary.com (2017). *Altruism.* Retrieved from: http://www.dictionary.com/browse/altruism.

Dixon, A. (2017, October 17). How Much Should I Spend on Rent? *Smartasset.com.* Retrieved from: https://smartasset.com/mortgage/how-much-should-i-spend-on-rent.

energypedia (2016). *Electricity Generation from Biogas.* Retrieved from: https://energypedia.info/wiki/Electricity_Generation_from_Biogas.

Field, C. B. (2014). *Climate change 2014: impacts, adaptation, and vulnerability: summaries, frequently asked questions, and cross-chapter boxes: a Working Group II contribution to the fifth assessment report of the Intergovernmental Panel on Climate Change.* Geneva: Intergovernmental Panel on Climate Change.

Forman, R.T.T. (2014). *Urban Ecology. Science of Cities.* Cambridge University Press: New York.

Gasparini, P., Di Ruocco, A., Bruyas, A.-M., Bruyas Amra, A.-M. (eds.) (n.d.). *Climate change and vulnerability of African cities. Research briefs.* Naples. Retrieved from: http://www.cluva.eu/CLUVA_publications/CLUVA_Climate-change-and-vulnerability-of-African-cities-Research-briefs.pdf.

Grabar, H. (2013, April 9th). *The Golden Age of Gondolas Might Be Just Around the Corner.* Retrieved from: https://www.citylab.com/transportation/2013/04/golden-age-gondolas-might-be-just-around-corner/5220/#slide1.

Hassan, R., Schules, R., Ash, N. (eds.) (2005). *Ecosystems and Human Well-being: Current State and Trends, Volume 1.* Washington: Island Press. Retrieved from: https://www.millenniumassessment.org/en/Condition.html.

International Institute for Environment and Development (IIED) (2017). *Connecting cities to basins. Meeting the water and sanitation SDG targets at scale: a focus on Dar es Salaam.* Retrieved from: https://www.iied.org/connecting-cities-basins#top.

John, R., Kombe, W., Mayunga, J. (2012). *D 5.4: Preliminary Findings on Social Vulnerability in the Selected Cities.* Deliverable of the research project “Climate Change and urban Vulnerability in Africa (CLUVA)”. Retrieved from: http://www.cluva.eu/deliverables/CLUVA_D5.4.pdf.

Love, D.C., Uhl, M.S., Genello, L. (2015). Energy and water use of a small-scale raft aquaponics system in Baltimore, Maryland, United States. In: *Aquacultural Engineering* 68 (2015) 19–27.

MailOnline (2014, December 10th). *Think your commute is bad? Homemade cable car suspended 1,575ft between two cliffs is lifeline for remote Chinese village.* Retrieved from: http://www.dailymail.co.uk/travel/travel_news/article-2868407/Think-commute-bad-Homemade-cable-car-suspended-1-575ft-two-cliffs-lifeline-remote-Chinese-village.html.

Mhagama, H. (2016, January 29). Tanzania: Dar es Salaam Has Five Districts As Ubungo, Kigamboni Added to It. *Tanzania Daily News (Dar es Salaam).* Retrieved from: http://allafrica.com/stories/201601291386.html.

Mirza, M. M. Q (2003). Climate change and extreme weather events: can developing countries adapt?. *Climate Policy*, 3(3), 233-248.

Molle, P., Lié, A., Boutin, C., Merlin, G. & Iwema, A. (2005). How to treat raw sewage with constructed wetlands: an overview of the French systems. *Water Science & Technology* Vol 51 No 9 pp 11–21.

Moss, B. (2010). *Ecology of freshwaters: a view for the twenty-first century.* Wiley-Blackwell: Oxford, UK.

Nelson and Pade (n.d.). *Recommended Plants and Fish in Aquaponics.* Retrieved from: https://aquaponics.com/recommended-plants-and-fish-in-aquaponics/.

Niang, I., Ruppel, O.C., Abdrabo, M.A., Essel, A., Lennard, C., Padgham, J. and Urquhart P. (2014): Africa. In: Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1199-1265). Cambridge, United Kingdom and New York: Cambridge University Press.

Pan-Africa START Secretariat, International START secretariat, Tanzania Meteorological Agency, Ardhi University (2011). *Urban Poverty & Climate Change in Dar es Salaam, Tanzania: A Case Study. Tanzania.* Retrieved from: http://www.taccire.suanet.ac.tz/xmlui/bitstream/handle/123456789/542/dar-case-study.pdf?sequence=1

Pauleit, S., Coly, A., Fohlmeister, S., Gasparini, P., Jørgensen, G., Kabisch, S., W. J., Kombe, S., Lindley, I., Simonis, Yeshitela, K. (eds.)(2015). *Urban vulnerability and climate change in Africa. A Multidisciplinary Approach.* Cham: Springer International.

Pötz, H., Bleuzé, P., & Sjauw En Wa, A. (2012). *Groenblauwe netwerken voor duurzame en dynamische steden.* Delft: Coop for life.

Pötz, H., Bleuzé, P., & Sjauw En Wa, A. (2012). *Groenblauwe netwerken voor duurzame en dynamische steden.* Delft: Coop for life.

Ramani Huria (2016). *The Atlas of Flood Resilience in Dar es Salaam.* Tanzania. Retrieved from: http://ramanihuria.org/data/.

Rigg, J. (2007). *An Everyday geography of the Global South.* Taylor & Francis e-Library.

Roser, M. & Ritchie, H. (2017) - „Food per Person“. *Published online at OurWorldInData.org.* Retrieved from: https://ourworldindata.org/food-per-person.

Saha, A., Donoso, M., Mohamed, A., Masikini, R., Abbott, V., & Anderson, E. (2014). *Water Atlas of the Wami/Ruvu Basin, Tanzania.* Global Water for Sustainability Program, Florida International University. Retrieved from: https://www.researchgate.net/publication/270569561_Water_Atlas_of_the_WamiRuvu_Basin_Tanzania.

Sangea, H., Upton, K., Ó Dochartaigh, B.É. (2016). *Africa Groundwater Atlas: Hydrogeology of Tanzania.* British Geological Survey. Retrieved from: http://earthwise.bgs.ac.uk/index.php/Hydrogeology_of_Tanzania.

Sudmeier-Rieux, K., Sandholz, S., Nehren, U., Rharade, L, Bayani, N., Ford, M. (2017). *Disasters and Ecosystems: Resilience in a Changing Climate, The Book.* Geneva and Cologne: United Nations Environment and TH Köln, Technical University, Cologne.

The Aquaponic Source (2018). *What is aquaponics?* Retrieved from: https://www.theaquaponicsource.com/what-is-aquaponics/.

The Health and Environment Linkages Initiative (HELI) (2017). *Climate Change.* Retrieved from: http://www.who.int/heli/risks/climate/climatechange/en/.

Tilley, E., Ulrich, L., Lütt, C., Reymond, P. & Zurbrügge, C. (2014). *Compendium of Sanitation Systems and Technologies - 2nd revised edition.* Duebendorf, Switzerland: Swiss Federal Institute of Aquatic Science and Technology (Eawag). Retrieved from: https://www.sswm.info/sites/default/files/reference_attachments/TILLEY%20et%20al%202014%20Compendium%20of%20Sanitation%20Systems%20and%20Technologies%20-%202nd%20Revised%20Edition.pdf.

United Nations Development Programme (UNDP) (2009). *Capacity Development: A UNDP Primer.*New York: UNDP. Retrieved from: http://www.undp.org/content/dam/aplaws/publication/en/publications/capacity-development/capacity-development-a-undp-primer/CDG_PrimerReport_final_web.pdf.

UN-Habitat (2014). *The State of African Cities 2014. Re-imagining sustainable urban transitions.* Nairobi: UN-Habitat. Retrieved from: https://unhabitat.org/books/state-of-african-cities-2014-re-imagining-sustainable-urban-transitions/.

UNISDR (2009). *2009 UNISDR Terminology on Disaster Risk Reduction.* Retrieved from: http://www.unisdr.org/files/7817_UNISDRTerminologyEnglish.pdf.

United Nations (2015). *Sustainable Development Goals. 17 Goals to Transform our World*. Retrieved from: http://www.un.org/sustainabledevelopment/sustainable-development-goals/.

United Nations (2017). *World Economic Situation and Prospects 2017.* New York: United Nations. Retrieved from: https://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/publication/2017wesp_full_en.pdf.

UN-Environment (2017). *UNEP Stories. Placing the environment at the heart of humanitarian response.* Retrieved from: http://www.unep.org/stories/story/placing-environment-heart-humanitarian-response.

Uponics (n.d.). *Best fish for aquaponics.* Retrieved from: http://uponics.com/aquaponics-fish/.

Watson, D. & Adams, M. (2011). *Design for Flooding: Architecture, landscape, and urban design for resilience to flooding and climate change.* Hoboken, New Jersey: Wiley.

World Bank (2017a). *Problems of Population Growth and Climate Change Converge in Dar-es-Salaam.* Retrieved from: http://www.worldbank.org/en/news/feature/2017/05/31/problems-of-population-growth-and-climate-change-converge-in-dar-es-salaam.

World Bank (2017b). *Life expectancy at birth, total (years).* Retrieved from: https://data.worldbank.org/indicator/SP.DYN.LE00.IN.

World Travel Guide (2018). *Dar es Salaam History.* Retrieved from: https://www.worldtravelguide.net/guides/africa/tanzania/dar-es-salaam/history/.

Base map generated from www.openstreetmap.org

Table of Maps

p. 12 - Land use Dar es Salaam.Own drawing.
p. 30 - Informal settlements 1982-2002. Own drawing. Based on: http://sedac.ciesin.columbia.edu/downloads/maps/urbanspatial/urbanspatial-dar-es-salaam-luse/urbanspatial-dar-es-salaam-luse.jpg.
p. 31 - Urban growth. Own drawing. Based on: https://www.researchgate.net/figure/8380198_fig6_FIGURE-7-Urban-growth-in-Dar-es-Salaam-Tanzania-1945-1997-area-of-the-urban-malaria.
p. 32 - Infrastructure. Own drawing.
p. 33 - Main infrastructure. Own drawing.
p. 33 - Representative typologies. Own drawing.
p. 39 - Wami Ruvu - water source. Own drawing. Based on: (Saha et al., 2014).
p. 39 - Wami Ruvu - landscape. Own drawing. Based on: (Saha et al., 2014).
p. 39 - Environmental threats. Own drawing. Based on: (Saha et al., 2014).
p. 39 - Water system. Own drawing. Based on: (Saha et al., 2014).
p. 40 - Green structure. Own drawing.
p. 41 - Flood risk and informal settlement. Own drawing. Based on: (Pan-Africa START Secretariat, 2011) and http://sedac.ciesin.columbia.edu/downloads/maps/urbanspatial/urbanspatial-dar-es-salaam-luse/urbanspatial-dar-es-salaam-luse.jpg.
p. 44 - Ramani huria. Own drawing. Based on: (Ramani Huria, 2016).
p. 58 - Selection Location - Risk. Own drawing.
p. 58 - Selection Location - Typology. Own drawing.
p. 59 - Selection Location - Visibility. Own drawing.
p. 59 - Conclusion design location. Own drawing.
p. 62 - Functions. Own drawing.
p. 63 - Connectivity. Own drawing.
p. 66 - Flood risk. Own drawing.
p. 67 - Elevation map. Own drawing.
p. 68 - Green structure. Own drawing.
p. 70 - Building density. Own drawing.
p. 70 - Informal settlements. Own drawing. Based on: http://sedac.ciesin.columbia.edu/downloads/maps/urbanspatial/urbanspatial-dar-es-salaam-luse/urbanspatial-dar-es-salaam-luse.jpg
p. 70 - Main infrastructure. Own drawing.
p. 70 - Administrative borders. Own drawing.
p. 71 - Functions. Own drawing.
p. 71 - Blue green structures. Own drawing.
p. 71 - Food production. Own drawing. Based on: http://www.cityfarmer.org/darmap.html#darmap.
p. 76 - Individual design location. Own drawing.
p. 77 - Design location Beke. Own drawing.
p. 77 - Design location Mona. Own drawing.
p. 96 - Infrastructure. Own drawing.
p. 97 - Connectivity. Own drawing.
p. 100 - Elevation map. Own drawing.
p. 100 - Green structure. Own drawing.
p. 100 - Low to high flood level. Own drawing.
p. 101 - Low to high flood level. Own drawing.
p. 102 - Water flow. Own drawing.
p. 103 - Vacant land. Own drawing.
p. 103 - Grocery access. Own drawing.
p. 103 - Water access. Own drawing.
p. 103 - Religious institutes. Own drawing.
p. 148 - Figure ground diagram. Own drawing.
p. 148 - Elevations. Own drawing.
p. 148 - Functions. Own drawing.
p. 148 - Connectivity. Own drawing.
p. 149 - Green. Own drawing.
p. 150 - Flood risk. Own drawing.
p. 198 - Sinza river basin strategy. Own drawing.
p. 200 - Strategic masterplan. Own drawing.
p. 238 - Infrastructure. Own drawing. Based on: https://www.un.org/Depts/Cartographic/map/profile/tanzania.pdf.
p. 238 - Administrative borders. Own drawing. Based on: http://mapeastafrica.com/wp-content/uploads/2014/07/Tanzania_admin.jpg.
p. 238 - Neighbouring countries. Own drawing.
p. 238 - River basins. Own drawing. Based on: https://www.researchgate.net/publication/312373453/figure/fig1/AS:471438105812994@1489411011502/Figure-1-Map-of-the-nine-River-Basin-Offices-in-Tanzania.png.
p. 238 - Agriculture. Own drawing. Based on: https://upload.wikimedia.org/wikipedia/commons/thumb/b/b0/Tanzania_agriculture_map-fr.svg/1200px-Tanzania_agriculture_map-fr.svg.png.
p. 238 - Average temperature per year. Own drawing. Based on: (Sangea, Upton & Ó Dochtaigh, 2016).
p. 238 - Köppen-Geiger climate zones. Own drawing. Based on: (Sangea, Upton & Ó Dochtaigh, 2016).
p. 238 - Hydrogeology - aquifer/flow type. Own drawing. Based on: (Sangea, Upton & Ó Dochtaigh, 2016).
p. 238 - Average precipitation per year. Own drawing. Based on: (Sangea, Upton & Ó Dochtaigh, 2016).
p. 240 - Wards. Own drawing. Based on: (Ramani Huria, 2016).
p. 240 - Religious institutions. Own drawing.
p. 240 - Soil in DAR. Own drawing. Based on: https://www.researchgate.net/profile/Stefan_Dongus/publication/236847698/figure/fig5/AS:299454256173073@1448406866807/Fig-5-Soils-of-the-Dar-es-Salaam-area-provisional-T-EMPLE-1970-35.png.
p. 240 - Educational/Health institutions. Own drawing.
p. 241 - Water source/users. Own drawing. Based on: (Saha et al., 2014).
p. 241 - Wami ruvu basin. Own drawing. Based on: (Saha et al., 2014).
p. 241 - Landscape. Own drawing. Based on: (Saha et al., 2014).

Table of Figures

Fig. 01 - Analytical framework and time planning. Own drawing.
Fig. 02 - Climate change impacts in Africa. Own drawing. Based on: http://www.zoinet.org/web/sites/default/files/maps/africa_map.jpg.
Fig. 03 - Hazards in african cities. Own drawing. Based on: UN-Habitat, 2014
Fig. 04 - Climate Change related death worldwide. Own drawing. Based on: (The Health and Environment Linkages Initiative (HELI), 2017).
Fig. 05 - Monthly rainfall Dar es Salaam. Own drawing. Based on: (Sangea, Upton & Ó Dochtaigh, 2016).
Fig. 06 - Relationship between main problems and aims. Own drawing.
Fig. 07 - Reaction chain for lack of coping capacity. Own drawing.
Fig. 08 - Negative housing cycle. Own drawing.
Fig. 09 - Negative water cycle. Own drawing.
Fig. 10 - Rainwater collection. Own drawing.
Fig. 11 - Aquaponics system. Own drawing.
Fig. 12 - Composting. Own drawing.
Fig. 13 - Biogas reactor. Own drawing. Based on: (Tilley et al., 2014).
Fig. 14 - Agriculture cycle. Own drawing.
Fig. 15 - Construction steps of chinampas. Own drawing.
Fig. 16 - Section of chinampas. Own drawing. Based on: http://www.ackmvmt.org/chinampas-ancient-knowledge-alternative-agriculture/.
Fig. 17 - Varying water level in canals. Own drawing.
Fig. 18 - Dimension and capacity of chinampas. Own drawing.
Fig. 19 - Canal depths. Own drawing.
Fig. 20 - Flow direction and hierarchy. Own drawing.
Fig. 21 - Food production capacity. Own drawing. Based on: (Roser & Ritchie, 2017) and (Pötz, Bleuzé & Sjauw En Wa, 2012).
Fig. 22 - French system: two-stage vertical flow constructed wetland. Own drawing. Based on: (Molle et al., 2005).
Fig. 23 - Septic tank. Own drawing. Based on: (Tilley et al., 2014).
Fig. 24 - Local circularity of flows and products. Own drawing.
Fig. 25 - Stakeholder relations. Own drawing.
Fig. 26 - Renting models. Own drawing.
Fig. 27 - Cable car banana transport in Gomera, Spain. Retrieved from: https://www.urlaub-im-olivenhain.de/seilbahnen.html
Fig. 28 - Cable car goods transport in Switzerland. Retrieved from: https://www.swissinfo.ch/ger/materialtransport-seilbahnen--eine-staendige-versuchung/36632108
Fig. 29 - Cable car milk transport in Isental, Switzerland. Retrieved from: https://www.aargauerzeitung.ch/schweiz/seilbahnunglueck-so-mancher-aelpler-laesst-sich-in-seiner-klapperkiste-transportieren-127006030
Fig. 30 - ‘tuin’ to cross rivers in Nepal. Retrieved from: http://www.appropedia.org/images/7/7d/Aerial_ropeways_Nepal_newdesign_tuininaction.jpg.
Fig. 31 - Sustainable development goals addressed within this project. Retrieved from: Sustainable Development Goals addressed within this project. Retrieved from: http://www.un.org/sustainabledevelopment/news/communications-material/.
Fig. 32 - CLUVA framework for assessing social vulnerability. Own drawing. Retrieved form: (Gasparini et al., n.d., p. 20).
Fig. 33 - Future monthly rainfall in Dar es Salaam. Own drawing.





Annex

spatial analysis / vulnerability /
theory paper



Infrastructure
- blue structure
- main roads



Administrative borders
- blue structure
- borders



Neighbour countries
- blue structure
- borders



River Basin
- blue structure
- Wami Ruvu basin
- river
- river basin



Agriculture
- blue structure
- millet/tabacco/cotton
- corn/sisal/cotton/cashew
- rice/tabacco/coffee/wheat/tea
- sorghum



Averade temperature / Year
- 26°C
- 24°C
- 22°C
- 20°C
- 18°C



Köppen-Geiger Climate Zones
- Af - Tropical rainforest
- Am - Tropical monsoon
- Aw - Tropical savannah
- BSh - Arid steppe (hot)
- BWh - Arid desert (hot)
- Csb - Temperature with dry summer
- Cwa - Temperate with dry winter
- Cwb - Temperate with dry winter



Hydrogeology - aquifer/flow Type:
- Unconsolidated
- Consolidated Sedimentary (Fracture)
- Consolidated Sedimentary (Intergranular/Fractures)
- Precambrian Basement
- Igneous (largely volcanic)



Averade precipitation/year
- 1700 - 1500mm
- 1200 mm
- 900 mm
- 500 - 700mm

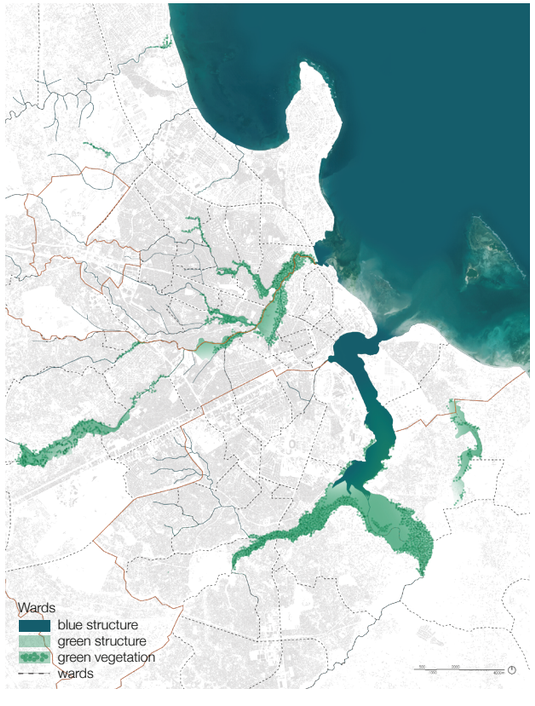
The spatial analysis gives an overview of the current structures and spatial conditions on several scales.

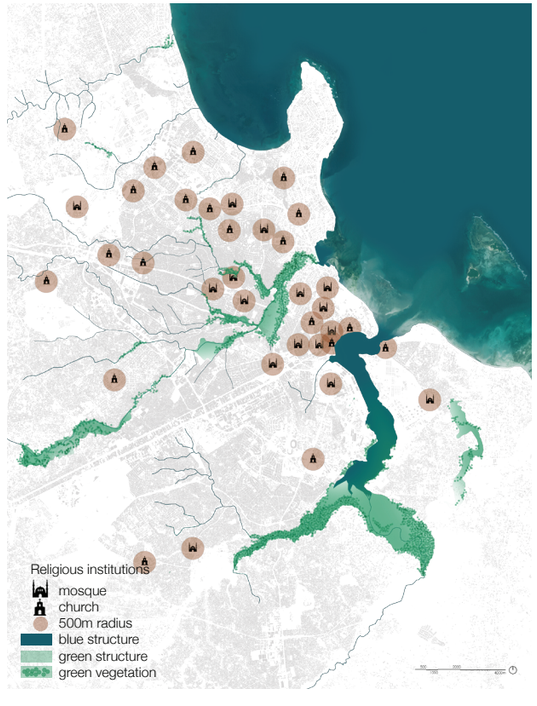
Tanzania is located at the eastern coast of Africa at the Indian ocean and has eight neighbouring countries. The mainland and the islands are divided into several regions. Dodoma is the capital of the country and is located in the centre of the country. There are several big cities in Tanzania, but Dar es Salaam is by far the biggest city of the country. The country is crossed by a road system which connects cities with each other and also connects Tanzania with its neighbouring countries. Railways also exist, but its network is not very extensive and lacks continuity.

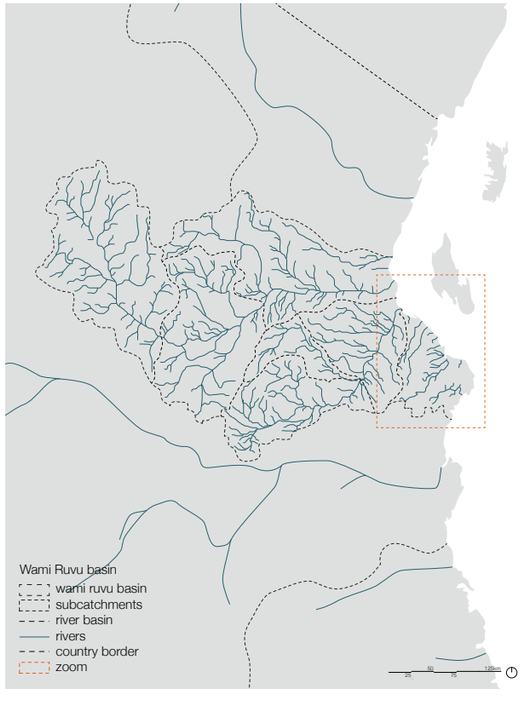
Tanzania is crossing several climate zones. According to the Köppen-Geiger classification, Dar es Salaam is located in a tropical savanna climate zone. Average temperatures are the highest in the coastal areas around Dar es Salaam. They are very stable all year long and only vary a few degrees between summer and winter. The precipitation is seasonal, as it has already been explained before. The annual average amount of rainfall in Dar es Salaam equals the major part of Tanzania. There is a very dry area in the central north of the country and a very wet one further in the south of the country.

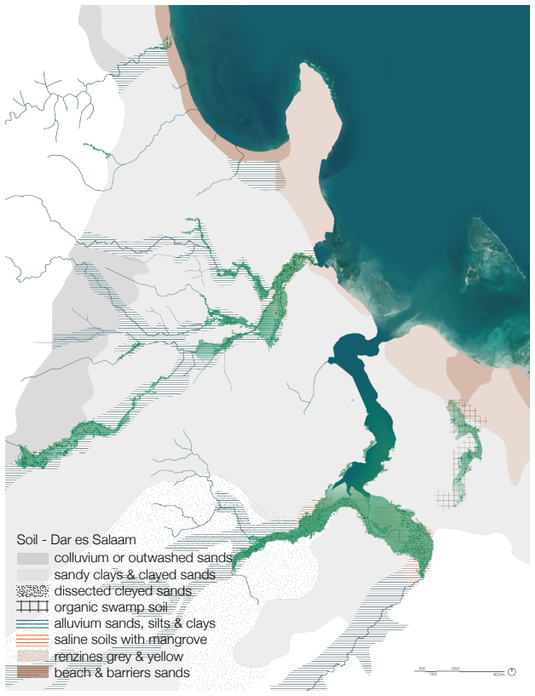
Many rivers run through Tanzania, encompassed by a number of river basins. Dar es Salaam is located in the Wami Ruvu Basin, which has a west-east orientation and ends at the coast. The aquifers around Dar es Salaam consist of unconsolidated and consolidated types and their productivities vary from moderate to high. The productivity can be limited by salination coming from the ocean (Sangea, Upton & Ó Dochartaigh, 2016).

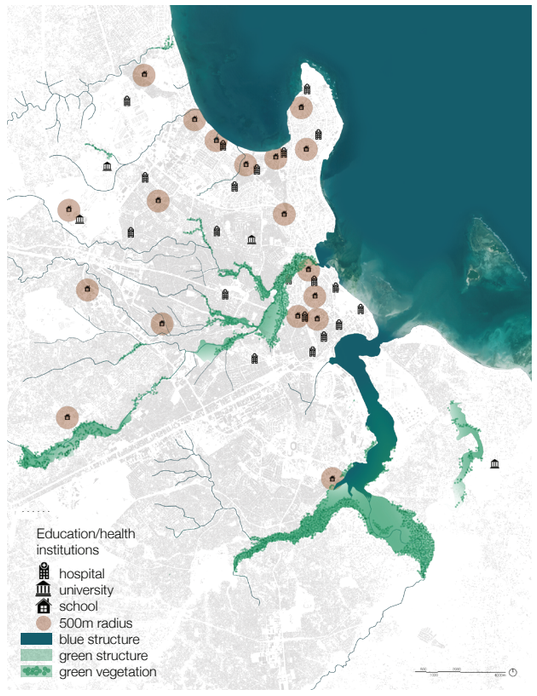
Different crops are being cultivated in Tanzania. Most dominant around Dar es Salaam is the production of rice, cotton, sisal and cashews.

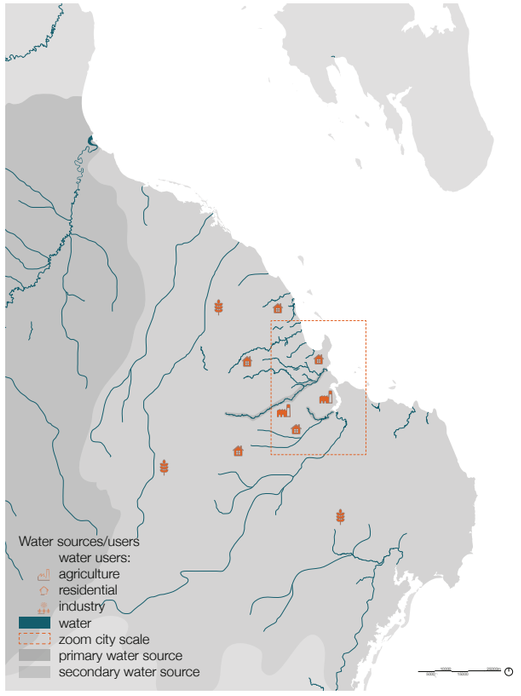

Wards
blue structure
green structure
green vegetation
wards

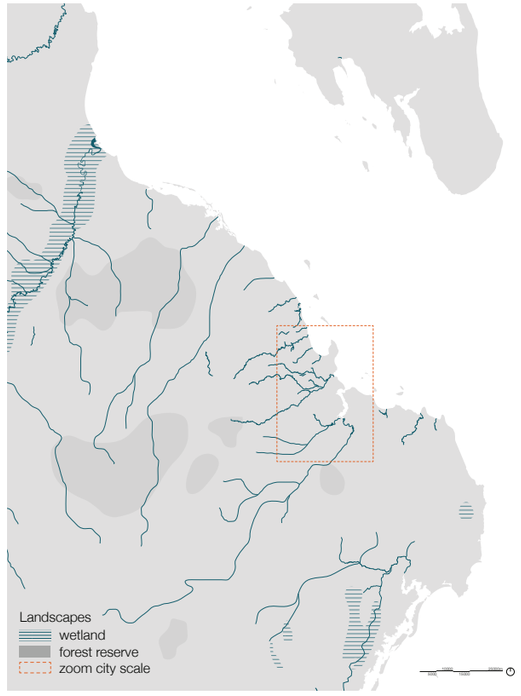

Religious institutions
mosque
church
500m radius
blue structure
green structure
green vegetation


Wami Ruvu basin
wami ruvu basin
subcatchments
river basin
rivers
country border
zoom


Soil - Dar es Salaam
colluvium or outwashed sands
sandy clays & clayed sands
dissected cleyed sands
organic swamp soil
alluvium sands, silts & clays
saline soils with mangrove
renzines grey & yellow
beach & barriers sands


Education/health institutions
hospital
university
school
500m radius
blue structure
green structure
green vegetation


Water sources/users
water users:
agriculture
residential
industry
water
zoom city scale
primary water source
secondary water source


Landscapes
wetland
forest reserve
zoom city scale

Vulnerability consists of several dimensions, for example the physical, ecological and social dimension (Mirza, 2003; UNISDR, 2009). These different dimensions of vulnerability cannot be seen and understood as independent elements but they are strongly related to and influence each other (Pauleit et al., 2015, p. 28).

The physical vulnerability includes structural elements among which “lifelines […] and informal settlements […] are the most vulnerable components” (Pauleit et al., 2015, p. 26). The vulnerability of physical structures depends on material, construction and location (Pauleit et al., 2015, p. 26).

The vulnerability of ecosystems relates to the system of “plant, animal, and microorganism communities” (Hassan, Schules & Ash, 2005, p. 27) of which they consist. Despite their wide range of benefits for human health, microclimate and other potentials, ecosystems are under a lot of pressure. The ongoing climate change as well as the unplanned urban expansions threaten natural habitats, decrease biodiversity and cause pollution (Pauleit et al., 2015, p. 27; Hassan, Schules & Ash, 2005; Gasparini et al., n.d.).

Social vulnerability refers to the vulnerability of social networks and components of individuals or communities and is determined by “demographic change; increasing population pressure by climate refugees; poverty; new formation of formal and informal settlements; and climate change” (Pauleit et al., 2015, p. 27). This dimension of vulnerability is the most difficult to understand individually, because of its strong dependence on other factors. This can be seen in the framework for the assessment of social vulnerability developed by CLUVA-project (Fig. 32). The physical vulnerability is considered to be one element of social vulnerability and since green areas and land typology (see number 9 and 10 in Fig. 32) can also relate to ecosystems, this dimension is included as well (Gasparini et al., n.d., p. 19).

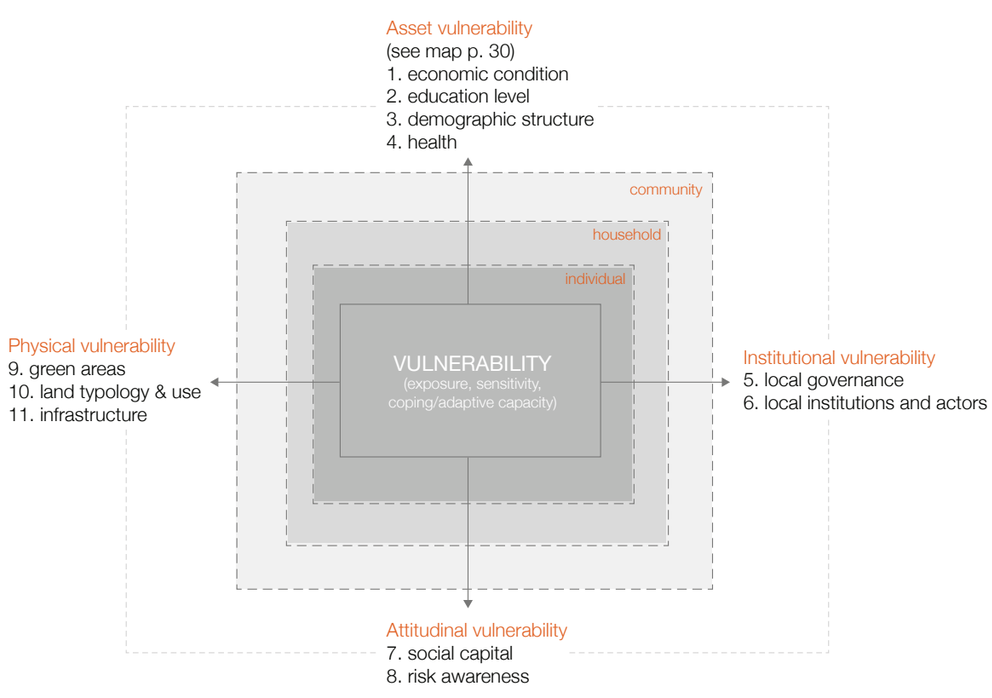


Fig. 32: CLUVA framework for assessing social vulnerability. Own drawing.

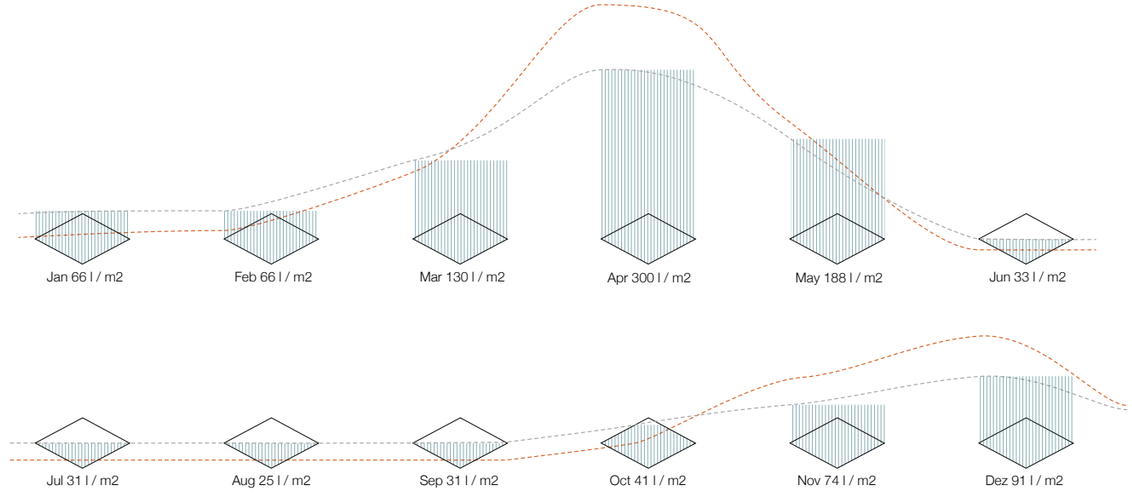


Fig. 33: Future monthly rainfall Dar es Salaam. Own drawing.

The impacts of climate change on human health in Africa – adaptation/mitigation strategies

AR3U022, Theory of Urbanism
MSc Urbanism, Delft University of Technology

Beke-Marleen Hörmann, 4622308

December 2017

Abstract – Climate change is estimated to indirectly kill 250 000 people globally between 2030 and 2050. Developing countries such as Tanzania, are increasingly affected. The changes in climate are particularly noticeable on a local scale in African cities, even though the causes of climate change need to be addressed globally. Physical health impacts, vulnerable housing and thermal stress are just a few negative impacts people experience. This paper aims to show that for African cities, adaptation strategies are more relevant than mitigation strategies. Adaptation is widely understood as adjusting to the conditions to cope with climate change, whereas mitigation addresses the root causes of climate change. In the case of Dar es Salaam, Tanzania adaptation plays a more important role than mitigation. This is because cities in Africa are very vulnerable to climate change, however people living in these cities do not contribute significantly to global greenhouse emissions. This paper reviews practical greenhouse adaptation and mitigation project examples from Dar es Salaam and discusses the methods for comparing one strategy with another. Urban planners need to define what their values and goals are, and from there they can use tools such as cost/benefit analysis to compare one strategy with another. Local and regional scale planning projects have the most efficient impact, in terms of the number of human lives saved.

Keywords – Climate change, adaptation, mitigation, Africa, health impacts, cost/benefit

1.0 Introduction

1.1 Climate Change

Since the Industrial Revolution and post-war urbanization, climate change has become one of the most discussed topics in the world. Human activity is one of the major causes of climate change. Use of fossil fuels and the release of carbon dioxide (CO_2) is creating a natural greenhouse, increasing sea temperatures, decreasing of sea and land ice sheets, causing glaciers to retreat, shrinking mountain snow cover, and raising sea levels (NASA, 2017). These effects are particularly noticeable in the global south such as in many African countries. The limited availability of resources and tools for governance and planning complicate the situation in Africa (Gasparini et al., n.d.).

1.2 Climate Change and African cities

The organization CLUVA (Climate Change and Urban Vulnerability in Africa) also states that particularly African cities are vulnerable to the effects of climate change (n.d.). Even though Africa produces the least greenhouse gases in the world, African cities are among the most vulnerable to climate change impacts. Dar es Salaam, Addis Ababa and Saint Louis are three of them (Gasparini et al., n.d.).

Dar es Salaam has a major issue with water. The city is effected by floods on a regular basis, which is mainly caused by heavy rain falls. Those floods destroy livelihoods and bring residents in danger. At the same time, the availability and accessibility of clean drinking water is unstable and insufficient (Pauleit et al., 2015; CLUVA, n.d.).

Saint Louis is also threatened by water issues. Due to the rising sea level, many seafront neighborhoods suffer from erosion. The bay of the river becomes wider and the water is expanding into the city flooding residential areas and important infrastructure.

Addis Ababa is facing extreme dry periods and heat waves every year. Climate change projections show that the durations of those periods will increase over the next 40 years. At the same time, heat waves are becoming more frequent and intense. Strategies for health services need to be developed to reduce the effects of climate change (CLUVA, n.d.).

1.3 Climate Change and health

The three city cases show how climate change effects cities on a local scale. Livelihoods are being destroyed by heavy rain falls, heat waves or rising sea level/erosion, which has a direct impact on human health. Particularly Africa is effected by the impacts of climate change on human health (Gasparini et al., n.d).

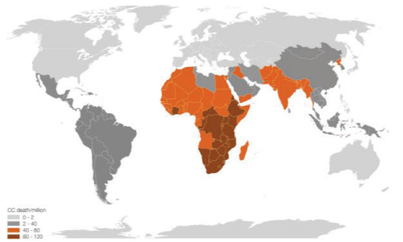


Figure 01: Death from climate change. Own drawing.

The urgency of the situation is shown in the map of climate change death (Fig. 01). It demonstrates the results of extreme weather conditions. Climate change mortality is expected to increase over the next 20 years (WHO, 2017; Patz et al., 2005). Changes in weather conditions such as rainfall and temperature expands disease affected areas and leads to more deaths. Examples of these diseases are water-related sicknesses such as diarrhea and vector-borne infections, including malaria (WHO, 2017). In addition, the extreme weather conditions are causing thermal stress on humans and reducing food production, reducing fresh water availability and interrupting energy supplies (Bambrick et al., 2011). Particularly vulnerable countries need to reduce the effects climate change in order to minimize the risk of health diseases (Kjellstrom et al., 2009).

Climate change is clearly a massive global issue, that has a particularly devastating effect on human health in African cities. What can be done to address this problem? This paper examines suggests adaptation and mitigation strategies to tackle climate change. These are commonly seen as complimentary, however one sort of strategy, adaptation, is much more relevant in the African context.

2.0 Adaptation and Mitigation

Adaptation strategies aim to cope with current and future dangers of climate change in order to protect communities, while mitigation strategies aim to decrease global warming over the long term (Hamin et al., 2009).

2.1 Adaptation Strategy - Health

Adaptation is widely understood as adjusting to the changed conditions in order to cope with climate change (Kjellstrom et al., 2009). In other words,

adaptation is any activity which allows people to stay healthy under changed climatic conditions. During history humans have had to adjust to the environment by developing new practices, cultures and livelihoods. The speed of this change and the speed of adaptation required is now increasing. Adaptation can be a physical adaptation of the urban environment or behaviour shifts of humans. For instance, physical adaptation can be done through infrastructure such as building defences or water protection, whereas behaviour shifts refer to individuals, for instance using less water or changes in agriculture (The Guardian, 2012).

The ability of societies to adapt will directly impact human health. This can be seen in following two examples. First, early warning systems for hazards and disease outbreaks can reduce the risk of health issues resulting in less pressure on emergency wards in local hospitals. Second, improved methods of food handling can be a response to climate change induced flooding and pressures on sanitation systems, because improved food handling reduces the risk of infection diseases such as cholera (Kjellstrom et al., 2009). These examples clearly show how adaptation strategies can have a direct impact on human health.

This paragraph describes a situation where climate change already take place; but what can society do reduce the risk climate change?

2.2 Mitigation Strategy - Health

Mitigation describes the reduction of the causes of climate change (Kjellstrom et al., 2009). This strategy aims to solve the problem at the origin, to reduce the amount of greenhouse emission into the atmosphere. Mitigation needs to be treated as a global issue but also be implemented on a human scale. This can be done in two different ways. Firstly, by reducing the amount of emission in the atmosphere and secondly, by getting greenhouse gases out of the atmosphere. This means increasing renewable sources or planting green structures to filter the air (UCAR, 2017). Mitigation strategies can be bottom up - or top down approaches. The protection and expansion of environmental infrastructure such as carbon sinks (forests, sea grasses, and other green infrastructures) is often planned by the government. Whereas individual participation such as reducing electricity use, reducing waste or reducing car use are examples of bottom-up approaches that can be stimulated by government or carried out on individual initiative (Kjellstrom et al., 2009; IPCC, 2007).

Regardless of whether they are bottom up or top down driven, there is a direct relation between mitigation strategies and human health and this is demonstrated by the following two examples. Firstly, the reduction of burning fossil fuels makes the air cleaner and decreases the number of respiratory illnesses. Secondly, improved infrastructure increases the number of people walking/cycling and improves physical fitness, which means less cardiovascular diseases (Kjellstrom et al., 2009). Infrastructure intervention is also a great example of how mitigation and adaptation strategies can be combined. This combination aims to reduce greenhouse emission and protect citizens from health impacts of climate change (Hamin et al., 2009).

2.3 Mitigation- and adaptation strategies

The majority of literature focusses on strategies that combine both adaptation and mitigation. Mitigation- and adaptation strategies can be complementary. Mitigation and adaptation can be treated as joint issues, a point which was clearly made in the IPCC Synthesis Report. The report states that neither adaptation nor mitigation itself can reduce the risks and impacts of climate change for communities (2007). Another example of the focus on ways in which mitigation and adaptation complement each other can be seen in the diagram below.

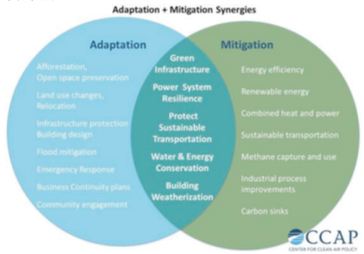


Figure 02: Connect the dots: Adaptation + Mitigation Synergies

Figure 02 shows adaptation- and mitigation actions and their possible overlaps. The aim of many organisations is to focus on projects of mitigation - and adaptation strategies. One of these synergies example is the improvement of green infrastructures. While green infrastructure can compensate water issues such as floods through infiltration, it also provides space for renewable energy and a reduces greenhouse emission. Particularly urban- and ecological protection aim to protect environment and citizens from risks by building a physical stone walls. Instead, green infrastructure can provide physical protection

(adaptation) but also provides space for trees or renewable energy sources in order to mitigate emission (CCAP, 2017).
However, the distribution of health impacts (climate deaths per million, figure 01) clearly shows that climate change need to be addressed globally.

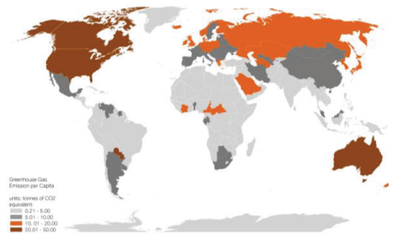


Figure 03: Greenhouse Gas Emission per Capita. Own drawing.

The map shows that western countries produce more greenhouse gasses and have the least number of climate change deaths. The global south such as African cities do not contribute significantly to the greenhouse emission on a global scale. However, they have the highest number of climate deaths. For that reason, African cities need to adapt to the impacts of climate change. African cities need to prioritize adaptation (Beg et al., 2002).

Dar es Salaam is one African city where adaptation strategies have top priority.

3.0 Case study – Dar es Salaam

3.1 Climate Change in Dar es Salaam

Dar es Salaam is one of many African cities which is vulnerable to climate change. The city floods on a regular annual basis, due to heavy rainfall and poor infrastructure. The socio-economic structure of the city complicates the situation. Approximately 70% of citizens live in informal settlements (slums) which are heavily affected by these floods. Informal settlements in the city are growing and therefore also the number of people being vulnerable to climate change. The urban rich possess the financial resources to adapt to these hazards, whereas the urban poor are forced to adapt to the impacts of climate change (Pauleit et al., 2015).

3.2 Implementation of mitigation- and adaptation strategies

Current projects in Dar es Salaam focus on climate change adaptation. Many organizations and institutes have been involved in adaptation projects in Dar es Salaam such as the World Bank, the Institute of Resource Assessment, the University of Dar es Salaam, the Ardhi University, the Tanzania Meteorological Agency (TMA), the Nordic Development Fund, and the Dar es Salaam council. Some examples of projects running in Dar es Salaam are listed below. Mostly, these projects protect locals from the impacts of climate change through promoting adaptation (A). There is a minor focus on mitigation (M) and therefore just a small overlap of both strategies (World Bank, 2017).

1. **Warning System:** The Tanzania Meteorological Agency implements early warning systems to forecast heavy rainfalls and floods. This adaptation project helps citizens to cope and prepare for upcoming hazards (UNDP, 2016). (A)
2. **Education:** Schools and universities educate communities on the health impacts of climate change, management of waste and water supply (World Bank, 2017). (A)
3. **Urban Protection:** Protection of the urban structure such as heavy sea walls, built infrastructure for storm water and drainage systems as well as strengthen water capacity in informal settlements (NDF, 2014). (A)
4. **Improved water infrastructure:** Improvement of existing storm water drainage, sewerage systems and waste management during extreme weather events (World Bank, 2017). (A)
5. **Informal Settlement:** The Tanzanian Government runs an identification project of informal settlement. This helps to react better on hazards but also to plan infrastructure such as water pipes, collection services and sanitation (United Republic of Tanzania, 2012). (A)
6. **Public awareness**: The National Adaptation Program of Action raises public awareness on the impacts of climate change and how adaptation strategies can be implemented. Activities such as planting trees along beaches, roads and houses have been done (United Republic of Tanzania, 2007). (A)
7. **Coastal Management:** The Kinondoni Integrated Coastal Area Management Project aims to protect local communities along the coast line. This protection project includes management of coral reefs and marine park protection (World Bank, 2017). (A)
8. **Seaweed farming**: Planting of seaweed in order to reduce fluctuations in water temperature and salinity (USAID, 2005). (A/M)

9. **Ecological protection**: Physical construction of sea walls in order to protect the natural coastal zones from erosion (United Republic of Tanzania, 2007). (A)

The case of Dar es Salaam shows clearly that organizations and government are focusing on adaptation strategies.

There is a minor focus on mitigation. This is because African cities should not repeat the mistakes of the large greenhouse gas emitters. Therefore, mitigation strategies have been included in Dar es Salaam when the situation allows. For example, the seaweed project helps to cope with thermal stress in the city but it also mitigates the fluctuation in water temperature which helps to stabilize the climate. This is a good example of a farming system that does not rely on fossil fuels. By developing solutions like this, African countries can 'leap-frog' the greenhouse gas emitting farming systems which have caused this problem in the first place. The use of distributed solar energy systems is another example of a leap frogging technology. The scale of these projects is still very small and doesn't significantly reduce the emission of greenhouse gasses. Citizens of cities like Dar es Salaam need to focus on adaptation because that is the only option they have.

Therefore, it is important to measure the impact of each adaptation project. Time and resources are limited and therefore it is also important to measure the efficiency of each initiative. What projects help the largest number of people for the lowest cost? What can be done quickly to save lives? The efficiency of adaptation strategies can be measured using a cost/benefit method which is suggested by Anton Cartwright (2013).

3.2 *Measurability mitigation- and adaptation strategies*

Cost-benefit analysis can be used to evaluate different climate change adaptation strategies. Broad definitions of benefit can be found in the paper of Anton Cartwright that suggests guidelines to define what cost and benefit mean. Cost are measured in time and financial terms, whereas benefit describes the value of the intervention. The value can be measured as the people effected by a certain intervention or the improvement of the environment (Cartwright et al., 2013). It is important to be clear about the set of values the planner is aiming for. For instance, the benefit of environmental impacts or the protection of citizens; a difficult ethical question.

Anton Cartwright suggests that part of the benefit matrix is people's wellbeing and health but also the frequency of effectiveness. The extent of benefit was also categorized in "saved lives"; big or small improvements. The paper gives an indication of which interventions might have an attractive- or unattractive cost-benefit ratios. Socio-institutional projects such as disaster- and water management services and early warning systems tend to be one of the best (low cost and high benefit); whereas ecosystem adaptation strategies and particularly infrastructural interventions tend to be expensive and have therefore have a high cost to benefit ratio (Cartwright et al., 2013).

Applying the cost-benefit analysis to the projects in the case study of Dar es Salaam area it becomes clear which projects have an attractive- or unattractive cost-benefit ratios in terms of adaptation efficacy. Warning systems, for instance, tend to have attractive cost-benefit ratios. The time and cost effort is comparable low to the huge impact an early warning system can have. It reaches out to an entire city/region and can possibly save lives through early preparation for the protection of livelihoods. The time effort of education is high but the outcome in the long-term is also. Education reaches the individual to help them understand climate change and its impacts in order to mitigate risks and prevent disasters. However, it is difficult to evaluate how many people have been educated or how many people understood how to mitigate and adapt to climate change. Therefore, knowledge can easily be implemented in daily routines and has a high frequency of use by individuals.

Urban protection in form of sea walls has generally an unattractive cost-benefit ratio. The building time and construction costs of a sea wall is quite expensive in comparison to how often it is used. Storm floods occur at most three times a year. While clusters of infrastructure like this protect people just in some limited areas; many other citizens may still be vulnerable to extreme conditions.

In comparison, ecological adaptation projects are more attractive than infrastructural protection. The costs of land and the growing time is high but the protection of the people is long-term, therefore the benefit is also good. Furthermore, ecological protection also meets mitigation aspects and improves climate which has a positive impact on human health. However, seaweed farming in Dar es Salaam also has an ecological approach towards climate change mitigation but has an unattractive

cost-benefit ratio. It takes a long time and effort to grow and maintain seaweed. The business model is not lucrative enough for farmers and therefore it is challenging to implement. This is a missed opportunity because in climate terms seaweed projects decrease the fluctuations of temperature and could have a positive environmental impact on an entire region. This is a good example of how important it is to properly measure environmental benefits. If projects are only assessed on their financial impact, there is a high risk that the environmental benefits will not be achieved.

Concluding, the cost-benefit analysis provides guidelines to evaluate the efficacy of adaptation/mitigation projects. In the case of Dar es Salaam some projects have an attractive cost-benefit ratio (low cost, high benefit) because of the large reachability in number of people but also spatial terms. However, cost/benefit efficacy should not just be assessed in financial terms; it also needs to be measured in environmental terms.

4.0 Conclusion

The paper demonstrates the relevance of mitigation- and adaptation strategies in African countries and describes the impact of climate change on human health and the urban environment.

Tanzania and other African countries produce the least greenhouse gases in the world, therefore these countries do not contribute significantly to the problem. The causes of climate change and the mitigation strategies need to be addressed globally. For that reason, adaptation strategies are the primary focus in African countries. In the case of Dar es Salaam the most efficient projects are community based education programs that help citizens prepare for extreme weather events and to adapt to the negative impacts of changing climate.

Cost/benefit analysis tools are crucial for directing effort to adapt to climate change. These tools help urban planners focus on which adaptation activity should be applied and under which circumstances. Furthermore, cost/benefit analysis helps urban planners evaluate whether their chosen strategy was successful or design additional steps that may need to be considered. A range of adaptation projects have already been trialed in Dar es Salaam. Of these, cost/benefit analysis shows that institutional projects are often more efficient than physical interventions. Finally, the analysis reveals interesting questions regarding the set of values an urban planner should choose. Is environmental impacts reduction more important than the number of lives saved? What are the most common goals of climate change adaptation projects in Tanzania, and other countries in Africa? These are difficult ethical questions related to adaptation strategies and cost/benefit analysis which need more research investigation.

5.0 References

Bambrick, H. J., Capon, A. G., Barnett, G. B., Beaty, R. M., & Burton, A. J. (2011). Climate Change and Health in the Urban Environment: Adaptation Opportunities in Australian Cities. *Asia-Pacific Journal of Public Health, 23(2),* 67S-79S. doi:10.1177/1010539510391774

Beg, N., Morlot, J. C., Davidson, O., Afrane-Okesse, Y., Tyani, L., Denton, F., Sokona, Y., Thomas, J. P., La Rovere, E. L., Parikh, J. K., Parikh, K., & Rahman, A. A. (2002). *Linkages between climate change and sustainable development.* Climate Policy, 2(2-3), 129-144. doi:10.3763/cpol.2002.0216

Cartwright, A., Blignaut, J., Wit, M. D., Goldberg, K., Mander, M., O'Donoghue, S., & Roberts, D. (2013). Economics of climate change adaptation at the local scale under conditions of uncertainty and resource constraints: the case of Durban, South Africa. *Environment and Urbanization*, 25(1), 139-156. doi:10.1177/0956247813477814

Center for clean air policy (CCAP) (2017). *Connecting the dots: Adaptation + Mitigation synergies.* Retrieved from: http://ccap.org/connecting-the-dots-adaptation-mitigation-synergies/

Centre for science education (UCAR) (2017). *Climate Mitigation and Adaptation.* Retrieved from: https://scied.ucar.edu/longcontent/climate-mitigation-and-adaptation

Climate Change and Urban Vulnerability in Africa (CLUVA) (n.d.). *Addis Ababa Ethiopia*. Retrieved from: http://www.cluva.eu/CLUVA_publications/CLUVA_Climate-change-and-vulnerability-of-African-cities-AddisAbaba.pdf

Climate Change and Urban Vulnerability in Africa (CLUVA) (n.d.). *Dar Es Salaam Tanzania*. Retrieved from: http://www.cluva.eu/CLUVA_publications/CLUVA_Climate-change-and-vulnerability-of-African-cities-DarEsSalaam.pdf

Climate Change and Urban Vulnerability in Africa (CLUVA) (n.d.). *Saint-Louis Senegal*. Retrieved from: http://www.cluva.eu/CLUVA_publications/CLUVA_Climate-change-and-vulnerability-of-African-cities-Saint-Louis.pdf

Field, C. B., & Barros, V. R. (2014). *Climate change 2014: impacts, adaptation, and vulnerability: Working Group II contribution to the fifth assessment report of the Intergovernmental Panel on Climate Change.* New York: Cambridge University Press.

Gasparini, P., Di Ruocco, A., Bruyas, A.-M., & Bruyas Amra, A.-M. (eds.) (n.d.). *Climate change and vulnerability of African cities. Research briefs.* Retrieved from: http://www.cluva.eu/CLUVA_publications/CLUVA_Climate-change-and-vulnerabili ty-of-African-cities-Research-briefs.pdf

Hamin, E. M., & Gurran, N. (2009). Urban form and climate change: Balancing adaptation and mitigation in the U.S. and Australia. *Habitat International,* 33(3), 238-245. doi:10.1016/j.habitatint.2008.10.005

Intergovernmental Panel on Climate Change (ICPP) (2007). *Climate Change 2007: synthesis report: part of the Working Group III contribution to the fourth assessment report of the Intergovernmental Panel on Climate Change.* Cambridge, UK: Cambridge University Press.

Intergovernmental Panel on Climate Change (IPCC) (2007). *IPCC Fourth Assessment Report: Climate Change 2007*. Retrieved from: http://www.ipcc.ch/publications_and_data/ar4/wg3/en/spmsspm-c.html

Kjellstrom, T., & Haylee, J. W. (2009). Climate change and health: impacts, vulnerability, adaptation and mitigation. *NSW Public Health Bulletin, 20(1-2)*, 5-9. doi:10.1071/NB08053

NASA (2017). *Climate change: How do we know.* Retrieved from: https://climate.nasa.gov/evidence/

Nordic Development Fund (NDF) (2014). *Dar es Salaam Metropolitan Development Project - Institutional Strenghtening for Urban Climate Adaptation and Mitigation [NDF C71].* Retrieved from: http://www.ndf.fi/project/dar-es-salaam-metropolitan-development-project-institutional-strenghtening-urban-climate

Patz, J. A., Campbell-Lendrum, D., Holloway, T., & Foley, J. A. (2005). Impact of regional climate change on human health. *Nature, 438*(7066), 310-317. doi:10.1038/nature04188

Pauleit, S., Coly, A., Fohlmeister, S., Gasparini, P., Jørgensen, G., Kabisch, S., W. J., Kombe, S., Lindley, I., & Yeshitela, K. (2015). *Urban vulnerability and climate change in Africa: a multidisciplinary approach*. Cham: Springer International.

The Guardian (2012). *What is climate change adaptation.* Retrieved from: https://www.theguardian.com/environment/2012/feb/27/climate-change-adaptation

World Bank (2017). *Dar es Salaam Case Study Overview Climate Change, Disaster Risk and the Urban Poor: Cities Building Resilience for a Changing World*. Retrieved from: http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1306291319853/CS_Dar_Es_Salaam.pdf

World Health Organization (WHO) (2017). *Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s.* Retrieved from: http://www.afro.who.int/publications/quantitative-risk-assessment-effects-climate-change-selected-causes-death-2030s-and

United Nations Development Programme (UNDP) (2016). *Strengthening Climate information and Early Warning Systems in Tanzania for Climate Resilient Development and Adaptation to Climate Change Project.* Retrieved from: https://info.undp.org/docs/pdc/Documents/TZA/Final%20Report%20MTR%20-%20Early%20Warning%20(003).pdf

United Republic of Tanzania (2012). *Formalisation of informal urban Settlements in Tanzania.* Retrieved from: http://mkurabita.go.tz/wp-content/uploads/2016/08/2014-2-20-13-34-40_mkurabita-innovations-2012.pdf

United Republic of Tanzania (2007). *United Republic of Tanzania national adaptation programme of action (NAPA).* Retrieved from: http://unfccc.int/resource/docs/napa/tza01.pdf

USAID (2005). *Smallholder Empowerment & Economic Growth Through Agribusiness & Association Development Through Agribusiness & Association Development.* Retrieved from: http://pdf.usaid.gov/pdf_docs/Pdacg997.pdf

Table of Figures

p. 02 – Fig. 01:
Climate Change related deaths worldwide. The Health and Environment Linkages Initiative (HELI) (2017). *Climate Change.* Retrieved from: http://www.who.int/heli/risks/climate/climatechange/en/

p. 03 – Fig. 02:
Center for clean air policy (CCAP) (2017). *Connecting the dots: Adaptation + Mitigation synergies.* Retrieved from: http://ccap.org/connecting-the-dots-adaptation-mitigation-synergies/

p. 04 – Fig. 03:
United Nations (UN) (2016). *Environmental Indicators.* Retrieved from: https://unstats.un.org/unsd/environment/air_greenhouse_emissions.htm

Sustainability of Flood Protection

A comparison of approaches for flood protection with regards to sustainability

AR3U022, Theory of Urbanism
Faculty of Architecture, Urbanism and the Built Environment
Technical University Delft

Mona zum Felde

4587618
M.zumFelde-1@student.tudelft.nl

December 2017

Abstract - Floods are the most frequent causes for disasters in the world, destroying livelihoods, economies and communities. Influenced by urbanization and climate change, the frequency and intensity of floods is most likely to increase in the future. At the same time, more and more people live in flood risk areas. These developments make flood protection more important than ever to protect urbanized areas and mitigate the effects of flooding. This paper gives an overview of three different approaches for flood protection, namely the structural, the non-structural and the ecology-based approach, and assess these with regards to their sustainability. The conclusion is, that non-structural and ecology-based measures are more sustainable. Nevertheless, they have to be combined with structural approaches in certain conditions, in order to provide sufficient flood protection in the future. This is important, because floods themselves are unsustainable as they interrupt the continuity of the flow of other systems.

Keywords - flooding, flood protection, sustainability

1. Introduction

Measures to protect urbanized and cultivated areas from floods become more and more important, as the risk of floods is rising. On the one hand, climate change and urbanization increase the frequency and intensity in which floods appear. On the other hand, due to the rising number of people living in cities, more people (are forced to) live in flood plains, putting human live and economic activity at risk (Pauleit et al., 2015).

Different approaches have been developed over time, in order to deal with this rising flood risk. This paper seeks to explore three existing approaches, namely the structural, the non-structural and the ecosystem-based approach. In a second step, sustainability will be explained and the sustainability of all three approaches assessed. The latter is becoming increasingly relevant with the exhaustion of resources and land and the need for long-term solutions which do not rely on them (Sudmeier-Rieux et al., 2017).

2. Approaches towards flood protection

Floods cause worldwide the most disasters already (Sudmeier-Rieux et al., 2017), and the intensity and frequency of flood events are going to increase in the future. The first main driver for this is the ongoing urbanization process, which interrupts the natural water flow and sealed surfaces increase the water run-off. An increased number of people live in areas prone to flooding, because of their attractive characteristics for development (Kundzewicz & Takeuchi, 1999) and the lack of space in less dangerous areas. Climate change is the second main driver to increase flood risk, due to a rising sea level and a change in precipitation patterns (Pauleit et al., 2015).

The fact that more people will be exposed more often to more extreme floods makes it more important than ever to think about flood protection and adaptation. Strategies are needed to deal with the "high uncertainty" (Kundzewicz, 2002, p. 11) that comes with climate change and urbanization. These processes also make it necessary to not only think about how to protect people from floods, but also how to live with them. The occurrence cannot be prevented and the intensity of floods in combination with the low proximity to utilised areas will make it inevitable in the future to find long term solutions, in which the one is not compromising and devastating the other (Kundzewicz & Takeuchi, 1999; Williams, 1994).

In the following, three existing approaches towards flood protection will be explained, namely the structural, the non-structural and the ecology-based approach.

2.1. Structural Approach

The structural approach is the most traditional one and seeks to physically protect areas from floods by the means of hard factors, like large-scale engineered structures. These include among others flood protection walls, dams, dikes, reservoirs and water channels (Kundzewicz, 2002; Kundzewicz & Takeuchi, 1999; Temmerman et al., 2013).

This approach is based on the 19th century view, that engineering is a way to control nature and use it for human needs. This forms the aim to eliminate floods completely in order to make previous flood plains usable for other functions like housing or agriculture. The expectation to be completely safe from flood risk did not change for a long time, even though this assumption has been proven to be wrong by many floods in different places, which had been previously claimed to be flood proof. The failure of flood protection measures has different causes. One reason is the way the needed dimension for flood protection is being calculated. They are designed for a certain maximum level of water flow and long term changes and variabilities, which can occur due to urbanization and climate change, are not taken into consideration. Another reason is the little meaning which is given to the maintenance of this kind of structures. Undetected damages and corrosion compromise the effectiveness even against calculated floods (Kundzewicz & Takeuchi, 1999; Williams, 1994).

The assumption of absolute safety from floods and the use of flood plains for other functions brings massive problems in case of failure of these structures. People living in areas claimed to be flood proof, are completely unprepared in case of flooding, which brings people and goods in danger. Because these floods are not natural, they are much more "rapid, unexpected and unpredictable" (p. 51), which makes it more difficult to warn people in time. Furthermore, due to the interruption of the natural drainage by the structure, the water cannot naturally flow back to its normal course so the flood water takes much longer to retrieve itself from utilized areas, likely to increase damages and costs (Williams, 1994).

Structural measures have been criticized, among other things, for their negative impacts on the environment. They interfere with the natural flow of water, destruct wetlands and habitats and decrease the water quality, which in return leads to additional economic costs. Another point of criticism is the lack of flexibility and adaptability to changing conditions (Kundzewicz, 2002; Williams, 1994).

A more recent definition by UNISDR (2009) focuses less on flood protection but stretches the aim of structural measures as "to reduce or avoid possible impacts of hazards" or "to achieve hazard resistance and resilience in structures or systems" (p. 28).

2.2. Non-Structural Approach

Another approach for flood protection is the non-structural approach, which includes "any measure not involving physical construction that uses knowledge, practice or agreement to reduce risks and impacts" (UNISDR, 2009, p. 28). It implies a change of thinking and behaviour, after realizing that structural measures alone are not able to protect people and goods. In this context, the term 'flood management' also occurs often (Kundzewicz & Takeuchi, 1999; Williams, 1994).

This approach does not focus on the physical protection against floods, but rather aims to reduce the occurrence of hazards and the physical, social and cultural impact and damage. A high diversity of non-structural or soft measures is available in order to influence the susceptibility to damage, the flow of water and the impact of floods. Zoning, early warning systems, disaster plans, water management, education and policies are just a few examples (see Fig. 1). They are usually not used individually but in combination with others, in order to strengthen each other and increase their effects (Kundzewicz, 2002, p. 4; UNISDR, 2009, p. 28).

Overview of non-structural measures:

Kundzewicz, 2002, p. 4
- Land-use planning
- Zoning
- Water management
  - floodplains and wetlands for storing
  - enhancing infiltration
  - reduce run-off
  - vegetation management
- Early warning systems
- disaster plans (evacuation)
- social and economic measures

UNISDR, 2009, p. 28
- policies and laws
- public awareness raising
- training and education

Kundzewicz & Takeuchi, 1999, p. 428f.
- accommodate floods
- reduce sensitivity to flood damage
- live with floods
- functioning for different purposes
- protection and re-naturalization of rivers
- flood mitigation system
- information and education

Fig. 1: Overview of non-structural measures by author.

Williams (1994) opposes, that while flood control with its structural measures only serves the individual, flood management with a diversity of non-structural measures are needed, in order to serve the safety of the society. The latter does not only affect the area where it is applied, but also positively reflects on other areas. Flood control in contrast, carries the risk of increasing floods somewhere else by protecting one specific area.

Despite the many co-benefits resulting from the implementation of non-structural measures, like reduced sensitivity, multi-functionality, mitigation of climate change and increase of biodiversity, the structural approach is still more dominant. Besides practical and technical barriers on the side of engineers and politicians, this is caused by a psychological barrier. Although communities might actually be safer and better prepared for floods by non-structural measures, they might not feel that way. A big flood wall has a stronger visual impact than for example a new zoning plan or vegetation for infiltration, which is why people feel less protected by the latter (Williams, 1994).

2.3. Ecology-Based Approach

The last approach explained in this paper is also the most recent one. The ecology-based approach aims, like the non-structural approach, to reduce hazards as well as damaging impacts, but by making use of the capacities of the natural environment and its ecosystems (Munang et al., 2013).

The basic idea this approach is based on, is that functioning ecosystems can balance themselves and adapt much better to changing conditions and extreme events, than designed systems and structures do. In addition, they provide services, which benefit people and communities (UNISDR, 2009, p. 12). Starting from small scale local initiatives, "ecosystem-based flood defence has been brought into large-scale practice as a regional solution" (Temmerman et al., 2013, p. 79).

Different means for protection, restoration and management of ecosystems are available, to address flood risk. Besides the protection of existing natural elements and systems, like mangrove forests, wetlands and marshes or the protection of ground water by creating recharge zones, floodplains are being restored, in order to give the natural water flow the needed space during extreme events. That way inhabited or utilised areas are not being reached by flood waters so easily. The protection and restoration of natural elements do not only give space to flood waters but also function as buffer area to temporarily store water, reduce the speed of water flow and decrease pollution (Munang et al., 2013; Temmerman et al. 2013).

The improvement of ecosystems also creates many co-benefits, such as the mitigation of climate change, disaster risk reduction and improvement of water quality. When talking about this approach, often the term `no regrets` approach is being used, since there are no negative consequences for the environment or inhabitants. Some might argue with a negative economic impact and high costs, though compared to other measures, the ones from this approach are more "cost-effective, robust and flexible" (Munang et al., 2013, p. 70) and reduce the costs for reparation of damages of the natural environment, which are prevented or naturally reduced (Munang et al., 2013; Temmerman et al., 2013).

Due to the cost-efficiency, the customisation to the local circumstances and conditions and the limited technical expertise needed for the implementation, this approach can not only be applied in developed but also in developing countries (Munang et al., 2013). The downside of this approach is the time and space needed until its means are functioning properly (Temmerman et al., 2013).

3. Sustainability

"Sustainability refers to the conservation and protection of irreplaceable and non-renewable natural resources." (Kriken, Enquist & Rapaport, 2010, p. 28)

"Sustainable development has been defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (United Nations, 2016).

Sustainability has been defined in many different ways, using a big range of different terminologies and contexts. Though the most common definition is based on a three-dimensional model. This model describes sustainability as the achievement of and the balance between three different dimensions, namely the social, economic and ecological dimension (Fig. 2). These dimensions are equally important in order to achieve sustainability and are strongly interdependent (Michelsen et al., 2016, p. 16).

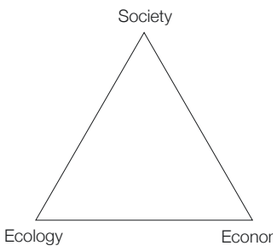


Figure 2: Sustainability Triangle. Own drawing based on Serageldin & Steer (1994).

This theoretical model to define sustainability is being supported by two main arguments. First, resources and values of all three dimensions are required in order to satisfy human needs. Second, each of the three dimensions is at risk, if one of the other dimensions is not being fulfiled. Therefore, the three dimensions "should be understood as independent but interrelated subsystems" (Michelsen et al. 2016, p.16).

Although all three dimensions are equally important by definition, foci can be identified in practice. According to Michelsen et al. (2016), developing countries are often focusing on the social and economic dimensions, as they are rated as being more urgent, while countries in the northern hemisphere are more focused on the ecological dimension.

Sustainability is regarded with increased importance in different contexts. This is due to the ongoing exhaustion of resources without sufficient alternatives as well as the extensive effects of climate change. Especially the uncertainty of future changes and regional variations call for more sustainable and adaptable solutions (Kundzewicz & Takeuchi, 1999). In this respect, sustainability also becomes more and more important for flood management strategies. Social and economic development cannot be seen isolated from ecological development, since ecological problems or hazards can for example compromise the fulfilment of the other two dimensions (Michelsen et al. 2016).

There are different criteria available to assess the sustainability of approaches for flood protection. Kundzewicz (2002) summarises three sets of criteria. The first is developed by Simonovic. He argues that the extend of "reversibility, fairness, risk, and consensus" (p. 6) define the sustainability of an approach. The second set is established by the Delft Hydraulic Laboratory. Here, the socio-economic aspects, use of natural resources, conservation of natural resources, public health and safety, flexibility and sustainability of infrastructural works are assessed to get an indication about the sustainability of an approach. Gardiner proposes the assessment of global environment, inter-generational equity, natural resources and local environmental quality as a third approach.

In the following paragraphs, the previously described approaches will be analysed regarding their sustainability. Despite the just explained possible criteria to assess approaches, the following assessment will be based on literature. To make the result more comparable, the fulfilment of the sustainability triangle (Fig. 3) will be assessed for each of the three approaches.

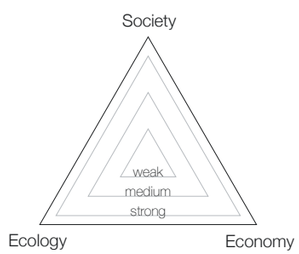


Fig. 3: Sustainability triangle as tool for comparison. Own drawing.

3.1. Sustainability of the Structural Approach

The structural approach is the most criticized approach regarding its sustainability in all three dimensions.

Economically, this approach is regarded as unsustainable, because of the continuous investments required. Physical structures for flood defence have to be continuously updated for rising flood risks. This has two main reasons. First, the calculations for the initial construction were not based on sufficient water capacities. Second, changing conditions increase the risk of floods due to more extreme events, for which the structures are not built. In addition to the necessary improvements, increasing maintenance costs also add to the high costs of structures. This is a problem especially for municipalities who only calculate the initial construction costs and face severe economic setbacks when it comes to maintenance and updating (Kundzewicz & Takeuchi, 1999; Temmerman et al., 2013).

The many side effects of engineered structures on the natural environment contribute to the notion, that this approach is also unsustainable in ecological terms. Engineered structures interrupt ecosystems, cause landslides, pollution and other hazards. As a result, natural mechanisms and capacities to deal with extreme events do not function anymore and can even increase the risk of flooding (Kundzewicz, 2002; Kundzewicz & Takeuchi, 1999; Temmerman et al., 2013). The latter relates back to the need for improvement and its economic unsustainability.

The biggest criticism in the social dimension of this approach is, that it is "closing options for future generations" (Kundzewicz, 2002, p. 6). This is the exact opposite of the basic definition and understanding of sustainability. Also the fact, that people are not prepared for floods anymore, as it is explained above, diminishes its sustainability, since this increases the damage if such an instance occurs. When no natural flood areas are left, the water will inevitably reach residential areas during extreme events and cause damages and losses, most likely in the poorest communities of the society (Kundzewicz, 2002; Kundzewicz & Takeuchi, 1999). This causes not only economic costs for repair but also societal costs (Gasparini et al., n.d.).

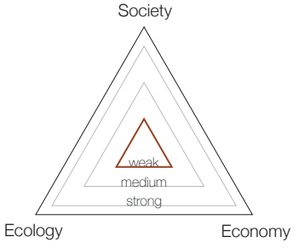


Fig. 4: Sustainability of the structural approach. Own drawing.

As a conclusion, the sustainability of the structural approach is weak in all three dimensions (Fig. 4).

3.2. Sustainability of the Non-Structural Approach

Kundzewicz (2002) states, that tools of the non-structural approach are "more flexible, less committing, and more sustainable" (p. 6) compared to engineered structures.

From an economic point of view, the strength of this approach is the long term management of flood risk, which considers many different factors. It aims not only to protect specific areas from flood risk but to reduce the occurrence of hazards itself. Furthermore, because its long term perspective, it prevents investments and development of certain uses in risk areas. As a result, costs for damage control and reparations are lower because the damages are being prevented or minimised in advance (Williams, 1994, p. 51).

The non-structural approach has limited negative impacts on the ecology. Small scale structural measures, which are also considered to belong to this approach, only interfere little with the natural environment and are therefore more sustainable. Other measures even specifically aim to restore ecosystems and their functions to make use of their capacities to infiltrate, retard and temporarily store water (Kundzewicz, 2002; Kundzewicz & Takeuchi, 1999; Williams, 1994). That way, natural capacities are not compromised to be controlled but embraced to the benefits of human societies.

The sustainability of the social dimension is provided by the better preparation for floods and the prevention of hazards. Tools like early warning systems and education about floods help to protect human lives and the adaptation of lifestyles, which also limit the damages of goods and properties. Zoning plans prevent people from settling in flood plains, so they do not even get into such dangerous living environments with all their consequences. The sustainability of this dimension is further strengthened by a variety of tools, which do not only address protection before the occurrence of an event but also for during and after it (Kundzewicz & Takeuchi, 1999).

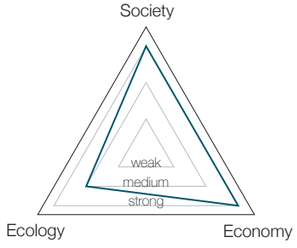


Fig. 5: Sustainability of the non-structural approach. Own drawing.

The sustainability in the social and economic dimension is therefore strong in this approach, while the ecological dimension is only intermediate (Fig. 5).

3.3. Sustainability of the Ecology-based Approach

The sustainability of the ecology-based approach is the least criticised. The reason for this is the definition of the approach itself, since it is using the natural capacities of ecosystems instead of controlling them (Temmerman et al., 2013). However, this approach is also the most recent one and not so much research has been conducted compared to the other two approaches.

The ecology-based approach claims to be more cost-effective compared to engineered structures. Like the non-structural approach, there is a focus on the prevention of hazards, which also has a positive impact on the economic dimension of sustainability (Munang et al., 2013; Temmerman et al., 2013).

In terms of the ecological dimension, this approach might be the most sustainable. The protection and restoration of ecosystems and their functions is a sustainable way to address flood problems, because the natural resources of the planet are being respected and protected instead of being exploited. At the same time, many co-benefits are being achieved like the improvement of water quality and the mitigation of climate change (Munang et al., 2013; Temmerman et al., 2013;).

The social dimension benefits from co-benefits like recreation, clean air and clean water. Communities are being protected mainly by prevention, like in the non-structural approach (Temmerman et al., 2013). This approach has no negative effects on human beings, though its sustainability in the social dimension has not been proven yet. The effectiveness of the ecology-based approach has been proven in rural areas, though future studies will have to show, if it is applicable in dense urban areas with limited space for the restoration of ecosystems. Also, there are no direct tools included to protect inhabitants in case of failure of ecosystems or short term solutions until full functioning. This implies that other measures are required temporarily to bridge that period and assure continuous flood protection, which weakens the social dimension towards sustainability if this approach is assessed individually.

While the sustainability of the ecological and economic dimension is strong in the ecology-based approach, it is only regarded intermediate in the social dimension (Fig. 6).

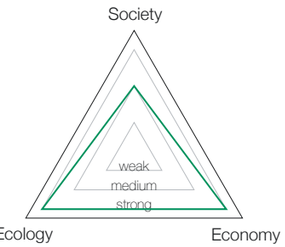


Fig. 6: Sustainability of the ecology-based approach. Own drawing.

4. Comparison & Discussion

A comparison of the three approaches (Fig. 7) shows differences regarding their sustainability. The structural approach is by far the least sustainable one, being weak in all three dimensions. The non-structural and the ecology-based approach are equally sustainable by being strong in two of three dimensions. While the ecological dimension is weaker in the non-structural approach, the ecology-based approach is insufficient in the social dimension.

The comparison also shows, that none of the approaches are sufficiently sustainable in all three dimensions by themselves. This leads to the conclusion that a combination of approaches is necessary, in order to achieve sustainability in all three dimensions. However, it is not only important to look at the sustainability of the approaches but also at their viability towards flood risk.

A distinction has to be made between riverine and coastal flooding as well as urbanized and rural areas. In urbanized areas usually much more values are at stake in case of flooding and there is a lack of space to apply non-structural or ecology-based measures for flood protection. The spatial limitation also applies to riverine flooding. In coastal areas, non-structural and ecology based measures can be applied even with other uses close to the coast, because they can be implemented in low waters towards the open sea. Rivers however, are usually much more enclosed by other uses around it, especially by residential areas, industries and agriculture, and also limited in width and depth. This makes it much more difficult to find sufficient space for these measures without compromising the demands of other functions (Kundzewicz, 2002; Temmerman et al., 2013).

This leads to the conclusion that a combination of non-structural and ecology-based measures is needed in rural areas and coastal zones (Fig. 8). In urban and river areas, structural measures are additionally required, in order to assure sustainability in all three dimensions as well as sufficient flood protection. In any case it is important to thoroughly assess the local conditions of each case individually, before ruling out measures of any of the three approaches (Kundzewicz, 2002; Temmerman et al., 2013).

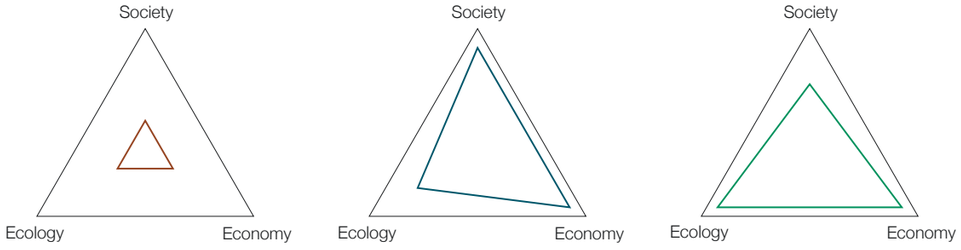


Fig. 7: Comparison of the three approaches' sustainability. Own drawing.

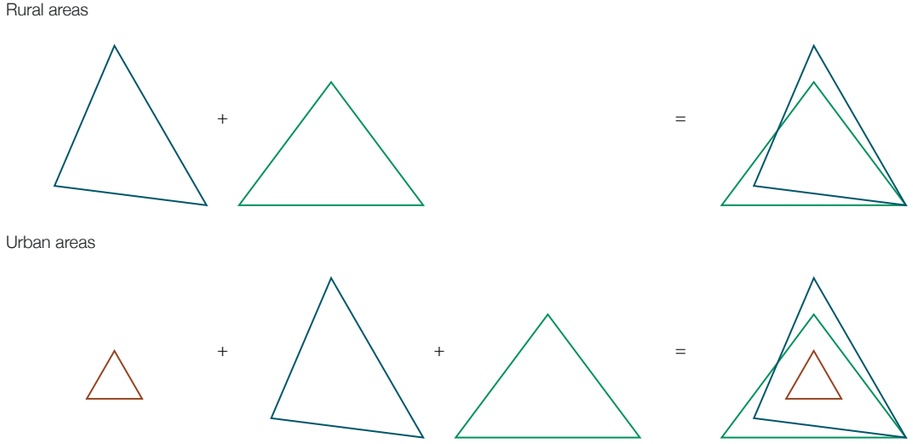


Fig. 8: Combination of approaches to achieve sustainability. Own drawing.

5. Conclusion

All three approaches aim to protect human beings from the impact of floods, though the means to achieve this are fundamentally different. Their effectiveness highly depends on the location, the amount of research it is based on and the moment in time. It can be concluded that a physical structure is most effective short after construction, while means of the ecology-based approach only a long time after their implementation. The spatial context as well as the type of flooding can alter the effectiveness of an approach, which make a thorough assessment of each location crucial.

The approaches also highly vary in their level of sustainability. The structural approach is the least sustainable one. The non-structural and the ecology-based approach are equally sustainable, each only showing weakness in one of the three dimensions of sustainability.

After the assessment of the effectiveness and sustainability of the approaches it can be concluded, that a mixture is necessary to achieve the best result, being effective and sustainable. It is important to give all dimensions of sustainability triangle the same importance. If they are not all achieved, they can compromise each other. This is also important for developing countries. If they start taking care of the environment now, they will not have to pay for that in the future and that way reduce the gap between the global north and south.

6. References

Gasparini, P., Di Ruocco, A., Bruyas, A.-M. & Bruyas Amra, A.-M. (eds.) (n.d.). *Climate change and vulnerability of African cities. Research briefs*. Naples. Retrieved from: http://www.cluva.eu/CLUVA_publications/CLUVA_Climate-change-and-vulnerability-of-African-cities-Research-briefs.pdf

Kriken, J., Enquist, P., & Rapaport, R. (2010). *City building : Nine planning principles for the twenty-first century.* New York: Princeton Architectural Press.

Kundzewicz, Z. W. (2002). Non-structural Flood Protection and Sustainability. *Water International.* 27:1, 3-13, DOI: 10.1080/02508060208686972

Kundzewicz, Z. W., & Takeuchi, K. (1999). Flood protection and management: quo vadimus? *Hydrological Sciences Journal,* 44(3), 417–432. https://doi.org/10.1080/02626669909492237

Michelsen, G., Adomßent, M., Martens, P. & von Hauff, M. (2016). Sustainable Development - Background and Context. In: Heinrichs, H. (et al.) (eds.), *Sustainability Science* (pp. 5-29). Dordrecht: Springer. Retrieved from: http://link.springer.com/book/10.1007/978-94-017-7242-6

Munang, R., Thiaw, I., Alverson, K., Mumba, M., Liu, J., & Rivington, M. (2013). Climate change and Ecosystem-based Adaptation: a new pragmatic approach to buffering climate change impacts. *Current Opinion in Environmental Sustainability,* 5(1), 67–71. https://doi.org/https://doi.org/10.1016/j.cosust.2012.12.001

Serageldin, I. & Steer, A. (Eds.) (1994). *Making Development Sustainable: From Concepts to Action*. Washington, D.C.: The World Bank. Retrieved from: http://documents.worldbank.org/curated/en/514901468326404981/pdf/multi-page.pdf

Sudmeier-Rieux, K., Sandholz, S., Nehren, U., Rharade, L., Bayani, N. & Ford, M. (2017). *Disasters and Ecosystems: Resilience in a Changing Climate*, The Book. Geneva and Cologne: United Nations Environment and TH Köln, Technical University, Cologne

Temmerman, S., Meire, P., Boumw, T. J., Herman, P. M. J., Ysebaert, T. & De Vriend, H. J. (2013). Ecosystem-based coastal defence in the face of global change. In: *Nature*. Vol. 403 (pp. 79-83). DOI: 10.1038/nature12859

UNISDR (2009). *2009 UNISDR Terminology on Disaster Risk Reduciton*. Retrieved from: http://www.unisdr.org/files/7817_UNISDRTerminologyEnglish.pdf

United Nations (2016). T*he Sustainable Development Agenda.* Retrieved from: http://www.un.org/sustainabledevelopment/development-agenda/

Williams, P. B. (1994). Flood Control vs. Flood Management. *Civil Enigineering,* 64(5), 51–54.



Colophon

Beke-Marleen Hörmann - 4622308
Mona zum Felden - 4587618

First mentor: Frank van der Hoeven
Second mentor: Frits van Loon
External advisor: Nathalie Jean-Baptiste, Ardhi University Tanzania
Research group: Design of the Urban Fabric - June, 2018
Master Thesis - Faculty of Architecture and the Built Environment -
Department of Urbanism - TU Delft

Please note that this is a joint project consisting of a
combined piece of work and two individual design parts.

Online documentation:
https://bkafrica.wordpress.com/category/beke-mona-in-tanzania/
https://www.instagram.com/urbanism.students.for.africa/

TU Delft

OOTA

Foundation

ent

54-471150.

n2008@yahoo.com

62-482889.

▶ Bajaji tour: fuzzy streetcape DAR

DAR

courtyards and chinampas for
urban water management in Dar es Salaam

Master Thesis - 2018
Beke-Marleen Hörmann I Mona zum Felden
Faculty of Architecture and the Built Environment
Urbanism I TU Delft