# Calming regional aridity

*How a regional strategy can mitigate water shortage and support just and resilient urbanism*

**Hidde van Beek** **22 June 2022**

Msc Thesis in Urbanism - P5 Report

**Calming regional aridity**
*How a regional strategy can support just and resilient urbanism: The case study of North-East Africa*

**key concepts**: arid climate; water shortage; transboundary cooperation; regional strategy; resilience; justice

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cover image based on EU Civil Protection and Humanitarian Aid (2014) and Hueske (2008) adapted by author.

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## Preface

This graduation thesis was done to complete the master track of Urbanism. The following report will address the issue of water shortage in arid regions. It will do so by first analysing the region of North-East Africa, whereafter main elements of a regional strategy as well as a local design are explained and illustrated. This thesis aims to contribute to existing research by combining research and design which resulted in design solutions as well as references which can be built upon by local decisionmakers.

I want to specifically thank both my mentors who guided me from start to finish. They both helped me stay on the right path as well as enlightened me with new insights along the way. Furthermore I want to thank my friends and family for supporting me during this graduation.

## Motivation

In recent years I have been learning more and more about the effects of climate change. The talk about climate change in countries such as the Netherlands has been focussed on issues such as sea level rise, flash floods, milder winters and hotter summers. While this is all true, the effects of climate change are far more severe in countries in the global south. It is expected, according to the IPCC, that climate change will make arid regions even hotter and drier. In these regions, water shortage is already a large problem which will be increasing due to climate change. If the effects of climate change on these areas are not mitigated, millions of people will be forced to migrate due to lack of water, crop failure and famine. Countries in the global south possess less resilience to the effects of climate change. This is the reason I will look into the task to a missing strategy for countries dealing with such conditions. In the hope that this research will provide more resilience for arid regions in water scarce conditions.

Image by Hassan (2020), adapted by author.

# Problem

# 1.1 Problem field

The problem field will discuss the main problems this research will build upon. This will be done by first looking at broader, worldwide problems. After these problems have been defined, a case study location will be chosen and explained, after which will be zoomed in and several location based problems will be explained. This problem field will conclude with a problem statement, which tries to summarize the aforementioned problems and will try to form a bridge towards the following research. This problem statement will lead to a main research question which this thesis will try to answer.

### 1.1.1 Arid regions worldwide

Regions with an arid climate (as defined by the Köppen climate classification in 1884), commonly known as deserts, are regions which receive very little rain. Despite the fact that these are often related to temperature, there is an actual difference in classification when looking at arid climates and temperature: the hot desert climate (BWh) and the cold desert climate (BWk). In this research the hot desert climate (BWh) will form a central part, as these have a larger impact on the water supply as higher temperatures cause more evapotranspiration. Moreover, higher temperatures cause water demand to rise for both agriculture and human consumption. This climate is most common in the MENA region (Middle--East and North Africa), but also exists in large parts of Australia, Central Asia and the United States. In the next decades, this desert climate is expected to increase to regions such as Southern Africa, South-America and Spain (Beck et al, 2018).

### 1.1.2 Water shortage: a global problem

Throughout the world, more than 2 billion people live in countries which experience water stress and lack access to safe drinking water. Even though access to water is a human right, water stress is getting worse in regions who are already dealing with critical levels, according to the United Nations (2021). This is especially a problem in Africa, where the most deaths related to water stress occur (World Meteorological Organization, 2021). This water stress causes problems for both people and biodiversity and a lack of water can cause national and regional unrest.



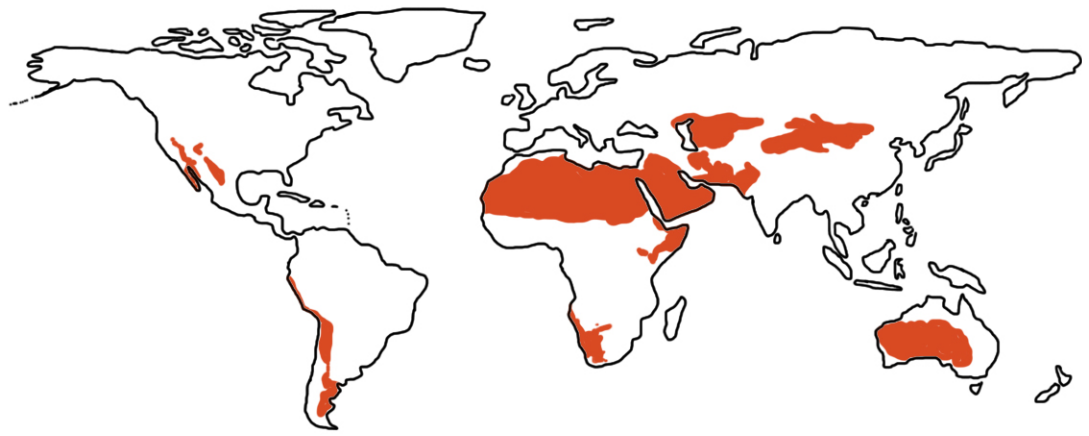


*figure 1.1: Arid regions worldwide (by author).*

*figure 1.2: Worldwide water shortage (by author).*

*figure 1.3: Arid regions dealing with water shortage (by author).*

### 1.1.3 Climate change

In the (near) future, water related issues throughout the world, like floods and droughts, are likely to increase due to climate change. The most recent IPCC report (IPCC, 2021) has shown several scenarios and in all scenarios there is an increase in periods and severity of droughts in most parts of the world. Moreover, the temperature will increase, resulting in more water usage in many parts of the world. Besides, this increase in temperature will result in more evapotranspiration from water reservoirs, the main source for freshwater in most regions. Water scarce regions already extract water from unsustainable sources such as groundwater in order to meet the high demands (Sowers et al, 2011). With an increase in demand because of climate change, these unsustainable sources are likely to deplete even faster. This is especially an issue in most parts of the MENA region, as water availability is expected to decrease due to both an increase in temperature and a decrease in precipitation (Waha et al, 2017).



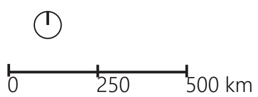
*figure 1.4: Climate change will increase droughts worldwide (Palmer, 2021).*

*figure 1.5: Droughts will intensify crop failure and famine (Tangeman, 2018).*

### 1.1.4 The case study of North-East Africa

In this research, North-East Africa will be picked as a case study for the following reasons. It is one of the most arid regions worldwide, with the Nile providing the region with a large flow of fresh water. Besides this flow of fresh water from the Nile, countries use the unsustainable source of groundwater, which results in a depletion of freshwater aquifers. Moreover, it is one of the most affected regions worldwide by climate change (IPCC, 2021). There is both an expected increase in temperature and a decrease in available water in the coming years. The instability of the region asks for a regional approach as countries currently mostly follow their own plans and strategies. The focus seems to lay on short term and technical solutions, instead of a long term, transboundary or nature based, approach (Sowers et al, 2011). There are several commissions in place to stimulate collaboration, but a common strategy seems to be missing. The countries that will be discussed in this research are the four countries Libya, Egypt, Sudan and Chad. These countries are rapidly urbanising and cities like Cairo, Alexandria and Khartoum belong to one of the largest of the continent. Despite their size, these cities lack proper infrastructure and infrastructure has not been upgraded for the past 100 years in Cairo (Edo et al, n.d.).

*figure 1.6: Case study area (by author).*



### 1.1.5 Rise in demand for water

In the coming years, it is expected that the demand for water will increase in the region. This is mostly because of population growth, which increases the demand for food and thus water use in the form of agriculture. In Egypt alone, there is an estimated growth of nearly 30 million people by 2030 to a total of 120 million which might even increase to 160 million by 2060 (Worldbank, 2022). In Egypt this accounts for a yearly growth of around 1.5%, which is lower than Sudan, where the annual population growth is more than 2% (Worldbank, 2022). More people require more water while the total supply cannot follow. But an increase in population is not the only cause for a rise in demand the coming years. Because of climate change, crops require more water, resulting in a rise of water consumption in the agricultural sector. This agricultural sector is in all four countries the major consumer for water, varying between 80-96% (FAO, 2015; FAO, 2016).

### 1.1.6 Unsustainable sources and use

Even though the region of North-East Africa undergoes major water stress, Egypt continues to reclaim large regions of desert lands for the transformation into agricultural land. This process of reclamation requires large amounts of water as new, arid regions need to be irrigated. This increase in demand for water will ultimately result in an increase in pressure on the Nile system (Sallam et al, 2014). On top of the land reclamation on its own, the irrigation systems throughout the region are inefficient and cause for more water to be used than necessary. Improving the efficiency of irrigation might not solve water stress on its own, but might contribute to a decrease in the issue (Multsch et al, 2017). In regions where extracting water from rivers is no possibility (Libya and desert regions of Chad, Egypt and Sudan), groundwater is extracted. Because groundwater is non-renewable, it leads to the depletion of the Nubian Sandstone Aquifer System (NSAS). Current extraction rates do not cause problems in the near future, but the rising demand for water combined with increased rates of extraction can result in a faster depleting water source. This, in time, will result in a complete depletion of the NSAS if no action is taken (Foster et al, 2006).

### 1.1.7 Transboundary conflicts and instability

Water from the Nile is shared between several countries, among these are the countries of Egypt, Sudan and Ethiopia. Because the water from the Nile is shared, actions in upstream countries such as the building of dams can create negative external effects downstream. In recent years, Ethiopia has constructed a dam in order to provide its country with hydropower. This creation of the grand renaissance dam has led to lower water levels downstream and can ultimately result in more water stress in the downstream country of Egypt (Wheeler et al, 2016). In these cases, transboundary cooperation can form a solution with the long term management of shared water resources, not only for the Nile, but for other shared water sources as well (i.e. the NSAS).



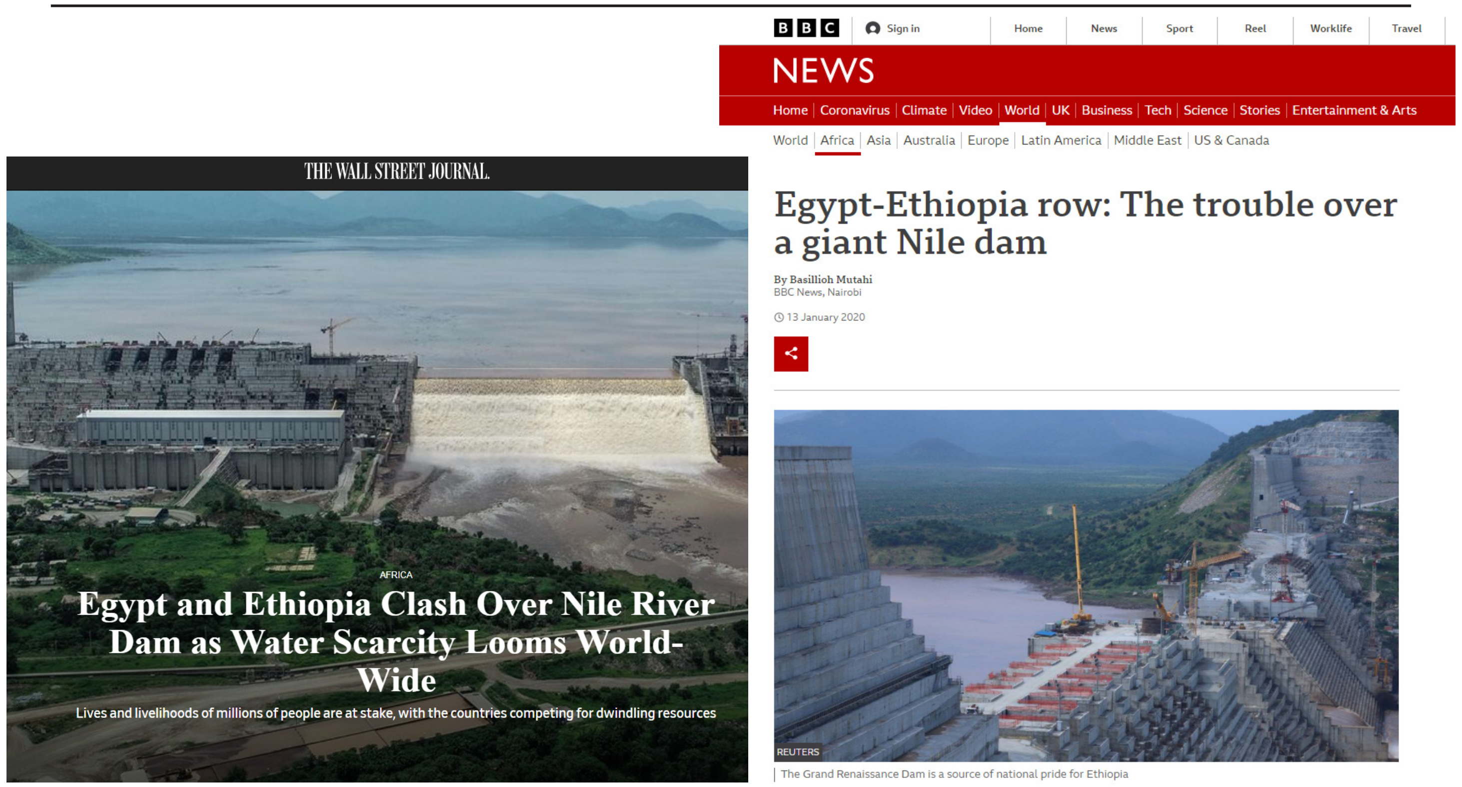



*figure 1.7: Newspaper articles discussing transboundary conflict (Mutahi, 2020; El-Fekki & James, 2021).*

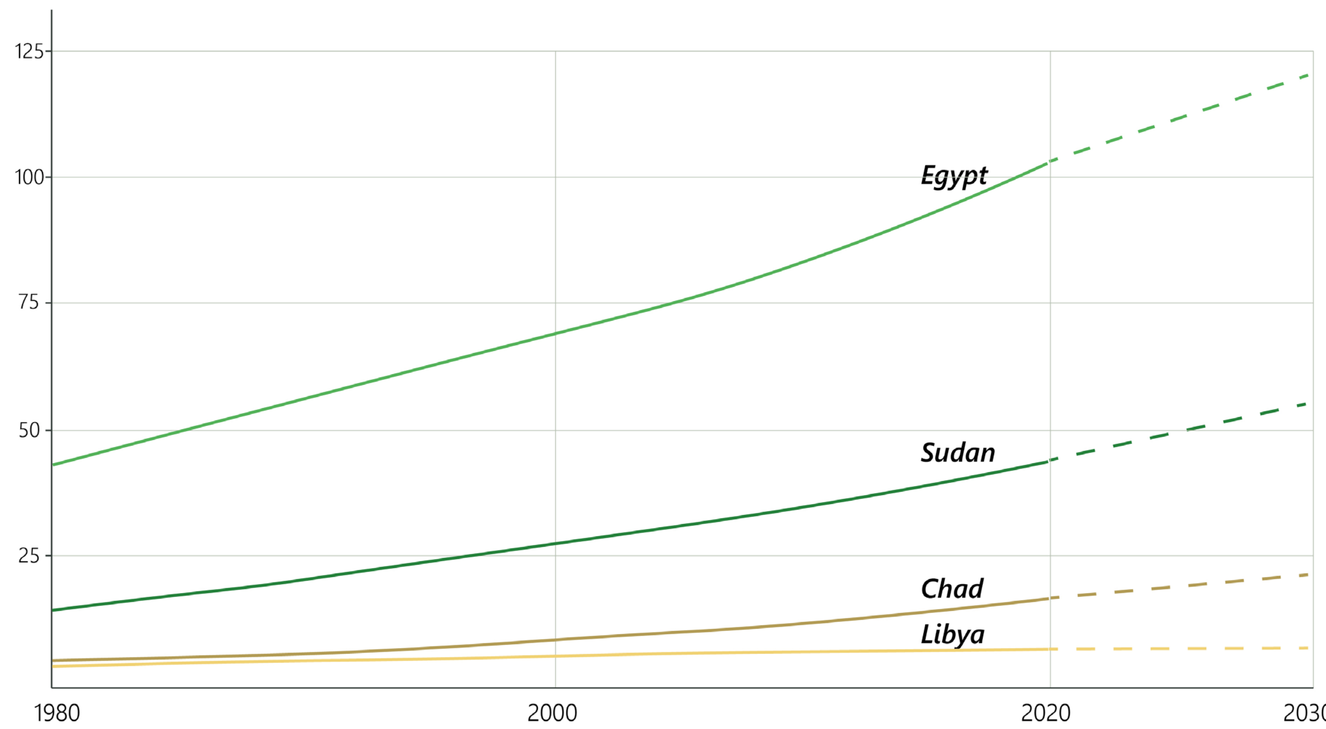



*figure 1.8: Population size and growth period 1980 - 2030 (by author, adapted from Worldbank, 2022)*

*figure 1.9: Farms in the desert, Egypt (NASA, 2018).*



## 1.2 Problem statement

**Arid regions** throughout the world experience long periods of drought. Combined with a high temperature, this can lead to **water shortage**. Due to climate change, this is **expected to worsen**, as areas become drier and temperatures increase. One of the regions where this problem occurs is the region of **North-East Africa**. In this region, **water stress is expected to increase in the (near) future** due to an increase in demand for water and a decrease of the availability. While most of these countries depend on a shared water source, **transboundary cooperation is lacking**. A regional strategy, to create a common framework, is needed to cope with this regional problem which can strengthen long term resilience.

*figure 1.10: Farms in Sudan (Financial Times, 2021).*



## 1.3 Research question

What elements does a **regional and transboundary strategy** need in order to address **current water shortage** and **mitigate the rising demand and decreasing supply** of water in **arid regions**? The case study of **North-East Africa**.

Image by United Nations Environment Program (n.d.), adapted by author.

## 2.1 Aim

This research aims to present key elements that are needed in a regional strategy to mitigate the problem of water shortage in regions with an arid climate. It will try to do so by investigating the case study of North-East Africa. After first clarifying the in-depth problems of the region, which provide the background for further research, the base for a strategy will be created through both a long term vision and a set of key principles or themes. This vision and key principles will aim to establish a goal which this strategy should be able to meet. These can later be used as guidelines for other projects with similar goals. The strategy later aims to guide these countries towards this common goal after which this strategy will be tested on a smaller site. This small design experiment aims to illustrate what the spatial result is of the strategy. This experiment can be used for other similar areas.

## 2.2 Research questions

What elements does a regional and transboundary strategy need in order to address current water shortage and mitigate the rising demand and decreasing supply of water in arid regions? The case study of North-East Africa.

**Sub research questions:**

How can water governance and the regional design of water provision support resilient urbanism?

What elements does a regional and transboundary strategy need to promote resilient urbanism?

**Operational research questions:**

How is water extracted?
What causes water shortage?

Who governs water provision?
What policies are planned or in place?

What urbanisation trends affect the region?
How do urbanisation trends affect the future of the region?



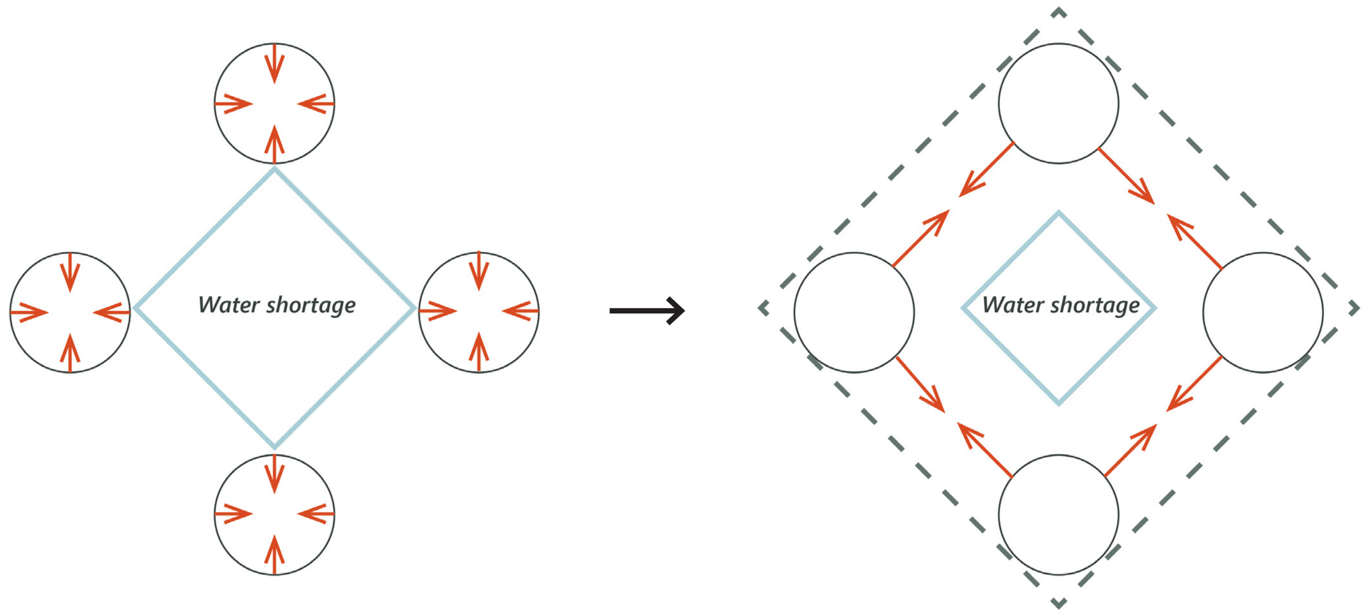



*figure 2.1: Aim (by author).*

## 2.3 Methodology

The research is split into four main parts: the first regional and local analysis to get more background information and insight into the main issues in the area, the regional strategy and the design experiment. The methods used for the main analyses are explained in paragraph 2.4.

The main operational questions, as previously stated, will help elaborate the context (both regional and local) of the region. The sub-questions will later help answer the research question.

The framework illustrating this process is shown on the right.



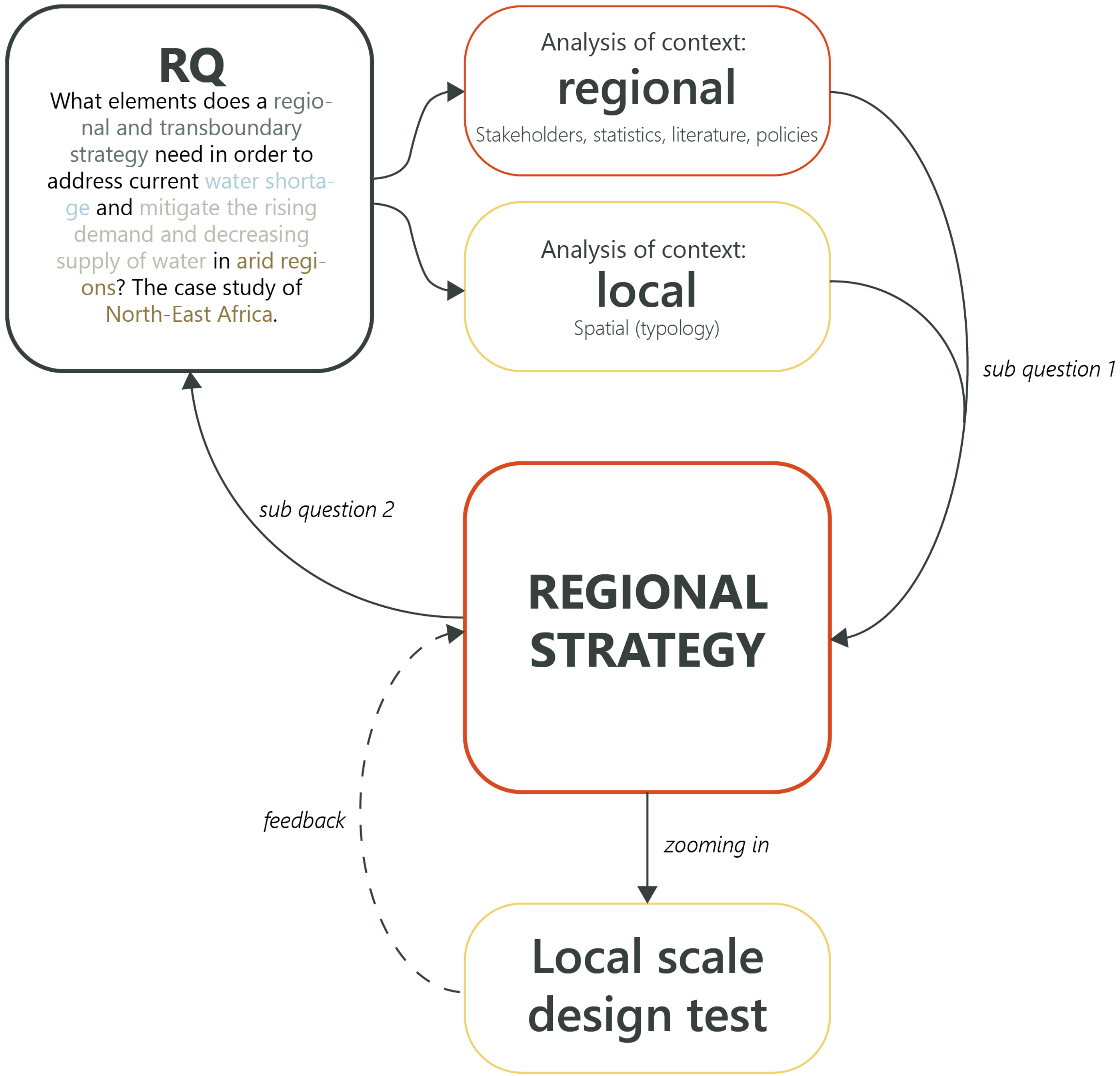



*figure 2.2: Methodological framework (by author).*

## 2.4 Main methods

### 2.4.1 Design experiment

The design experiment will be done to test the regional strategy on city level, which can provide feedback for this strategy.

### 2.4.2 Literature review

This method consists of reviewing various academic sources. By reviewing these sources, the existing academic theory can be understood and reviewed. These sources will be filtered according to main key words, time of publishing and the amount of citations. An old source with limited citations will for instance rarely be used while a new source with few citations can be. There will be tried to have mostly sources of the last 5 years. Sometimes older sources will be used as well. Because the case study region has not been extensively researched, sources can be limited and therefore older publications are used.

### 2.4.3 Policy analysis

There are already various policies and strategies in place affecting decisions from stakeholders. This method will be used to review these strategies and policies to see which parts can be used in the creation of a regional strategy. Before this can be done, these documents need to be properly analysed and reviewed. These reviews will be done by mainly focussing on finding key themes or principles used in these documents and linking these with each other and with other policies or strategies.

### 2.4.4 Spatial analysis

Not only does this approach require maps in various scales, it also combines other methods such as sections to set up a typology. The goal is to create a sort of atlas which distinguishes various types of cities by their source of water and their size. These studies are throughout the entire case study area.

### 2.4.5 Stakeholder analysis

For a stakeholder analysis a few things will be done. A list of stakeholders will be made with the corresponding scales and sector (public, private, civic) for each stakeholder. For each individual stakeholder a level of power and interest will be noted, as well as the sphere of influence in relation to the four countries in the case study region. This can then be used to see which stakeholder has power or interest in which specific region.

### 2.4.6 Statistical analysis

For this method, data from external open sources will be used and reviewed. It will be tried to retrieve the most recent data possible. Because the case study covers multiple countries, there is the possibility that various sources need to be used. If this is the case, it will be tried to match these sources as well as possible.

## 2.5 Relevance & ethics

### 2.5.1 Social relevance

Around the world, a lot of urban regions face water shortage. In recent years, this problem has become worse. In regions facing water shortage, the demand for water is rising due to both an increase in population and in prosperity. In coming years, these issues will rise even further, as climate change will increase heavy rainfall while also increasing periods and severity of droughts. This calls for strategies to decrease the demand for water and increase the supply, mitigating water shortage. This thesis can provide an example on how to deal with these kinds of areas and how to provide these countries and regions with a strategy to tackle the effects of climate change.

### 2.5.2 Scientific relevance

Worldwide, regions with an arid climate are increasing due to climate change. Desertification causes droughts to arise in regions which did not experience these events before. Urban areas and agriculture increases the pressure on water, which results in a lack of water in these dry and arid regions. This thesis can provide a set of key strategies to tackle these problems. This can be applied to arid regions in general, but can also be used as a blueprint for other regions facing similar issues. It can also be used as an example on how to tackle regions with a specific climate and a specific lack of resources.

### 2.5.3 Ethics

The role taken in this research will be the role of regional planner at first. This will be done to evenly spread the attention for all countries discussed in the research so that the strategy takes into account all governing sides of the story. However, the local population must not be neglected in this large-scale research, because the goal is to make sure water will still be available for everyone in the future. Therefore, during the research there will be zoomed in and out to apply this strategy on a smaller scale. The strategy and its interventions will be studied to take into account the needs of the people so they can really benefit from these changes. The crucial part here is to reflect on the strategy through the design experiment on the city scale. This design experiment must provide insight on the effects on the local population.

*figure 2.3: When taking a regional approach, local communities can not be neglected, image by El-Gassier (2019).*

## 2.6 Timeplan

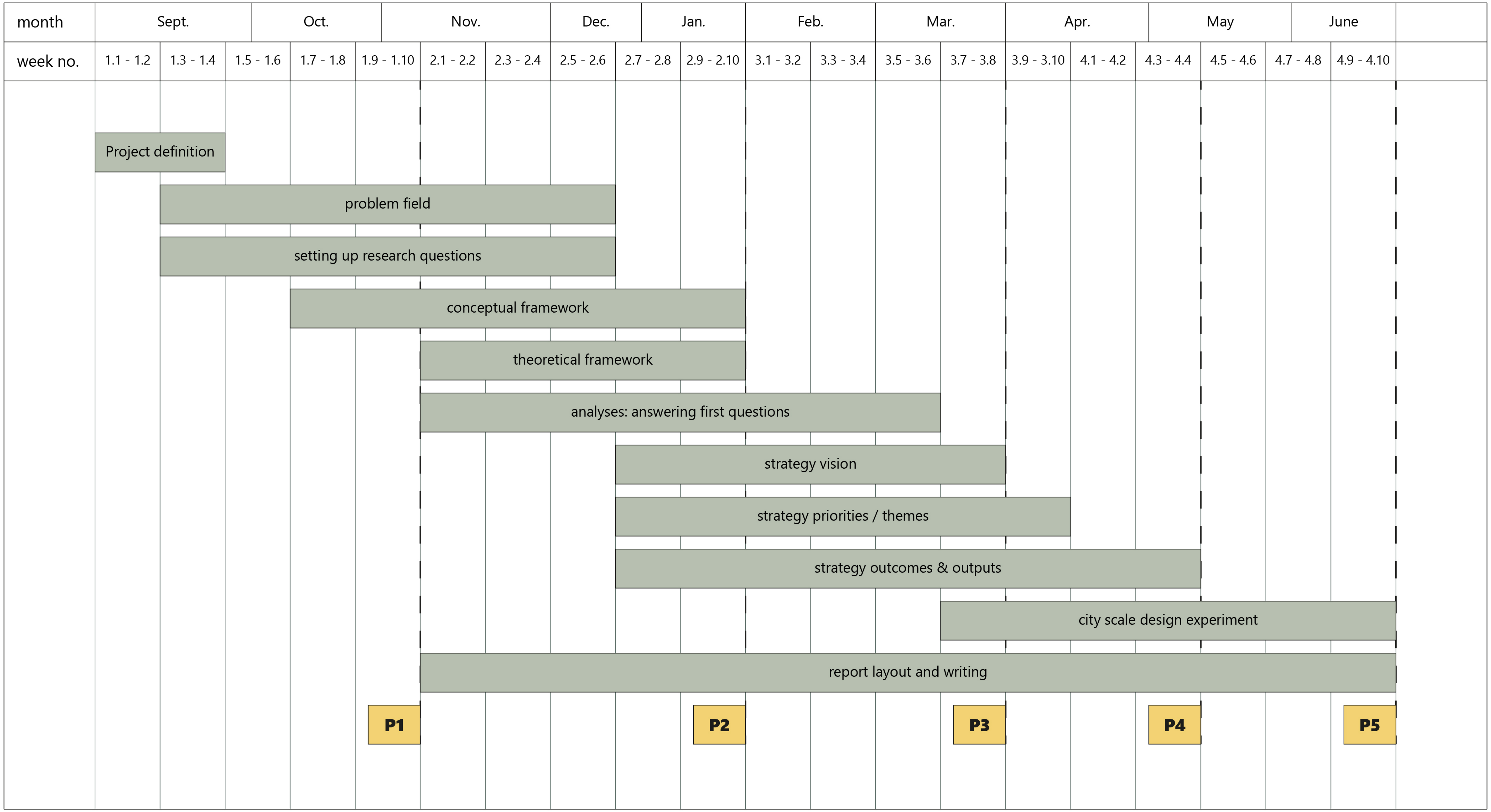



*figure 2.4: Timeplan (by author).*

Image by Tohami (2020), adapted by author.

# 3.1 Theory

### 3.1.1 Arid climate

As mentioned in an earlier chapter, regions with an arid climate are the driest on earth. These regions are classified by the Köppen climate classification as BWh and BWk: the hot and cold arid climate. These letters stand for the various climate classes and their variations. The climates are distinguished by mean annual precipitation (BW) and mean annual temperature (h and k) (Beck et al, 2018). Worldwide, the BWh classification is the most common and most parts of this climatic class can be found in the MENA (Middle-East and North-Africa) region (Peel et al, 2008). In these hot arid regions, water shortage is a common issue. Because of high temperatures and very limited rainfall, external resources and groundwater provide these regions with additional water, which make these regions or countries dependent.

### 3.1.2 Shortage, scarcity and stress

Because the amount of available water can be defined with several terms, this paragraph will discuss the various terms used in literature. Throughout literature, the terms water scarcity, water shortage and water stress are overlapping and are not always concretely defined. The United Nations (2021) defines water stress (SDG report 2021) as a phenomena when 25% or more of a country's renewable water resources is withdrawn. Water scarcity is defined (United Nations, n.d.) as a scarcity because of either physical issues and shortages or because of institutional problems. These physical issues can range from little rainfall to overuse in agriculture and are oftentimes related to institutional problems as well. The FAO (n.d.) makes a distinction between absolute water scarcity, which is <500 $m^3$ per year per capita, and water stress, which is between 500 and 1000 $m^3$ per year per capita, these numbers are based on the 'Falkenmark indicator' or 'water stress index' as defined by Falkenmark et al (1989). This theory uses the numbers 1667, 1000 and 500 $m^3$ per capita per year and these correspond to water stress, water scarcity and absolute water scarcity. The levels of water stress and scarcity however, are always dynamic and are the result of an imbalance of availability and demand (Mekonnen & Hoekstra, 2016). A growing population, for instance, will have an increase in demand which will result in a worsening of water scarcity. The main objections to using the Falkenmark indicators are that the indicators do note take into account the fact that countries can adapt to a lower availability of water.
Moreover does it not take into account the possible virtual water, water gained by imports of food and water, which has been an effective way to deal with water shortage in many Middle Eastern countries (Chenoweth, 2008). Another downside to the aforementioned theory is that availabilities of water are sometimes not related to the actual renewable water sources or the internal water resources. If a country has no water stress but extracts all its water from (non-renewable) groundwater sources, then the country is fully dependent on a depleting source. The same goes for internal water resources, if a country is fully dependent on external water resources, it is more vulnerable to event happening outside its borders. These two terms are merged by the term Internal renewable water resources (IRWR), which refers to the average annual flow generated from endogenous precipitation (FAO, 2003). The IRWR of one country shows the amount of water this country can always rely upon. In addition to the total amount of IRWR, a country can then choose to use external or non renewable sources to provide its population with additional water.



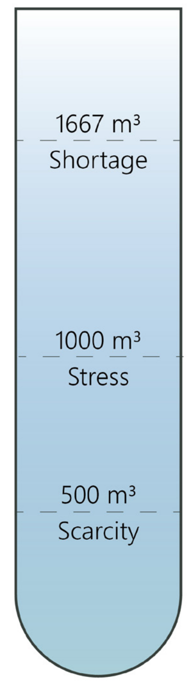



*figure 3.1: The difference between shortage, stress and scarcity (by author).*

*figure 3.2: Arid regions dealing with water shortage (by author).*

### 3.1.3 External and non-renewable water resources

For some countries the use of external or non-renewable water resources is no case of choice, as the IRWR are as low that the country is forced to use these types water resources. This is the case for many riparian countries who depend on the water from a river or for countries with an arid climate who therefore receive very little precipitation and thus depend on the use of groundwater. These two examples will be discussed in this paragraph.

**Non-renewable water resources: groundwater**

Subsurface water can be divided into two main categories: the unsaturated upper layer and the saturated layer underneath, usually called groundwater. When this saturated layer is permeable, or parts of it are permeable, it is called an aquifer. When precipitation events bring water to the surface, three things can happen: water flows over land to a nearby stream, water evaporates or water infiltrates into the ground. This infiltrated water can then either flow to surface water or flow from the unsaturated upper layer to the saturated layer beneath (groundwater), if this occurs it is called recharge. These aforementioned processes are illustrated in figure X. This recharge of groundwater can take months or years and is dependent on the permeability of the soil (Fitts, 2002).

Groundwater can be accessed in several ways. In ancient times the groundwater was often accessed by finding springs or geysers. In more recent history, groundwater is extracted through pumping. Because this pumping is done in a rate which is faster than the recharge of the groundwater, this extraction of groundwater is seen as non-renewable. However, many regions and countries still depend on the extraction of groundwater as a water source because other sources are less or not available.

**External water resources**

In many parts of the world and accounting for roughly 60% of the total global freshwater flows, transboundary rivers transport water from one country to another. Surface water is called transboundary if its watershed is shared between two or more countries. Throughout the world, around 260 water basins are defined as such (Earle et al, 2010). In most cases, these rivers depend on either melting water from glaciers or from large amounts of precipitation in upstream parts of the river. In the cases when the downstream regions or countries receive not enough water from endogenous precipitation, these countries depend on the inflow of water from these transboundary river systems. This is illustrated in figure X. This can either be a small part of the total demand of water, but external water can also be a major source for fresh water in these water-scarce downstream regions. In these cases, transboundary cooperation is needed to secure these water resources. This transboundary water management not only counts for river basins, but added to this are also large aquifers which span multiple countries beneath the surface.

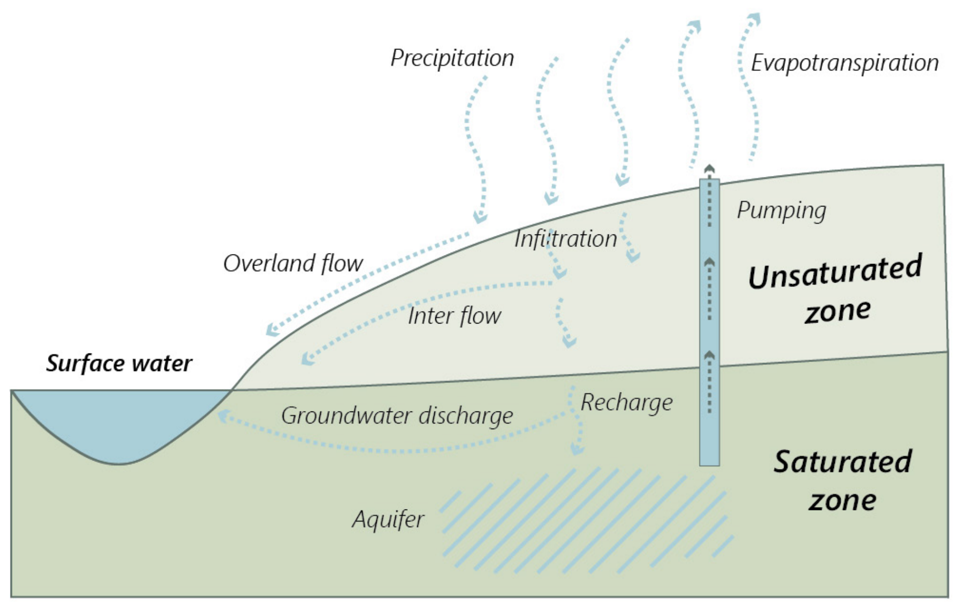



*figure 3.3: The saturated and unsaturated zones (by author, based on Fitts (2002)).*

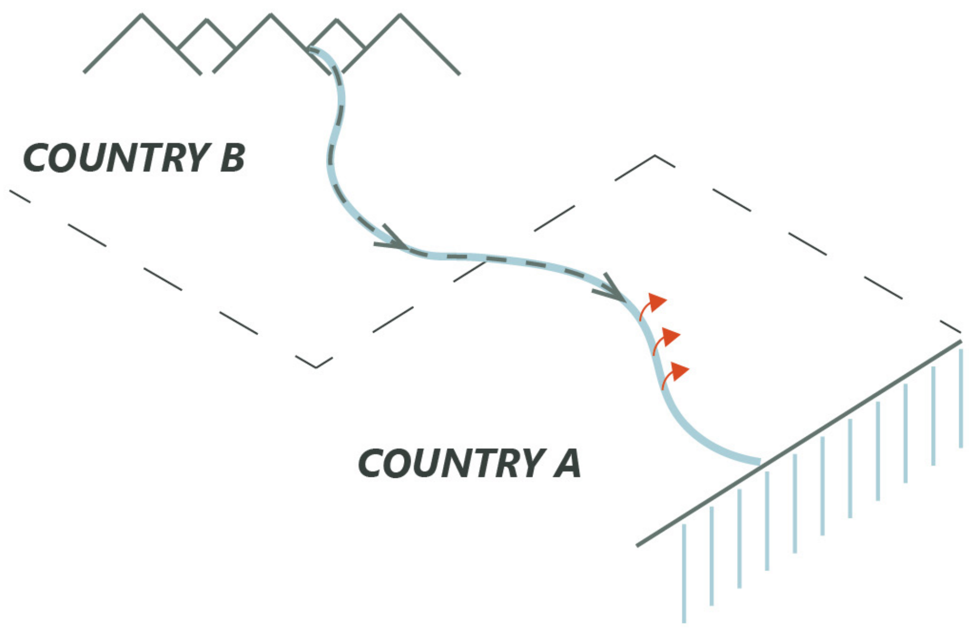



*figure 3.4: Country A being dependent on water flowing from country B (by author).*

### 3.1.4 Limited territorial sovereignty

Water related disputes are not the most common cause for conflict, they do however occur and due to climate change these conflicts are more likely to increase. In countries which deal with water scarcity, it is found that there is more transboundary cooperation over shared water resources. This cooperation for water resources can form a contribution to cooperation on other issues and can be the starting point for peace and development if such cooperation exists (Earle et al, 2010). Yalew et al (2021) discusses the theory of the morality of states from Walzer (2015). According to this theory, water should be distributed with respect to the country's sovereignty or the right to exploit their own resources. In this theory however, two contradicting points arise. The first one, absolute sovereignty, is the claim that any state can extract the water flowing through its own country without taking into account the consequences on other countries. The second point however, called absolute territorial integrity, is that downstream countries have the right to all water along the river, including upstream states. In this case development which impacts the downstream country is also prohibited if it affects the natural flow of the river. These two claims cause conflict because of contradicting assumptions. The first one often being referred to by upstream countries while the latter greatly favours the downstream states. There is however also a third middle ground position called limited territorial sovereignty. This position states that countries have the right to exploit their internal resources in such a way that it does not cause harm to the resources other states. The United Nations 1997 "Convention on the Law of the Non-navigational Uses of International Watercourses" proposed that all shared water resources should be utilized in a 'equitable and reasonable manner' (United Nations, 1997). Even though the proposal by the United Nations follows the third position (limited territorial sovereignty), terms such as equitable and reasonable are not exact and because it is vague, it is not clear what this entails. This convention however, is currently the only universal applicable framework for shared water resources. Within the SDGs (United Nations, 2021) there however is little mention of such equitable or reasonable utilization of water resources. It however states that universal access to water is a human right, which is in line with the position of limited territorial sovereignty. Moreover SDG target 6.5 states the goal of implementing integrated water resource management including transboundary cooperation. It still remains very difficult to measure such goals and in SDG 6 such criteria do not exist in detail. It does however show that there is ambition to implement the concept of limited territorial sovereignty.

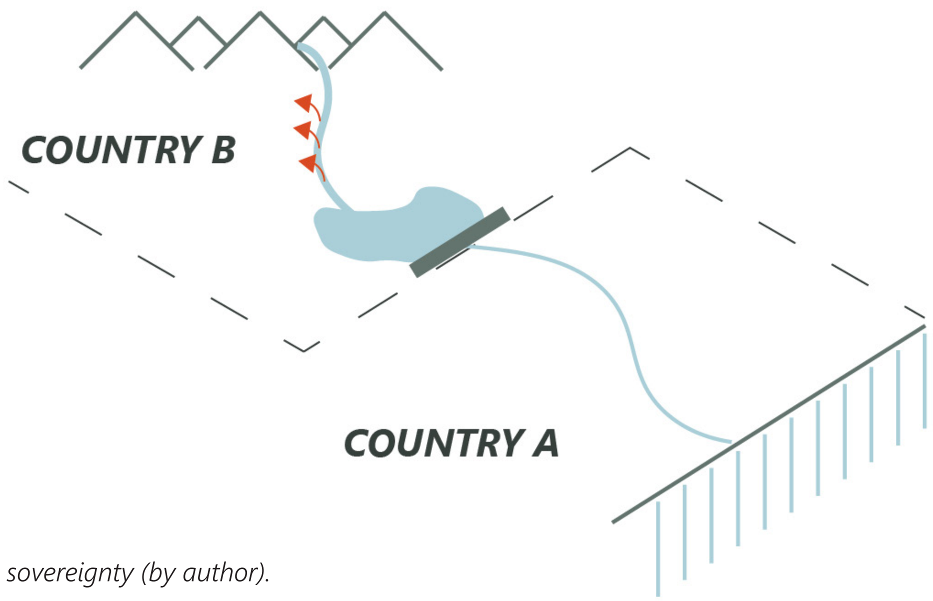



*figure 3.5: Absolute sovereignty (by author).*

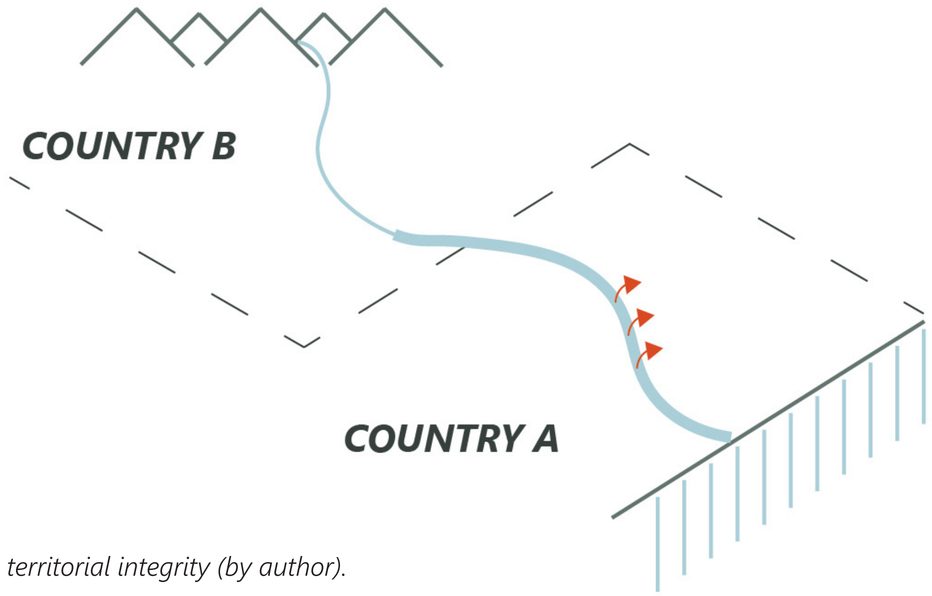



*figure 3.6: Absolute territorial integrity (by author).*

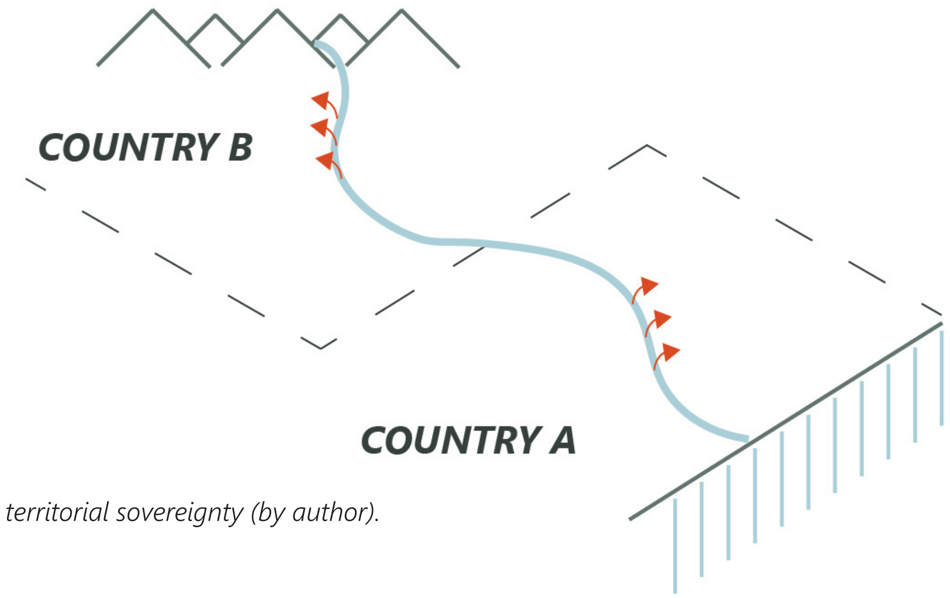



*figure 3.7: Limited territorial sovereignty (by author).*

### 3.1.6 Adaptive planning

The availability of water is dependent on various events and sources. High precipitation events can follow long periods of droughts and the other way around. Because these are uncertain events, the spatial planning dealing with such issues should be adaptive towards these events. This means, according to Rauws & Roo (2016), that planning itself should not envision only one possible future, but should assume various possible trajectories. Adaptive planning should in this case aim to support a range of configurations based on a set of goals or objectives. In cases of water availability, adaptive planning can support a wide range of amounts of available water. This should lead to the creation of plans in times of both heavy rainfall and droughts without being limited by certain conditions. The flexibility that this form of planning can offer, is a positive contribution to cooperative behaviour (Dinar et al, 2014).

### 3.1.7 Transboundary cooperation

With adaptive planning on a national level and only the extraction of resources in equitable and reasonable manner, a country within a watershed is still dependent on decisions by other countries. Transboundary cooperation can in these cases be of help. Even if treaties will not directly solve water related issues, they can form a platform on which negotiations are organised and can promote transparency on decision making about these shared water resources (de Stefano et al, 2012). Because these shared water resources are often not equally distributed spatially, national policies are not enough. Cooperation requires a high level of commitment to create resource allocations and shared policies, and can be difficult to sustain for a long period of time. Collaboration between several countries can prove to be an effective strategy, however it is unlikely to solve problems such as zero sum games. In these cases other strategies are needed (Imperial, 2005).

### 3.1.8 Resilience and Justice

It is inevitable for a system to come across shocks and surprises. Water levels depend on many factors which can not be exactly predicted on a long term. Climate change is one of the most urgent issues of this time, long term effects are uncertain and effects on precipitation are difficult to predict. In cases of droughts, the availability of water not only depends on the amount of rainfall, but also on external factors such as demand for water, efficiency of agriculture and availability of external or non renewable sources. For a system to overcome long period of drought it needs to be resilient. Resilience is defined as a system that can absorb shocks while remaining in the same state while also building the capacity to adapt and learn (Folke et al, 2002). Resilient urbanism seems to follow this definition, as its form is focussed on short term responses on shocks and emergencies. However, it should be cautious to not neglect long term adaptability and justice. Often, 'resilient urbanism', as reviewed by Davoudi (2014), is less focussed on long term objective. It should however not forget long term adaptability. Another downside with resilience is that resilience itself can be unjust. Fainstein (2015) discusses the fact that resilience should not be given as a label to justify unjust actions and gives the example of displaced communities because of protection against sea level rise. A just and resilient system should first look at the impact on vulnerable populations and develop alternatives that would protect and improve the situation of this group. Just and resilient urbanism should both be resilient to shock on the short term and be adaptive to long term changes while maintaining social justice. Vulnerable and poor populations should be prioritised. After each shock, just and resilient urbanism should aim to built back better.



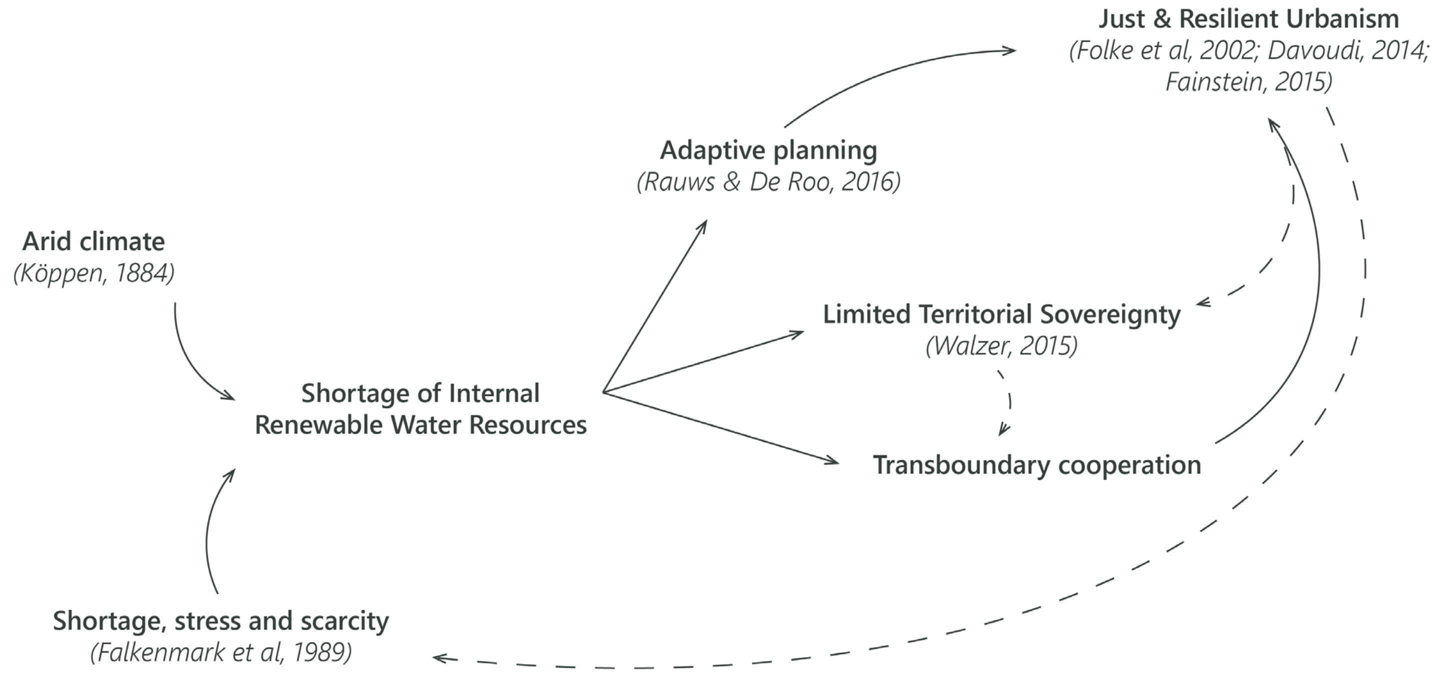
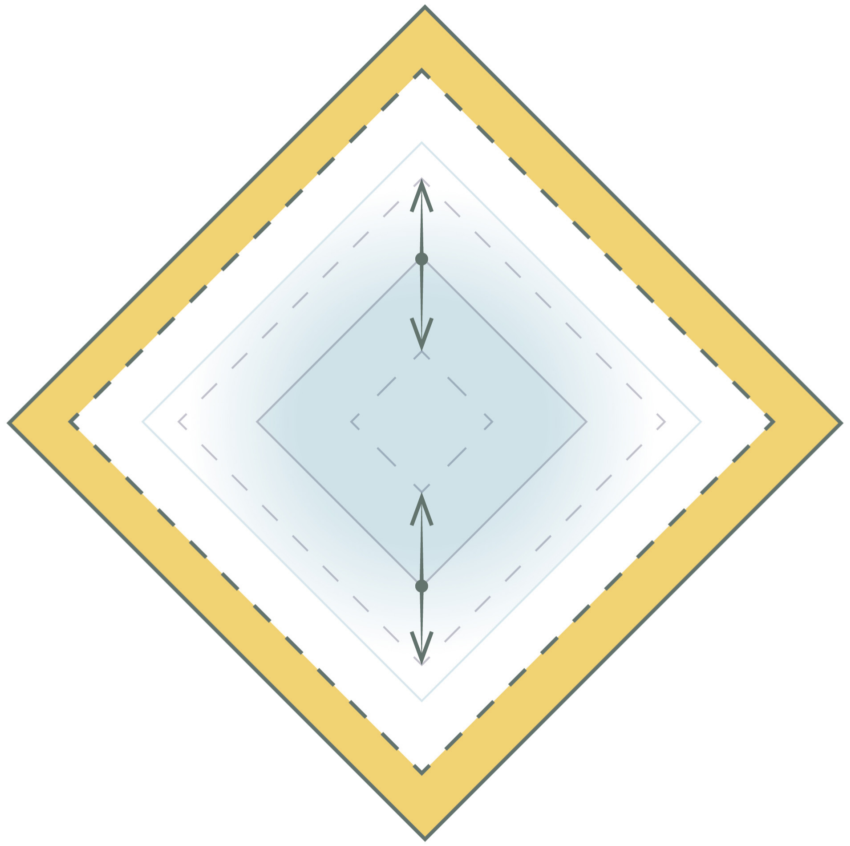
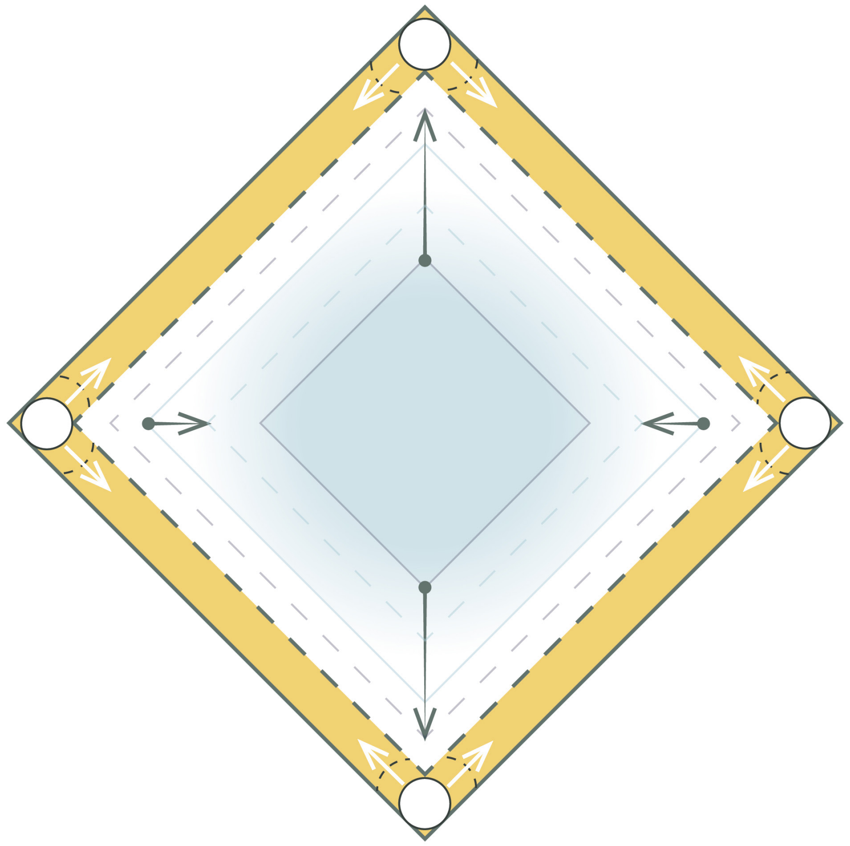


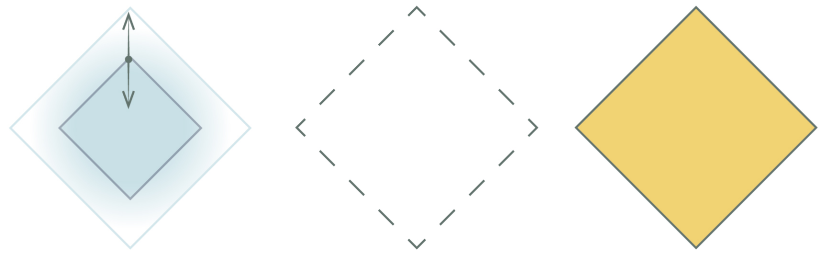

*figure 3.8: Theoretical Framework (by author).*





**1.**

*figure 3.9: Conceptual Framework, part 1 (by author).*




**2.**

*figure 3.10: Conceptual Framework, part 2 (by author).*


## 3.2 Conceptual framework

Both conceptual frameworks shown on the right illustrates the current situation and the transition. These pages will describe how the transition will be to the new and desired framework.

1.

Currently there are a lot of conditions resulting in water shortage. The demand for water is high, while the supply is not stable. Conditions like heavy rainfall and droughts cause a fluctuation in availability of water and countries are therefore experiencing a shortage of water. There are very little measures and plans in place to adapt to the variable availability of water and there is therefore a need for cooperation and adaptation to meet this demand for water.

2.

By improving the transboundary cooperation, countries can learn and benefit from each other. Countries will no longer use more water than needed, which leaves more water for others to use. Supply of water will therefore increase. In combination with a decrease in demand for water, due to the improved efficiency of use, countries will face less shortage of water.

3.

The framework on the next page illustrates the goal with its main aspects. It shows how a transboundary framework or strategy can bring countries together to serve a common purpose. This common purpose is resilience towards the threat of water shortage. When working together towards this goal, the efficiency of water use will be improved and therefore the use and demand will decrease. This will overall decrease the probability of water shortage in the region.

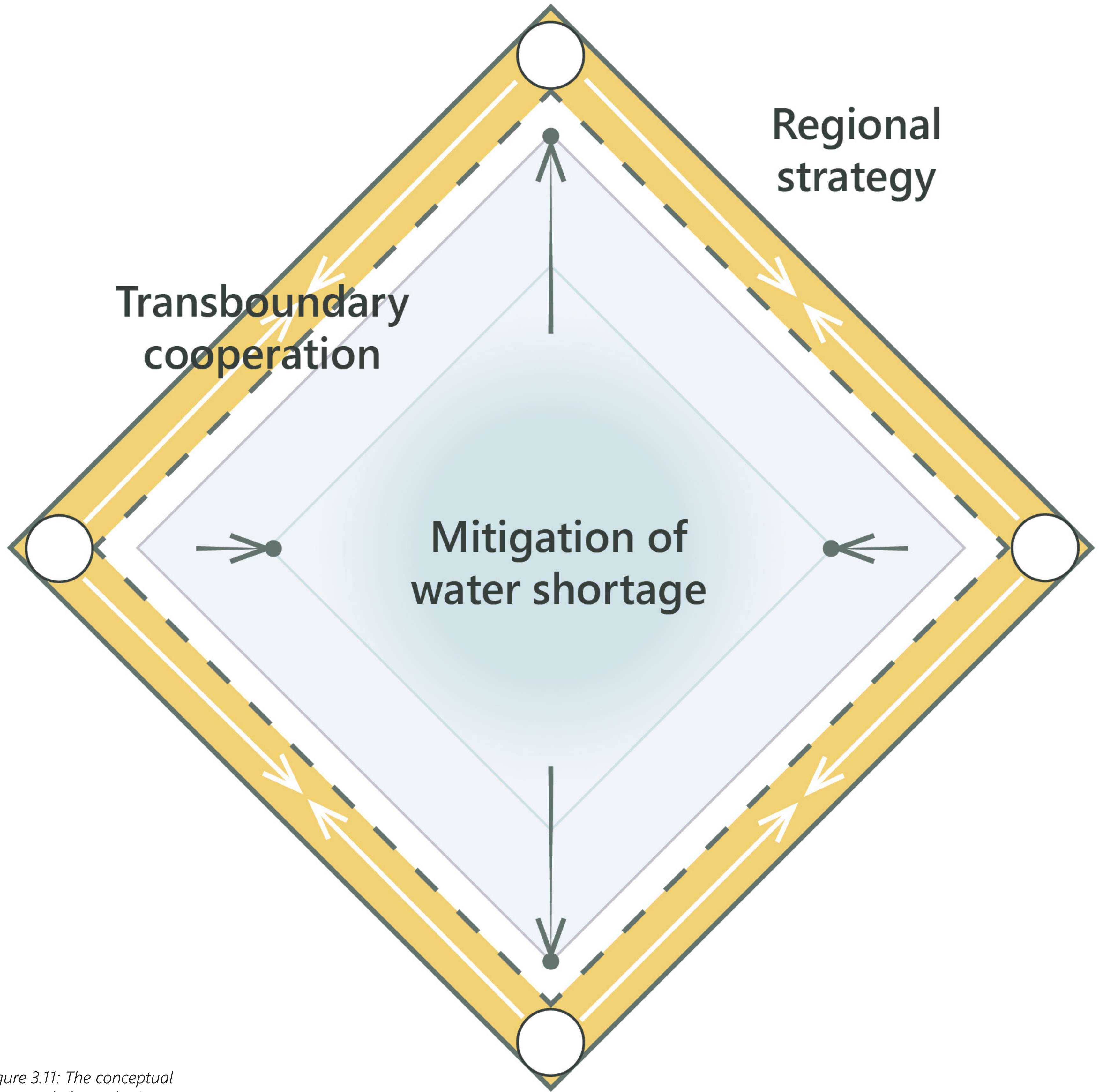



*Figure 3.11: The conceptual framework (by author).*

Image by Colin (2018), adapted by author.

# 4.1 Water provision and supply

Each country or region extracts its water from other sources and each country is dependent on other factors. Desert regions without nearby fresh water require groundwater extraction and villages near rivers depend on the wet season. In this chapter, first the two main sources for water in the region will be explained broadly: groundwater from the Nubian Sandstone Aquifer System and the Nile. This allows for better insight in these two sources, after which for each country the amount of water extraction and use will be explained. This will be done in combination with a map which shows the most important water bodies and their infrastructure.

### 4.1.1 The Nile

The Nile, one of the largest rivers in the world, shares its river basin with eleven countries. Among these countries are both Egypt and Sudan, which are the two downstream countries. The Nile river consists of two large rivers, the White and Blue Nile. These two rivers come together south of the capital of Sudan: Khartoum.

Further north, the river Atbara connects to the Nile. At the border of Sudan and Egypt, the Aswan High Dam forms Lake Nasser, from which both countries are dependent for their water supply. In the Nile delta, the river splits into multiple branches, out of which the Rosetta and Damietta branch are the two largest. These two branches then meet the Mediterranean Sea.

In this chapter, the Nile and its water will be discussed in the paragraphs about both Egypt and Sudan. In these paragraphs, the amounts of extraction and water use, will be further researched.

### 4.1.2 Nubian Sandstone Aquifer System

The Nubian Sandstone Aquifer System is one of the largest aquifers in the world. It spans all four countries discussed in this research and covers around 2.2 million km$^2$ (Foster et al, 2006). There has been very little recharge in recent years, which means that the source is depleting. Current extraction rates will deplete this groundwater source within the next 300 years (Foster et al, 2006). Because over the past year the amount of extraction from this aquifer system has been rising, the rate of depletion is increasing. It is therefore of importance that this aquifer is monitored and a long term plan is made (Ahmed & Abdelmohsen, 2018).


figure 4.1: Main water basins and the NSAS (by author).



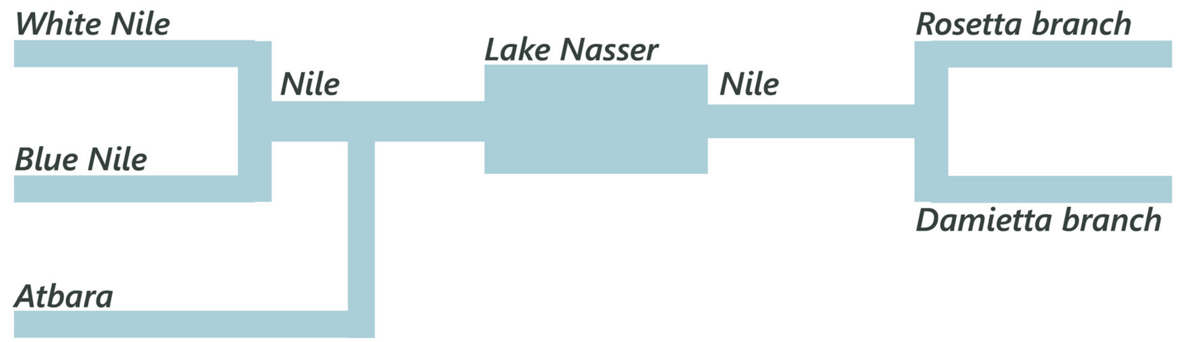
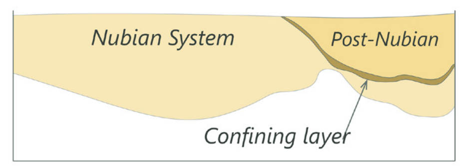



figure 4.2: Schematic overview of the Nile flow (by author).



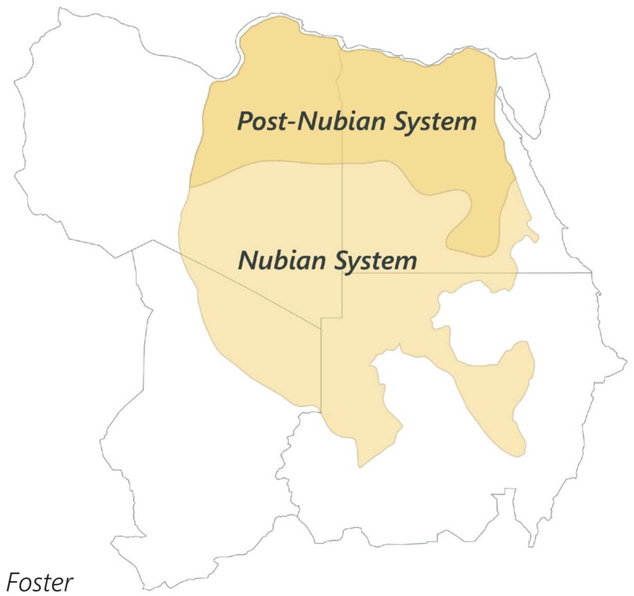




figure 4.3: Overview of the NSAS (by author, based on Foster et al, 2006).

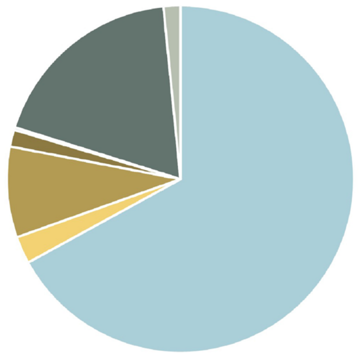
### 4.1.3 Egypt

The country of Egypt is mainly dependent on the Nile. Under the 1959 Nile Waters Agreement with Sudan, 55.5 BCM/year was allocated to Egypt, which flows from the Sudan via the Nile into Lake Nasser. This number was based on the annual flow from the Nile, 84 BCM/year at the time, excluding the evapotranspiration (FAO, 2016; Negm & El-Khouly, 2021). Because of the dependency on the Nile, Egypt is one of the worlds countries with the highest dependency ratio. Out of all the renewable water sources, more than 95% is external water (FAO, 2016).

Because of its climate and location, some towns and cities further from the Nile depend on groundwater sources. Most of the extracted groundwater is from shallow, renewable sources, which comes from seepage from irrigation canals, the Nile and irrigation loss (Negm & El-Khouly, 2021). This shallow groundwater is however easily polluted and therefore difficult to rely upon. A more reliable source of groundwater is the Nubian Sandstone Aquifer System, which is deep groundwater. The annual extraction was 2.1 BCM in 2017 and has been increasing in recent years (Negm & El-Khouly, 2021). The main threat with the extraction of groundwater is that this is a depleting source. Increasing the dependency on groundwater and thus the annual extraction, will result in a faster depletion.

Due to the rise in demand for water, Egypt has been looking to find other, more renewable sources. Annually, around 1.3 BCM is harvested from flash floods and rainfall (El-Rawy et al, 2020), with an increase in heavy rainfall due to climate change, this can be an opportunity to increase the collection of water from precipitation. Another unconventional source for water is the process of desalination. In Egypt, this is increasingly becoming a source for water in regions close to the Mediterranean and Red Sea, especially in tourism resorts. In 2010, the annual rate of desalination was around 0.2 BCM (FAO, 2016). However, in recent years this amount has been growing and there are plans to increase the capacity, size and amounts of desalination plants (Negm & El-Khouly, 2021).

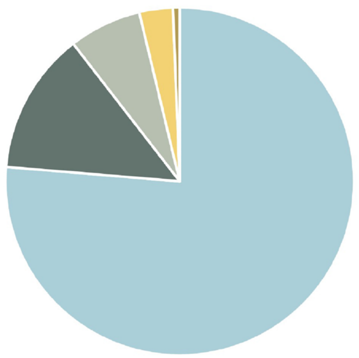
When there is limited available water, all water needs to be used as efficiently as possible. This is the reason Egypt has also been re-using agricultural and municipal wastewater. The re-use of agricultural drainage water contribute for 15.4 BCM annually and municipal wastewater is re-used for 1.3 BCM each year. There is however a limit to reusing agricultural water, which is estimated around 8 to 9 BCM each year, because of health and environmental risks (Negm & El-Khouly, 2021).



- Lake Nasser (67%)
- Deep groundwater (2,5%)
- Shallow groundwater (8,5%)
- Rainfall (1,6%)
- Desalination (0,2%)
- Re-used drainage water (18,6%)
- Re-used municipal wastewater (1,6%)

*figure 4.4: Water supply (by author).*

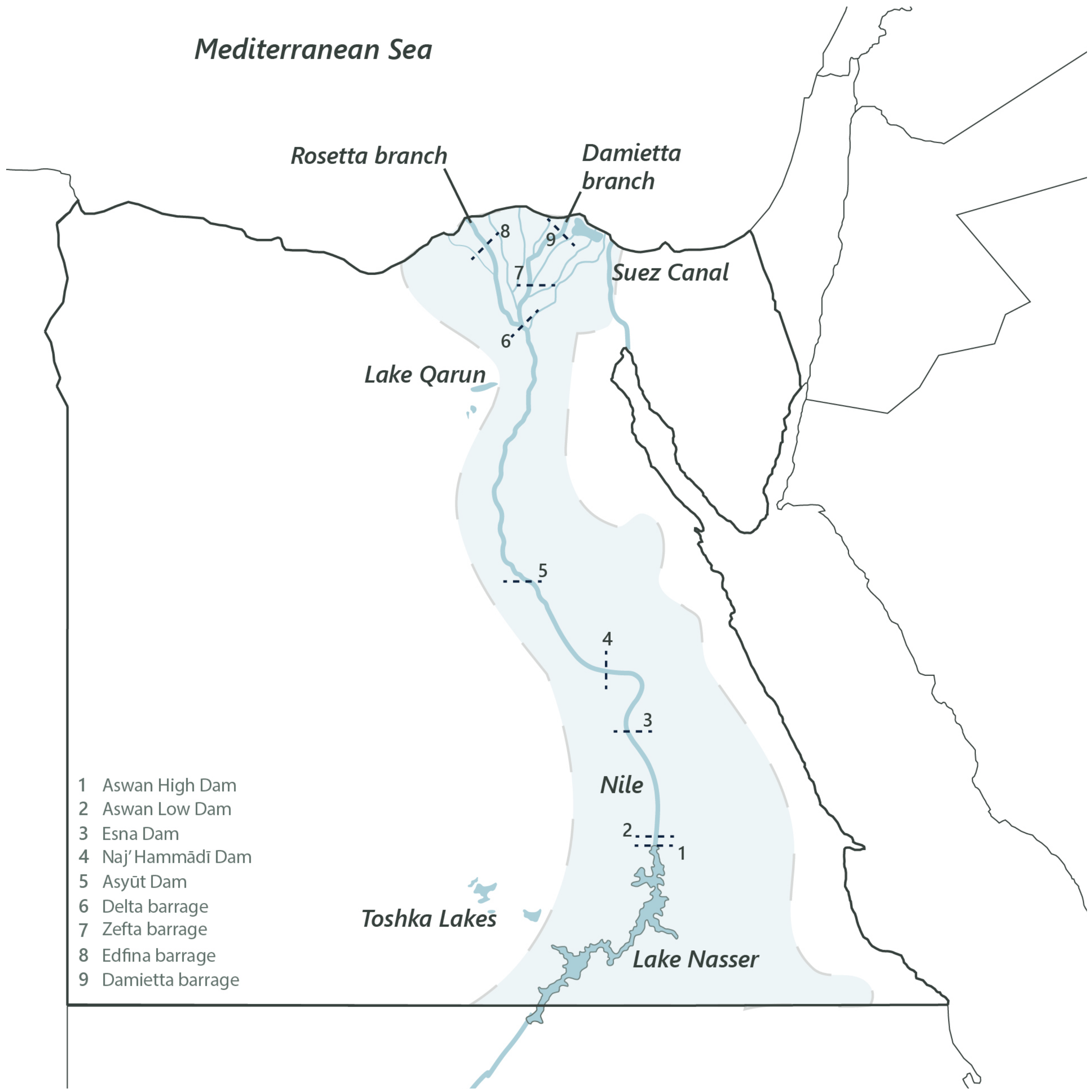
*figure 4.5: Water use (By author).*



- Agriculture (76%)
- Municipal use (13%)
- Net. Industrial use (7)
- Evaporation loss (3%)
- Environmental use (1%)



*figure 4.6: Water system in Egypt (by author).*



### 4.1.4 Sudan

Unlike Egypt, Sudan has a lot more water and is less dependent on external sources. This has a lot to do with the precipitation in southern Sudan, where rainfall is more common than in the dry northern region. In the centre of the country, at the capital of Khartoum, the White and Blue Nile meet and form the Nile river, which flows to the country of Egypt. At the border with Egypt in Lake Nasser, the water is divided according to the Nile Waters Agreement. At this location, 18,5 BCM is allocated to Sudan. Another (approximately) 19,3 BCM is extracted at other dams in the country (FAO, 2015). This is done at the following dams: Rosseires dam, Sennar dam, Jabal Awlya dam, Khashm dam, Merowe dam and the recently completed Upper Atbara and Setit dam complex (Khairy et al, 2019).

While most of the country is dependent on water extracted from dams along the Nile, a major threat is tied with this method of extraction: evapotranspiration. Current reservoirs along the Nile already cause around 5 BCM to evaporate annually and with the construction of more dams in recent years, this number has been increasing (Khairy et al, 2019). On top of this, is the evapotranspiration in the southern swamps of the country, which is approximately 19,3 BCM (FAO, 2015).

Water from the Nile is the major source for water in the country, however, a small amount of groundwater is also extracted, as well as surface water. Despite the fact that the country receives an average yearly precipitation of 250 mm, the extracted surface water only contributes 1 BCM each year. This high amount of rainfall, which will partly increase due to climate change, offers a lot of potential to provide the country with more water in the (near) future.

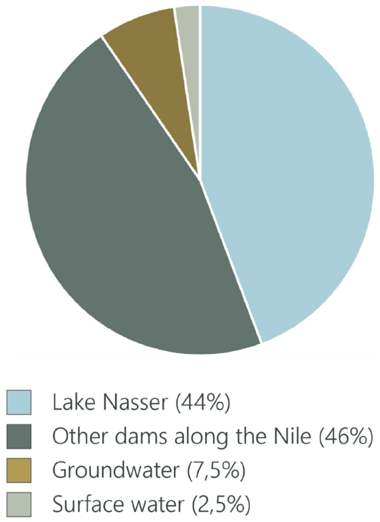



*figure 4.7: Water supply (by author).*

*figure 4.8: Water use (By author).*

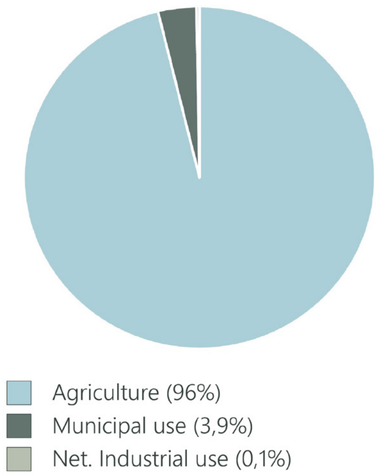



*figure 4.9: Water system in Sudan (by author).*

### 4.1.5 Libya

The country of Libya consists for a large amount of desert. Only a small strip of land along the Mediterranean coast is cultivatable and therefore used for agriculture. This is also the area where its major cities are located. Because the country consist for 95% out of desert land (Abdudayem & Scott, 2014), the country has very little renewable water resources, and therefore depends for the majority on groundwater. Its annual non renewable groundwater extraction is somewhere around 5 BCM and amounts for 85% of its total water supply (FAO, 2016). Next to this, the country also relies on renewable groundwater (10%), surface water (3%) and desalination (1%).

To transport the extracted groundwater, the country has constructed The Great Man-Made River, which transports water from the inland deserts to the north. In these northern areas, this water is mainly used for agricultural water. While the original plan was to use this extracted groundwater to reclaim desert land for agriculture, urban and industrial demand were too high (Sowers et al, 2010). This Great Man-Made River project consists of various phases, in which it was completed. The current situation of the project is shown on the image on the right page, where all the different extraction sites are noted.

Despite the large extraction of groundwater, the country has faced various water shortages in the past. In these periods, urban and industrial water have a priority over agricultural water, which can lead to less agricultural output. Because the most of the food is used for domestic use (only 0,3% of agricultural produce was exported in 2009), these events of scarcity can cause prices to rise and ultimately can result in food scarcity (Abdudayem & Scott, 2014).

In recent years, the prices of groundwater have begun to rise. This is mainly because of the increased depth out of which water needs to be pumped. Because desalination methods have become cheaper, groundwater is now almost as expensive as desalination (Sowers et al, 2010). This might cause a shift towards the use of more (sustainable) desalinated water. In a country where the (renewable) water resources are limited, every possible method must be investigated to increase the amount of water supply. In the future, sustainable desalination in coastal areas seems promising, however current desalination plants are not sustainable enough. Next to this, most plants in Libya are not well maintained which worsens the efficiency of these plants.

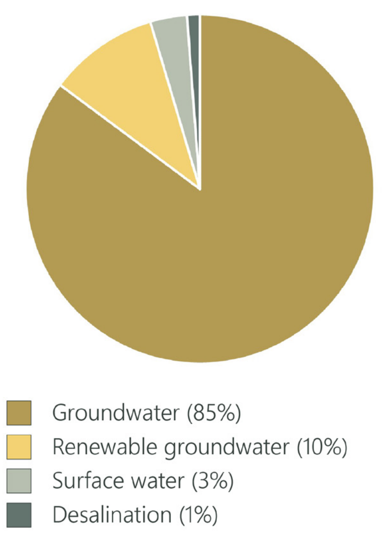



*figure 4.10: Water supply (by author).*

*figure 4.11: Water use (By author).*

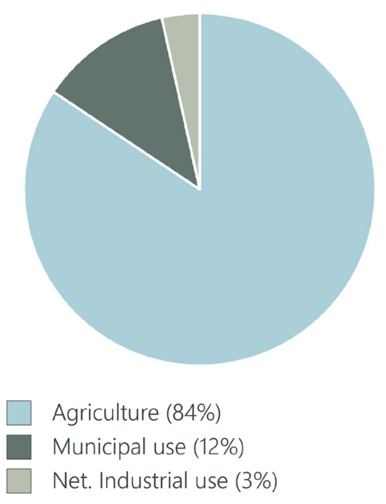
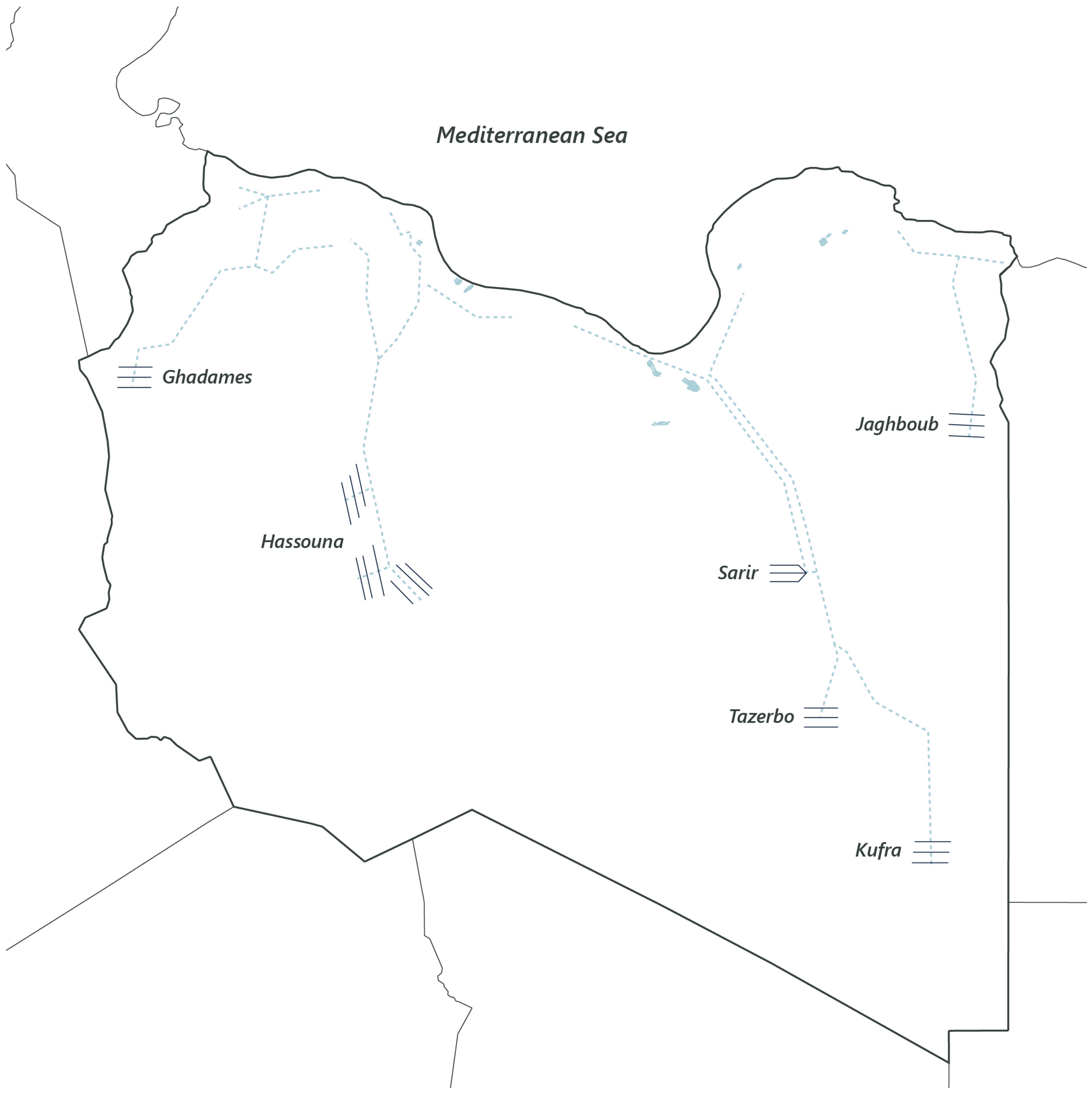





*figure 4.12: Water system in Libya (by author).*



### 4.1.6 Chad

Chads major water systems are linked to its major lake: Lake Chad. Both the Logone River and the Chari are located in the south and flow through its capital N'Djamena towards the lake. Similar to the situation of Sudan, Chad gets most of its water from these rivers, which provide the country with external surface water.

One of the main threats to the country is the drying of Lake Chad. This lake has been drying up in the 1980s which severely decreased its size. Current increasing population and rising temperatures due to climate change remain to put the lake at risk of further degradation (Pham-Duc et al, 2020).

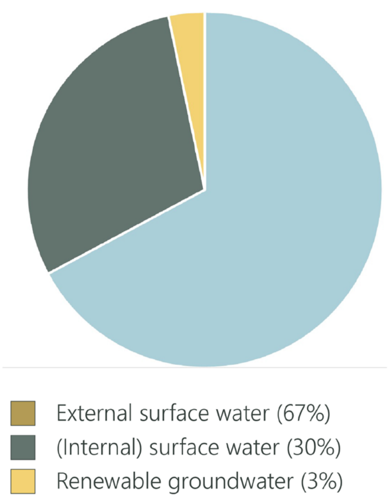



*figure 4.13: Water supply (by author).*

*figure 4.14: Water use (By author).*

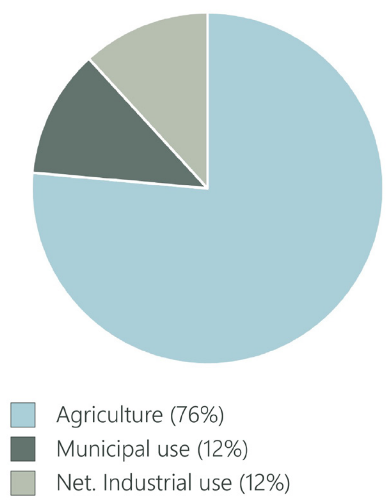



*figure 4.15: Water system in Chad (by author).*

### 4.1.7 North-East Africa

As can be seen in the image on the right, most major cities are located next to or near a major water body. These water bodies allow for either fresh water or a strategic (coastal) location for international trade. All four countries depend on several water sources, with the Nile providing Egypt and Sudan with the majority of water, Libya provided by groundwater and Chad provided by other, smaller rivers and its lake. It can be said that for each country, different problems can arise. When one country is dealing with shortage of water, another might have enough to supply its demand. By improving dialogue in the region, countries can improve cooperation which can result in more resilience towards periods of drought.

Next to this, it is important to take into account the importance of the Nubian Sandstone Aquifer System, which provides a large part of the region with fresh (unsustainable) water. Stepping away from this resource can be a major challenge, however it needs to be taken into account to improve the resilience and sustainability of the region.

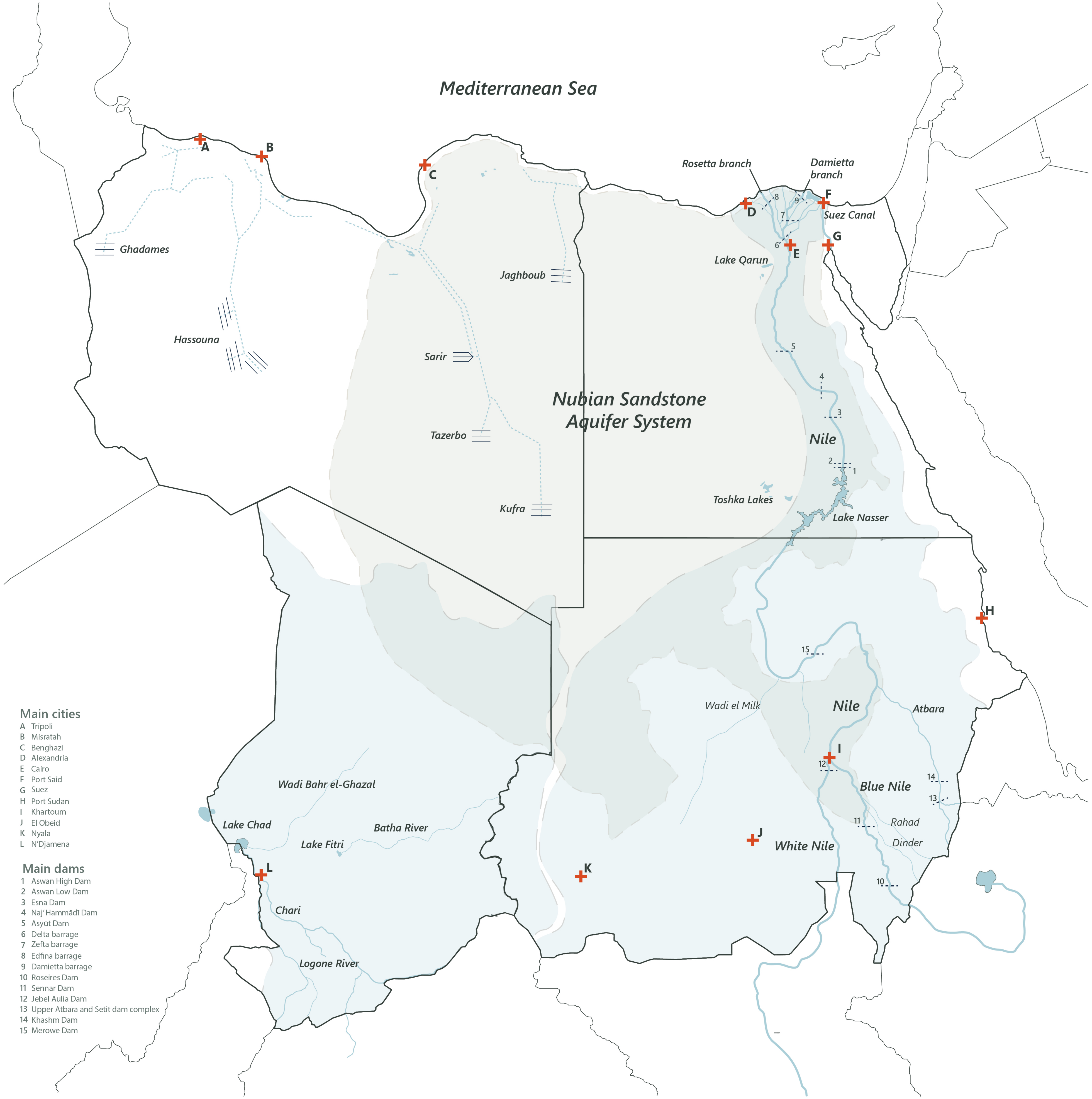



*Figure 4.16: The regional water systems (by author).*

# 4.2 Stakeholders

In this chapter, a stakeholder analysis will be done. This analysis will be done by looking at the following items:

**Scale**
The scales this analysis will take into account are the following: the local, national, supranational and global scale. The local scale takes into account all stakeholders that are bound by smaller regions and are not acting on a national level. The national level stakeholders are parties that are representing their interest on a nation wide scale. The supranational stakeholders differ from the global stakeholders in the sense that these are on the level of multiple countries but do not span entire continents.


**Sector**
The stakeholders will be divided into the following three groups:


**Countries of interest**
Not all stakeholders act in all four countries, therefore a distinction is made so that in a later process this can be filtered. This can be of use in a later stage, because when zooming in, several stakeholders become of higher importance than others.

**The supply – use process**
On the right page, an image with the water supply and use process is shown. This process starts at the conservation of nature and water resources and ends at the re-use of wastewater. Some stakeholders only have interest or power in one of these parts. Therefore, a distinction need to be made for each stakeholder, where these have impact on.

**Power / interest**
Each stakeholder will be mapped according to their level of power and interest. This will be done in a power-interest matrix. In this matrix, the axes consists of the level of interest and power where each stakeholder is placed upon.



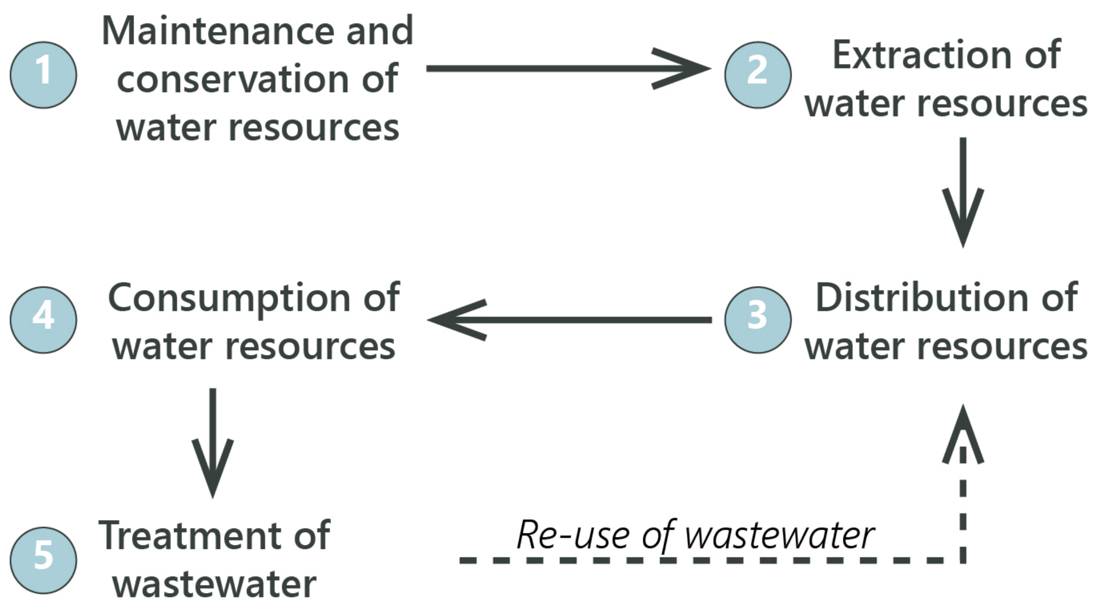



*Figure 4.17: The process from maintenance to re-use of wastewater (by author).*

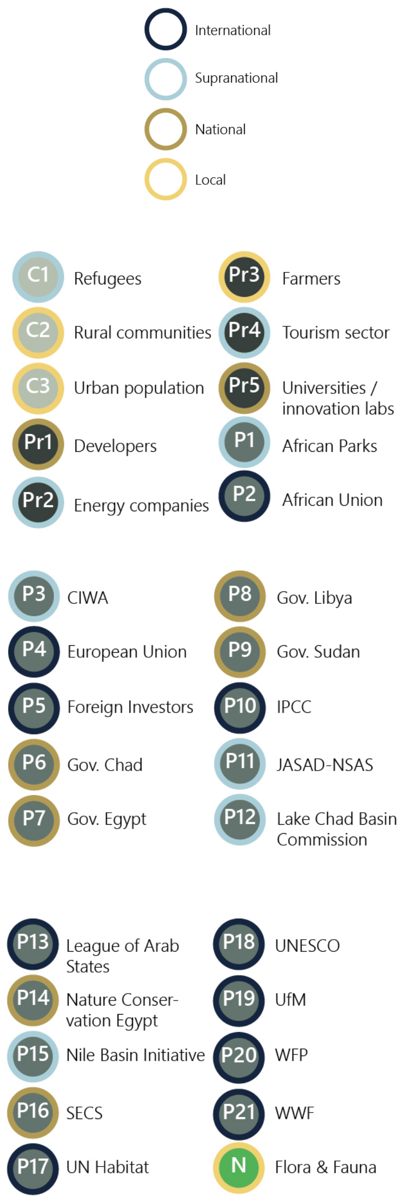
### 4.2.1 Maintenance and conservation of water resources

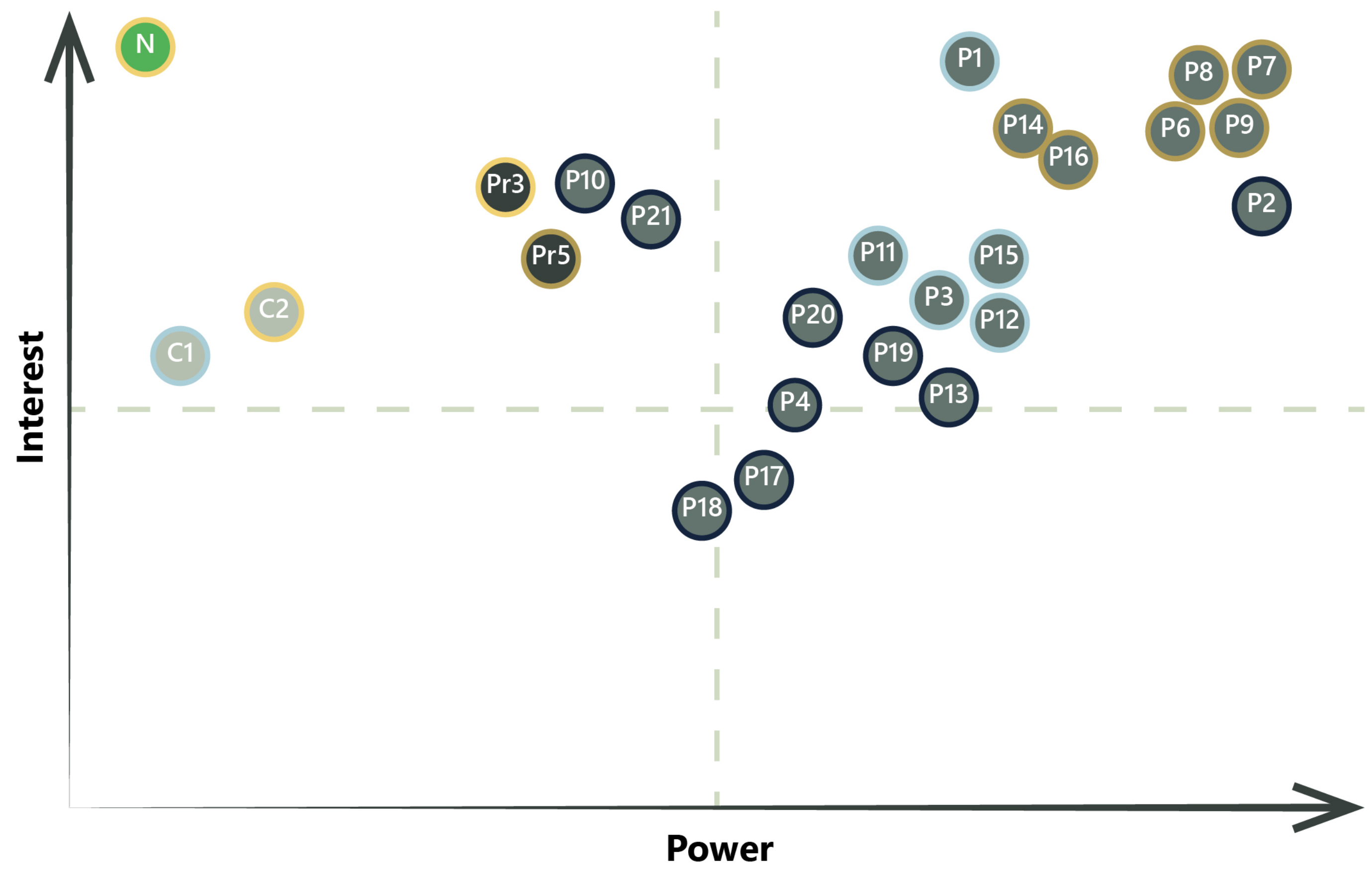
Maintenance and conservation of resources is done at different scales. On large scales, important nature areas need to be protected while on a small scale local water sources need to be protected against pollution. Besides the governments of each country, the most important stakeholders are stakeholders involved in conservation of nature and the environment. These are African Parks (P1), Nature Conservation Egypt (P14) and Sudanese Environment Conservation Society (P16). While these are very important and influential stakeholders, others dealing with the water resources and their region need to be involved as well. These are stakeholders like CIWA (P3), the Nile Basin Initiative (P15) and the Lake Chad Basin Commission (P12). Meanwhile, when dealing with a large region such as this, the African Union is also a major stakeholder, especially when dealing with transboundary regions.

### 4.2.2 Extraction of water resources

During the extraction of water resources, the most important stakeholders are the ones involved in the management and strategies for the specific water resources. These are stakeholder such as CIWA (Cooperation in International Waters in Africa, P3), the Nile Basin Initiative, the JASAD-NSAS (Joint Authority for the Study and Development of the NSAS, P11) and the Lake Chad Basin Commission. Most of these stakeholders are transboundary and together with the governments and the African Union, they form the most important stakeholders for the extraction of water resources. This means that in this phase, cooperation between countries is one of the most important elements.

*Figure 4.18: Power-interest matrix for maintenance and conservation stakeholders (by author).*



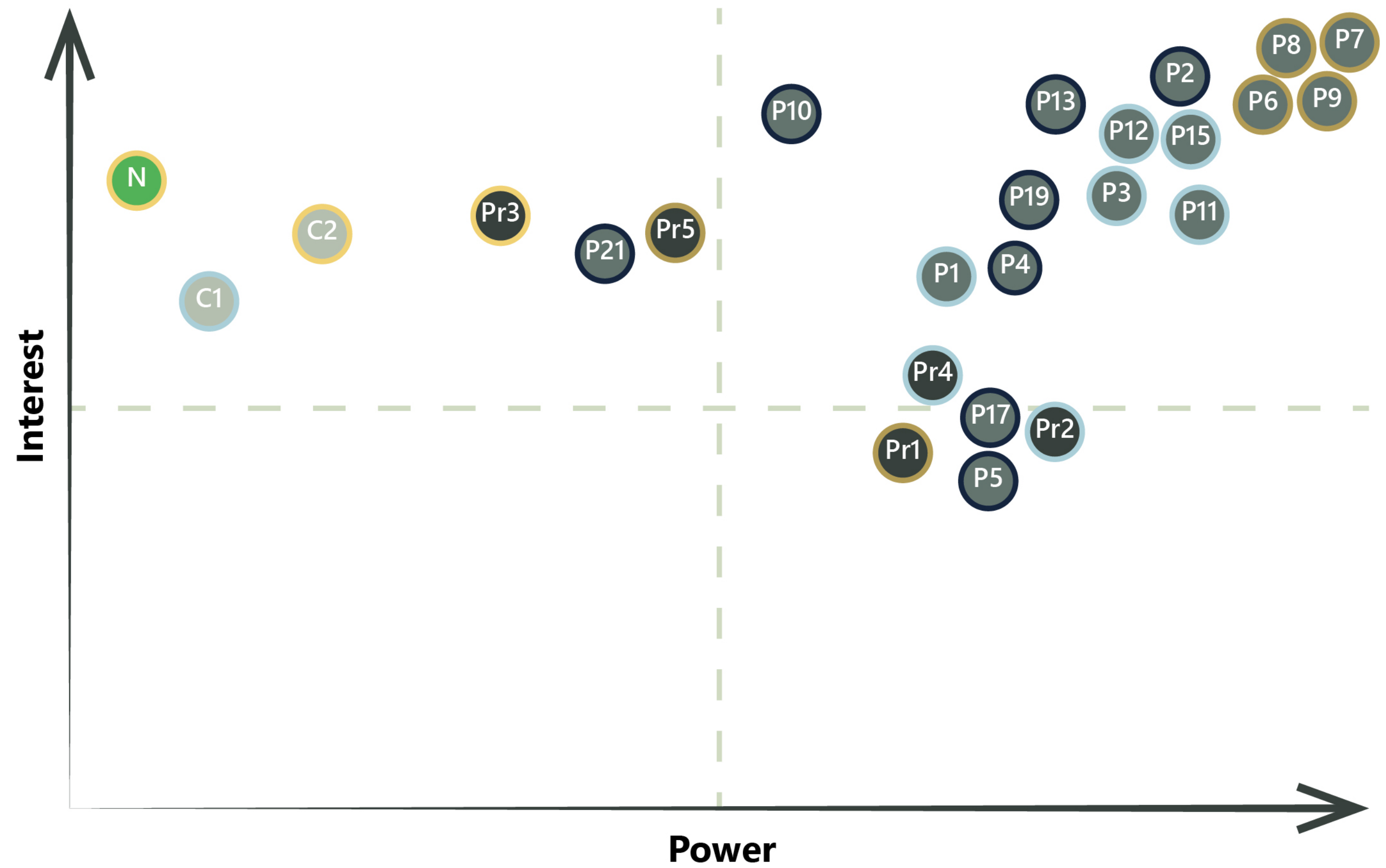




*Figure 4.19: Power-interest matrix for extraction stakeholders (by author).*

### 4.2.3 Distribution of water

For the distribution of water, more local and national stakeholders are involved. Besides the governments of the specific countries, developers play a major role. Developers can make sure city expansions gain proper access to drinking water and can make sure older parts of the city get renewed with more modern systems. The users: urban and rural population as well as farmers, are the groups with most interest, while lacking power. Governments must make sure that these stakeholders are represented in decision--making.

### 4.2.4 Consumption of water

Even though the government is the stakeholder most in power during this part of the process, its interests lays mainly at the users of water: farmers, urban and rural population. Due to the fact that farmers use most of their country's water resources, this is the group with the most interest in changes in this part. Furthermore, there are a wide range of supra- and international stakeholders also interested in this part since disruptions can cause negative external effects. Especially when this is about shared resources.

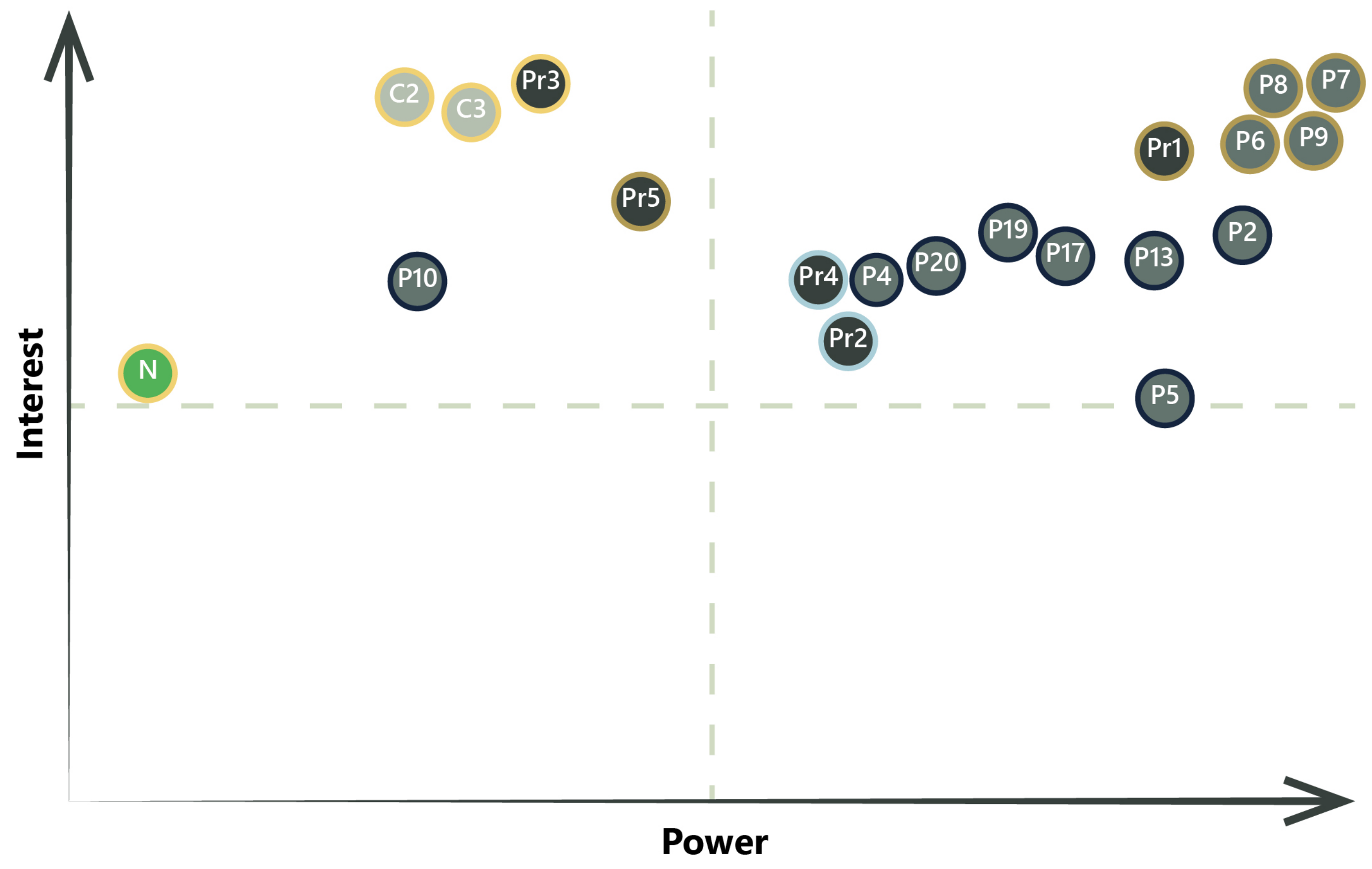
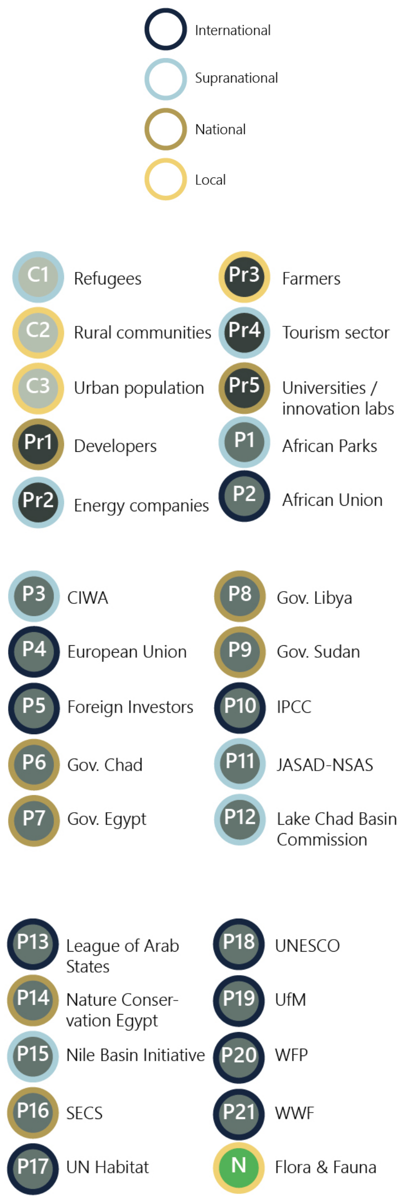



*Figure 4.20: Power-interest matrix for distribution stakeholders (by author).*



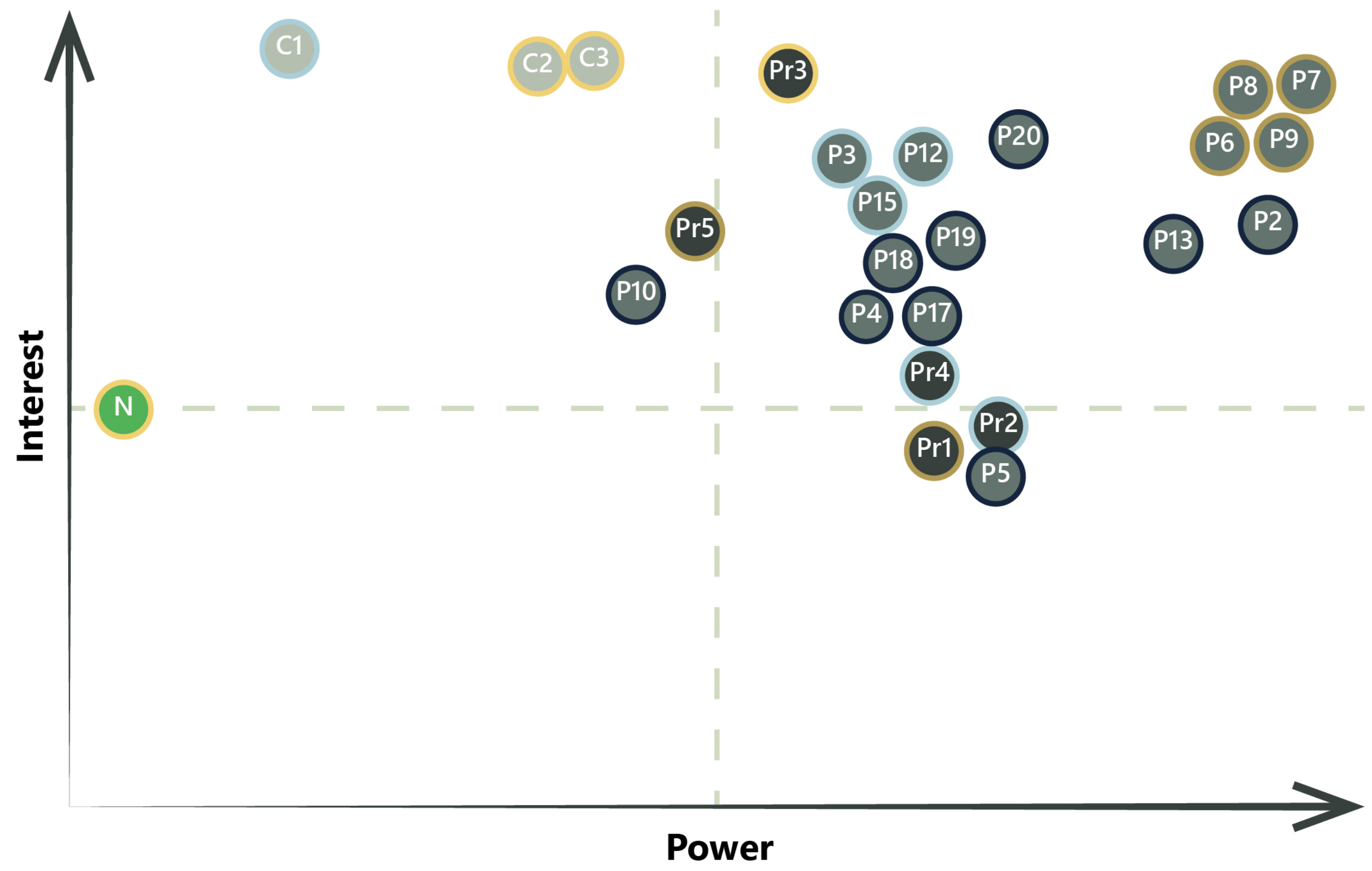




*Figure 4.21: Power-interest matrix for consumption stakeholders (by author).*

## 4.2.4 Treatment and re-use of water

For the last part of the process, there is a slight difference between the treatment and re-use of water since both affect the stakeholders differently. Worth noting is that this is the part where the user has the most power, since these groups can re-use (and treat) water themselves. Next to this group there are supranational stakeholders who have high interest due to the effect on the transboundary water use and international stakeholders who have higher power due to their influence on decision-making.

## 4.2.5 Conclusion

Previous pages have shown that for every part of the process, other stakeholders are involved. It is however also clear that the most important stakeholders have influence or interest in all parts of the process from conservation to reuse. Besides the governments of the individual countries, there are multiple groups of stakeholders visible. The most important groups are the following: the users of water (e.g. farmers), the supranational stakeholders involved with management of water resources and a group of international stakeholders who have influence on decision-making of the governments (e.g. the African Union). When proposing and implementing a strategy, it is important to keep in mind the demands and influence of these stakeholders to try to involve them wherever possible.

*Figure 4.22: Power-interest matrix for treatment stakeholders (by author).*

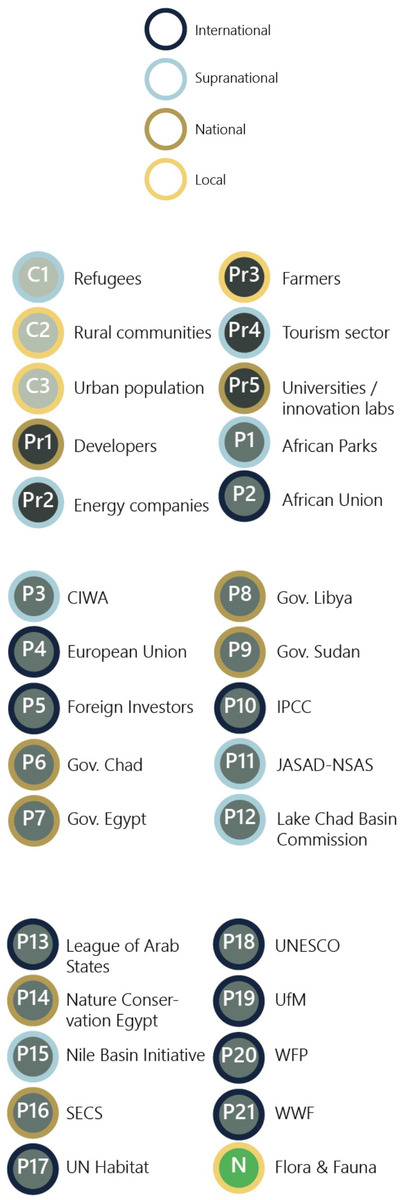
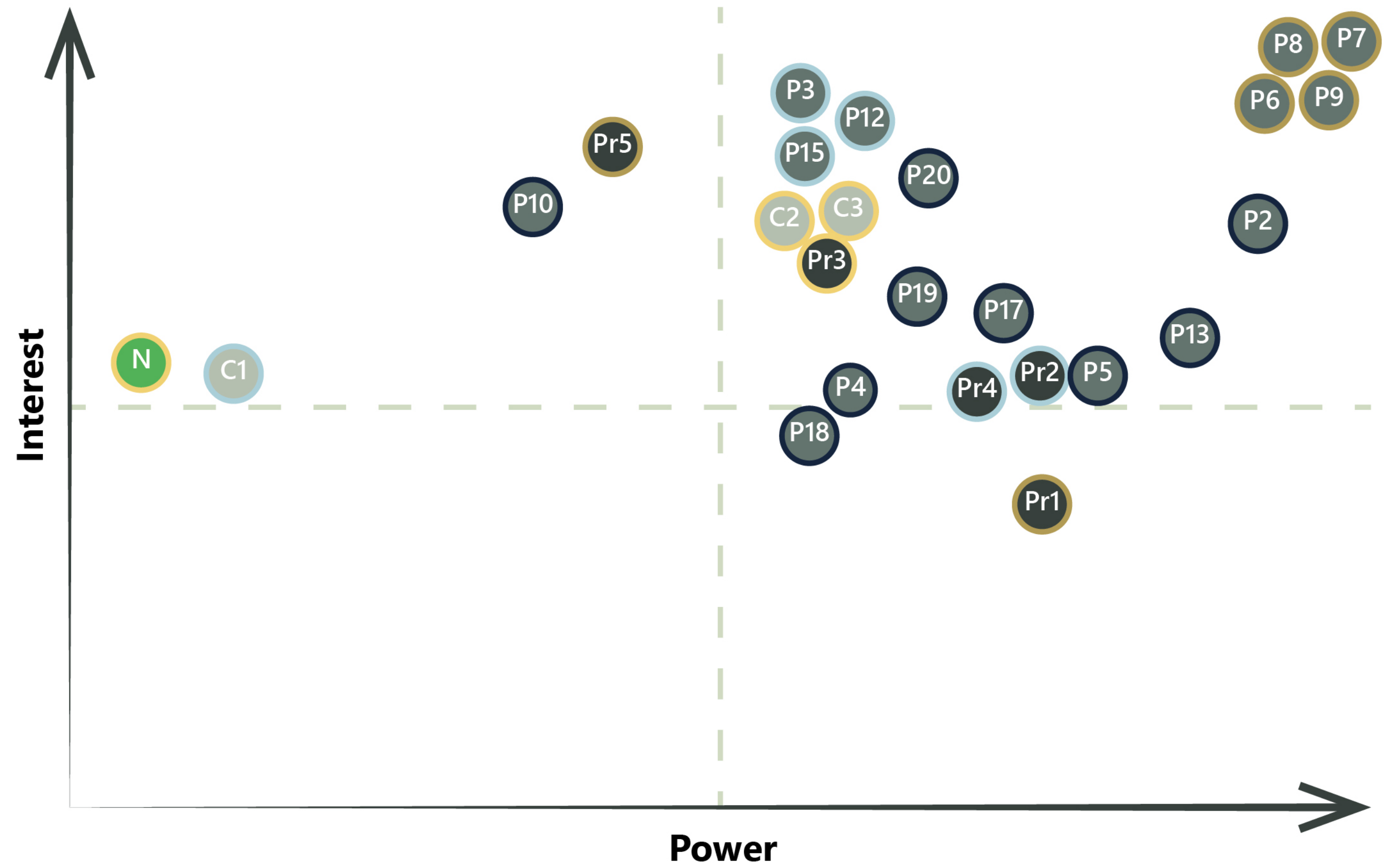
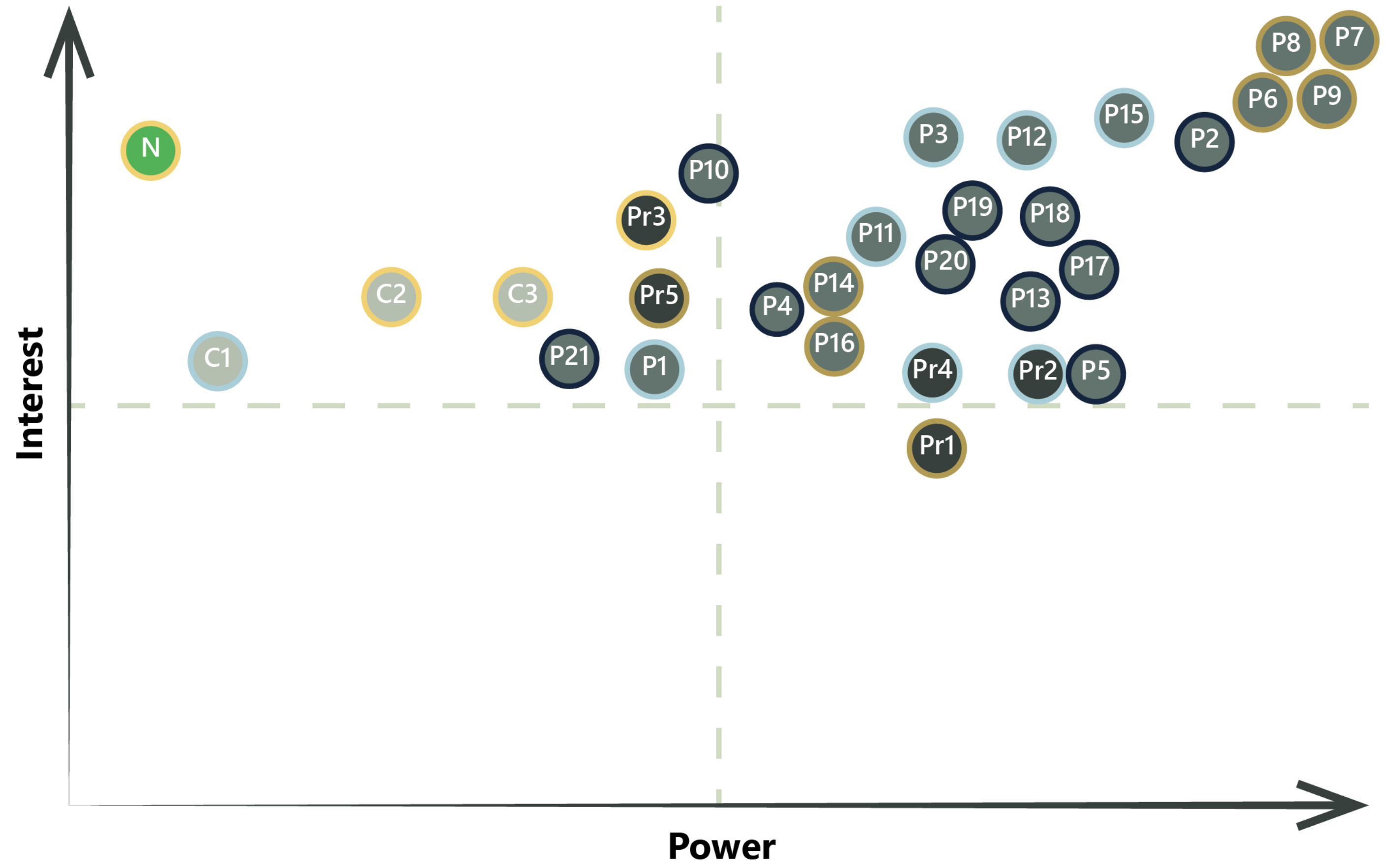



*Figure 4.23: Power-interest matrix conclusion (by author).*





## 4.3 Existing strategies

In the North-East African region, there are already various policies, strategies and plans in place that promote cooperation. When trying to create a trans-boundary strategy for this region, it is important to know and take into account these various strategies and try to create one that is in line with existing plans. In this chapter, existing plans will be looked at and it will be tried to define the core idea for these plans. After this analysation, there will be tried to define core themes and principles for the region as a whole, which can be used at a later stage when defining themes for a strategy.

#### 4.3.1 Lake Chad basin action plan

This is the main action plan for the Lake Chad basin and is created for the years 2015-2025. The Lake Chad basin consists of many countries, among which are the three countries of Libya, Sudan and Chad. The Lake Chad Basin Commission (LCBC) is a commission with the goal to protect and manage water resources in and around Lake Chad. The action plan, created by the LCBC, has the goal to not only restore security and peace in the basin, but to also create a hub for regional development. The idea is that this hub should improve food security, employment and social inclusion.

To do this, seven priority themes are listed, which are the following:

- Supporting producers and their value chains
- Securing access to natural resources and managing conflicts
- Improving living conditions through public investments
- Facilitating transport and trade
- Preserving the environmental capital of the lake
- Better managing the water resources of the basin
- Dissemenating information, improving knowledge, and monitoring of the environment

(Lake Chad Basin Commission, 2016)

#### 4.3.2 Union for the Mediterranean action plan

The Strategic Urban Development Action Plan, in short Action Plan, has been created as a goal for the year 2040 and serves as a framework to offer sustainable urban development across the Mediterranean. It does so by encouraging coordination, promoting partnerships and local empowerment, highlighting the role of heritage and by supporting implementation and monitoring of spatial interventions.

The Action Plan has six main strategic actions, which are the following:
- To coordinate & enhance cohesion
- To educate & strengthen capacity
- To envision & govern together
- To connect & protect
- To implement & manage
- To monitor & communicate

These actions are presented as a wheel, which means that there is no beginning and end and they should continue to reinforce each other. Each action has a set of key objectives and tools, which can be used by both national and local governments (Rocco et al, 2021).

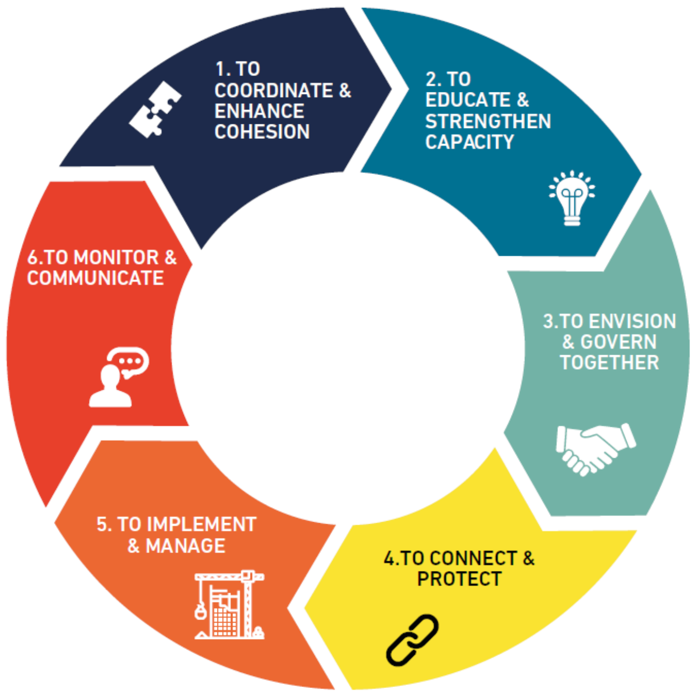



*Figure 4.24: UfM action plan illustration (Rocco et al, 2021).*

#### 4.3.3 NBI Strategy 2017-2027

The Nile Basin Initiative is a neutral platform for all basin states to collaborate and discuss water related issues. It aims to maximize win-win situations and decrease risks for current and future generations. The initiative has created a strategy to serve the objective of achieving sustainable socio- economic development and utilizing and benefiting from the shared water resources in a equitable manner. An important note is that Egypt did not participate in the consultation for the strategy. The strategy has created the following six goals:

- Enhance availability and sustainable utilization and management of transboundary water resources of the Nile Basin

- Enhance hydropower development in the basin and increase interconnectivity of electric grids and power trade.

- Enhance efficient agricultural water use and promote a basin approach to address the linkages between water and food security

- Protect, restore and promote sustainable use of water related ecosystems across the basin

- Improve basin resilience to climate change impacts

- Strengthen transboundary water governance in the Nile Basin

(Nile Basin Initiative, 2017)

## 4.4 Urbanisation

This chapter aims to analyse the development of the region and its cities. This will first be done by looking at the larger, region scale. Analyses on this scale will provide insight in the connections, similarities and contradictions of the region. When zooming in, a typology will be created to analyse several cities and villages by their level of importance and their location. This location will be based on the forms of extraction. This smaller scale analysis will be done by using the three layer approach, which will explore the occupation, networks and substratum layer. This approach, in combination with sections will create a typology which can be used at a later stage.

*Figure 4.25: Regional map showing urban areas and vegetation (by author).*

### 4.4.1 Growth of metropolitan areas

On the right page, maps with the size of metropolitan areas and their growth between the years 2000 and 2020 are shown. The largest metropolitan areas are located next to the Nile, which can be explained by their strategic location next to a major water body. When looking at the growth between the years 2000 and 2020, it can be noticed that every metropolitan area has been growing the past 20 years. However, there are various differences in amount of growth, especially when comparing this growth to the growth of their respective countries.

In Libya, all cities have been showing an increase in population. However, the capital Tripoli (113%) has grown less than the country itself (128%) and other major cities Benghazi (149%) and especially Misratah (298%) have seen a far greater increase in size. In Egypt, there is much less difference in growth between cities. While the primary and capital city of Cairo has shown a growth of 153%, this is comparable with other cities of Alexandria (149%), Suez (143%) and Port Said (145%). Meanwhile, the country itself has also shown a similar growth pattern (149%). Moving south and looking at the countries of Chad and Sudan, the growth is much stronger. While Sudan has shown a growth of 160%, Chad has almost doubled in size (196%). Metropolitan areas in these countries have also been exploding, with the cities of Nyala (280%) and N'Djamena (206%) as best examples.

This information is important when creating a strategy for the region, because the difference in growth can have very different consequences of this strategy. Mildly growing cities require a different approach than the exploding metropolitan areas.

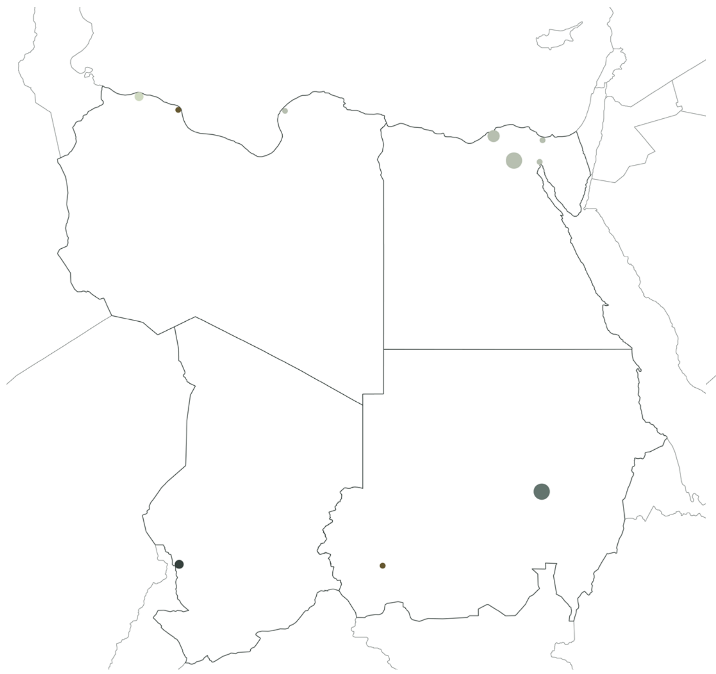



*Figure 4.26: Growth of metropolitan areas between 2000-2020 (by author).*

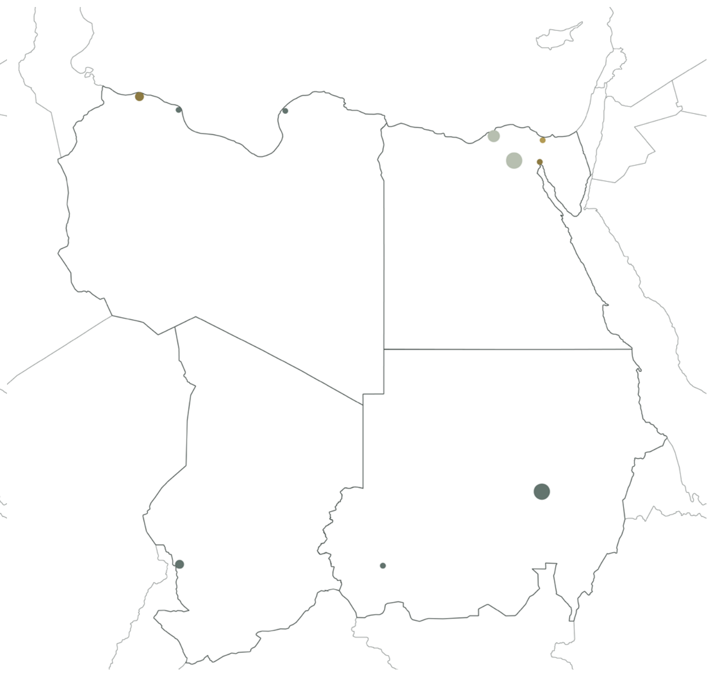



*Figure 4.27: Growth of metropolitan areas between 2000-2020, compared to their country (by author).*

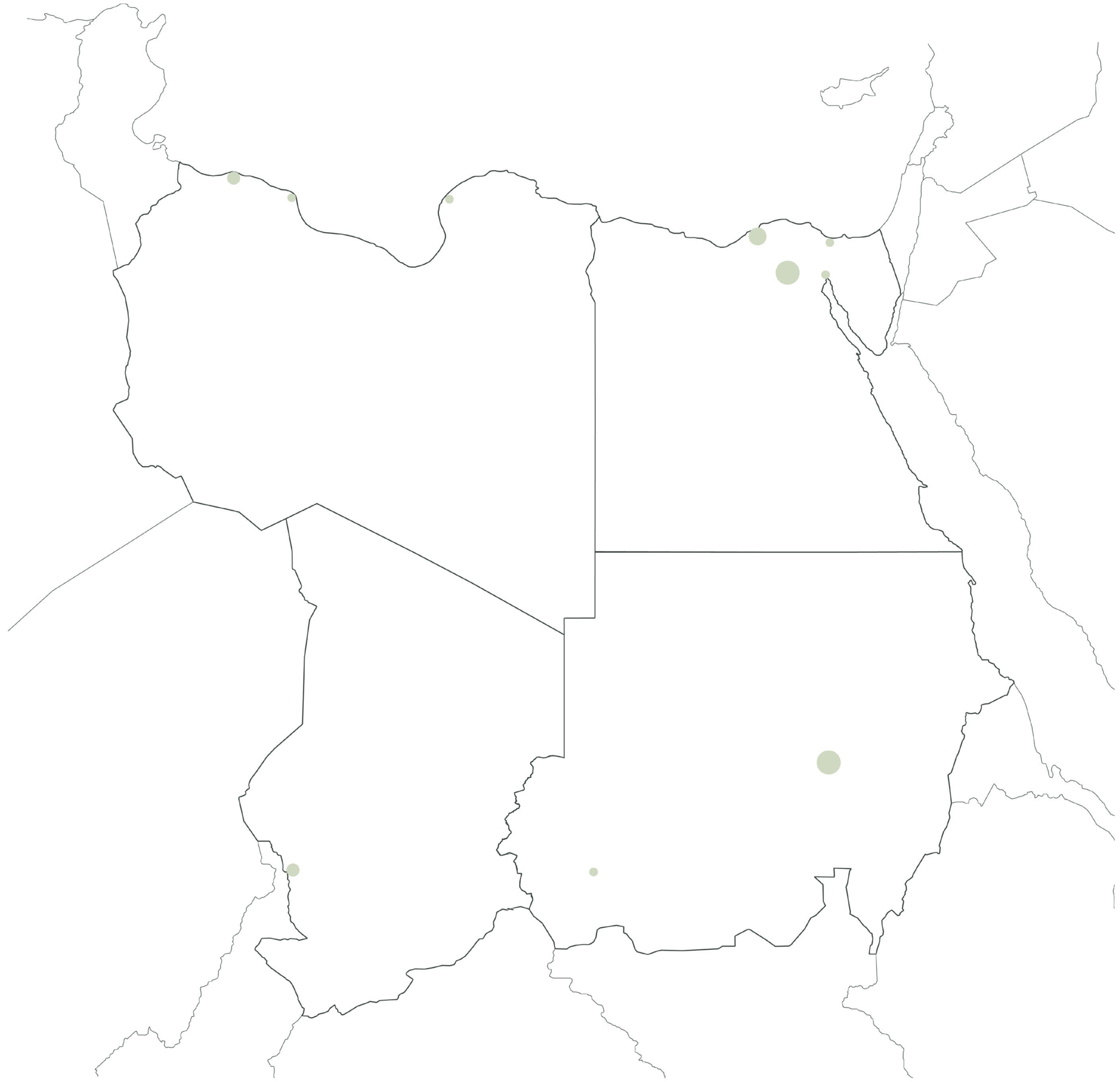



*Figure 4.28: Size of metropolitan areas (by author).*

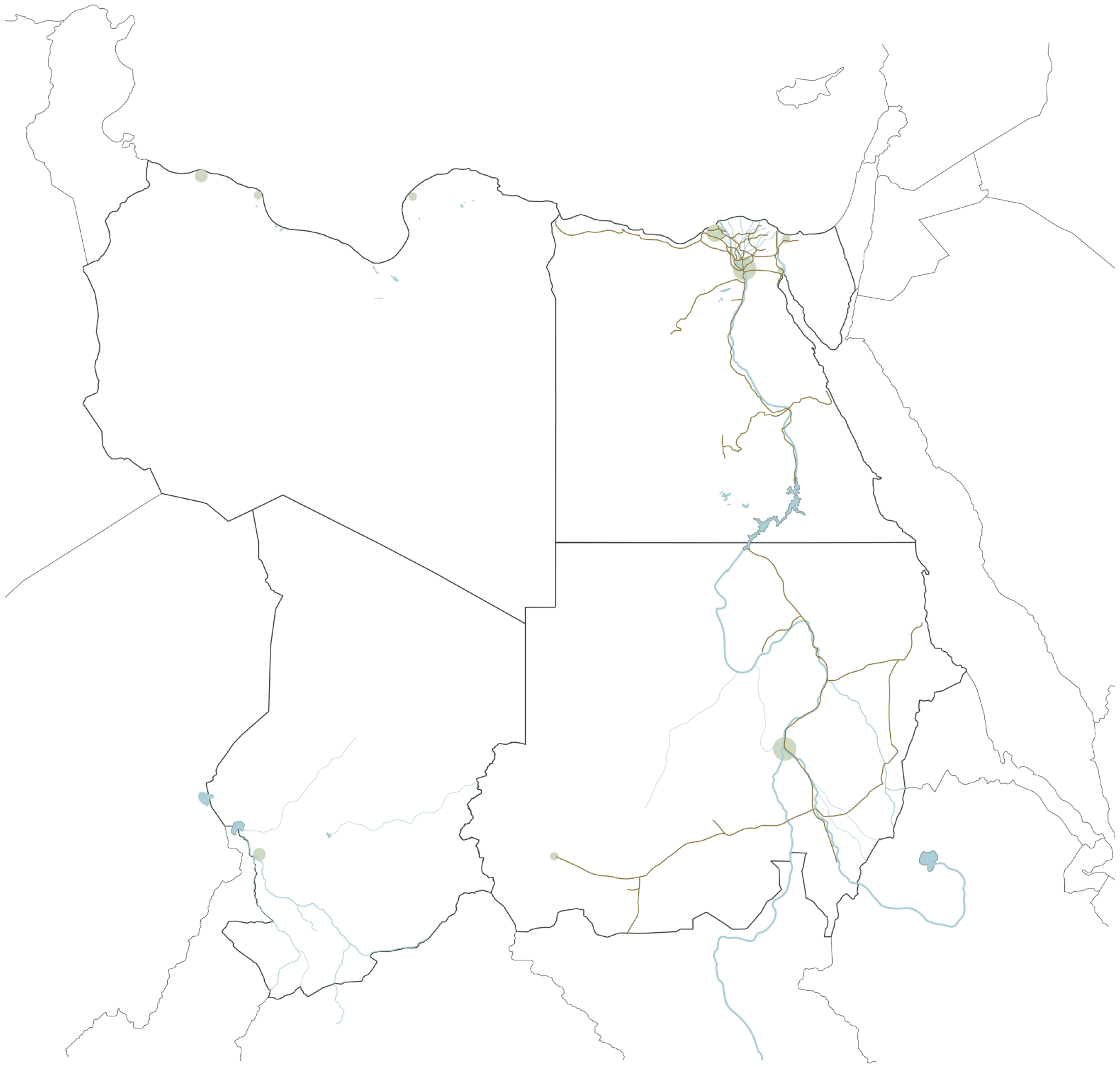


*Figure 4.29: Rainway network (by author).*



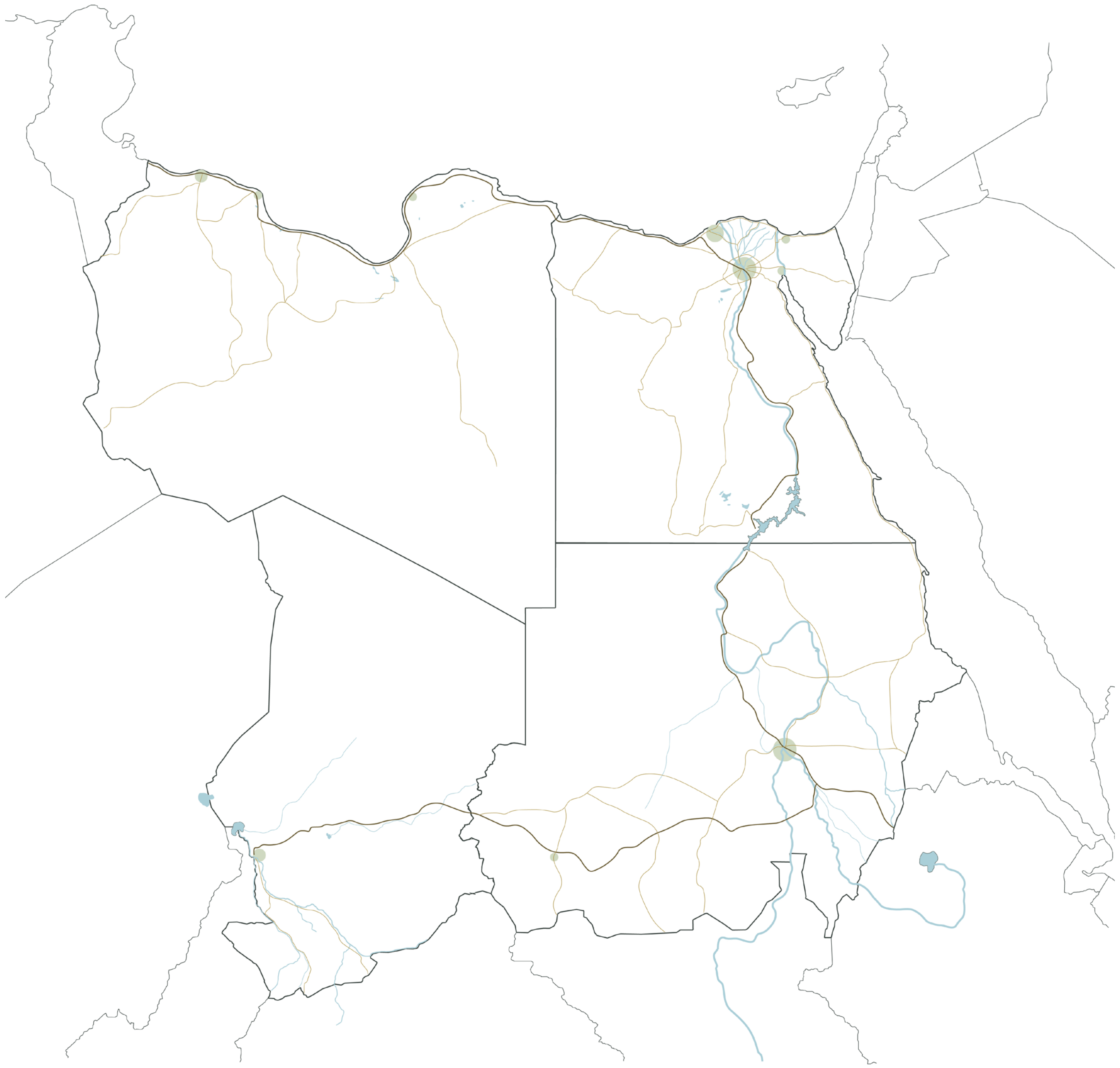


*Figure 4.30: Road network (by author).*


Image by Hanssen (2021), adapted by author.

## 5.1 Introduction to the Typology

To zoom in, a typology will be created. Cities and villages will be picked according to two aspects: their location in relation to a water body and the rank of the city or village (primary, secondary, tertiary). This should then provide a number of types which should be representative for the region. These types will be analysed by looking into three different layers in order to see whether the layers strengthen or weaken each other. These layers will be individually explained on the following pages, whereafter the individual sites will be shown and analysed.

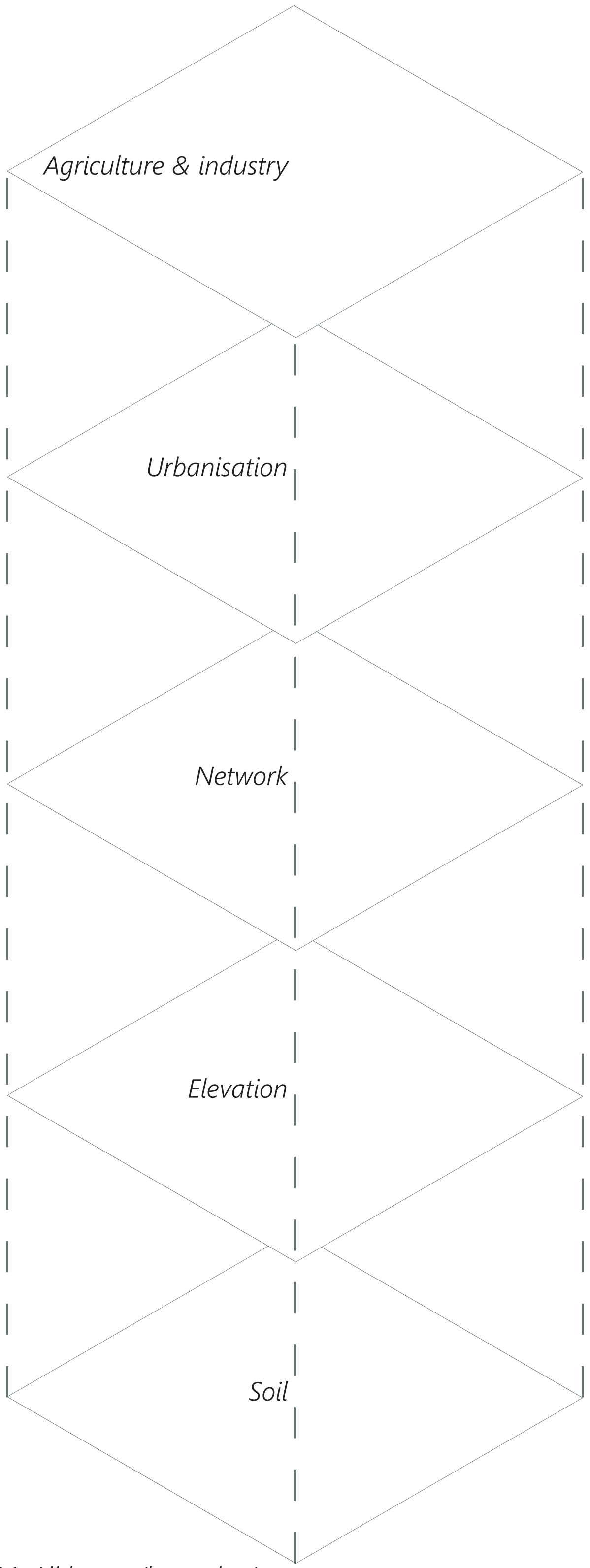



*Figure 5.1: All layers (by author).*

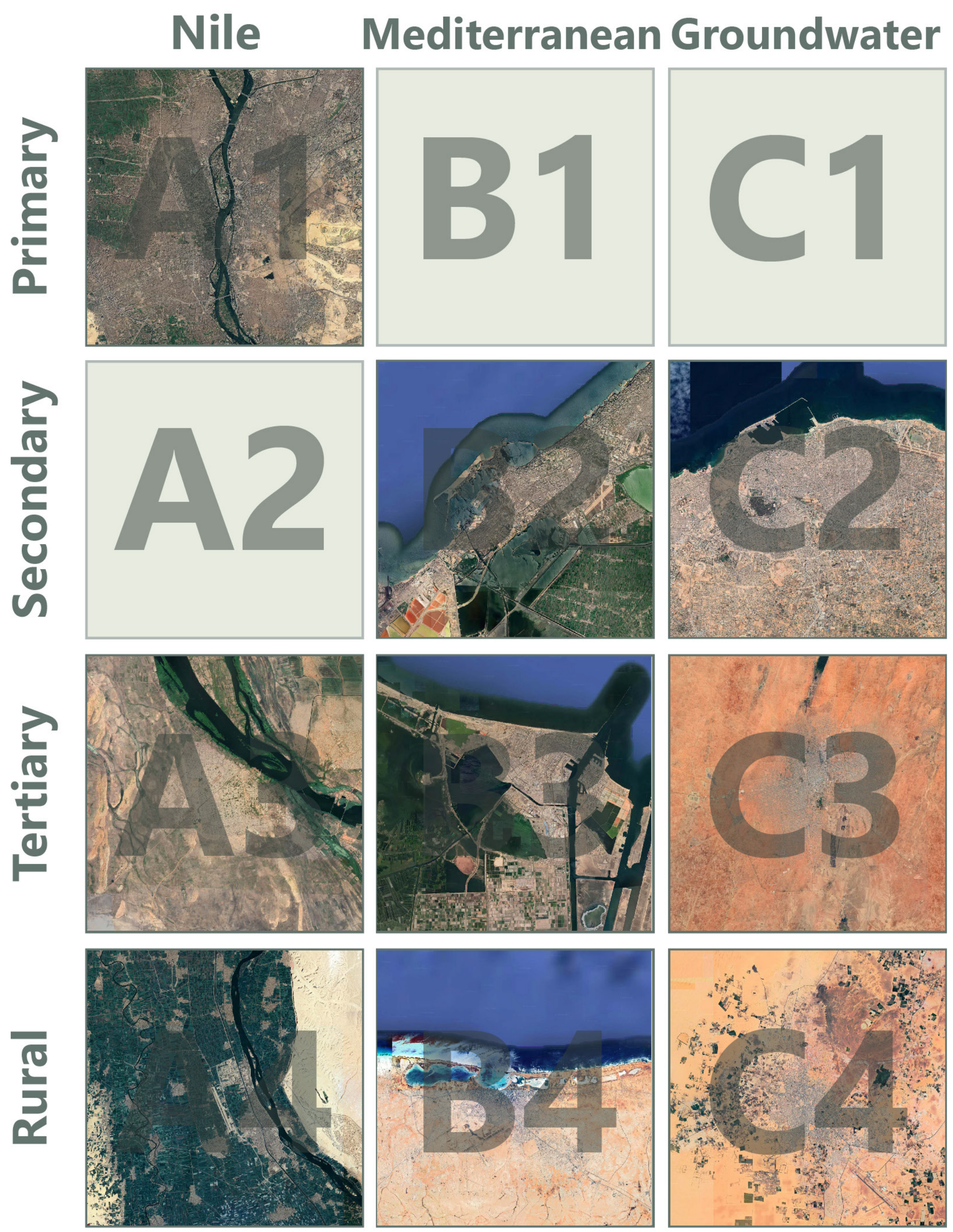



*Figure 5.2: Type matrix used (by author).*

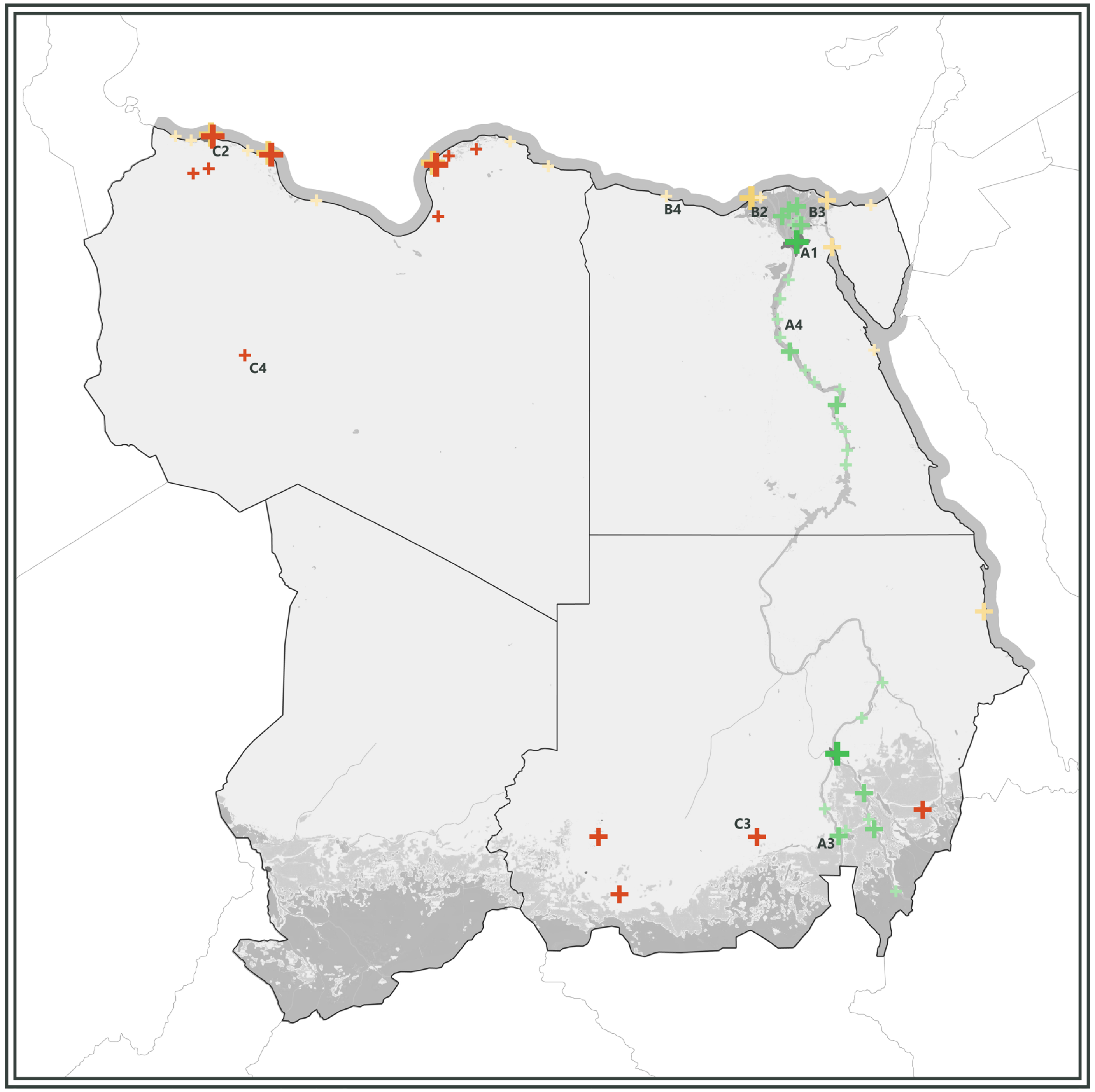
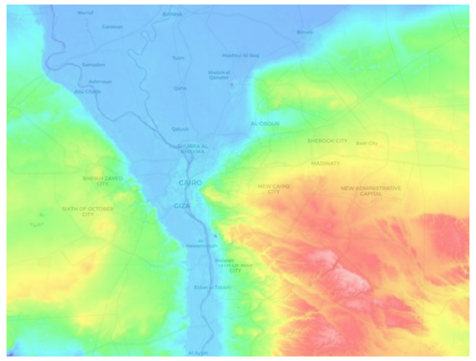



*Figure 5.3: Each type and similar cities (by author).*
*+ (Groundwater)*
*+ (Mediterranean)*
*+ (Nile)*



**5.1.1 The substratum layer**

The substratum layer, also known as the underlying layer or foundation layer, is the basis of the analysis. To get better insight into the foundation of these cities and villages, there will be looked into two main aspects: the (sub)soil and the elevation.
The elevation maps will give insight where rivers and steep hills are located. The maps will be based on the research provided by Yamazaki et al (2017), which mapped global terrain elevations. This research, illustrated in an interactive map as in figure X, will be translated into new maps based on the scale and location in the typology.



The soil layer will be illustrated by looking into the Soil atlas of Africa by the European Commission (Jones et al, 2013). This atlas provides an in depth analysis of all the soils present in the African continent and gives insight where each soil is present. This can be used to relate each location of this typology to the individual soil types. The atlas itself gives an analysis in a broader sense of the soil of the continent, its history and other aspects as well. For this layer analysis, only the individual soils and the corresponding SWOT is looked into due to the limited availability of time. Later research can zoom into the individual soils more in depth. The analysis aims to find insights whether the layers above (network and occupation) are in line with the soil and elevation layer.

**5.1.2 The network layer**

The network layer consists of everything related to infrastructure and movement: roads, railways, ports, airports and waterways. All these individual parts will be mapped by looking into open sources, such as Google maps and OpenStreetMap. On the right, these individual elements are shown.

**5.1.3 The occupation layer**

The occupation layer will be split in two: one illustrating the urbanisation (planned and unplanned) and one illustrating the agriculture and industry.

The urbanisation is split into two categories to make a distinction between planned and unplanned urbanisation. In here, planned is seen as urbanisation where the structure has been created according to a (formal) plan. Unplanned urbanisation is located in areas where there is very little structure visible. The distinction can illustrate how cities have expanded and what kind is most present in the cities and villages, this ultimately will give insights about the use of water and which kinds of adaptations are possible.

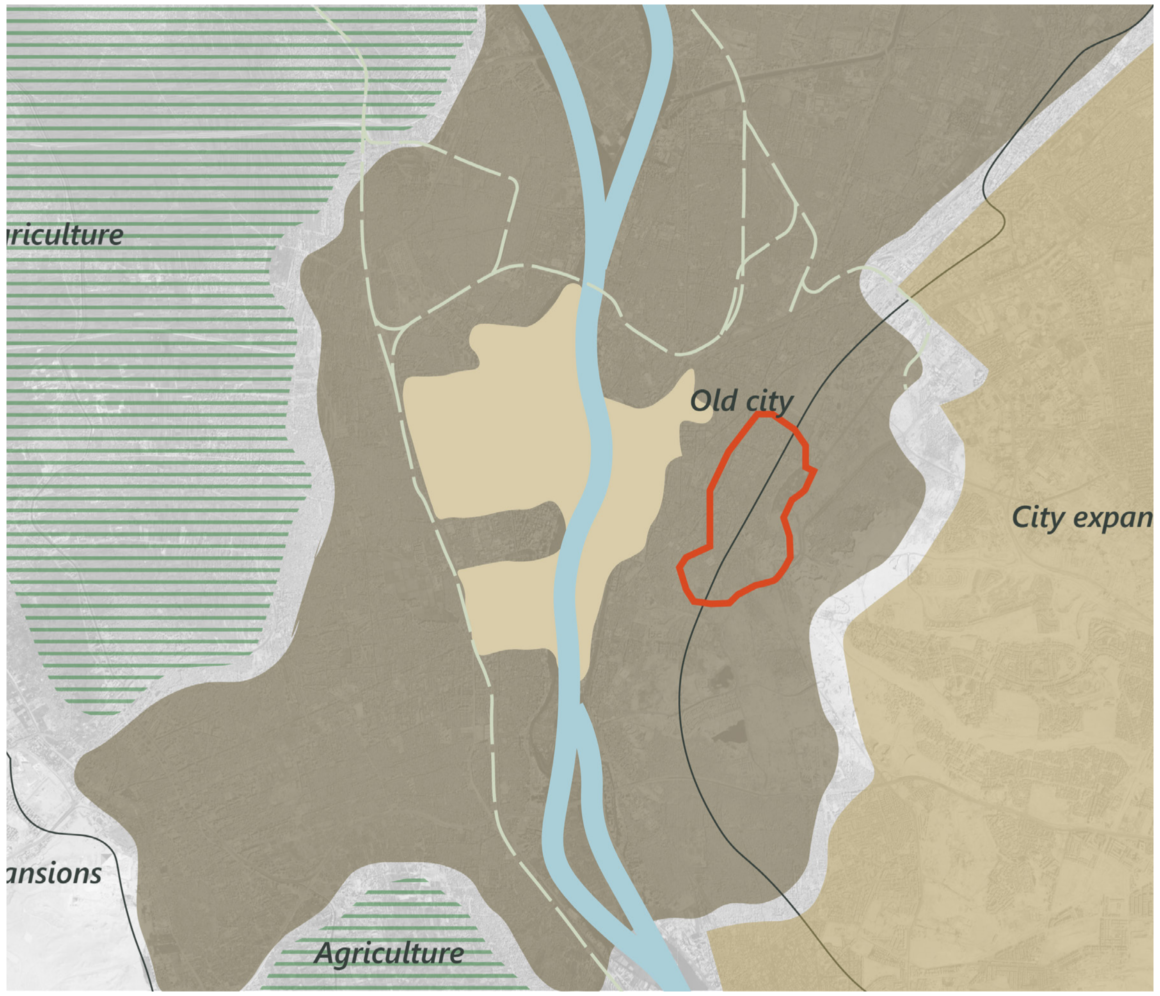
Mapping the agriculture and industry on a separate layer will allow for insights of the relation of the urbanisation and the surrounding landscape. When a lot of agriculture is present, most of the water in the area will be used to supply this sector. Both this and the urbanisation sublayers are mapped according to open source maps such as Google maps and OpenStreetMap.

## A1: Cairo

Cairo is located next to the Nile. While the fluvisol soil next to the river allows for a fertile soil and good farmland, the leptosols further away from the river are more suitable for construction. The old city, located between the elevated east and the Nile in the west expanded towards the river and then outwards, which means that a lot of the fertile fluvisol soil has been covered by city. Only towards the North-west, agriculture is still present. New city expansions are located further away from the river, as more space is available in these locations. Most new projects are firmly planned and should illustrate a new city. Further towards the west, the city has been construction what is called a new Cairo, which should provide enough housing for its current growth in population.

It seems that throughout history, Cairo has been losing its connection to the water (and substratum). New expansions are located further and further away from the polluted Nile. Nature is not present anymore and has been replaced by infrastructure and densely populated neighbourhoods to keep up with its growing population.

Figure 5.4: A1 conclusion (by author).





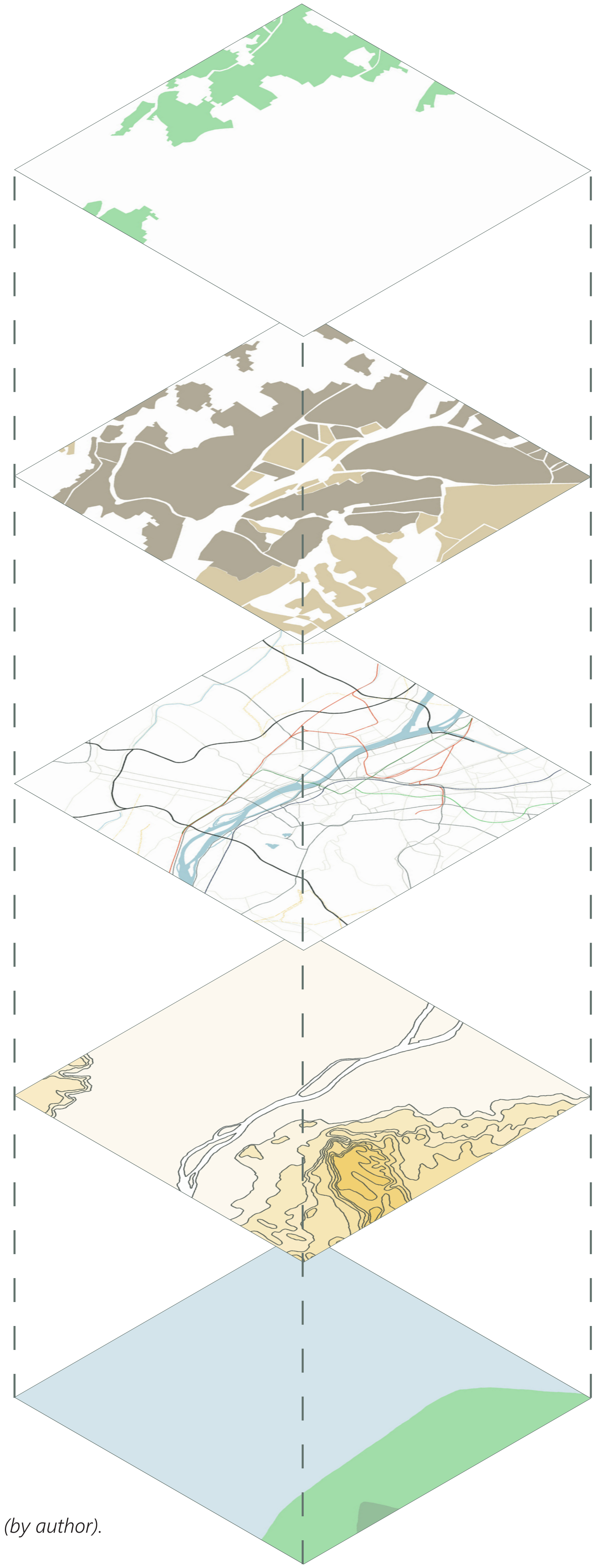




Figure 5.5: A1 conclusion (by author).

## B2: Alexandria

The city, located on the Mediterranean Sea, has mainly been built on Arenosol soils. While these soils are good for farmers as they are easy to work with, they are also prone to erosion and contain less nutrients than nearby fluvisol soil. The part along the sea is the only piece of land in this area that is elevated. This is also the area where the city was founded. This piece of land was less prone to flooding and nearby fertile (fluvisol) soil could supply it with enough food. Southeast, the saline solonchak soil makes it difficult to farm but this area is also not suitable to build on.

The old, formal city has been built near the sea on an elevated piece of land. The city has then expanded to the north and south, with a major port area nearby. This port is one of the main seaports on the Mediterranean and important for Egypt's economy. While most parts of the city are unplanned, recent developments have been formally planned near the centre.

Because of its location along the coast, Alexandria has been prone to flooding. With the risk of sea level rise in the near future, the city is hesitant to expand into the lower laying parts. While agriculture is important to supply the city and its region with enough food, farms are mainly located on these lower laying parts. With a population growing at a fast pace and a port dominating the urbanised area, it is important to investigate where the city can expand and how it can remain resilient in the next coming decades.

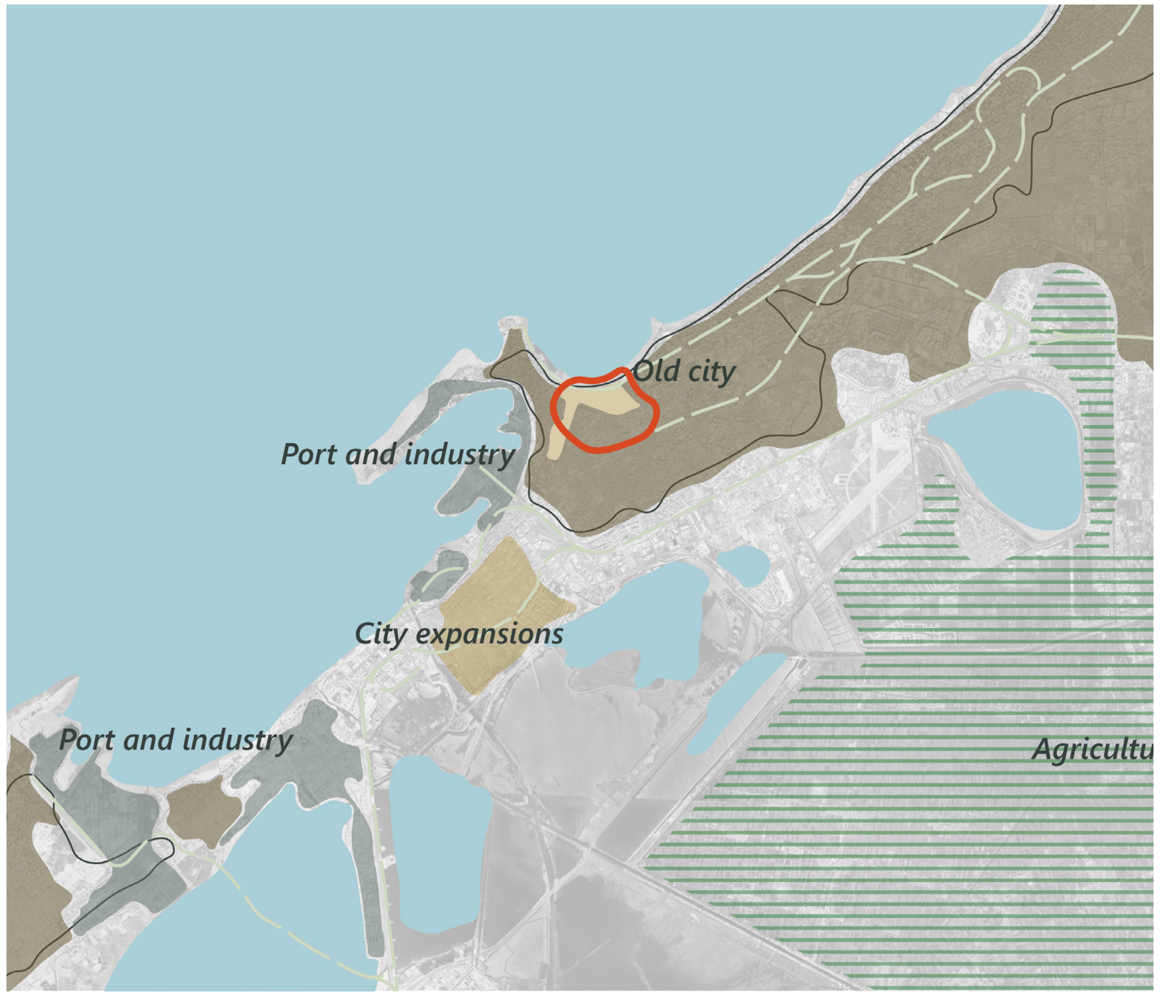



*Figure 5.6: B2 conclusion (by author).*

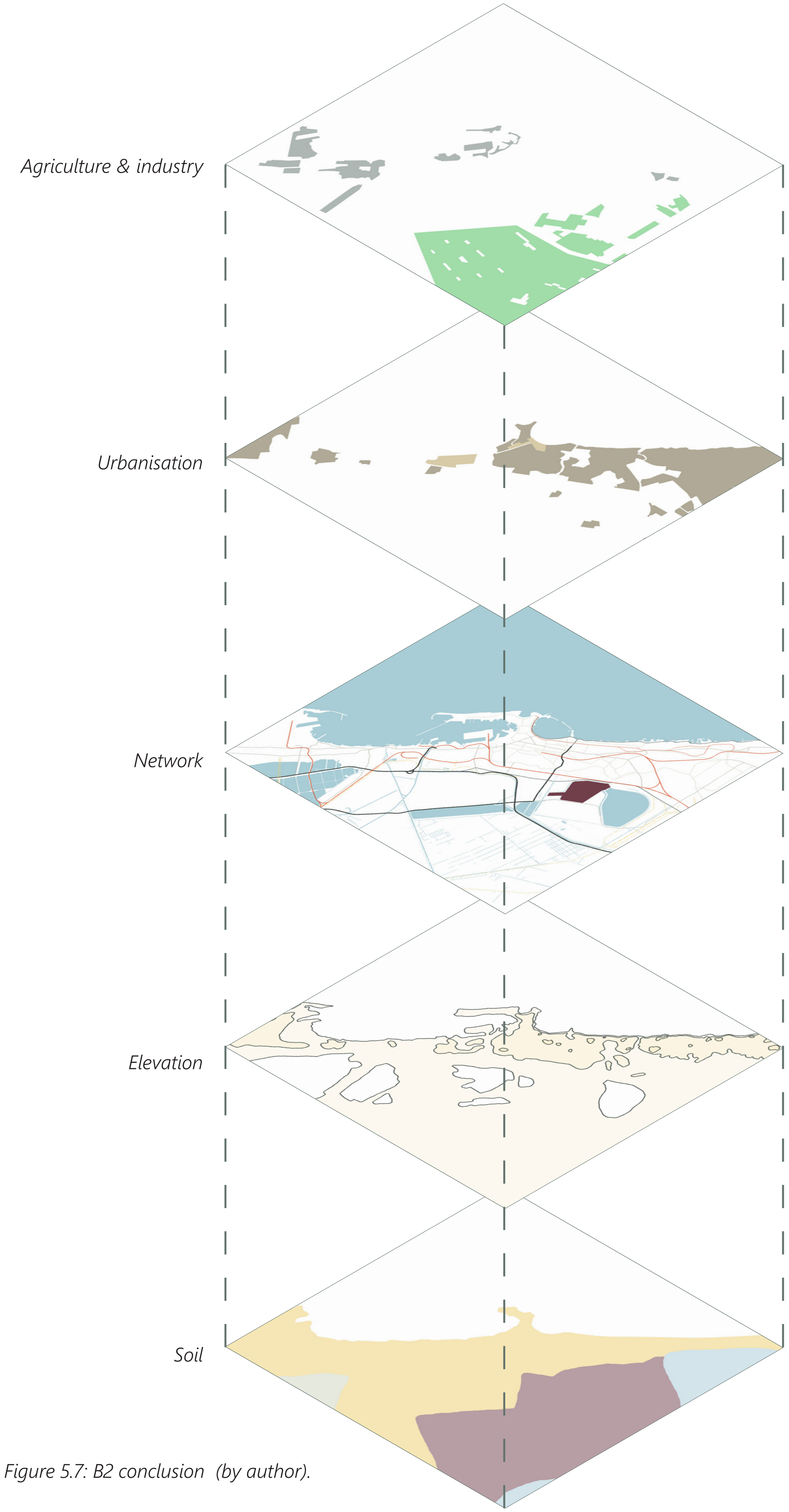



*Figure 5.7: B2 conclusion (by author).*

## C2: Tripoli

The country of Libya is mainly dependent on groundwater sources as the country itself does not have any major freshwater sources. Its capital, Tripoli, is located on the Mediterranean. The soil the city is located on (Arenosols and Calcisols) are not fertile and prone to erosion. This, together with the lack of freshwater sources, can be the reason the city does not have large agricultural areas nearby.

The old city centre was constructed on the coast, next to the current port. New expansions, both planned and unplanned are located more inland. It is very notable that large parts of the city are planned. This might have something to do with its colonial past. Early in the 20th century, the country was a colony of Italy and during this time the city was home to many Italians (Italian Benghazi, 2018). Although the mapping itself does not directly present evidence, it can be suggested that this colonial period caused planned city expansions.

Without any major water bodies except the Mediterranean Sea, no agriculture and very little industry, the city mainly consists of residential buildings without relation to water. The largest threat for the city is the lack of water because of droughts so it is important to improve the water related infrastructure of the city and maximise the possible renewable water sources such as rainwater.

*Figure 5.8: C2 conclusion (by author).*





*Figure 5.9: C2 conclusion (by author).*

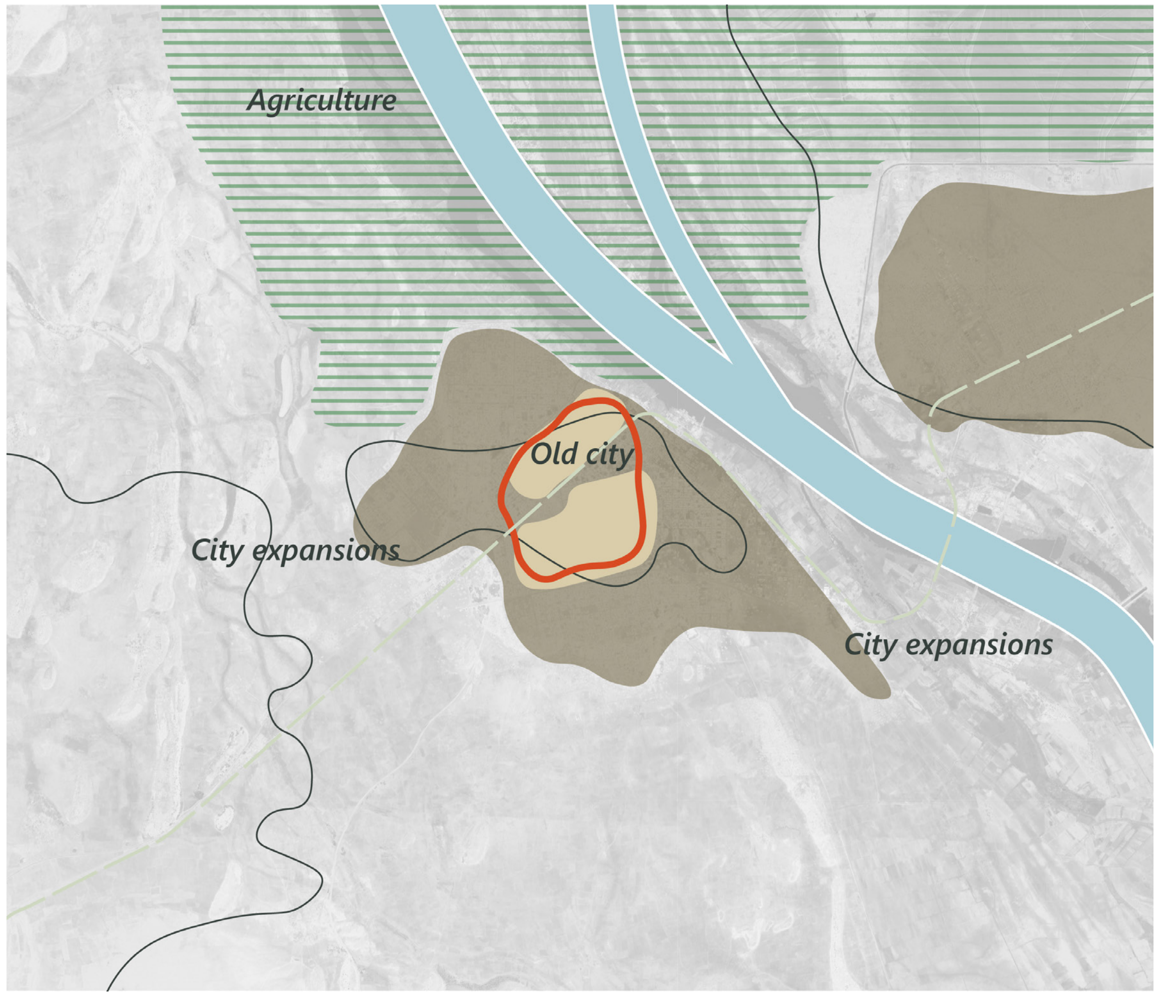
## A3: Kosti

The city of Kosti is located in Sudan, near the border with South-Sudan. The city is situated on vertisol soil, which is fertile, and the less fertile arenosols. Kosti is also located on the elevated part next to the Nile. This part provides resistance against flooding, which prior to the construction of dams along the river was a major risk in these kinds of cities.

The city has besides its strategic location along the Nile also connections towards both the railway and road network in the region, which makes the city very well connected. The city was founded by a Greek merchant (Chaldeos, 2017), which can explain the planned city centre. As time passed, the city also expanded to lower elevated areas in a more unplanned way.

The analysis shows that the city itself has a strong relation with the water, as the Nile has determined both the location of the city and its agricultural and urban expansion. For future developments it is important to not neglect this relation with the river and to further build upon this. Let the subsurface and nature be a central piece in its future.

*Figure 5.10: A3 conclusion (by author).*



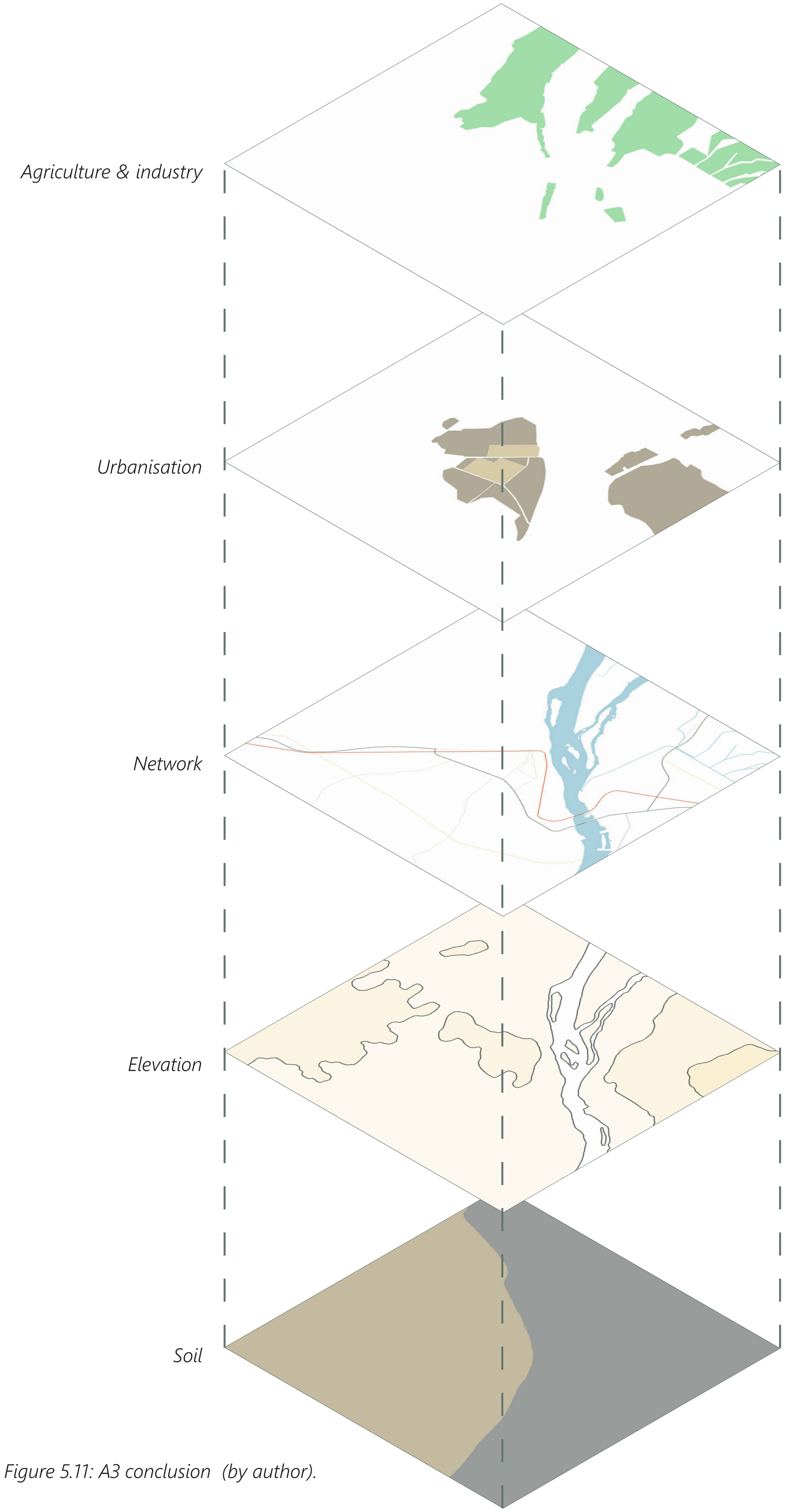




*Figure 5.11: A3 conclusion (by author).*

## B3: Port Said

This port city is located on the Mediterranean and next to the Suez Canal. Port Said and its surrounding area has been built on saline solonchak soil, which makes it difficult to use the soil. The oldest part of the city has been built on an elevated piece of land on the coast, which is similar to Alexandria's situation, although more planned.

The cities importance has greatly increased due to the construction of the canal, which made it an important port city. Water is mainly seen as a tool for transportation. Lakes to the south and west of the city are used for fishing and are brackish and can therefore not be used for irrigation or drinking water.

*Figure 5.12: B3 conclusion (by author).*

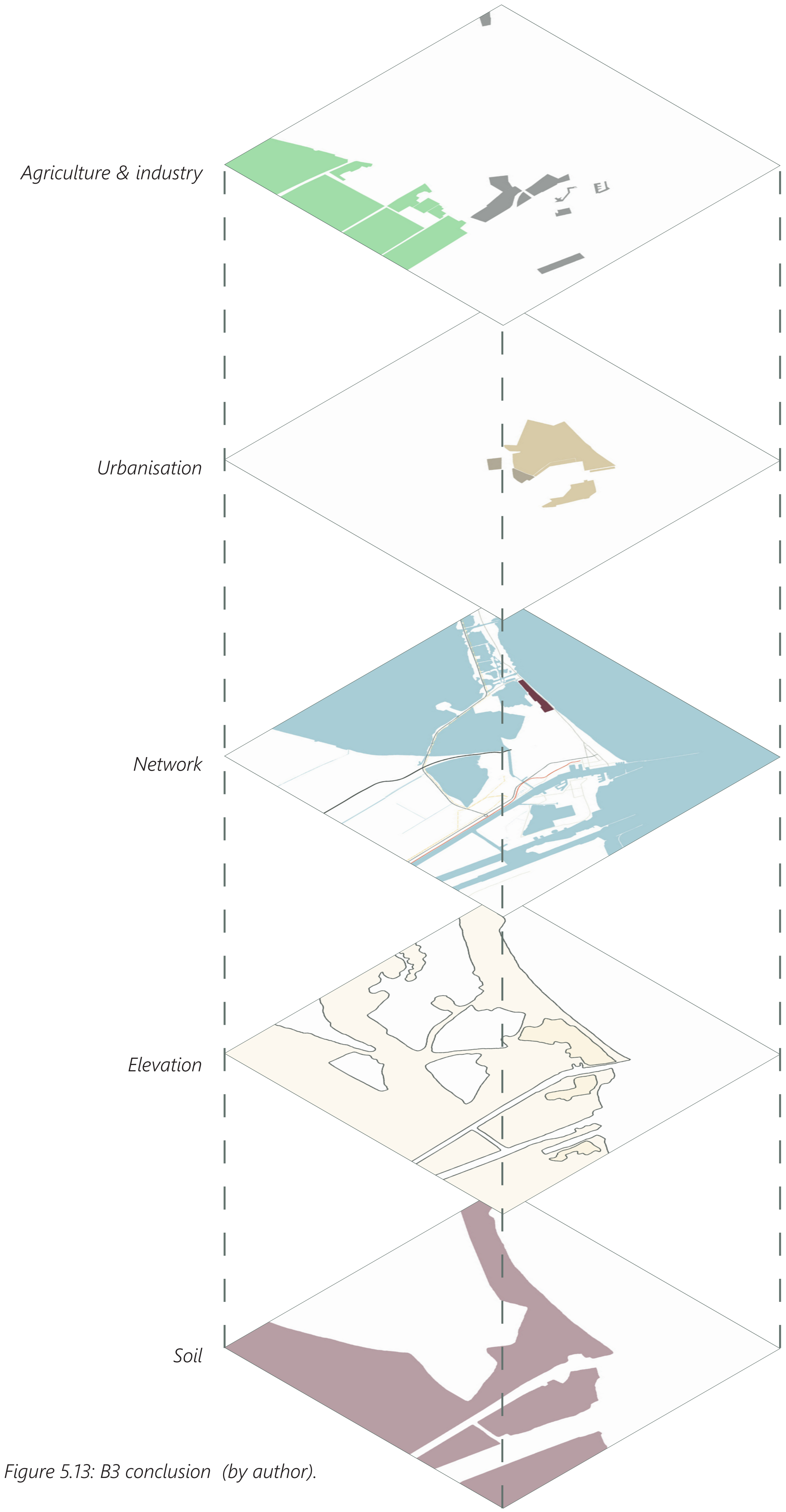




*Figure 5.13: B3 conclusion (by author).*

## C3: El Obeid

The Sudanese city of El Obeid is located in an arid region. With only some small streams nearby, the city is mainly dependent on ground- and rainwater. While the relatively fertile luvisol soil is located underneath the most parts of the surrounding area, agriculture remains minimal due to the lack of constant supply of water.

The location of the city raises questions about why the city was founded in this location in the first place. Additional research shows that the city was used in the slave trade business in the 19th century (Holroyd, 1839). This might also explain why the city is very well connected to both the road and railway network.

Despite its good infrastructural connection to other cities in the region, El Obeid remains to be well connected to water. The expected population growth of its country will result in more expansions and more need for water. Neighbourhoods need to improve their water infrastructure as well as start to collect their own water from the limited annual rainfall. The fact that there is very little agriculture present in the area means that most of the collected water can be used for municipal consumption instead of agriculture.

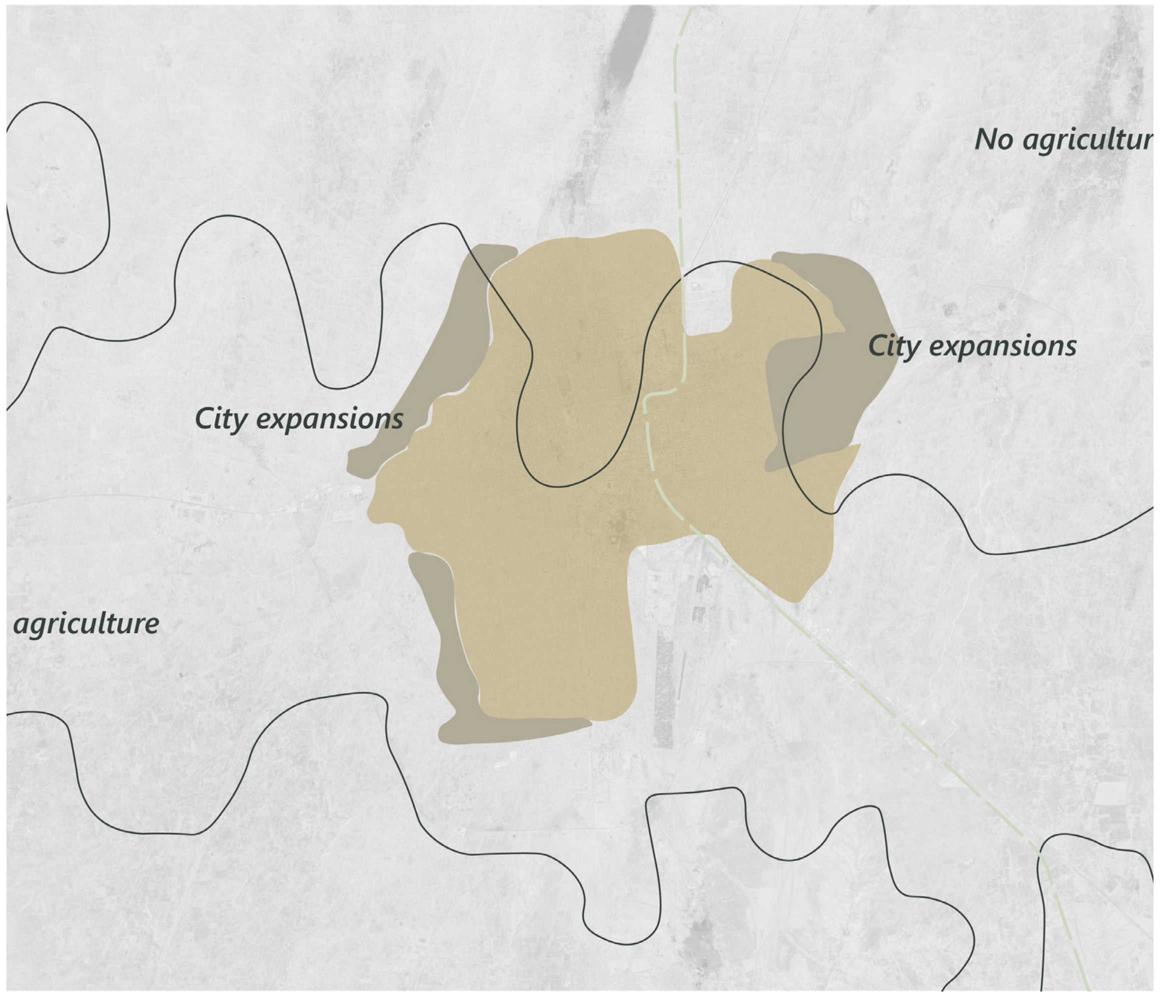



*Figure 5.14: C3 conclusion (by author).*

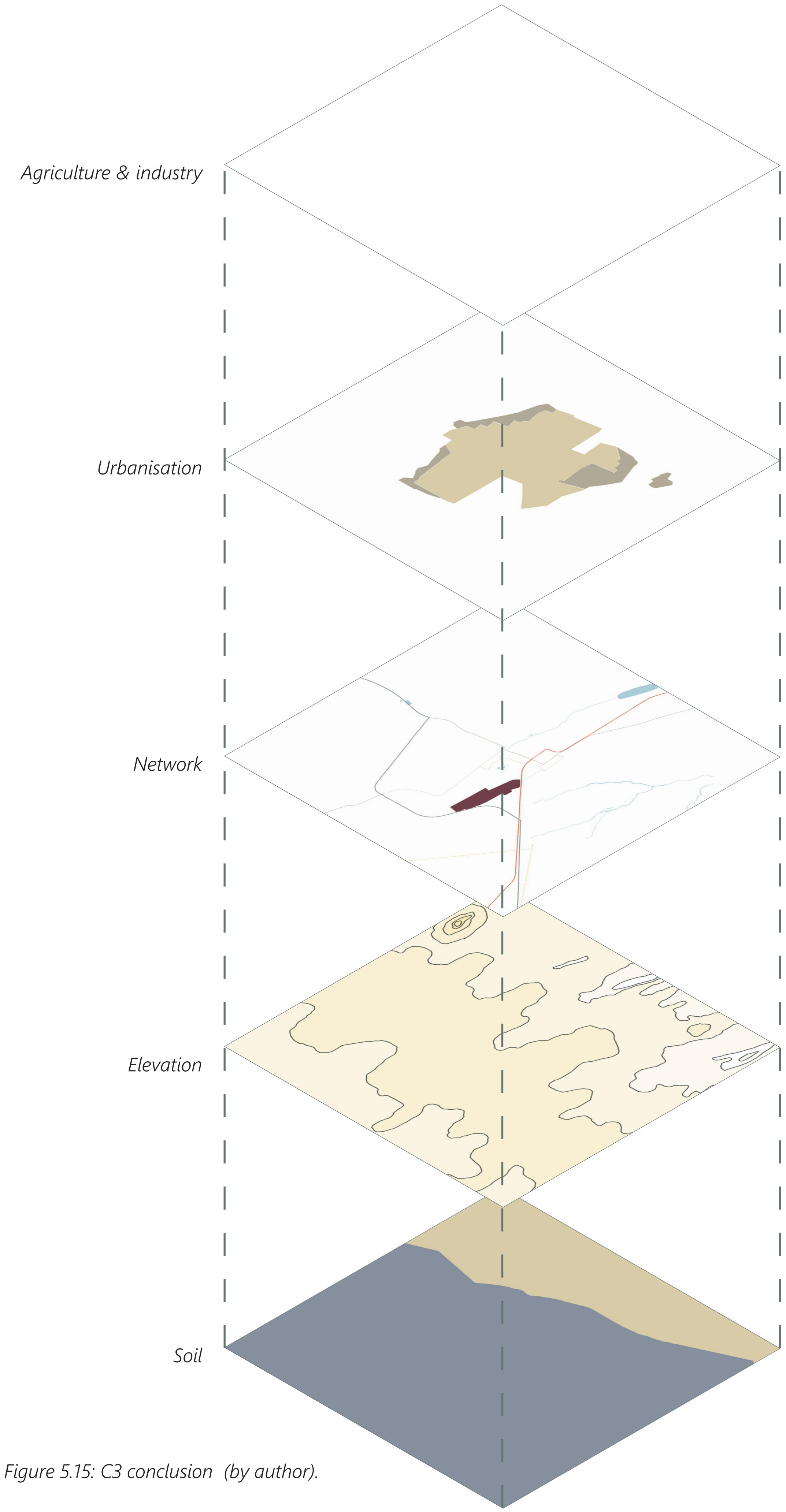


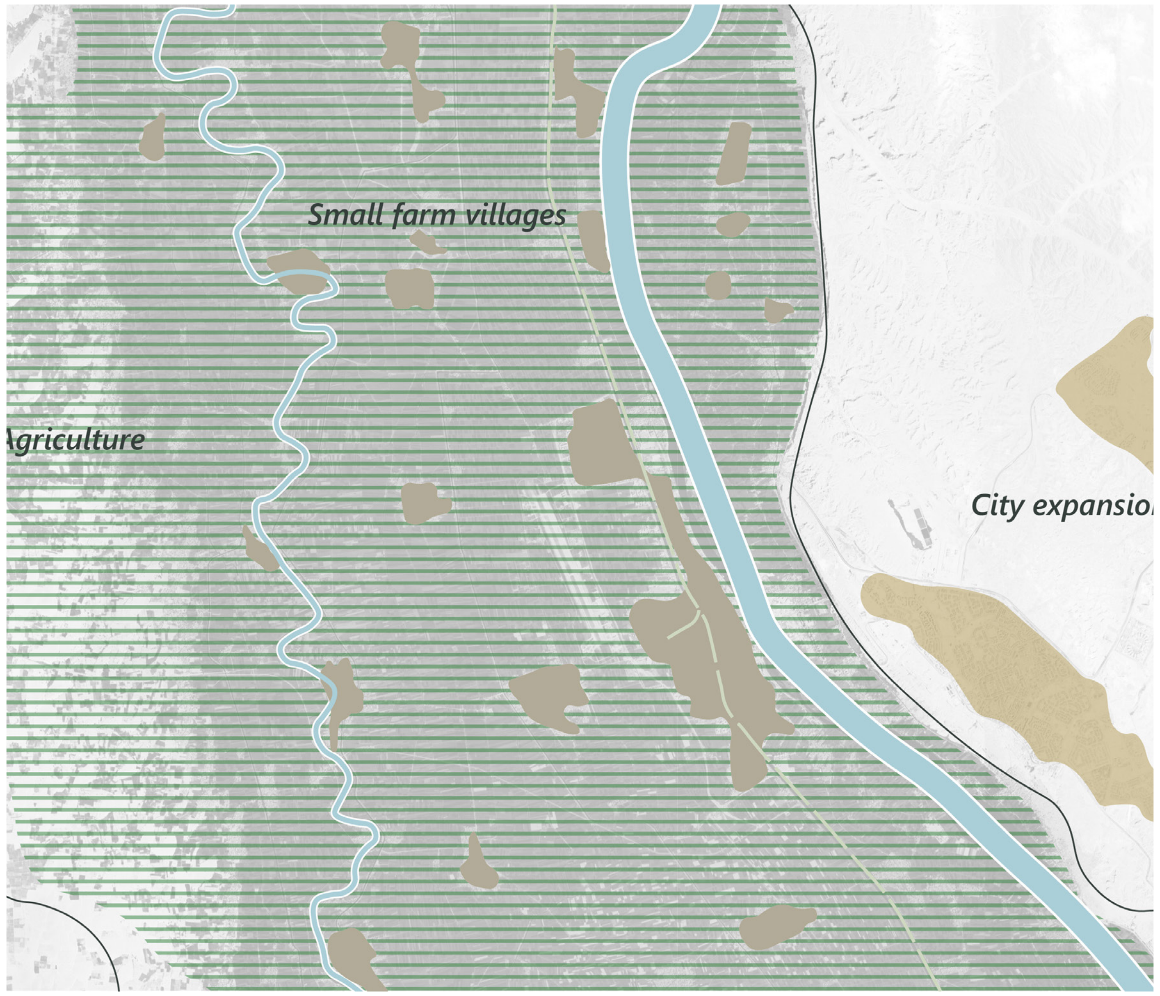

*Figure 5.15: C3 conclusion (by author).*

## A4: Minya

The city of Minya is located along the Nile in Egypt. The city has been founded on the fertile fluvial soil. On the other side (eastern) of the river, steeper elevations separate the fertile soil from more sandy soils. New city expansions, which are more planned, are located on these leptosol soil which is good for construction. Other small villages are located near Minya, which are supported by the large agricultural area next to the river.

While the fluvisol soil supports these large agricultural areas, the country tries to reclaim land to the west which is situated on top of less fertile soils (e.g. gypsisols). This requires more and more water and is far less sustainable.

*Figure 5.16: A4 conclusion (by author).*



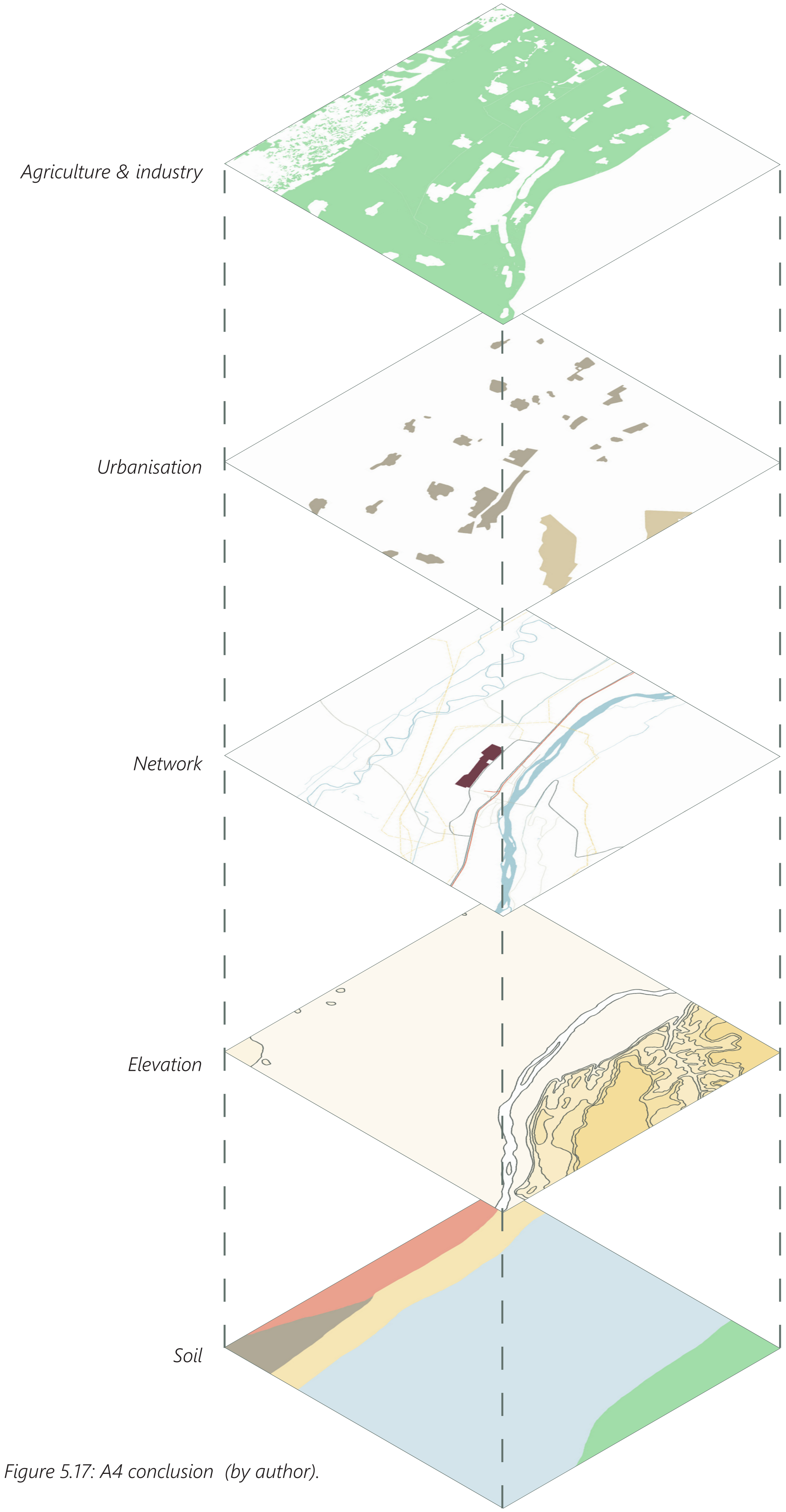



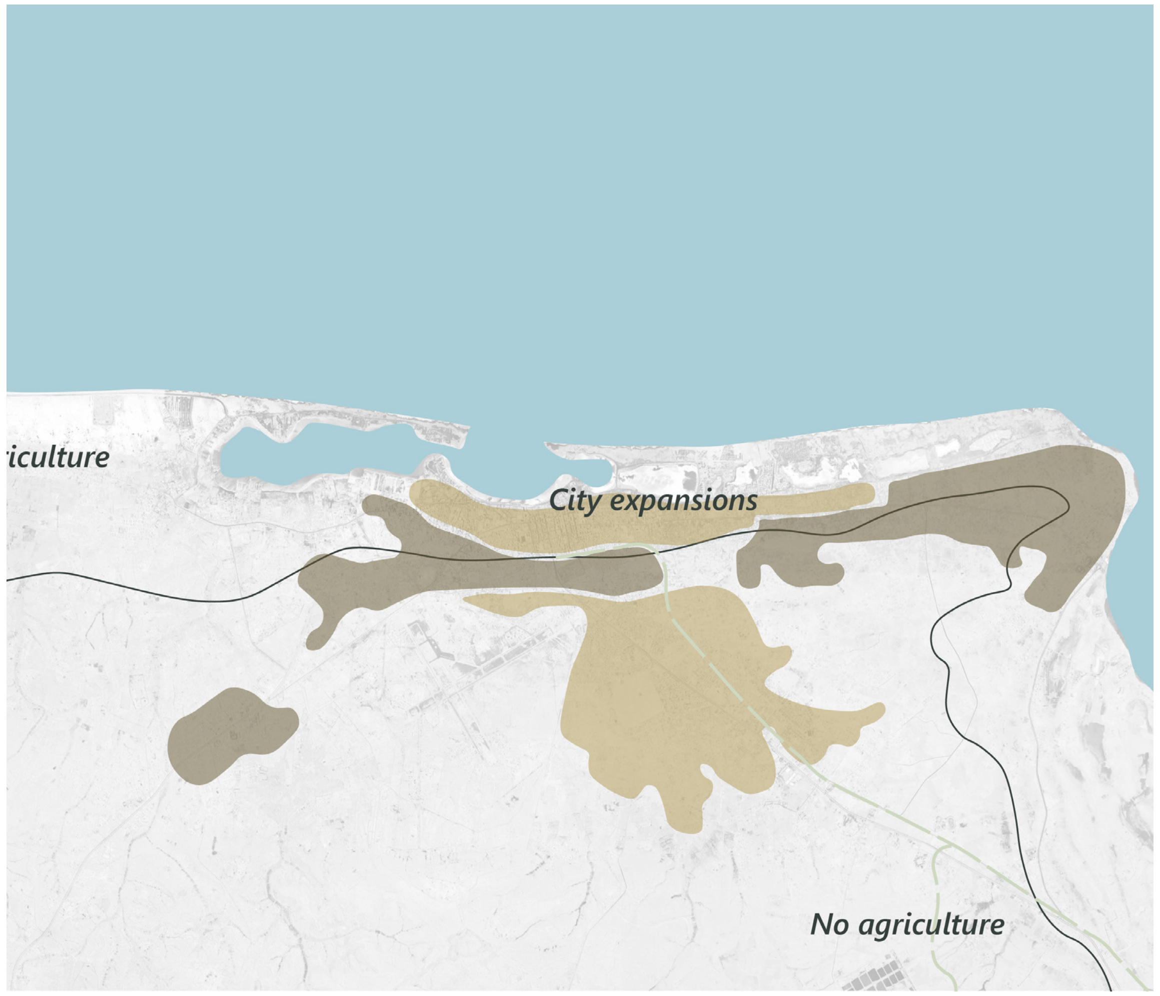

*Figure 5.17: A4 conclusion (by author).*

## B4: Mansa Matruh

The Egyptian city of Mansa Matruh is popular among tourist because of its location on the Mediterranean coast. There is no agriculture in the area, which can be explained by looking into the soils. The most present soils, leptosols and calcisols are not as suitable for agriculture as the fluvisols along the Nile, which is where most of the agricultural area in Egypt is located. The sandy soils near Mansa Matruh are very suitable for construction, although because its lack of freshwater the city has not expanded as much.

Most expansions are related to tourism (e.g. hotels and shopping areas). These newer areas are located closer to the water, while older parts of the city were constructed on more elevated pieces of land further away from the sea. It is also notable that the city does not have a major port, despite being on the coast.

*Figure 5.18: B4 conclusion (by author).*



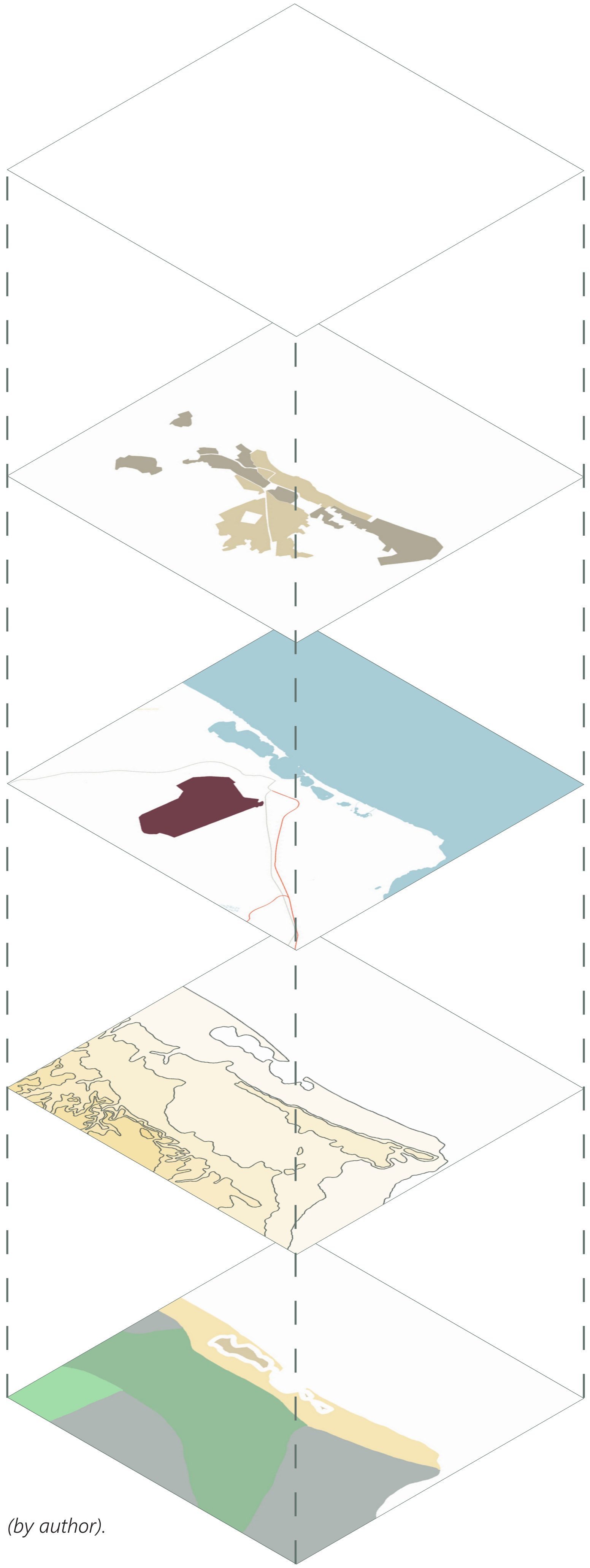




*Figure 5.19: B4 conclusion (by author).*

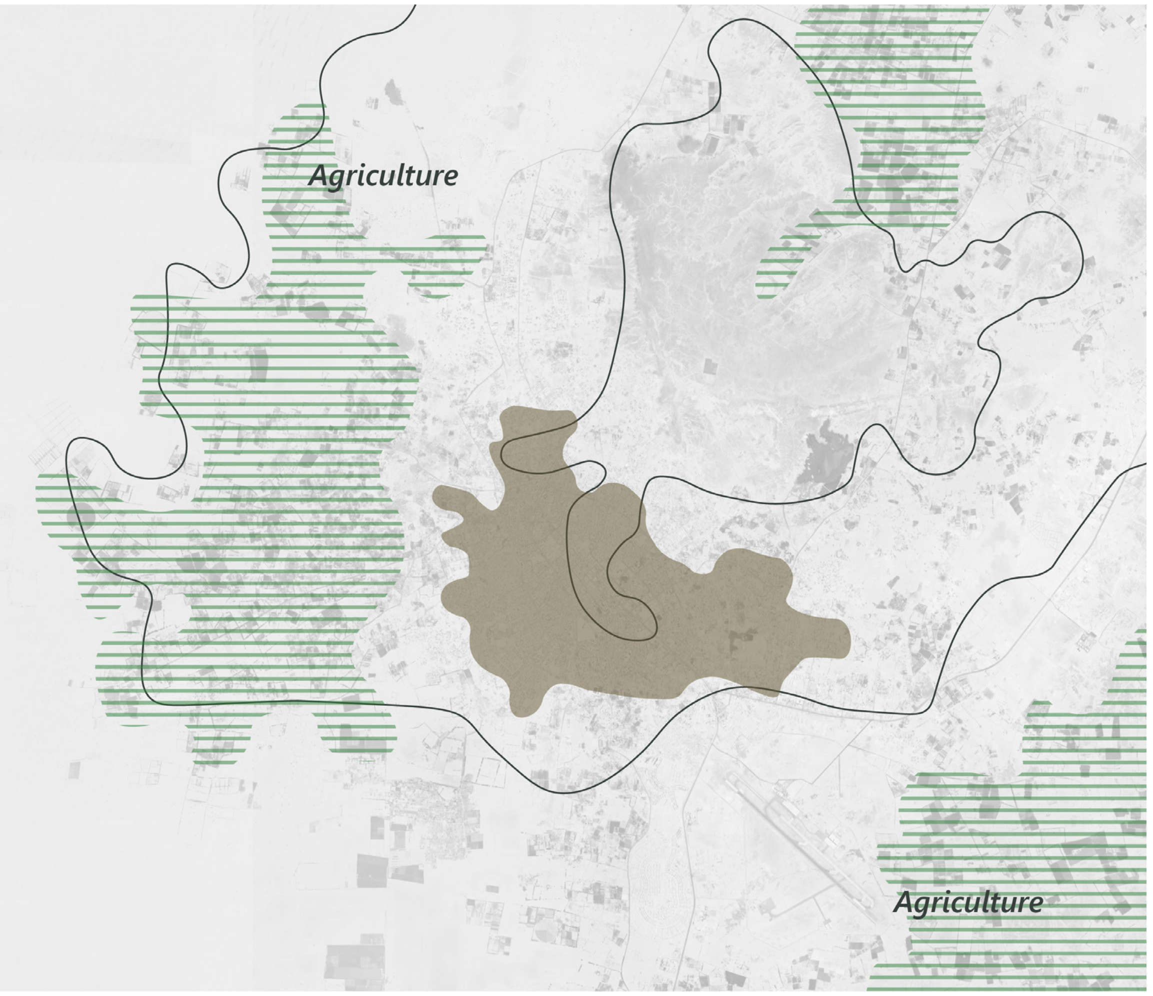
## C4: Sabha

The city of Sabha is located in the Saharan desert in Libya. The city is located on cambisol soil, which is good for agriculture but is very prone to erosion. However, the city and its region is dependent on groundwater for the supply of water. The precipitation is limited, so rain does not support the farms in the region, so irrigation by groundwater is the only current option.

The city of located south of a large hill, which protects it from wind in the north. As can be seen on the map(s), the agricultural area is very much spread out across the area near the city. This seems to be because there are various different owners of these farms, with each their own small plot.

Because of its dependency on (unsustainable) groundwater, the city cannot expand very fast, and the population does not grow as fast as cities of similar size with more available water and prosperity. The future of these kinds of cities will require a more sustainable use of (ground) water, so that there will be enough available water in the coming decades.

*Figure 5.20: C4 conclusion (by author).*



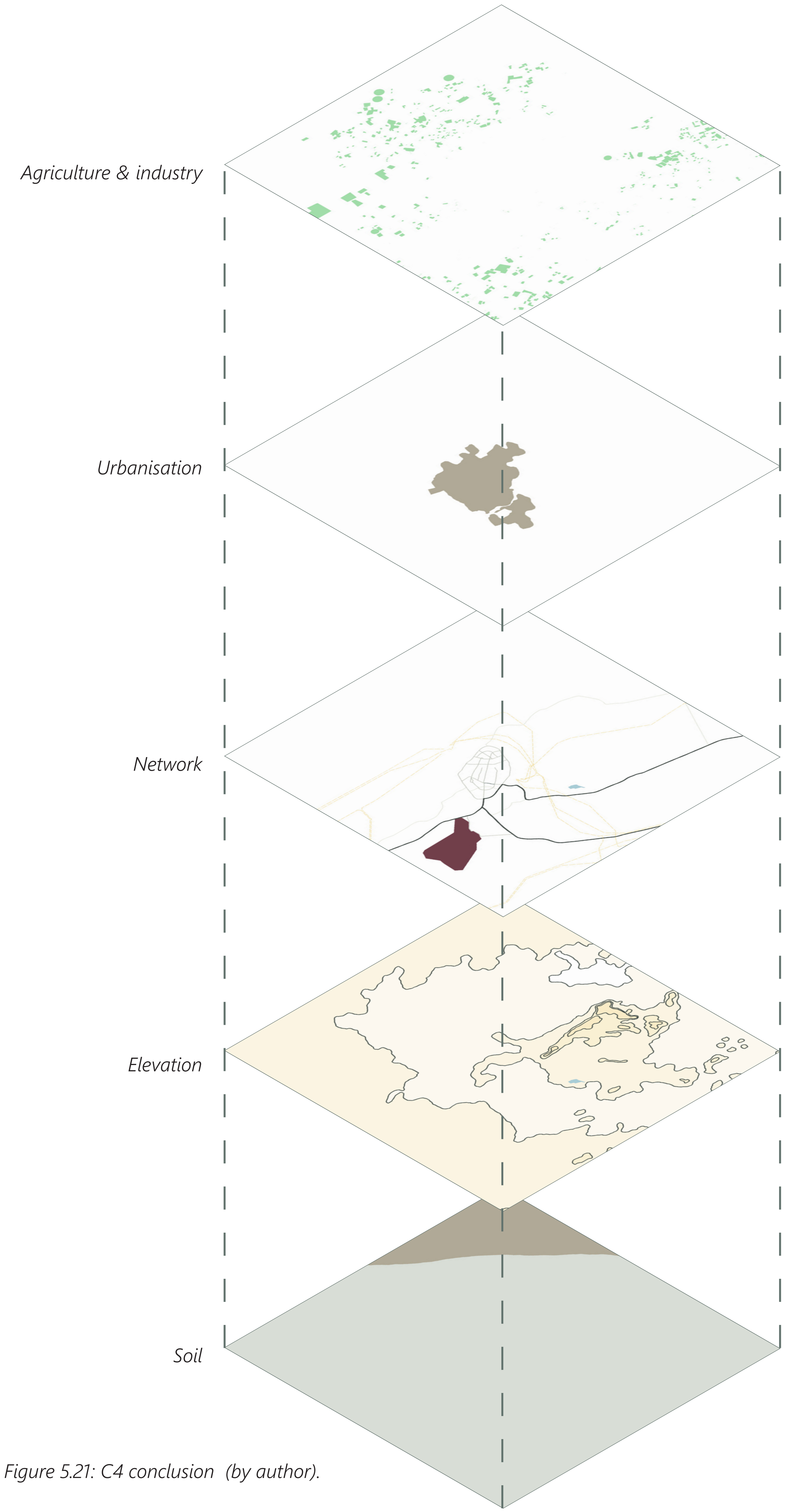




*Figure 5.21: C4 conclusion (by author).*

## 5.2 Conclusions

As can be seen on previous pages, all nine types are very different. It can be said that for all types, these cities in some form relate to their soil underneath, although at different levels. It seems that the larger the city, the less the urbanised area reflects the soil underneath, as large cities such as Cairo and Alexandria have urbanised areas located on top of fertile soil. This makes sense as larger cities cannot always plan their expansions beforehand, especially in more informal areas.

This study of these various types also highlights that one regional strategy will have very different consequences for each city. What may be a solution for one city, will not solve anything in another. This means that for a regional strategy to be effective on the small scale as well, it needs to zoom in to see what the implications are on this smaller site. By zooming in, different elaborations can be designed or planned for each type so that the strategy itself will be as coherent and thorough as possible.

Although these differences between each type are apparent, it would be of value to review these differences by looking into similar cities as well in further research, so that for each individual type multiple cities are analysed. By doing this, anomalies can be detected because it can be the case that one individual city does not behave as others of the same type would have. This will result into clearer conclusions upon which can be built later.




*Figure 5.22: All conclusion (by author).*

Image by Moharram (2019), adapted by author.

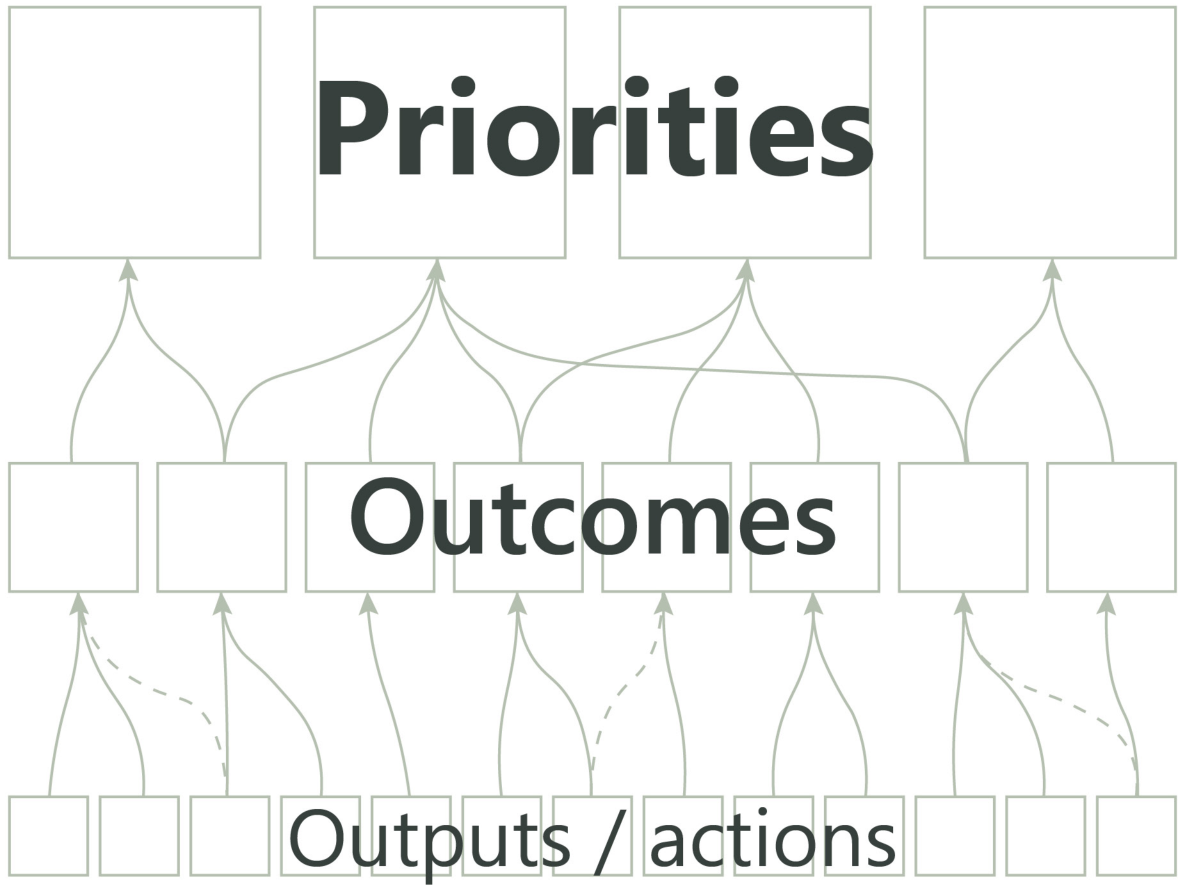
## 6.1 Structure of the strategy

In the following pages, the main priorities, outcomes and outputs of the regional strategy will be elaborated. But before diving into this strategy, the structure will be explained. The main structure of this strategy is based on the Basin Development Strategy & MRC Strategic Plan from the Mekong River Commission (Mekong River Commission, 2021). The main structure of this strategic plan is shown on the right. Using this strategic plan as a basis, combined with ideas extracted from other strategic plans for basins such as the Colorado and Missouri rivers (Martin et al, 2021; NOAA/NIDIS, 2020), this structure builds on the strengths of existing plans.

For this strategy, **six main priorities** will be used. These six priorities will form the basis for the strategy and should reflect the most important goals. These are more general goals, which can be used to build (local) policies and plans around. The goals also reflect the main problems in the area and can be used to overcome these weaknesses and threats such as lack of sustainable water sources or bad water quality. To reach these goals, certain (expected) outcomes are proposed. Each outcome should contribute to one or more goals. These outcomes are more specific and can therefore be used to link the strategy to individual targets of the Sustainable Development Goals (United Nations, 2021). These SDG's are also linked to the aforementioned priorities, but can because of the genericness of these priorities not be tied to specific SDG targets. To be able to achieve the outcomes in this strategy, a set of outputs or actions are created for each outcome. These individual outputs should be able to illustrate how these outcomes are achievable and which steps must be taken and by which stakeholders these steps must be taken. To illustrate this, each output will be linked to a scale (local, national, supranational), a set of stakeholders (sorted by power and interest) and to a style of governance (hierarchical, network, market) as discussed by Meuleman (2019). These styles of governance will help illustrate through which methods governments and other stakeholders should collaborate.

The structure of the strategy is illustrated on the next page. The individual pieces of the strategy (priorities, outcomes and actions) are elaborated in the following pages.

*Figure 6.1: Strategy structure (by author).*



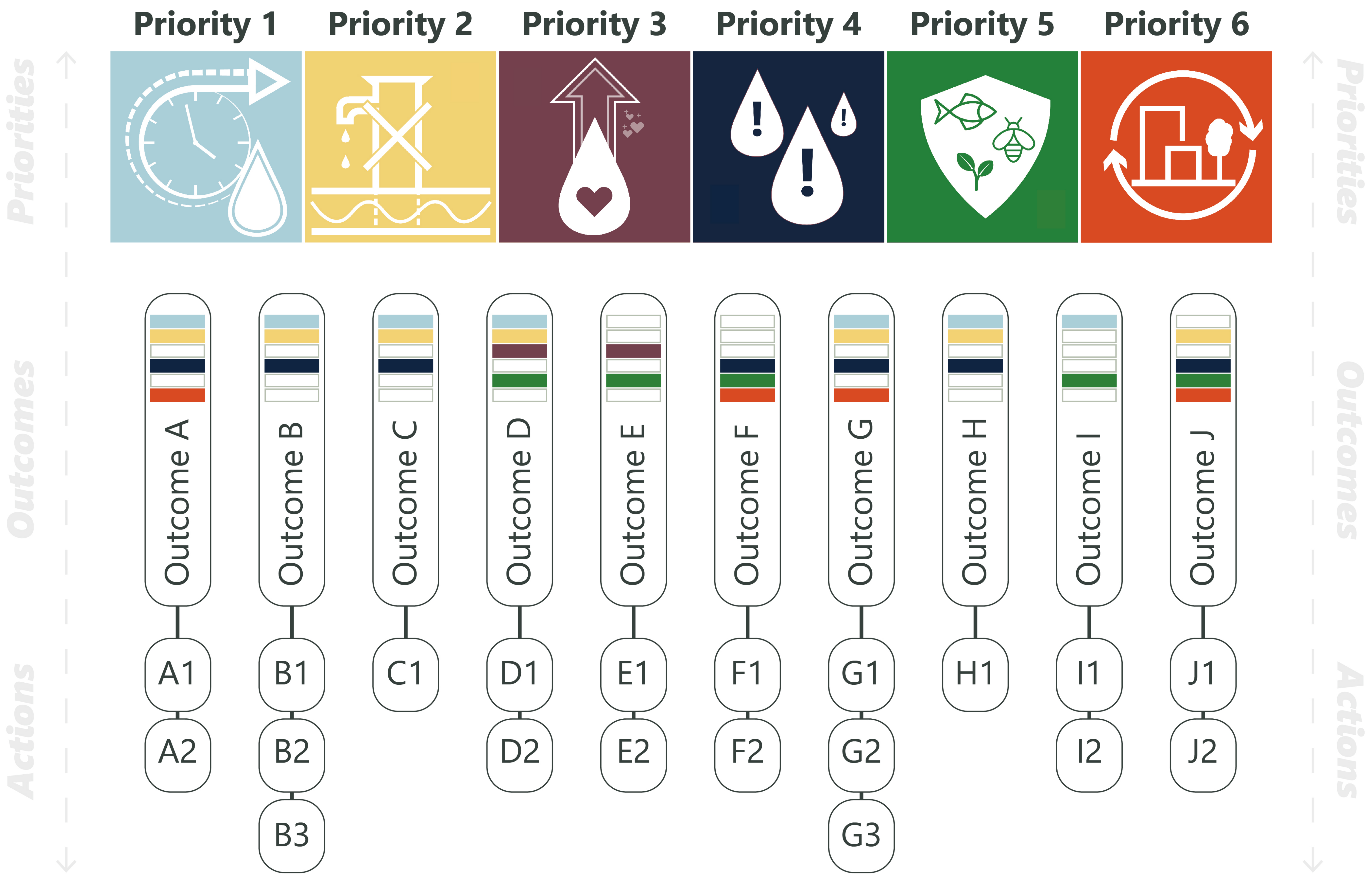

Priorities
Outcomes
Actions
Priority 1
Priority 2
Priority 3
Priority 4
Priority 5
Priority 6
Outcome A
A1
A2
Outcome B
B1
B2
B3
Outcome C
C1
Outcome D
D1
D2
Outcome E
E1
E2
Outcome F
F1
F2
Outcome G
G1
G2
G3
Outcome H
H1
Outcome I
I1
I2
Outcome J
J1
J2
Priorities
Outcomes
Actions

*Figure 6.2: Vision map  (by author).*

**Legend**

- *Limit groundwater extraction*
- *Up to date desalination plants*
- *Innovate old plants*
- *Build new sustainable plants*
- *Improve near water biodiversity*
- *Improve irrigation efficiency*
- *Protect important nature areas*
- *Inner city water re-use and improved infrastructure*
- *Improve cooperation*

## 6.2 Main priorities

### Priority 1: Long term availability of water

Water must be available in the long term. Current water use depletes water resources too fast and a lot of unsustainable and external sources are needed to meet the water demand. To make sure there is enough water available not only now but also in the future, other methods must be used to meet the rising demand for water. This means that the amount of renewable water in these countries must increase. This increase of renewable water can result in an increase of resilience towards droughts and other water related shocks. This long term availability should be achieved both on local and supranational scale. Where local communities can help with collecting rainwater and decreasing their water use, governments and supranational stakeholders can help regulate water use and create incentives for renewable water sources.

### Priority 2: To decrease dependency on unsustainable sources

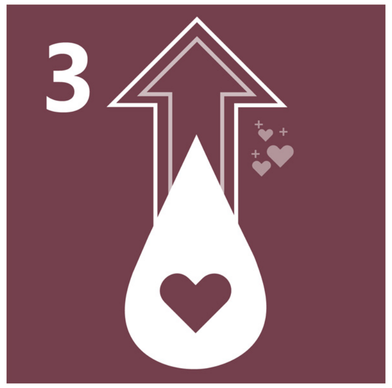
There is currently too much dependency on unsustainable sources. Many regions depend on groundwater as their main water supply but this groundwater is a depleting source and can in time no longer be usable. Desalination plants are currently unsustainable and cost too much for the amount of water which is extracted. By decreasing these unsustainable source or making them more sustainable and by increasing the use of renewable methods and by improving these, cities, regions and countries will no longer be dependent on depleting or non renewable sources.

### Priority 3: To improve quality of water

The quality of water is currently low. By not regulating the quality of water, a lot of rivers and streams get contaminated with pollution. To be able to re-use (waste-) water, these regulations must be put in place. Moreover, if people know the value of water, pollution will most likely decrease. Green spaces next to water are also able to filter pollutants and create cleaner water. These measures all result in a higher quality of water which can promote the re-use of this water.













### Priority 4: Mitigating current shortage of water

While the use of unsustainable sources can be harmful on the long term, the region itself is already dealing with current water scarcity. This means that actions must be taken to mitigate current water scarcity as well. This comes down to increasing the amount of available water but also decreasing the use and demand for water. The agriculture sector is the sector with the highest demand for water, increasing the efficiency in which water is used will play a large part in decreasing the use of water in this sector. Besides the large use of water, it is also important to monitor this use and supply of water. By detecting droughts beforehand, regions and cities can be prepared and take measures before larger problems arise.

### Priority 5: To improve biodiversity and protect the environment

Large extractions of water and land reclamations are harming the environment and biodiversity. Agricultural land is expanding and these new areas require a lot of water. Because of these expansions, biodiversity is slowly decreasing. In areas where the environment depends on groundwater, groundwater extractions are causing disruptions and harming the environment. By protecting important nature areas and improving the relation between people and nature, biodiversity can improve and the environment can be protected.

### Priority 6: To make cities resilient and sustainable

Cities in this region have a large demand for water. Meanwhile, the infrastructure for (waste-) water is in most cases not well developed. To make sure that these cities are able to deal with the large flow of new people in both inside the city as well as in new developing areas, cities will need to be both resilient and sustainable. While this also goes for smaller villages, the amount of people living in cities combined with the rapidly urbanising nature of these countries, makes for that this issue is far more urgent inside cities in this region.

# *“Harvesting rainwater can contribute towards more accessible and available water.”*

## Outcome A Re-use of rainwater


### Description of Outcome

According to the United Nations (Baguma et al., 2012), harvesting rainwater can contribute towards more accessible and available water. During the wet season, water can be collected, which can then be used in times of drought. While this solution might not completely solve problems of water shortage, it will be able to contribute to a larger supply of water.

## Output A1 Collecting and re-using rainwater

### Description of Output

The collection of rainwater is something that can be done on both the small and the large(r) scale. Individual households can collect water on their roofs while municipalities can choose to collect rainwater on squares and roofs of larger buildings. This is the case for both urban and rural areas. Rainwater, after filtering, can be used for showers and toilets, and should decrease the use of other freshwater sources.

To implement this, municipalities and local communities must be given adequate funds and capacity to be able to both afford and choose this intervention. Both market and networked governance are important to support this to emphasise both the various stakeholders (market) and so that smaller initiatives are encouraged and subsidized (market). Because this intervention can happen on such a small scale that individual households are able to implement it, dialogue is needed between municipalities and civilians to promote this solution. Moreover, municipalities are able to implement it themselves on larger squares or larger municipal buildings with suitable roofs.

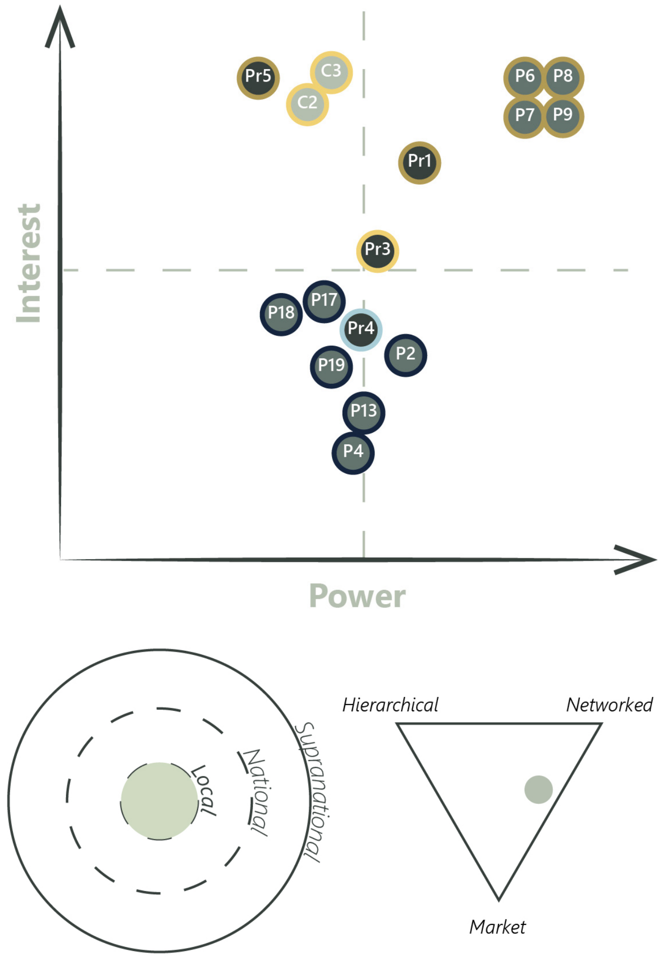



*Figure 6.3: Stakeholders, scale and governance type of A1 (by author).*



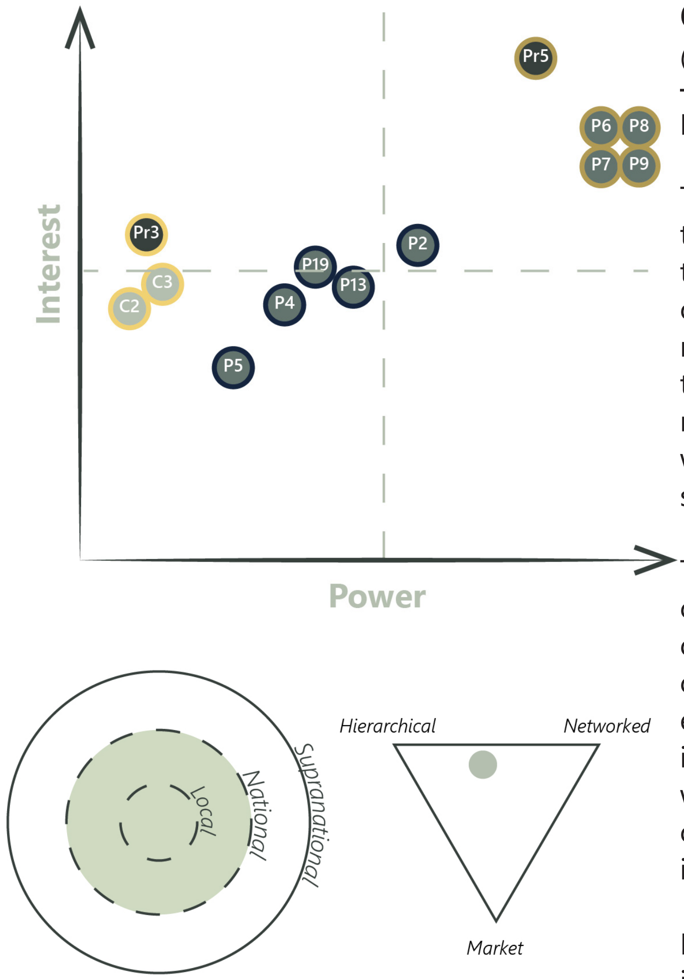



*Figure 6.4: Stakeholders, scale and governance type of A2 (by author).*

## Output A2 Educating people about re-use

*(Also contributing to outcomes D and G)*

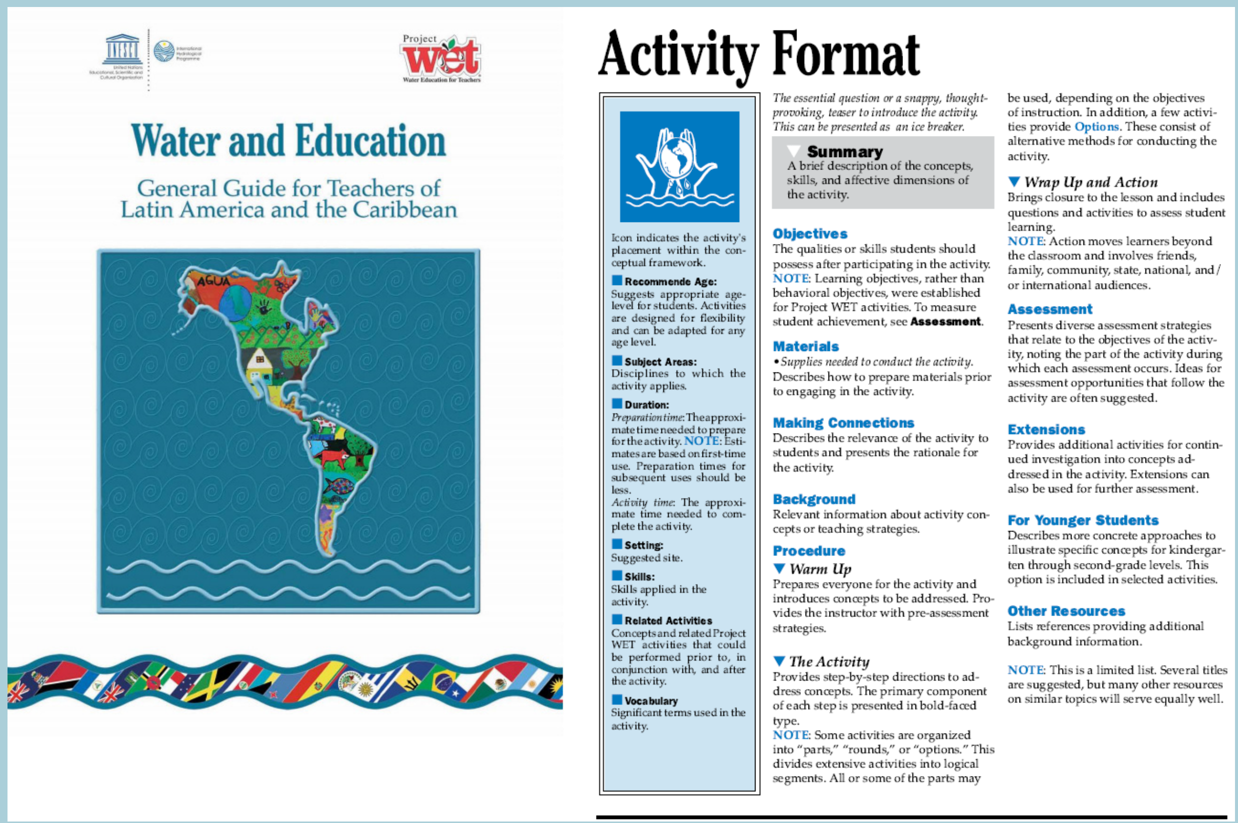
### Description of Output

To make sure that people know how important it is to re-use (rain)water, education in this matter needs to be improved. If people were to learn about re-use of water, they would know both the benefits and the methods to re-use water. This would allow individuals to come up with ideas themselves and would accelerate the transition. Communities or neighbourhoods would be able to create their own infrastructure based on general ideas about re-use.

This action needs to be implemented on every educational level, from primary school to higher education. Next to this, national programs need to be created to emphasise the value of re-using water. An example for this is the General guide for educators in the Americas and the Caribbean (UNESCO, 2012) where children are taught about the sustainable use of water. This resulted in various successful programs in the region.

It is important that the government and the most influential universities and research facilities play a major role by setting an example. These stakeholders should provide funds to schools to be able to teach children, and to provide incentives to involve local communities.

# General guide for teachers of Latin America and the Caribbean


Water and Education

General Guide for Teachers of Latin America and the Caribbean

# Activity Format

Icon indicates the activity's placement within the conceptual framework.

**Recommende Age:** Suggests appropriate age-level for students. Activities are designed for flexibility and can be adapted for any age level.

**Subject Areas:** Disciplines to which the activity applies.

**Duration:** *Preparation time*: The approximate time needed to prepare for the activity. NOTE: Estimates are based on first-time use. Preparation times for subsequent uses should be less. *Activity time*: The approximate time needed to complete the activity.

**Setting:** Suggested site.

**Skills:** Skills applied in the activity.

**Related Activities** Concepts and related Project WET activities that could be performed prior to, in conjunction with, and after the activity.

**Vocabulary** Significant terms used in the activity.

*The essential question or a snappy, thought-provoking, teaser to introduce the activity. This can be presented as an ice breaker.*

**Summary** A brief description of the concepts, skills, and affective dimensions of the activity.

**Objectives**
The qualities or skills students should possess after participating in the activity. NOTE: Learning objectives, rather than behavioral objectives, were established for Project WET activities. To measure student achievement, see **Assessment**.

**Materials**
• *Supplies needed to conduct the activity.*
Describes how to prepare materials prior to engaging in the activity.

**Making Connections**
Describes the relevance of the activity to students and presents the rationale for the activity.

**Background**
Relevant information about activity concepts or teaching strategies.

**Procedure**
*Warm Up*
Prepares everyone for the activity and introduces concepts to be addressed. Provides the instructor with pre-assessment strategies.

*The Activity*
Provides step-by-step directions to address concepts. The primary component of each step is presented in bold-faced type.
NOTE: Some activities are organized into "parts," "rounds," or "options." This divides extensive activities into logical segments. All or some of the parts may be used, depending on the objectives of instruction. In addition, a few activities provide Options. These consist of alternative methods for conducting the activity.

*Wrap Up and Action*
Brings closure to the lesson and includes questions and activities to assess student learning.
NOTE: Action moves learners beyond the classroom and involves friends, family, community, state, national, and / or international audiences.

**Assessment**
Presents diverse assessment strategies that relate to the objectives of the activity, noting the part of the activity during which each assessment occurs. Ideas for assessment opportunities that follow the activity are often suggested.

**Extensions**
Provides additional activities for continued investigation into concepts addressed in the activity. Extensions can also be used for further assessment.

**For Younger Students**
Describes more concrete approaches to illustrate specific concepts for kindergarten through second-grade levels. This option is included in selected activities.

**Other Resources**
Lists references providing additional background information.

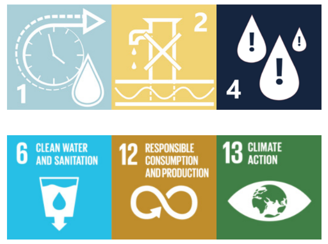
NOTE: This is a limited list. Several titles are suggested, but many other resources on similar topics will serve equally well.

*Figure 6.5: The activity format from the guide (UNESCO, 2007).*

This example in the Americas and Caribbean shows that by teaching children at a young age about the value of water, they can become conscious about the sustainable use of water. This group can then transfer this new knowledge to other people as well. This is a joint program between UNESCO IHP and Project WET International Foundation (UNESCO, 2007).

The guide contains various small exercises which help children learn about water systems and value. Each individual exercise is aimed at a specific age group with explanation about the tasks and requirements. Because of this, all possible exercises are structured and easy to teach. The structure and format of this guide is shown in the image on the left.






## Outcome B Increased desalinated water availability

### Description of Outcome

Currently desalinated water makes up for only a small part of the total water supply. This desalination of water can be done sustainably and when done sustainably, can provide more renewable water for coastal areas. The emphasis should be on making these desalination plants sustainable and then scaling up these operations. Next to this, current plants are often not well maintained and should therefore be renewed and improved.

*"Desalination of water can be done sustainably and when done sustainably, can provide more renewable water for coastal areas."*

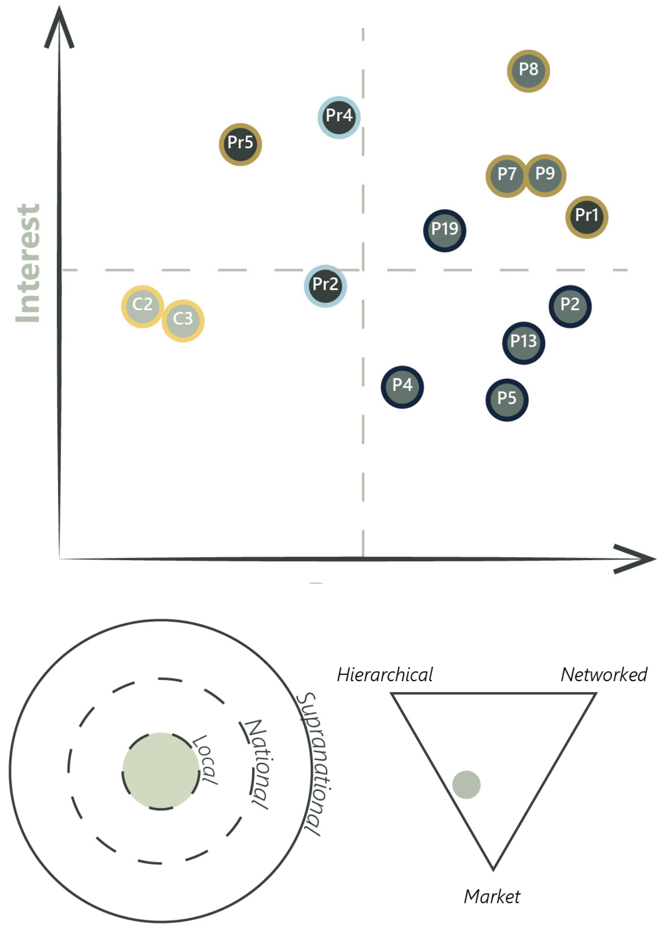



*Figure 6.6: Stakeholders, scale and governance type of B1 (by author).*

## Output B1 Constructing sustainable desalination plants

*(Also contributing to outcome D)*

### Description of Output

Current desalination plants are often powered by non-renewable energy sources. This causes the desalinated water to be very unsustainable. By creating new sustainable desalination plants, coastal areas will be able to become more self sufficient. Recently there have been developments worldwide that would make it easier to provide sustainable desalinated water: solar powered desalination plants. MIT, in collaboration with China (Chandler, 2020) have developed a way to make desalination way more efficient which can be suitable for coastal areas in water-scarce areas.

This action requires active governance with emphasis on the hierarchical and market sides. Subsidies must be provided to be able to construct these sustainable plants over cheaper unsustainable alternatives. Moreover, countries must choose for these sustainable alternatives over cheaper unsustainable water sources.

## Sustainable desalination

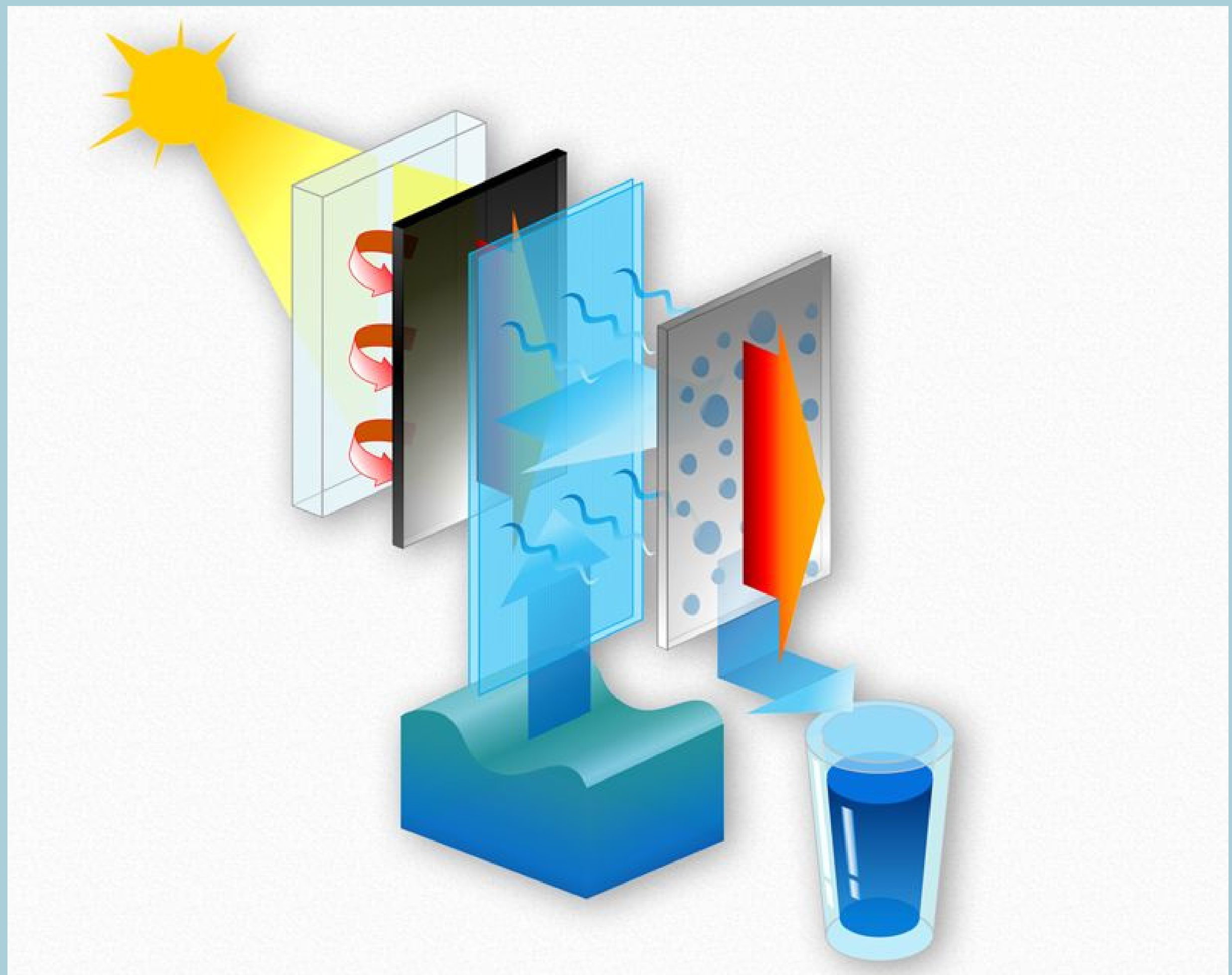
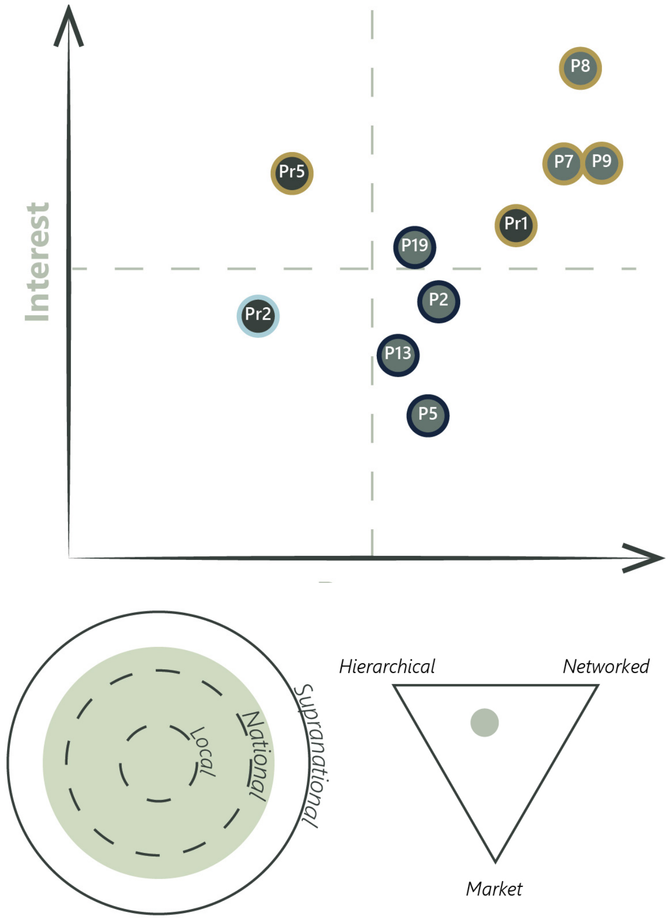


*Figure 6.7: The basic structure of the proposed desalination system (MIT, 2020).*

Current desalination plants often use unsustainable methods to desalinate water. Recently, MIT, in collaboration with China, has created an efficient way to use solar energy to power desalination. This system could provide 5 litres of drinking water per hour for every square metre of solar collecting area (MIT, 2020).

A combination of both additional research as well as scaling up the application of technologies like this can increase the amount of sustainable water in the region. Especially in coastal areas with little or no access to freshwater and dependency on unsustainable sources. Innovations like this are important and should be used to further improve the sustainability and resilience of the region.



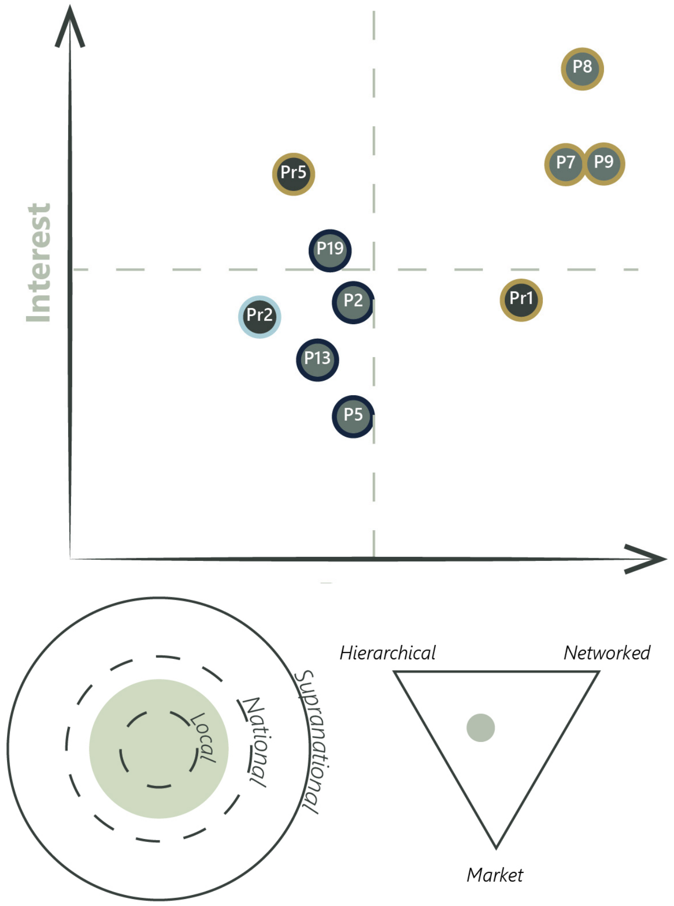



## Output B2 Providing subsidies to improve technology

### Description of Output

Besides the construction of new plants, current plants need to be improved. There are many existing plants that require improvements to be able to function sustainably. Because of this, research must be done to find sustainable methods of extraction water and improvements of technology. This can be done by setting up educational programs, providing subsidies to innovations or fund research programs.

*Figure 6.8: Stakeholders, scale and governance type of B2 (by author).*




## Output B3 Improving and maintaining existing plants

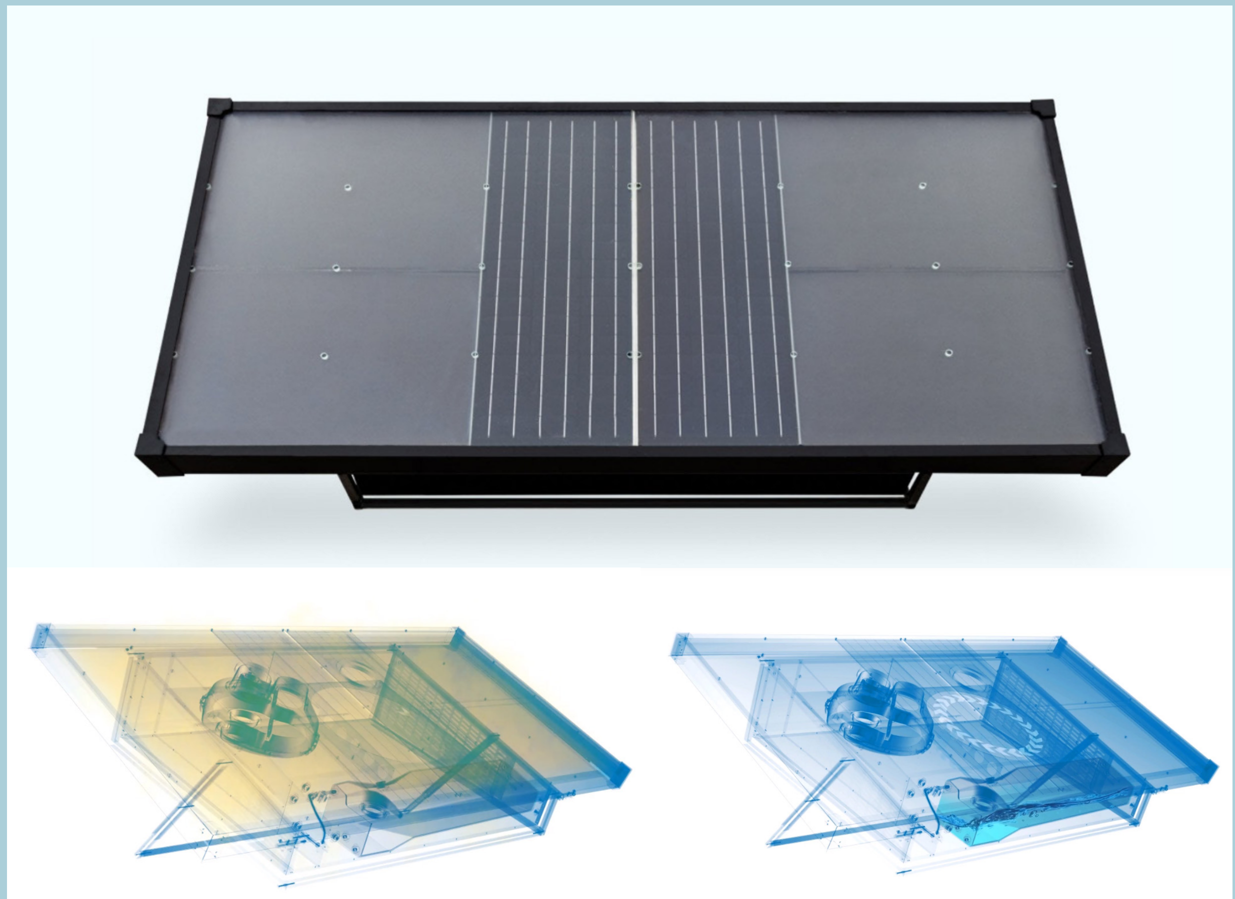
### Description of Output

Current desalination plants are often neglected and not well maintained. Besides improving these plants, they usually require regular maintenance as well. Governments should actively monitor existing plants and make sure maintenance is done frequently. Subsidies should be provided to improve these existing and outdated plants.

*Figure 6.9: Stakeholders, scale and governance type of B3 (by author).*

*"Desalination plants are currently neglected and need to be improved to increase efficiency and sustainability."*

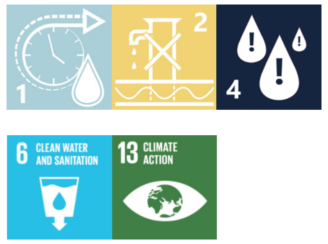
## Source, an alternative for inland cities and villages



Source is a company that has found a method to create clean drinking water from sunlight and air. For this method no water is needed so it creates water by itself. This can be a solution for inland cities and villages which are now dependent on groundwater sources. Even though the costs are currently high, further innovations like this will most likely decrease in cost in the future and provide a viable solution for arid regions worldwide (SOURCE Global, 2022).

*Figure 6.10: Solar power extracts water vapor from the air, which is then consensed into liquid (SOURCE Global, 2022).*





## Outcome C Improved regional cooperation

### Description of Outcome

Improving regional cooperation will result in better communication amongst the countries, possibly reducing water shortage and increasing the availability. Increased communication can bring forward drought warnings so that countries or regions are more prepared. In these cases these countries would be able to use their water for maximum benefit and efficiency.

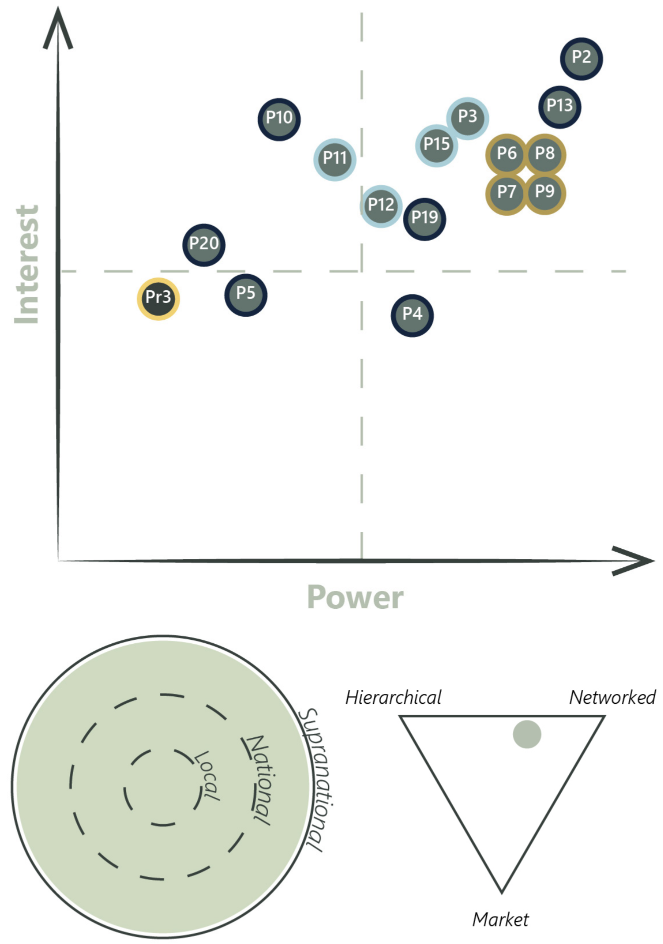



*Figure 6.11: Stakeholders, scale and governance type of C1 (by author).*

## Output C1 Improving regional cooperation

*(Also contributing to outcome F)*

### Description of Output

One of the key elements of this strategy is to strengthen regional cooperation. By creating a platform where countries regularly collaborate to tackle water availability and shortage, the different points of view can be used to come up with more inclusive solutions. Through conversations, countries will know each others standpoints and can actively try to mitigate the problem for all. This allows countries to also come up with solutions that are both transboundary in scope and in effect where multiple sides can benefit from and strengthen each other.

## Water Diplomacy Framework for the Mekong

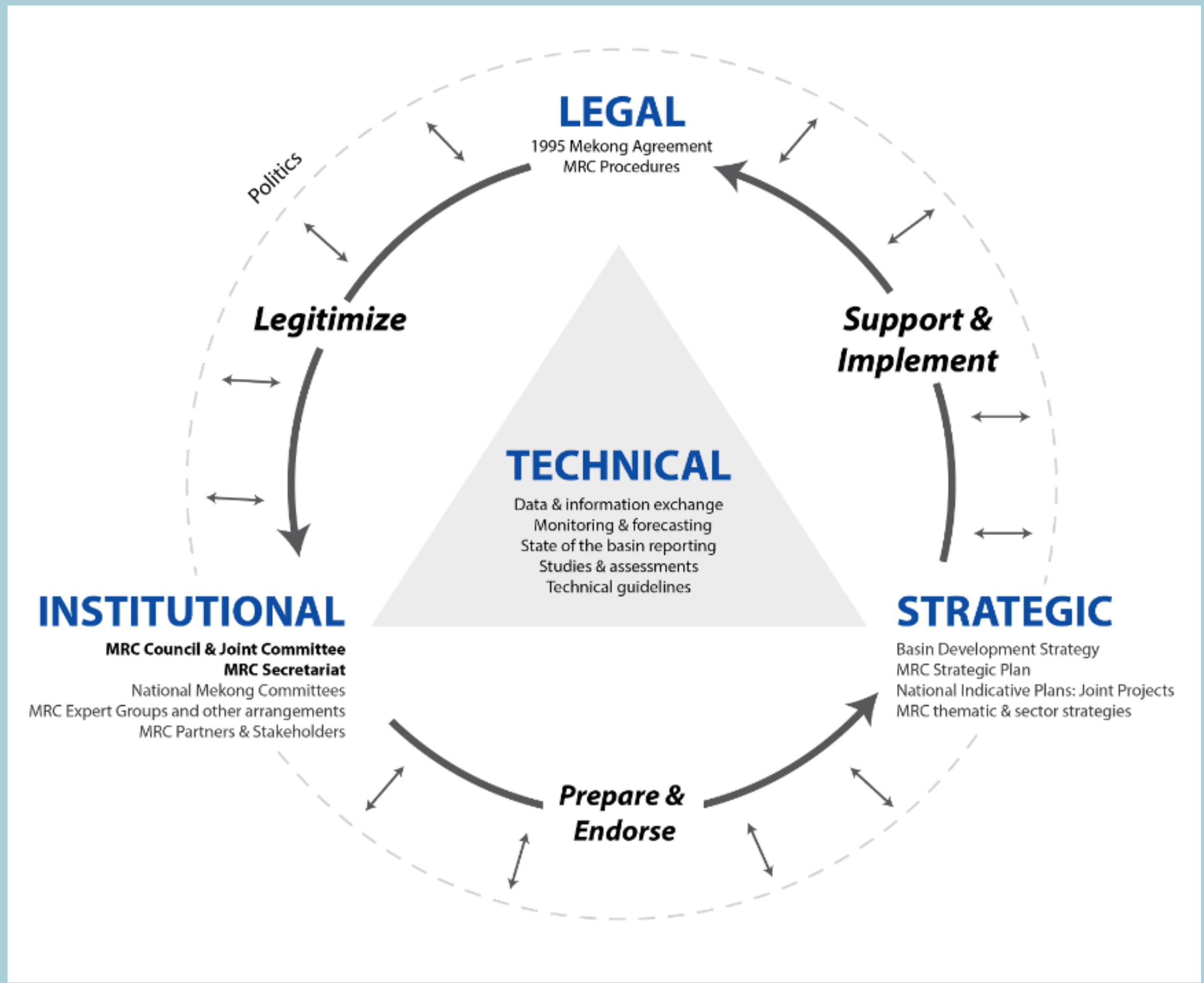
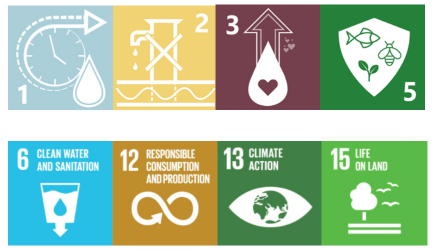



*Figure 6.12: The water diplomacy framework for the Mekong (Kittikhoun & Staubli, 2018).*

The Mekong River Commission has provided its member states with a diplomacy framework. This framework is at its basis a technical framework, based on scientific viewpoints. It helped reduce tensions in the past and remains to do so for possible future political conflicts (Kittikhoun & Staubli, 2018). Frameworks like this Water Diplomacy Framework for the Mekong can provide guidelines for member states.





### Outcome D Less unsustainable groundwater depletion

**Description of Outcome**

The current extraction rates of groundwater will result in a depletion of the aquifers. By regulating the use of groundwater and using it only in times of droughts and absolute scarcity, aquifers will no longer deplete at a fast rate. Policies must be created to make sure that this unsustainable use of water will be reduced.

> *"By regulating the use of groundwater and using it only in times of droughts and absolute scarcity, aquifers will no longer deplete at a fast rate."*

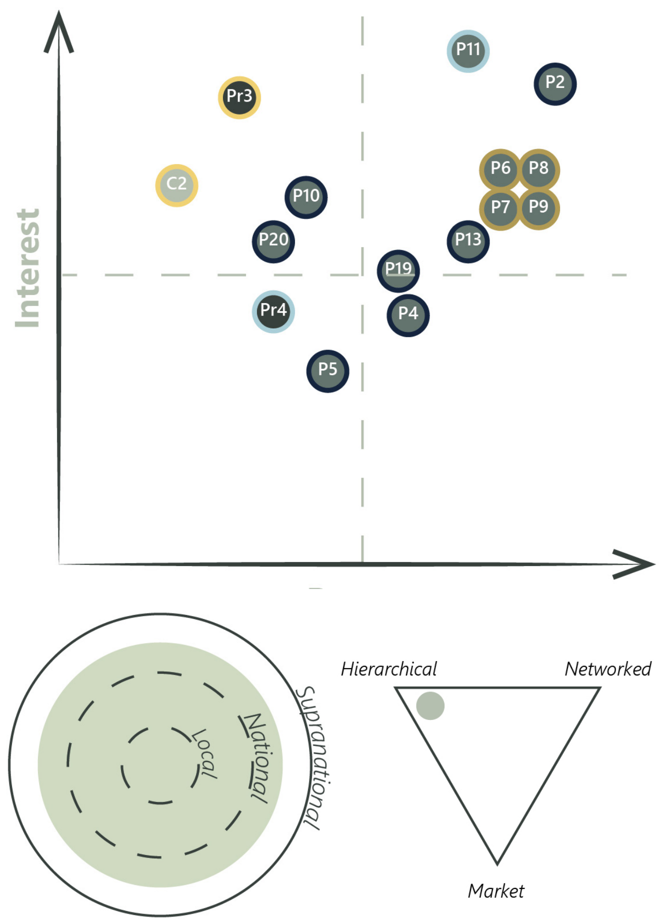



*Figure 6.13: Stakeholders, scale and governance type of D1 (by author).*

### Output D1 Regulating groundwater extraction

*(Also contributing to outcome J)*

**Description of Output**

Groundwater extraction must be regulated. This means putting a maximum capacity on the amount of groundwater extraction that can be done per user. While this means that large agricultural companies will be able to use less water, this also means that these actors will seek other, more sustainable methods to gain and use water. In time this must result in a decrease of groundwater use while increasing the use of more sustainable sources such as (sustainable) desalination.

## Output D2 Increasing non sustainable water costs

*(Also contributing to outcomes A, B, G and J)*

### Description of Output

While regulating water use by putting a maximum capacity on its use will help solve the depletion of groundwater, other methods must also be sought. By increasing the costs of unsustainable water use, people will be more careful to use water. This means that efficiency of water use will be increasing and people will no longer use water without thinking of the amount of use. In these cases, it is important to not neglect less fortunate people who already struggle to afford water. Exceptions must be made for those who struggle for clean drinking water.

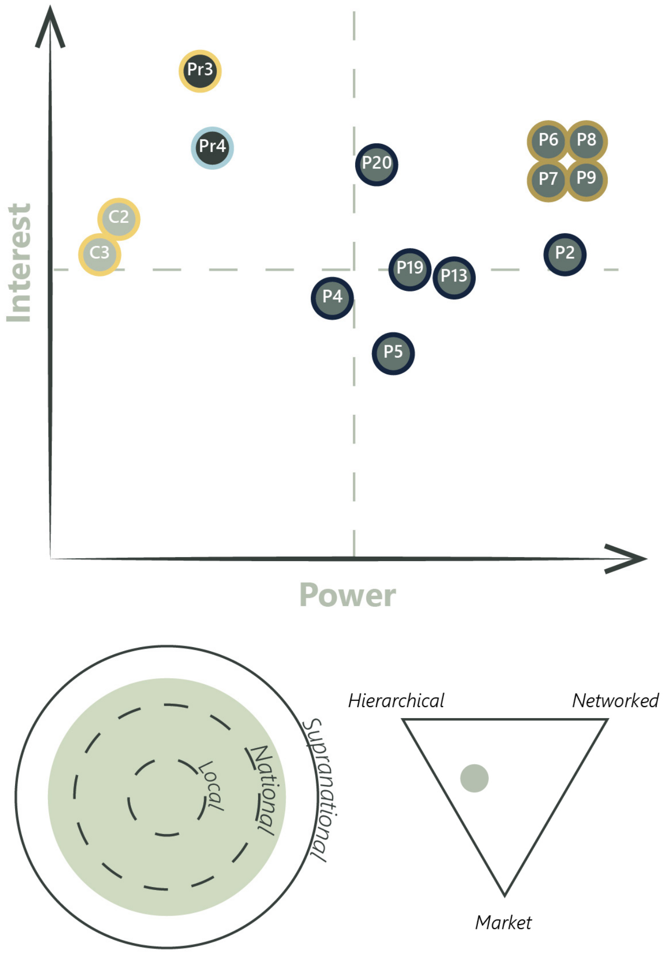



*Figure 6.14: Stakeholders, scale and governance type of D2 (by author).*

*"By increasing the costs of unsustainable water use, people will be more careful to use water, water use will go down and efficiency will go up."*



## Outcome E Improved water quality


### Description of Outcome

Water quality will be improved. This will be done by regulating the quality of water both in natural waterways and while extracting the water. By looking at water quality as early in the process as possible, every aspect of the process can be improved in terms of quality of water. This will not only result in a better quality of drinking water, it will also protect the environment from disasters. In areas where wastewater is dumped into areas without taking care of the pollution, policies must be set into place to take actions against major pollution.

*"Improving the quality of water will allow health of the population to improve as well as biodiversity to increase."*

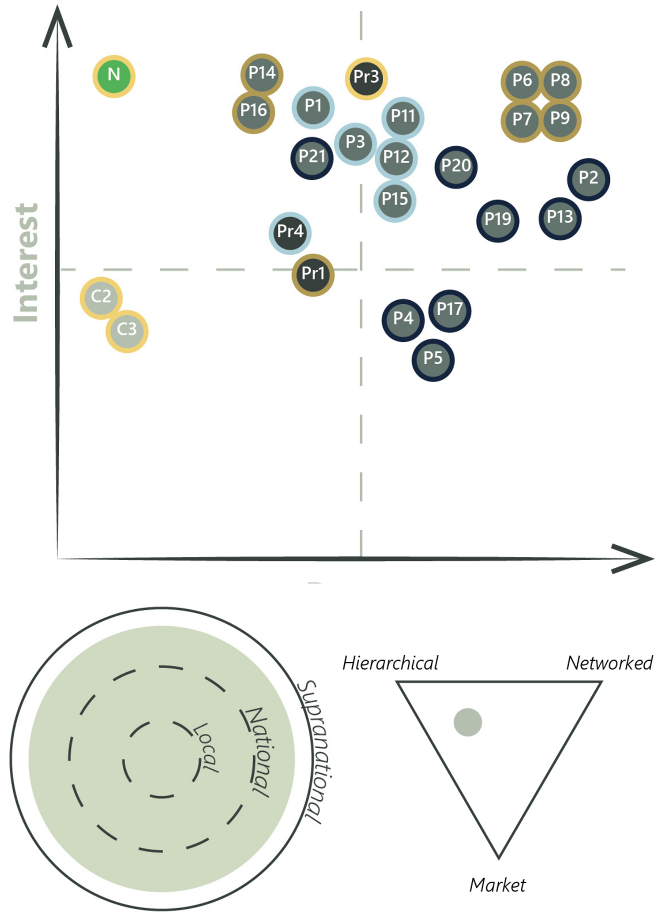



*Figure 6.15: Stakeholders, scale and governance type of E1 (by author).*

## Output E1 Regulating water quality and wastewater

### Description of Output

By regulating water quality throughout the process as well as in rivers and lakes, there will be less pollution. Improving this will allow health of the population to improve as well as biodiversity to increase. By making sure wastewater is not directly dumped but filtered and possibly re-used, water availability might increase as well. This requires action on all scales. Where governments can set policies to regulate the quality of water, municipalities, governates and provinces must be able to act on these policies.

## Output E2 Improving wastewater infrastructure

*(Also contributing to outcome G)*

### Description of Output

Regulating wastewater is not enough. Current infrastructure does not allow re-use of (waste-) water and wastewater is frequently dumped in rivers and lakes. Infrastructure needs to be improved, especially inside large cities and informal settlements.

To be able to achieve this, governments need to give adequate funds so that municipalities are able to tackle these issues on a smaller scale. The emphasis should be on areas where the largest improvements can be made and where the costs are the lowest.

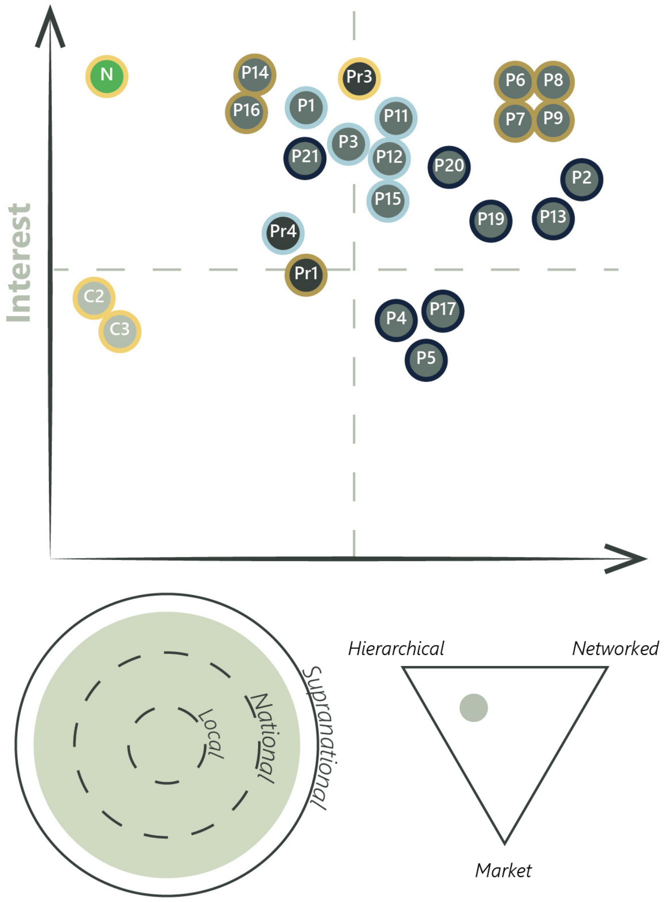



*Figure 6.16: Stakeholders, scale and governance type of E2 (by author).*



# Drought Early Warning Systems

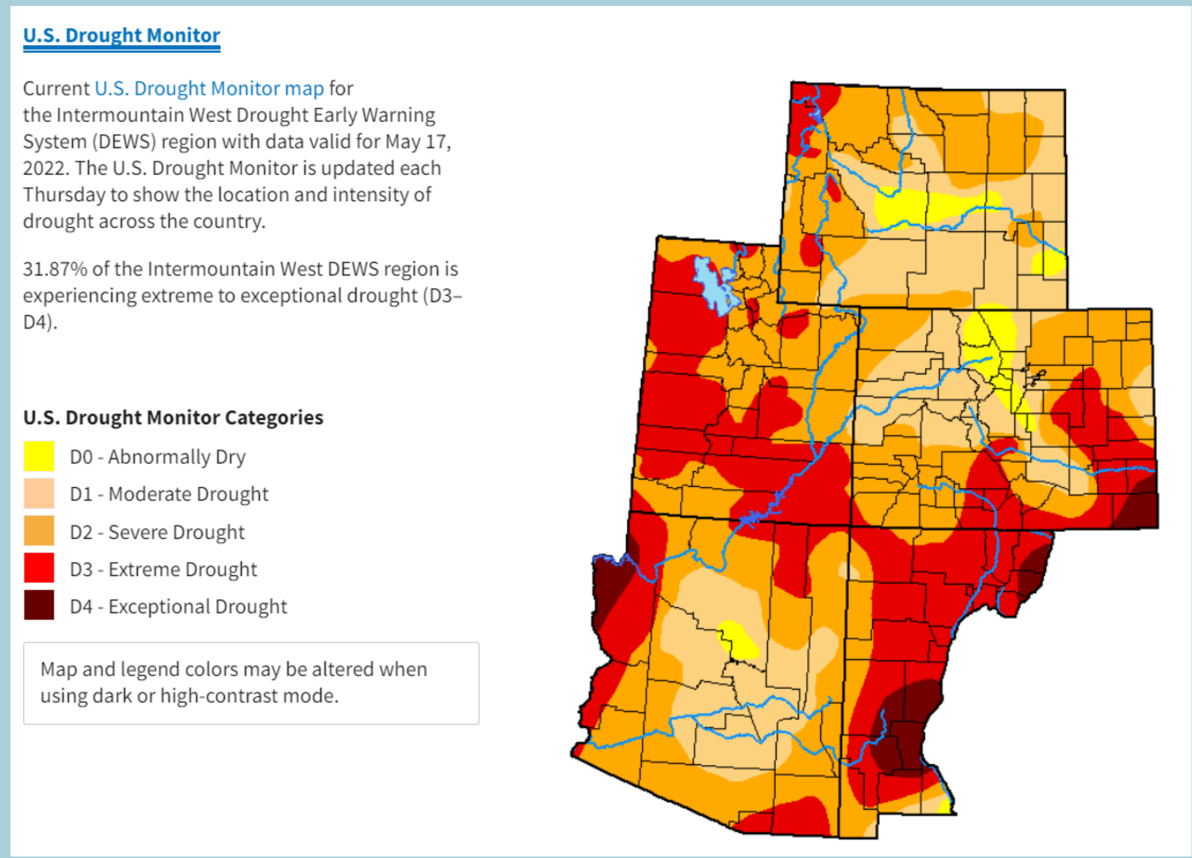



*Figure 6.17: Drought level for the Intermountain West region (NOAA/NIDIS, n.d.).*

Worldwide, there are several Drought Early Warning Systems (DEWS), one of these is the DEWS in the USA. This system uses knowledge of different stakeholders (e.g. forecasting, monitoring and scientific research) both regional and local to give decisionmakers useful and accessible information. In the United States, this system is split into various regions with varying water tables because each region's water system behaves differently. This means that stakeholders can see the warning of droughts specifically for their own region instead of the whole country and to try and prevent or mitigate these droughts (NOAA/NIDIS, n.d.).

For each specific region, a map is marked with colours corresponding to levels of drought. Besides this, each region also has an individual strategic plan, addressing the main challenges in the region. Because the variation on a small scale, local stakeholders can act according to their own level of drought, instead of being tied to regional policies without major impact.

## Outcome F Scarcity warnings

### Description of Outcome

A platform must be developed where countries will be able to see droughts and scarcity before it happens. This can be done by actively registering and monitoring availability, extraction and use. Creating these early warnings will allow countries to be able to adjust their water use beforehand, take measures and seek aid to mitigate the issues when they do appear. Long periods of scarcity will be shortened and long term issues such as biodiversity loss and crop failure will be reduced.


*"Creating these early warnings will allow countries to be able to adjust their water use beforehand, take measures and seek aid to mitigate the issues when they do appear."*

## Output F1 Monitoring water availability

*(Also contributing to outcome C)*

### Description of Output

By monitoring water availability, small changes will be visible. These small changes, such as a week without rain or a period of intense heat will have an effect on the total availability of water. Noticing the effect on the supply of water will allow countries, regions or cities to take adequate measure before large problems occur. Monitoring this availability of water will need more cooperation on all scales as small changes need to be detected and passed along. If one region is dealing with minor water shortage, another region might have excess water which can be provided.

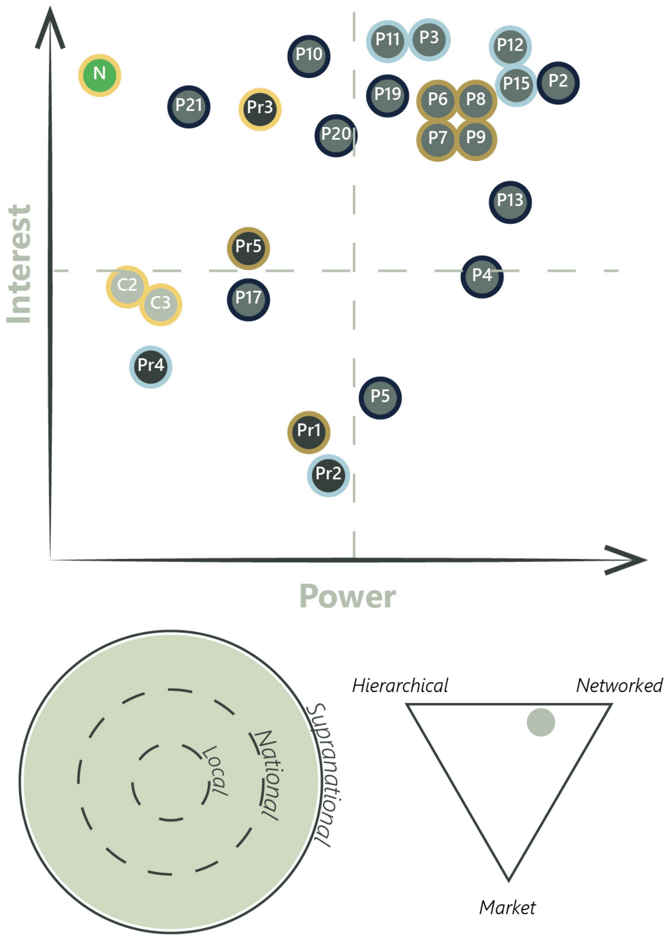



*Figure 6.18: Stakeholders, scale and governance type of F1 (by author).*



*"By monitoring the extraction and availability of groundwater, the right measures can be taken in time."*

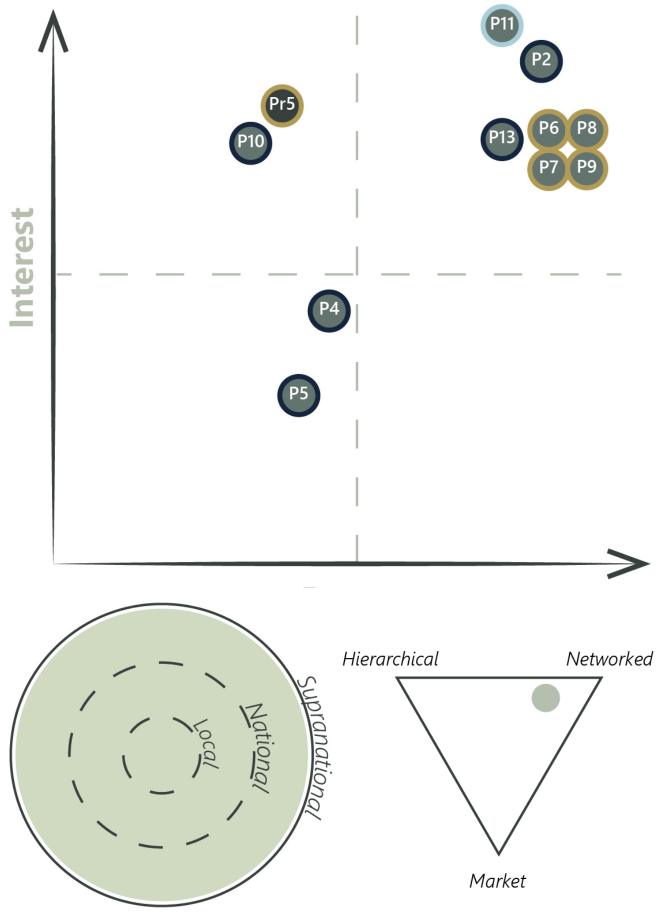



*Figure 6.19: Stakeholders, scale and governance type of F2 (by author).*

## Output F2 Monitoring groundwater extraction

*(Also contributing to outcome D)*

### Description of Output

Groundwater extraction can form a major future threat. If extraction rates rise, full depletion will arrive sooner and sooner. By monitoring the extraction and availability of groundwater, the right measures can be taken in time, if needed. If water scarcity occurs, groundwater extraction can be increased if the availability allows it. Without knowing the regular extraction rates and total supply, a right amount of increased extraction can not be estimated. To allow for this groundwater monitoring to be functioning as needed, countries need to cooperate so that extraction rates in other countries and regions are noticed as well.

## National Framework for Groundwater Monitoring US

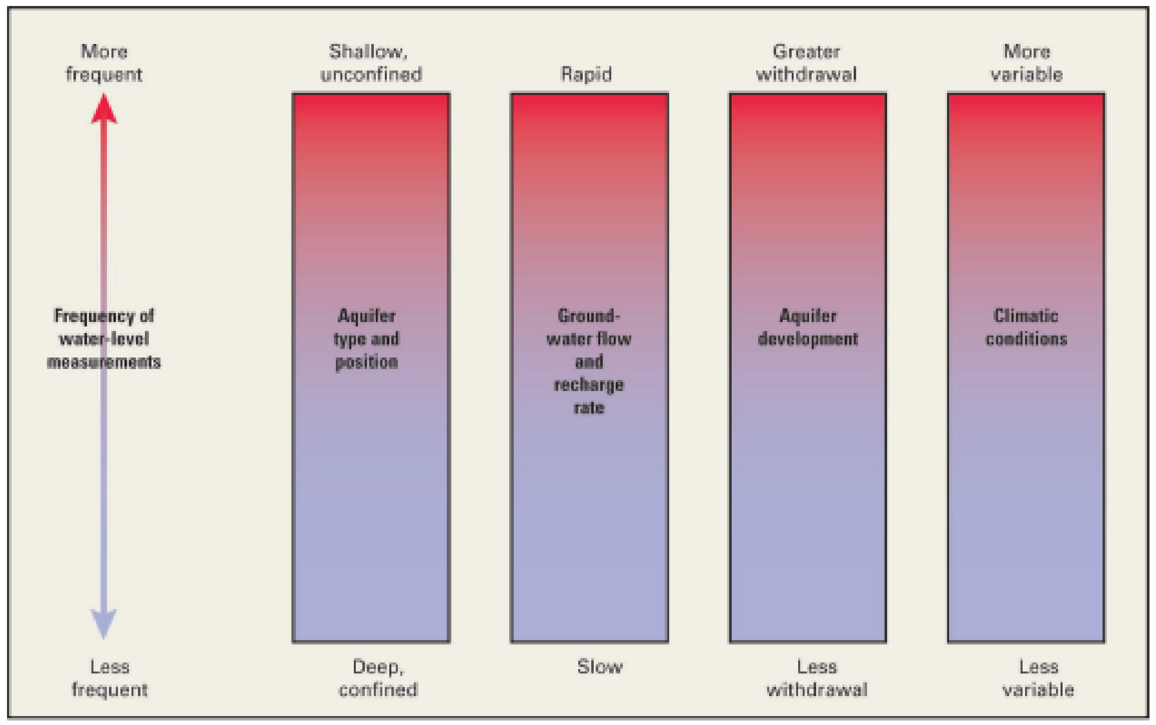



*Figure 6.20: Elements which decide the frequency of water-level measurements (Advisory Committee on Water Information, 2013).*

In areas dependent on groundwater, it is important to monitor the health of these groundwater systems. In the United States, a national program was created to monitor the extraction and levels of groundwater. Such a system can provide insight in declining levels and can provided early warnings for areas where depletion is at risk. This framework gives insights in all the different elements of groundwater extraction with the goal to inform decisionmakers and users, mainly on national and regional scales (Advisory Committee on Water Information, 2013).



## Outcome G Re-use of wastewater

### Description of Outcome

Because of the limited total water availability, every method needs to be investigated to be able to use all of the available water at maximum efficiency. One of these methods is the re-use of wastewater. This wastewater comes from homes, industry and agriculture and can be used in a various ways. By connecting the various steps of the cycle of water use, wastewater can for instance be used for irrigation of crops. Wastewater can be treated which in turn can be used again to irrigate crops. Because agriculture is one of the main users of water in this region, agricultural wastewater reuse can increase the total water supply and reduce shortage of water. Next to this, water can also be reused in households. Besides the aforementioned reuse of rainwater, households can for instance also reuse shower water to water plants in their neighbourhood.

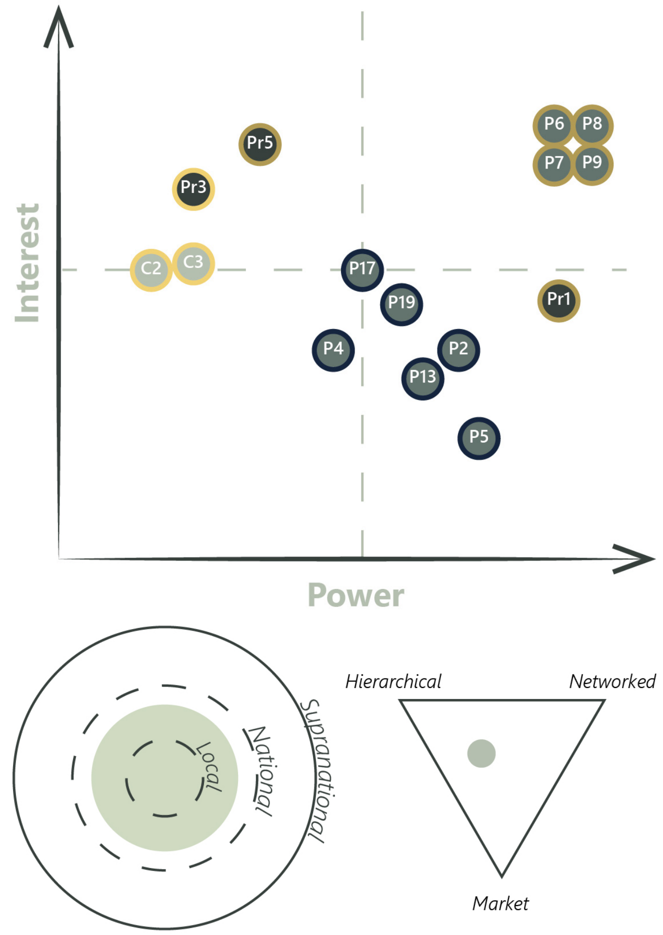



*Figure 6.21: Stakeholders, scale and governance type of G1 (by author).*

## Output G1 Improving water reuse infrastructure

*(Also contributing to outcomes A and J)*

### Description of Output

Current infrastructure does not allow enough wastewater to be reused. Wastewater is dumped into rivers and lakes which causes pollution while also dumping water that can be used in agriculture. Governments need to provide funds to governates and municipalities so that these can improve the infrastructure on a smaller scale. Farmers need to construct systems that captures wastewater and residential areas need to be provided with proper infrastructural improvements. In most cities water infrastructure is not well constructed and outdated.

This action needs to be applied on all scales, both regional and local to maximize efficiency of reuse. Even though rural villages require other infrastructural changes than urban and large agricultural areas, they too need to be provided with proper piping and small treatment plants.

## Output G2 Subsidizing and promoting water reuse

*(Also contributing to outcome A)*

### Description of Output

Current stakeholders often do not know about the value of reuse or find it too expensive to contribute to the cause. To improve and change this, countries need to both promote and subsidize the reuse of wastewater. This can be done by national programs of advertisements as well as improving local infrastructure and advising people how to improve on their water use. Schools should educate people on the various methods reuse is possible and should invest time and money in investigating innovations.

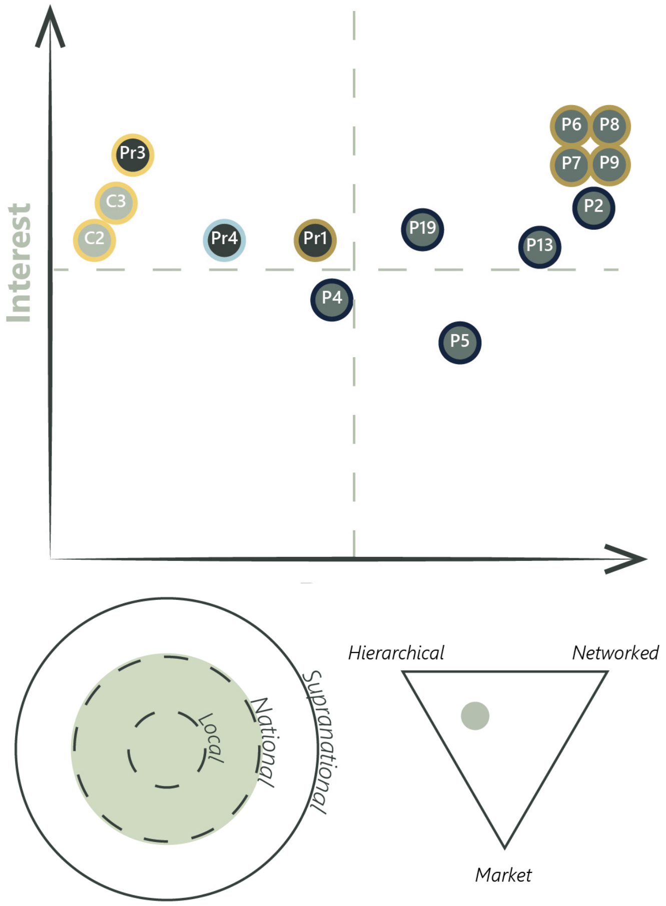



*Figure 6.22: Stakeholders, scale and governance type of G2 (by author).*

## Output G3 Promoting ecological and technological filters

*(Also contributing to outcome I)*

### Description of Output

Wastewater needs to be filtered and treated to make sure that the output is clean enough to use. To provide for this cleaner water, there are various types of filters. Ecological filters, for instance plants, can filter the water and provide for a cleaner output. By integrating this into urban or rural areas and promoting this sustainable way of filtering, wastewater can be seen as a resource instead of just an output. When ecological methods of filtering are not possible, other methods like treatment plants or smaller technological solutions are also possible.

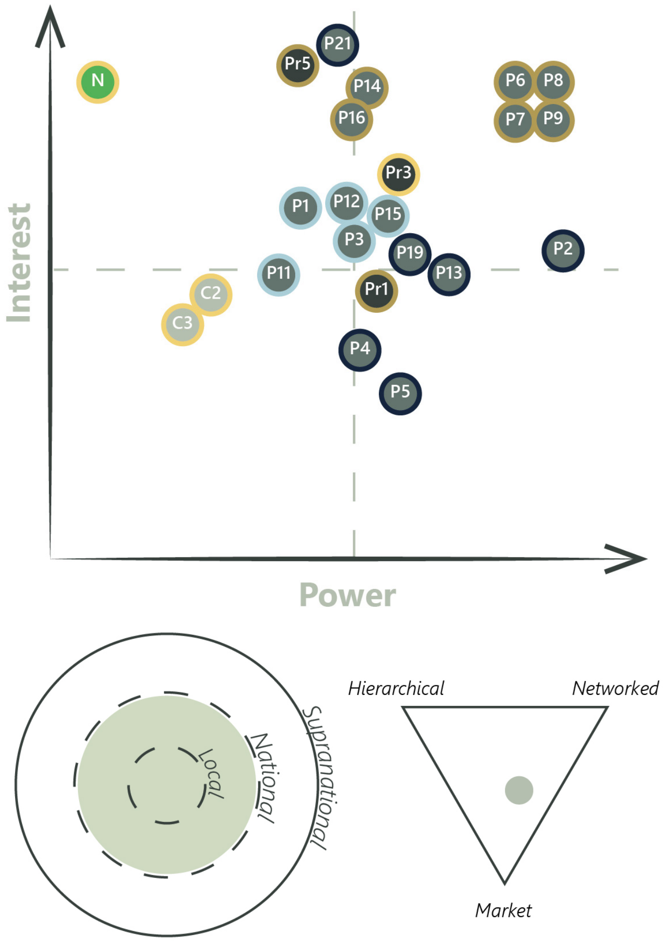



*Figure 6.23: Stakeholders, scale and governance type of G3 (by author).*



## Outcome H Improved agricultural water use efficiency


### Description of Outcome

Evidence has shown that current agricultural water use is not as efficient as possible for most of these countries. By improving the efficiency of water use in the agricultural sector, a lot of water can be saved, providing more water for other sectors as well. This means that methods in which the water is used for irrigation needs to change, as well as aforementioned reuse of agricultural water. Next to this the type of crops also play an important role in the use of water. Some crops grow better in an arid environment and require less water than is currently used.

> *"By improving the efficiency of water use in the agricultural sector, a lot of water can be saved."*

## Output H1 Changing and improving irrigation methods

*(Also contributing to outcome J)*

### Description of Output

The method of irrigation is both important for the crops and for the use of water. Using inefficient methods of irrigation can lead to overuse of water, whereas improving the irrigation can greatly reduce overall water use. A study from Multsch et al (2017) shows that improving the irrigation efficiency can greatly reduce water shortage in the region. This proves that investigating in agriculture can reduce the pressure on water resources, which together with other actions can mitigate the problem for the region.
Although this action requires action from farmers on a small scale, regional funds and regulations need to be provided to motivate these stakeholders to change their way of farming. The region or countries themselves must set a set of policies to nudge possible fence sitters to the right direction. Next to the set of policies, farmers need to be provided with education as to why this change is necessary and what benefits there are for them.

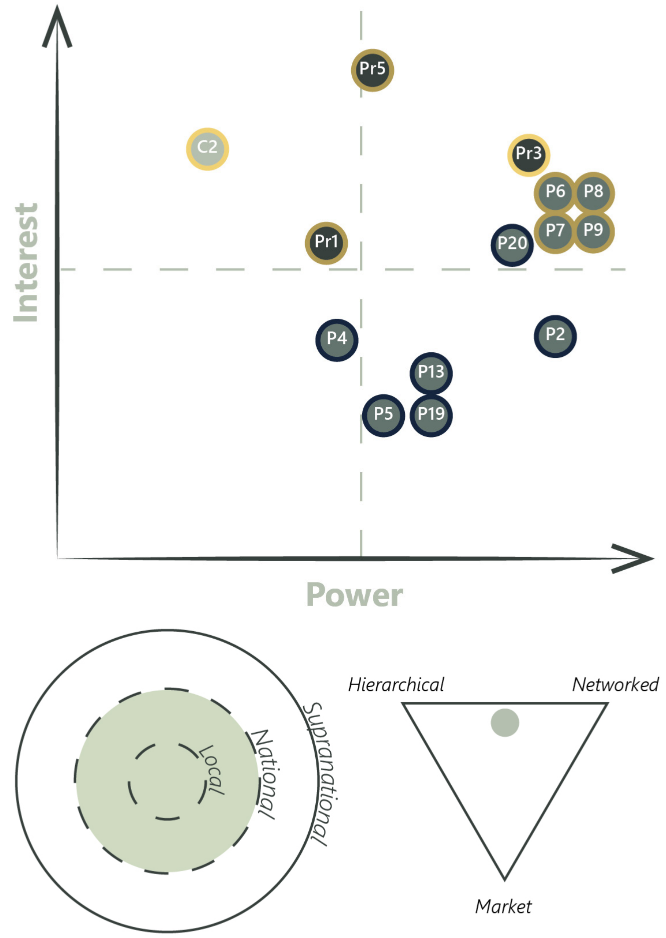



*Figure 6.24: Stakeholders, scale and governance type of H1 (by author).*

## Nature-based solutions (NBS) to combat droughts


*Figure 6.25: Restauration of wetlands leads to the region of La Mojana being less prone to droughts and floods (UNDP Climate, 2021).*

Around the world, various nature-based solutions have decrease the threat of droughts. Two major solutions that can be used are the restoration of both wetlands and forests. By restoring these areas, nature becomes more resilient in periods of drought and can overcome water shortages. This resilience will also decrease the loss of water in these areas.

In Colombia, the restoration of the wetlands La Mojana have decreased the risk of drought. Besides this, they have also decreased the risk of floods and increased biodiversity.



## "By decreasing the evaporation from large lakes, more water will be available to be extracted."

### Outcome I Decreased evapotranspiration of large water bodies

**Description of Outcome**

Due to climate change, temperatures will rise in the coming decades. Currently, a lot of water is extracted from large lakes such as Lake Nasser and Lake Chad. Due to high temperatures, water will evaporate from these lakes, resulting in less available water. Even though this amount of evaporated water is not as significant as other threats, is does lower the amount of available water. By decreasing the evaporation from large lakes, more water will be available to be extracted.

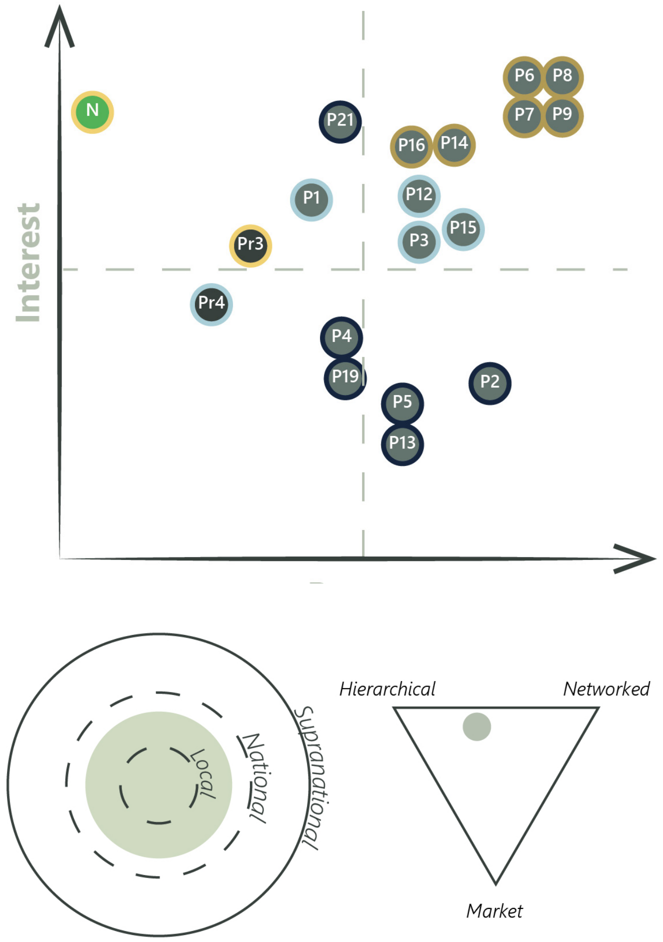



*Figure 6.26: Stakeholders, scale and governance type of I1 (by author).*

### Output I1 Increasing (near-) water biodiversity

*(Also contributing to outcome E)*

**Description of Output**

By increasing vegetation and biodiversity near and in these larger lakes, water quality will be improved, and evaporation might decrease. The latter is dependent on the amount of vegetation, as larger types of vegetation have more impact in the reduction of evaporation, the arid region restricts the amount of species that are able to grow there. There is evidence that nature-based solutions can provide an increase in quality of water, this is the case for wetlands (Acreman et al, 2021). Further research is needed to provide insight on how a possible increase in vegetation can reduce evapotranspiration for the region.

## Output I2 Nature protection

*(Also contributing to outcomes D and E)*

### Description of Output

In the region, droughts and high temperatures put a lot of pressure on nature. Next to this, governments prefer to reclaim desert lands to increase agricultural production, putting even more pressure and decreasing biodiversity. Instead of large agricultural reclamation projects, countries should focus on protecting nature and increasing biodiversity whenever possible. There are various international stakeholders who can assist with the protection of nature, such as African Parks, which focusses on the conservation of wildlife and biodiversity in the continent. By appointing areas which are under threat of both urban expansions and desertification, the region can protect itself against the loss of species in the future.

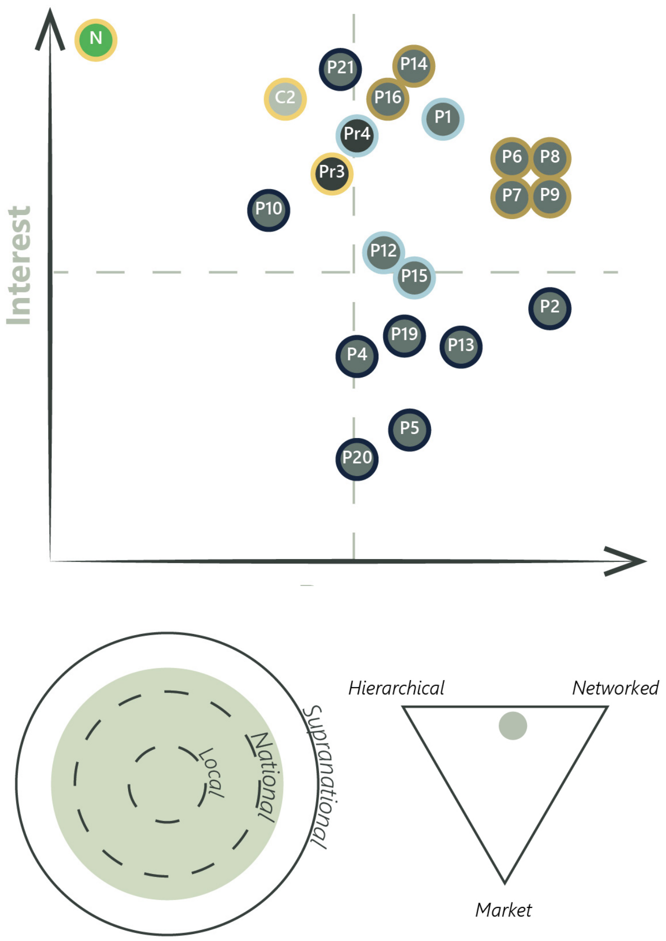



*Figure 6.27: Stakeholders, scale and governance type of I2 (by author).*



## Outcome J Decreased water use

### Description of Outcome

A seemingly easy way to reduce shortage of water is to reduce the current use of water. There are a few measures that can be taken to reduce the use of water in the short term. By educating people the value of water, people might choose to use less. This can reduce the use of water in cities, but also in agriculture. Because this action must result in voluntary reduction of use, it is important to simultaneously implement policies which restrict the maximum use of water for large users such as agricultural companies.

## Output J1 Creating (water value) awareness

*(Also contributing to outcome D)*

### Description of Output

Just like output A2, education people about the value of water will in time result in a more sustainable lifestyle for the people living in these countries. However, municipal water use is not as large as agricultural water use. The education focussed on teaching people about the value of water should be pointed towards farmers who overuse water when irrigating crops. Simultaneously with educating these people, innovations should be funded which decrease the water use for the largest users of water.

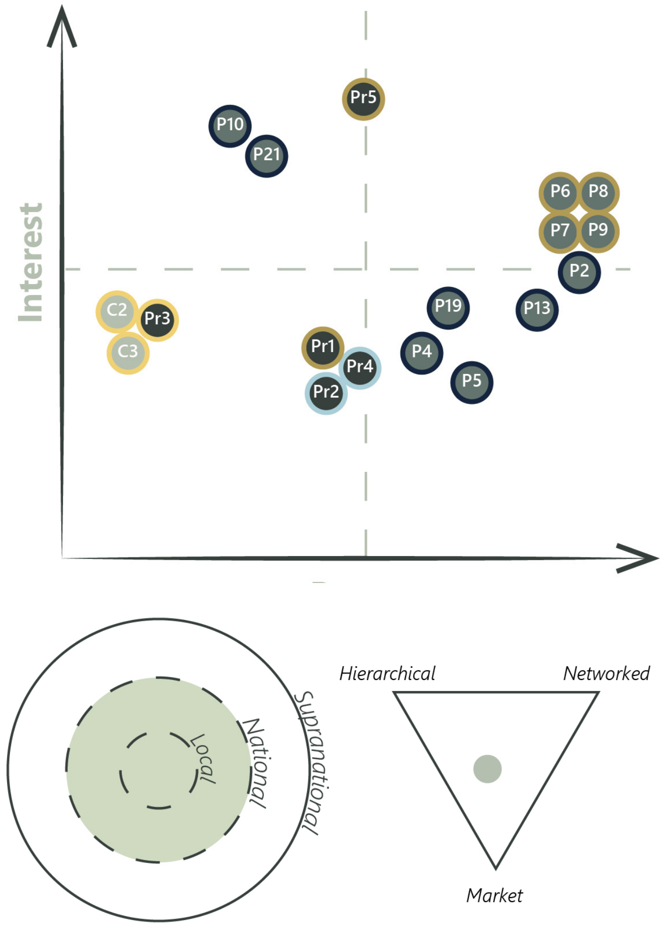



*Figure 6.28: Stakeholders, scale and governance type of J1 (by author).*

*"The education focussed on teaching people about the value of water should be pointed towards farmers who overuse water when irrigating crops."*

## Output J2 Regulating overconsumption

*(Also contributing to outcome D)*

### Description of Output

Educating people can only do so much. By putting regulations into place which restricts overuse of water, the use of agriculture will go down. Farmers will seek more innovative ways to irrigate their crops, resulting in more available water during droughts. Evidence has shown that by increasing the price of water, water shortage can be tackled (Tang et al, 2013). These policies must be focussed on large users instead of all users. Poor and vulnerable communities can already have difficulties with access to cheap water and increasing costs for these groups only makes it worse.

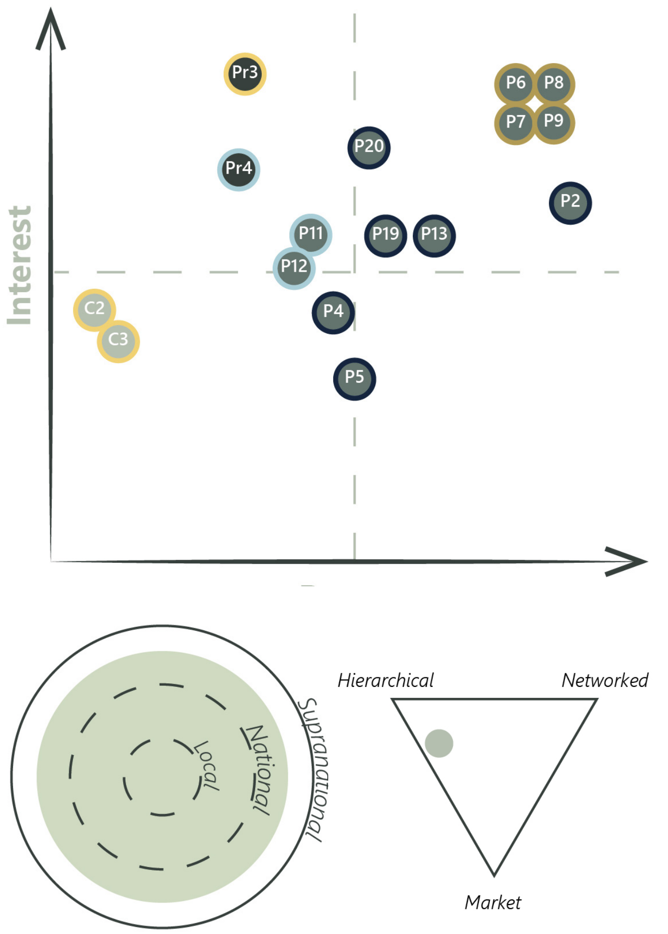



*Figure 6.29: Stakeholders, scale and governance type of J2 (by author).*


Image by Valkova (2015), adapted by author.

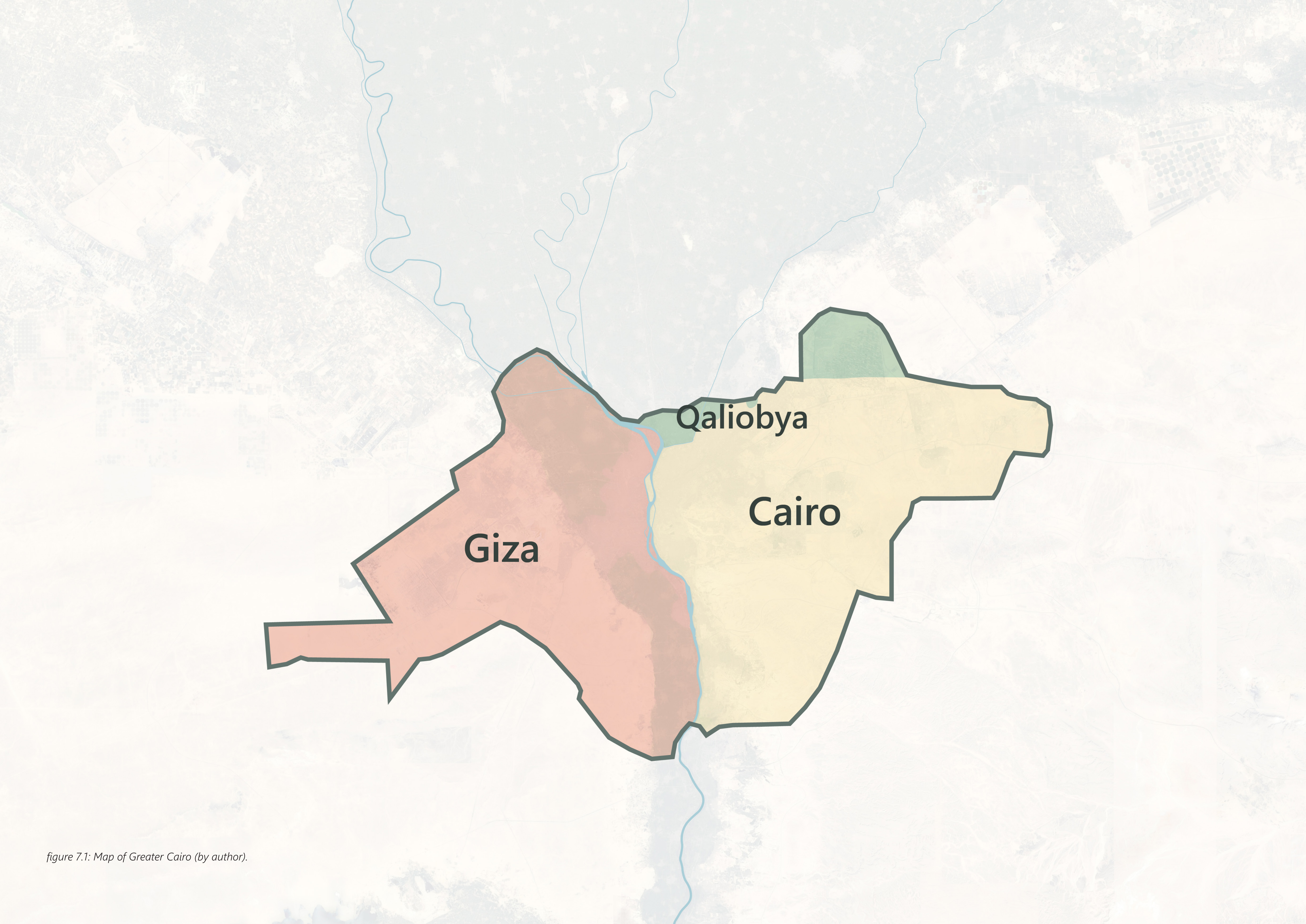



*figure 7.1: Map of Greater Cairo (by author).*

## 7.1 Greater Cairo

To get a better sense of the effect of the regional strategy proposed in the previous chapter on a smaller scale, this chapter will zoom in into Greater Cairo and propose designs on this smaller scale. The Greater Cairo region consists of parts of three governorates: Cairo, Gizeh and Qaliobya (as shown on the previous page). Because of the time limitations of this research, this region will be the only smaller scale case study. However, previous chapters have emphasised the importance of regional differences. Therefore it remains important to keep in mind these differences when potentially applying such designs on another sites.

## 7.2 Typology

The Greater Cairo region is a very large and complex region. Therefore, the design phase will be done by looking into the four main urban fabric types. These four types represent the majority of the city and are very different from each other. By looking into each type individually, the main design components can be shown on a smaller scale while also serving as input for city-wide solutions. For each type, a example neighbourhood will be chosen, which will illustrate the main elements. In each example neighbourhood a building, street and third element will be chosen to zoom into. These three elements will then be used to formulate main design solutions.

## A. Dense, old, unplanned

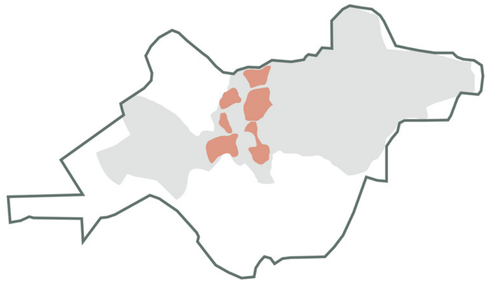
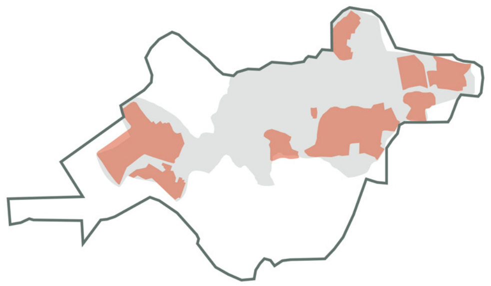


*figure 7.2: Image illustrating type A by Higgins (n.d.).*

*figure 7.3: Image illustrating type C by Looch (2021).*

## C. New, planned





## B. Old, planned

*figure 7.4: Image illustrating type B by* Cairo Scene (2021).

*figure 7.5: Image illustrating type D by Mohamed (2021).*

## D. Dense, new, unplanned

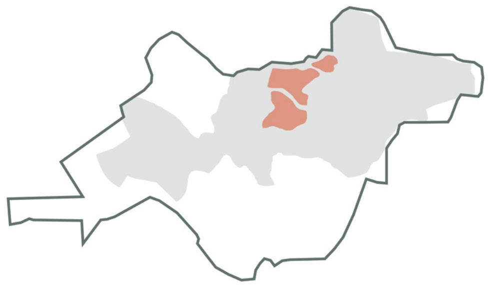
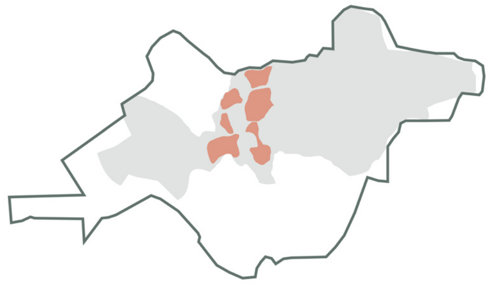


*Figure 7.6 (left) by Higgins (n.d.), figure 7.7 (right) by Azabache (2019) and figure 7.8 (bottom) by El-Rashidi (n.d.).*

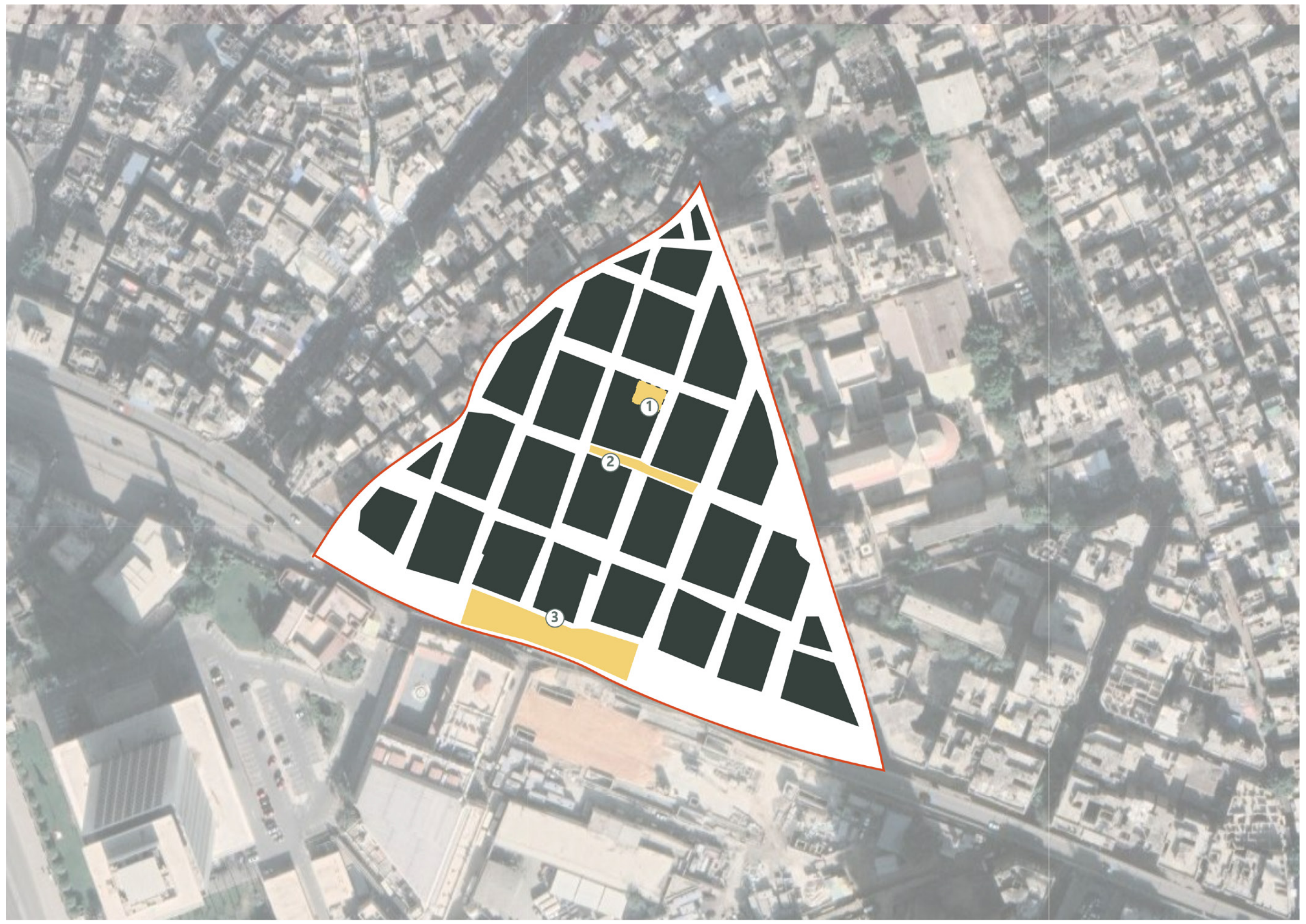




**7.3.A Dense, old, unplanned**

The sample neighbourhood is shown below and images of similar neighbourhoods are shown on the left page. This type consists mainly of small residential buildings which are densely packed, with small streets in between. These neighbourhoods are mainly located close to the river, and are oftentimes informally constructed and unplanned. Because of this unplanned nature of these areas, water infrastructure can be lacking and solutions should often be implemented through a bottom-up approach. The next pages will explain which solutions are possible in these neighbourhoods in the case of a building and two different streets (narrow and wide).

*Figure 7.9 (top) illustrating the location of the specific type in relation to the urban area (by author).*
*Figure 7.10 (bottom) illustrating the example neighborhood (by author).*



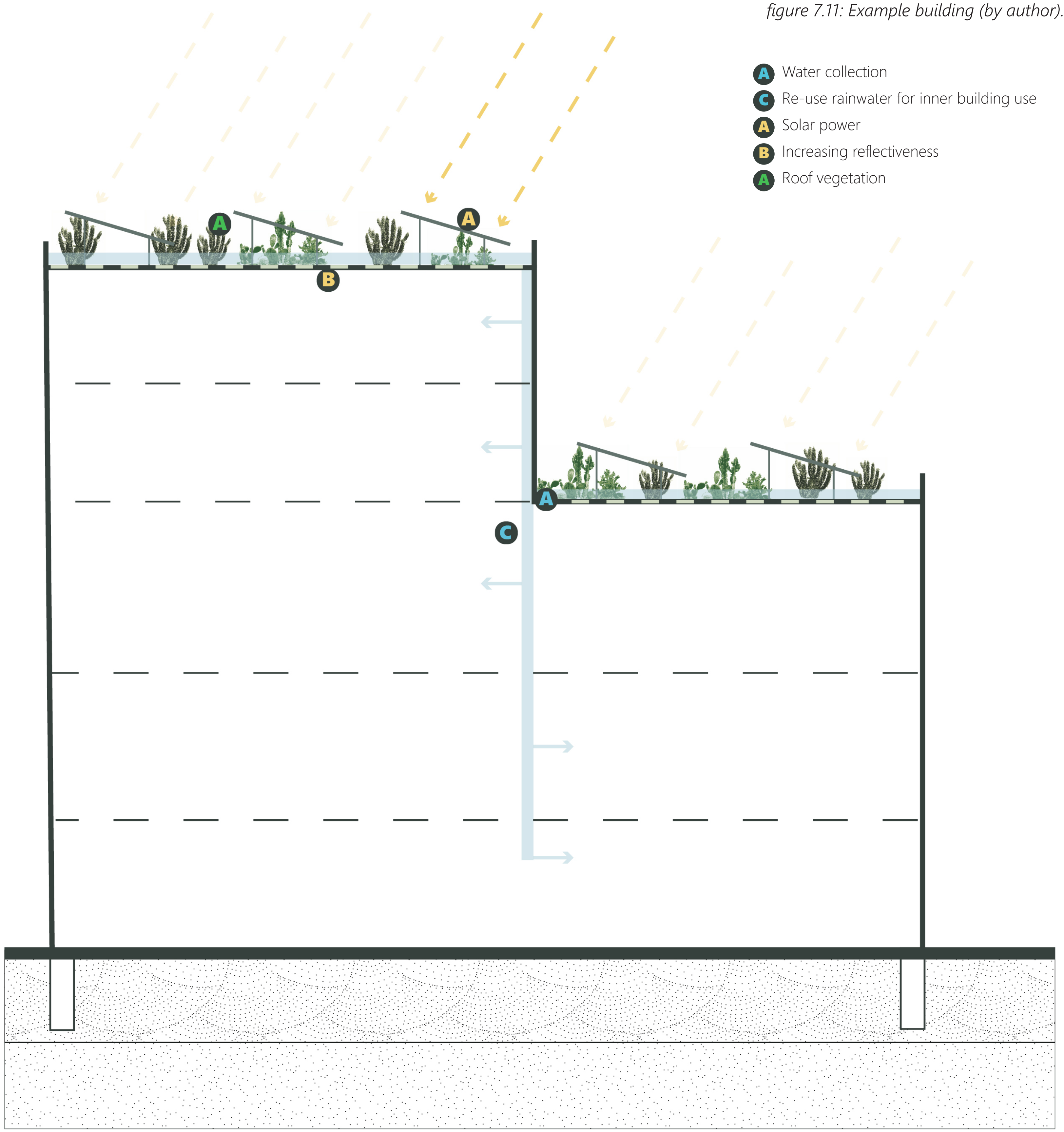



*figure 7.11: Example building (by author).*

- A Water collection
- C Re-use rainwater for inner building use
- A Solar power
- B Increasing reflectiveness
- A Roof vegetation

**Type A: Residential building**

Residential buildings in these unplanned neighbourhoods require small interventions which are also applicable through a bottom-up approach. This is why the roofs are the most important in these dense areas. Because of the high density, the majority of the surface in this neighbourhood is the roofs. The most urgent issues are the increasing urban heat island (UHI) effect, the shortage of water and the flash floods during heavy intense rainfall.

To tackle the UHI effect, two major solutions are proposed: increasing biodiversity and increasing reflectiveness of the roofs. The latter can be achieved by painting the roofs or changing the material, the former is possible by planting cacti on the roofs. Cacti are very drought resistant and do not require large transformations to the buildings themselves. Research has shown that planting cacti on roofs can very much help with reducing the heat stress in these urban areas (Wark, 2010).

*figure 7.12: Cacti used as roof vegetation (Kokai, 2015).*

Besides addressing the UHI, roofs can also be used to collect solar power and rainwater. By improving both, buildings can become more sustainable while the surrounding urban areas can also rely on these sources.

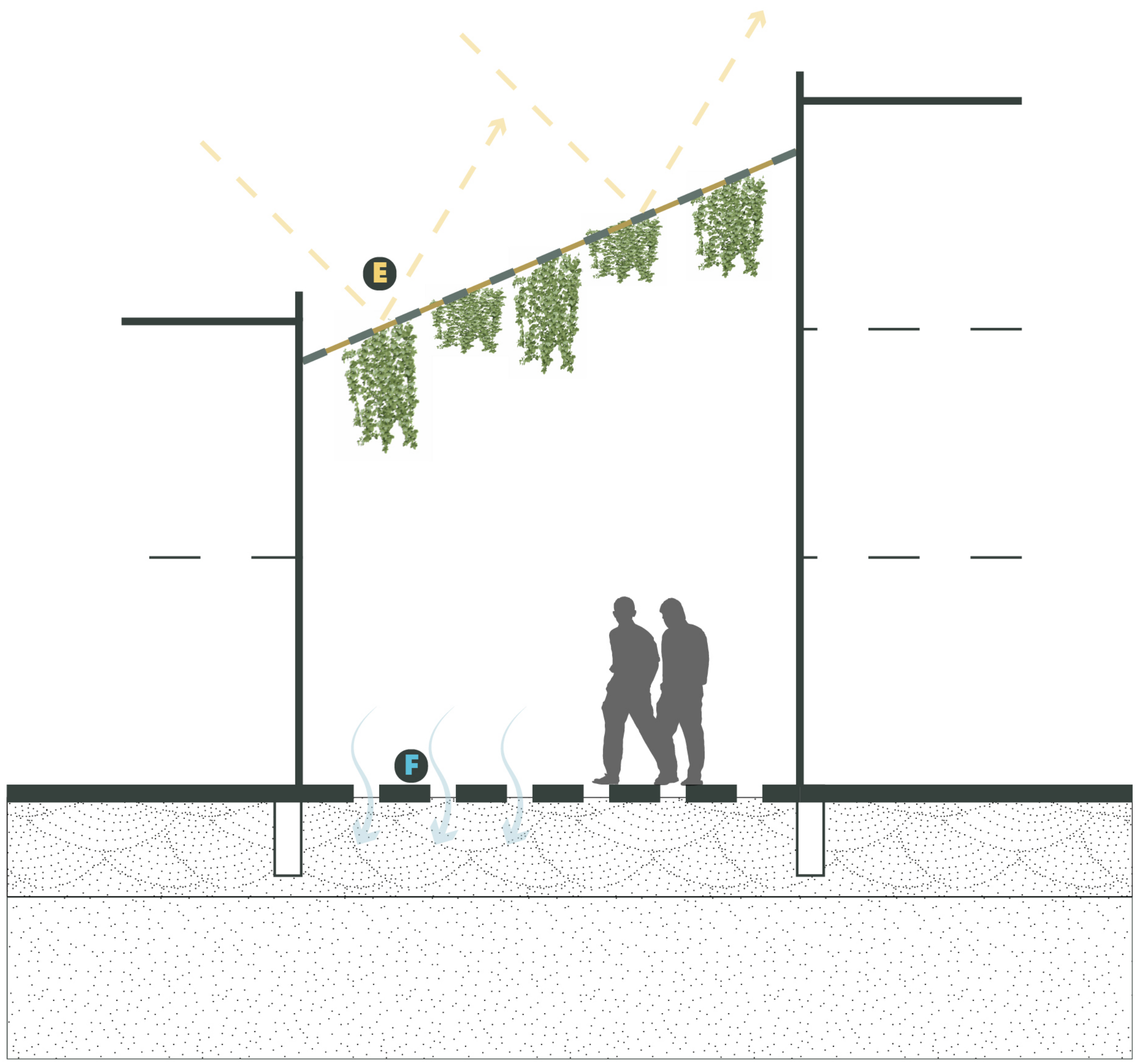



*figure 7.13: Example street (by author).*

F Permeable pavement
E Sidewalk shading



**Type A: Street (narrow)**

In these kinds of neighbourhoods, the streets are usually very narrow. However, because of the previously discussed UHI effect, these streets can get hot during summer. It is therefore important to increase shading in these streets. This can be done by increasing the vegetation above the street (pergola) or by adding pieces of fabric which span across the street. Both solutions are shown on the images below. While the former can also actively reduce the UHI, the latter is more effective during droughts, as plants are often not resilient enough to persist in these periods without any rainfall.

While the greater Cairo region is usually lacking rainfall, there are periods where flash floods because of heavy rainfall occur. To become more resilient to these events, streets need to be able to handle heavy rainfall, which can be achieved by increasing the permeability.

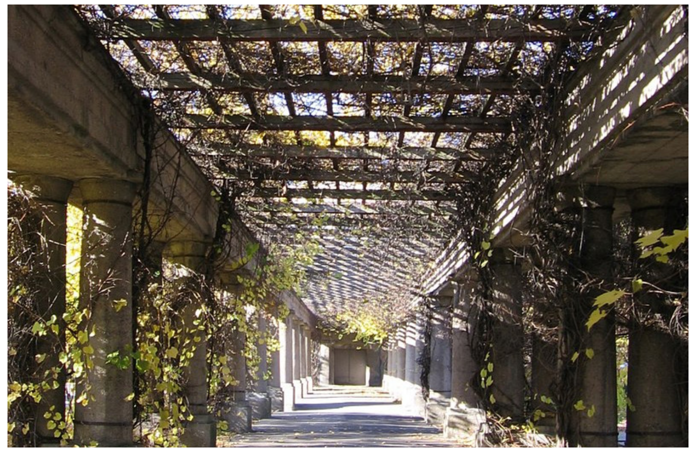


*figure 7.14 (top): Pergola in Wroclaw (Julo, 2005).*
*figure 7.15 (bottom): Calle Sierpes in Seville (M., 2021).*

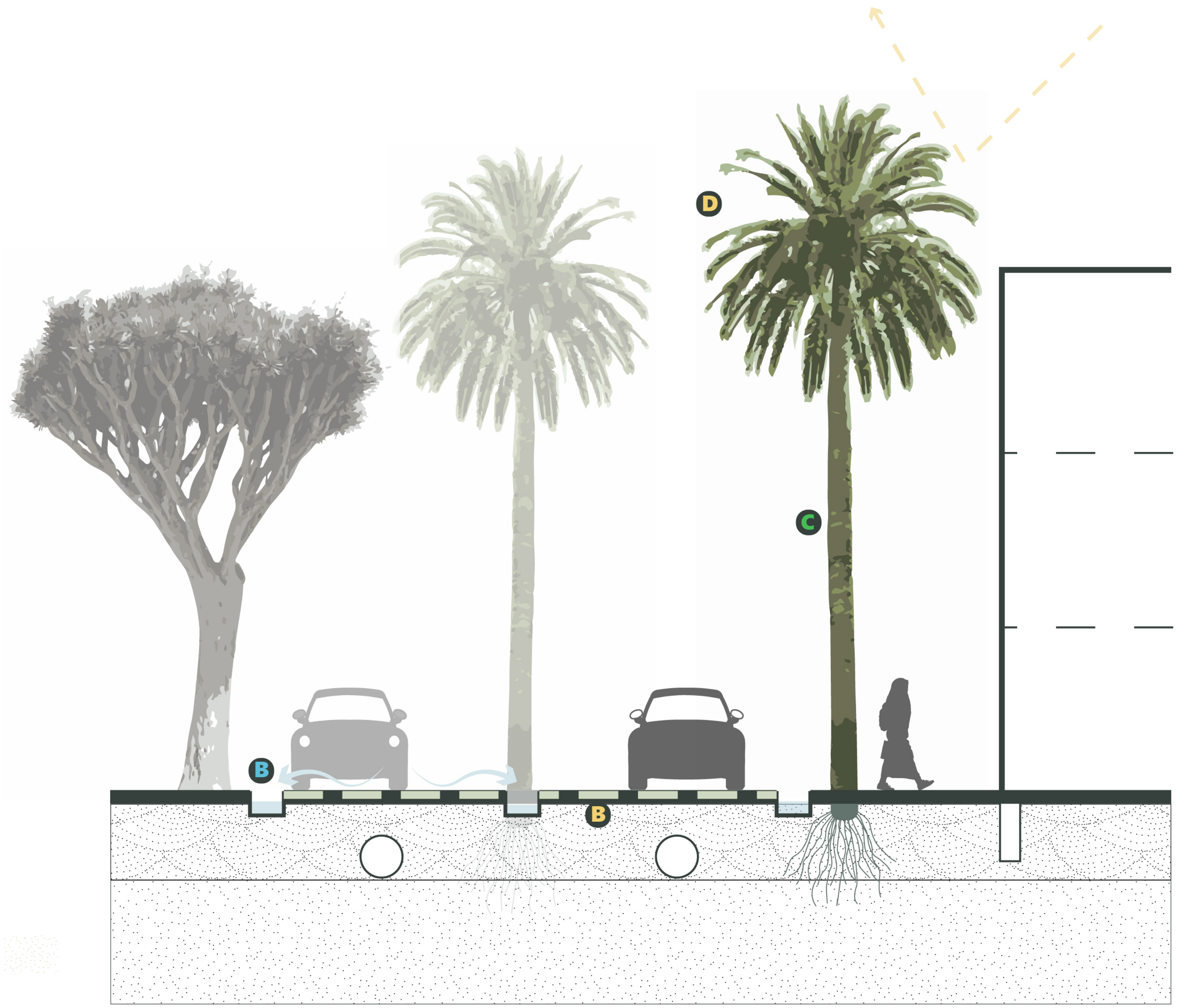



*figure 7.16: Example street (by author).*

- B Water collection (street)
- B Increasing reflectiveness
- D Increasing (natural) shading
- C Increasing biodiversity and native species

**Type A: Street (wide)**

Dense neighbourhoods likes these are often surrounded by large roads with multiple lanes where there is little green. In recent years, public green has in some areas been replaced with more car lanes to battle the traffic congestions. To address the UHI as well as to tackle the pollution in these traffic corridors, the green needs to be brought back, preferably with native species which require less water. Trees can meanwhile provide shading on the sidewalks, making it more bearable to go outside in summer months. Shading can also be achieved by constructing an urban canopy, which is illustrated in the image below. Interventions like this, as well as the addition of trees, can help cool urban areas.

Large paved areas like these are also suitable to collect water and decrease the heat absorption. The latter can be done by painting the streets, which will be further discussed in a later type.

*figure 7.17: Urban canopy (Budds, 2017).*

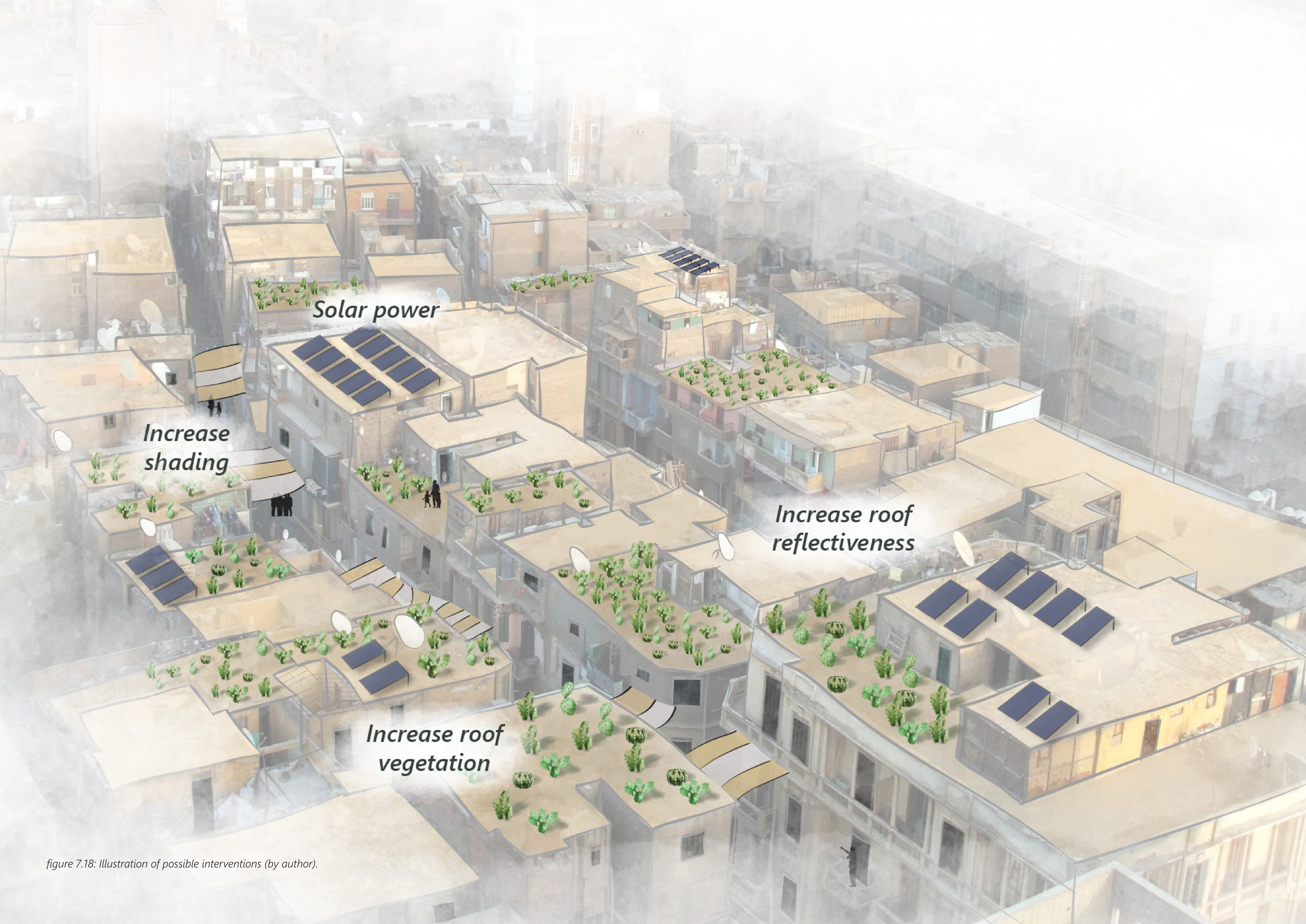



*figure 7.18: Illustration of possible interventions (by author).*

### 7.3.B old, planned

The second example neighbourhood highlights richer and greener areas in the city. These neighbourhoods are often constructed in the colonial period and contain larger residential buildings as well as many embassies. They contain both public and private green and the areas are car oriented. This type is mostly located next to the river and in the centre of the urban region. Because of the larger plots and larger private areas, a bottom-up approach is needed to involve the plot owners as well. For this neighbourhood type a building, a street and a square will be investigated.

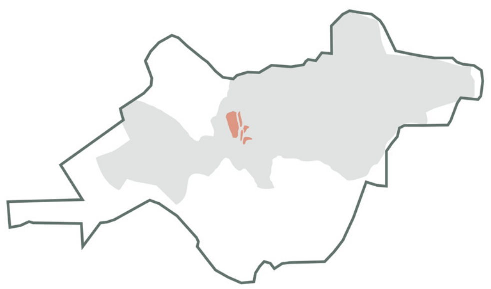


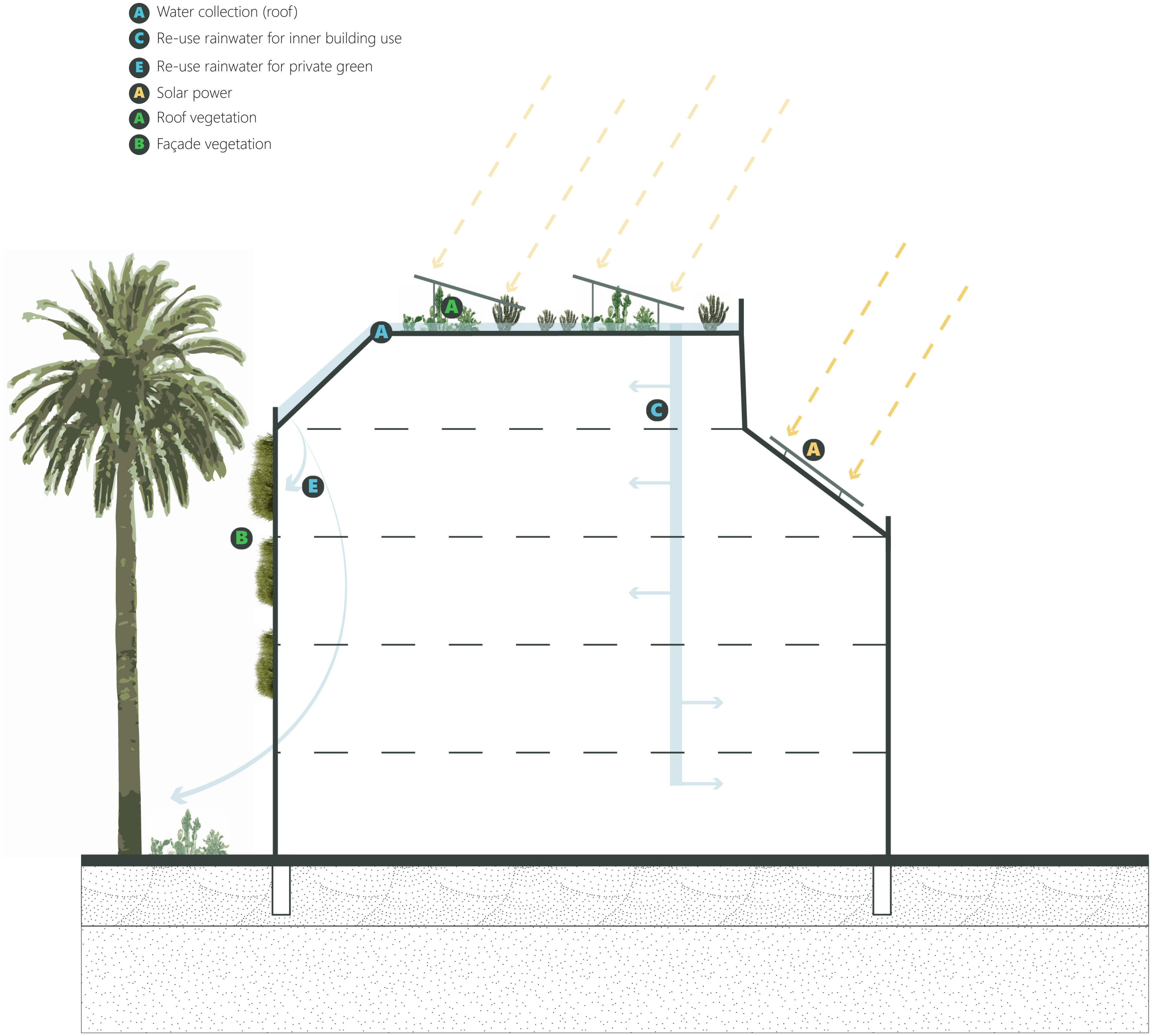
Figure 7.19 (top) illustrating the location of the specific type in relation to the urban area (by author).
Figure 7.20 (bottom) illustrating the example neighborhood (by author).


Figure 7.21: The Cairo neighbourhood Garden City (Cairo Scene, 2021).

**Type B: Residential building**

Buildings in this type are very different from the previous type. They are larger and often have varying roofs. Moreover, the plots usually also contain (small) private gardens. However, a lot of the design solutions discussed for the previous type, can also be used here. Solar panels can be installed to generate power and water can be collected to water plants as well as contribute to the household's water supply. Vegetation can be increased and needs to be changed to be more in line with the increasing droughts. When using native species like cacti, less water needs to be used to maintain a certain level of biodiversity.

*figure 7.22: Example building (by author).*



**Type B: Street**

In car oriented neighbourhoods like these, it is important to make sure that the paved areas remain to a minimum. By collecting rainwater on streets and using this water to sustain public green, the use of freshwater is kept to a low amount. Besides this, it is also important to make use of native species instead of large patches of green which requires more water.

Below, an image is shown of how it is possible to reduce the heat absorption of paved roads. These solutions are easy to apply and can be done by residents themselves while also having an impact on city scale.

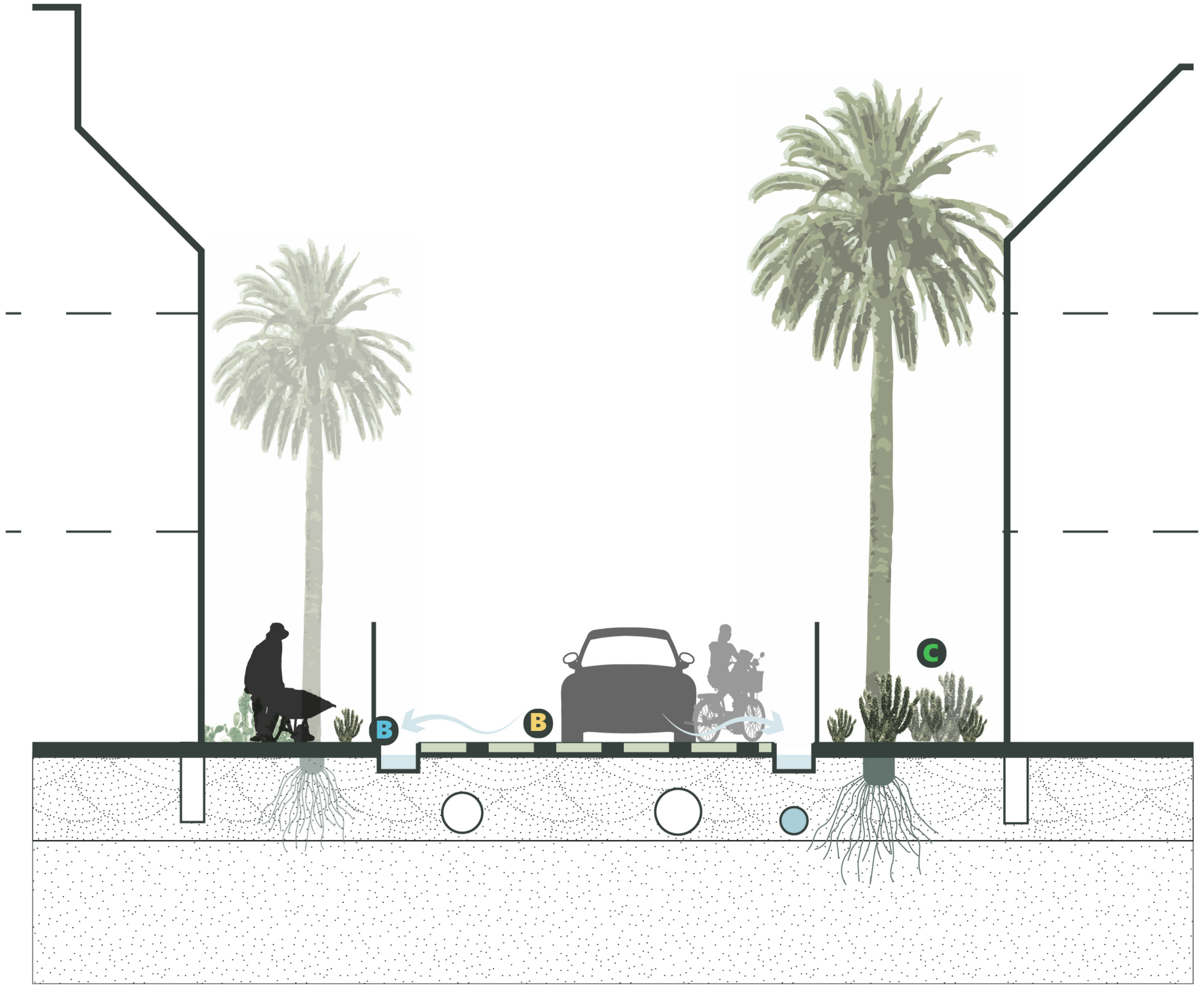
*figure 7.24: Painting streets white in Los Angeles helped reduce the UHI effect (Abdallah, 2018).*

*figure 7.23: Example street (by author).*

B Water collection (street)

B Increasing reflectiveness

C Increasing biodiversity and native species



### Type B: Square

Large squares are ideal for collecting water and smaller squares can also contribute to the total water supply. By making sure water is collected on these locations throughout the city, the total demand for water can decrease. This collection of rainwater can be used for toilets and showers, but also for public and private green. In combination with the previously mentioned painting of the streets, these squares no longer contribute to the UHI. Moreover, these squares can be surrounded by trees and native plants, resulting in an increase of biodiversity and shading without increasing the total water demand.

*figure 7.26: Water can be collected in various ways, increasing the total water supply (Baldwin, 2018).*

*figure 7.25: Example square (by author).*

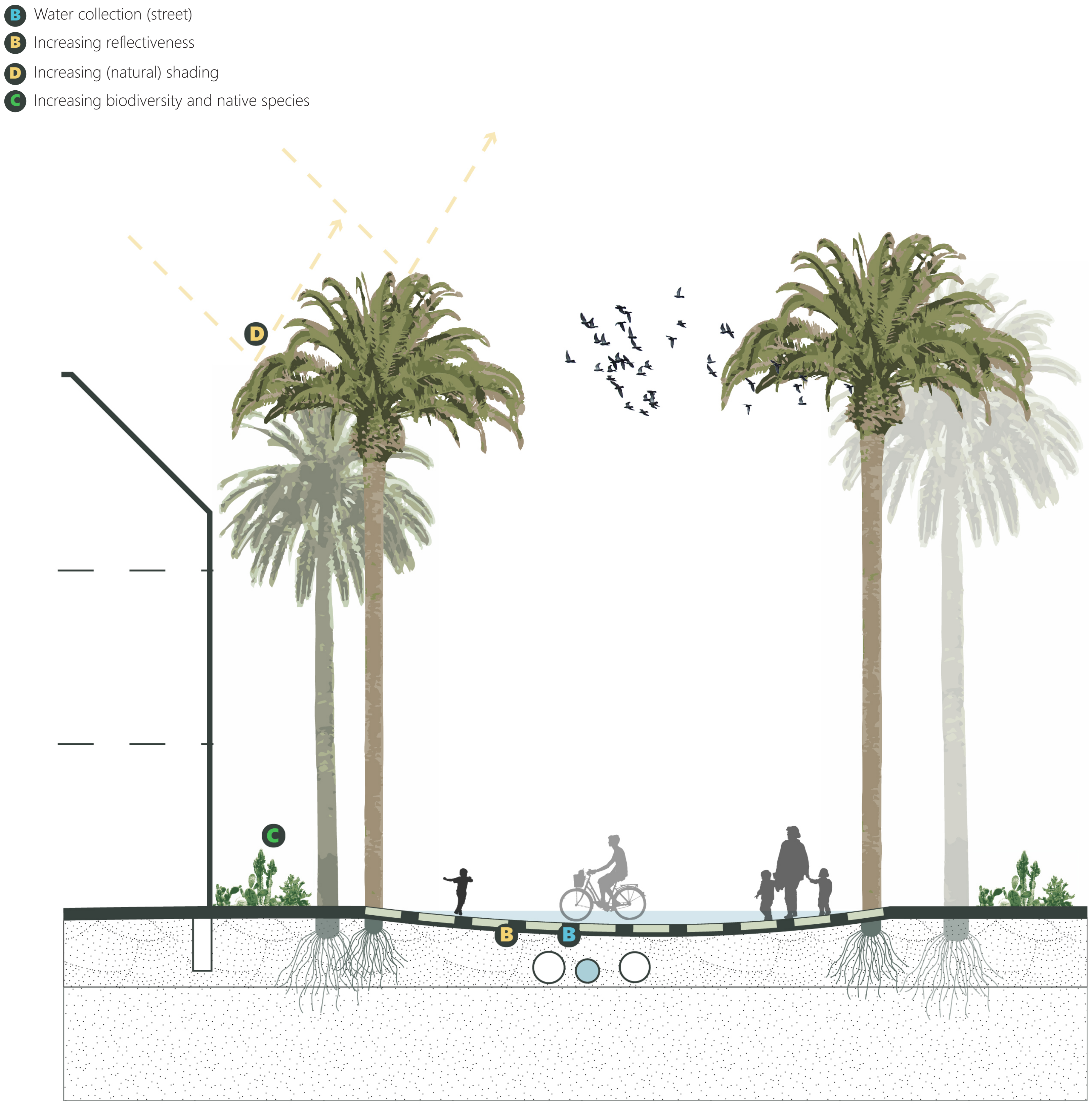
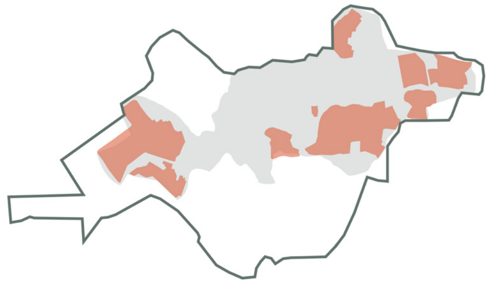



figure 7.27: Illustration of possible interventions (by author).

Figure 7.28 (left) by EGE (n.d.), figure 7.29 (right) by Selia (2020) and figure 7.30 (bottom) by Looch (2021).

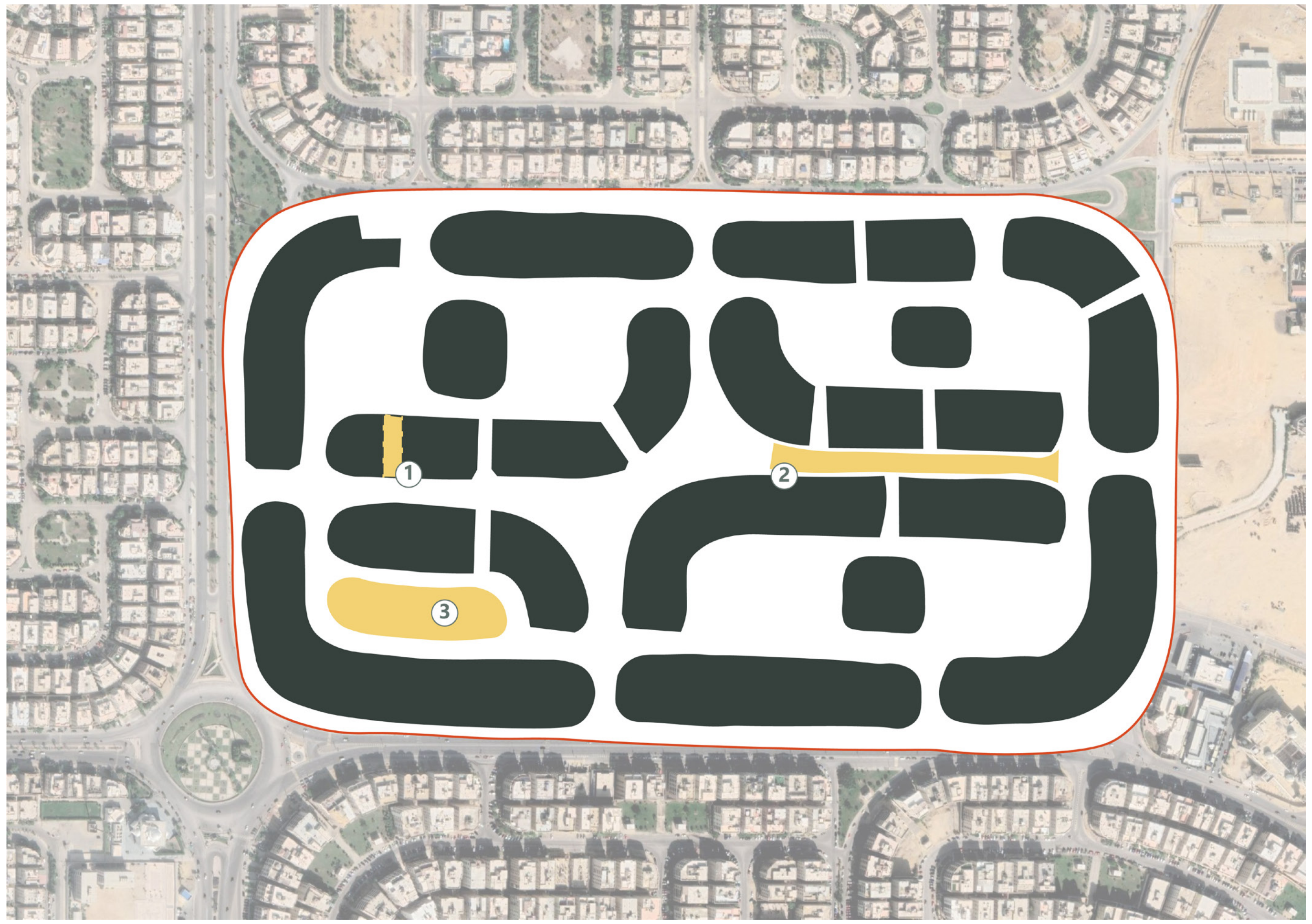




### 7.3.C New, planned

Because of rapid population growth, the city of Cairo needs to expand its urban area. This is currently mainly done in the desert area outside of the city. This third type aims to look into these new urban expansions. These areas are formally planned and are constructed at a fast pace. The neighbourhoods are car oriented and contain large grass patches between the residential buildings. Because of its location in the desert, these regions require a lot of water. Their current state is very unsustainable. To investigate possible design solutions for this type, a building, street and park will be looked into.

Figure 7.31 (top) illustrating the location of the specific type in relation to the urban area (by author).
Figure 7.32 (bottom) illustrating the example neighborhood (by author).



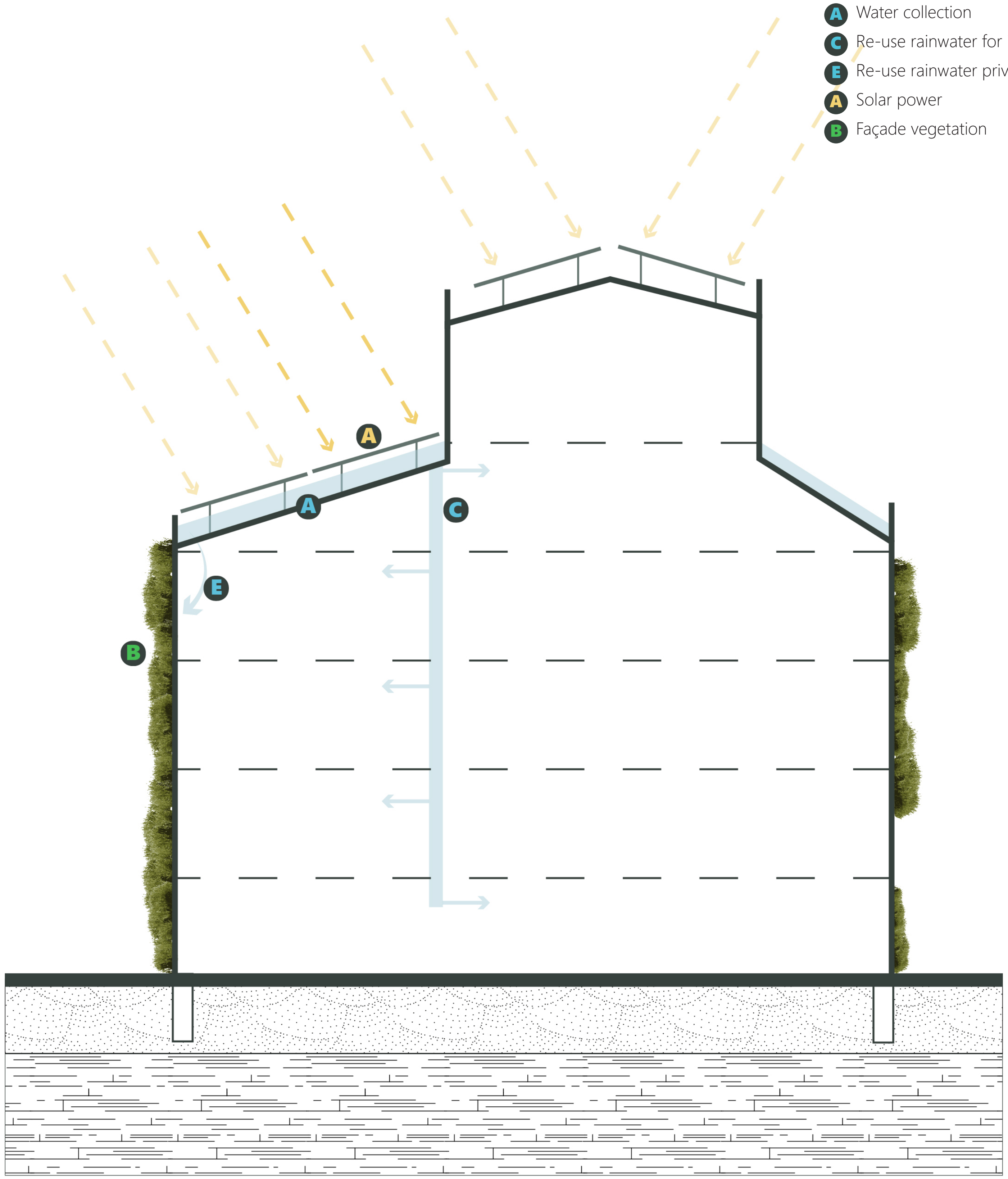



*figure 7.33: Example building (by author).*



**Type C: Residential building**

The major difference between this residential building type and the others is that this type is currently being built in most urban expansions. This means that changes and improvements can directly be implemented in newly built areas. To make sure that buildings are more self sufficient, rainwater and solar power is collected on the roofs. Buildings should be painted in a light colour, to make sure that heat is kept outside as much as possible. Besides this, it is also possible to add green to facades to create an extra protective layer against the heat outside.

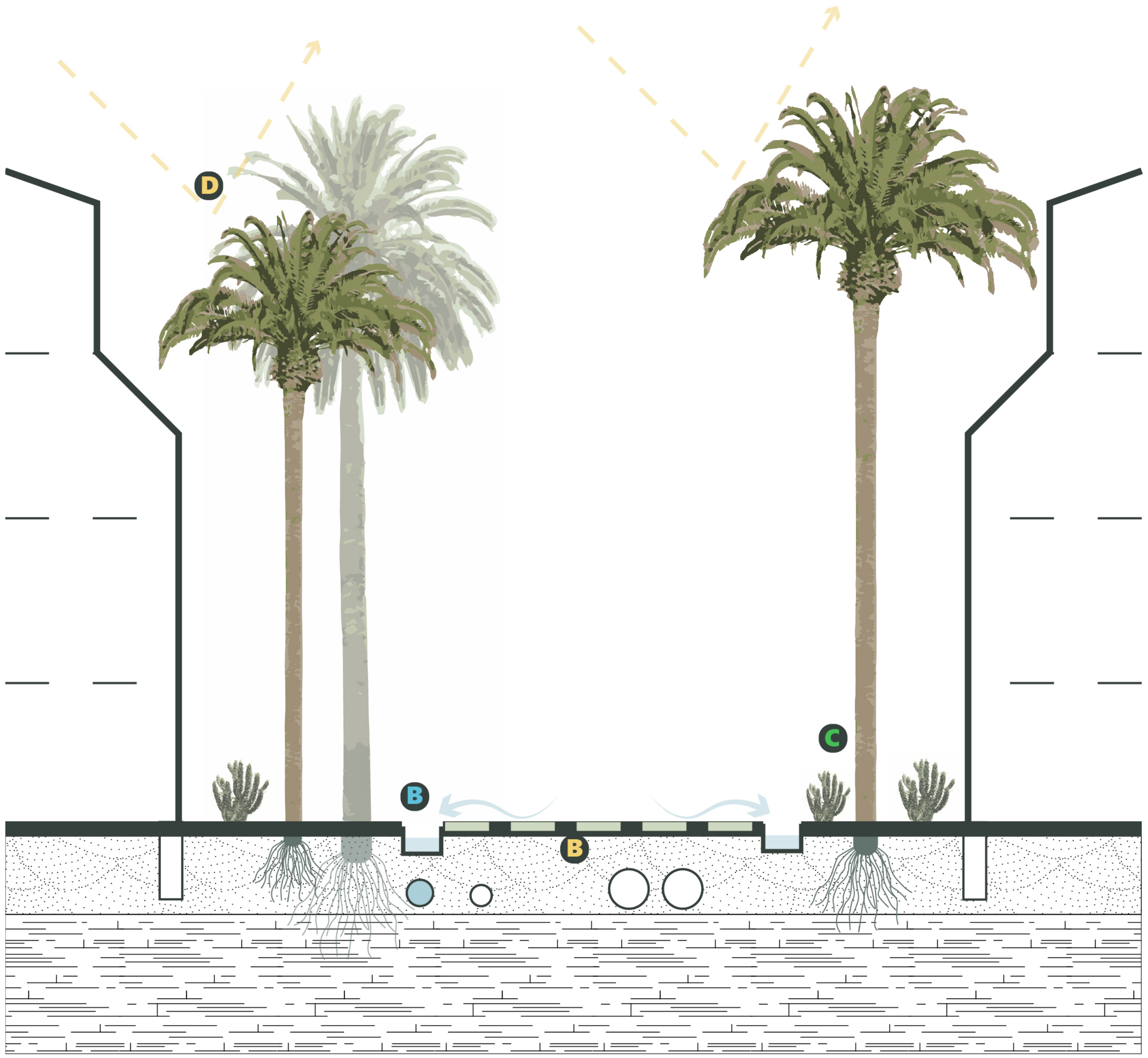





*figure 7.34: Example street (by author).*

- B Water collection (street)
- B Increasing reflectiveness
- D Increasing (natural) shading
- C Increasing biodiversity and native species

**Type C: Street**

Streets in these car oriented neighbourhoods are large asphalt concrete areas. During periods with long intense heat, these paved areas will reach unbearable temperatures. It is therefore important to reduce the heat absorption of these areas, as well as increase the shading in the streets as much as possible. This can be done by implementing previously discussed principles: adding trees and painting the streets. Next to this it is also important to increase the biodiversity of these areas. Native species are often looked down upon, and people prefer large patches of grass. However, native species like cacti can add a lot of value to the area without requiring lots of water.

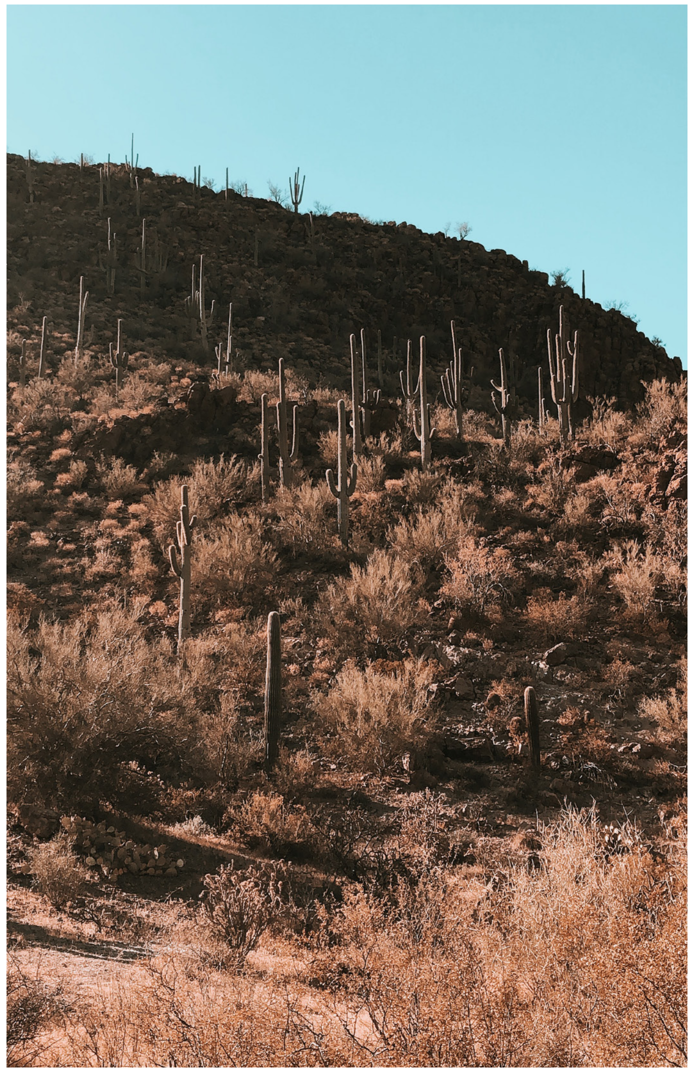


*figure 7.35: Drought resilient plants (In Beta, 2020).*

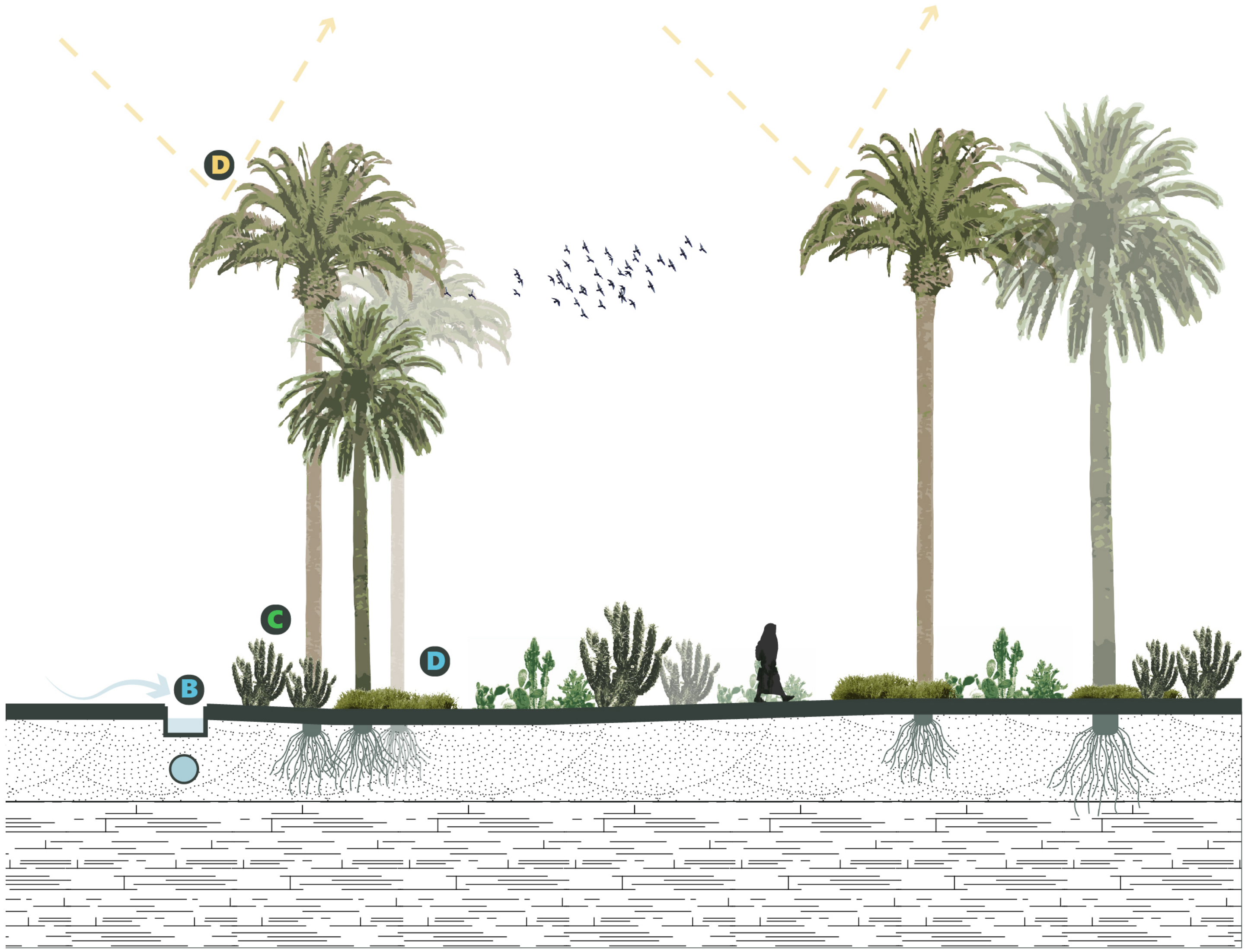



*figure 7.36: Example park (by author).*

- B Water collection (street)
- D Re-use rainwater public green
- D Increasing (natural) shading
- C Increasing biodiversity and native species

**Type C: Park**

Most green areas in these neighbourhoods are green patches which are regularly irrigated. In a region with constant water shortage, this is surprising. These grass patches require a lot of water, and while they look nice, they do not contribute to the local biodiversity. This is why it is important to replace these areas with native species which can both contribute to the local biodiversity as well as require less water to grow. This will reduce the demand for water in these newly built areas and improve the sustainability and resilience of the city. For green areas that do require being irrigated occasionally, collected rainwater can provide a solution.


*figure 7.37: Illustration of possible interventions (by author).*

### 7.3.D Dense, new, unplanned

The final type consists of areas with newly unplanned high-rise. These areas are located in the edges of the old city, but closer to the Nile than the formally planned new urban areas (type C). These neighbourhoods are mostly car oriented with some larger parking areas in between buildings. They lack green areas as most surface is paved and buildings are uncomfortably hot during summer months. This type will look into the design solutions for a building, street and parking lot.

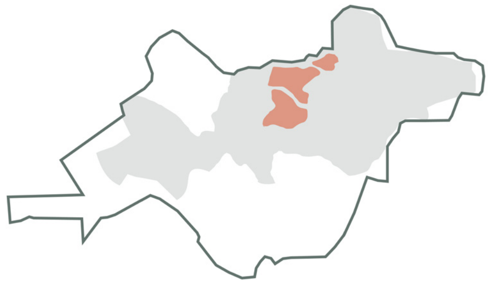


*Figure 7.38 (top) illustrating the location of the specific type in relation to the urban area (by author).*
*Figure 7.39 (bottom) illustrating the example neighborhood (by author).*




*Figure 7.40 (top) High-rise buildings common in these neighbourhoods (Mohamed, 2021).*

## Type D: Residential building

High-rise buildings can become very hot during summer. Without proper ventilation and shading, these buildings become unliveable. Therefore it is important to make sure these buildings all have proper (natural) ventilation as well as as much shading as possible. This shading can be achieved by constructing a second façade. This second façade can be flexible so it can both provide shading as well as support ventilation inside the building. Below a reference is shown illustrating how this façade can act as an extra barrier for sunlight, as well as a reference on how frugal innovations like translucent shading systems can support resilient urbanism. Roofs can be used to collect solar power and rainwater and green can be planted on both roofs and façades to increase local biodiversity.

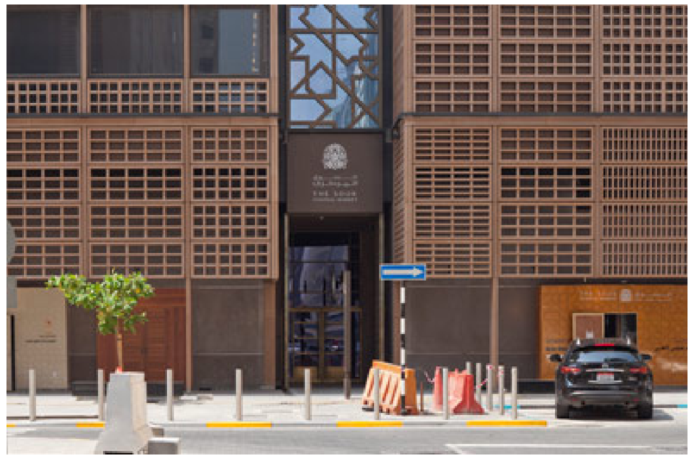
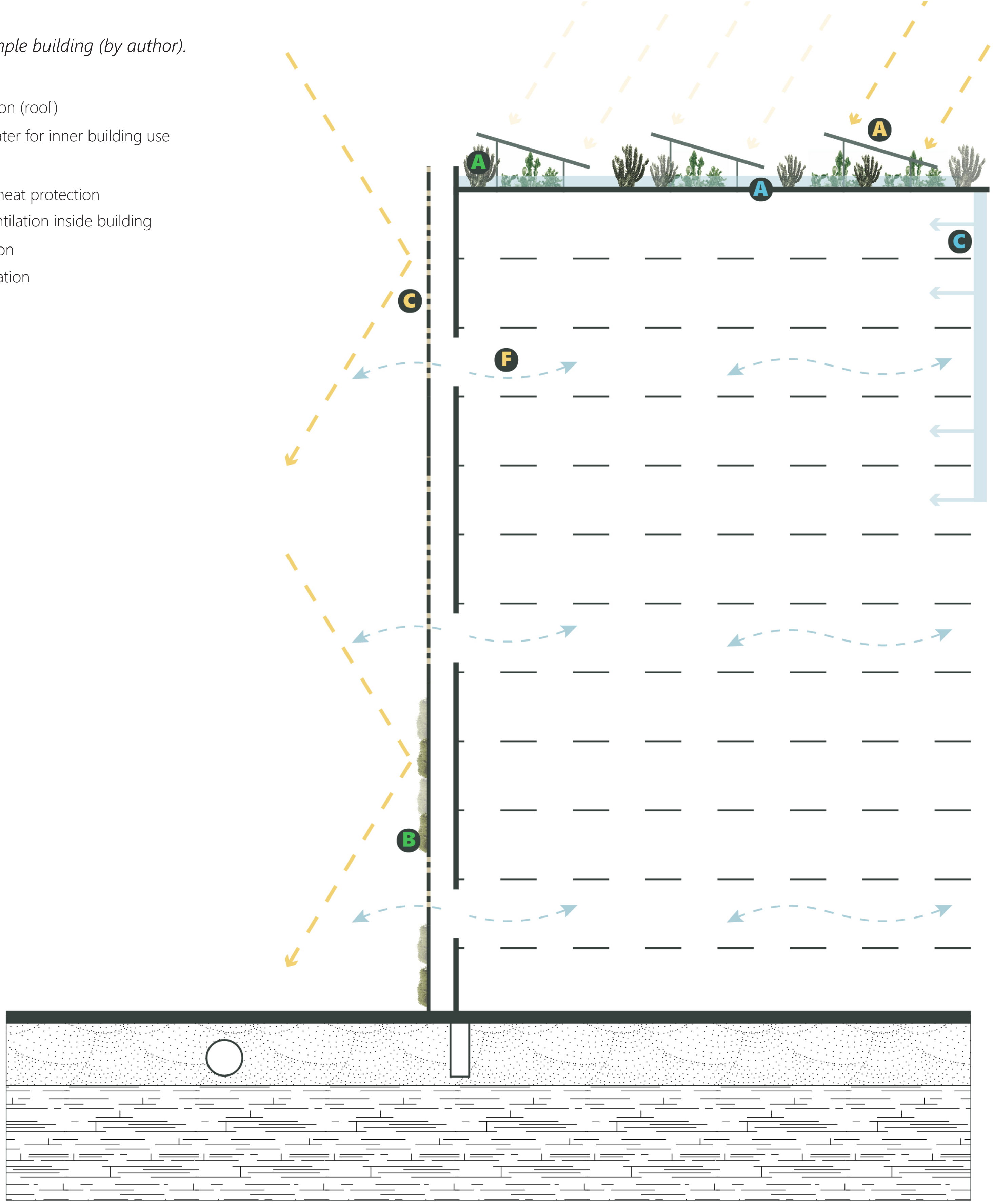


*figure 7.42 (top): Facade in Abu Dhabi (Frearson, 2011).*
*figure 7.43 (bottom): Textile facade elements (Baldwin, n.d.).*



*figure 7.41: Example building (by author).*

- A Water collection (roof)
- C Re-use rainwater for inner building use
- A Solar power
- C Sunlight and heat protection
- F Increasing ventilation inside building
- A Roof vegetation
- B Façade vegetation

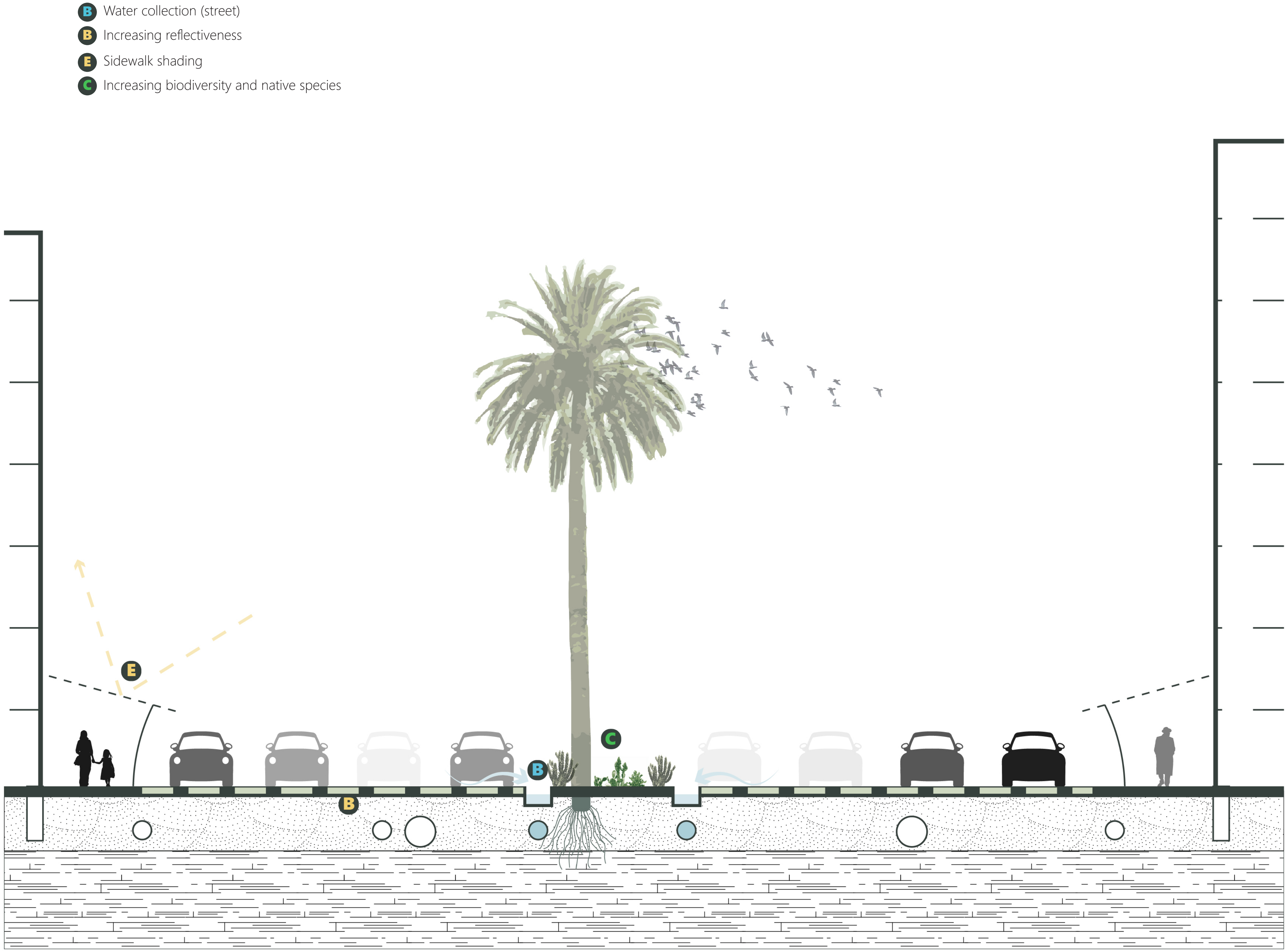


**Type D: Street**

High density neighbourhoods require a lot of infrastructure. Most of these neighbourhoods are surrounded by large roads with multiple lanes for cars. As mentioned on previous pages as well, it is important to reduce the heat absorption on these streets. Besides this, shading needs to be created to make sure sidewalks are usable all year round, even during the hot summer months.

*figure 7.45: Shaded walkway (Barbara K, 2019).*

*figure 7.44: Example street (by author).*



**Type D: Parking lot**

In areas where cars are dominant, parking lots are also present. These large paved areas require a lot of space. To increase the sustainability of these areas, cars can be parked under shaded structures which can be used to generate solar power or increase biodiversity. Next to this, water can be collected on the parking lot itself which can be added to the municipal water supply.

*figure 7.47: Green roof on top of parking lot (LiveRoof, n.d.).*

*figure 7.46: Example parking lot (by author).*

- B Water collection (street)
- F Permeable pavement
- A Solar power
- C Increasing biodiversity and native species

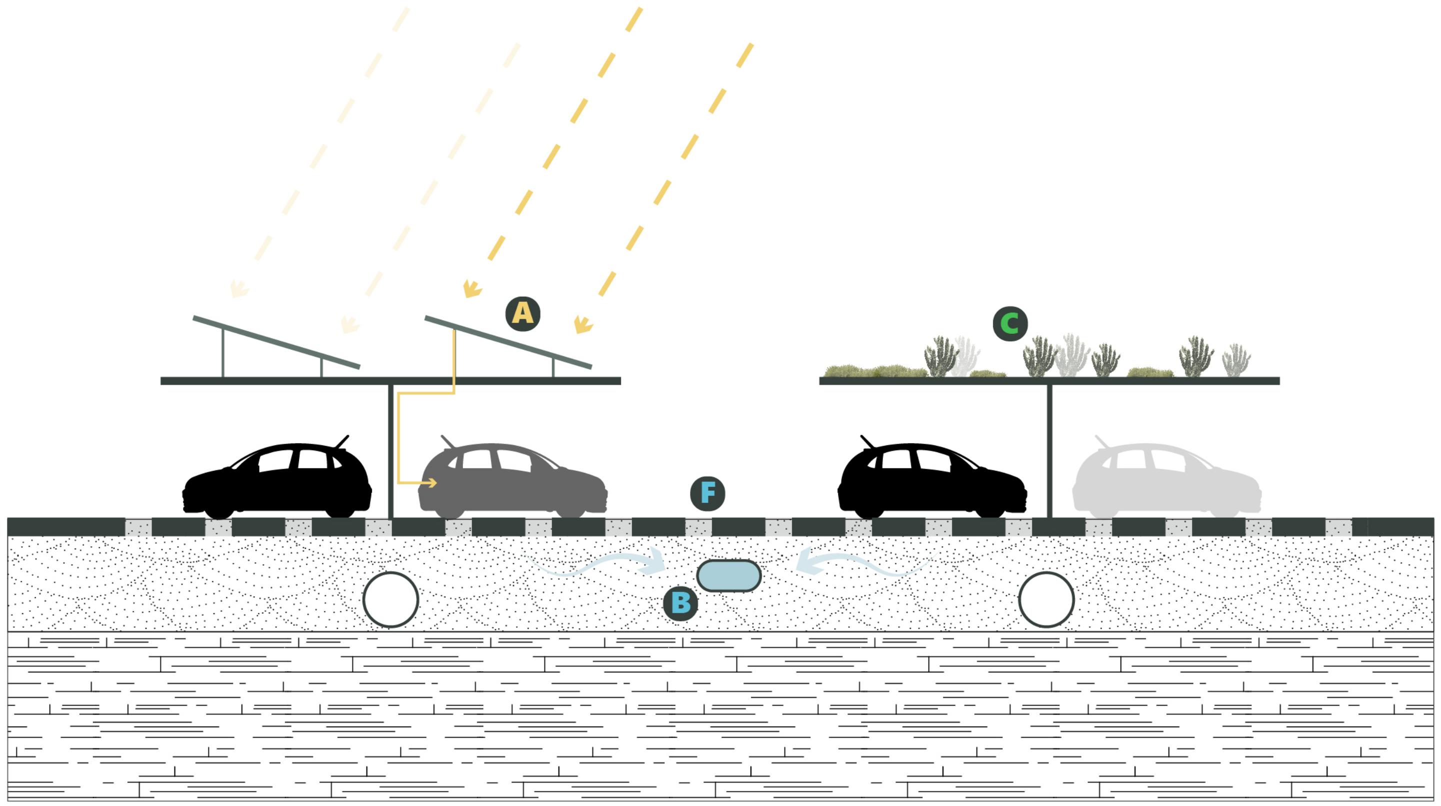



*figure 7.48: Illustration of possible interventions (by author).*


Image by Dascal (2019), adapted by author.

## *Depleting sources*

**85%**
of Libyas fresh water comes from a depleting source

1. Depleting groundwater sources.
2. Rapidly expanding cities increase pressure on resources.
3. Unsustainable and unmaintained desalination plants.

## *Agricultural demand*

**75 - 96 %**
of the fresh water is used for agriculture

4. Evaporation and increased extraction lead to disappearing lakes.
5. Water polution due to lack of wastewater regulations.
6. Sea level rise is a threat to the Nile delta and its agriculture.

## *Rapid urbanisation*

**210 million people**
will be expected to live in this region by 2030 (currently ± 165 million)

- A. Increasing efficiency of irrigation will decrease water use.
- B. Sustainable energy sources.
- C. Improving the relation between water and urban areas.
- D. Increase regional cooperation and water sharing.
- E. Sustainable desalination.

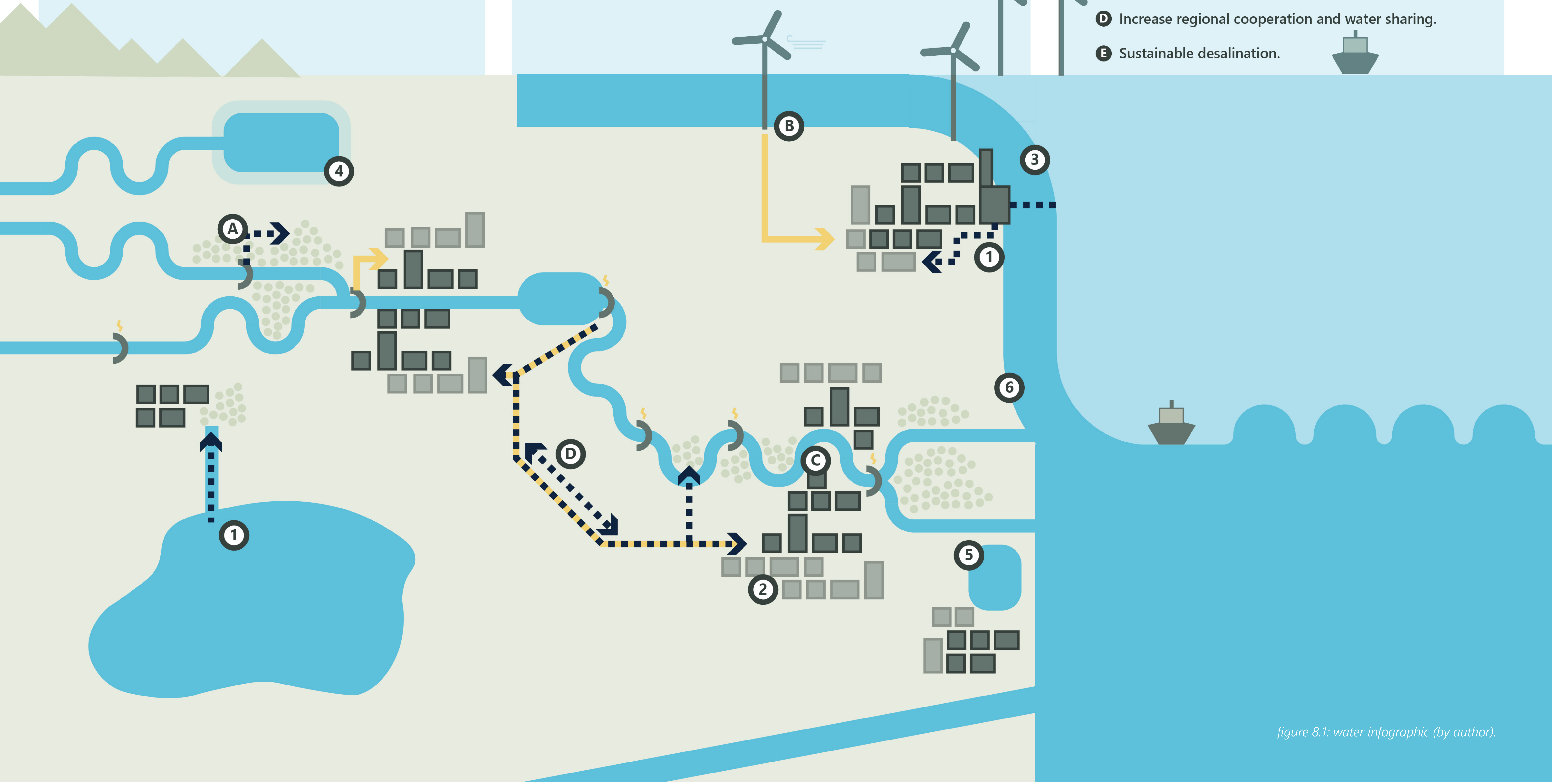


*figure 8.1: water infographic (by author).*

## 8.1 Sub research questions

**How can water governance and the regional design of water provision support resilient urbanism?**

The aim of the first sub research question was to provide input for the regional strategy. By analysing both regional and local aspects of the region, such as the extraction of water, the most important stakeholders and the three main layers of smaller sites, a conclusion could be formed explaining how governance and regional design can support resilient urbanism. This provided input for the creation of the strategy, which is expressed in the priorities, outcomes and outputs.

The regional strategy should guide policy- and decisionmakers on how cities can expand renew without compromising water availability. This should be reflected in the main priorities, as well as explained and elaborated further in the outcomes and outputs. These outputs should then provide direct insights on how it can be done. This water governance should make sure that these priorities are set for both past and present while also keeping in mind both large and small scale effects and solutions. It should be emphasised that designs on a regional scale have many implications on a smaller scale, which should properly be investigated before applying them in regional policies.

**What elements does a regional and transboundary strategy need to promote resilient urbanism?**

While the first sub research question aimed to investigate what the strategy needed in terms of input, the second sub question aimed to analyse the main elements of this regional strategy and what it needs to promote resilient urbanism. This was done by looking at the implications this strategy has on a smaller scale. This feedback then provides improvements of the strategy and an answer to this question.
The regional strategy need to be able to be connected to other policies and action plans in the region. By creating main priorities and applying the SDG's into the strategy, other plans can link their own themes or actions to these priorities and SDG's. By creating a hierarchy inside the strategy itself, people can link to it and act according to their own possibilities. Local communities can more easily act when specific actions or outputs are mentioned. Governments meanwhile can link other national plans to proposed priorities or outcomes. Next to this, it is important that this strategy promotes resilient urbanism by looking at both present shortage while also keeping in mind future threats to water availability.

## 8.2 Conclusions

**What elements does a regional and transboundary strategy need in order to address current water shortage and mitigate the rising demand and decreasing supply of water in arid regions? The case study of North-East Africa.**

*"It is most important that a transboundary and regional strategy is flexible both on the axis of time and on the axis of scale."*

This research has provided insight into various aspects influencing the availability of water in North-East Africa. The analysis on the supply and use of water has shown that there are various regional differences, but that the main extractor of water is the agricultural sector. Meanwhile, rivers provide the majority of the region with water, while there are areas which depend almost fully on groundwater, especially in Libya. This illustrates that a regional strategy should keep in mind regional variations and be flexible to national and even local circumstances. The analysis on stakeholders and existing action plans further illustrated how complex the situation actually is. Each phase in the process of water supply has different people involved, with each their own agenda. Current action plans are often not linked to each other which makes it more difficult to apply these on both large and small scale. Meanwhile, the analysis on the urbanisation of the region showed that cities are rapidly expanding and the region is becoming more and more urbanised. This means that most problems will occur inside the urban areas, where most people are located. Zooming in on various locations and using the layer approach to investigate the connection between the subsurface, network and occupation layers illustrated further how different each location can be. While there are similarities between several locations, further research is required to really pinpoint which locations can be grouped and which locations are exceptions. This analysis however provided insight into the importance of zooming in to get more specific local scale inputs. Because of aforementioned analyses, the elements that a strategy needs could be further clarified. It is most important that a regional and transboundary strategy acts on two main axes.

The first axis is the axis of scale. The strategy needs to provide input which can be used as guidelines on a larger scale while still being able to adjust to local scale differences and demands. The larger scale should provide input for regional decisionmakers which they can use to make sure that the regional path forward is coherent and countries do not negatively affect each other. On the smaller and more local scale, local stakeholders should be provided with specific outputs or actions that can make sure that these stakeholders can actively contribute to the goal. Next to this it is important to keep in mind the regional differences. A coastal city has different demands than an inland city and a city next to a major river has different demands than a city next to a little stream or lake. Only by addressing problems through all scales can the problem be addressed and mitigated.

The second axis is the axis of time. As the research question itself states: "to address current water shortage and mitigate the rising demand and decreasing supply of water", current measures can negatively affect the sustainability and resilience of the region. By implementing solutions that reduce the shortage on a short term while also keeping in mind the long term affect of these solutions, the resilience and sustainability of the region will increase. It is important that the region tackles the issues of today. However, with implementing the changes that are needed, stakeholders should always keep in mind the effect it has on the long term.

A regional transboundary strategy should be flexible on both axes. A national decision in Egypt should not negatively effect the future of a local town in Libya and the other way around. The interdependency on water resources should always be kept in mind when planning for both present and future.

## 8.3 Reflection

### Reflection on the approach and methodology

The project started on a large transnational scale, with the issue of water shortage. This issue is a common problem in the world and the region of North-East Africa seemed a good case study both because of its complexity and its proximity to Europe. This meant that the European context and my knowledge could provide (new) insights in the region and could contribute to a wider frame of research. However, the region itself was unknown to me besides some common knowledge on the situation. This outside perspective allowed me to have a neutral view on the complex issues without any political preference. By thoroughly investigating and researching the region and the background of the water related issues, I gained new insights which for myself could contribute to the research as a whole.
The lack of knowledge on the region itself however also limited the research in a way that I was limited to an outside perspective. Choosing not to go on field trip(s) or speak to local people hindered insights from the sites itself and I was therefore not able to include perspectives from either local communities or specialists of the region. However, by investigating a typology during the process, I was able to include local scale insights in the project. Even though this did not include perspective from local communities, it did give insights of the differences between the regions and the importance of the small scale in this large region.

### Reflection on further research and transferability

The focus of the research was to investigate possible elements of a regional strategy and its effects on a large and small scale to come up with guidelines for future strategies for similar regions. Its main limitation has to do with the limited amount of time and therefore the issues that have only been touched on a surface level. These are mainly the integration of existing policies and the small scale differences. For this research, existing policies have only been included in the form of a small analysis of existing strategies about water bodies in the region. These include the NBI Strategy, UfM Action Plan and the Lake Chad Development and Climate Resilience Action Plan. While these three action plans are important for the region, they do not include all perspectives. There are several other strategies for the region and besides these, there are also policies by governments themselves.Further research can possible continue to research these policies to see if and how they can be included in a strategy and whether a strategy in its presented form can be applied with these existing policies. It can be the case that several policies limit the effectiveness of such a strategy and that the strategy would be more effective if presented in another format or with other elements.
Further research can expand on the typology created in this report. While the typology currently only touched upon the smaller scale on a surface level, it can be improved by looking into several other sites to see if the investigated sites actually represent the region. In this research, the country of Chad has been touched, but when zooming in and investigating the typology, the research did not include the country. Further research should provide information whether all four countries can follow the elements this strategy provided.
Next to the implications on the region and further research on the region itself, this report should provide insights on how other regions worldwide can deal with similar issues. Further research should point out if this study is universal or if it is too specific to be applied on other arid regions as well.

### Reflection on ethics and SDG's

This research was done from a western perspective. Because the case study was done in the global south, this has its downsides. Compared to research that was done from the perspective of someone more familiar with the region, this study was done without much knowledge of local politics and the influence of national policies. This means that the conclusions can have very little effect on the region if the local policies do not allow for such a strategy to be applied. While the strategy itself can work from a theoretical point of view, the goal must be to eventually implement such strategies. This means that local politics cannot be neglected and must be incorporated in such research in order for the result to be applied.

Besides the effect of politics on such a project, the research also has an influence on local (vulnerable) communities. From an external point of view, these groups can often be neglected. Because I was not able to visit the case study location during the research, I was unable to talk to people from this location. This means that their individual demands were not incorporated into the research. While some parts of a country or city might seem unsustainable or inefficient from an external perspective, local perspectives might see this different. It is however also possible that these communities value their own perspective more than an external perspective, which can possibly view the area in a more objective way.
This external point of view is the main angle of this research and should have provided elements on which can be built by both stakeholders and communities from this region, as well as actors from other parts of the world, dealing with similar issues.

Image by El-Gassier (2020), adapted by author.

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