*META*VALLEY

Explorations of an *adapted* geodesign framework
to integrate a regenerative approach and planning
in the Metropolitan Area of the Valley of Mexico

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P5 Report

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MSc Urbanism thesis

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**Unless otherwise specified, all drawings have been created by the author*

Preface

It is clear that there are high levels of social injustice in Mexico City . If Lefebvre defines the organisation of space as a dimension that reflects social justice, then inequalities (Lefebvre, 1984) as differences that have implications for social justice, should be embbeded in the organisation of space. It is important then to understand the relation of space and the unequal distribution of resources to plan for social justice.

Arturo Ortiz and Elias Cattan, inspired me years ago, to work with these injustices in a systemic way, which was the approach I took on with this research. I hope the reader enjoys reading through the report, which was built with high hopes for catalysing a regenerative change in the Metropolitan Area of the Valley of Mexico.

I would like to greatly thank my mentors Alexander Wandl and Diego Sepulveda for their suppor and twhose insight and extensive knowledge guided me throughout the research, and even more whose genuine concern about the topic was always an inspiration. I am still amazed at how it would take me ten steps to realise where I wanted to get, when they would know it before I even took the first step.

Furthermore, this report would not have been here without the support of my friends and family. My greatest and most heartful tokens of appreciation out tgoo my mom and to Mortiz. To my mom, firstly for giving the opportunities throughout my life that ultimately led me here, for reminding always to believe in what I do, and overall, for being a constant source of inspiration. To Moritz, for his unconditional support throughout the year, I believe he took the best and worst out of the process, thank you for always being by my side and reminding why I was doing this. Further, I would like to thank my fellow graduates and friends, Ranee, Michelle, Bhavya, and Franka (also to Lieke and Tessa) , who enriched my research with their critical input and evenmore, who made this journey very bearable.

Lastly, I would like to thank the workshop attendees in Mexico City and to thank CONACYT who has provided me the financial foundation to pursue my studies.

"In defense of water and soil", photography taken by Livia Coronas in Zumpango, State of Mexico, as part of her recollection of evidence of the 20 million homes built in the presidential term in between 2000-2006.
[Corona, 2018]

Contents

Introduction

The thesis departed from the problem that is the lack of integration between theories like Regenerative Development and Design (RDD) and planning practices. Theories like RDD take a systematic approach towards bringing sustainable and adaptable solutions to the built environment. Theories like this are highly relevant because they embrace cities as the complex systems that they are.

The thesis used the case study of the Metropolitan Area to answer to the question of how to integrate then, RD, and planning practices. It used the working hypothesis that by integrating the geodesign framework as a methodological basis and the Social-Ecological Systems Framework (SESF) as a theoretical/analytical basis, the previous could be achieved. The SESF was used to address the use of social-ecological systems, governance, and multiscalarity, while the geodesign framework was mostly used to achieve transdisciplinarity.

The report then presents the methodology that was used to explore such issue. As the hypothesis indicated, the research integrated the SESF as a structured language into the geodesign framework. The SESF language helped to answer the questions that the original geodesign model asked. Throughout the process of developing the methodology, the geodesign framework was adapted to enhance its use of multiscalarity, which it actually did not possess, and its use of transdisciplinarity.

The first modification improved the use of multiscalarity in the adapted framework by dividing the Resource System in two different types of scales: into system and subsystems, and into an assessment and designing area. It also developed the selection of the criteria, the methods to model and the modelling of the Macro-scale of the Resource System before than the rest of the framework The second and third modifications aimed to enhance the use of transdiscplinarity by 1) enhancing the designing amongst the stakeholders and co-designing between the stakeholders and the designers by 2) using an anticipatory-agent based modelling method in the Process Model,)and by integrating the Change Models of the stakeholders and geodesign team rather than selecting from them.

The adapted geodesign framework was then broken into seven steps whose results are presented in each of Chapters 5 to 10. Chapter 8 presents the Process and Change models of the researcher, Chapter 9 presents the same models, but developed by the stakeholders in a workshop which was held in Mexico City , and finally Chapter 10 presents the last iteration of the Change Model in which the the knowledge from both set of parties was integrated.

The report then follows through the conclusions and further discussion of the research.

1. Problem field, context and problem statement

This chapter presents the theory of Regenerative Development and Design (Mang & Reed, 2002), which is a field that has from the concept of sustainability .and which provides a new an wholseome approach to designing. Regenerative approaches focus on designing human systems that can co-evolve with the natural systems, embracing the inherent complexity of cities..

However, in practice, there is a lack of integration between approaches like Regenerative Development and Design and planning practices.This chapter talks about the problem of integrating a regenerative approach with planning, and elaborates approaches that some authors have taken to integrate it.

On the other hand it also presents the context of the Metropolitan Area of the Valley of Mexico which was used to explore how to integrate the mentioned theory with planning practices.

1.1 Problem field:
Lack of integration between the Regenerative Development and Design theory and planning

Cities can be understood as complex dynamic systems which are composed of various components and/or agents with interdependent behavior which ultimately give rise to emergent behaviours (Zagare, 2018). Such components can be biophysical, like the resources that flow that amongst actors, and across multiple scales and sectors (Williams, 2019) or even socio-cultural, for instance like the social capital. In such complex systems, the smallest change produces a considerable impact that resonates in the entire system. In order to design and plan with cities, it is important to have an understanding of the previous qualities.

Regenerative Development and Design (RDD) is an emerging field evolving from the concept of sustainability and provides a new a wholesome approach to designing. Regenerative approaches focus not only on minimizing the damage to the natural and built environment, but on reverting the degeneration of the environment by designing human systems that can co-evolve with the natural systems, embracing their complexity.

Regenerative development was defined by Pamela Mang and Bill Reed from Regenesis group (2002) as "a system of technologies and strategies for generating the patterned whole system understanding of a place, and developing strategic systemic thinking capacities, and the stakeholder engagement/ commitment required to ensure regenerative design processes to achieve maximum systemic leverage and support, that is self-organising and self-evolving." Regenerative design is defined by the same authors (2002) as "a system of technologies and strategies based on an understanding of the inner working of ecosystems that generates designs to regenerate rather than deplete underlying life support systems and resources within social-ecological wholes."

Regenerative development and design, therefore, deals with 1) systems of technologies and strategies, 2) the generation of the whole system understanding of a place, 3) the development of strategic system thinking capacities, 4) the engagement of the stakeholders required to ensure regenerative design.

However, in practice, there is a lack of integration between approaches like Regenerative Development and Design and planning. Similar disintegration issues between theories that aim to improve or restore the built environment from a systemic perspective in the built environment have been previously addressed by other authors like Picket et Al. (2003), Scott et Al. (2003), Aalto et Al. (2018), van der Leer et Al. (2018), and Boelens and de Roo (2014). All of the authors conclude that the gap in between such theories and planning is due mostly to the lack of understanding, and even more, the lack of integration of the social and ecological systems and governance, as well as the lack of multiscalar and transdisciplinary approaches.

Authors	*Theory*	Integrative approach	*Practice*
Picket et al. (2003)	*Ecology, socialecology*	Socialecological resilience metaphor	*Urban planning and design*
Scott at al. (2003)	*Ecosystems approach*	Multiscalar and sectoral approach with a governance framework	*Spatial planning frameworks*
Marcus et al. (2018)	*Socioecological knowledge*	Transdiscplinary frameworks	*Urban planning and design*
Van der Leer et al. (2018)	*Circular economy*	Socio-ecological-technical systems	*Urban planning*
Boelens & de Roo (2014)	*Resilience*	Actor-relational approaches	*Urban planning*

Table 1.1 Approached to integrate systemic theories to improving to restoring the built environment and planning

Table 1.1 shows a summary of the approaches that the previous authors had taken to integrate the theory and planning realms. Picket and collaborators (2003) specifically research how to improve the link in amongst the ecological, socio-economic, and planning worlds, through the use of socio-ecological resilience. Scott and collaborators (2013), research three methods on how to bridge the Ecosystems Approach and the Spatial Planning frameworks through better planning processes across the natural and built environments. Marcus and collaborators (2018) target the gaps in between the socioecological knowledge and urban planning and design. While, van der Leer et al. (2018), research the integration of Circular Economy to Urban Planning through horizontal and vertical systems. One of their concluding remarks points out to the need to investigate how the understanding of socio-ecological-technical-systems can improve the integration of urban planning and CE..

1.2 Context
The Metropolitan Area of the Valley of Mexico as a case study

From the previous section, it can be concluded that to apply regenerative approaches into planning practices in any conext, it is indispensable to integrate, in a transdisciplinary way, the socio-economical, and the eco-technical systems. In the MAVM these systems can be operationalised in relation to the pressing conditions that are deteriorating the area. The social system is very closely related to the housing production systems, while the ecological and technical systems are mainly related to the urban water management.

Thus, a regenerative approach cannot be implemented in the MAVM until the planning processes are properly integrated with the housing development processes and the water management processes.

1.2.1 Evolution of the urbanisation and water management in the MAVM

The Metropolitan Area of the Valley of Mexico lays at the height of 2250 m a.s.l. in the endorheic Valley of Mexico surrounded by the mountains of the Trans Mexican Volcanic Belt. In the area where a group of lakes once existed, now lays one of the biggest urbanised areas in the world with over 22 million people living there.

However, the urbanisation processes, on one hand, have led the MAVM to have an unsustainable urban sprawl, while the linear water management, on the other hand, has led to high levels of water scarcity in the region. In the next pages, the evolution of such processes is described and it is presented in a diagrammatic schematisation in Figure 1.3 .

<1800

The Valley of Mexico and its five ancient lakes were formed when, after a period of high volcanic activity, the Chichinautzin range appeared in the South of what today is the MAVM. The retention of the water that, would previously flow down to the Pacific, formed the five ancient lakes and with that, brought in a new layer of organic matter and clay in the center of the basin.

With the arrival of the Aztec civilisation and the founding of Tenochtitan a long history of duality between the water management and the urbanisation in the basin thus began.

Figure 1.1 Section of mural by Mexican artist Diego Rivera depicting Tenochtitlan [Zupacnic, 2018]

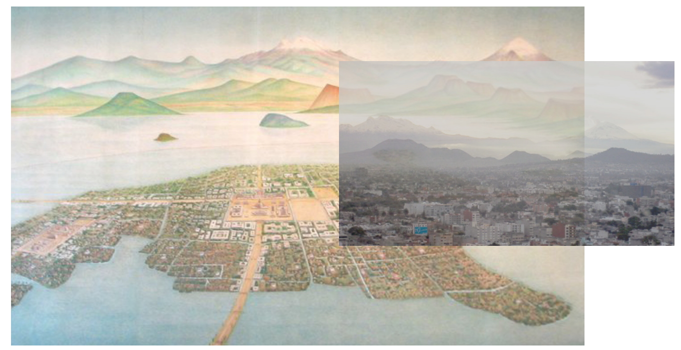

Figure 1.2 Overlay of the mural image with a recent picture of the MAVM that shows much the city has extended over what was once were the lakes.

1800-1950

A long time after the Spanish Conquestet and Mexico's Independence, Mexico City kept growing, during the Porfiriato. In 1900, the Gran Canal de Deasgue was inaugurated to carry out black water through the Tunnel de Tequixquiac (Burns, 2009). Simultaneously, major urban growth and expansion, happened in the 1950s due to an accelerated economic and demographic growth after the private sector invested in the manufacturing industry. Due to the Mexico City State's (formerly called Federal District at the time) restricting policies, the construction of such industry happened mostly outside the boundaries of Mexico City, which also directed the housing sprawl towards borderline areas (Iztapalapa, Iztacalco, Cuajimalpa, Madgdalena Contreras, Tlahuac and Naucalpan and Tlanepantla). As the city grew, in 1954, the second Tunel de Tequixquiac was built in order to cope with the increasing wastewater (Burns, 2009).

In the meantime, underground water was being extracted from the aquifer to supply with clean water to the increasing population (Burns, 2009). However, the new paved and impermeable areas inhibited the natural recharge of the aquifer, which meant thatset the rate of water extraction was to be greater than its infiltration, i.e. recharging rate. As a consequence, floodingsflooding and subsidence were prompted and as a countermeasure, the Lerma system was built in 1951 to pump 5 m^3/s of water from a neighbouring basin to recharge the aquifer in the MAVM. Two years after, the Cutzamala system, was incorporated to pump another 15 m^3/s more (Burns, 2009). However, the enormous rise in population raise ended upinduced demanding even more water demand and. Consequently, the water that was initially destined to refill the aquifer ended up being directly used as clean water for the inhabitants, leaving the city flooding and sinking at the same time.

Nevertheless, the city kept growing economically, demographically and geographically. With that, Iirregular settlements also increased and the informal market became officially recognised. These areas receive the names of colonias populares, which translates to informal settlements (Montejano, 2016).

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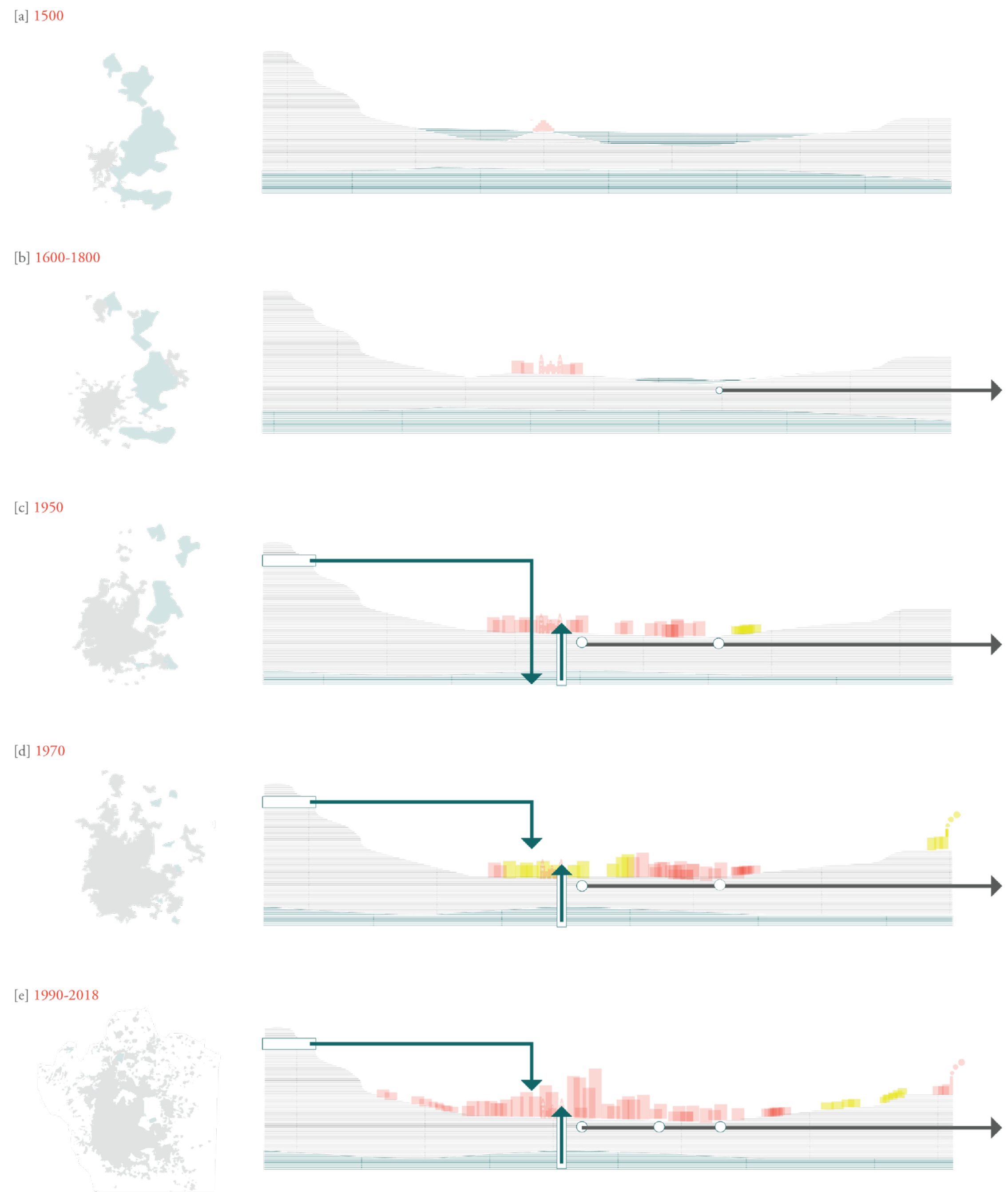

Figure 1.3 Schematisation of the evolution of the MAVM throughout time

1950-1990

In the 1970s, spatial planning was oficallyofficially consolidated on a national level in Mexico. The Secretaría de Asentamientos Humanos y Obras Públicas (SAHOP) was created in 1976 after the participation of the mexicanMexican government in the First Conference of Human Settlements in Canada. The SAHOP had the rights to adquireacquire land and to build proyectsprojects to provide infrastructure and services (Estrada et Al, 2017). Simultaneously, probably as a response to the increasing need for housing and the quick expansion of the informal market the Instituto del Fondo Nacional de la Vivienda para los Trabajadores (INFONAVIT) was created in 1972 along with a law that stipulated that 5 % of the worker's salary was to be destined to a to get the worker a credit for the acquisition of a house at a better interest rate that he or she could obtain at athe private bank's. . The SAHOP would promote the provision of social housing while the INFONAVIT would actually produce it. The INFONAVIT, took a very active role in the definition of the standards for the location and the plans for the social housing stock and would also participate in the adquisitionacquisition of land and the construction of the housing (Estrada et Al, 2017).

In the meantime, with such a housing boom, the need to extract more water, and bring transport more fresh water as well asnd to evacuate more waste water keept increasing for which the Emisor Oriente (d(deep sewage system) was built in 1975, supposedly, as the ultimate piece of hydraulic infrastructure that the city would need (Burns, 2009).

In the 1980s, during a brief period of time, spatial planning and the management of the natural resources, including the water system fell in the hands of one single dependency, theinstitution, the Secretaríaade Desarrollo Urbano y Ecología (SEDUE) (Estrada et Al, 2017). The SEDUE was created in roderorder to armoniseharmonies the local and the national objectives as in this decade the decentralisation reforms took place which allowed for the local governments to have an active role in the planning of the territory as well.

1990-2019

In 1992 that brief period ended when SEDUE ceased to exist and the Secretaría de Medico Ambiente, Recursos Naturales y Pesca (by then SEMARNAP and currently SEARNAT) took over the ecology matters and the new Secreataría de Desarrollo Social (SEDESOL) took over the social matters. Somehow on a national level, not onyonly an integrated pplanningplanning with the natural environment ceased to exist but the overall spatial planning did.sptial planning ceased to exist. On the local level, however, the spatial planning dependencies remaninedremained as they were (Estrada et Al, 2017).

In the late 90s the INFONAVIT suffered a major transformation as well, as it became in debted due to the high amount of credits it had given. The institution withdrew from the real stateestate market production and became solely a facilitator of the credits (Estrada et Al, 2017). The construction of social housing development fell in hands of the private market. The latter has been the major cause of urban sprawl in the MAVM, as the competition amongst the private housing developers for the reduction of costs began. StandarisedStandardised housing and the acquisition of cheap land became the rule of the game. By this time, the once heavy manufacturing industry in the periphery had faded to give space to a services based sector concentrated in the center of the State of Mexico City (center of the metropoli) and a to a light manufacturing sector scattered in small centralities in the State of Mexico (periphery of the metropoli) (Montejano, 2016) . The previous meant than the cheaperapter land remained in the peripheral and rural areas of the metropoli. Local institutions in charge of spatial planning failed to realise the chaos they were submerging into with the previous..

On the other hand, rural property in Mexico had been initially a social property destined to collective agriculture production, called propiedad ejidal. One of the main characteristics of such property is that it could not be sold as a protection measure for the small farmers. Fortunately, for the private developers, in 1993, a new reform allowed for the ejidos to be divided, privatised, and sold. In a few years, millions of hectares were available to be developed (Estrada et Al, 2017).

Following the same idea to reduce costs, the new social housing developments became agglomerations next to highways of 3,000 to 20,000 less than 50 m^2 duplex houses with shared walls and minimal and decaying infrastructure (water, electricity and sewage), minimal or null services (Estrada et Al, 2017), limited public transportation links, and thus, car commuting distances of an average of 21.9 km to centric jobs (Montejano, 2016).

In the decade of the 2000s, the population living in such housing environments became that ofas large as 3 million, 15% of the metropolitan population. Even more, it is not surprising to say that in certain municipalities the abandonment of such housing has reached up toto 45% of the total housing stock (Montejano, 2016), which has only reinforced the informal housing market. Such informal market, follows the same principles mentioned above (lack of services, lack of infrastructure, lack of transportation links) at lower prices.

Whereas for the water system, m, the Emisor Oriente , on the contrary of what was originally planned, was not enough infrastructure to cope with the unmeasured growth, for which the latest addition to the wastewater infrastructure is the Tunel Emisor Oriente. bBuilt in between 2008 and 2014 it which carries out the waste water to a water treatment plan in the state of Hidalgo. In the meantime the inhabitants of the MAVM keep suffering from the gratgreat irony of having severe water scarcity and heavy rainfalls that, instead of helping with the droughts, only create severe floodingsflooding while more water is pumped out of the underground and pumped up from other basins 1000m towards them.

Lastly in 2013, the ecological matters and the spatial matters were merged in a same institution: the Secretaría de Desarrollo Agrario, Territorial y Urbano (SEDATU) . However, such merging only happened in a federal level and not in a local one.

Overall the processes and Tthe consequences of the up-to-now linear approach to urbanisation and water management have led to major urban sprawl and water scarcity in the MAVM.

1.2.2 Consequences of a sectoral and linear planning in the MAVM

The sectoral and linear planning that has been applied in spatial planning over the past decades and centuries have led the MAMV to have an deteriorating social-ecological system. The following paragraphs will give more insight into the specific problems at hand.

1.2.2.1 Consequences in the social system: marginalisation

The current form of urban sprawl, mainly driven by the production of social and informal housing in the periphery social housing system, has caused the social fragmentation of the MAVM.

Figure 2.4 shows the location of the social housing areas and the so called informal colonias populares. This map is the result of a thorough study made by Priscilla Connolly (2005) in which the classification of the different types of urban settlements, based on the date in which they were urbanised and their housing production type, is shown. Figure 2.5 shows the marginalisation index developed by the Instituto Nacional de Estadística y Geografía (INEGI) with data from the census of 2010. The marginalisation index takes into account education and access to health indicators on one hand and the access to water, electricity and sewage on the other.

When one correlates the marginalisation maps with the classification of urban settlements mentioned above, it becomes clear how the social housing areas along with the informal settlements are the most marginalised areas in the MAVM.

Abandonded housing

The demand for housing and the lack of supply have pressed governmental authorities to assist in providing affordable housing, especially for lower-income classes. For that reason, they decided to start governmental programs which allow workers to get low-interest loans designed finance their homesteads. The prospect of profit from these loans has led private developers to plan and built massive settlements on the outskirts of Mexico, where land is cheap, at rapid rates. In fact, housing was built so quickly that the infrastructure associated with a decent living, like water and electricity supply, often did not followed the same rate of deployment and left many without access to essential infrastructure.

Moreover, the settlements were planned without much thought for social life and interaction amongst dwellers, mainly serving as accommodation between workdays. The placement of the developments in the periphery and the rudimentary state of transportation infrastructure cause long commute times to jobs, not only depriving families of time together but even forcing workers to stay in the city overnight, tearing apart families during weekdays. The settlements usually offer few jobs and possibilities for social activities, making the life in the settlements unacceptable for many families. The families which accept the financial losses of leaving, abandon their homes and turn to informal settlements. With little opportunity to sell their properties due to the obviously precarious living situations in the settlements, the homes often stay unoccupied and therefore unattended (Seattle Times, 2014).

Figure 1.4 " More to come" photography taken by Livia Coronas in Ixtapaluca, State of Mexico, as part of her recollection of evidence "Two Million Homes for Mexico" of the 20 million homes built by the presidential term in between 2000-2006 [Corona, 2018]. The picture depicts the deteriorating conditions hat have caused familes to abandon their houses increasingly

Figure 1.5 Connolly's classification of urban settlements in the MAVM (Elaborated with data from Connolly, 2005) The areas in the thick hatch correspond to the social housing developments whereas the ones in the thinner but denser hatch correspond to the 'colonias populares

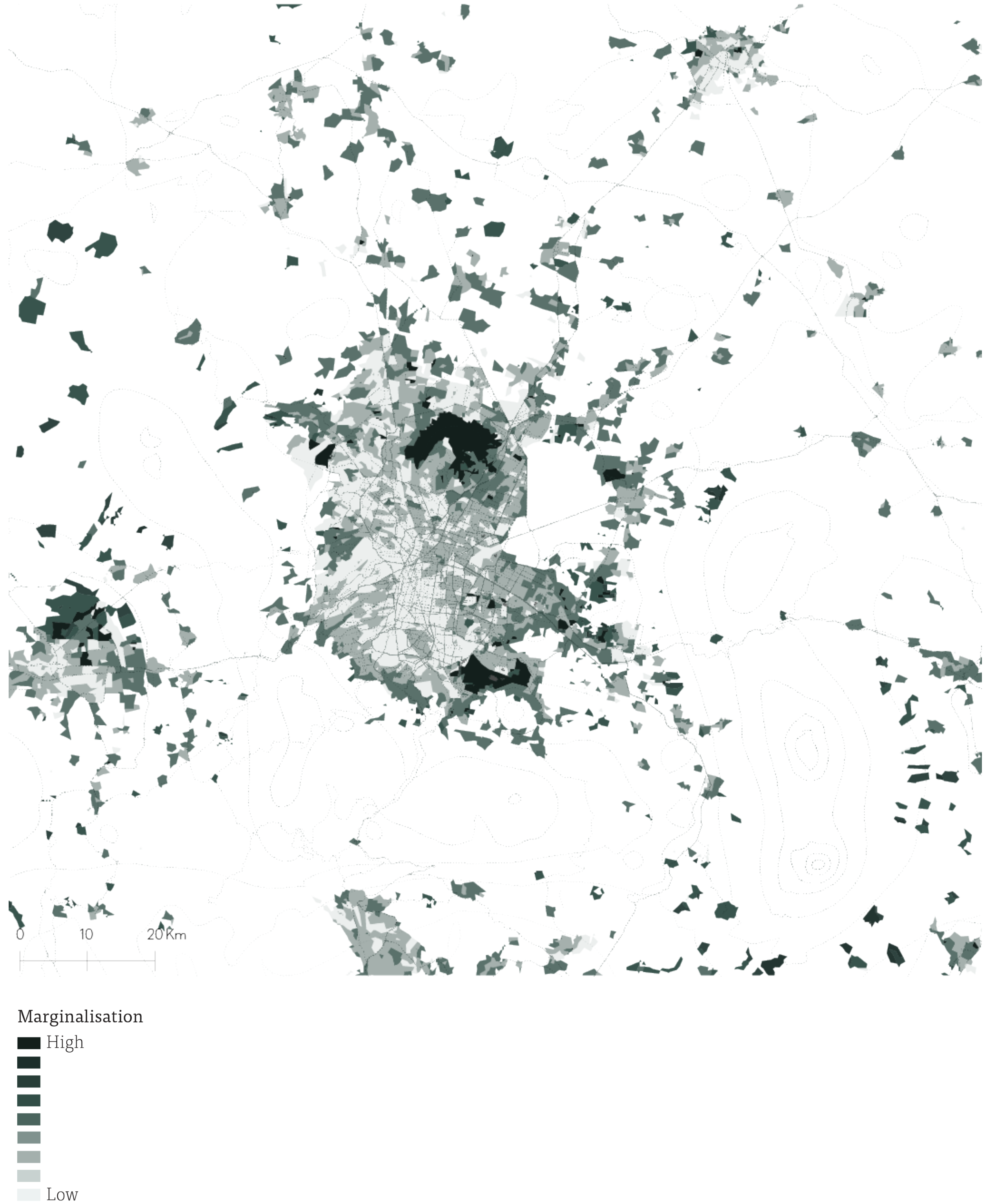

Figure 1.6 Marginalisation in the MAVM (Elaborated with data from INEGI, 2010). The map depicts how the areas in the periphery are the most marginalised, which as seen in Figure X are usually the social and the informal housing.

1.2.2.2 Consequences in the ecological system: water scarcity in the MAVM

Figure 1.8 depicts the water flows in the basin and Figure 1.9 shows the percentages of the uses of this flows. The figure shows how 68% of the water that the MAVM uses is extracted from the aquifer. 22% is brought from other basins (mainly the Lerma-Cutzamala system) and only 8% of the wastewater is treated and reused. Out of this, 35% of it, is lost due to leakages in the water pipes system. Even though the MAVM finds itself in an endorheic basin, only 3% of the 11% of the rainwater runoff is used as clean water. 75% of the rainwater is evaporated and only 14% is infiltrated to the aquifer, which means that the groundwater is still being extracted at a higher rate than it is being refilled. Finally, out of the wastewater and runoff water, only 9% is treated. The rest is pumped away to the basin of Tula where it is semi-treated and thrown back into the ocean (Deltares, 2018, Burns, 2009)., being thus lost for any further services.

Such an unsustainable water system has an immense impact on every citizen in the MAVM, regardless of how marginalised they are. Water scarcity increases the risk of subsidence, droughts and flooding. Figure 1.10, 1.11, and 1.12 expose such risks in the MAVM.

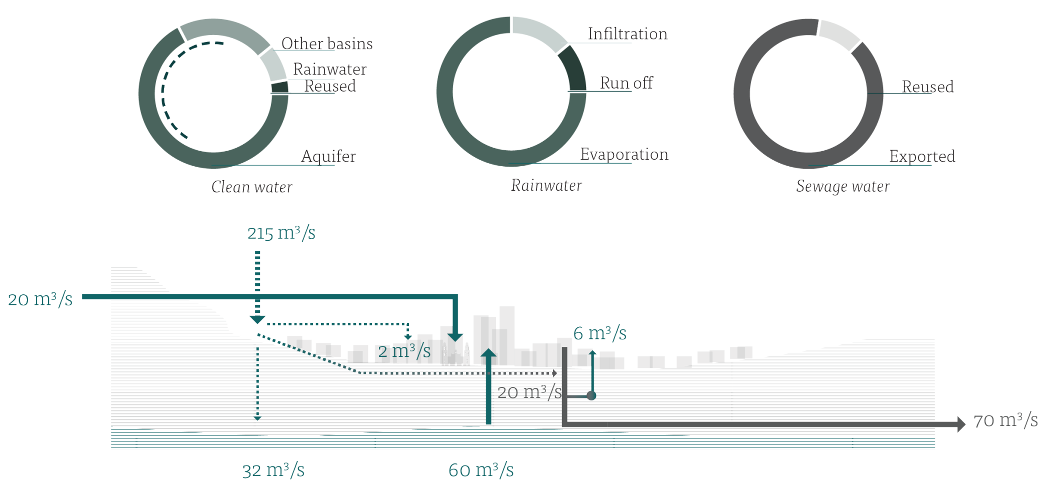

Figure 1.7 Schematisation of the current conditions of the water system in the MAVM

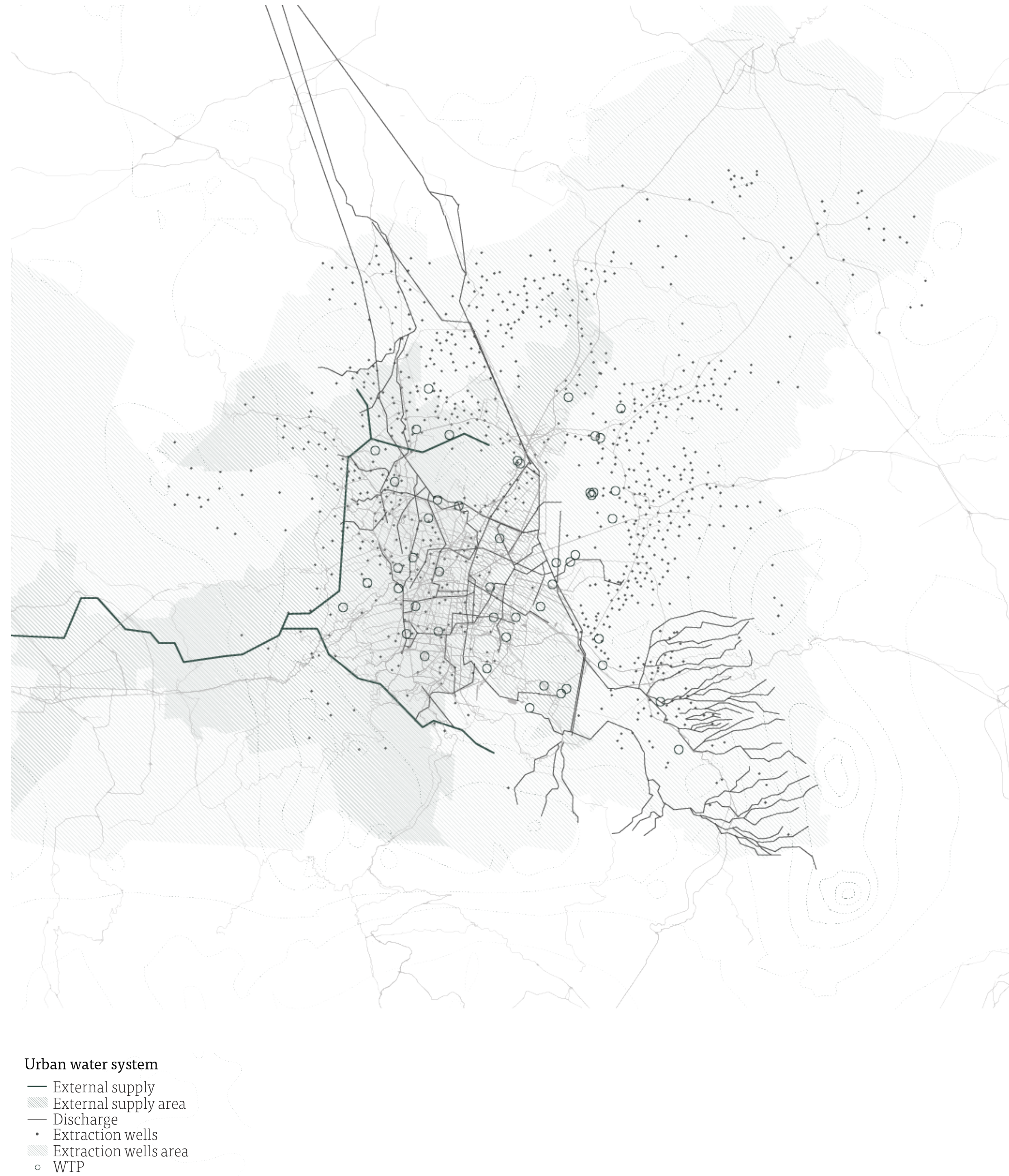

Figure 1.8 Subsidence risk (Elaborated with data from INEGI, 2010)

Figure 1.9 Draught risk (Elaborated with data from INEGI, 2010)

Figure 1.10 Flooding risk (Elaborated with data from INEGI, 2010)

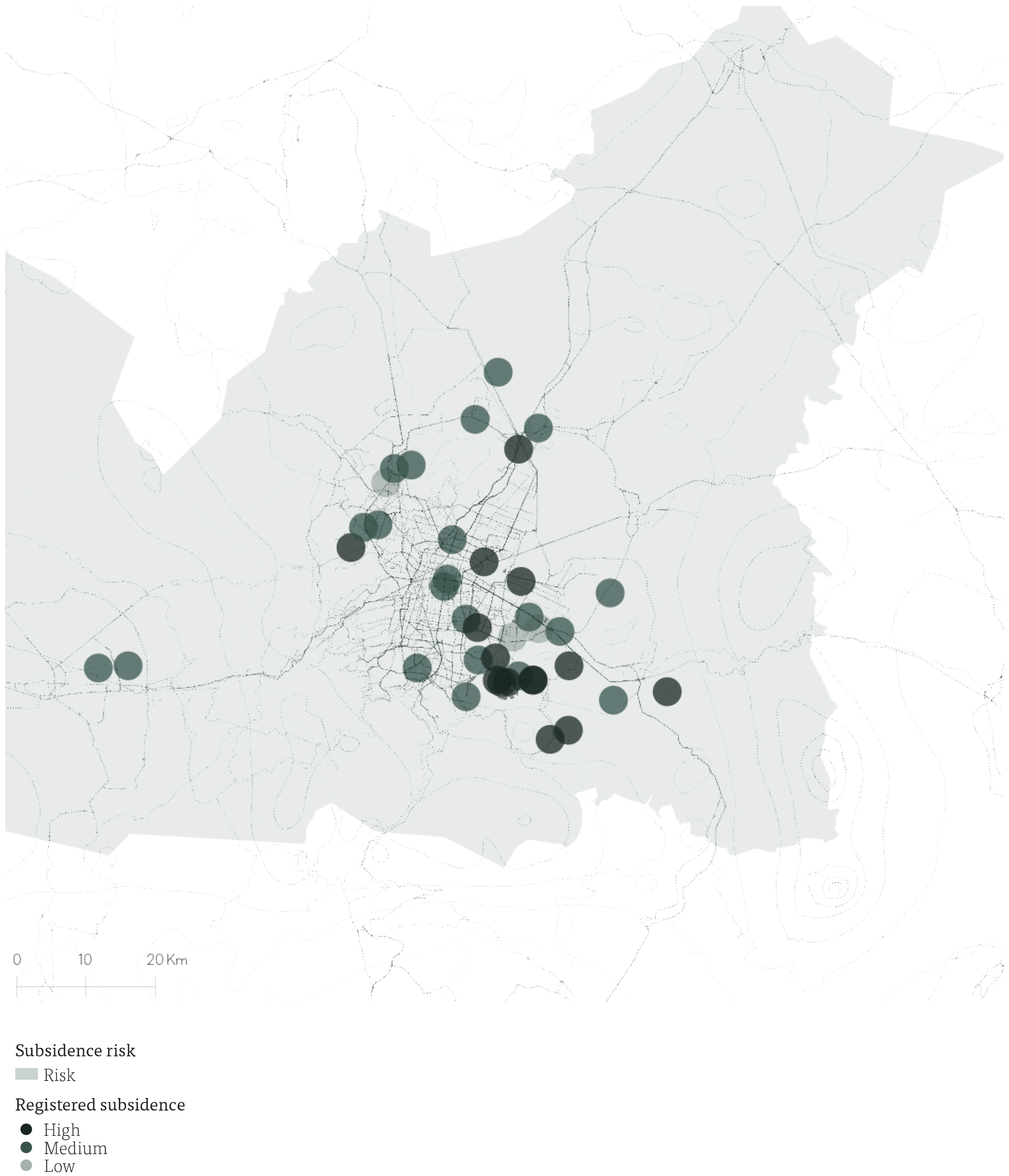

Figure 1.11 Subsidence risk (Elaborated with data from INEGI, 2010)

1.3 Concluding remarks: main challeges

Approaches like Regenerative Development and Design (RDD) are not properly integrated with planning practices. The lack of integration of the social and ecological systems with governance frameworks, and with multiscalar and transdisiplinary approaches that would integrate not only the stakeholders of the place but also the designers limits the implementation a field as promising as RDD.

The MAVM which has a long history of sectoral and linear planning had the potential to be a proper case study for the thesis and to be equally benefited from a regnerative approach. The current form of urban sprawl in the MAVM, mainly driven by the production of social and informal housing in the periphery has caused the social fragmentation of the MAVM, leaving the peripherial areas with high rates of marginalisation. While on the otherhand, the unsustainable management of the water system has led to the depletion of the resource, requring urgently alternative measures to handle the hidrological system.

1.4 Problem statement

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The theory of Regenerative Development and Design has not been properly integrated with planning practices so far. Therefore, its lack of integration limits the potential of a regenerative approach in the case study of the Metropolitan Area of the Valley of Mexico.

The lack of understanding and, even more, of integration of the social, the ecological and the governance systems stands as a main reason for which it is hard to integrate Regenerative Development with the planning realm.

Especifically, in the MAVM, this disintegration is vey much highlighted with the sectoral planning that has prevailed in the region for decades. On one hand, urban sprawl in the MAVM has been mainly driven by the public subsidised social housing developments and the creation of informal settlements. On the other hand the unsustainable water management, have caused deteriorating conditions in the MAVM and its basin. Therefore, the MAVM serves perfectly as a case study for the eploration on how to solve the theory-planning disintegration.

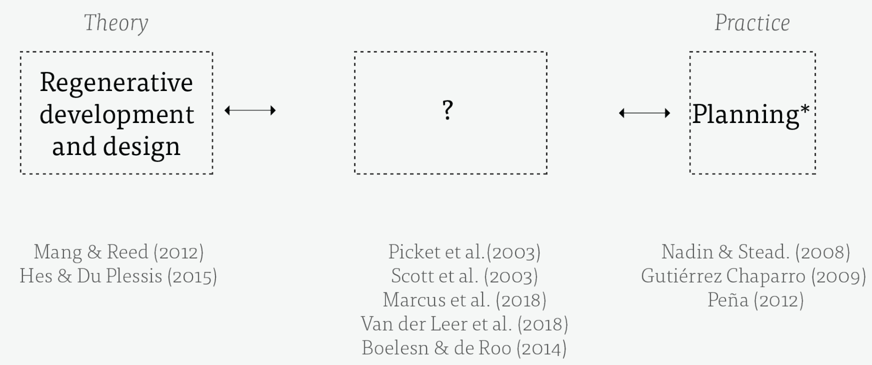

Figure 1.12 Currently, there is a gap that does not allow for the integration between Regenerative Development and Design and Planning

1 Plannign is referred to as sectoral plannin in the MAVM

2. Theoretical underpinning

This chapter presents the utheoretical underpinning which was used to develop the research approach and the methdology in the research.

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The chapter presents the underpinning of related to

- the Social-Ecological Systems Framework (SESF)
- the Actor-Relational Approach
- the geodesign framework
- cellular automata modelling and agent-based modelling

Social-Ecological Systems Framework (SESF)

The SESF was proposed by Ostrom (2009) as a mutilevel, nested framewok that can analyse the interactions and outcomes achieved in a SES. It provides a common language that helps understand the relationships among four first-level subsystems in a SES, as well as their relation to their political and geographical setting and other related ecosystems. The subsystems presented are the Resource System (RS) , the Resource Units (RU) , the Governance System (GS) , and the Actors (A).

In the framework, the relation Interactions-Outcomes is affected by the Resource units, the Resource Systems the Actors and the Governance Systems. The Resource Systems (ex. forests, water systems, wildlife) contain the Resource Units (ex. trees, flow and amount of water, animals). The Governance System (ex. government, specific rules for a behaving in a forest set the rules and conditions for the Actors (ex. individuals using the forest for recreation, extraction, or sustenance). The Resource Units are inputs to the Interactions-Outcomes relation and part of the Resource Systems, which set the conditions for the I-O relation. The GovernanceSystems are inputs to the Interactions-Outcomes and define and set the rules for the Actors that particpate in such relation (Ostrom, 2009).

Each of the First Tier variables is defined by Second and even Third tier varibles,.In other words the main 6 subsystems are compose of sub-sub-systems, as well. There are 56 listed variables that are written on Table 2.1. They can be understood as potential explanatory factors for the previous tier variables (McGinnis and Ostrom, 2014)

The Methodology chapter explains more in detail how the framewok, its variables and its relations are applied in this study.

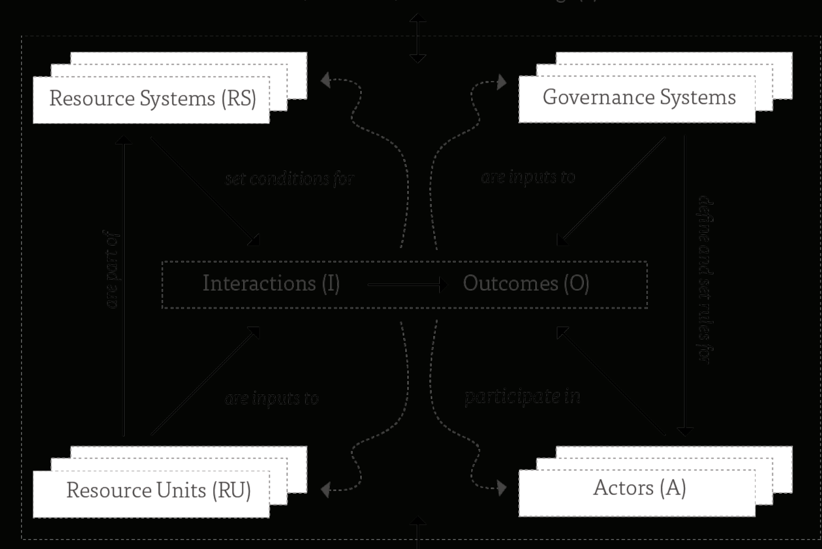


Figure 2.1 Social-Ecological Systems Framework (Adapted from McGinnis & Ostrom, 2014)

First-tier variables	Second-tier variables
Related ecosystems (ECO)	ECO1 – Climate patterns
	ECO2 – Pollution patterns
	ECO3 – Flows into and out of focal SES
Social, economic, and political setting (S)	S1-Economic development
	S2-Demographic trends
	S3- Political stability
	S4- Other governance systems
	S5-Markets
	S6- Media organisations
	S7-Technology
Resource system (RS)	RS1 – Sector (e.g., water, forests, pasture, fish)
	RS2 – Clarity of system boundaries
	RS3 – Size of resource system*
	RS4 – Human-constructed facilities
	RS5 – Productivity of system
	RS6 – Equilibrium properties
	RS7 – Predictability of system dynamics*
	RS8 – Storage characteristics
	RS9 – Location
Governance system (GS)	GS1 – Policy area
	GS2 –Geographic scale of governance system
	GS3 – Population
	GS4 – Regime type
	GS5 – Rule-making organisations
	GS6 – Rules-in-use
	GS7 – Property-rights systems
	GS8 – Repertoire of norms and strategies
	GS9- Network structure
	GS10- Historical continuity

Table 2.2 Social-Ecological Systems Framework (McGinnis & Ostrom, 2014)

First-tier variables	Second-tier variables
Resource unit (RS)	RU1 – Resource unit mobility*
	RU2 – Growth or replacement rate
	RU3 – Interaction among resource units
	RU4 – Economic value
	RU5 – Number of units
	RU6 – Distinctive characteristics
	RU7 – Spatial and temporal distribution
Actors (A)	A1 – Number of relevant actors*
	A2 – Socioeconomic attributes
	A3 – History or past experiences
	A4 – Location
	A5 – Leadership/entrepreneurship*
	A6 – Norms (trust-reciprocity)/social capital*
	A7 – Knowledge of SES/mental models*
	A8 – Importance of resource (dependence)*
	A9 – Technologies available
Interactions (I)	I1 – Harvesting
	I2 – Information sharing (D)
	I3 – Deliberation processes
	I4 – Conflicts
	I5 – Investment activities (D)
	I6 – Lobbying activities
	I7 – Self-organizing activities (E)
	I8 – Networking activities
	I9 – Monitoring activities
	I10 – Evaluative activities (D)
Outcomes (O)	O1 – Social performance measures (e.g., efficiency, equity, accountability, Sustainability)
	O2 – Ecological performance measures (e.g., over-harvested, resilience, biodiversity, sustainability)
	O3 – Externalities to other SESs

Table 2.1 Social-Ecological Systems Framework (McGinnis & Ostrom, 2014)

Actor-relational approach

The Problem field section in this report addresses how four group of authors have discussed the integration of sustainability theories and planning practices through the understanding and use of social-ecological systems and interdisciplinarity. Boelen and Roo (2014) amongst this group of authors pay special attention to how to achieve co-evolutionary planning through the integration of the actors involved in the planning process.

Boelens and Roo (2004) highlight the importance of understanding the complexity of reality to achieve the mentioned integration and suggest that one tool for arriving at such understanding is story-telling. For story-telling, the authors refer to the bridging of factual, agreed, and imagined understanding within a wider collective of human and non-human actors. They take the micro-scale of the actor in its location as the point of departure, highlight how the formal and informal institutions condition behaviours, and evidentiate how actors individually or collectively could be become involved in co-evolutionary processes with each other and with technologies (Boelens and Roo, 2004). The usual planners/designers interest and techniques are not conceived as an orchestrating or facilitating role in this process, but rather as an integral part of the possible co-evolutionary assemblages.

The actor-relational approach then proposes seven steps to achieve the co-evolutionary integration. It suggests to (1) identify the unique selling points of the region in question, (2) to develop actor analyses, to (3) develop opportunity maps defined from the interaction of the first two steps, (3) to do round tales with the actors, (5) to develop business cases, (6) to develop regime initiatives developing resilient assemblages and finally () to develop an associative democracies (Boelens and Roo, 2004). The two last steps develop the proposal further in depth for it to be able to be adapted in the region or area in the matter.

The Methodology chapter explains more in detail how this approach was usd to guide the study, specially for the integration of the designer and the stakeholders.

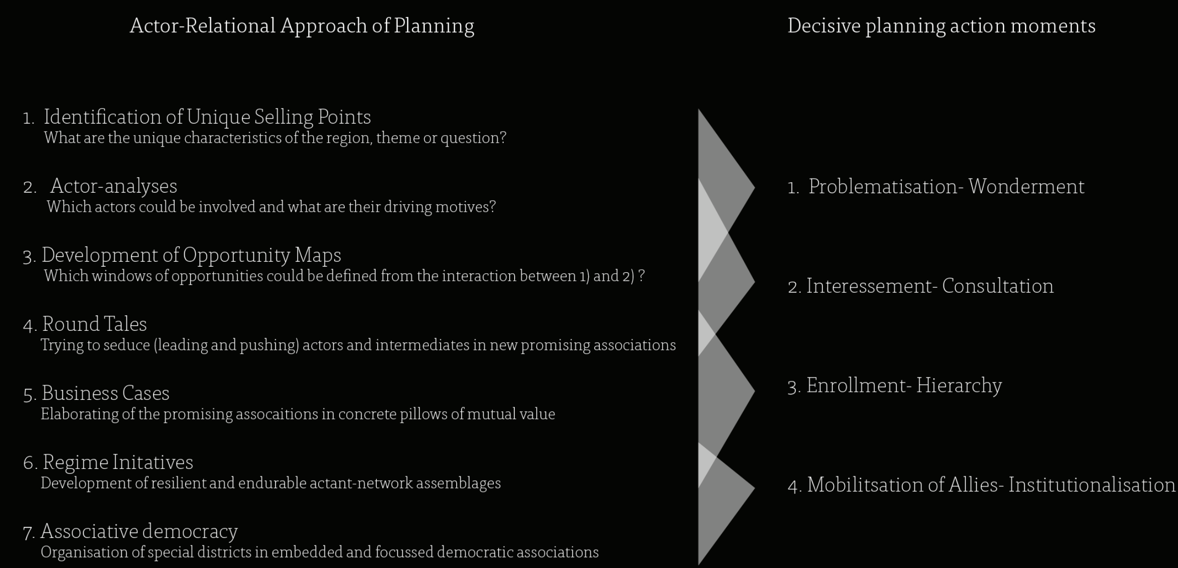


Figure 2.2 Actor-Relational- Approach for Planning (Adapted from Boelens and de Roo, 2014)

Geodesign

Geodesign is defined as the development and application of design-related processes that intent to change the geographical study areas in which they are applied or realised (Steinitz, 2013). Steinitz's (2013) framework for geodesign consist of six questions that are answered by a geodesign team in three iterations during the project and which are called models. The six models are as follows (Steinitz, 2013) :

- Represenation model- How should the study are be described in context, space and time?
- Process model- How does the study operate?
- Scenario-evaluation model- Is the current study area working well?
- Change model- How might the study are be altered?
- Impact model- What differences might the changes cause?
- Decision model- How should the study area be changed?

During the first iteration of the framework, the questions are answered in an descending order, and they are treated as why questions. In the second iteration, the questions are trated as how questions and they are asked in reverse/ascending order. In the third iteration the questions are asked in descending order again, and they address the what, where and when questions. After the third iteration, the geodesign team is supposed to assess if the design is satisfactory. If it is not, corrections and ammendments are done in the corresponsing models. If the design is good, the stakeholders assess the design and provide their feedback to the geodesign team.

More on the use of the geodesign framework in the study is elaborated on the Methodology chapter.

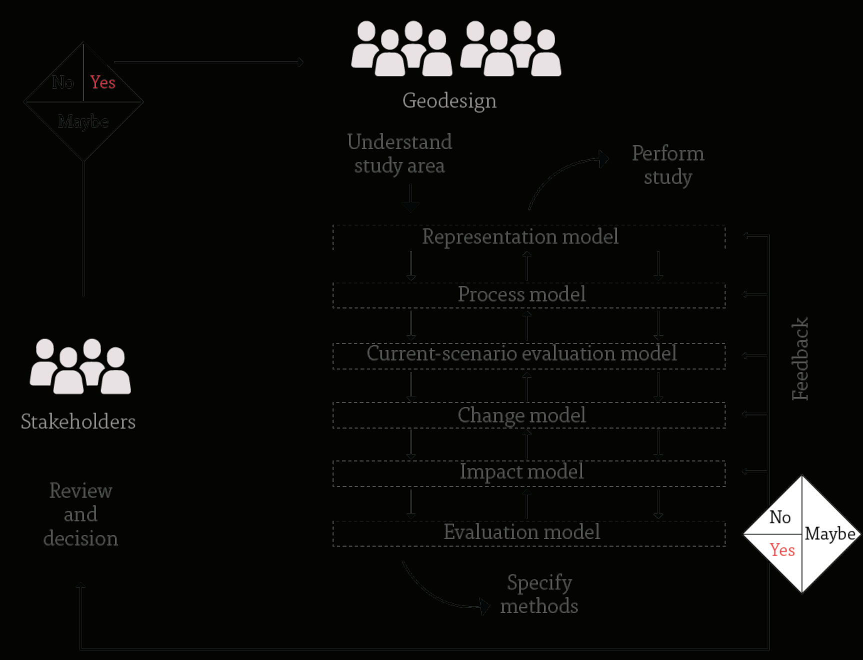


Figure 2.3 Geodesign framework (Adapted from Steinitz, 2013)

Agent-based modelling and cellular automata

Models are simplifications of real-world systems which can be subjected to tests and simulations of the reactions of the real system caused by changes in their state and function (Clarke, 2014). Models are valued based on their calibration, their design, their tractability, their performance and their validity. Agent-based models (ABM) and cellular automata (CA) are both modelling approaches to complex systems, and both have proven to succeed in the previously mentioned criteria (Clarke, 2014). Both CA and ABM focus on simulating microscale elemental agents and actions that over time and space, result in aggregate forms of behaviour, which for the case of SES would not only allow to simulate the changes in the system but also the emergent properties of the system. Cellular models are usually preferred when the geographic space is a grid (GIS raster), and when the state is known and stable (Clarke, 2014). Examples of their usage are land use change models and urban growth models. CA was conceived by Stainslaw Ulam in 1940s. It is composed of three elements: a grid of cells, a set of initial conditions, and a set of rules that are applied to change the states of the cells (Clarke, 2014). Agent-based models, are used when the basis of the model is instead a behavioural unit with a relation to space: a pedestrian, a household, a business, etc. and when the modelled process consists of interactions over time among one or more types of agents which end producing a spatial pattern, namely land use or a habitat type

. ABMs consist of agents specified at specific model scales and types; decision -making heuristics; learning or adaptive rules procedure for agent engagement; an environment that can both influence and be impacted by the agents. The main difference between the two is that in the CA approach, the agents are bound to stay in place and interact only with the neighbours. Few research has been done focused on the modelling of SES with CA or ABM. Engelen et al. (1995) and other like Clarke et al., Wu and Webster, and Sante et al. Have maily focused on CA(Clarke, 2014), while authors like Murray-Rust et al. (2009) have researched ABM uses.

More on the use of cellular automata modelling and its usee a as a spatial decision-support tool is elaborated on the Methodology chapter.

3. Research approach

This chapter presents the research clarification of the thesis. It evidentiates the precise and punctual problem that the thesis aims to tackle as well as the concepts related on how to tackle it.

The chapter presents then:

- the research question and sub-research questions,
- the working hypothesis,
- the research aims,
- and the conceptual framework.

3.1 Research question

How can regenerative development and design be integrated with the planning practice of the case study of the in the MAVM in order to circumvent its current deteriorating social-ecological system?

In order to answer the previous question, a working hypothesis was made. The hypothesis indicated that the geodesign framework (Steinitz, 2013) could be used as a methodological framework to integrate regenerative development and spatial planning, while the Social-Ecological Systems Framework (SESF) (Ostrom, 2009) could be used as a theoretical basis.The SESF was presumed to provide a structured language that would allow to integrate social, ecological and governance systems across multiple scales while on the other hand the geodesign framework seemed to a be proper method to to integrate the stakeholder's and the designer in than interative process of analysis, design and evaluation.

Based on the research question and the hypothesis five sub-research questions have been formulated and will guide the research.

1 How can geodesign be adapted to be integrated with the social, ecological systems framework?

2 What social-ecological system characteristics can be identified in the MAVM that could function as value generating capacities?

3 How can the value generating capacities of the social-ecological system be turned into regenerative strategies?

4 How does the MAVM function perform as a social-ecological system?

5 What strategy or strategies promote regenerative development in the MAVM?

3.2

3.3 Research aims

The main aim of the research was to provide a framework, using geodesign and social-ecological systems, to integrate Regenerative Development and Design and planning practices. The purpose of the framework would be to provide a more integrated and collaborative method for planning towards regenerative development.

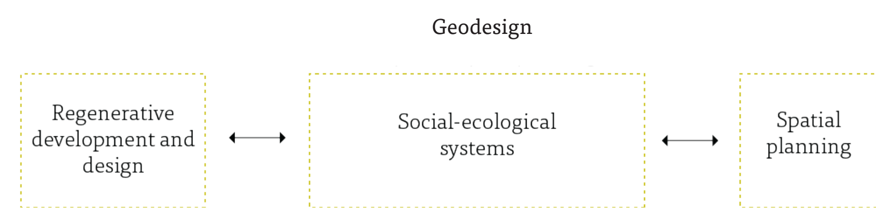


Figure 3.1 Main research aim

The second aim was to use the social-ecological system in the MAVM as a case study for developing the framework. The specific objective within such case study was to provide a regenerative strategy for the future development of the MAVM taking advantage of the value generating capacities of the social-ecological system.

3.4 Conceptual framework

The conceptual framework is based on the hypothesis presented above. The hypothesis proposed the use of the geodesign framework as a methodological approach and the Social Ecological System Framework (SESF) as a theoretical approach to integrate the Regenerative Development and Design theory and the planning practices in the MAVM. In Figure 3.2, the red rectangle represents the space in which the two approaches can explore how to integrate regenerative theory and planning.

FFigure 4.4 and Figure 3.4 show accordingly, how the methodological framework and the theoretical framework aimed to do so. Figure 4.4 specifies the SESF as the theoretical framework used. The diagram shows the two systems that the SESF suggests to use: the Resource Systems and the Governance Systems. The acronym ARA appears underneath the Governance System; it stands for the Actor Relational Approach (ARA) theory (Boelens, 2014). The ARA was the secondary theory in the study used to guide the collaborative processes.

Furhther , Figure 3.4 presents geodesign as the methodological framework proposed. Within the geodesign framework, the use of agent based-modelling is also shown. Eventhough, the agent-based modelling is one of the many methods used in this study, it is presented here as it is one of the most important ones.

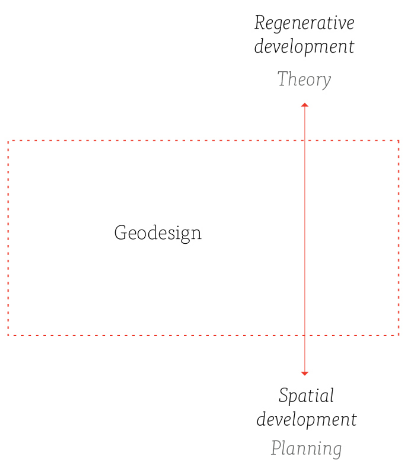


Figure 3.2 Conceptual framework constructs

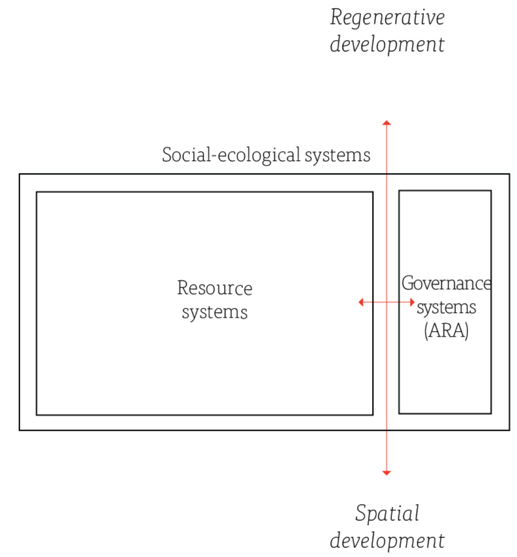


Figure 3.3 Theoretical framing for the conceptual framework

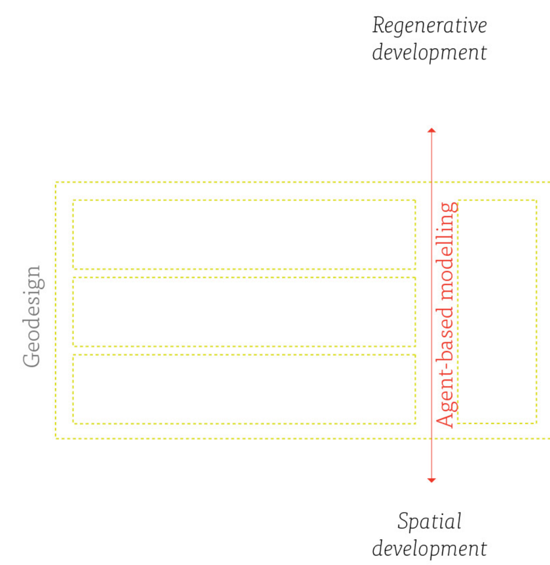


Figure 3.4 Methodological framing for the conceptual framework

Finally, Figure 4.6 shows a more detailed version of the conceptual framework. The diagram is divided in four main sections, the three on the left correspond to the Resource System and the one on the right corresponds to the Governance System in the MAVM. Read from top to bottom, Figure 4.6 shows how the unsustainable water management and the urbanisation processes in the MAVM (mentioned in the Problem field) influence the current state of the social-ecological system. The latter lead to a lack of services and infrastructure (or in other words, marginalisation) of the social and informal housing developments. The top part, lastly shows how these variables lead to deteriorating social-ecological systems.

In the middle and bottom section, the diagram shows how regenerative design uses the value generating capacities of the ecological and the social system in the MAVM as well as more collaborative processes in the governance system to have a regenerative water system and regenerative housing developments. Finally, the diagram shows how the previous lead to the desired social-ecological system.

The diagram overall shows how, when the control variables are introduced (the regenerative design strategies and the collaborative processes) the desired outcomes from the study (regenerative social-ecological system) can be achieved.

In the next pages the Geodesign, agent-based modelling, the Social-Ecological Systems Framework,and the Actor Relational Approach are further explained.

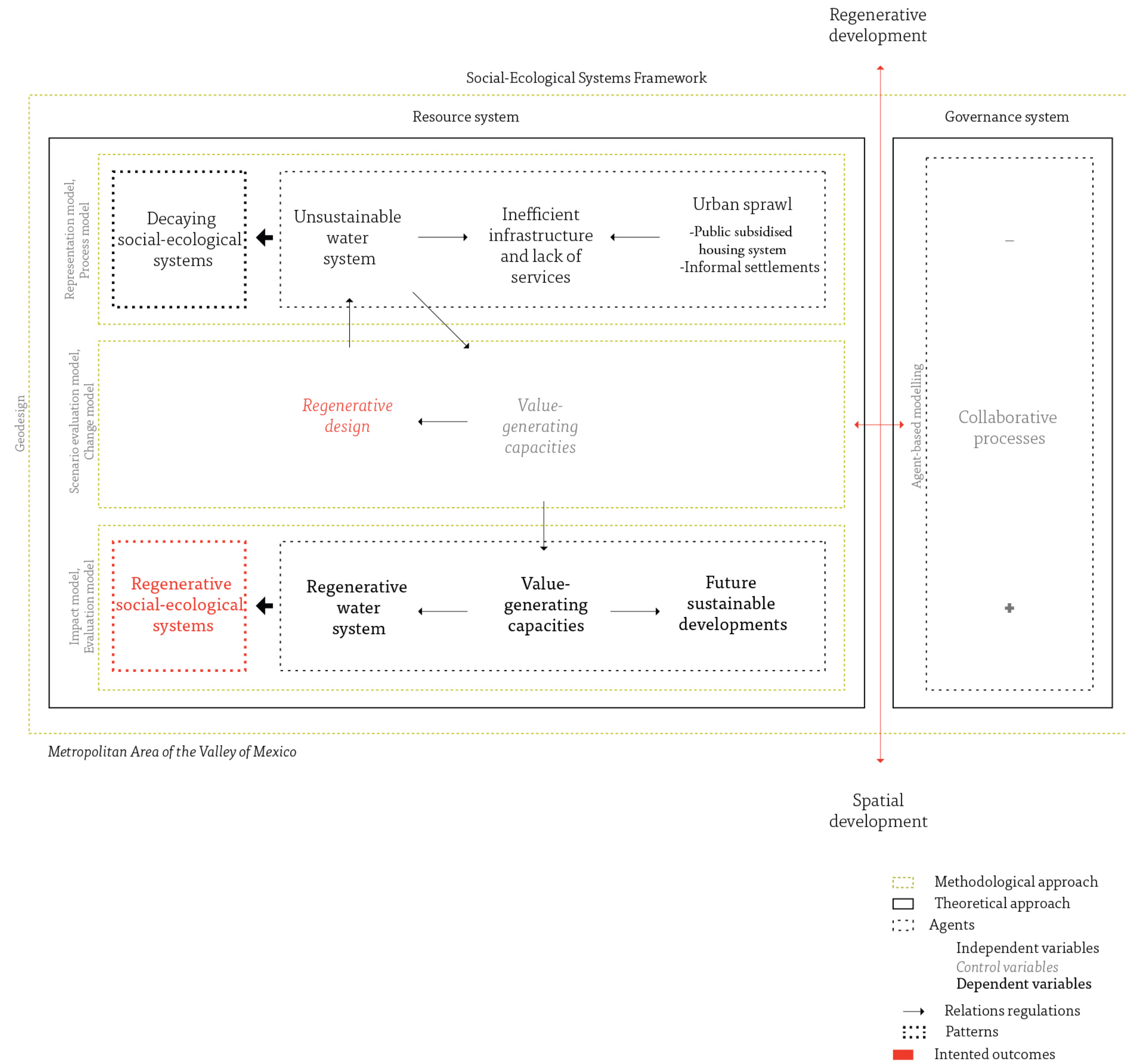


Figure 3.5 Detailed version of the conceptual framework

4. Methodology

The working hypothesis presented previously suggested that the use of the geodesign framework and the Social-Ecological System Framework (SESF) could facilitate the integration of Regenerative Development and Design and planning practices. The working hypothesis led to the development of an adapted version of the geodesign framework, which was tested with the MAVM as a case study.

This chapter then presents the methodology behind the adapted framework. The chapter shows the aims of using a combined framework of geodesign and the SESF, the description of how it was integrated, and other modifications it suffered to achieve its aims. The framework is further presented in the form a roadmap along with its related methods and output so that future studies can easily replicate the methodology here presented.

4.1 Geodesign framewok as an analytical and design framework

The next pages present the supporting methodology that worked as the backbone for the study. It is considered worth mentioning that in the field of Urbanism, the methodology of any study is usually supported by two frameworks: an analytical framework and a planning/designing one. However, the methodology in this chapter only presents one: an adapted version of the original geodesign framework, which is guided by the structured language of the Social-Ecological Systems Framework (SESF). The reason for using the mentioned framework solely is because the geodesign framework, by itself, possesses the qualities of being able to both, analyse and design iteratively. Nijhuis et al. (2016) describe the previous by breaking the word 'geodesign' in two. According to them 'Geo' stands for the representation of the modelling, analytical and visualisation capacities of GIS, while 'design' stands for the representation of the spatial planning and design which turns the existing situations into preferred ones.

4.2 Building an adapted geodesign framework

As mentioned before, the problem field found that the disintegration between Regenerative Development and Design and planning practice is due mostly to the lack of understanding and even more, of integration amongst the social and the ecological when planning and designing. The authors Picket et al. (2003), Scott et al. (2003), Marcus et al. (2018), Van der Leer et al. (2018), and Boelens & de Roo (2014) propose the use of social-ecological systems that integrate governance frameworks, multiscalarity, and transdisciplinarity to bridge the gap. The thesis, therefore, used the geodesign framework and integrated it with the Social-Ecological Systems Framework to address the four previous points. The geodesign framework was mostly used to achieve the desired transdisciplinarity, while the SESF was used to address the use of social-ecological systems, governance, and multiscalarity.

Geodesign framework

As a reminder for the reader, the geodesign framework and the Social-Ecological Systems Framework are explained briefly below, however, for more information, please refer to the Theoretical Underpinning Chapter.

The geodesign framework proposed by Steinitz (2014) is an iterative process of six questions that are asked three times during the project by a geodesign team and presented to a group of stakeholder's to receive approval or feedback. During the first iteration of the framework, the questions are answered in descending order, and they are treated as why questions:

- Representatio n model- How should the study are be described in context, space, and time?
- Process model- How does the study area operate?
- Scenario-evaluation model- Is the current study area working well?
- Change model- How might the study area be altered?
- Impact model- What differences might the changes cause?
- Decision model- How should the study area be changed?

In the second iteration, the models are answered as how questions and they are asked in reverse/ ascending order. In the third iteration, the questions are asked in descending order again, and they are addressed as what, where, and when questions. After the third iteration, the geodesign team is supposed to assess if the design is satisfactory. If it is not, corrections and amendments are done in the corresponding models. If the design is good, the geodesign team then shows the results to the stakeholders, who assess the design and provide their feedback to the geodesign team. If the feedback is positive, the stakeholders proceed to use the results as they please, and if it not, the study may be repeated, with the necessary amendments. Usually the framework is depicted as an extremely linear process, however, in reality, it is rather non-linear and iterative.

Social-Ecological System Framework

Social-Ecological Systems Framework The SESF, on the other hand, is a framework proposed by Ostrom (2009) which uses a precise and structured language to study social-ecological systems. More importantly, the framework proposes seven main variables to be used for studying such systems, which are the Setting, the Resource System, the Resource Units, the Governance System, the Actors, Interactions, and Outcomes variables.

4.2.1 Adapting the geodesign framework to integrate the Social-Ecological Systems Framework

As mentioned previously, the integration of the geodesign framework and the SESF addressed the use of social-ecological systems, governance, multiscalarity, and trandiscplinarity that the Problem Field found to be crucial to integrate Regenerative Development with planning practices.

The first step to integrating the frameworks, therefore, was to decide that the geodesign framework would use the seven SESF variables to give answers to each of its models. Further, the variables that would answer the questions in each model were identified.

- The Representation Model is supposed to describe the study area in relation to its spatial context, so, accordingly, the Setting, the Resource System, and the Resource Units were used to describe the model.
- The Interactions variables were used to answer the questions of how the study area operate (Process Model);
- and the Outcomes variables were used to assess if it is working properly (Evaluation Model).
- The Interactions were used as well as to answer the questions of what differences might take place (Change Model),
- and Outcomes to answer what changes that that thcause (Impact Model) in the system;
- Finally, the Governance System and the Actors variables were used to describe what should be considered when taking the final design decision (Decision Model).

The second step was to activate the variables according to how each of the iterations were addressed. The results were having that the first iteration would identify the study criteria the variables (why), the second iteration would select the modeling methods for the variables (how), and the third iteration would model them (what, where, and when).

Figure 4.1 shows in a diagram all the previously described. However the research found that the newly integrated framework did not actually use multiple scales. Even more, the research also found that that even though the geodesign framework promoted a trandiscplinary approach, it could be further enhanced, as it already that the it provided a soild structure for integrating the stakeholders and the geodesign team. Accordingly, further modifications were made to the framework addressing this two issues, therefore Figure 4.1 does not show the final adapted geodesign framework but only depicts how the Geodesign and the SESF were integrated. The next section addresses the final adaptations that the framework went through, and presents the final version of the methdology used in the thesis.

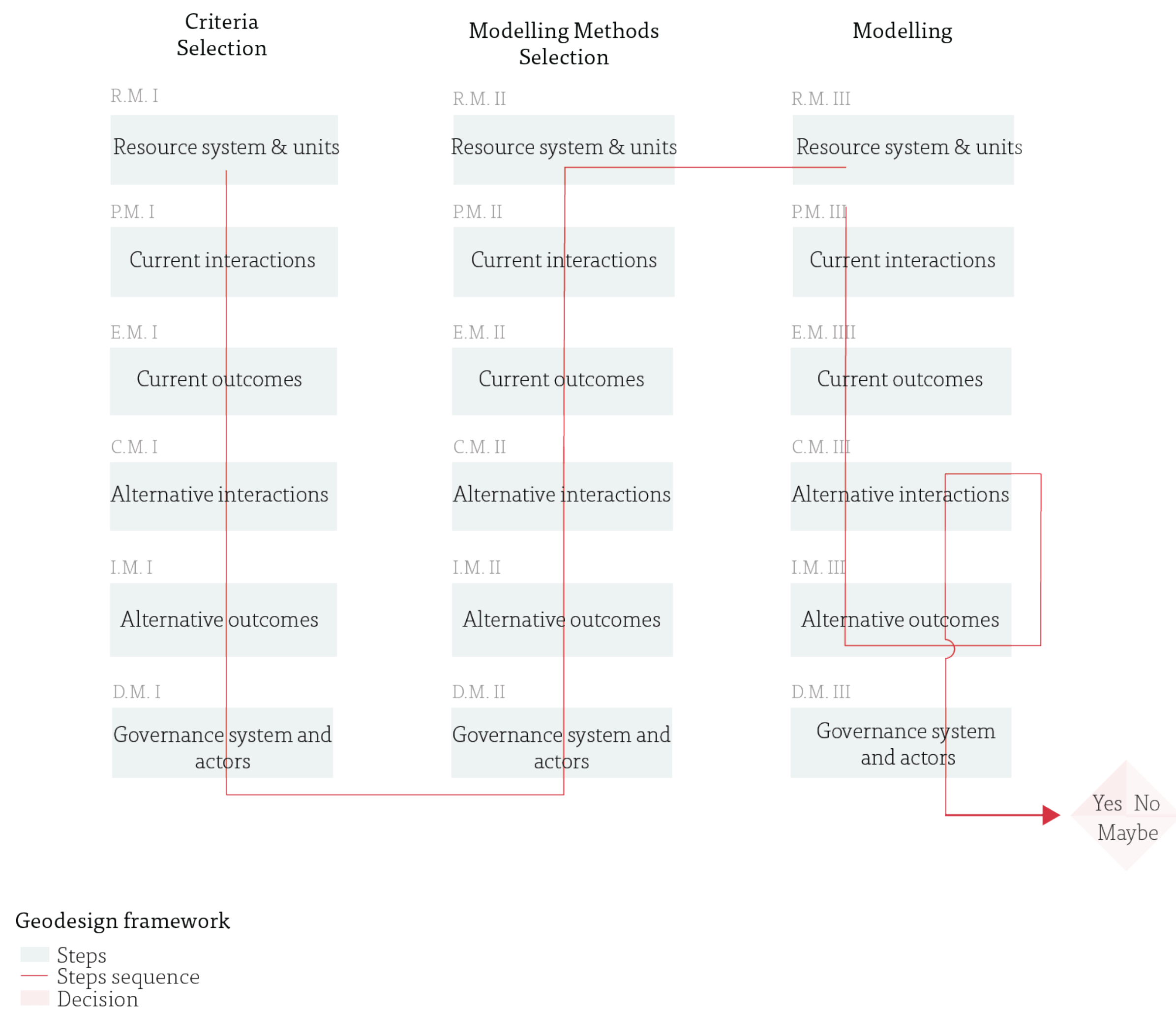


Figure 4.1 Integration of the SESF variables into the geodesign framework

4.2.2 Enhancing multiscalarity and trandisciplinarity in the framework

Even though the integration of geodesign and SESF tackled the use of social-ecological systems, governance, multiscalarity and transdisciplinarity that the problem field found out to be key concepts in the integration of Regenerative Development and planning practices (Picket et al. (2003), Scott et al. (2003), Marcus et al. (2018), Van der Leer et al. (2018), and Boelens & de Roo (2014)) , there were still some amendments that had to be done to the newly integrated framework. A summary of the adaptations is shown in Table 4.1 and explained further in detail in the next pages

The framework suffered four main adaptations. Three of them were developed in order to enhance the use of multiple scales and transdiscplinary approaches. The last one was developed as a response to the constraint of not having a geodesign team but rather only one designer developing the study, referred to in further pages as the researcher.

The first modification improved the use of multiscalarity in the adapted framework by 1.1) dividing the Resource System i two different types of scales: into system andsubsystems, and into an assessment and designing area, and by 1.2) developing the selection of the criteria, the methods to model and the modelling of the macro scale of the Resource System before than the rest of the framework The second and third modifications aimed to enhance the use of transdiscplinarity by enhancing the co-designing amongst the stakeholders and between the stakeholders and the designers by 2) using an anticpatory-agent based modelling method in the Process Model and by integrating the Change Models of the stakeholders and geodesign team rather than selecting from them.

Concept	*Tackled in*	*Issue*	*Changes in the SESF*	*Changes in the GF*
Social-ecological systems	SESF	*None*	*None*	*None*
Governance frameworks	SESF, GF	*None*	*None*	*None*
Multi scalarity	None	Constraint: Nor the SESF nor the GF incluse the use of multiple scales in their frameworks	The Resource System was divided in two different types of scales: into systems and subsystems and into a macro and a Meso-scale	The selection of the criteria, selection of the methods to model, and modelling of the macro-scale of Resource System had to be done first than the rest of the framework (Iteration 0)
Trans discplinarity	GF	Enhancement: Co-designing amongst actors	*None*	Use of an anticipatory-agent based modelling method not only in the Change Model , but also in the Process Model
		Enhancement: Co-designing between stakeholders and the geodesign team	*None*	Stakeholder's and Geodesign team's integration of Change Models into a new Change Model rather than the comparisson and selection from them
		Constraint: Master thesis had to be developed individually	*None*	The researcher played the role of the geodesign team

Table 4.1 Summary of key adaptations to the geodesign framework

Figure 4.2 Integration of the SESF variables into the geodesign framework

The four adaptations that the geodesign framework had ater it was previously integrated with the SESF are described as follows.

Multiscalarity

The first amendment concerned multiscalarity. Social-ecological systems are considered to be nested systems with emergent properties. They are considered to be systems that enclose smaller systems and that are simultaneously being enclosed by greater systems. Therefore, any action in the system resonates throughout all the scales. Nor the SESF nor the geodesign consider the use of multiple scales in their frameworks. Even though it would seem that the SESF, uses two scales: the Resource Systems and the Resource Units, the Resource Units are considered rather analysis/design elements than analysis/designs components or, even more, than analysis/design areas. Due to all the previous, the research modified the frameworks as follows:

The Resource System was divided in two different ways: it was divided into two different subsystems and two different assessment-design areas. The two different subsystems corresponded to the social and the ecological subsystems that compose Resource System. The two analysis-design areas were categorized as Macro-scales and Meso-scales. The Macro-scale was used to assess and study the characteristics and performance of the social and the ecological subsystems and the Meso-scale was used to design with the social-ecological subsystems in the MAVM. As mentioned previously, the Resource Units were not used as a scale but rather as physical patches of land and digital pixels which contained the information regarding the characteristics and performance of the Resource System. Finally, in order to achieve such changes, the geodesign framework was modified by having the Macro-scale of the Representation Model modelled before the rest of the framework. Figure 4.2 further illustrates how each of the scales were used differently depending if the Interventions or the Outcomes were being modelled.

Even though all the previously mentioned scales were operationalised until the framework was actually developed, for clarification purposes the Figure 4.3 exemplifies how the different scales were used in the thesis.

As Figure 4.3 shows, the Resource System used was the MAVM, the Macro-scale was the MAVM as well and the Design area was the rectangle highlighted in black. This design area was used because the major concentration of value-generating capacities were located there. The Ecological Subsystem is made up of the aquifers in the MAVM and the Social Subsystem is made up of AGEB. An AGEB AGEB is an acronym, standing for Area-Geo Estadistica Basica, or Basic Geostatistical Area and it is the smalles level of geography at which Mexico's Census tabulates demographic data (Geoanalitica, 2016). The Resource Units were patches of land of 240x230 m that appear in form a grid in the image, they were selected as they were the smallest size that the software to develop the modelling was able to handle.

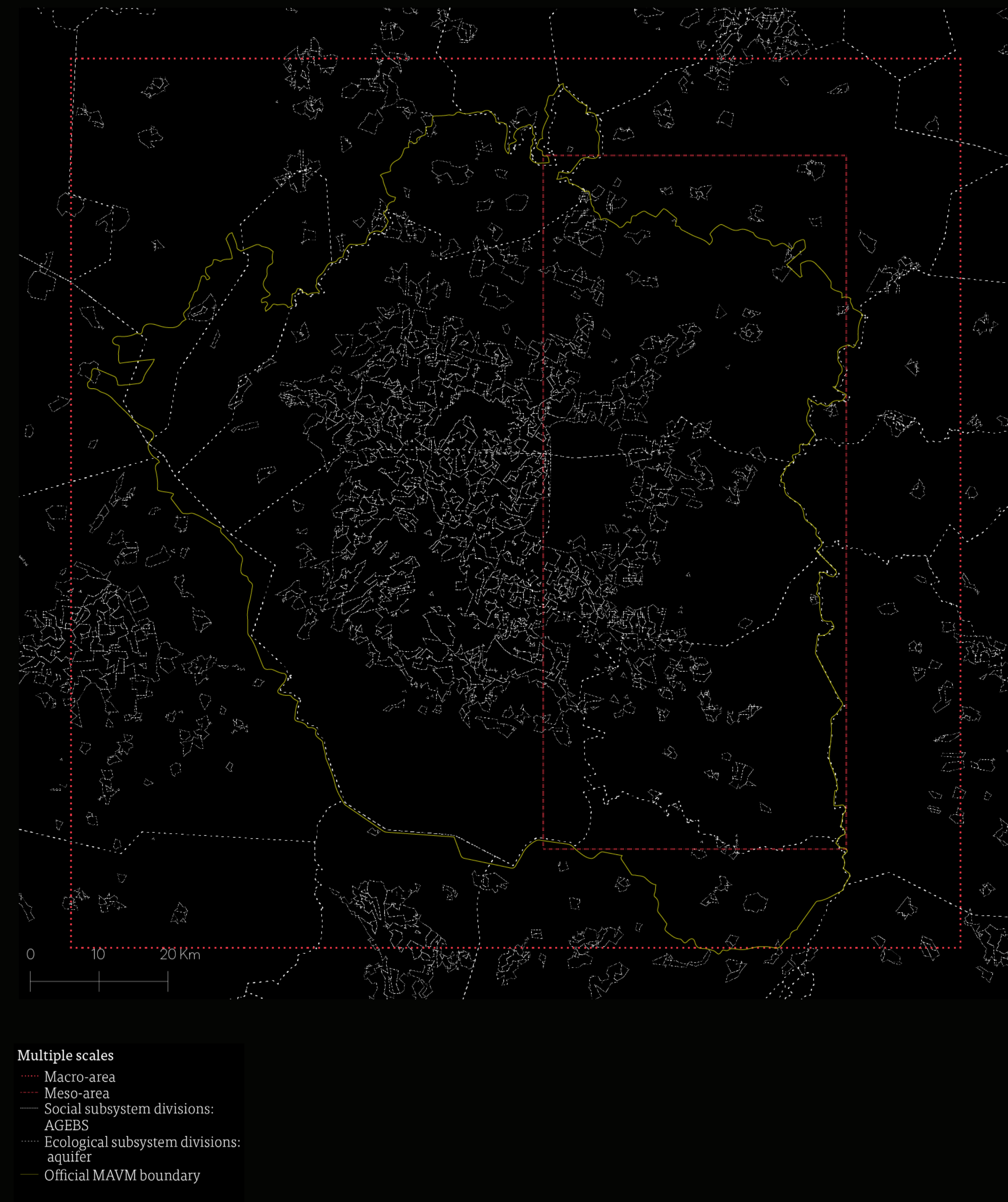


Figure 4.3 System, Subsystems, Macro-scale, and Meso-scale used in the study

Transdisciplinarity

While multidisciplinary and interdisciplinary approaches promote the interaction and synthesis of different academic disciplines, according to Steiner and Posch (2006), transdisciplinary approaches promote even more, the interaction between academic and practitioners in order to promote a mutual learning process between them. By definition, geodesign promotes transdiscplinarity by integrating the stakeholders review and feedback of the project at the end of the three iterations. However, the research noticed it was possible to enhance it even more with one of the methods that the frameworks that Steinitz proposes to develop the Change Model (2014). The modifications proposed enhance the further integration amongst the stakeholders and between the stakeholders and the geodesign team.

The method referred in the previous sentences is a mixed anticipatory-agent based modeling. With such method the geodesign team firstly models the changes that could be preferred for the system and following, the stakeholders model the changes they seem fit to be developed. In both cases the agent-based model, provides an immediate response on what the outcomes of the interventions are. The first change to the method concerns the better integration amongst stakeholders, for such, the thesis proposes that the method is not only used to model the changes but also the processes. For this modification to work, as a condition, the modeling of the processes has to be done as it actually happens in the studied context and the Change Model has to be done in an co-elaborated manner. This way, the actors would enhance their understanding of their own capacities and interests, as well as the ones from their fellow-stakeholders, and develop a better understanding of the outcomes that their decisions have, which would ultimately enhance the roles and decisions that they would take when co-developing the Change Model.

The second modification concerns the better integration between the stakeholders and the geodesign team. Usually, after all the possible changes are modelled in the framework, the Decision Model compares them and selects the preferred one. The modification proposed is to integrate the proposals rather than select from them. The modification requires then the development of one last Change Model by the geodesign team in which the knowledge gained from the original geodesign's team change models and the stakeholders' is used.

No geodesign team

The last change realised was done due to the nature of the present Master thesis. The thesis is developed individually and due to time constraints, it was necessary for me, referred to in further pages as the researcher, to represent the entire geodesign team's interests and decisions.

The changes in regards to the use of mutilple scales and more trandsiplinary approaches are suggested to be followed in case this study is replicated, however, the modification for not including a geodesgin team is not considered necessary unless the projec requires it for similar resons.

4.3 Adapted geodesign framework roadmap, methods and output

The adapted geodesign framework was broken into seven steps.

- The first step is the Iteration 0, it is an adaptation to the original geodesing framework in which the selection of the criteria to study , to model, and the modelling of the Representation Model takes place.
- The next step is considered the Iteration 1, which would be the original framework's first iteration. In this iteration, the criteria to study the current interactions and outcomes, and the possible future interactions and outcomes is selected. In this iteration the analyses of the governance system and the actors are also developed.
- The Iteration 2 follows accordingly, in which the methods to model each of the variables that give answer to the geodesign questions are selected
- The last iteration, as mentioned before, was broken into 4 sub-iterations. The first sub-iteration is considered more of a -preiteration, and it develops a catalogue of all the possible interactions and outcomes in the system and builds the agent-based modell to be used in the next sub-iterations
- In the second sub-iteration the researcher (the geodesign team) models the interactions and outcomes for a Business-As-Usual development and for aregenerative development according to previous and gathered expertise.
- In the third sub-iteration, the stakeholders deelop the same processes as in the previous step in form of a workshop.
- Lastly, the researcher integrates the knowledged gather from the previous ubs-iterations in one last Change Model, in order to achieve a co-designed strategy between the stakeholders and the researcher (who represents the design realm)

In the next pages, the framework is explained as a roadmap, along with its related methods and output, and a shematic vsualisation of thits steps, so it can be repeated in further studies.

Step 1

The Setting, the Resource System, and the Resource Units of the Macro-scale were modelled as the first step. The aim the Representation Model was to identify the distinctive capacities of the MAVM (the Macro-scale) , in order to select which area would be best to design in.

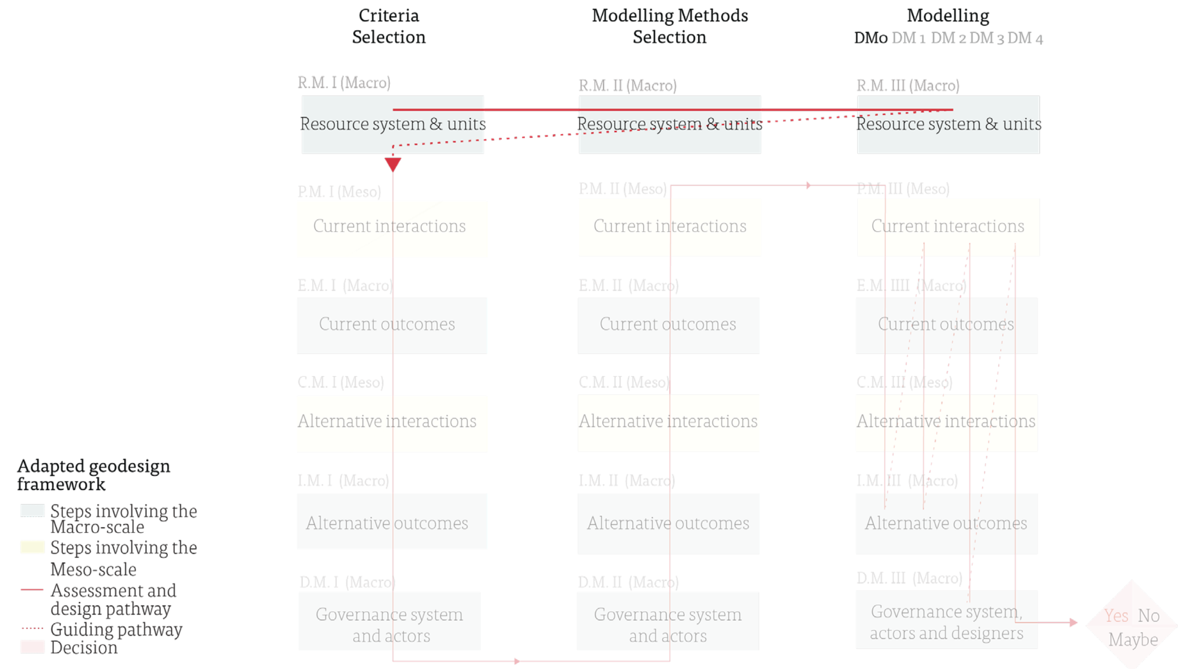
Steps per iteration	*Methods*	*Research output*	*Refer to*
The RM1-MACRO identified and operationalised the Setting, the Resource System, the Resource Units variables	Literature review of the theories of SESF and geodesign, of policies, and documents of the MAVM		Chapter 5
The RM2-MACRO identified the method which would be used to model the variables	Literature review of GIS mapping methods		Chapter 5
The RM3 modelled the variables	Analysis and mapping of demographical and geographical data; GIS spatial analysis (hydrology and surface analysis); GIS network analysis (space syntax and accessibility analysis)	Catalogue of maps, selection of the Meso-scale	Chapter 5

Step 2

With the Meso-scale selected, the next step was to develop the first iteration as usual. This next step combined the use of both the Macro and the Meso scale as it realised the scoping of the current and possible future interactions that take place in the Meso-scale and their outcomes in the Macro-scale.It also realised the scoping of the governance system and the actors involved in the Macro-scale.

Steps per model	*Methods*	*Research output*	*Refer to*
Identification and operationalisation of the Interaction variables in the Meso-scale			Chapter 6
Identification and operationalisation of the Outcome variables in the Macro-scale			Chapter 6
Identification and operationalisation of possible alternative Interaction variables in the Meso-scale	Literature review of the theories of SESF and geodesign, of policies, and documents of the MAVM	Literature review of the theories of SESF and geodesign, of policies, and documents of the MAVM	Chapter 6
Identification and operationalisation of possible alternative Outcome variables in the Macro-scale			Chapter 6
Identification and operationalisation of the Governance System and the Actors variables in the Meso-scale			Chapter 6

Step 1



Step 2

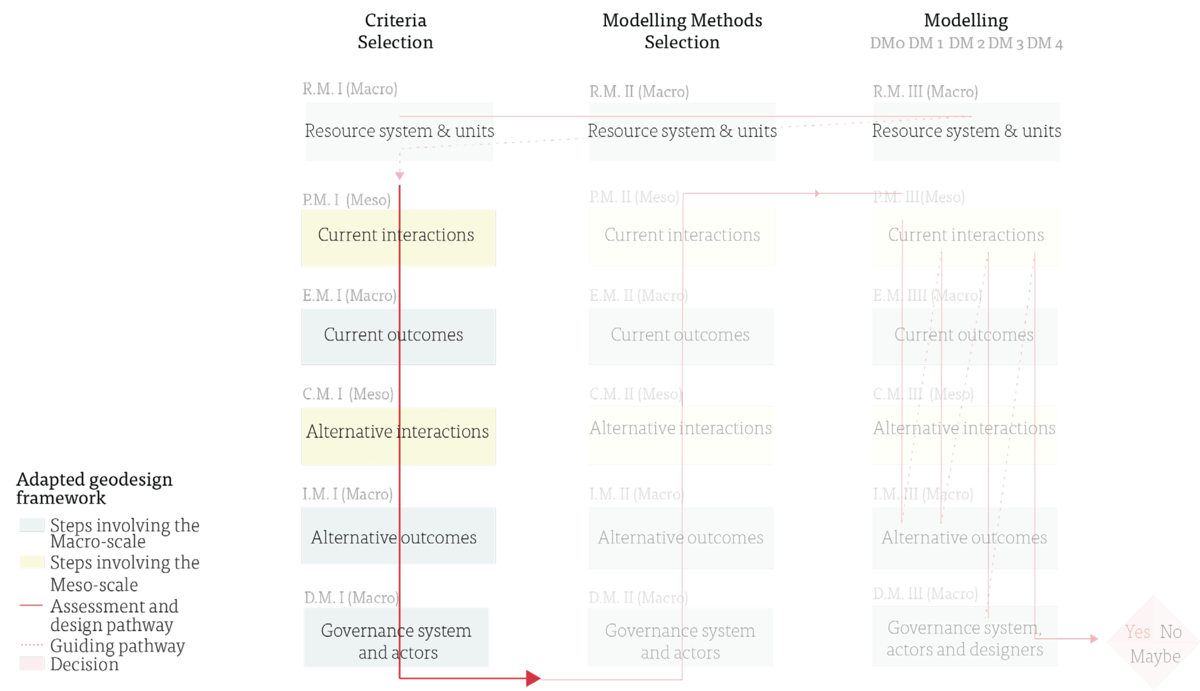


Figure 4.4 Steps 1 and 2 in the adapted geodesign framework

Step 3

The next step was to identify the methods that would be used to model the variables identified in the previous step.

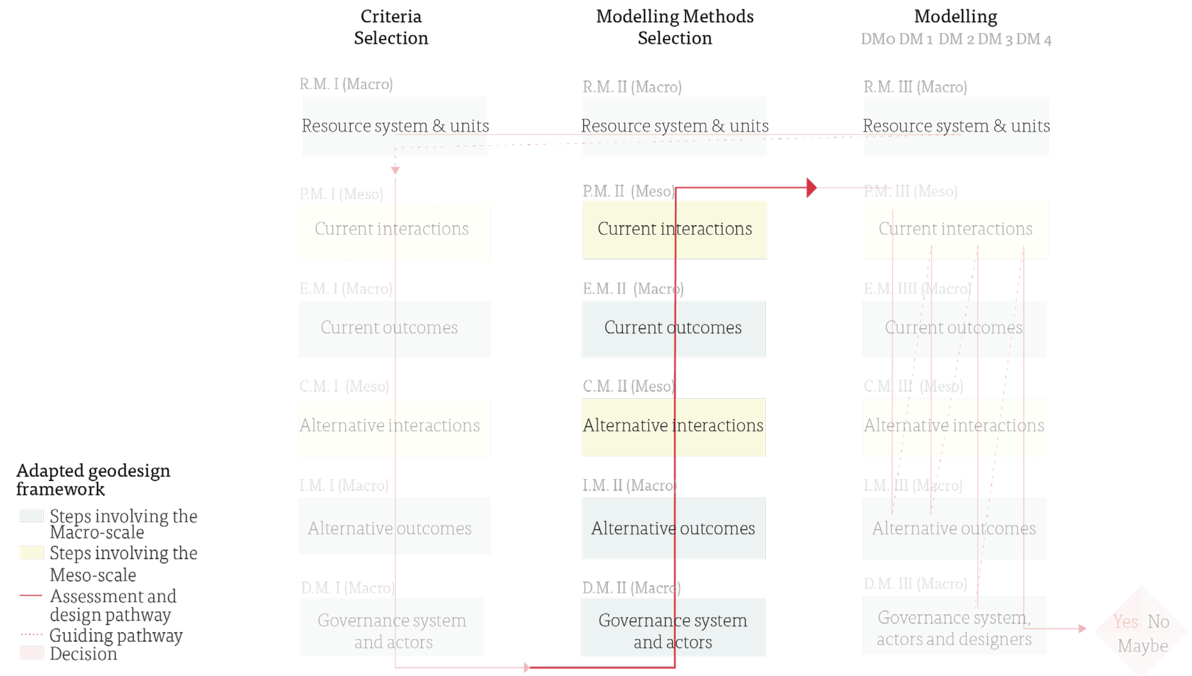
Steps per model	*Methods*	*Research output*	*Refer to*
Identification and operationalisation of the Interaction variables in the Meso-scale			Chapter 7
Identification of the methods to model the Interaction variables in the Meso-scale	Literature review of geodesign and of agent-based modelling		Chapter 7
Identification of the methods to model the Outcome variables in the Macro-scale		Selection of an anticipatory agent based modelling method	Chapter 7
Identification of the methods to model the possible alternatie Interaction variables in the			Chapter 7
Identification of the methods to model the Governance System and Actors interests in the Macro -scale	Literature review of actor-relational approaches		Chapter 7

Step 4

The following step was to develop the first modelling of the third iteration. In this step, the researcher, developed a catalogue with all the possible interactions that could take place in the Meso-scale. evaluated what would be the outcomes in the Macro-scale and developed a spatial decision support tool to be able to develop the anticpatory agent-based modelling with the stakeholders.

Steps per model	*Methods*	*Research ouput*	*Elaborated on*
Modelling of all the current interactions: including their location, time of deployment, and foreseen stakeholders agencies	Overlay and extraction of GIS data; literature review; interviews		Chapter 7
Modelling of the outcomes of such interactions	Defining and modelling performance indicators; programming of cellular automata model as a spatial decision suppor tool	Catalogue of possible interactions with their respective performance indicators; spatial decision support tool	Chapter 7
Modelling of all the possible interactions: including their location, time of deployment, and foreseen stakeholders agencies	Overlay and extraction of GIS data; literature review; interviews		Chapter 7
Modelling of the outcomes of all the possible alternative interactions	Defining and modelling performance indicators; programming of cellular automata model as a spatial decision suppor tool		Chapter 7

Step 3



Step 4

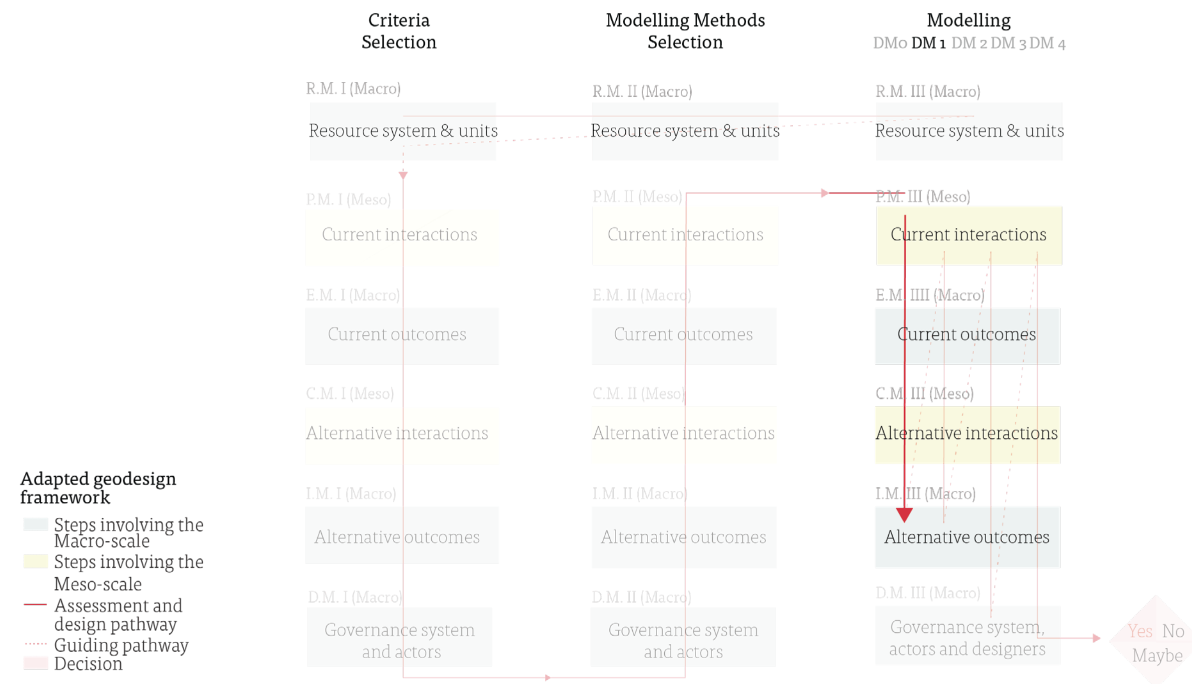


Figure 4.5 Steps 3and 4 in the adapted geodesign framework

Step 5

Further the first part of the anticipatory-agent based modelling method was developed. The researcher selected and assessed with the spatial decision support tool the current and future interactions that she considered appropriate for the Process model and the Change Models.

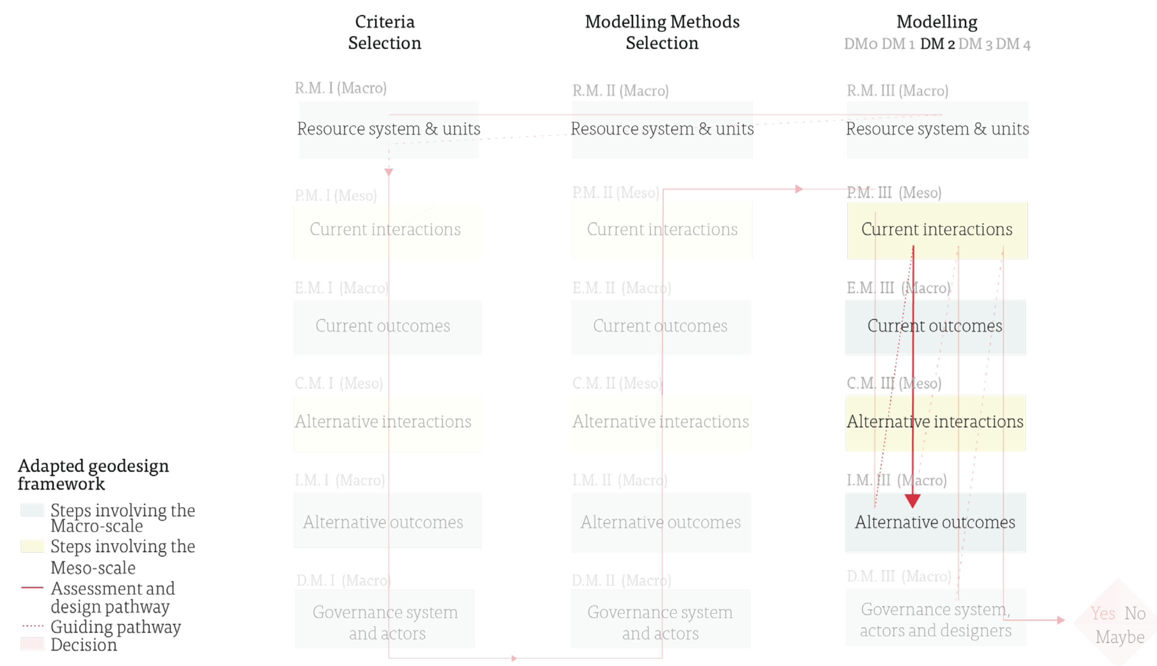
Steps per model	*Methods*	*Research output*	*Refer to*
Selection of the Interaction variables in the Meso-scale		Scenario 1a	Chapter 8
Assessment of the Outcomes in the in the Macro-scale	Cellular Automata modelling as a spatial decision suppor tool	Scenario 1a performance	Chapter 8
Selection of the Interaction variables in the Meso-scale variables in the Meso-scale		Scenario 1b	Chapter 8
Assessment of the Outcomes in the in the Macro-scale	Cellular Automata modelling as a spatial decision suppor tool	Scenario 2a performance	Chapter 8

Step 6

Furthermore, the stakeholders developed the second part of the anticipatory-agent based modelling method. First, they selected and assessed with the spatial decision support tool the interactions that according to their current capacities, functions, and interests they would develop. Next, the stakeholders selected collectively (and assessed with the tool) the interventions that they agreed could lead to a regenerative development. The stakeholders developed this step, guided by the researcher, in a workshop held in Mexico City.

Steps per model	*Methods*	*Research ouput*	*Elaborated on*
Selection of the Interaction variables in the Meso-scale according to the current capacities, functions and interests of the stakeholders	Workshop: roundtables	Scenario 2a	Chapter 9
Assessment of the Outcomes in the s in the Macro-scale	Cellular Automata modelling	Scenario 2a performance	Chapter 9
Selection of the Interaction variables in the Meso-scale in a collective manner and aiming for a regenerative development	Workshop: roundtables	Scenario 1b	Chapter 9
Assessment of the Outcomes in the in the Macro-scale	Cellular Automata modelling	Scenario 2b performance	Chapter 9

Step 5



Step 6

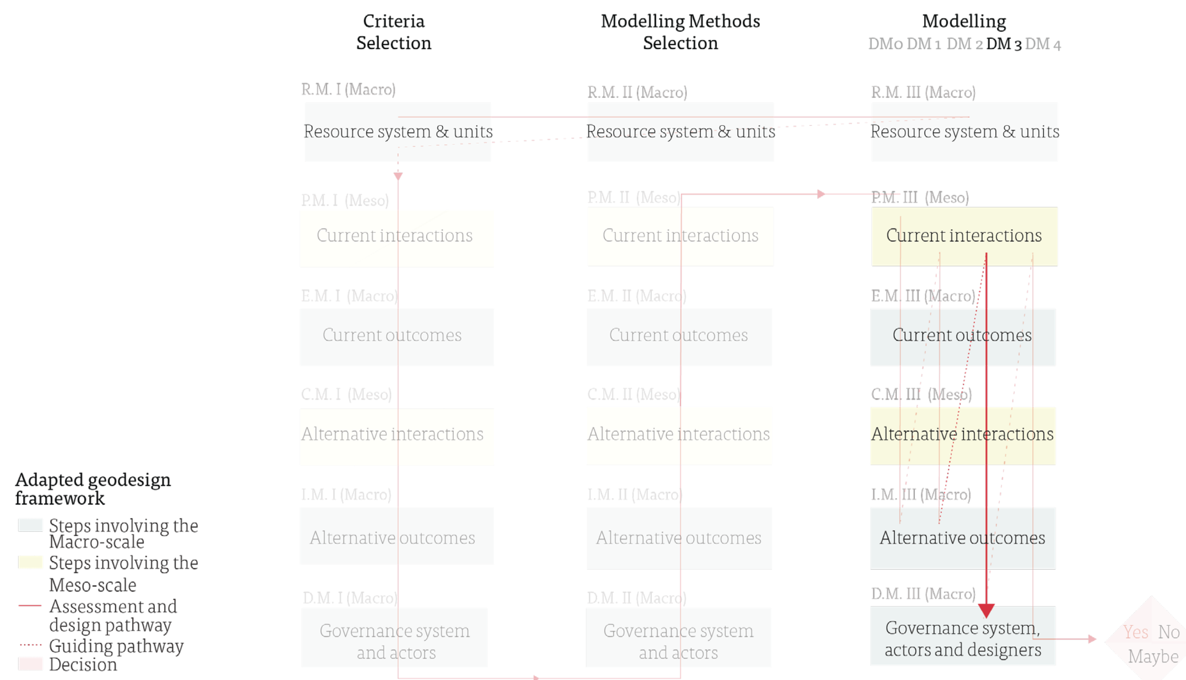


Figure 4.6 Steps 5 and 6 in the adapted geodesign framework

Step 7

Finally, the researcher integrated the results from the Change models developed both, by the stakeholders and by the researcher by and incorporating the knowledge gained into one last Change Model.

Steps per iteration	*Methods*	*Research output*	*Refer to*
Selection of the Interaction variables in the Meso-scale according to the knowledge gained from the previous iterations		Scenario 3	Chapter 10
Assessment of the Outcomes in the in the Macro-scale	Cellular Automata modelling	Scenario 3 performance	Chapter 10

Step 7

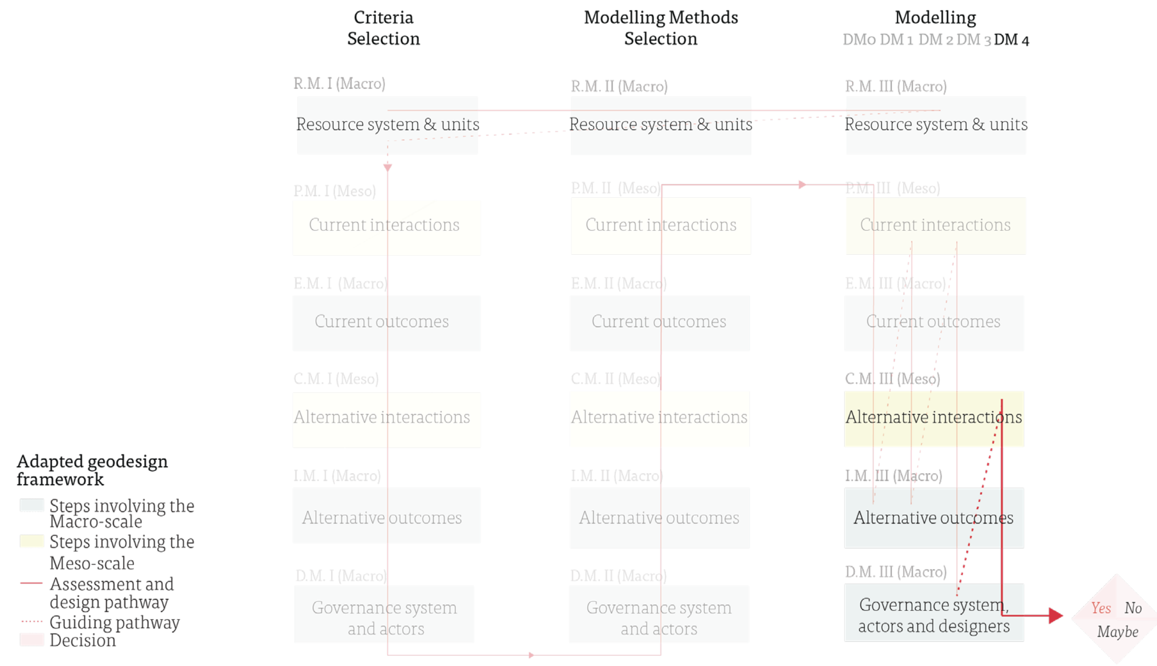


Figure 4.7 Step 7 in the adapted geodesign framework

4.4 Methods description

4.4.1 Literature review

- Documents and policies: documents and data gathered mainly from government sources that describe the current statuts of the MAVM as well as any future plans for the region
- Theories: information regarding the Regenerative Development and Design theory, complex adaptive systems, social-ecological systems, and actor-relational approaches
- Methods: information regarding a framework for geodesign, a framework to analyse social-ecological systems, agent-based modelling and decision-support tools

4.4.2 Mapping

Geographic Information Systems allow to process great quantities of data and to develop different types of anlyses with it. The software ArcGIS Pro was mainly used to develop this method. This software possess several toolboxes that allow to develop general anlyses, spatial analyses and network analyses which are described below.

- Analysis and mapping of demograhical and geographical data: It consits of the mapping of the hisotirc evolution that led to the current state of the MAVM as well as its consequences in regards to social aspects like indexes of marginalisation, and to ecological aspects related to water scarcity as flooding, subsidence and drought vulnerabilities.
- Spatial analysis- This tool allows to asses how close is a feature from others. This was used to assess the acccesibility to emplyment centers in the periphery
- Network analysis- Similar to the proximity analysis, this tool is used to assess the accesibility of certain areas to the public transport network as well as the street network.
-

4.4.3 Interviews

Interviews were developed via Skype or over the phone , in order to assess certain topic, positions or ainterests, mainly of the stakholders involved in the research.

4.4.4 Programming of cellular atuomata model as a spatial-decision-support tool

An agent-based model constitutes a number of agents which interact with each other and with their environment, over time space and time, and even more, that can change their decisions as in how they interact as a response to the immediate simulation of the outcomes (Mathews et al., 2007, Clarke, 2014).

In order to develop said mixed-anticipatory-agent-based modelling method, all the possible interactions and their outcomes had to be embedded in a programmable modelling environment previously to the development of the method. The software NetLogo, developed at the Center for Connected Learning and Computer Based Modelling (NetLogo, 2019) provided such platform. The software uses a type of agent-based model called cellular automata. The main difference between most of the agent-based models and cellular automata, is that in the latter, the agents are bound to stay in place and interact only with their neighbours (Clarke, 2014). Furthermore, the software was programmed in a way so that it could be used as a comprehensible spatial-decision-support tool in the next sub-iterations. For more information, refer to chapter 7

4.4.5 Defining and modelling performance indicators

In order to assess the outcomes of the interactions over the system, four pefromance indicators were defined and modelled in the research. This is not explained here as it would overstep on the many of the results of the framework, and it would be very unclear for the reader to follow through. Therefore, for detailed information refer to Chapter 8 and Chapter 9,, where their definition is presented along with their modelling.

4.4.6 Workshop

The development of the third sub-iteration of the Modelling Iteration was held in a workshop in Mexico City, organised by the researcher. The workshop was divided in three main events which are explained in further detail in Chapter 9. Same as above, this is not explained here as it would overstep on the many of the results of the framework, and it would be very unclear for the reader to follow through.

4.5 The methdology within the research framework

It is worth mentioning that the development of the adapted geodesign framework was done with previous knowledge and clarity of what was the problem field, of what the context was, and of which were the research questions, research aims and main methodologies, theories and concepts that would be used in the study. Therefore, even though the methodology actually provides a roadmap to replicate the thesis, the framework itself could not have been developed without previously gathered all the data understand what was the aim of the study. Figure 4.8 illustrate a summary of the steps that had to be taken previously in the research to formulate the methodology, as well as the steps that followed the development of the adapted geodesign framework.

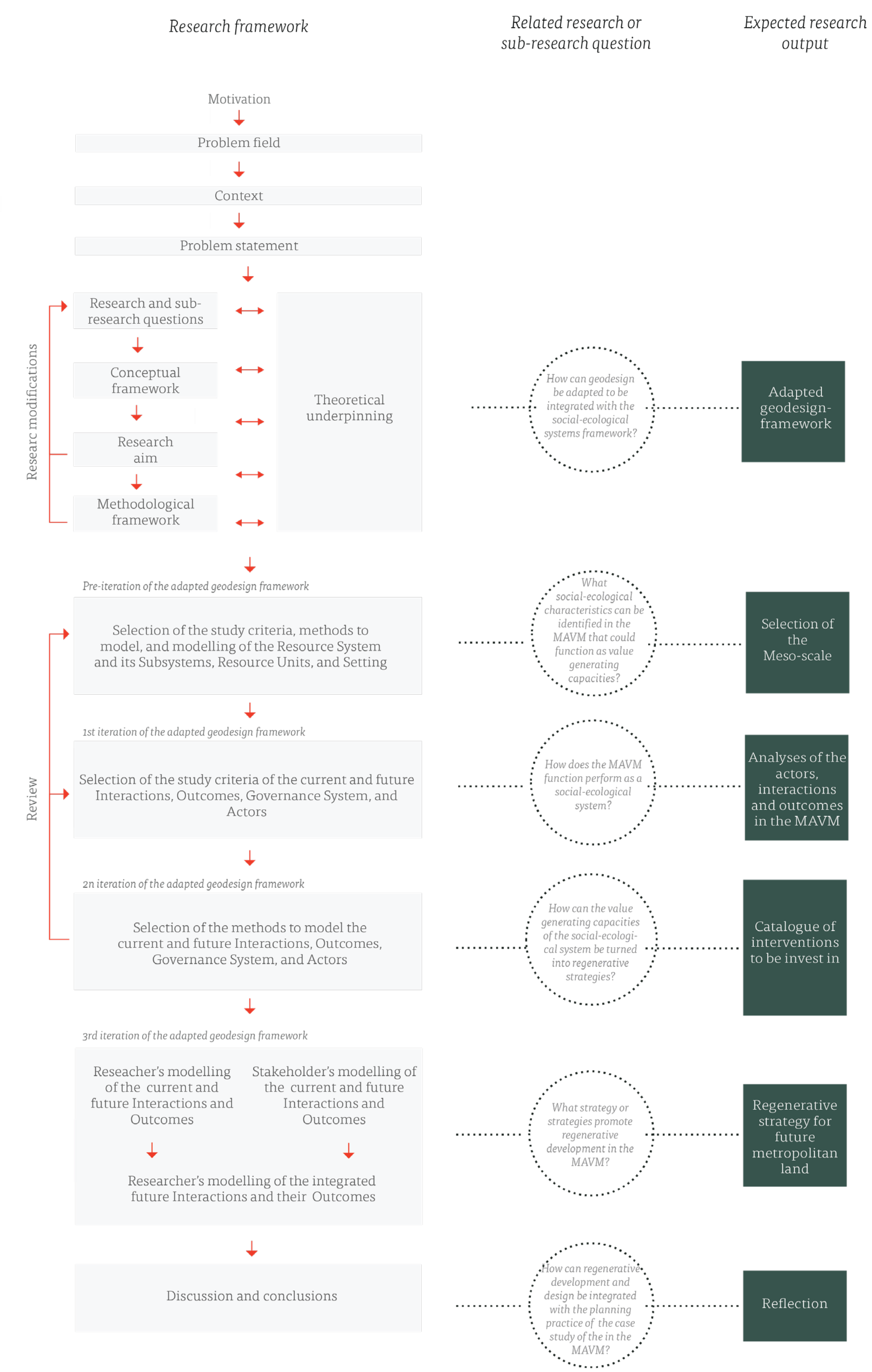


Figure 4.8 Overview of the research framework along with its reearch questions, reseach sub-questions, and research output

5. Selection of the criteria, selection of the modelling methods, and modelling of the Macro-scale *Iteration 0*

The Representation Model used the Setting, the Resource System, and Resource Units variables to understand the spatial context of the study. The criteria selection of the Representation Model can be understood as a justification of which areas were selected be studied; the selection of the method can be understood as how they were modelled; and the modelling can be understood as what, where, and when was modelled.

As mentioned before, in the Methodology Chapter, the Resource System was divided according to two types of scales: systems/subsystems and assessment/design areas. The assessment area contains the resource system and its subsystems, and the design area is part of the resource system and its subsystems. As also mentioned before, the Representation Model studied the assessment area/Macro-scale, its resource systems and its subsystems to understand the spatial context of the study and furthermore, to select the design area that was used to design within the next steps of the framework.

This chapter then presents:

- -the identification, operationalisation, and modelling of the Resource Systems and their selected descriptive second-tier variables
- the-identification, operationalisation, and modelling of the Resource Units and their seleted descriptive second-tier variables/ selection of the Meso-scale
- the-identification and operationalisation of the Setting and its selected descriptive second-tier variables

The Representation Model used the Setting, the Resource System, and Resource Units variables to understand the spatial context of the study. Table 5.1 shows a summary of the identification and the operationalisation of the variables. Further in the chapter, these are explained in detail and presented in a catalogue of maps.

5.1 Identification, operationalisation, and modelling of the Resource Systems and Subsytems in the Macro-scale
Representation model I, I, III (Macro-scale)

The studied Macro-scale was the Metropolitan Area of the Valley of Mexico (MAVM). As mentioned before, the Macro-scale is considered to be the e in the research. It contains the Resource Systems to be studied and its subsystems. The MAVM is most commonly known as the conurbation around Mexico City and Mexico City itself. It is located in the central region of Mexico and lays in a natural basin mostly surrounded by strips of highlands, except small opening it has on its Northern side.

Since the 1940s there have been different proposals to establish the official limits of the MAVM as it has experienced constant growth. On December 22[nd] of 2005, the Federal Government, the government of Mexico City, and the government of the State of Mexico finally agreed upon the normative boundaries and size of the MAVM. The official boundary and size of the MAVM was then defined by the political divisions that enclose the 16 mayoralties of Mexico City, 67 municipalities on the neighbouring State of Mexico and 1 municipality on the neighbouring State of Hidalgo (Mexican Routes, 2019).

The Resource Systems studied in the research were the social and the ecological systems that integrate the Metropolitan Area of the Valley of Mexico (MAVM). The previous are explained further in detail below.

First-tier variables	*Operalisation*	*Second-tier variables*	*Operalisation*
Resource System (RS1)	Social system	RS2- Clarity of the system boundaries	MAVM
		RS3- Size of the resource system	MAVM
		RS5 – Productivity of the system	Social performance
		RS9 – Location	MAVM
Resource System (RS2)	Ecological system	RS2- Clarity of the system boundaries	MAVM
		RS3- Size of the resource system	MAVM
		RS5 – Productivity of the system	Ecological performance
		RS9 – Location	MAVM
Resource subsystem 1 (SRS1)	Social subsytem	Clarity of the system boundaries	AGEBS
		Size of the resource subsystem	AGEBS
		Productivity of the system	Accesiblity to infrastructure and to services
Resource subsystem 2 (SRS2)	Ecological (hidrological) subsytem	Clarity of the system boundaries	Aquifer
		Size of the resource system	Aquifer
		Productivity of the system	Water infiltration and extraction
Resource Units 1 (RU1)	Non-value and value-generating capacities in the social subsystem	RU3 – Interaction among resource units	Self organisation properties [2]
		RU5 – Size of units	One NetLogo cell: 230 x 20 m
		RU6- Distinctive characteristics	Slope, landprice, existing social and informal housing, public transport/walking accesibility to employment centers , existing water treatment plants, rainfall
Resource Units 2 (RU3)	Non-value and value-generating capacities in the ecological subsystem	RU3 – Interaction among resource units	Self organisation properties [3]
		RU5 – Size of units	One NetLogo cell: 230 x 20 m
		RU6- Distinctive characteristics	Rainfall, runoff , soil permeability, slope , existing water treatment plants, existing social and infor-mal housing
Setting (S)	MAVM	S2-Demographic trends	Population growth
		S7-Technology	Transportation network

Table 5.1 Operationalisation of the Setting, Resource System and Resource Units variables

2 Defined in the next Chapter, as part of the interactions in the Resource System mes

3 Same as above

Figure 5.1 Normative boundaries of the MAVM (Elaborated with data from INEGI, 2016)

5.1.1 Social Resource Systems and Subsystems

Social Resource System

The size, location, and boundaries of the social system are defined by the size, location, and boundaries of the MAVM. Whereas the productivity of the system can be widely interpreted, in this research, the productivity is considered to be the social performance that the system can achieve. The researcher defined such performance as a function of the accessibility to services and the accessibility to infrastructure that the population in the MAVM has.Resource system

Social Subsytem System

Basic Geostatistical Areas (AGEBS) define the size and the boundaries of the social subsystems in the MAVM. Their size is usually bigger than an urban/rural block and smaller than a municipality or mayoralty. They are the smallest level of geography at which Mexico Census tabulates demographic data (Geoanalitica, 2016). Therefore, they are perfect aggregates to study the social performance of the MAVM.

5.1.2 Ecological Resource System and its Subsystems

Ecological Resource System

The size, location, and boundaries of the ecological system are also defined by the size, location, and boundaries of the MAVM. The productivity is considered to be the ecological performance that the system can achieve. The researcher defined such performance as the balance of the water that is being infiltrated and extracted from the system.

Ecological Subsystem

The size and the boundaries of the aquifers in the MAVM define its ecological subsystems. They are the smallest level of geography at which data about the infiltration and extraction rates in the system can be retrieved. Therefore, they were used to study the ecological performance of the MAVM

Social subsystem
AGEBs boundaries
AGEBs in the MAVM

Figure 5.2 AGEBS within the MAVM (Elaborated with data from INEGI, 2016)

Ecological subsystem
Aquifers boundaries
Aquifers in the MAVM

Figure 5.3 Aquifers in the MAVM (Elaborated with data from INEGI, 2016)

5.2 Identification, operationalisation, and modelling of the Resource Units/ Selection of the Meso-scale

This section presents the identification, operationalisation, and modelling (Figure 5.4 to Figure 5.11) of the Resource Unit variables and their respective descriptive second-tier variables. As mentioned in the Methodological framework, the Resource Units are considered to be rather analysis/design elements than analysis/designs components or, even more, than analysis/design areas. Therefore, they were operationalised as the non-value and value generating capacities in each of the Resource Systems and Subsystems.

The Resource Units in the social system have the size of a NetLogo cell[4] (230 meters by 240 meters). As mentioned in the Methodology Chapter, NetLogo was the software used to develop the spatial decision support tool that used agent-based modelling to assess the performance of the interactions in the Process and Change Models. The interactions amongst the Resource Units were defined as self-organisation properties, defined further in Chapter 6. The distinctive characteristics for the Resource Units in the social system are the slope, the land price, the existence of social and informal housing, the accessibility to employment centers by public transport or by foot, the existence of water treatment plants and the amount of rainfall in the MAVM.

Resource Units of the Social System

The distinctive characteristics for the Resource Units in the ecological system are the slope, the existence of social and informal housing, the accessibility to employment centers by public transport or by walking, the existence of water treatment plants and the amount of rainfall in the MAVM.

Resource Units of the Social System

The distinctive characteristics of the ecological system are the runoff, the soil permeability, the slope, the existence of water treatment plants, the existence of social and informal housing and the amount of rainfall in the MAVM.

As it was previously mentioned, the research is developed under the assumption that future social and informal housing developments in the MAVM will be located in the periphery, as they answer to greater economic/political forces which are beyond the scope of this study. Therefore, first off, to work with the assumption, the Meso-scale had to be necessarily located in the periphery, in areas where there is less slope and where the price of the land is low.

Once the area with low slopes and low land price was located, the areas with better soil permeability, with the most water treatment plants, the most rainfall, and the most runoff were overlaid with them. The result of the overalying is highlighted the Eastern area, highlighted in Figure 5.4 to Figure 5.11 This area was used as the Meso-scale, used to design with further in the process.[5]

4 The methods to develop the Process and the Change Models are actually selected in the second iteration of the geodesign framework. However, when the methodology to develop the thesis was constructed, the agent-based modelling method was selected to be used predeterminedly as it had the potential to increase the transdisciplinarity in the geodesign framework.

5 The selection of the Meso-scale did not take place until after modelling the distinctive characteristics of Resource Units, however the report shows its location in the following maps so that the reader can notice said capacities more easily in the selected area.

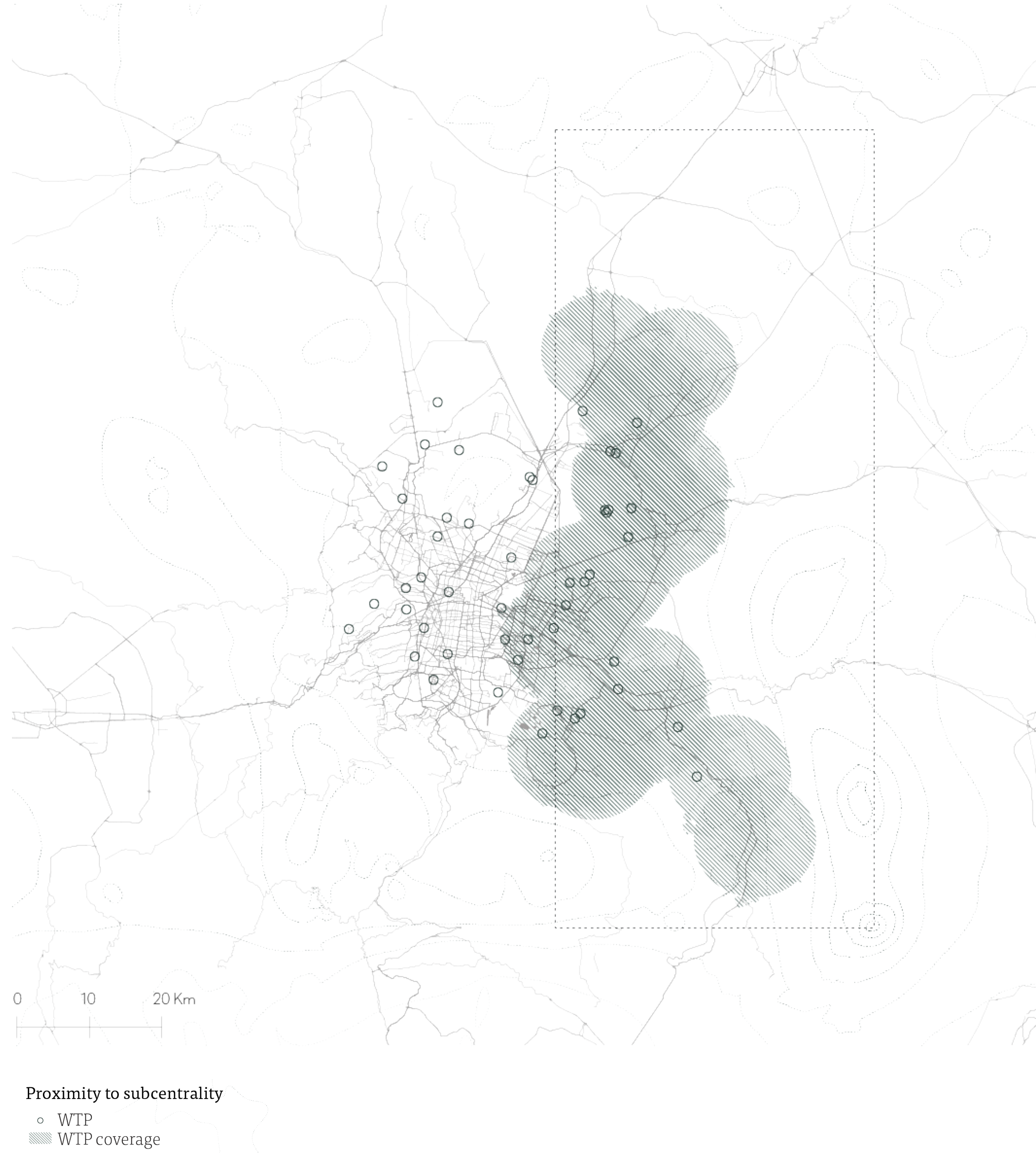


Figure 5.4 This map shows where the existing water treatmet plants are located in the MAVM and shows a catchment area of 8-10 km of the water treatment plants in the in the Meso-scale6 (Elaborated with data from CONAGUA, 2017)

6 Due to a represeNtation issue, the map does not show the catchment area for all of the water tratment plants in the Macro-scale as it actually should.

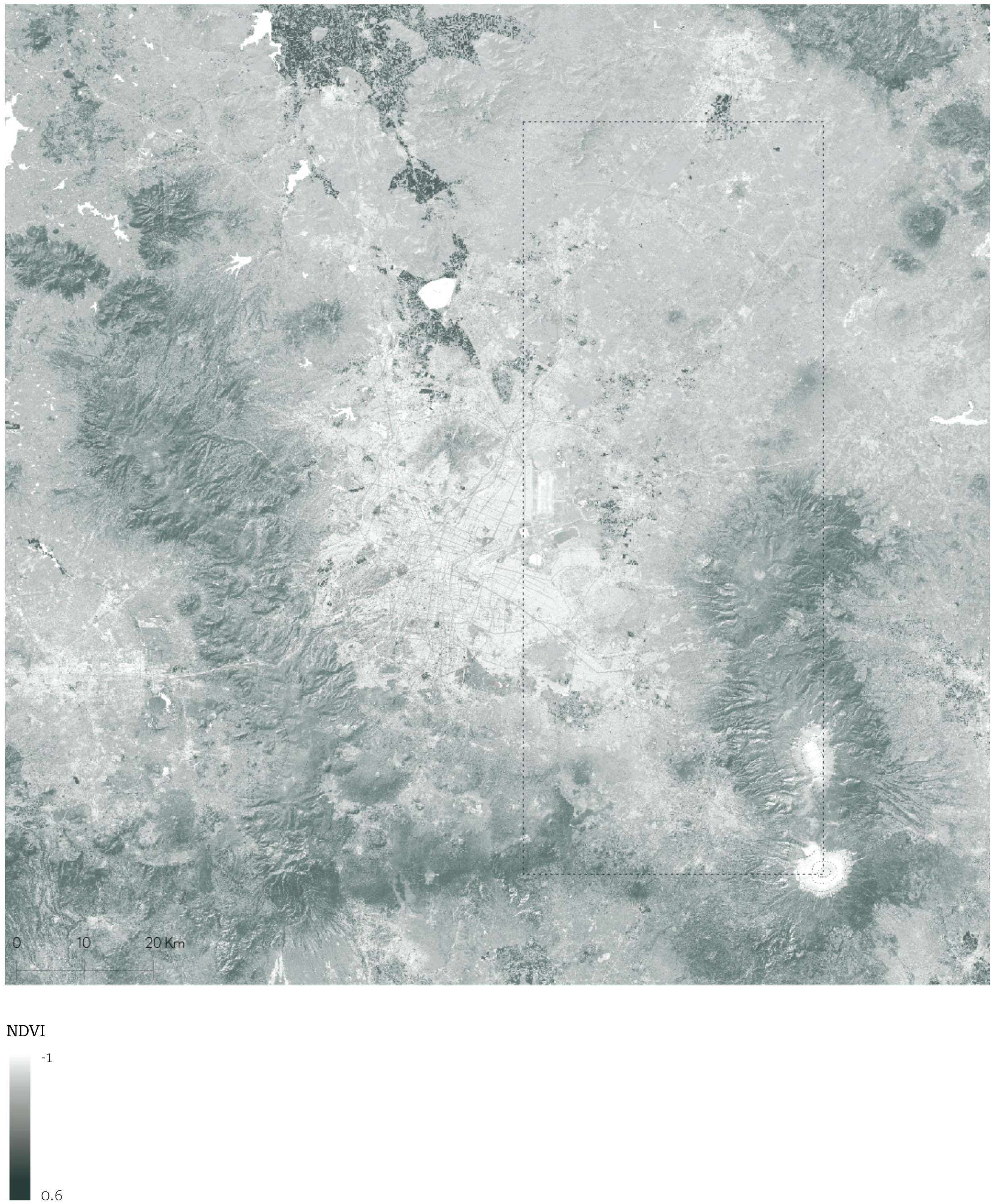


Figure 5.5 The NVDI is a graphical indicator of the amount and type of vegetation in an area. Values in between -1 and 0 usually correspond to areas with rocks or covered with pavement. Values in between 0 and 0.6 usually indicate the presence of low vegetation and values closer to 1, usually indicate the presence of high and dense vegetation. With the help of surface analysis tools in ArcGIS PRO, this index was created in order to show which areas have more or less soil permability according to if they are paved or not. (Elaborated with data from USGS, 2019)

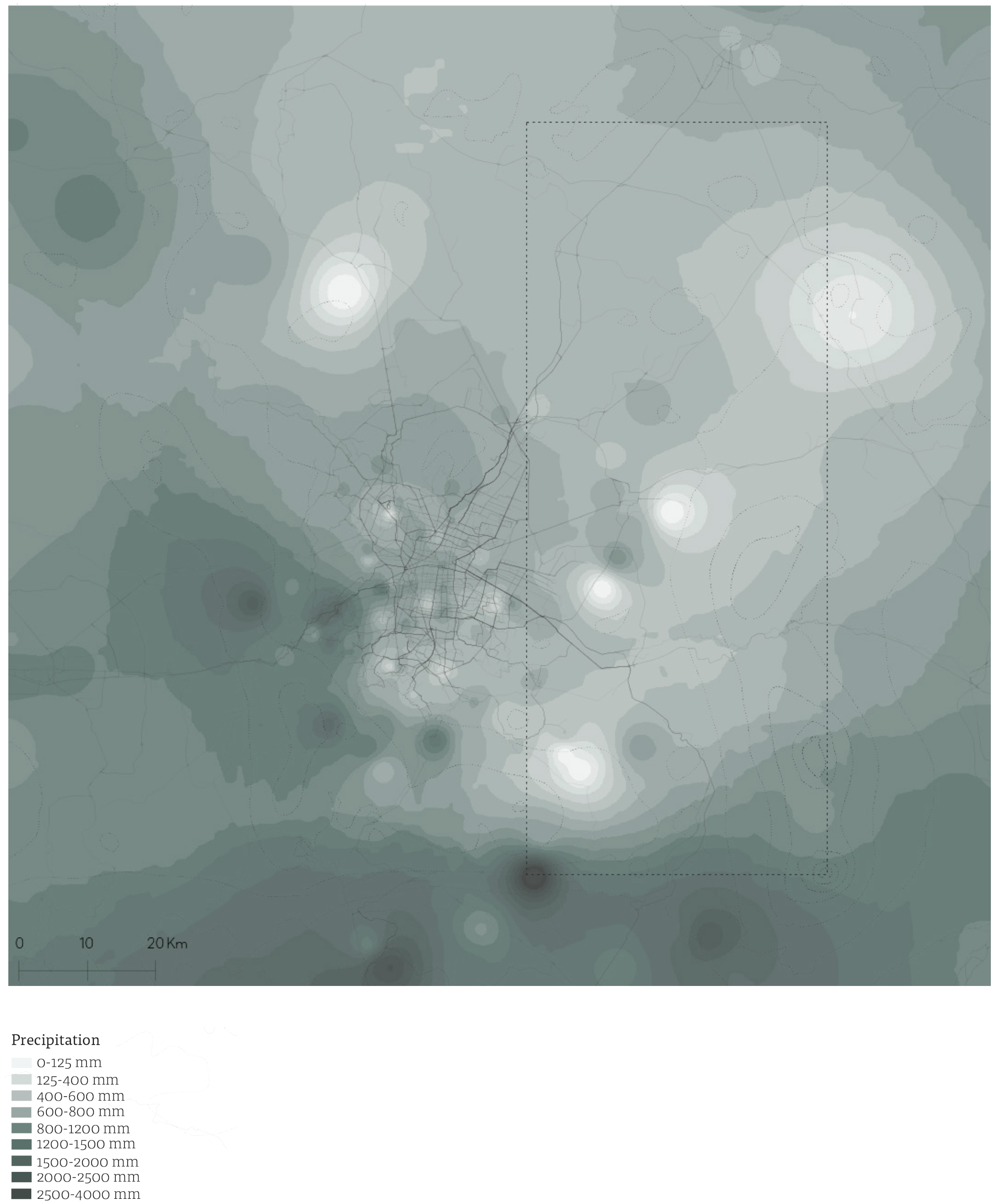
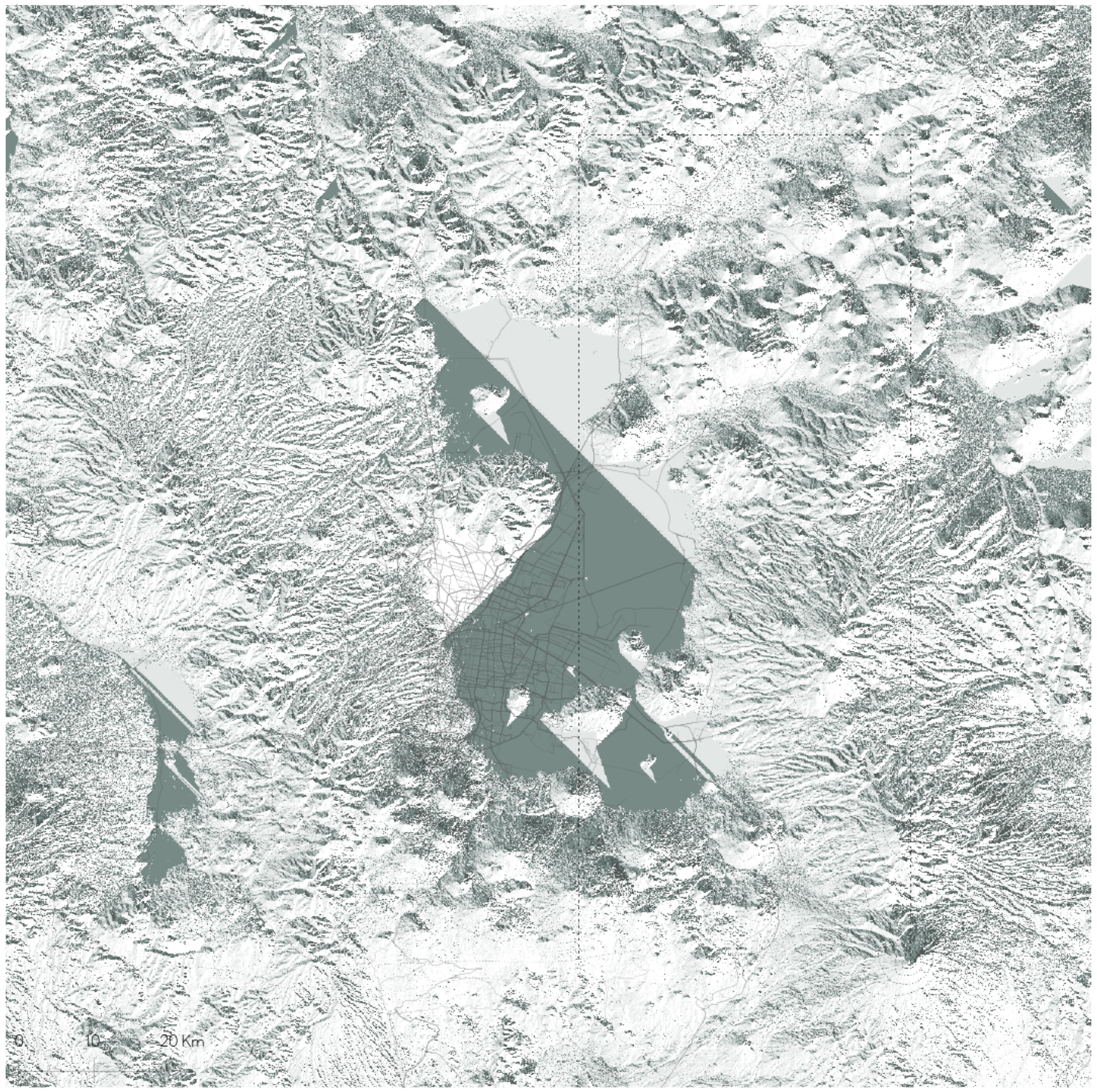


Figure 5.6 The map depicts the amount of precipitation that falls per year in the Macro-scale (Elaborated with data from INEGI, 2010)

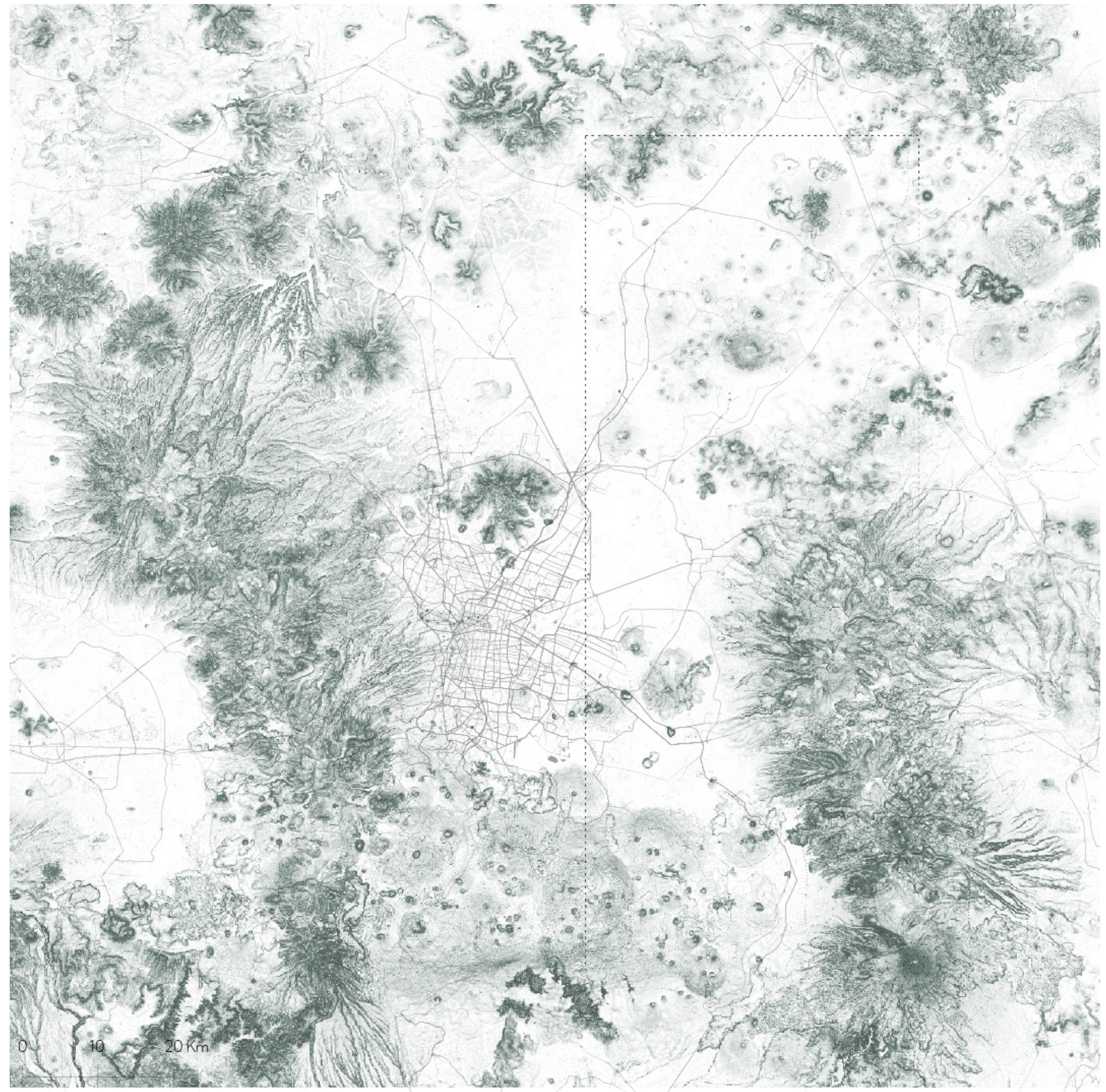


Runoff accumulation

1

128

Figure 5.7 The map shows the paths that runoff water is more likely to take according to the topography of the land. (Elaborated with the help of the hyrology toolbox in ArcGIS PRO and with an elevation dataset obtained from JAXA, 2010)

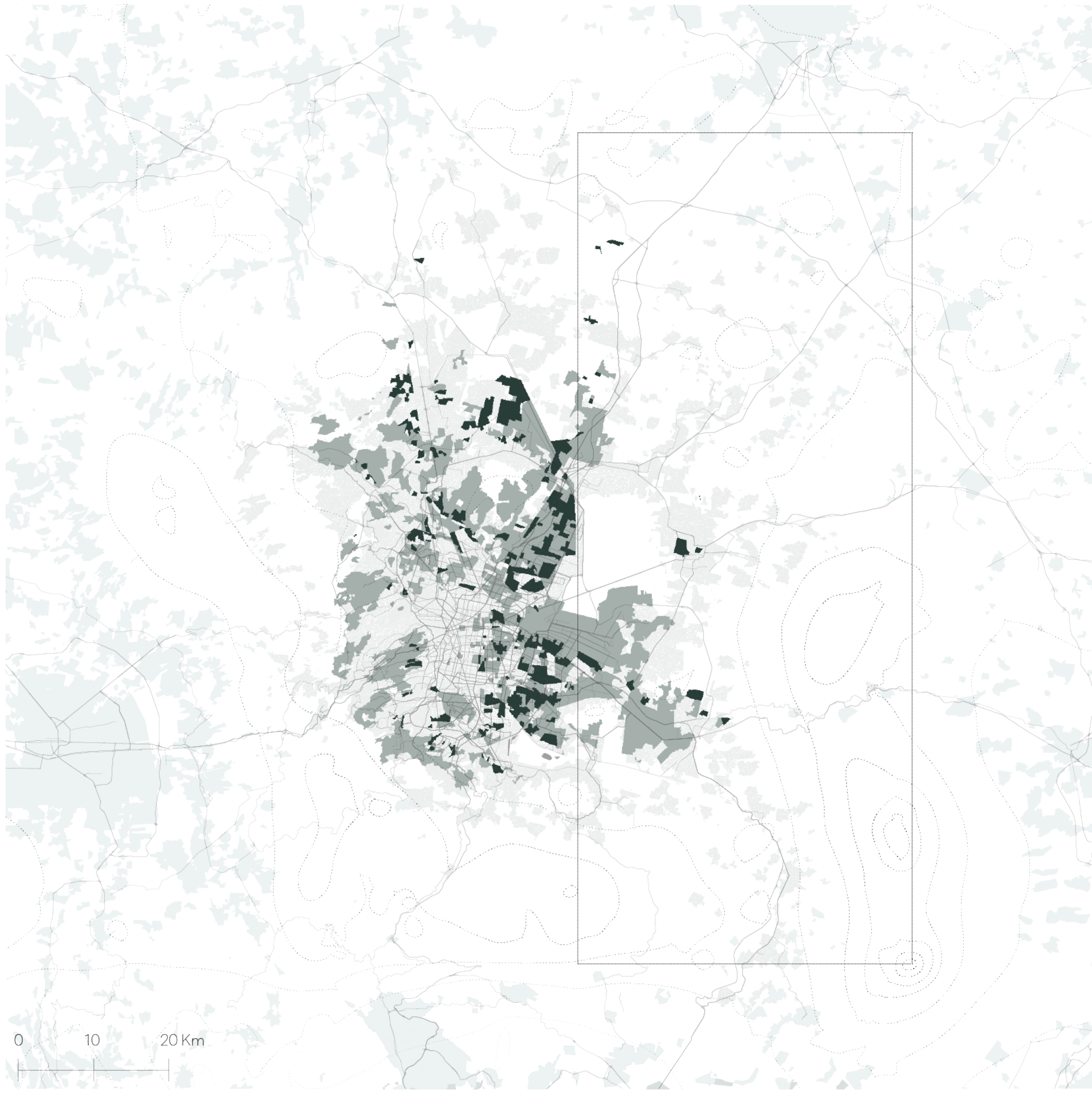


Slope

0°

78°

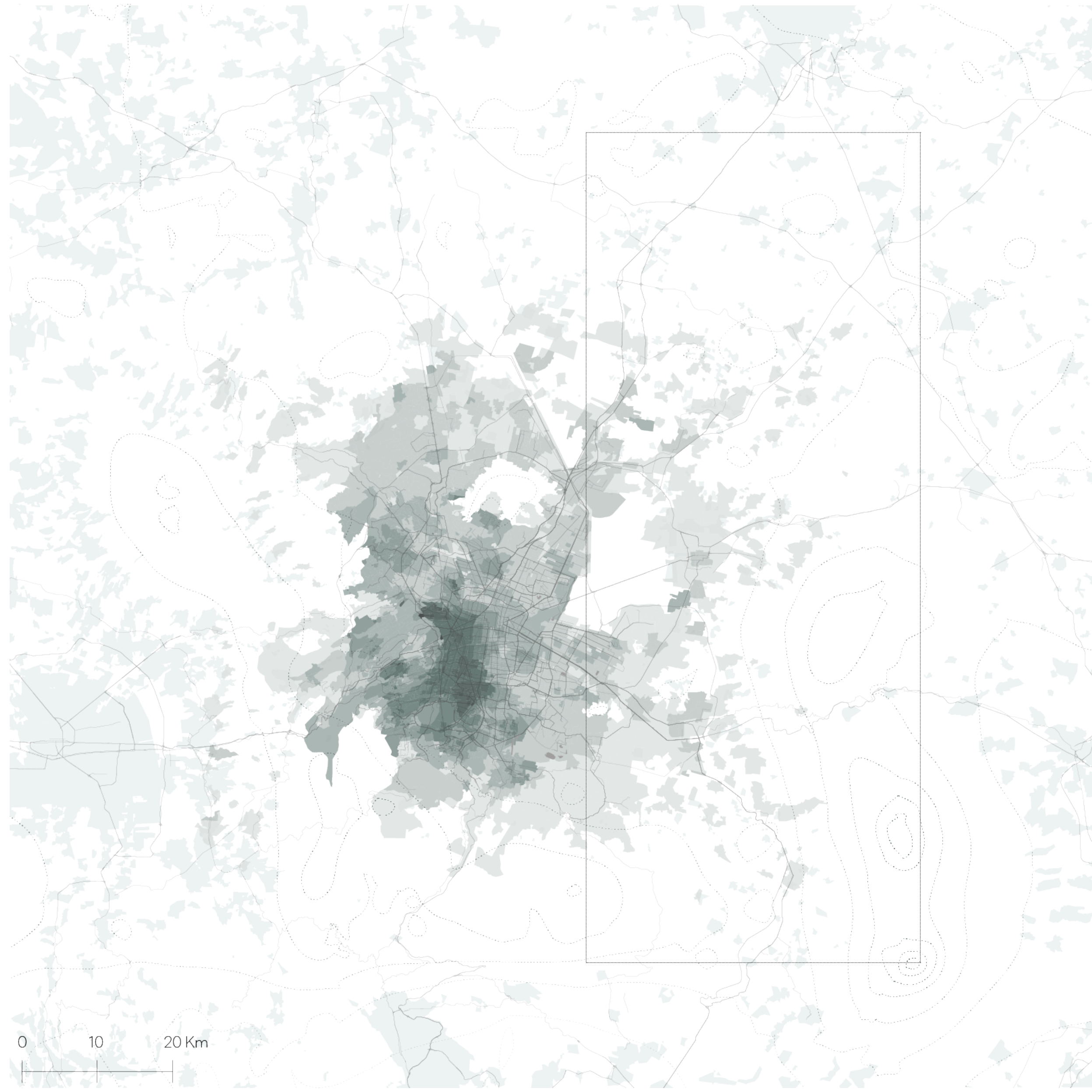
Figure 5.8 The map depicts the degree of the slopes in the Macroarea of the study. (Elaborated with the surface analysis toolbox in ArcGIS Pro and with an elevation dataset obtained from JAXA, 2010)



Social and informal housing

Informal housing
Social housing

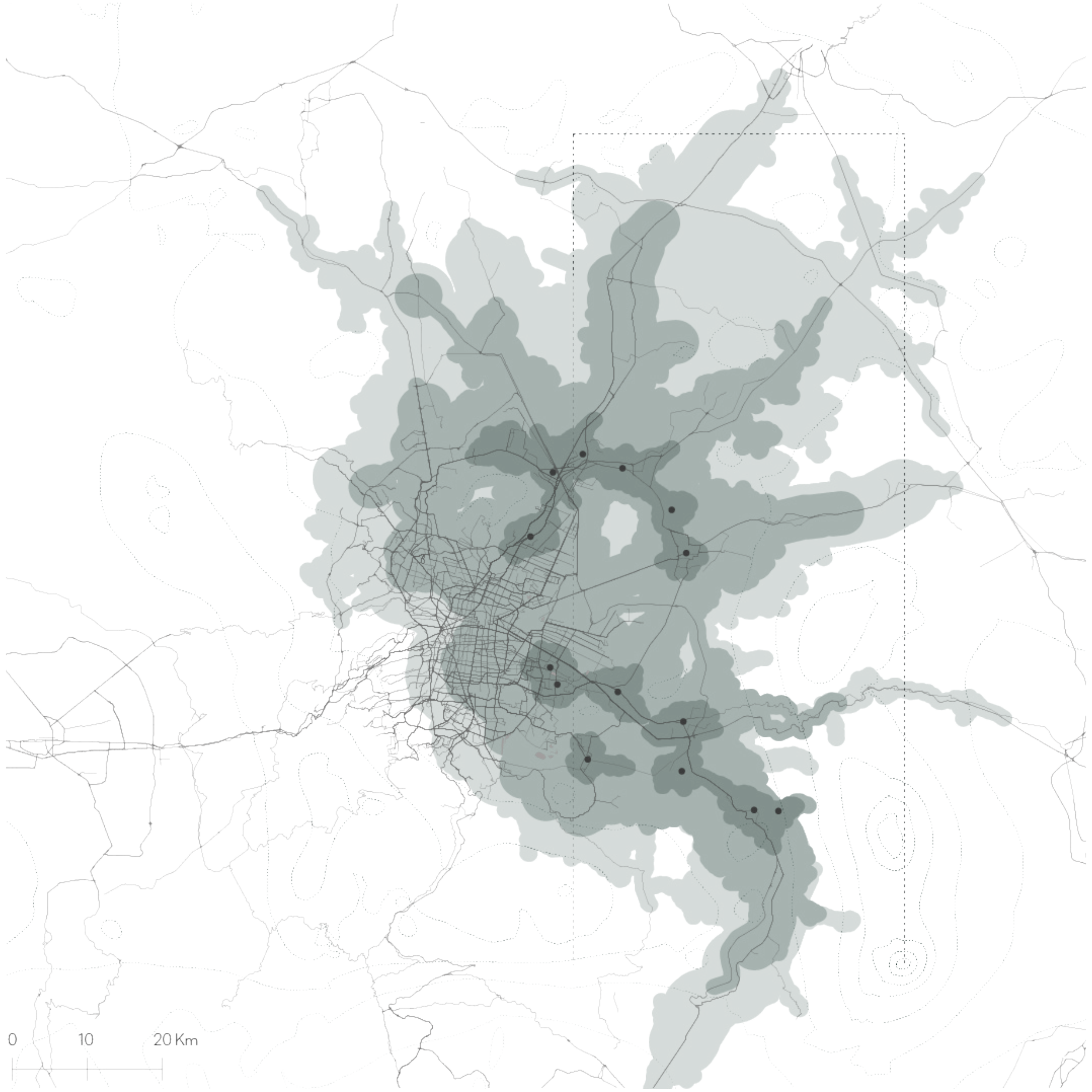
Figure 5.9 Location of the social housing developments and the social housing developments in the MAVM (Elaborated with data from INEGI, 2016 and Connolly, 2005)



Landprice

<6,320 MXN
6,320- 12,639 MXN
12,639- 18,959 MXN
18,959- 25,278 MXN
25,278- 31,598 MXN
31,598- 37,918 MXN
37,918- 44,237 MXN
44,237-50,557 MXN
50,557-56,876 MXN
56,876-63,196 MXN
No data

Figure 5.10 The map details the price per squared meter of land in the MAVM (Elaborated with data from Propertari , 2016)



Public transport and pedestrian accesibility

- <20 min
- < 40 min
- > 40 min

Figure 5.11 Employment centers are considered economic centralities where a collection of services and infrastructure is located. The more accesible a social housing development or an infommal housing development is to these emplyment centers, the more accesibility to services it is considered to have. This map shows the public transport/pedestrian accesibility in the Macro-scale to such centers. It was elaborated using a tailored-accesibility method which is explained in the next five pages. (Elaborated with data from Open Street Maps 2019, and ESRI 2019, and Suarez and Delgado, 2008.)

Public transport and pedestrian accesibility analysis

Usually, a proximity analysis uses network datasets to obtain the service areas that are reachable from a specified set of points within a specified amount of time by a specified means of transport. Therefore, in order to obtain the public transport and pedestrian accessibility to the employment centers highlighted in Figure 5.12 [7] it would have been necessary to have such network datset. Unfortunately, there is no such dataset for the MAVM, for which a tailored-accesibility analysis had to be developed.

It is important to know that the reason why such dataset does not exist is probably that there are no official public transportation routes nor official stops in the street network of the MAVM. In Mexico City and in the State of Mexico, private companies operate the so-called rutas. These are small vans that circulate the main streets, collecting and dropping off passengers where they require a stop either to hop in or to hop off. The previous condition, offered the possibility to develop an accessibility analysis as if such rutas where private cars that were circulating the primary and secondary streets.

The aim of the analysis was to obtain accesibility rings within transportation times of 20 min, 40 min and over 60 min, either with the rutas or walking or using doing both. Therefore two sets of data had to be realised and further on combined. The first set of data obtained the services areas with driving times of 10 min, 20 min, 30 min, 40 min, and 50 min. Each of the service areas was then intersected with a buffer of 1 km of the primary and secondary streets. Such buffer was obtained as in order to get the network where the rutas would be circulating in, and it was set to 1 km considering that future housing developments may settle next to the roads, even if there are no streets laid out in those areas yet. The second set of analyses obtained the buffer areas of the employment centers with walking times of 10 min (1 km) , 20 min (3 km) and 30 min (4.5 km). The reason why the second data set was obtained like such, and not with the official ArcGIS tool, was to consider that future housing developments may be located in areas where there is no street infrastructure yet.

Then, following the logics of knowing that the less a person rides the more they can walk, and the more they ride, the less they can walk, the next combinations of datasets were realised (Figure 5.14):

- For transportation times of under 20 min: 10 min driving time + 10 min walking time (
- For transportation times of under 40 min: 30 min driving time + 10 min walking time, 20 min driving time + 20 min walking time, and 10 min drive + 30 min walking time
- For transportation of over 40 min: 50 min driving time + 10 min walk, 40 min driving time + a 10 min walk, 30 min driving + a 10 min walk, 10 min driving + a 30 min walk

7 Please not the research refers to the employment centers and not the greater employment area, as the study was eveloped under the assumption that future housing developments will be most likely located in the periphery.

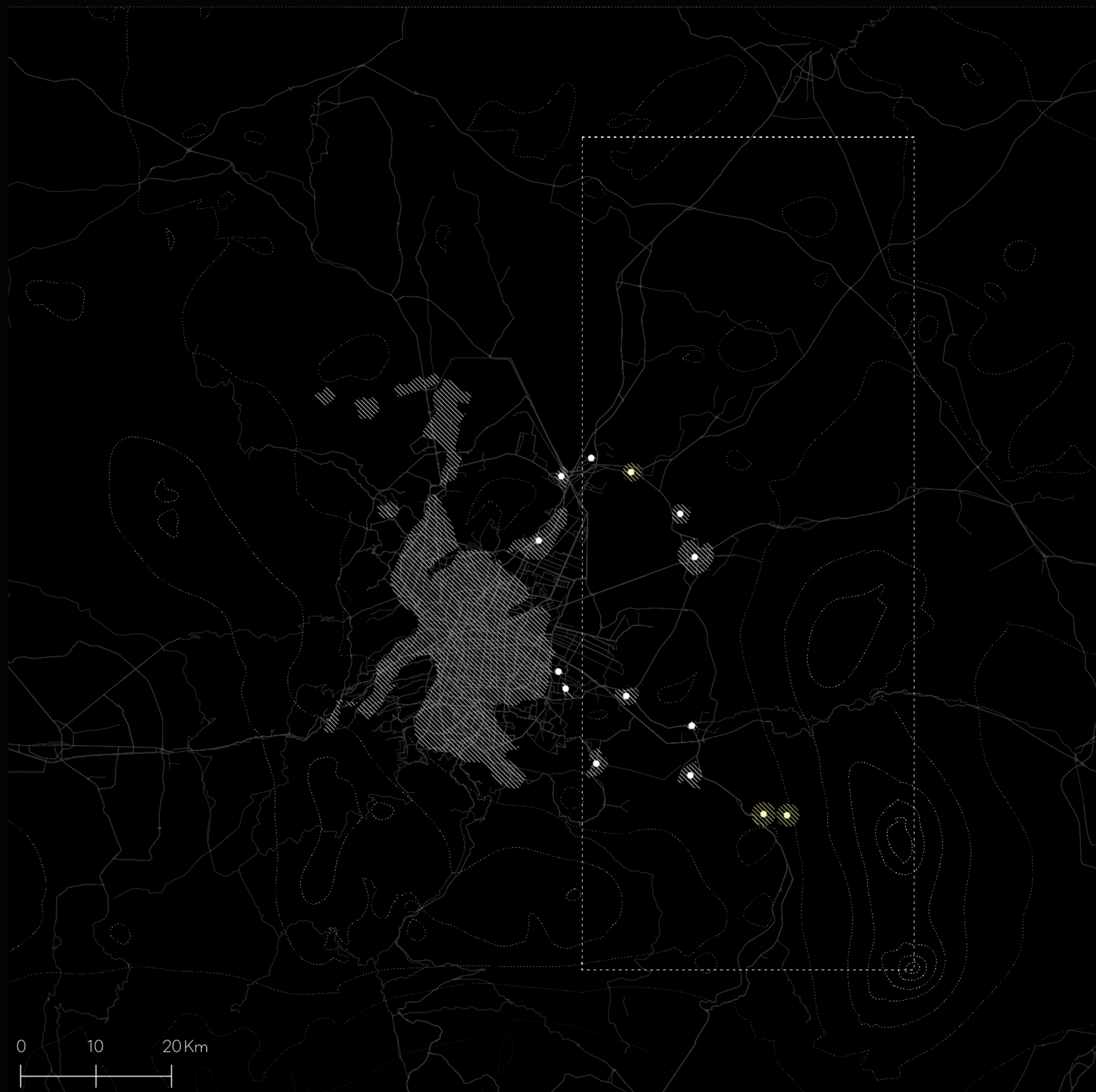


Figure 5.12 The map shows in a white hatch the location of the main employment area in the MAVM and of the secondary employment centers identified in the study of Suárez and Delgado (2008). The map also shows in a yellow hatch the location of future potential employment centers obtained from the space syntax analysis shown in Figure 5.13 (Elaborated with data from INEGI, 2010)

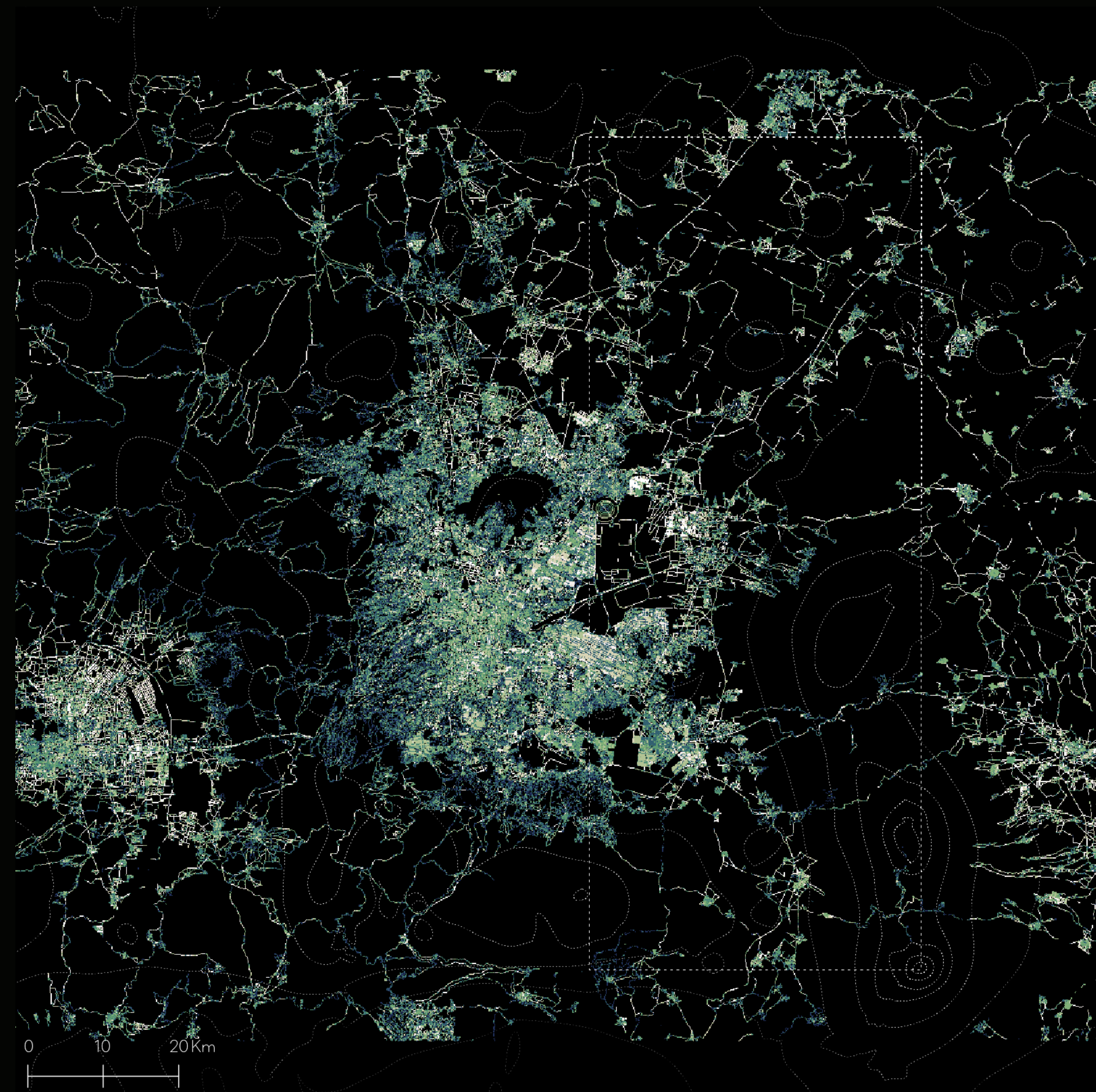
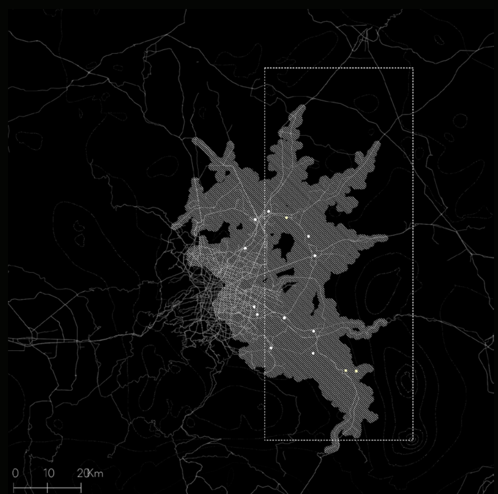
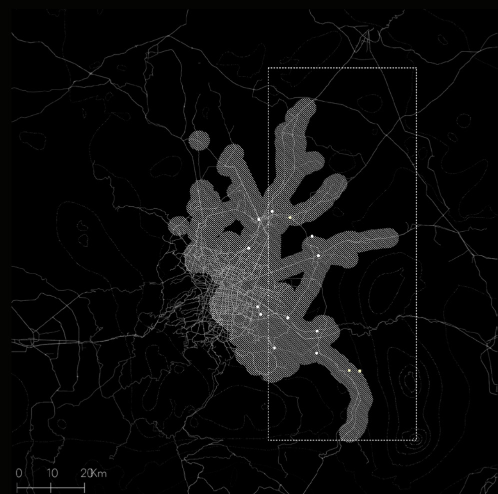


Figure 5.13 The subcentralities higlighted in yellow in Figure 5.11 are a result of the place syntax analysis shown on the image above. In order to develop such analysis, the Place Syntax Tool (PST), developed by the Chalmers University of Technology (Chalmers, 2019) was used. Within some of its features, street network analyses can be run to measure the accessibility and the integration of such network. Specifically, for this study an analysis was realised to show reachable each segment of the network is from each other segment within the boundary conditions. The results of the analysis helped to determine which areas have the potential to become more frequented and therefore more likely to eventually become employment centers. These areas appear with the brighter colors in the map. (Elaborated with data from Open Street Map, 2019.)

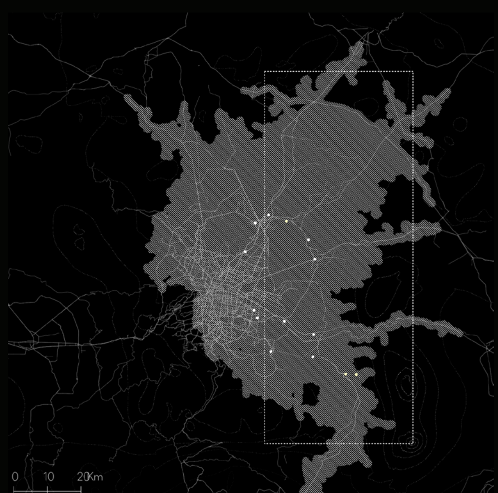
a) 10 min drive + 10 min walk



b) 30 min drive + 10 min walk



b2) 20 min drive + 20 min walk



c) 50 min drive + 10 min walk

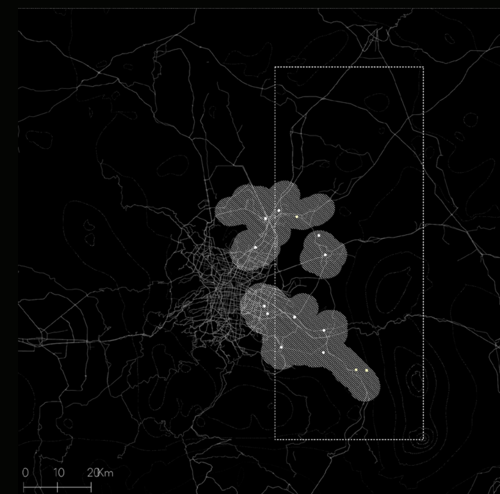
c2) 40 min drive + 10 min walk

Figure 5.14 Possible commuting times under 20 min (a), under 40 min (a + a2 + a3), and over 40 min (c + c2 + c3 + c4)

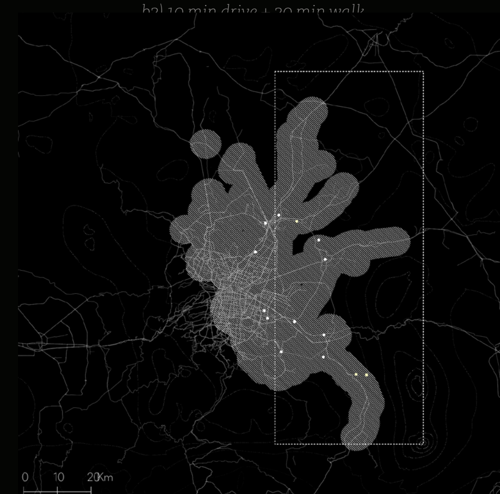
Public transport and pedestrian accesibility

Accesibility

Primary and secondary streets



b3) 10 min drive + 20 min walk



c3) 30 min drive + 30 min walk

c) 10 min drive + 30 min walk

6. Identification of the Interactions, Outcomes, Governance System, and Actors *Criteria selection I*

Once the Meso-scale was selected in the Iteration 0, the Iteration I of the framework realised the scoping of the current and possible future Interactions in the Meso-scale, and their respective present and future outcomes in the Macro-scale. Further, it also realised the scoping of the Governance system and the Actors involved in the Macro-scale.

This chapter then presents the:

- Identification and operationalisation of the present Interactions and Outcomes (Process and Evaluation Model I)
- Identification and operationalisation of the possible alternative Interactions and Outcomes (Change and Impact Models I)
- Identification and operationalisation of the Governance System and Actors (Decision Model I)

6.1 Identification of the current interactions and outcomes
Process Model I and Evaluation Model I

The Process Model I answered to the question of how the study area operates with the use of the Interactions variables. It defined and understood processes that were relevant to the study (Table 6.1). Furthermore it distinguished two types of interactions, the ones that the SESF names as investment activities, and the self-organising activities. The Evaluation Model I identified and operationalised the criteria that the research used to assess if the study area was working well (Table 6.1). Below, they are explained in detail.

6.1.1 Identification and operationaliation of the interactions
Proces Model I

Interactions in the social system

Figure 6.1 shows the different types of investments that take place, as of today, in the social system of the Meso-scale. The relations between the investments are considered to be either systemic or optional. The systemic relations, expressed in the diagram with the dark arrows, are considered to be some of the self-organising properties in the system.

The dark arrows in the diagram between the interactions indicate a systemic relation amongst the investments, while grey arrows indicate an optional relation between the investments. To explain the previous, for instance, the diagram shows that currently, there are optional investments for installing rainfall catchment systems in the social and housing developments. However, once the investments in the rainfall catchment technologies are realised, there will be necessarily an investment to either infiltrate the harvested rainfall into the ground or to treat it and use it as household supply water.

Further, the diagram also shows that there are investments to develop social housing with low accessibility to employment centers, and that same as with the social and informal housing, the future developments may or may not invest in rainwater catchment systems. The new developments also have a systematic need to invest in the disposal of their wastewater. The wastewater is either discharged or treated. Once treated, it is either use as infiltration water or supply water.

First-tier variables	*Operalisation*	*Second-tier variables*	*Operalisation*
Interactions (I1)	Current Interactions	I5 – Investment activities (D)	*Current investments in the social subsystems:* -renovation of informal and social housing -development of new housing in areas with low accesibility to emplyment centers -rainwater catchment -source separation -water treatment
			Current investments in the ecological subsystem: -rainwater catchment -runoff discharge to sewage -runoff natural infiltration -groundwater extraction
		I7 – Self-organizing activities (E)	*Emergent activities in the social subsystem* Every 10 years the most accesible areas become employment centers
			Emergent activities in the ecological subsystem Water is infilitrated to neighbouring aquifers when any one has reached its balance
Outcomes (O1)	Currrent Outcomes	O1-Social performance measures	Current social performance
		O2-Ecological performance measures	Current ecological performance
		O4- Others	Current governance performance

Table 6.1 Operationalisation of the current Interaction and Outcome variables

Interactions in the ecological system

Figure 6.1 shows the different types of investments that take place, as of today, in the ecological system of the Meso-scale. The. The diagram shows the investments over the precipitation and the groundwater. There are investments to retain the rainwater, and to discharge, to treat or to infilitrate the runoff. If the runoff is being discharged, it could either be discharged completely to an external basin or to be treated as wastewater.

6.1.2 Identification and operationaliation of the current Outcomes *Evaluation Model I*

As mentioned before in Chapter 4 and 5, the Evaluation Model I studied the social, the ecological, and the social-ecological. The social performance is a function of the accessibility to services and infrastructure, while the ecological performance is considered to be a function of the balance of the infiltration and extraction rates from the aquifer.

Figure 6.1 show how certain interactions, like harvesting rainwater or treating water affect both, the social and the ecological performance. The diagrams also show that developing housing developments in specific areas affect the social performance and that infiltrating the runoff or modifying the extracting water affect the ecological performance.

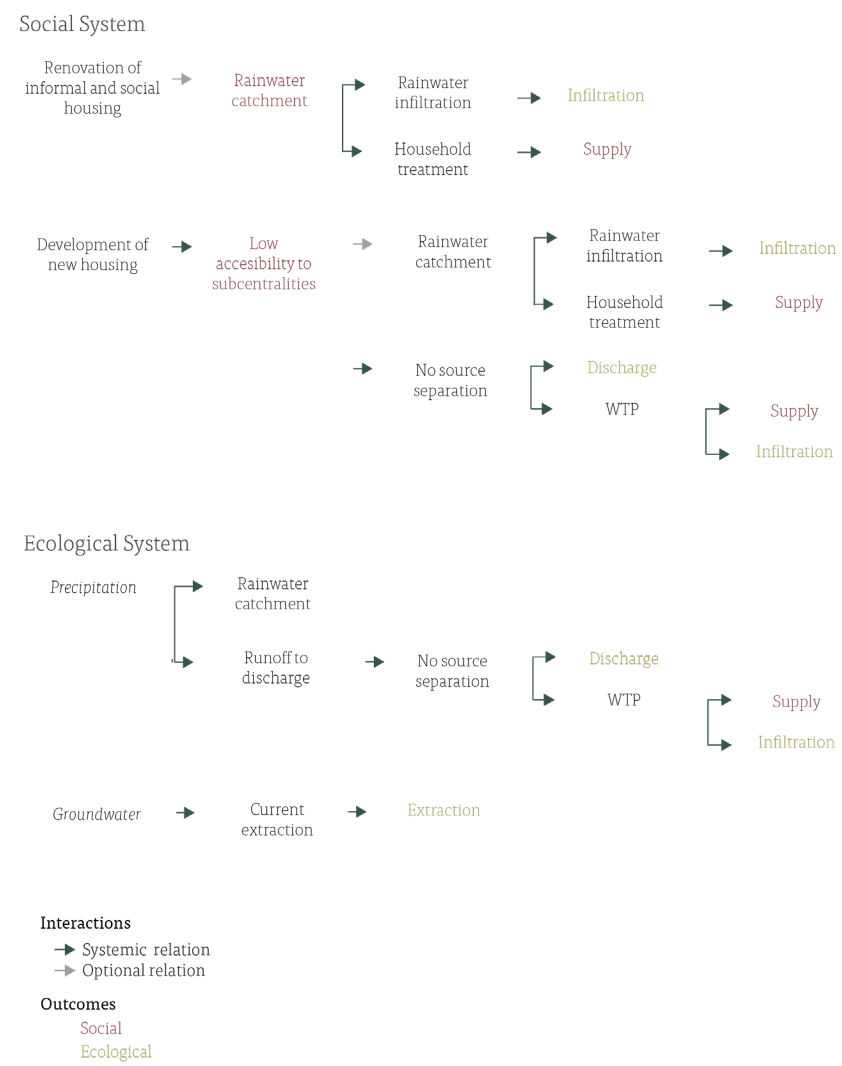


Figure 6.1 Current interactions in the social and the ecological systems

6.2 Identification of the possible alternative interactions and outcomes
Process Model I and Evaluation Model I

This se the different types of investments that could take place in the social and the ecological system of the Meso-scale, respectively. The possible future outcomes resulting from such interventions are further operationalised in Table 6.2.

6.2.1 Identification and operationaliation of the interactions
Proces Model I

Interactions in the ecological system

Figure 6.2 and Figure 6.3 show the different types of investments that could take place in the social and the ecological system of the Meso-scale, respectively. The relations between the investments are considered to be either systemic or optional, as well.

Figure 6.2 illustrates that, in addition to the possibility to install rainwater catchment systems, there could also be future investment in separating the wastewater in the existing developments. In regards to the development of future social housing, there could be investments, not only to develop in low accessible areas to the employment centers, but also in the accessible and highly accessible areas. Further, in each of them, there could be investments in source separation and rainwater catchment.

Interactions in the ecological system

Further, in the ecological system, the additional interventions could be to not only infiltrate the runoff once it is in the flat areas but to also delay it, to either infiltrate it, retain it and treat it, or to discharge it, at a slower speed.

6.2.2 Identification and operationaliation of the Outcomes
Evaluation Model I

The impact model indicated which consequences might the changes cause. The performance measurements to be studied are the same as in the Evaluation Model with the addition of the regenerative performance measure. The previous measures the increment or decrement of the mean value of the social-ecological performance and the governance performance in between the Process and the Change Models.

The alternative outcome variables foreseen to happen are the improvement of the social-performance, the ecological performance , the governance performance. The investment performance is foreseen to be the same or better. The regenerative performance is the fifth outcome variable and it will evaulate the improvement or decline of the social-ecological and the governance performance.

First-tier variables	*Operalisation*	*Second-tier variables*	*Operalisation*
Interactions (I2)	Possible alternative interactions	I5 – Investment activities (D)	*Future alternative investments in the social subsystem* -source separation in the informal and social housing -rainwater catchment in the informal and social housing -development of housing in high accesible areas to employment centers -development of housing in average accesible areas to employment centers -development of housing with low accesibility to employment centers -source separation in new devlopment areas -rainwater catchment in new development areas- -water treatment plants for new development areas
			Future alternative investments in the ecological subsystem -rainwater catchment -discharge of runofff -delay of runoff infiltration of the delayed runoff -catchment of the delayed runoff -discharge of the delayed runoff -treatment of the caught runoff infiltration of the caught runoff -decreased extraction of the groundwater -augmented extration of the groundwater
		I7 – Self-organizing activities (E)	Emergent activities in the social subsystem : -Systemic relations between investments -Every 10 years the most accesible areas become employment centers
			Emergent activities in the social subsystem: -Sytemic relations between investments -Water is infiltrated to neighbouring aquifers when any one has reached its balance
Outcomes (O)	Possible alternative outcomes	O1-Social performance measures	Future alternative social performance
		O2-Ecological performance measures	Future alternative ecological performance
		O4- Others	Future alternative governance performance
			Regenerative performance

Table 6.2 Operationalisation of the possible alternative Interaction and Outcome variables

Social System

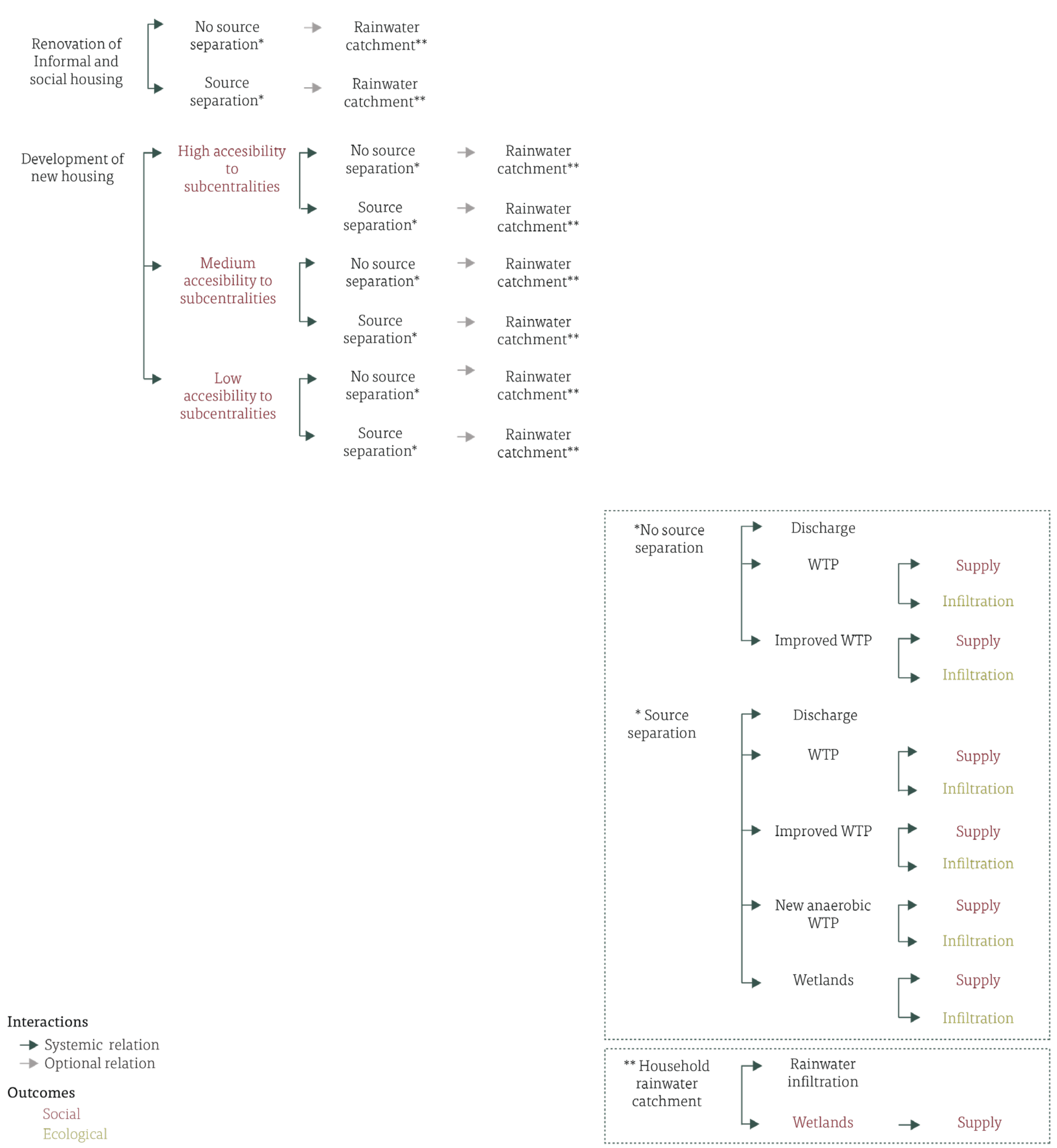


Figure 6.2 Possible future interactions in the social system

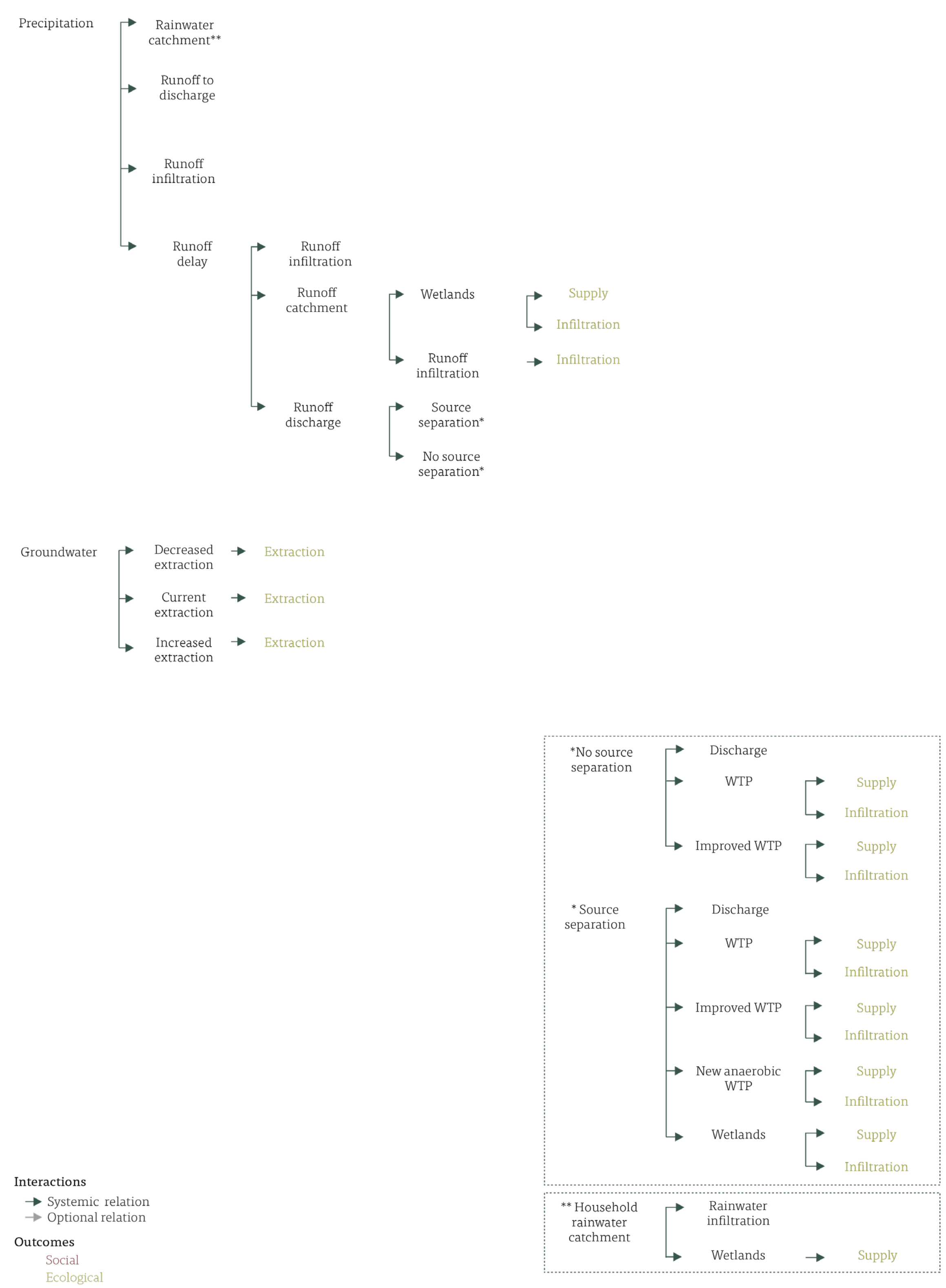


Figure 6.3 Possible future interactions in the ecological system

6.3 Identification of the governance system and actors
Decision Model I

This section presents the identification and the operationalisation of the Governance Systems and Actors involved in the study (Table 6.3). The Governance Systems are further described according to the rule-making organisations that integrate them, and their network structure. The Actors are described according to their socioeconomic attributes, the knowledge on social-ecological systems, and in which ways are they dependant to the system (Table 6.3). Further below on Figure 6.4 the specific functions, capacities, and interests of each of the governance organisations and the actors is shown in and described more in detail.

The research found three different governance systems in the MAVM that were relevant to the study: the environmental, the territorial, and the housing governance systems.

The environmental governance system is represented on a National level by SEMARNAT, and on a Federal Entity level by SEDEMA in Mexico City and by SEDEMA in the State of Mexico. The capacities of the three institutions mostly relate to the creation, coordination, and application of policies related to the natural environment. The previous institutions have a hierarchical and collaborative relation with, CONAGUA, on a national level, and on a regional level wit SACMEX (Mexico City) and with CAEM (State of Mexico). The last three organisations manage and provide technical assistance to regulate and protect national water, to provide and distribute drinking water, and to reuse sewage water. Therefore CONAGUA, SACMEX, and CAEM have the role of both, providing regulations and being active stakeholders. Further on, companies with ecological impact also belong to these type of governance.

The territorial governance is integrated on a National level by SEDATU, on a Federal level by SEDUVI in Mexico City and SEDUVYM in the State of Mexico. Both levels of institutions ensure a sustainable urban and rural development by planning coordinating, administrating, and executing territorial policies and land use regulations. The governments of the Federal entities and of the Municipalities and Mayoralties in Mexico City and the State of Mexico, respectively, are also involved in the territorial governance as they write and promote the development plans for each of their territories.

Lastly, the housing governance system in the MAVM is composed of two rule- organisations and three different groups of actors. The CONAVI is the commission in charge of developing the social housing sector by developing and promoting financing programs. The credit execution companies are also rule-making organisations that give access to housing schemes by providing the financing schemes that CONAVI approves of. The private social housing development companies, the social housing civil associations and the informal housing civil associations develop the housing for low-income population in the MAVM. The difference between the previous two is that the private companies are interested mainly in the profit they can make, while the civil associations are interested in aiding families into obtaining a dignified household. However, the civil housing associations, are also know for having strong political obligations. Anyhow, while the first two develop the housing under formal arrangments most of the time, the civil associations that develop the informal housing, usually with political ties, follow a rather almost every time an informal procedure to obtain land to offer to the families that cannot afford to pay the formal financing schemes.

First-tier variables	*Operalisation*	*Second-tier variables*	*Operalisation*
Governance System (GS)	Environmental, governance system	GS5- Rule-making organisations	SEMARNAT/ SEDEMA, SEDEMA CONAGUA/SACMEX, CAEM SEDATU-SEDUVI, SEDUVYM
		GS6- Rules in use	Rules related to sustainable management of the environment
		GS-9 Network structure	See Figure 7.4
	Territorial governance system	GS5- Rule-making organisations	SEDATU-SEDUVI, SEDUVYM Federal entities Muncipalities/mayoralties(local governments)-
		GS6- Rules in use	Rules related to sustainable management of the territory
		GS-9 Network structure	See Figure 7.4
	Housing governance system	GS5- Rule-making organisations	CONAVI, credit execution companies
		GS6- Rules in use	Rules related to the provision of housing for all
		GS-9 Network structure	See Figure 7.4
Actors (A)	*From the the environmental, system:* CONAGUA/ SACEMX,CAEM Green impact companies	A2- Socieconomic attributes	Figure 6.5
		A7- Knowledge of SES	Knowledge of SES
		A8- Importance of resource (dependance)	Dependence on the economical productivityin the system
	From the territorial system: Federal entities governments and local governments	A2- Socieconomic attributes	See Figure 6.5
		A7- Knowledge of SES	Knowledge of SES
		A8- Importance of resource (dependance)	Dependence on the ecological and economical productivity of the system
	From the housing system: Private social housing development companies, social housing civil associations, informal housing civil associations	A2- Socieconomic attributes	Figure 6.5
		A7- Knowledge of SES	Knowledge of SES
		A8- Importance of resource (dependance)	Dependence on social and economical productivity of the system

Table 6.3 Operationalisation of the SESF

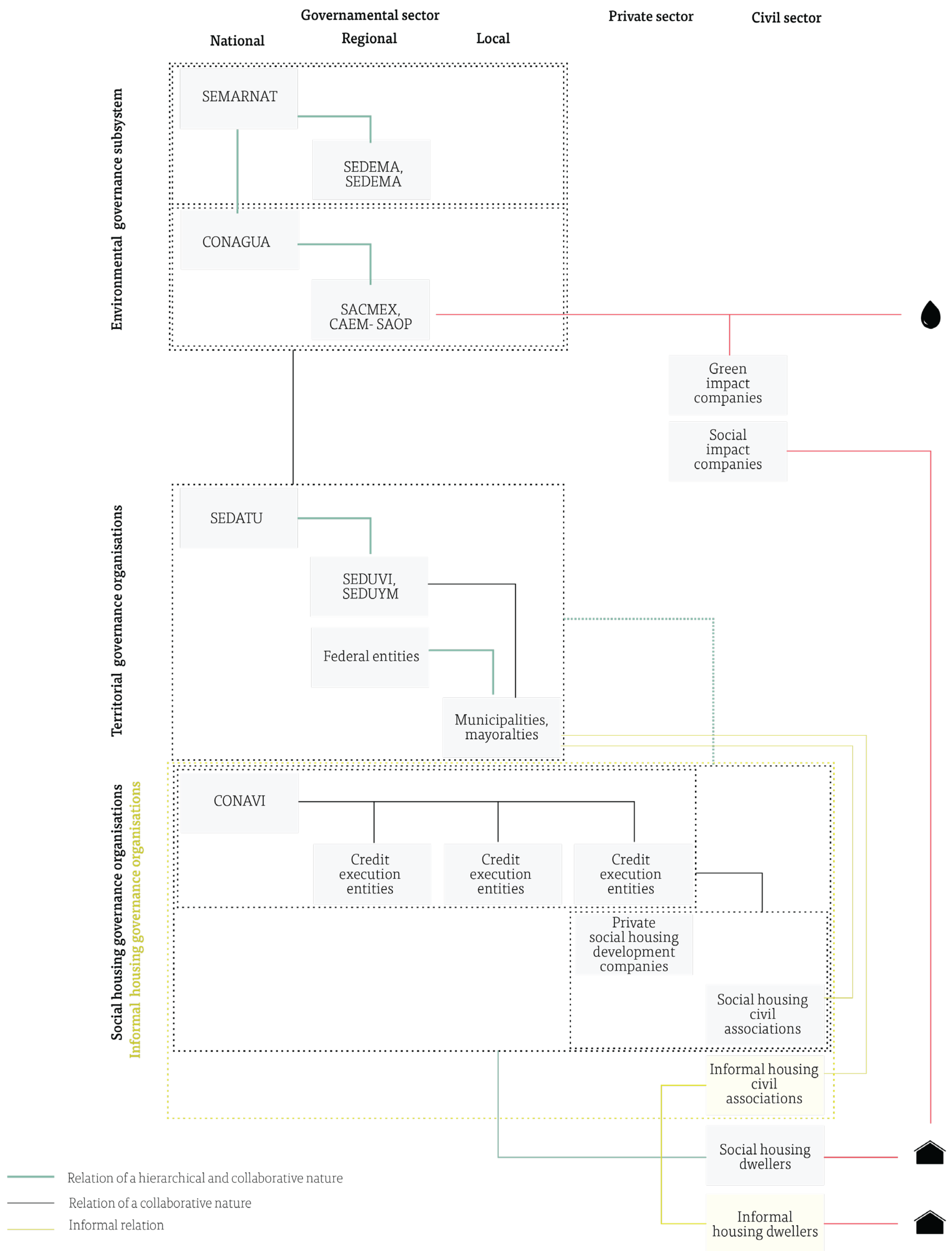


Figure 6.4 Governance system and actors network (Elaborated with data from Gobierno de México (2019) , Estrada (2017), Escamilla y Sanots (2012), Fernández de la Vega (2017), Montejano et al (2018), Jaquin (2012), Moreno et al (2013), Pradilla (2016), and Sánchez (2012) and further verified on interviews with Dr. Victor Hugo Hofman, and Arq. Anahí Arriaga)

Name	*Description of functions*	*Description of capacities*	*Interest in*
Natural Environment and Resources Secretariaat	To integrate criteria and tools to protect, conserve and sustainabiliy use natural resources.	The creation, coordination and application of policies related to the natural environment	Indirectly to the water system
Natural Environment Secretariaat-Natural Environment Secretariaat	To protect, preserve and sustainably use the natural resources as to reach a sustainable development of the ecosystems.	The creation, coordination and application of policies related to the natural environment	Indirectly to the water system
National Water Comision	To administrate, regulate and protect the national water	The management and the provision of technical assistance	Water system
Water System of Mexico City- Water Comision of the State of Mexico	To provide and distribute drinking water; to treat and resue sewage and residual water - To provide water to municipalities, communities and smaller developments and to aid with excess rain water	The management and the provision of technical assistance	Water system
Taller 13, ORU	To build and manage proyects focused on green strategies	The creation and coordination of green strategies	Water system
Provive- Comunidades que Renacen	To find, remodel and resell abandonded social housing	The provision of technical assitance anc capacitation	Abandoned social housing
Agricultural, Territorial and Urban Development Secretariaat	To ensure housing provision and a sustainable urban and rural development	The planning, coordination, administration and execution of territorial policies and land use	Social housing and informal housing
Urban and Housing Development Secretariaat- Urban and Metropolitan Development Secretariaat	To guide and improve mobility, autosustainable growth and the maimum use of urban land-To contribute to territorial ordenance so that personal, professional and familiar potential can be reached	The planning, coordination, administration and execution of territorial policies and land use	Social housing and informal housing
Mexico City, State of Mexico	To write and promote development plans for each State	The suggestion and promotion of policies and plans related to the built environment and land use	Social housing and informal housing
No specific names	To write and promote development plans for each municipality or mayoralty	The suggestion and promotion of policies and plans related to the built environment and land use	Social housing and informal housing
National Housing Comision	To verify the actions of the urban development in the public social and housing sector	The development of financing programs for the subsidies and savings for housing	Social housing
INFONAVIT, FOVISSTE, SIF, Hipotecaria Nacional, Su casita, GE Money	To allow workers of the State to save and acces to housing schemes that can improve their heritage and improve their life in a sustainable way	The administration and operation of the financing system for the State workers construction, adquisition or improvement of the housing	Social housing
Casas GEO, ARA, Hoemy, SARE	To develop housing which people are proud to inhabit	The design and build social housing proyects	Social housing
No specific names	To develop social housing for low-income population	The design and build social housing proyects	Social housing
No specific names	To develop informla housing for low-income population	To provide the land and organisation for informal housing proyects	Informal housing
No specific names	To inhabit and live the environment	Raise voices, vote	Social housing
No specific names	To inhabit and live the environment	Raise voices, vote	Informal housing

Figure 6.5 Description of the functions, capacities and interests of the governance system and actors network (Elaborated with data from Gobierno de México (2019) , Estrada (2017), Escamilla y Sanots (2012), Fernández de la Vega (2017), Montejano et al (2018), Jaquin (2012), Moreno et al (2013), Pradilla (2016), and Sánchez (2012) and further verified on interviews with Dr. Victor Hugo Hofman, and Arq. Anahí Arriaga)

7. Researcher's catalogue of interactions and of outcomes *Modelling I*

This chapter presents the first sub-iteration of the Modelling Iteration. In this sub-iteration the researcher developed all the possible interactions that can take place in the Meso-scale. The chapter presents a thorough catalogue with specific physical interventions from which the researcher and the stakeholder were able to choose to develop the next sub-iterations. The catalogue includes the location, the social performance, the ecological performance, the time of deployment, the monetary costs, and the involved stakeholders of each of the investments.

As mentioned before in the Methodological Chapter, each of the methods to do the modelling appear next to their immediate results for the purpose of clarity in the report (rather than having one entire chapter with all of the methods). Therefore, the chapter presents the methods use to build the agent-based model, the methods use to model the location of the interventions, and the methods use to model their social and their ecological performance and the methods used to obtain the costs, time of deployment, and involved stakeholders per intervention.[8]

8 The methods to model, the time of deployment, monetary costs, and the interested stakeholders mainly included literature review, therefore they are not explained in further detail. The costs and time of deployment were obtained from the literature review of Burns, E. (2009), Comisión de Cuenca De Los Ríos Amecameca Y La Compañía (2009), Isla Urbana (2019), and Redacción (2015). The prices that the studies showed were divided either by m^3/s, Ha, or number of units and then multiplied by the corresponding quantities of each iteration. On the other hand, Decision Model I in the first iteration, provided information need to predict the foreseen agencies over the interventions.

Programming agent-based modelling as a spatial-decision support tool.

As mentioned in the Methodological Chapter, the adapted geodesign framework used a mixed-anticipatory-agent based modelling method to model the Processes and the Changes in the next sub-iterations.

An agent-based model constitutes a number of agents which interact with each other and with their environment, over time space and time, and even more, that can change their decisions as in how they interact as a response to the immediate simulation of the outcomes (Mathews et al., 2007, Clarke, 2014). In this thesis, the investments in the social and the ecological system represented the agents in the model. Whereas the interactions were represented as the decisions that the researcher or the stakeholders took over the investments, along with the emergent properties of such investments[9].

In order to develop said mixed-anticipatory-agent-based modelling method, all the possible interactions and their outcomes had to be embedded in a programmable modelling environment previously to the development of the method. The software NetLogo, developed at the Center for Connected Learning and Computer Based Modelling (NetLogo, 2019) provided such platform. The software uses a type of agent-based model called cellular automata. The main difference between most of the agent-based models and cellular automata, is that in the latter, the agents are bound to stay in place and interact only with their neighbours (Clarke, 2014). Furthermore, the software was programmed in a way so that it could be used as a comprehensible spatial-decision-support tool in the next sub-iterations. Figure 7.1 shows how the interface of the software looked like once programmed. The corresponding programming code is attached in Appendix 1, along with a link to a platform where the model has been uploaded for its further use.

Thus, in order to embed the interactions in the tool, they had to be developed thoroughly along with their outcomes. Therefore the next section elaborates on the method used to define and model the social and ecological performance of each intervention.

9 Refer to Chapter 6.1 and 6.2 for more information

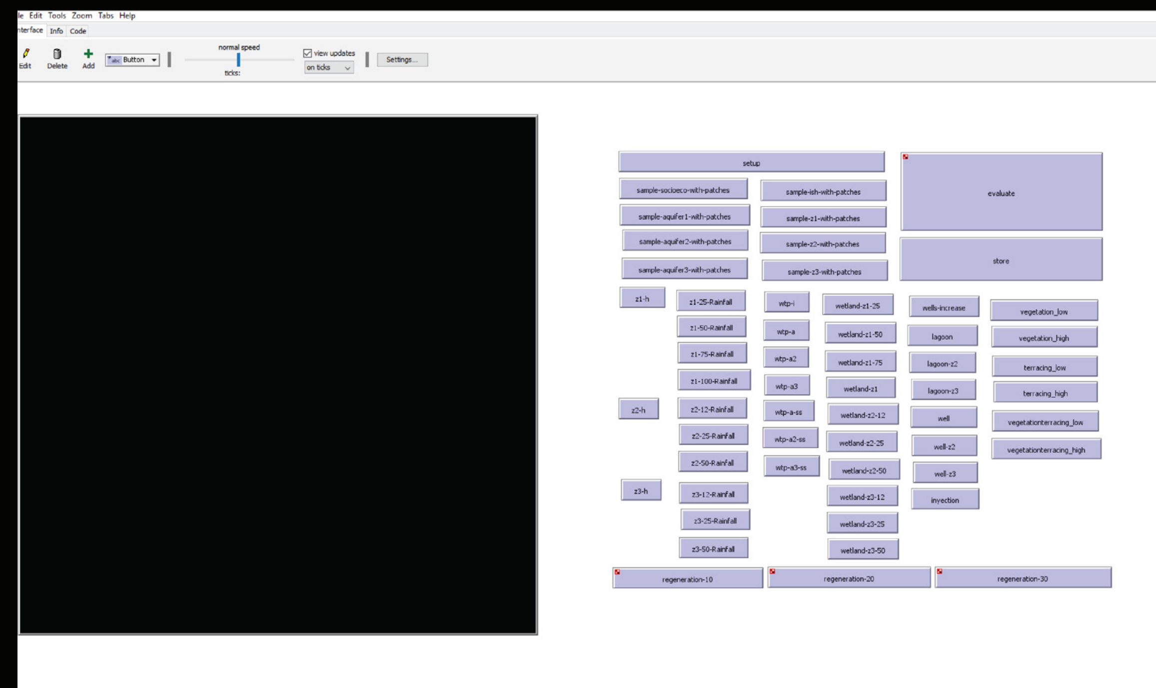


Figure 7.1 NetLogo programmed interface

Defining and modelling the performance of the interactions over the ecological subsystems

The ecological performance of the indicators is expressed according to the performance that they have per aquifer. Therefore, the ecological performance of each of the interventions is modelled as a function of the impact that they have on the infiltration and extraction rates of each individual aquifer, i, as expressed in Formula 1.

$$EP_i = \frac{(IR_i + ER_i)}{2}$$

Formula 7.1 Ecological performance of an aquifer

For fair evaluation, a linear ranking interpolation/mapping was realised to to assess the performance changes of each aquifer in relation to their optimal usage values. Optimal utilisation was awarded with a score of 100%, whereas worst-case usages, with scores of 0%. Table 7.2 shows the collected data regarding the infiltration and extraction rates of each aquifer and their corresponding performance rating on a relative scale[10].

The observed performance (in terms of infiltration and extraction) of each aquifer was assessed against the maximum performance at which it could be operating. For the infiltration, this relative performance is the percentage of current infiltration compared to the maximum infiltration. Higher values indicate a infiltration performance closer to a maximum performance. For the extraction, the ratio of actual extraction to maximum extraction is subtracted from a nominal value of one in order to assess the actual non-extractionn ratio. Similarly, to the previous a higher value would imply better performance, since less water would be extracted.

Finally, as Formula 1 indicates, to obtain the total rating for the ecological performance the mean value of the infiltration and exfiltration ratings was obtained, where again higher values mean better performances.

	Infiltration			*Extraction*			*Total*
Aquifer	Observed	Maximum	Rating	Observed	Maximum	Ratingt	Rating
Chalco	2.62	5.01	52.3%	3.1	5.82	1-53.3%=46.7%	49.5%
Cuautitlán	11.31	21.18	53.4%	13.16	20.73	1-63.5%=36.5%	45%
Texcoco	4.93%	7.3%	67.5%	7.82	10.53	1-74.3%=25.7%	46.6%
Total	35.12	55	63.9%	60	72	1-83.3%=16.7%	42.1%

Table 7.2 Ranking data for the infilitration and the extraction rates

10 Each of the maximum values for the infilitration rates were obtained by adding for each of the aquifers current infilitration rates plus the difference in between the total amount of infilitration as of present in the MAVM (35 m^3/s) divided by three and the total amount of infilitration that could take place in the MAVM (addition of 20 m^3/s of the current water that is disposed as runoff) divided by three. Similarly, each of the maximum values for the extraction rates were obtained by adding for each of the aquifers current extraction rates plus the difference in between the total amount of extraction as of present in the MAVM (60 m^3/s) divided by three and the total amount of extraction that could take place in the MAVM (addition of 12 m^3/s for an increase of 2,500,000 inhabitants) divided by three

Defining and modelling the performance of the interactions over the social subsystems

The social performance (SP) is the mean value function of the service accessibility (SA) and the infrastructure accessibility (IA) per AGEB, according to the Formula 2

$$SP_j = \frac{AS_j + AI_j}{2}$$

Formula 7.3 Socia l pefomance of an AGEB

Where the accessibility to services (AS), accessibility to services is defined by the time needed to commute to the employment centers. Instead of the usual linear mapping approach used in the ecological performance, the accesibility to services was obtained using a categorical approach in which values were assigned as shown in Table 7.4

Commuting time	*Performance value*
< 20 min	100
> 20 min , <40 min	66
< 40 min	33

Table 7.4 Accesibility to services

Further on, the infrastructure accessibility was defined as

$$AI = \frac{AW + ASw + AE}{3}$$

Formula 7.5 Accesiibility to infrastructure

Where (AE) is the accessibility of water, (ASw) is the accessibility of sewage and (AE) for the accessibility to electricity.

Similarly, the infrastructure accessibility index categorically ranks the access towards water, sewage and electricity of an intervention individually between a maximal rating of 100% for the optimal solution and a minimal rating of 0% for the worst solution. For the accessibility to clean water, to sewage or to electricity, the ranking correspond as in Table 7.6.

The first column of the table (withou taking into accoun the header column) corresponds to the total value of the intervention[11], the second to a reduction factor which considered the spatial impact of the intervention[12], and the third column corresponds to a reduction factor which takes into account if the water being treated is combined black and greywater or if they are separated[13]. The values for the rest of the interventions are further shown in the table.

	Original value	Reducting factor 1	Reducting factor 2	Final value
AW= Rainfall + treated water				
Rainfall catchment	50			50
WTP (improved)	50	0.78		39.15
WTP (to anaerobic)	50	0.78		39.15
New WTP 2 (zone 2)	50	0.13		6.5
New WTP (zone 3)	50	0.087		4.35
WTP (to anaerobic) w/ source separation	50	0.783	0.26	20.28
New WTP 2 (zone 2) w/ source separation	50	0.13	0.26	1.69
New WTP (zone 3) w/source separation	50	0.087	0.26	1.13
Wetlands	50		0.74	37
ASw= Treated water				
WTP (improved)	100	0.78		78
WTP (to anaerobic)	100	0.78		78
New WTP 2 (zone 2)	100	0.13		13
New WTP (zone 3)	100	0.087		8.7
WTP (to anaerobic) w/ source separation	100	0.783	0.26	78.3
New WTP 2 (zone 2) w/ source separation	100	0.13	0.26	40.56
New WTP (zone 3) w/source separation	100	0.087	0.26	3.38
Wetlands	100		0.74	2.26
AE=Biogas				
WTP (to anaerobic) w/ source separation	100	0.783	0.26	78.3
New WTP 2 (zone 2) w/ source separation	100	0.13	0.26	40.56
New WTP (zone 3) w/source separation	100	0.087	0.26	3.38
Wetlands	100		0.74	2.26

Table 7.6 Accesibility to clean water, to sewage , and to electricity

Selection of the location of the interventions

The criteria to select the location of the interventions is listed in detail in Table 7.1 and presented in form of maps through the catalogue.

11 In the case of cleanwater, half of it can provide from rainfall and half from the water treatment of wastewater, therof the values of 50 instead of 100

12 •The values were with a rule of three, in which 23 WTP equaled 100%, and 18 WTP equales 78%, 3 WTP, 13%, and 2 WTP, 8%.

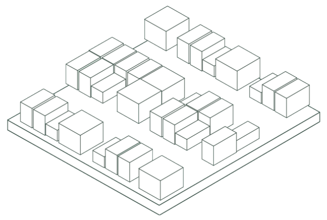
13 •74 % of the wastewater in a household is greywater, while 26% is blackwater (Edwin et al., 2013)

Investment	*Location selection criteria*
Development of social housing in Zone 1	Intersection of areas over 100 Ha with accesibility to employment centers under 20 min, with slope under 7.8°, and with landprice under 6,319 MXN/m² Substraction of areas with built environment or under conservation
Development of social housing in Zone 2	Intersection of areas over 100 Ha with accesibility to employment centers under 40 min, with slope under 7.8°, and with landprice under 6,319 MXN/m² Substraction of Zone 1 and of areas with built environment or under conservation
Development of social housig in Zone 3	Intersection of areas over 100 Ha with accesibility to employment centers over 40 min, with slope under 7.8°, and with landprice under 6,319 MXN/m² Substraction of Zone 1 and 2 and of areas with built environment or under conservation
Rainall in Zone 1	Zone 1
Rainfall in Zone 2	Zone 2
Rainfall in Zone 3	Zone
Source separation in Zon 1	Zone 1
Zone separation in Zone2	Zone 2
Source separaion in Zone 3	Zone 3
WTP, improved, anaerobic	Location of existing WTPs
New WTP -Zone 2	WTP placed outside of the cachment areas of 8-10 Km of the existing WTP
New WTP - Zone 3	WTP placed outside of the cachment areas of 8-10 Km of the existing WTP
Wetlands Zone 1	Zone 1
Wetlands Zone 2	Zone 2
Wetlands Zone 3	Zone 3
Augmented extraction wells	Location of existing etraction wells
Infiltration lagoons	Intersection of the pour areas (r= 50 mm[14]) with runoff accumulation over 68, areas with NDVI in between 0.4 and 0.8, and slope under 7.8° Substraction of areas with built environmentor under conservation
Infilitration lagoons (minus Zone 2)	Intersection of the pour areas (r= 50 mm) with runoff accumulation over 68, areas with NDVI in between 0.4 and 0.8, and slope under 7.8° Substraction Zone 2 and of of areas with built environment or under conservation
Infilitration lagoons (minus Zone 3)	Intersection of the pour areas (r= 50 mm) with runoff accumulation over 68, areas with NDVI in between 0.4 and 0.6, and slope under 7.8° Substraction of Zone 3 and of areas with built environment or under conservation
Infilitration wells	Infilitration lagoons
Infilitration wells (minus Zone 2)	Infilitration lagoons (minus Zone 2)
Infilitration well (minus Zone 3)	Infilitration lagoons (minus Zone 3)
Inyection wells	Location of existing WTP
Vegetation in low slopes	Intersection of the areas with runoff accumulation in bewteen 1 and 102.6, areas with NDVI in between 0.2 and 0.6, and slope under 23.4° Substraction and of areas with built environment or under conservation
Vegetation in high slopes	Intersection of the areas with runoff accumulation in bewteen 1 and 102.6, areas with NDVI in between 0.2 and 0.6, and slope in between 31.2° and 46.8° Substraction and of areas with built environment or under conservation
Terracing in low slopes	Vegetation in low slopes
Terracing in high slopes	Vegetation in high slopes
Vegetation - terracing in low slopes	Vegetation in low slopes
Vegetation - terracing in high slopes	Vegetation in high slopes

Table 7.7 Summary of the criteria used to select the locations of the investments

14 The areas in Chalco and Texcoco where there are already retention lagoons werr given a bigger radius, according to their predetermined size

Development of future housing- Zone 1



The development of the housing in Zone 1 is accesible within a 20 min drive by public transport and/or walking of the highlighted employment centers.
Each of the interventions on the right, present different densities for the future housing developments. As, the total amount of increase in the population in the set timeframe of development (till 2050) is of 2,500,0000 inhabitants (UOIT, 2019), this allowed for more flexiblity to combine Zone 1 with Zone 2 or Zone 3 (see below) in the Process and Change Model, .

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

Zone 1 (25%)

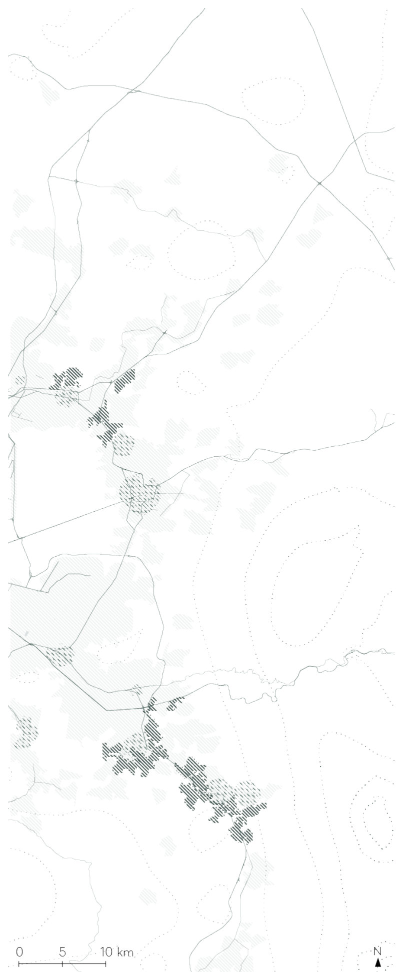


Figure 7.2

Density of: 22.5 inhabitants/ Ha
Population: 120, 465 inhabitants

Possible to be be paired with : All

Social performance: 50

Ecological performance:0

Economic performance: Depends on the housing developer

Time of deployment: 5 years

Possible stakeholders' involvement:

SEMARNAT/SEDUVYM
Social housing,developers,
social housing civil associations,
informal housing civil associations

Zone 1 (50%)

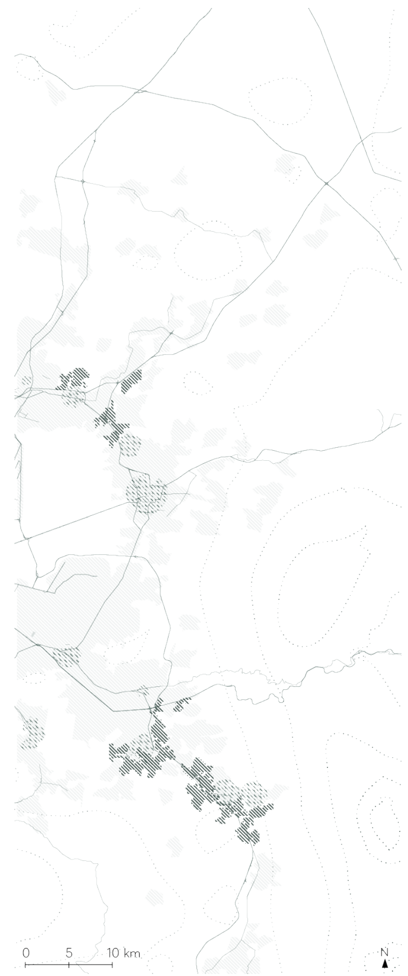


Figure 7.3 .

Zone 1 (75%)

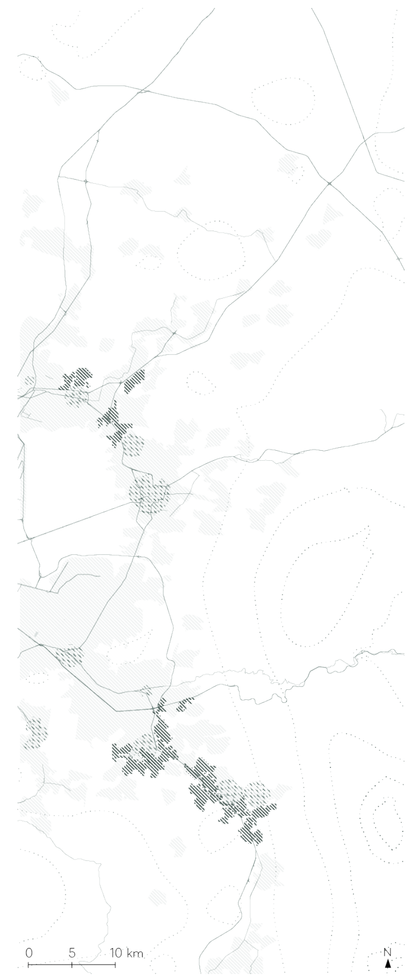


Figure 7.4

Zone 1

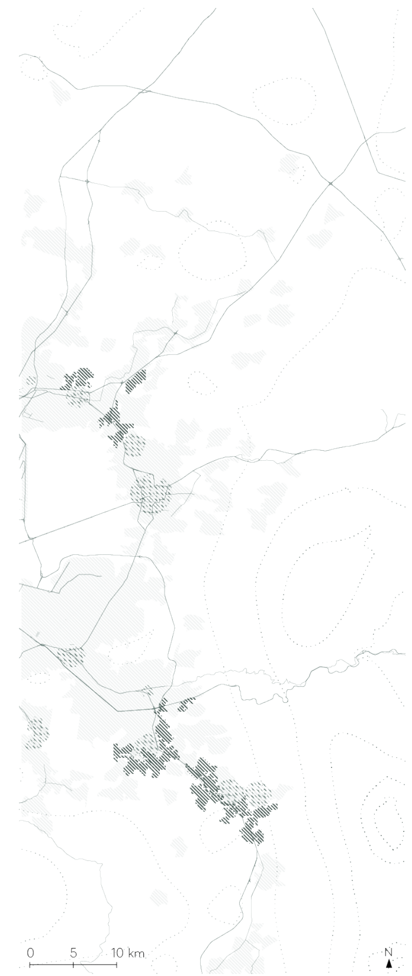
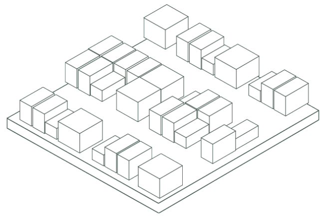


Figure 7.5

Zone 1 (50%)	Zone 1 (75%)	Zone 1
Density: 45 inhabitants/ Ha Population: 20, 930 inhabitants Possible to be be paired with : All	Density: 67.50 inhabitants/ Ha Population : 31,395 inhabitants Possible to be be paired with : All This density is considered the best	Density: 90 inhabitants/ Ha Population: 481, 860 inhabitants Possible to be be paired with : All This is the MAVM average density
Social performance: 50	Social performance: 50	Social performance: 50
Ecological performance:0	Ecological performance:0	Ecological performance:0
Economic performance: Depends on the housing developer	Economic performance: Depends on the housing developer	Economic performance: Depends on the housing developer
Time of deployment: 5 years	Time of deployment: 10 years	Time of deployment: 10 years
Possible stakeholders' involvement: SEMARNAT/SEDUVYM Social housing,developers, social housing civil associations, informal housing civil associations	Possible stakeholders' involvement: SEMARNAT/SEDUVYM Social housing,developers, social housing civil associations, informal housing civil associations	Possible stakeholders' involvement: SEMARNAT/SEDUVYM Social housing,developers, social housing civil associations, informal housing civil associations

Development of future housing- Zone 2



The development of the housing in Zone 1 is accesible within a 40 min drive by public transport and/or walking of the highlighted employment centers.
Each of the interventions on the right, present different densities for the future housing developments. As, the total amount of increase in the population in the set timeframe of development (till 2050) is of 2,500,0000 inhabitants (UOIT, 2019), this allowed for more flexiblity to combine Zone 1 with Zone 2 or Zone 3 (see below) in the Process and Change Model, .

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

Zone 2 (12.5%)

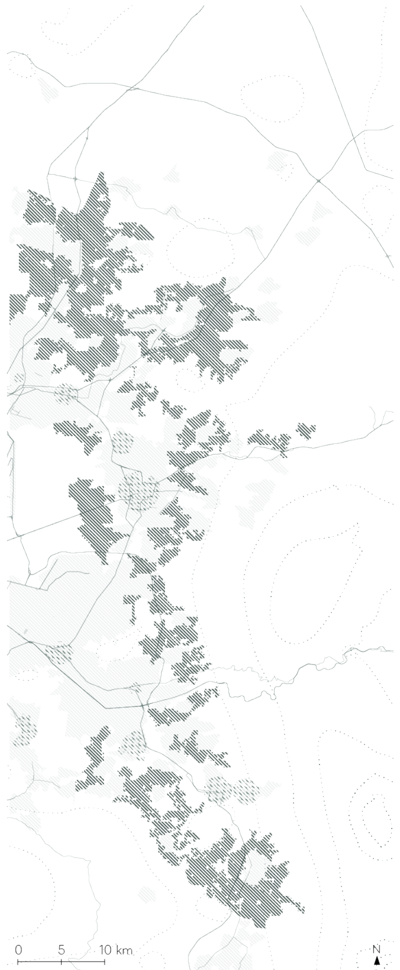


Figure 7.6

Density of: 11.25 inhabitants/ Ha
Population: 497,085 inhabitants

Possible to be paired with: Zone 1 (All), Zone 3 (All)

Social performance: 33

Ecological performance:0

Economic performance:Depends on the housing developer

Time of deployment: 10 years

Possible stakeholders' involvement:

SEMARNAT/SEDUVYM
Social housing,developers,
Social housing civil associations,
Informal housing civil associations
Credit execution entities

Zone 2 (25%)

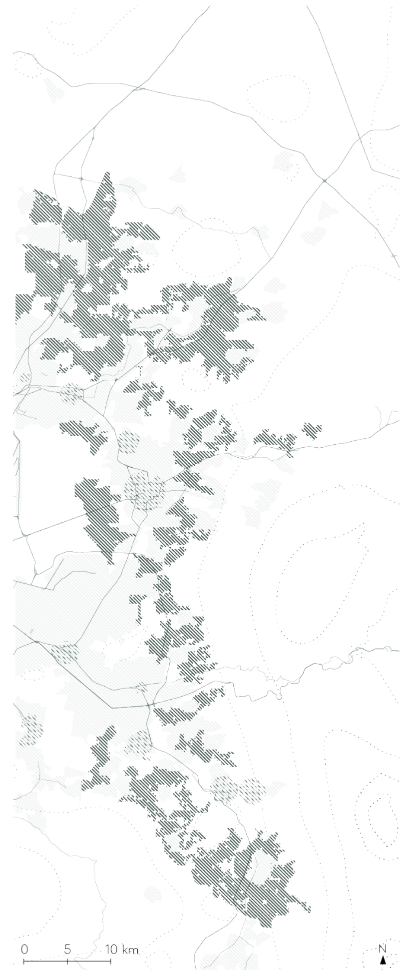


Figure 7.7 .

Density of: 22.5 inhabitants/ Ha
Population: 994, 117 inhabitants

Possible to be paired with: Zone 1 (All), Zone 3 (12.5%)

Social performance: 33

Ecological performance:0

Economic performance: Depends on the housing developer

Time of deployment: 20 years

Possible stakeholders' involvement:

SEMARNAT/SEDUVYM
Social housing,developers,
Social housing civil associations,
Informal housing civil associations
Credit execution entities

Zone 2 (50%)

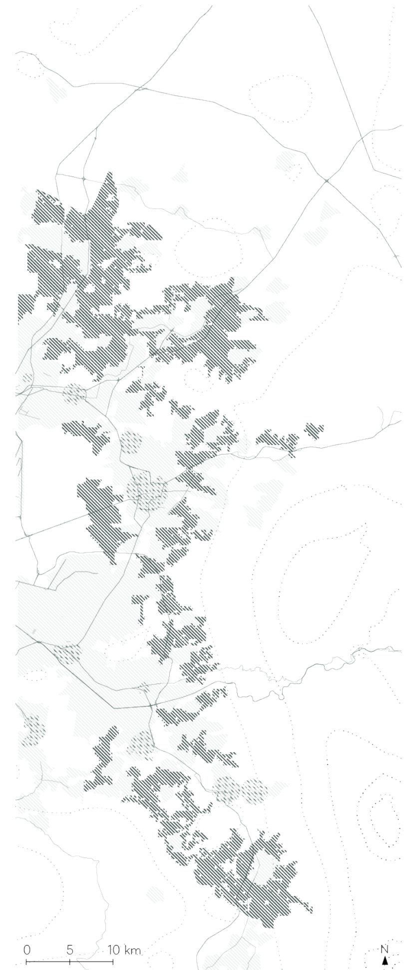


Figure 7.8

Density of: 5 inhabitants/ Ha
Population: 1,988,235 inhabitants3 (12.5%)

Possible to be paired with: Zone 1 (All), Zone 3 (12.5%)

Social performance: 33

Ecological performance:0

Economic performance: Depends on the housing developer

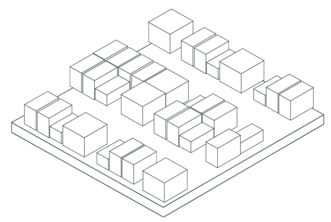
Time of deployment: 30 years

Possible stakeholders' involvement:

SEMARNAT/SEDUVYM
Social housing,developers,
Social housing civil associations,
Informal housing civil associations
Credit execution entities

Development of future housing- Zone 3

Zone 3 (12.5%)



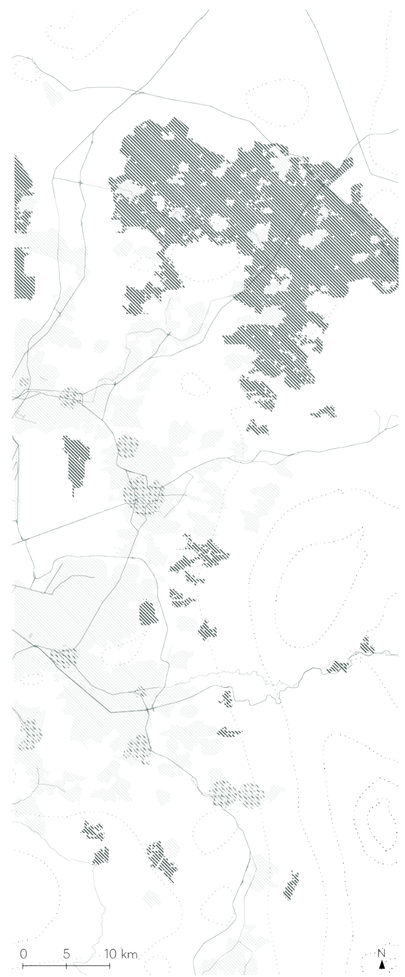


Figure 7.9

The development of the housing in Zone 1 is not accesible within a 40 min drive by public transport and/or walking of the highlighted employment centers.
Each of the interventions on the right, present different densities for the future housing developments. As, the total amount of increase in the population in the set timeframe of development (till 2050) is of 2,500,0000 inhabitants (UOIT, 2019), this allowed for more flexiblity to combine Zone 1 with Zone 2 or Zone 3 (see below) in the Process and Change Model..

Density of: 11.25 inhabitants/ Ha
Population: 520, 053 inhabitants

Possible to be be paired with : All

Social performance: 16.5

Ecological performance:0

Economic performance: Depends on the housing developer

Time of deployment: 10 years

Possible stakeholders' involvement:

SEMARNAT/SEDUVYM
Social housing,developers,
Social housing civil associations,
Informal housing civil associations
Credit execution entities

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

Housing developments within less thant 20 min of subcentralities

Zone 3 (25 %)

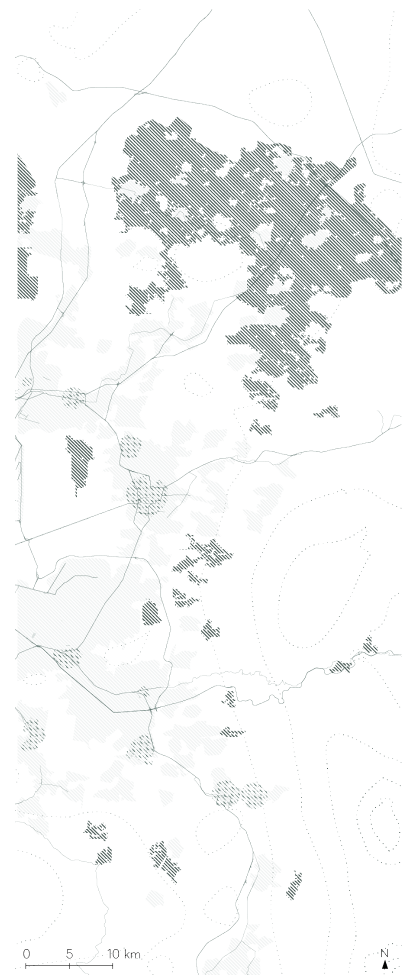


Figure 7.10 .

Density of: 22.5 inhabitants/ Ha
Population: 1,040,107 inhabitants

Possible to be be paired with : Zne 1 (All), Zone 2 (12.5%)

Social performance: 16.5

Ecological performance:0

Economic performance: Depends on the housing developer

Time of deployment: 10 years

Possible stakeholders' involvement:

SEMARNAT/SEDUVYM
Social housing,developers,
Social housing civil associations,
Informal housing civil associations
Credit execution entities

Zone 3 (50%)

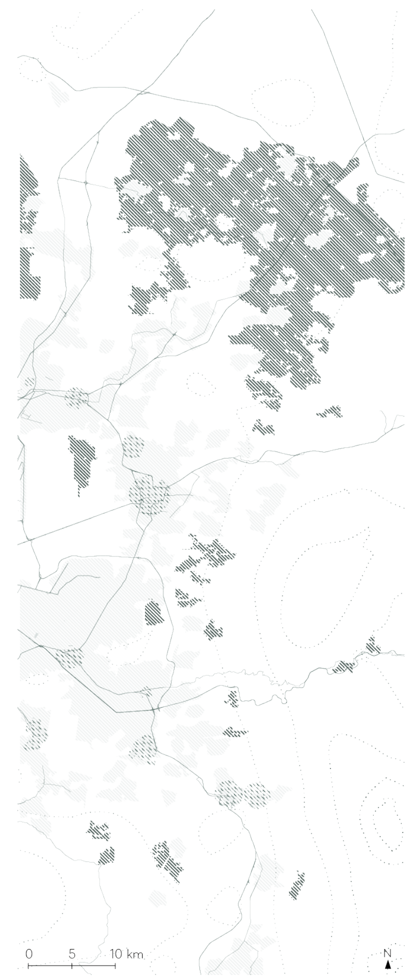


Figure 7.11

Density of: 45 inhabitants/ Ha
Population: 2,080,215 inhabitants

Possible to be be paired with : None

Social performance: 16.5

Ecological performance:0

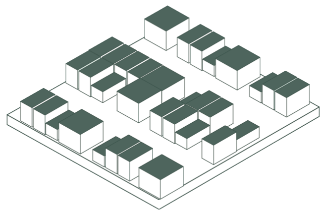
Economic performance: Depends on the housing developer

Time of deployment: 20 years

Possible stakeholders' involvement:

SEMARNAT/SEDUVYM
Social housing,developers,
Social housing civil associations,
Informal housing civil associations
Credit execution entities

Catchment of rainwater in Zone 1



The intervention consists in the installation of a rainwater catchment system on the rooftops of the housing developments. The catchment system includes household system for treating the rainwater so it can be used as normal tap clean water. (Isla Urbana, 2019)

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

Zone 1 (25%)

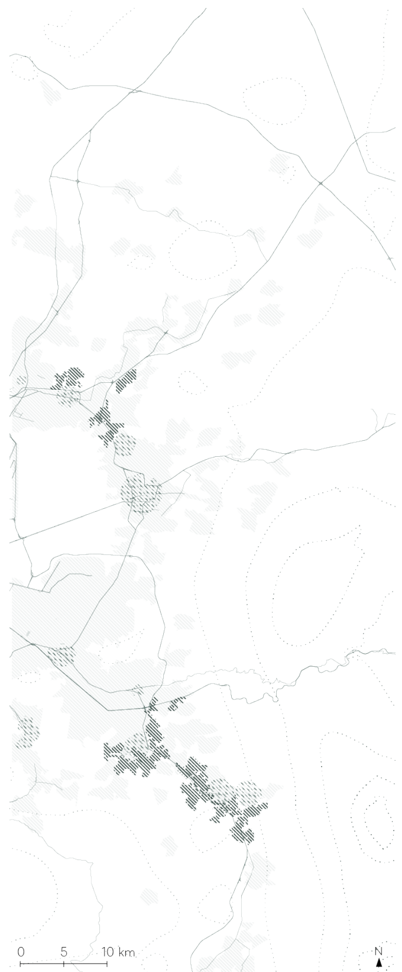


Figure 7.12

Zone 1 (25%)
Social performance: 8.25
Ecological performance: Cuautitlán Pachuca: 0.17 Texcoco: 0.09 Chalco: 2.41
Economic performance: 161,620 MXN/ hh
Time of deployment: According to housing developments time/ immediately
Possible stakeholders' involvement: SEMARNAT/SEDUVYM Social housing,developers, Social housing civil associations, Informal housing civil associations Credit execution entities Social impact companies Ecological impact companies

Zone 1 (50%) | Zone 1(75%) | Zone 1

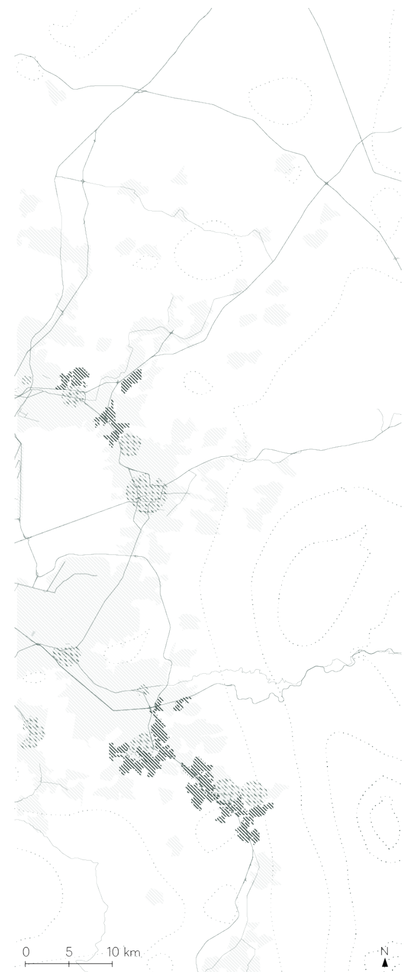


Figure 7.13

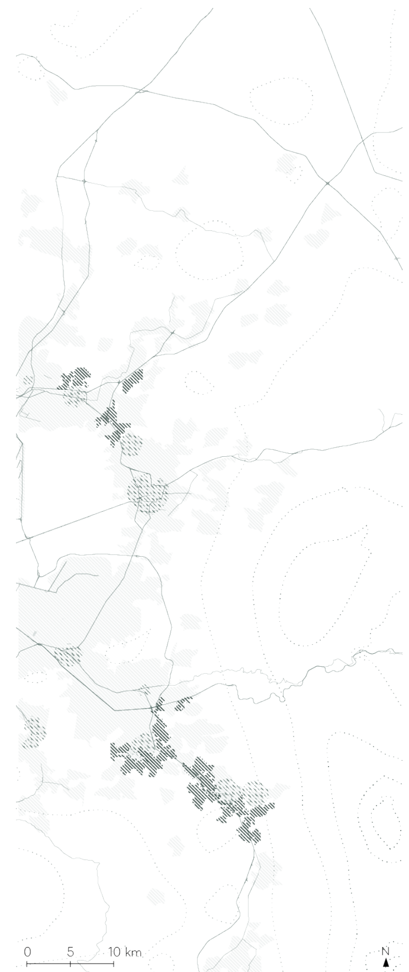


Figure 7.14

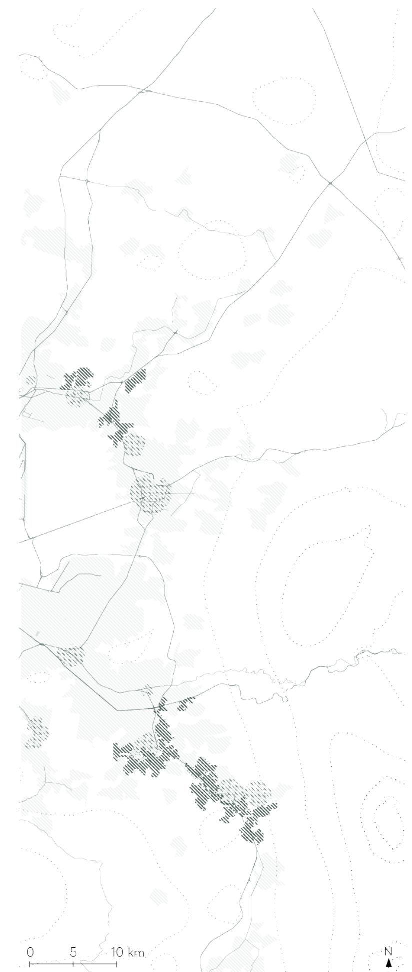
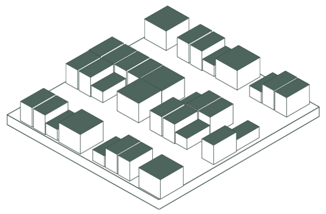


Figure 7.15

Zone 1 (50%)	Zone 1(75%)	Zone 1
Social performance: 8.25	Social performance: 8.25	Social performance: 8.25
Ecological performance: Cuautitlán Pachuca: 0.34 Texcoco: 0.19 Chalco: 4.82	Ecological performance: Cuautitlán Pachuca: 0.51 Texcoco: 0.28 Chalco: 7.23	Ecological performance: Cuautitlán Pachuca: 0.68 Texcoco: 0.38 Chalco: 9.64
Economic performance: 161,620 MXN/ hh	Economic performance: 161,620 MXN/ hh	Economic performance: 161,620 MXN/ hh
Time of deployment: According to housing developments time/ immediately	Time of deployment: According to housing developments time/ immediately	Time of deployment: According to housing developments time/ immediately
Possible stakeholders' involvement: SEMARNAT/SEDUVYM Social housing,developers, Social housing civil associations, Informal housing civil associations Credit execution entities Social impact companies Ecological impact companies	Possible stakeholders' involvement: SEMARNAT/SEDUVYM Social housing,developers, Social housing civil associations, Informal housing civil associations Credit execution entities Social impact companies Ecological impact companies	Possible stakeholders' involvement: SEMARNAT/SEDUVYM Social housing,developers, Social housing civil associations, Informal housing civil associations Credit execution entities Social impact companies Ecological impact companies

Catchment of rainwater in Zone 2



The intervention consists in the installation of a rainwater catchment system on the rooftops of the housing developments. The catchment system includes household system for treating the rainwater so it can be used as normal tap clean water. (Isla Urbana, 2019)

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

Zone 2 (12.5%)

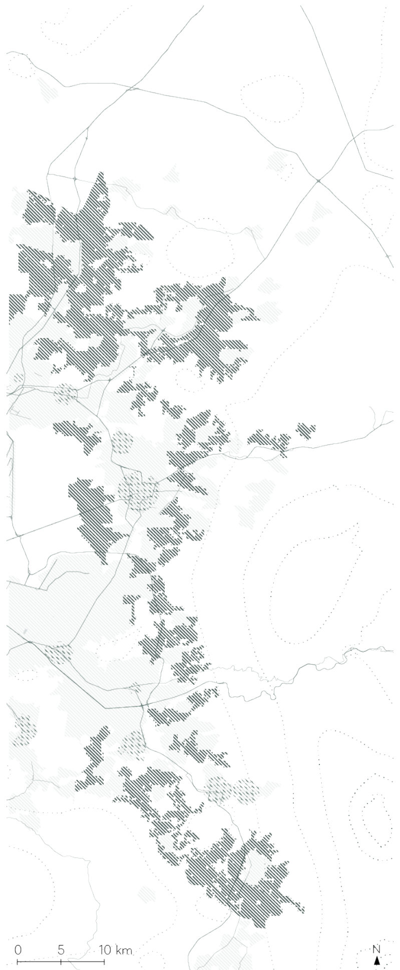


Figure 7.16

Social performance: 8.25

Ecological performance:

Cuautitlán Pachuca: 0.62
Texcoco: 0.33
Chalco: 0.37

Economic performance: 161,620 MXN/ hh

Time of deployment: According to housing developments time/ immediately

Possible stakeholders' involvement:

SEMARNAT/SEDUVYM
Social housing,developers,
Social housing civil associations,
Informal housing civil associations
Credit execution entities
Social impact companies
Ecological impact companies

Zone 2 (25%)

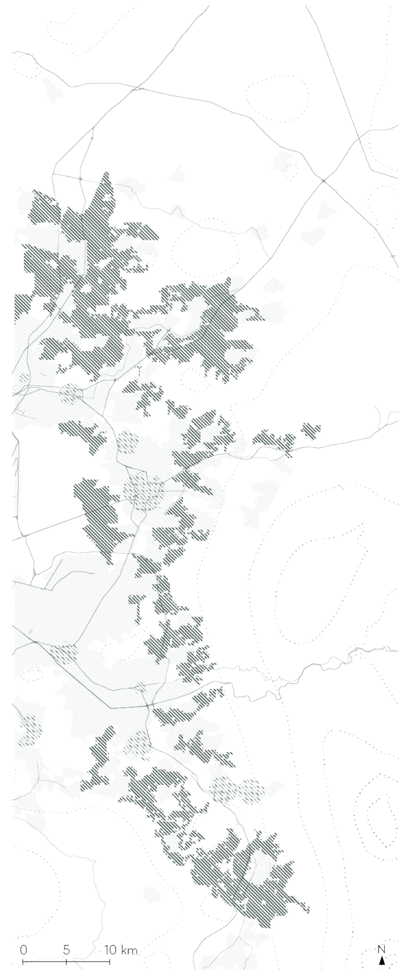


Figure 7.17

Social performance: 8.25

Ecological performance:

Cuautitlán Pachuca: 1.24
Texcoco: 0.66
Chalco: 0.74

Economic performance: 161,620 MXN/ hh

Time of deployment: According to housing developments time/ immediately

Possible stakeholders' involvement:

SEMARNAT/SEDUVYM
Social housing,developers,
Social housing civil associations,
Informal housing civil associations
Credit execution entities
Social impact companies
Ecological impact companies

Zone 2 (50%)

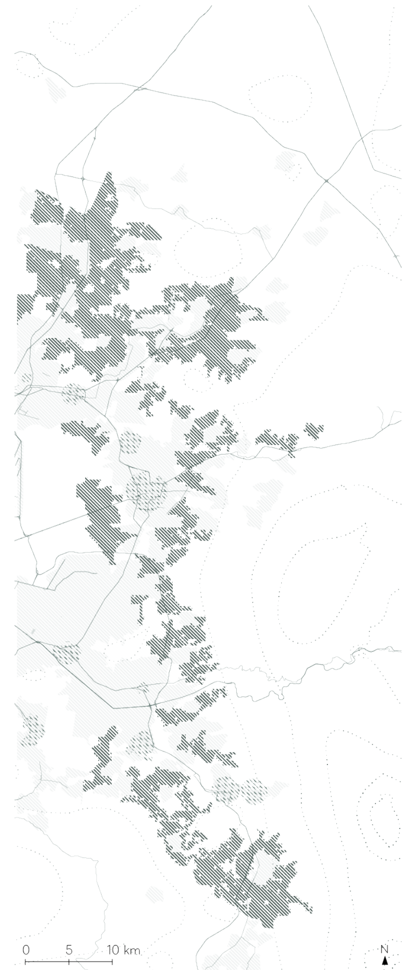


Figure 7.18

Social performance: 8.25

Ecological performance:

Cuautitlán Pachuca: 2.48
Texcoco: 1.32
Chalco: 1.48

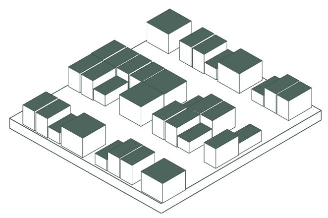
Economic performance: 161,620 MXN/ hh

Time of deployment: According to housing developments time/ immediately

Possible stakeholders' involvement:

SEMARNAT/SEDUVYM
Social housing,developers,
Social housing civil associations,
Informal housing civil associations
Credit execution entities
Social impact companies
Ecological impact companies

Catchment of rainwater in Zone 3



The intervention consists in the installation of a rainwater catchment system on the rooftops of the housing developments. The catchment system includes household system for treating the rainwater so it can be used as normal tap clean water. (Isla Urbana, 2019)

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

Zone 3 (12.5%)

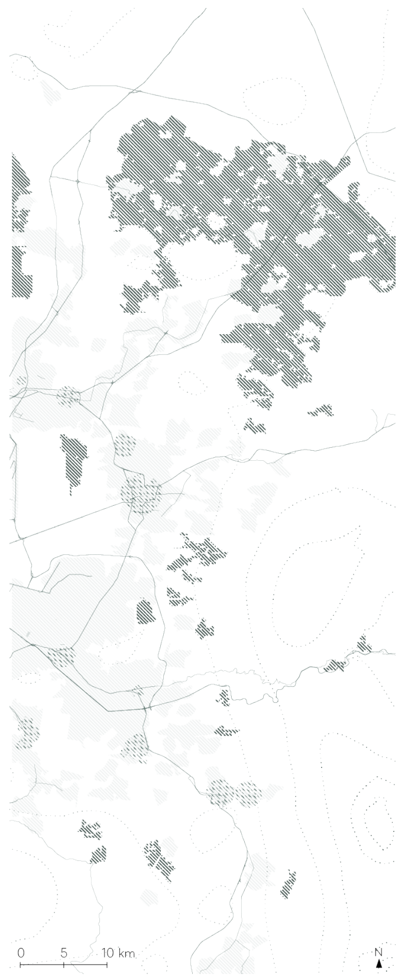


Figure 7.19

Social performance: 8.25

Ecological performance:

Cuautitlán Pachuca: 1.23
Texcoco: 0.09
Chalco: 0.05

Economic performance: 161,620 MXN/ hh

Time of deployment: According to housing developments time/ immediately

Possible stakeholders' involvement:

SEMARNAT/SEDUVYM
Social housing,developers,
Social housing civil associations,
Informal housing civil associations
Credit execution entities
Social impact companies
Ecological impact companies

Zone 3 (25%)

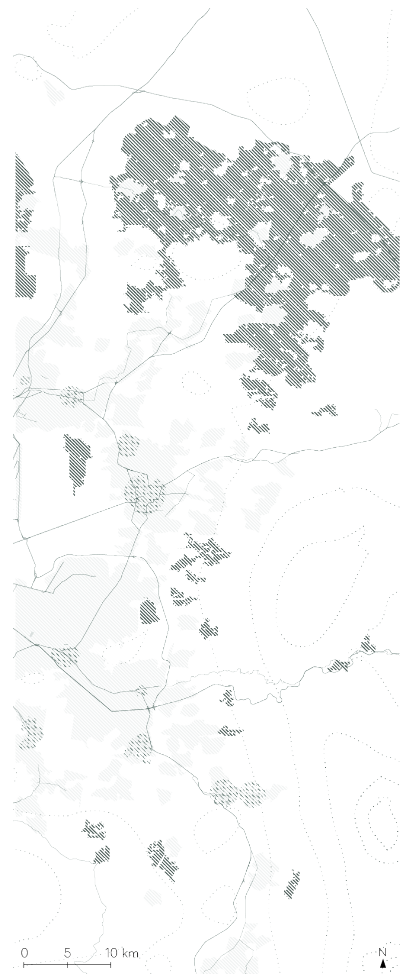


Figure 7.20

Social performance: 8.25

Ecological performance:

Cuautitlán Pachuca: 2.47
Texcoco: 0.18
Chalco: 0.10

Economic performance:161,620 MXN/ hh

Time of deployment: According to housing developments time/ immediately

Possible stakeholders' involvement:

SEMARNAT/SEDUVYM
Social housing,developers,
Social housing civil associations,
Informal housing civil associations
Credit execution entities
Social impact companies
Ecological impact companies

Zone 3 (50%)

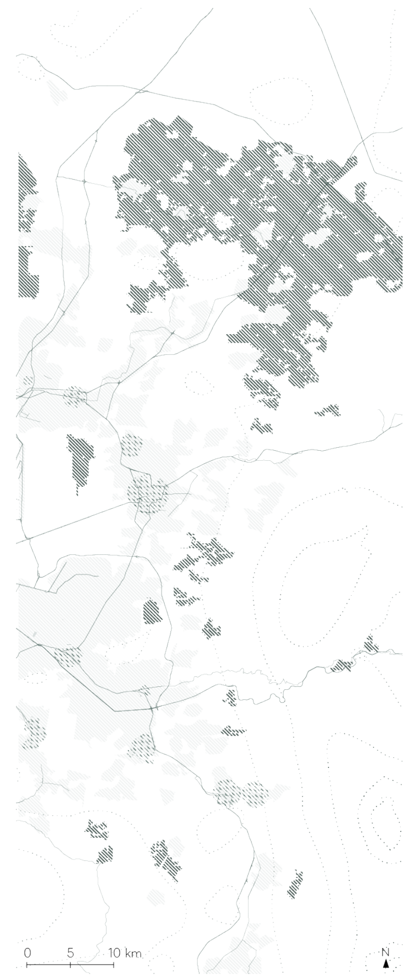


Figure 7.21

Social performance: 8.25

Ecological performance:

Cuautitlán Pachuca: 4.95
Texcoco: 0.36
Chalco: 0.21

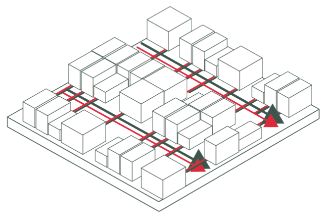
Economic performance: 161,620 MXN/ hh

Time of deployment: According to housing developments time/ immediately

Possible stakeholders' involvement:

SSEMARNAT/SEDUVYM
Social housing,developers,
Social housing civil associations,
Informal housing civil associations
Credit execution entities
Social impact companies
Ecological impact companies

Source separation in Zone 1



Source separation is a very easy-to-do intervention in the housing developments . It could be installed in each house to separate the black and and greywaters.
It does not have any social nor ecologial perfromance added value.

It is necessary to be developed in order to use:
-wetlands

If paired with wetlands, the economical cost of any intervention related to the anaerobic treatment of wastewater decreases considerably, as the water treatment plants requires less capacity
-

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

Zone 1 (25%)

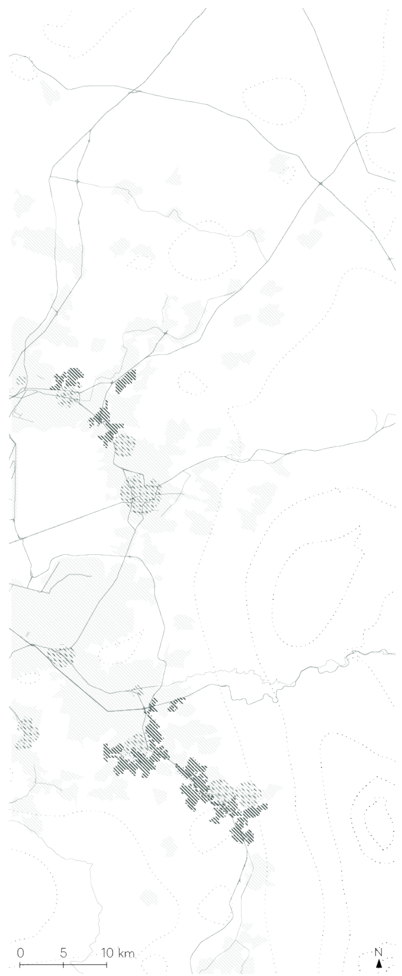


Figure 7.22

Social performance: 0

Ecological performance:0

Economic performance: ~0 MXN

Time of deployment: According to housing developments time/ immediately

Possible stakeholders' involvement:

SEMARNAT/SEDUVYM
Social housing,developers,
Social housing civil associations,
Informal housing civil associations
Credit execution entities
Social impact companies
Ecological impact companies

Zone 1 (50%)

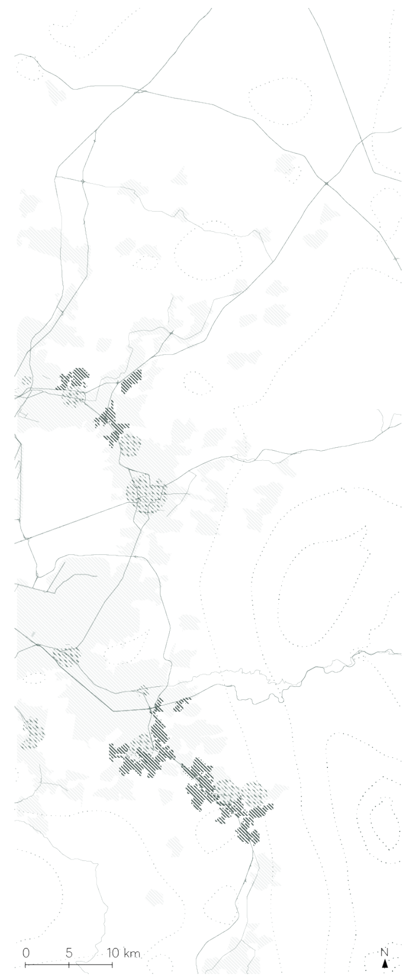


Figure 7.23 .

Description:

Social performance: 0

Ecological performance:0

Economic performance: ~0 MXN

Time of deployment: According to housing developments time/ immediately

Possible stakeholders' involvement:

SEMARNAT/SEDUVYM
Social housing,developers,
Social housing civil associations,
Informal housing civil associations
Credit execution entities
Social impact companies
Ecological impact companies

Zone 1 (75%)

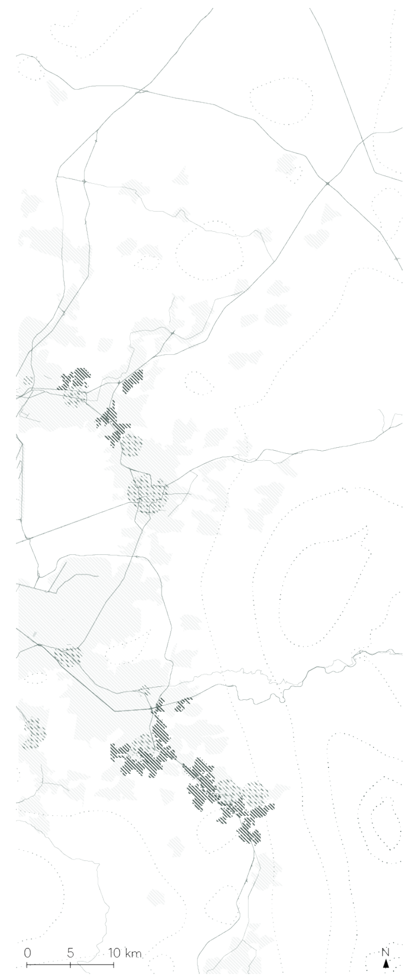


Figure 7.24

Description:

Social performance: 0

Ecological performance:0

Economic performance: ~0 MXN

Time of deployment: According to housing developments time/ immediately

Possible stakeholders' involvement:

SSEMARNAT/SEDUVYM
Social housing,developers,
Social housing civil associations,
Informal housing civil associations
Credit execution entities
Social impact companies
Ecological impact companies

Zone 1

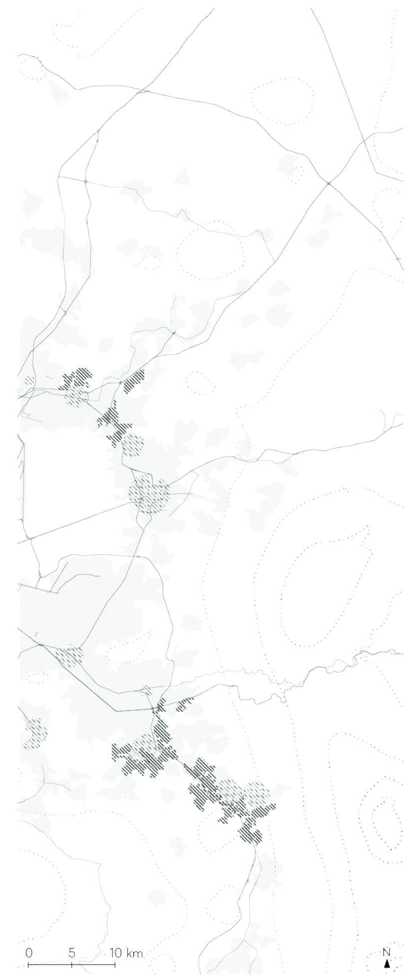


Figure 7.25

Description:

Social performance: 0

Ecological performance:0

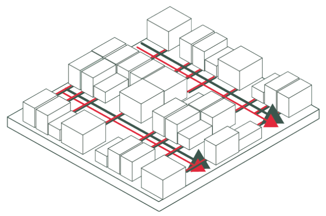
Economic performance: ~0 MXN

Time of deployment: According to housing developments time/ immediately

Possible stakeholders' involvement:

SEMARNAT/SEDUVYM
Social housing,developers,
Social housing civil associations,
Informal housing civil associations
Credit execution entities
Social impact companies
Ecological impact companies

Source separation in Zone 2



Source separation is a very easy-to-do intervention in the housing developments . It could be installed in each house to separate the black and and greywaters.
It does not have any social nor ecological perfromance added value.

It is necessary to be developed in order to use:
-wetlands

If paired with wetlands, the economical cost of any intervention related to the anaerobic treatment of wastewater decreases considerably, as the water treatment plants requires less capacity
-

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

Zone 2 (12.5%)

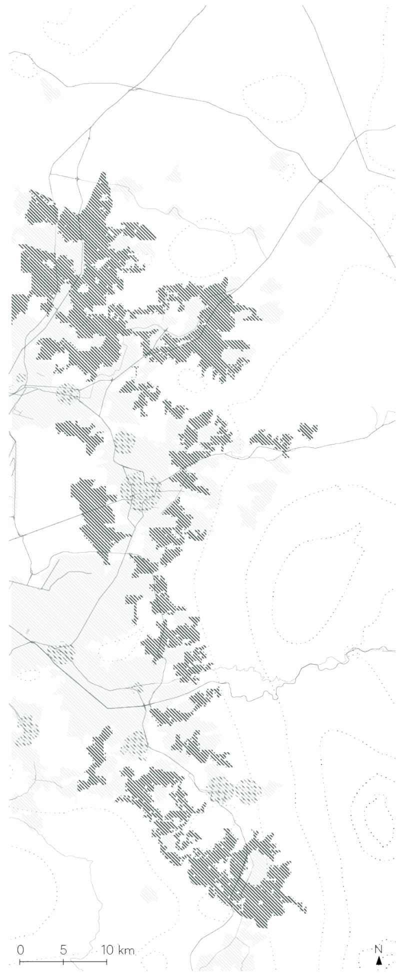


Figure 7.26

Social performance: 0

Ecological performance:0

Economic performance: ~0 MXN

Time of deployment: According to housing developments time/ immediately

Possible stakeholders' involvement:

SEMARNAT/SEDUVYM
Social housing,developers,
Social housing civil associations,
Informal housing civil associations
Credit execution entities
Social impact companies
Ecological impact companies

Zone 2 (25 %)

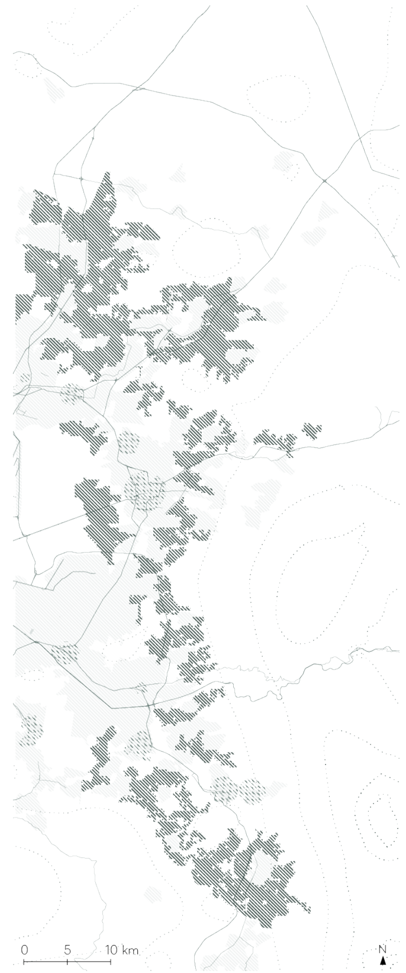


Figure 7.27 .

Social performance: 0

Ecological performance:0

Economic performance: ~0 MXN

Time of deployment: According to housing developments time/ immediately

Possible stakeholders' involvement:

SEMARNAT/SEDUVYM
Social housing,developers,
Social housing civil associations,
Informal housing civil associations
Credit execution entities
Social impact companies
Ecological impact companies

Zone 2 (50 %)

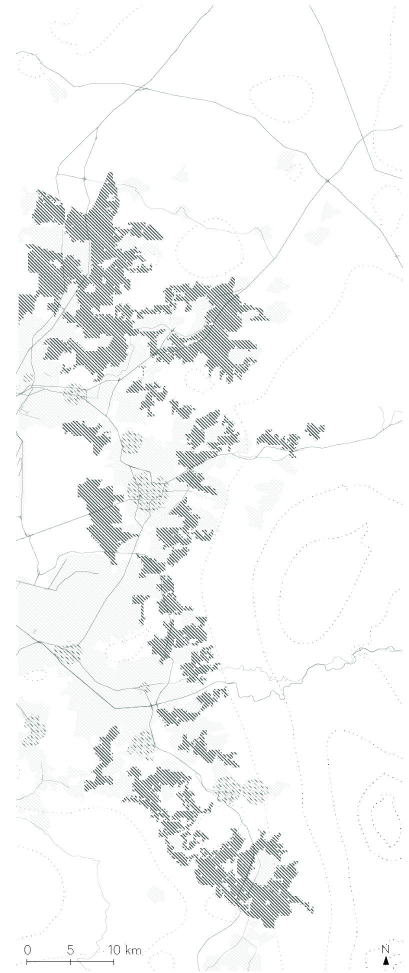


Figure 7.28

Social performance: 0

Ecological performance:0

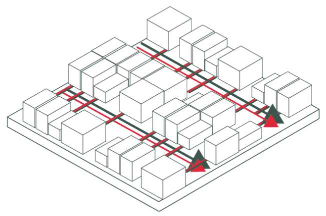
Economic performance: ~0 MXN

Time of deployment: According to housing developments time/ immediately

Possible stakeholders' involvement:

SEMARNAT/SEDUVYM
Social housing,developers,
Social housing civil associations,
Informal housing civil associations
Credit execution entities
Social impact companies
Ecological impact companies

Source separation in Zone 3



Source separation is a very easy-to-do intervention in the housing developments . It could be installed in each house to separate the black and and greywaters.
It does not have any social nor ecologial perfromance added value.

It is necessary to be developed in order to use:
-wetlands

If paired with wetlands, the economical cost of any intervention related to the anaerobic treatment of wastewater decreases considerably, as the water treatment plants requires less capacity
-

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

Zone 3 (12.5%)

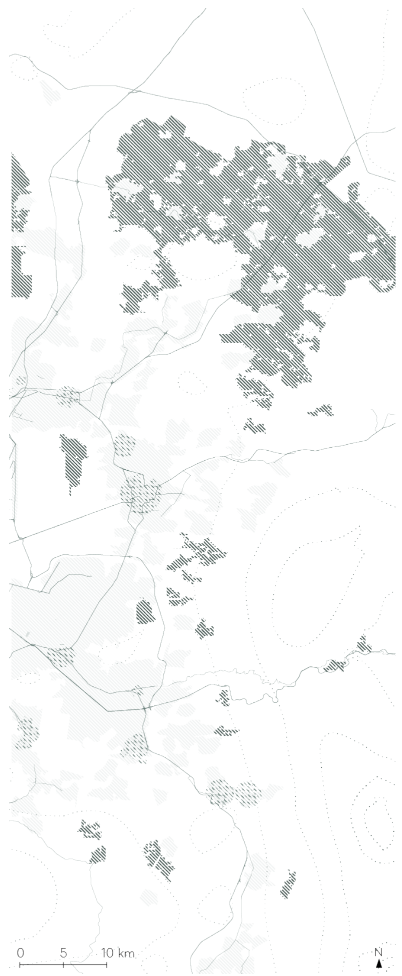


Figure 7.29

Social performance: 0

Ecological performance:0

Economic performance: ~0 MXN

Time of deployment: According to housing developments time/ immediately

Possible stakeholders' involvement:

SEMARNAT/SEDUVYM
Social housing,developers,
Social housing civil associations,
Informal housing civil associations
Credit execution entities
Social impact companies
Ecological impact companies

Zone 3 (25%)

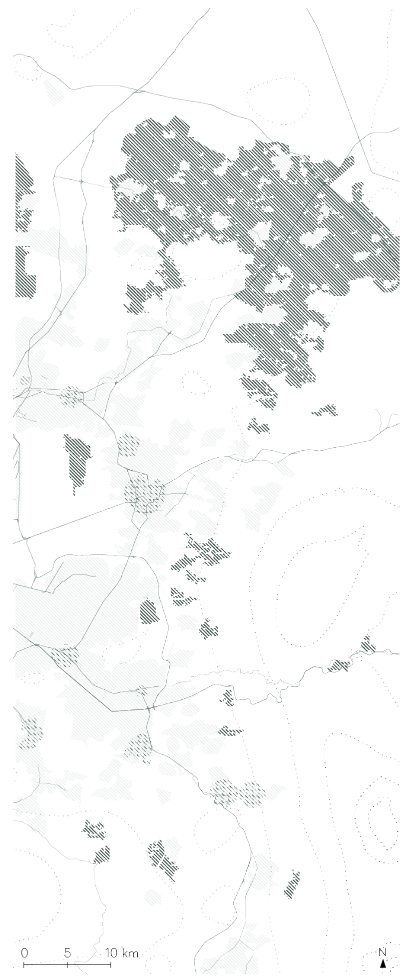


Figure 7.30 .

Social performance: 0

Ecological performance:0

Economic performance: ~0 MXN

Time of deployment: According to housing developments time/ immediately

Possible stakeholders' involvement:

SEMARNAT/SEDUVYM
Social housing,developers,
Social housing civil associations,
Informal housing civil associations
Credit execution entities
Social impact companies
Ecological impact companies

Zone 3 (50%)

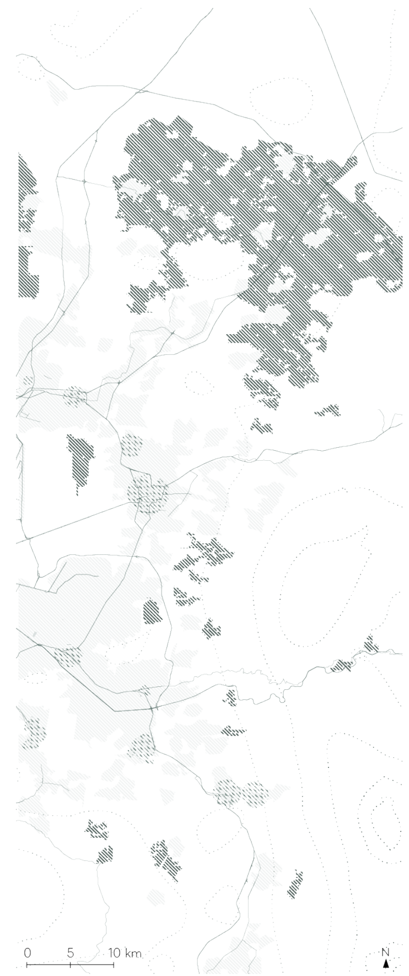


Figure 7.31

Social performance: 0

Ecological performance:0

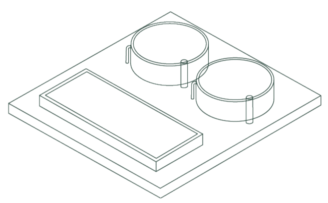
Economic performance: ~0 MXN

Time of deployment: According to housing developments time/ immediately

Possible stakeholders' involvement:

SSEMARNAT/SEDUVYM
Social housing,developers,
Social housing civil associations,
Informal housing civil associations
Credit execution entities
Social impact companies
Ecological impact companies

Water treatment in existing water treatment plants at current rate



This intervention was developed as a current interaction in the MAVM. It does not add any value to the social nor the ecological system because it is already considered in the infiltration and extraction rates and in the social performance of theexisting AGEBS.

Currently the WTPs work at a 55% rate of their total capacity.

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

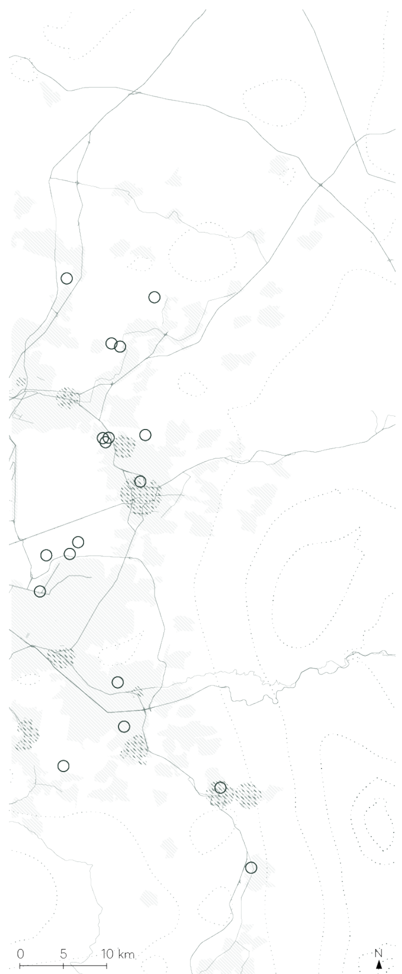


Figure 7.32

Description:

Social performance: 0

Ecological performance: 0

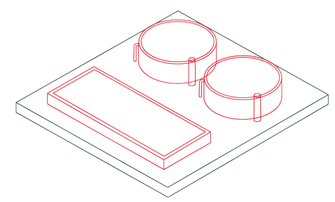
Economic performance: 0 MXN

Time of deployment: 0 years

Possible stakeholders' involvement:

SEDATU/SEDUVYM
CONAGUA/CAEM
Local and statal governments
Ecological impact companies

Water treatment in existing water treatment plants at improved rate (w/network)



This intervention would renovate the existing water treatment plants so that they could work at their full capacacity. If used, it has the capacity to supply water treatment to 78% of the territory, including the current built environment and any future housing developments.

In order to develop the intervention the collaboration between the local and statal governments and CONAGUA/ CAEM is needed. Even though CONAGUA.CAEM are in charge of treating the water, the local government are the ones who provide the sewage infrastructure to carry the wastewater to the WTPs.

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

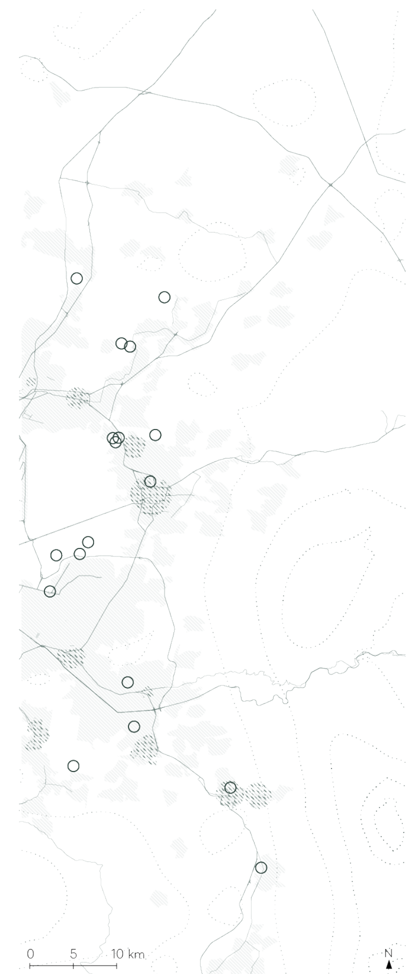


Figure 7.33

Description:

Social performance: 19.37

Ecological performance:

Cuautitlán Pachuca: 1.28
Texcoco: 5.69
Chalco:5.72

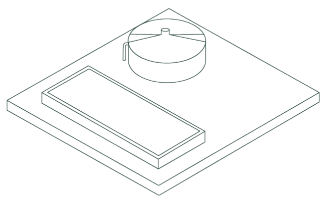
Economic performance: 480,000,000 MXN

Time of deployment: 10 years

Possible stakeholders' involvement:

SEDATU/SEDUVYM
CONAGUA/CAEM
Local and statal governments
Ecological impact companies

Water treatment in existing plants turned into anerobic plants (when no source separation)



This intervention would renovate the existing water treatment plants into anaerobic plants with gasoelectrics so that they could work at their full capacacity and produce energy.
If used it has the capacity to supply water treatment to 78% of the territory, including the current built environment and any future housing development.

It would treat all the wastewater

In order to develop the intervention the collaboration between the local and statal governments and CONAGUA/CAEM is needed. Even though CONAGUA.CAEM are in charge of treating the water, the local government are the ones who provide the sewage infrastructure to carry the wastewater to the WTPs.

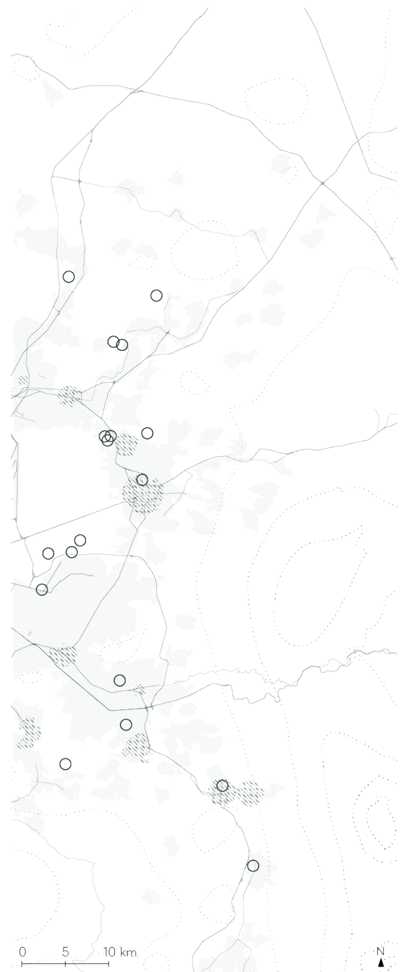


Figure 7.34

The collaboration between the local and statal governments is necessary for its development

Social performance: 32.27

Ecological performance:

Cuautitlán Pachuca: 2.89
Texcoco: 12.82
Chalco: 12.88

Economic performance: 4,320,000,000MXN

Time of deployment: 10 years

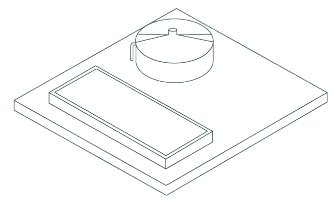
Possible stakeholders' involvement:

SEDATU/SEDUVYM
CONAGUA/CAEM
Local and statal governments
Ecological impact companies

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

Water treatment in new anerobic plants (when no source separation)



This intervention would build new water treatment plants so that they could cover the 22% left of the territory that the existing plants cannot reach.

It would treat all the wastewater

In order to develop the intervention the collaboration between the local and statal governments and CONAGUA/CAEM is needed. Even though CONAGUA.CAEM are in charge of treating the water, the local government and statal government are the ones who provide the sewage infrastructure to carry the wastewater to the WTPs.

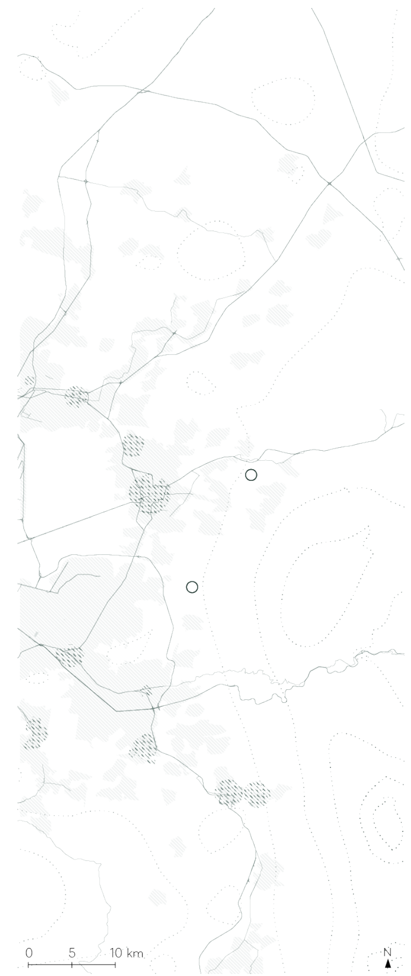


Figure 7.35

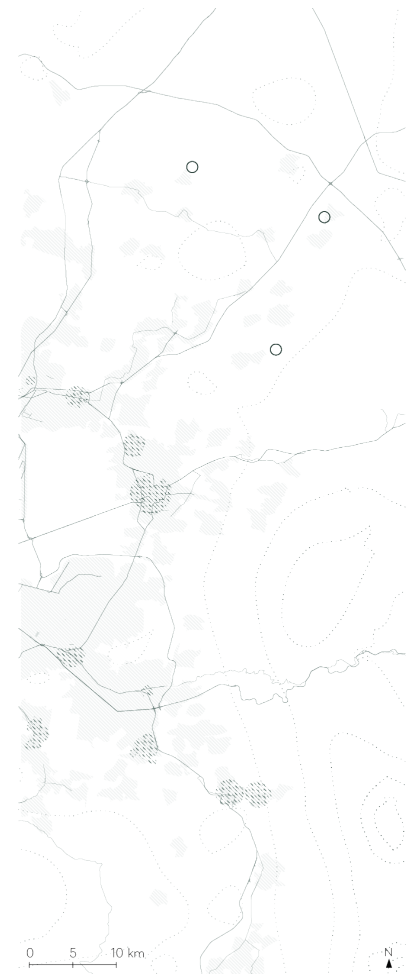


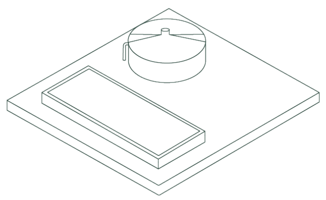
Figure 7.36

Figure 7.35	Figure 7.36
The collaboration between the local and statal governments is necessary for its development	The collaboration between the local and statal governments is necessary for its development
It covers areas in Zone 2 and 3	It covers areas in Zone 3
Social performance: 5.36	Social performance: 3.57
Ecological performance: Cuautitlán Pachuca: 0 Texcoco:4.74 Chalco: 0	Ecological performance: Cuautitlán Pachuca: 3.61 Texcoco: 0 Chalco: 0
Economic performance: 869,000,000 MXN	Economic performance: 1,269,000,000 MXN
Time of deployment: 3 years	Time of deployment: 3 years
Possible stakeholders' involvement: SEDATU/SEDUVYM CONAGUA/CAEM Local and statal governments Ecological impact companies	Possible stakeholders' involvement: SEDATU/SEDUVYM CONAGUA/CAEM Local and statal governments Ecological impact companies

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

Water treatment in existing plants turned into anerobic plants (when source separation)



This intervention would renovate the existing water treatment plants into anaerobic plants with gasoelectrics so that they could work at their 22% of their capacacity and produce energy.
If used it has the capacity to supply water treatment to 78% of the territory, including the current built environment and any future housing development.

It would only treat blackwater, therefore it is necessary for it to be developed along with:
-Source separation interventions

In order to develop the intervention the collaboration between the local and statal governments and CONAGUA/CAEM is needed. Even though CONAGUA.CAEM are in charge of treating the water, the local government are the ones who provide the sewage infrastructure to carry the wastewater to the WTPs.

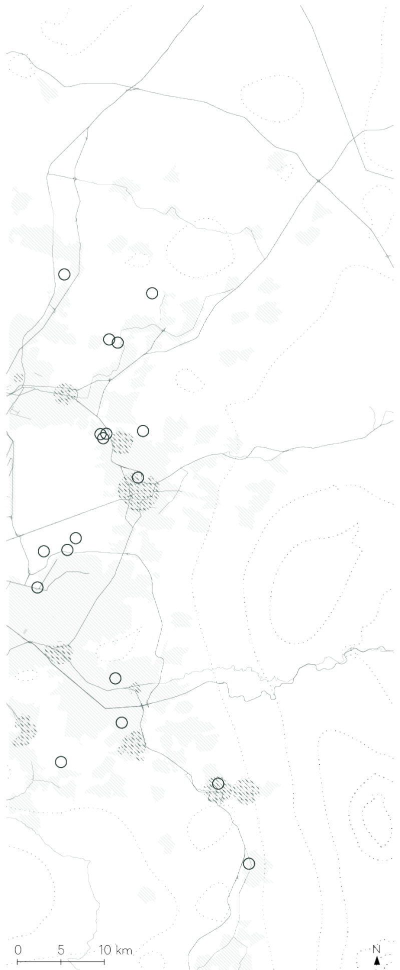


Figure 7.37

It is necessary to be developed along with with Source sepration interventions.

It is also necessary to have a collaboration between the local and statal governments and CONAGUA/CAEM

Social performance: 27.49

Ecological performance:

Cuautitlán Pachuca: 0.75
Texcoco-3.33
Chalco-3.35

Economic performance: 1,622,400,000 MXN

Time of deployment: 5 years

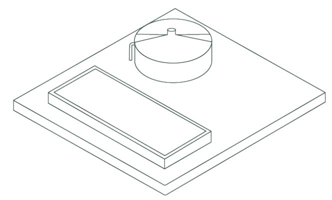
Possible stakeholders' involvement:

SEDATU/SEDUVYM
CONAGUA/CAEM
Local and statal governments
Ecological impact companies

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

Water treatment in new anerobic plants (when source separation)



This intervention would build new water treatment plants with gasoelectrics so that they they could cover the 22% left of the territory that the renovated existing plants cannot reach.

If used, it has the capacity to supply water treatment to 22% of the territory, including the current built environment and any future housing development.

It would only treat blackwater, therefore it is necessary for it to be developed along with:
-Source separation interventions

In order to develop the intervention the collaboration between the local and statal governments and CONAGUA/CAEM is needed. Even though CONAGUA.CAEM are in charge of treating the water, the local government are the ones who provide the sewage infrastructure to carry the wastewater to the WTPs.

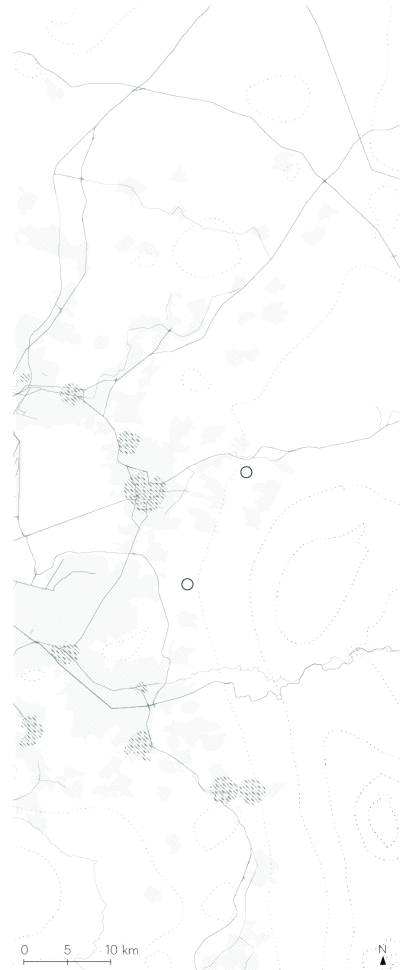


Figure 7.38

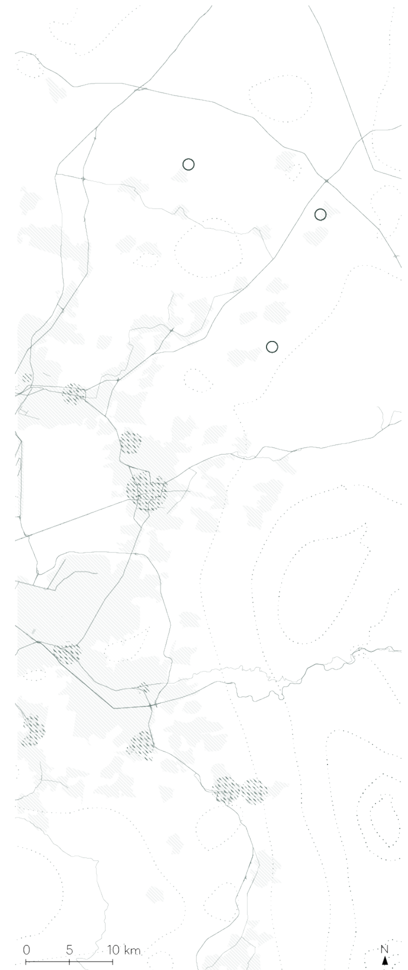


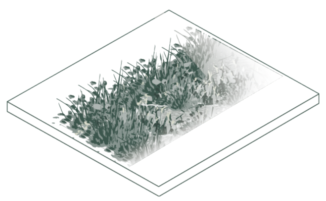
Figure 7.39

Figure 7.38	Figure 7.39
It is necessary to be developed along with with Source sepration interventions. It is also necessary to have a collaboration between the local and statal governments and CONAGUA/CAEM	It is necessary to be developed along with with Source sepration interventions. It is also necessary to have a collaboration between the local and statal governments and CONAGUA/CAEM
Social performance: 4.57	Social performance: 3.13
Ecological performance: Cuautitlán Pachuca: 0 Texcoco-1.23 Chalco- 0	Ecological performance: Cuautitlán Pachuca: 0.94 Texcoco-0 Chalco-0
Economic performance: 225,940,000 MXN	Economic performance: 337,740,000 MXN
Time of deployment: 3 years	Time of deployment: 3 years
Possible stakeholders' involvement: SEDATU/SEDUVYM CONAGUA/CAEM Local and statal governments Ecological impact companies	Possible stakeholders' involvement: SEDATU/SEDUVYM CONAGUA/CAEM Local and statal governments Ecological impact companies

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

Grey water treatment in wetlands in Zone 1



This intervention would build wetlands to treat the greywater from the new housing developments in Zone 1.

It would only treat greywater, therefore it is necessary for it to be developed along with:
-Source separation interventions

In order to develop the intervention the collaboration between the local and statal governments and CONAGUA/CAEM is needed. Even though CONAGUA.CAEM are in charge of treating the water, the local government are the ones who provide the sewage infrastructure to carry the wastewater to the WTPs.

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

Zone 1 (2.5%)

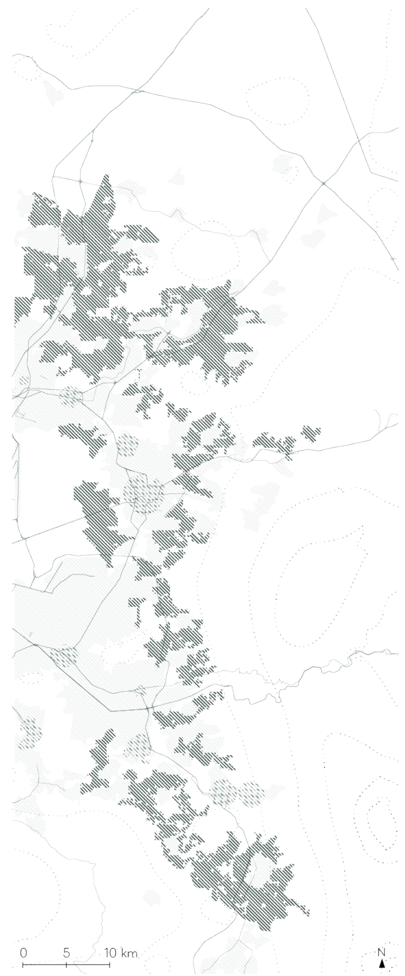


Figure 7.40

Zone 1 (2.5%)
Social performance: 6.1
Ecological performance: Cuautitlán Pachuca: 0.026 Texcoco: 0.014 Chalco: 0.34
Economic performance: 9,519 MXN
Time of deployment: 1 year
Possible stakeholders' involvement: SEMARNAT/SEDEMA Local and Statal governments CONAGUA/CAEM Social housing,developers, social housing civil associations, informal housing civil associations social impact companies, ecological impact companies

Zone 1 (25%)

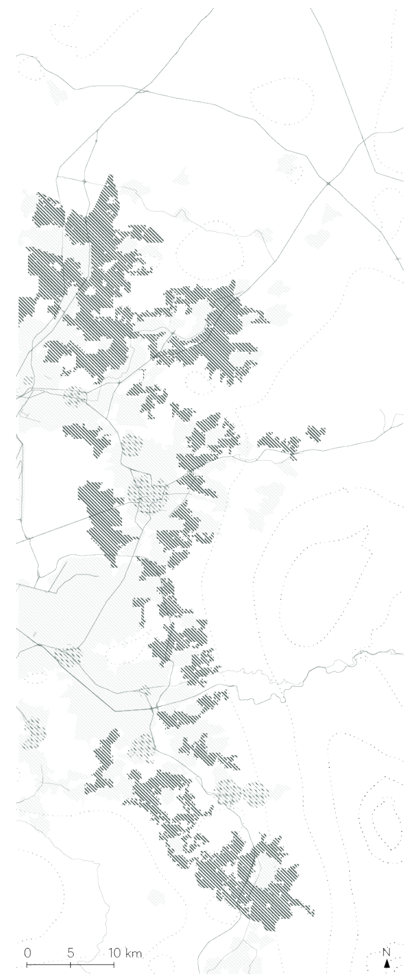


Figure 7.41

Zone 1 (50%)

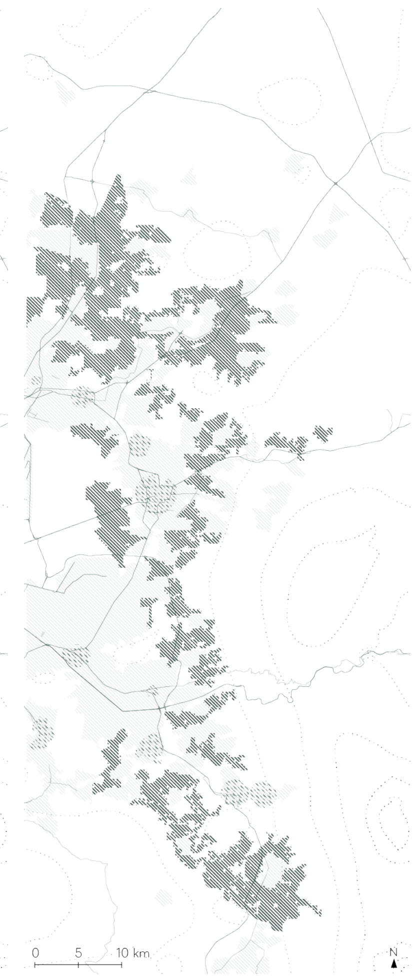


Figure 7.42

Zone 1

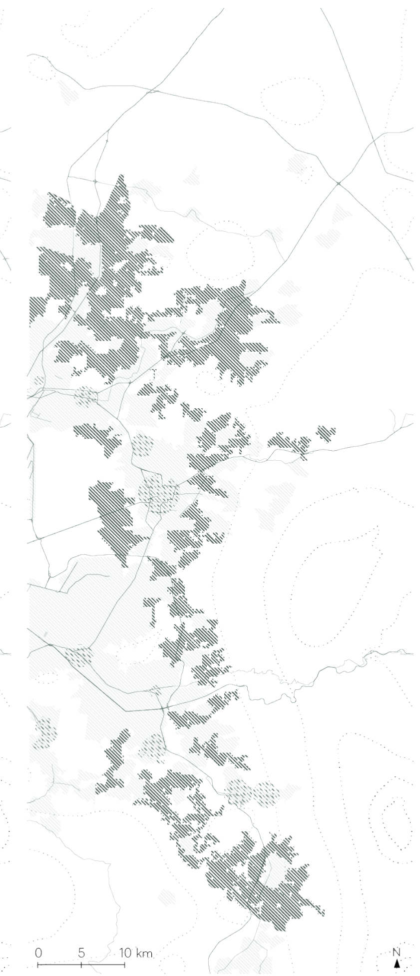
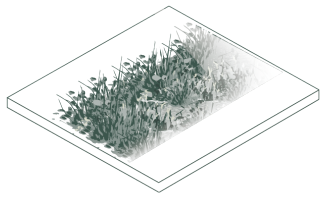


Figure 7.43

Zone 1 (25%)	Zone 1 (50%)	Zone 1
Social performance: 6.1	Social performance: 6.1	Social performance: 6.1
Ecological performance: Cuautitlán Pachuca: 0.05 Texcoco: 0.3 Chalco: 0.76	Ecological performance: Cuautitlán Pachuca: 0.10 Texcoco:0.05 Chalco: 1.53	Ecological performance: Cuautitlán Pachuca: 0.20 Texcoco:0.094 Chalco: 3
Economic performance: 20,696 MXN	Economic performance: 41,604 MXN	Economic performance: 83,000 MXN
Time of deployment: 1 year	Time of deployment: 1 year	Time of deployment: 1 year
Possible stakeholders' involvement: SEMARNAT/SEDEMA Local and Statal governments CONAGUA/CAEM Social housing,developers, social housing civil associations, informal housing civil associations social impact companies, ecological impact companies	Possible stakeholders' involvement: SEMARNAT/SEDEMA Local and Statal governments CONAGUA/CAEM Social housing,developers, social housing civil associations, informal housing civil associations social impact companies, ecological impact companies	Possible stakeholders' involvement: SEMARNAT/SEDEMA Local and Statal governments CONAGUA/CAEM Social housing,developers, social housing civil associations, informal housing civil associations social impact companies, ecological impact companies

Grey water treatment in wetlands in Zone 2



This intervention would build wetlands to treat the greywater from the new housing developments in Zone 2.

It would only treat greywater, therefore it is necessary for it to be developed along with:
-Source separation interventions

In order to develop the intervention the collaboration between the local and statal governments and CONAGUA/CAEM is needed. Even though CONAGUA.CAEM are in charge of treating the water, the local government are the ones who provide the sewage infrastructure to carry the wastewater to the WTPs.

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

Zone 2 (12.5%)

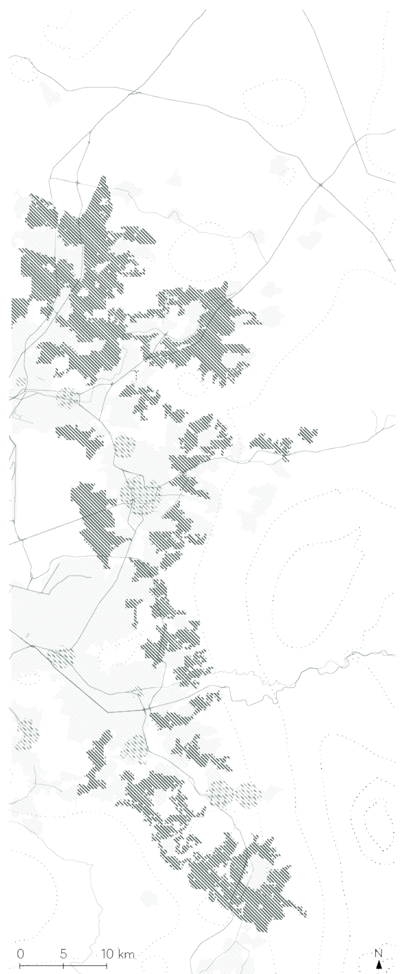


Figure 7.44

Description:

Social performance: 6.1

Ecological performance:

Cuautitlán Pachuca: 0.27
Texcoco: 0.29
Chalco: 0.58

Economic performance: 43,000 MXN

Time of deployment: 1 year

Possible stakeholders' involvement:
SEMARNAT/SEDEMA
Local and Statal governments
CONAGUA/CAEM
Social housing,developers,
social housing civil associations,
informal housing civil associations
social impact companies,
ecological impact companies

Zone 2 (25%)

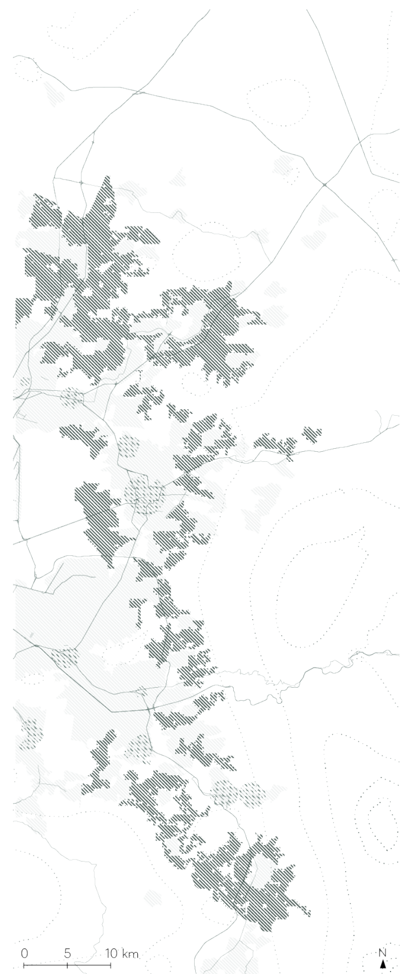


Figure 7.45

Description:

Social performance: 6.1

Ecological performance:

Cuautitlán Pachuca: 0.55
Texcoco: 0.58
Chalco: 1.17-

Economic performance: 86,382 MXN

Time of deployment: 1 year

Possible stakeholders' involvement:
SEMARNAT/SEDEMA
Local and Statal governments
CONAGUA/CAEM
Social housing,developers,
social housing civil associations,
informal housing civil associations
social impact companies,
ecological impact companies

Zone 2 (50%)

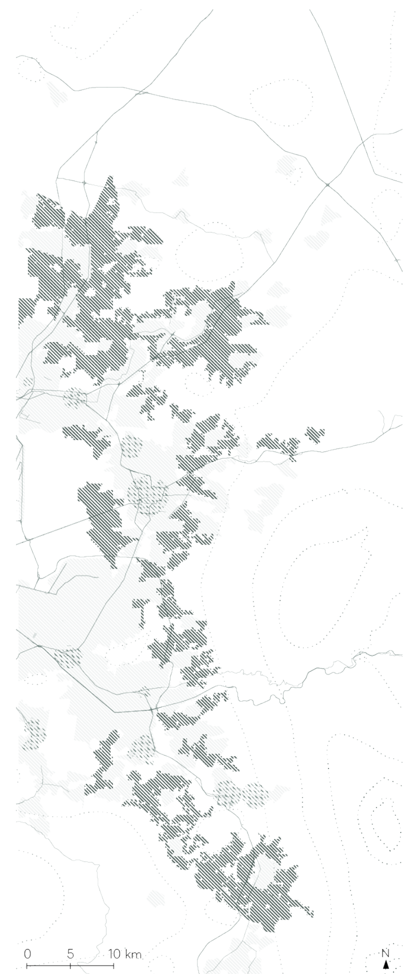


Figure 7.46

Description:

Social performance: 6.1

Ecological performance:

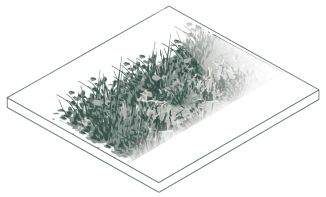
Cuautitlán Pachuca: 1.10
Texcoco:1.13
Chalco: 2.31

Economic performance: 171,001 MXN

Time of deployment: 1 year

Possible stakeholders' involvement:
SEMARNAT/SEDEMA
Local and Statal governments
CONAGUA/CAEM
Social housing,developers,
social housing civil associations,
informal housing civil associations
social impact companies,
ecological impact companies

Grey water treatment in wetlands in Zone 3



This intervention would build wetlands to treat the greywater from the new housing developments in Zone 3.

It would only treat greywater, therefore it is necessary for it to be developed along with:
-Source separation interventions

In order to develop the intervention the collaboration between the local and statal governments and CONAGUA/CAEM is needed. Even though CONAGUA.CAEM are in charge of treating the water, the local government are the ones who provide the sewage infrastructure to carry the wastewater to the WTPs.

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

Zone3 (12%)

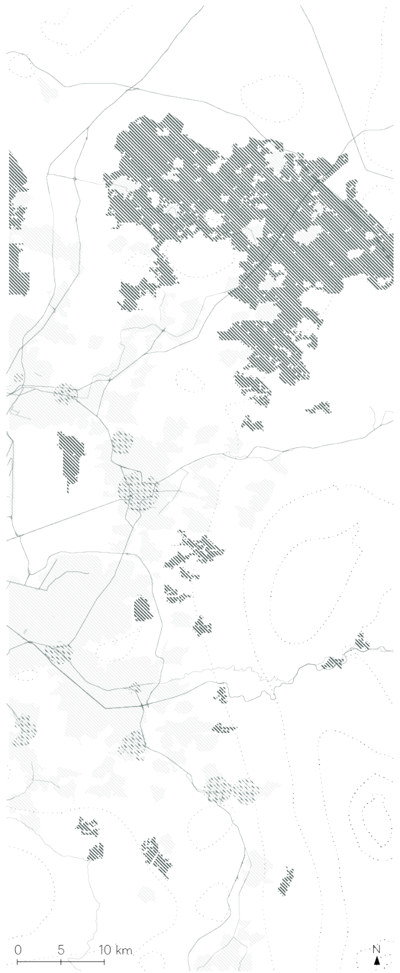


Figure 7.47

Description:

Social performance: 6.1

Ecological performance:

Cuautitlán Pachuca: 0.54
Texcoco: 0.07
Chalco: 0.04

Economic performance: 44,000MXN

Time of deployment: 1 year

Possible stakeholders' involvement:
SEMARNAT/SEDEMA
Local and Statal governments
CONAGUA/CAEM
Social housing,developers,
social housing civil associations,
informal housing civil associations
social impact companies,
ecological impact companies

Zone 3 (25%)

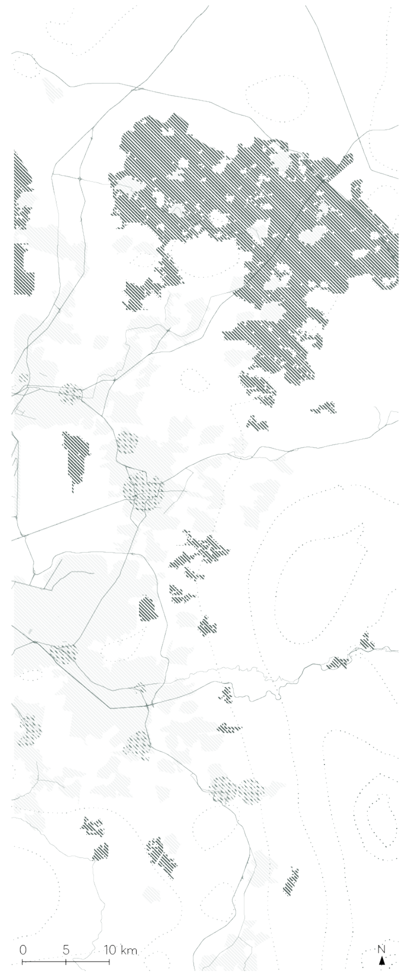


Figure 7.48

Description:

Social performance: 6.1

Ecological performance:

Cuautitlán Pachuca: 1.08
Texcoco: 0.14
Chalco: 0.08

Economic performance: 86,380 MXN

Time of deployment: 1 year

Possible stakeholders' involvement:
SEMARNAT/SEDEMA
Local and Statal governments
CONAGUA/CAEM
Social housing,developers,
social housing civil associations,
informal housing civil associations
social impact companies,
ecological impact companies

Zone 3 (50%

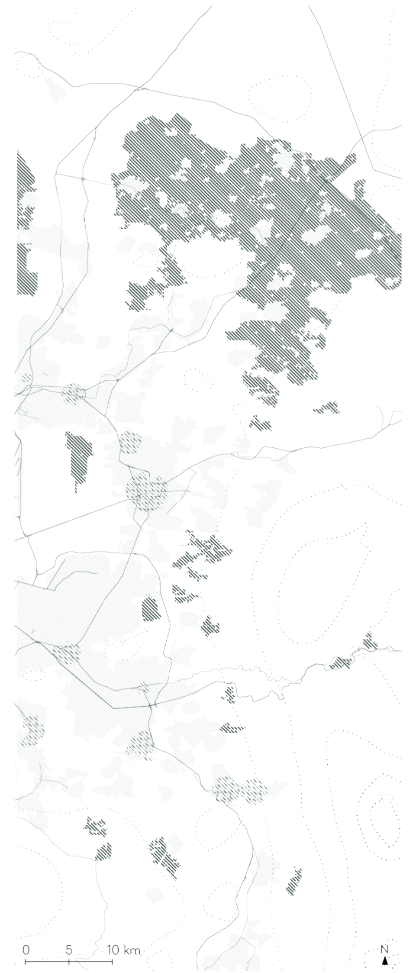


Figure 7.49

Description:

Social performance: 6.1

Ecological performance:

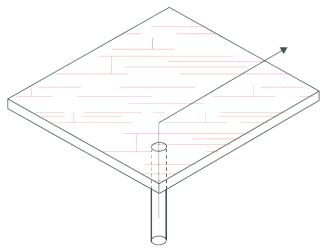
Cuautitlán Pachuca: 2.19
Texcoco: 0.28
Chalco: 0.25

Economic performance: 176, 290 MXN

Time of deployment: 1 year

Possible stakeholders' involvement:
SEMARNAT/SEDEMA
Local and Statal governments
CONAGUA/CAEM
Social housing,developers,
social housing civil associations,
informal housing civil associations
social impact companies,
ecological impact companies

Water extraction from wells at increased rate



This intervention considers the extraction from the wells in the three aquifers in the Meso-scale could be increased to that of 35 m^3/s.if the 2,500,000 new inhabitants (UOIT, 2019) in the MAVM would use the water from the three aquifers in the Meso-scale..

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

Zone 1.5

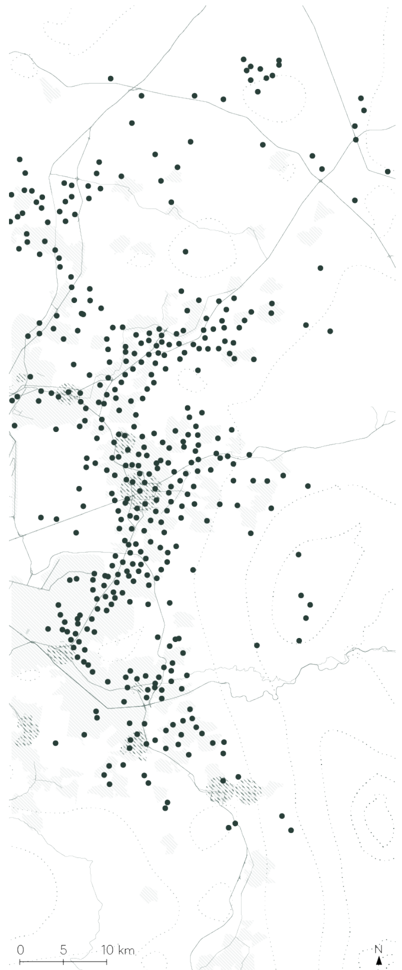


Figure 7.50

Description:

Social performance: 0

Ecological performance:

Cuautitlán Pachuca: -18.25
Texcoco: -94.15
Chalco: -73.69

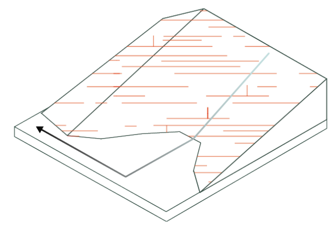
Economic performance: -

Time of deployment: 30 years (gradually)

Possible stakeholders' involvement:

SEMARNAT/SEDEMA
SEDATUSEDUVYM
CONAGUA/CAEM

Discharge of runoff and wastewater at increased rate



This intervention considers the discharge of the wastewater in the MAVM, including the runoff water would increase by 6 m^3/s, according an increase of the population of 2,500,000 new inhabitants (UOIT, 2019).

It does not affect the social-performance of the Meso-scale nor the Macro-scale in in any way. It affects a related ecosystem in the North of the MAVM. It does, however, have a great monetary cost.

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

Zone 1.5

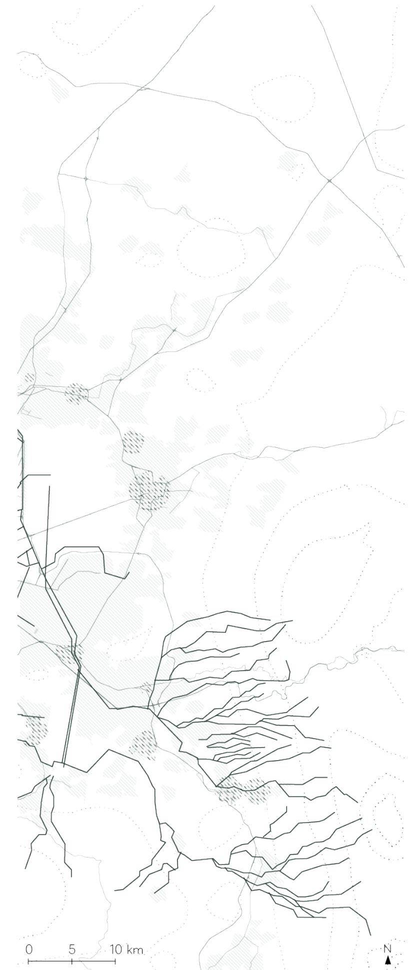


Figure 7.51

Description:

Social performance: 0

Ecological performance: 0-

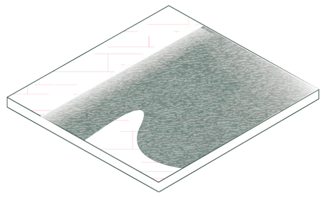
Economic performance:
18,000,000,000 MXN

Time of deployment: 30 years (gradually)

Possible stakeholders' involvement:

SEMARNAT/SEDEMA
SEDATUSEDUVYM
CONAGUA/CAEM

Runoff infiltration in artificial infiltration lagoons



This intervention develops infiltration lagoons in the selected areas. It is divided in four different types of intervention zones, the first does not take into account futue housing developments deployments, prioritising these areas over the housing. The last three prioritse the respective developments in Zone 1, Zone 2 and Zone 3 over the infiltration lagoons.

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

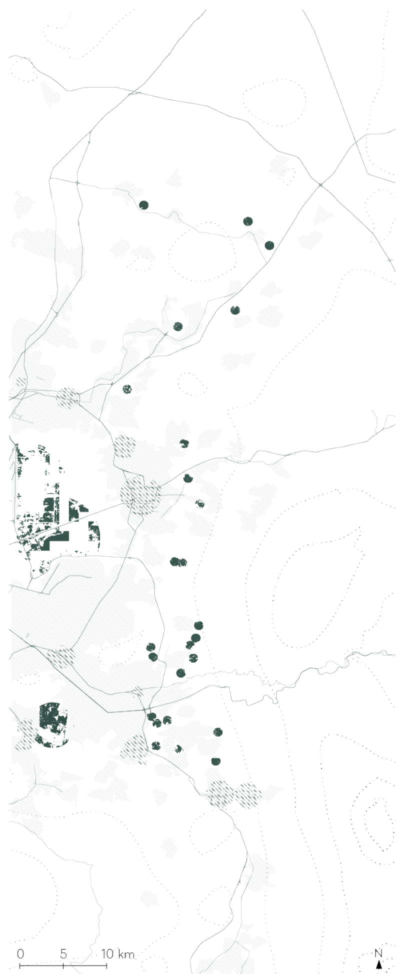


Figure 7.52

Respecting future development in Zone 1

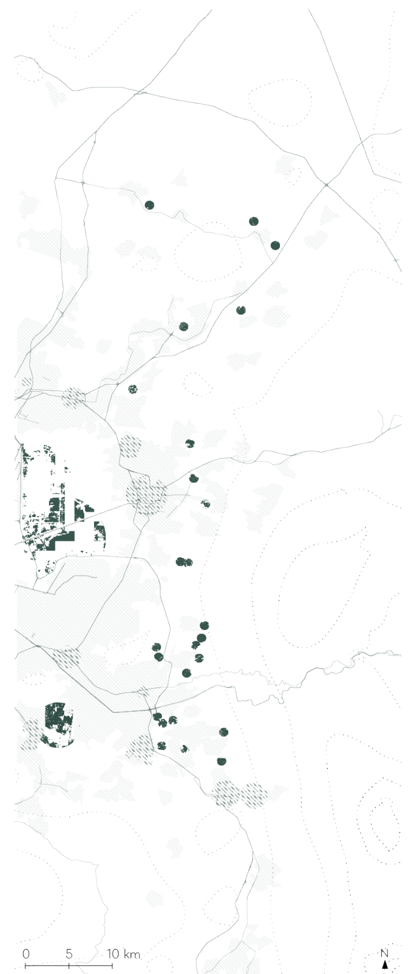


Figure 7.53

Respecting future development in Zone 2

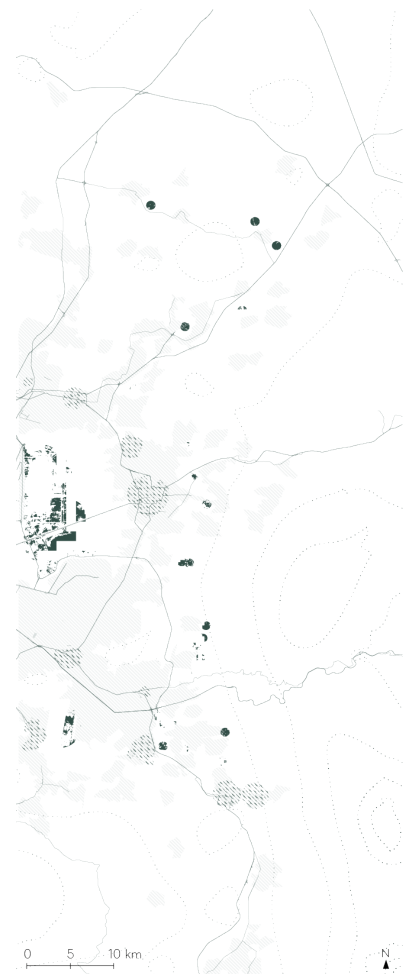


Figure 7.54

Respecting future development in Zone 3

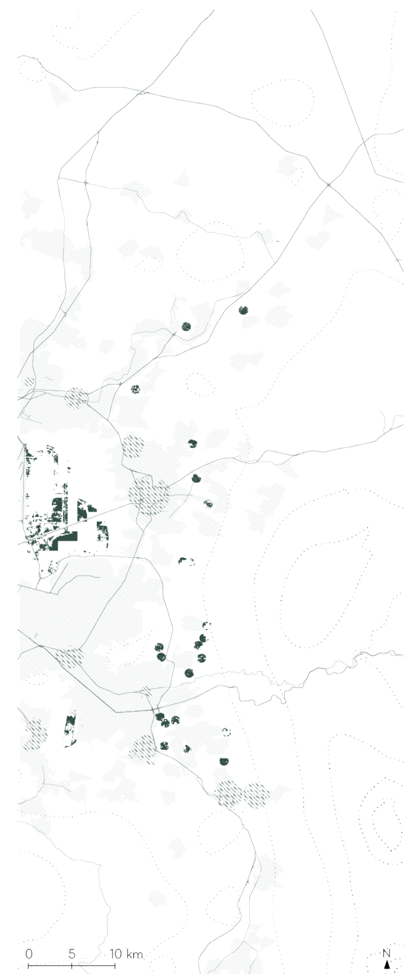
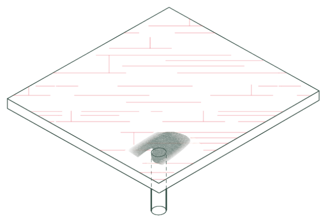


Figure 7.55

Figure 7.52	Figure 7.53	Figure 7.54	Figure 7.55
	The infiltration lagoons respect the development of Zone 1.	The infiltration lagoons respect the development of Zone 2.	The infiltration lagoons respect the development of Zone 3
Social performance: 0	Social performance: 0	Social performance: 0	Social performance: 0
Ecological performance: Cuautitlán Pachuca: 2.05 Texcoco: 5.97 Chalco: 8.69	Ecological performance: Cuautitlán Pachuca: 2.05 Texcoco:5.97 Chalco:8.69	Ecological performance: Cuautitlán Pachuca: 1.5 Texcoco-25.3 Chalco- 6.08	Ecological performance: Cuautitlán Pachuca: 0.89 Texcoco- 32.60 Chalco-11.82
Economic performance: 479,402,000 MXN	Economic performance: 479,402,000 MXN	Economic performance: 333,410,000 MXN	Economic performance: 423,038,000 MXN
Time of deployment: 2 years	Time of deployment: 2 years	Time of deployment: 2 years	Time of deployment: 2 years
Possible stakeholders' involvement: SEMARNAT/SEDEMA SEDATUSEDUVYM CONAGUA/CAEM	Possible stakeholders' involvement: SEMARNAT/SEDEMA SEDATUSEDUVYM CONAGUA/CAEM	Possible stakeholders' involvement: SEMARNAT/SEDEMA SEDATUSEDUVYM CONAGUA/CAEM	Possible stakeholders' involvement: SEMARNAT/SEDEMA SEDATUSEDUVYM CONAGUA/CAEM

Runoff infiltration in artificial infiltration wells



This intervention develops infiltration wells in the selected areas.
It is divided in four different types of intervention zones, the first does not take into account futue housing developments deployments, prioritising these areas over the housing. The last three prioritse the respective developments in Zone 1, Zone 2 and Zone 3 over the infiltration wells.

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

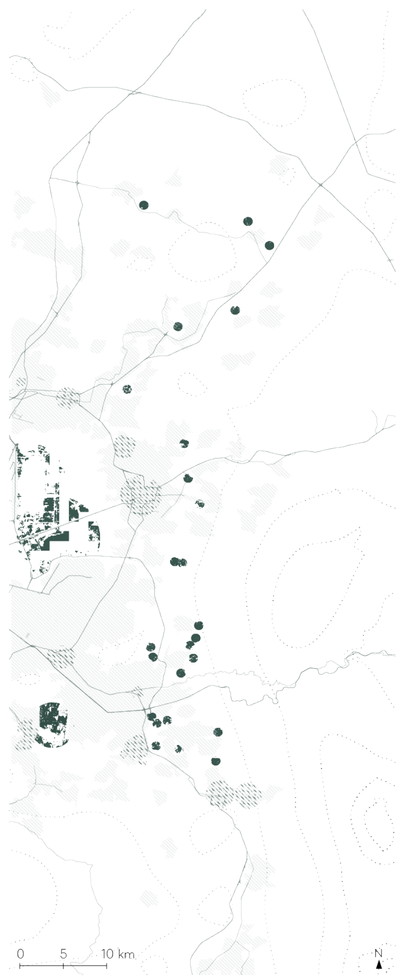


Figure 7.56

Description:

Social performance: 0

Ecological performance:

Cuautitlán Pachuca: 4.53
Texcoco: 4.53
Chalco: 4.53

Economic performance: 382,336 MXN

Time of deployment: 2 years

Possible stakeholders' involvement:

SEMARNAT/SEDEMA
SEDATUSEDUVYM
CONAGUA/CAEM

Respecting future development in Zone 1	Respecting future development in Zone 2	Respecting future development in Zone 3

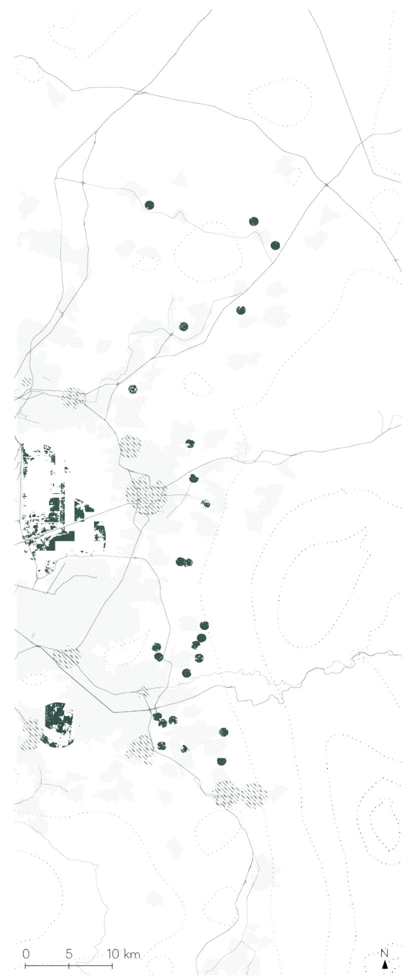


Figure 7.57

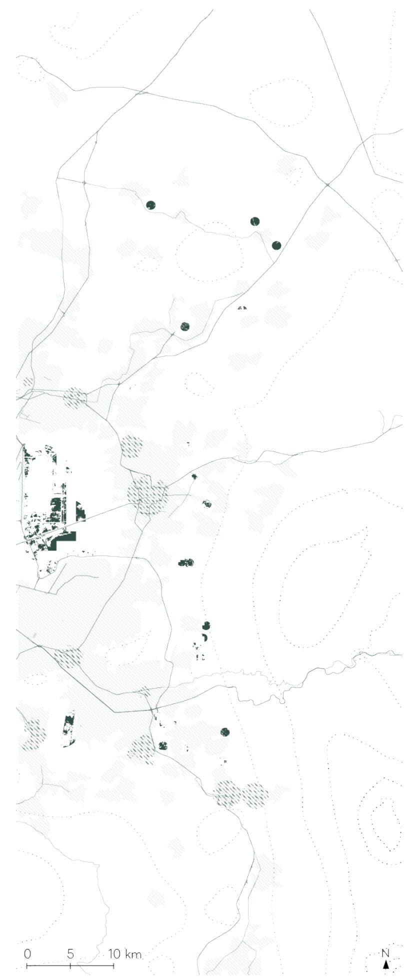


Figure 7.58

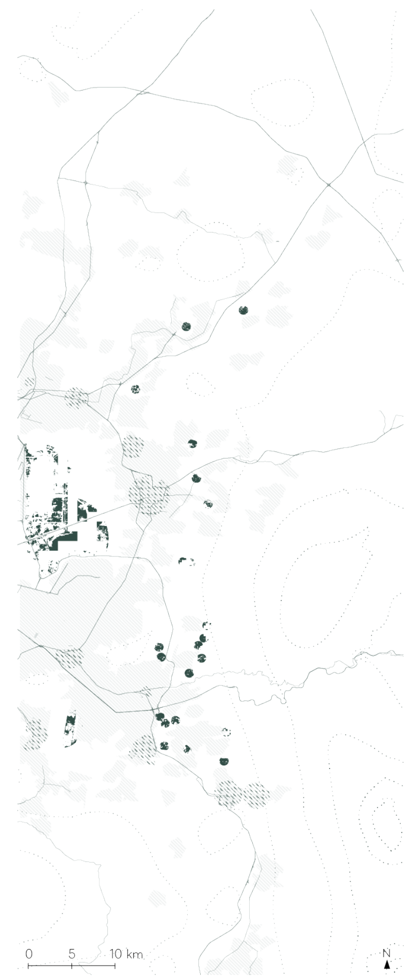
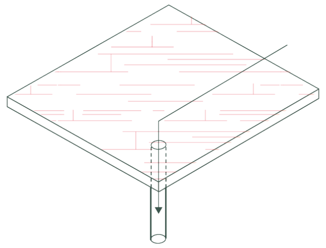


Figure 7.59

The infiltration lagoons respect the development of Zone 1.	The infiltration lagoons respect the development of Zone 2.	The infiltration lagoons respect the development of Zone 3
Social performance: 0	Social performance: 0	Social performance: 0
Ecological performance: Cuautitlán Pachuca: 4.53 Texcoco: 4.53 Chalco: 4.53	Ecological performance: Cuautitlán Pachuca: 4.53 Texcoco: 4.53 Chalco: 4.53	Ecological performance: Cuautitlán Pachuca: 4.53 Texcoco: 4.53 Chalco: 4.53
Economic performance: 382,336 MXN	Economic performance: 382,336 MXN	Economic performance: 382,336 MXN
Time of deployment: 2 years	Time of deployment: 2 years	Time of deployment: 2 years
Possible stakeholders' involvement: SEMARNAT/SEDEMA SEDATUSEDUVYM CONAGUA/CAEM	Possible stakeholders' involvement: SEMARNAT/SEDEMA SEDATUSEDUVYM CONAGUA/CAEM	Possible stakeholders' involvement: SEMARNAT/SEDEMA SEDATUSEDUVYM CONAGUA/CAEM

Water infiltration with inyection wells



This intervention develops inyection wells next to the WTP.
This is the most costly intervention to infiltrate wate and the least efficient over time, as it requires high maintenance. It also requires for the water to be purified with a tertiray treatment before it is inyected.

Zone 1.5

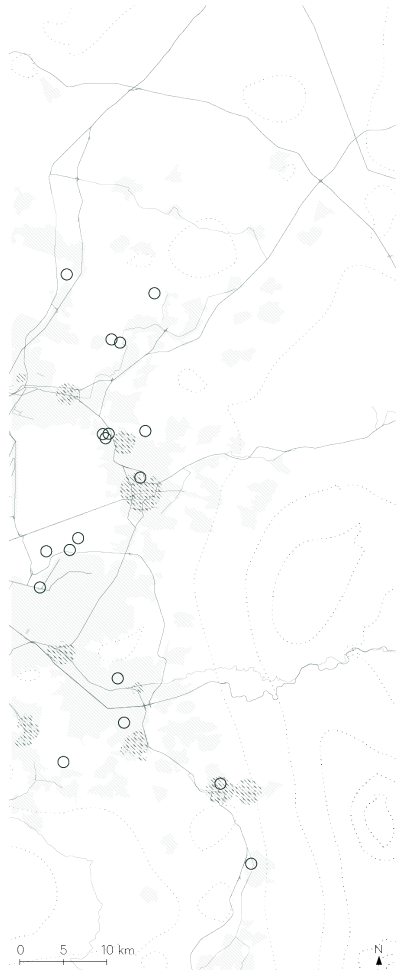


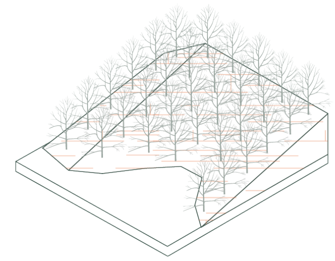
Figure 7.60

Description:
Social performance: 0
Ecological performance: Cuautitlán Pachuca: 0.23 Texcoco: 0.68 Chalco: 0.99
Economic performance: 11,948 MXN
Time of deployment: 5 years
Possible stakeholders' involvement: SEMARNAT/SEDEMA SEDATUSEDUVYM CONAGUA/CAEM

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

Water infiltration with increased vegetation on the hillsides



This intervention decreases the runoff on the hillsides with the use of vegetation.

It is divided in two zones of intervention: the areas with low slope and the areas with high slope.

Low slopes	High slopes

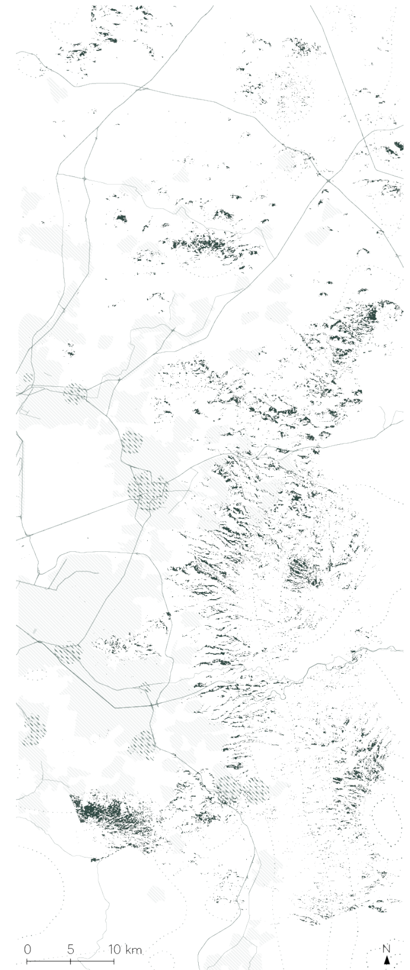
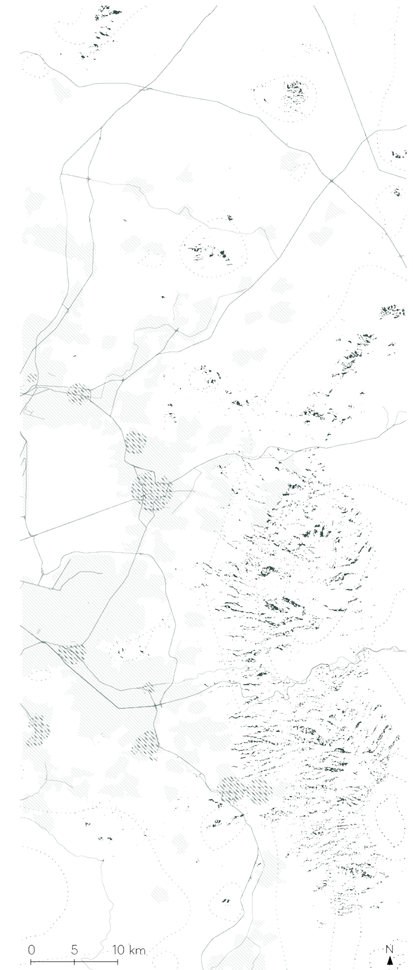
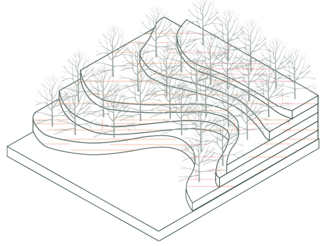

	

Figure 7.61	Figure 7.62
	Description:
Social performance: 0	Social performance: 0
Ecological performance: Cuautitlán Pachuca: 0.88 Texcoco: 2.34 Chalco: 3.74	Ecological performance: Cuautitlán Pachuca: 0.19 Texcoco:1.05 Chalco: 2.05
Economic performance: 1,2444,430,000 MXN	Economic performance: 504,180,000 MXN
Time of deployment: 5 years	Time of deployment: 5 years
Possible stakeholders' involvement: SEMARNAT/SEDEMA SEDATUSEDUVYM CONAGUA/CAEM	Possible stakeholders' involvement: SEMARNAT/SEDEMA SEDATUSEDUVYM CONAGUA/CAEM

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

Water infiltration with terracing on the hillsides



This intervention decreases the runoff on the hillsides with the use of terracing.

It is divided in two zones of intervention: the areas with low slope and the areas with high slope.

Low slopes	High slopes

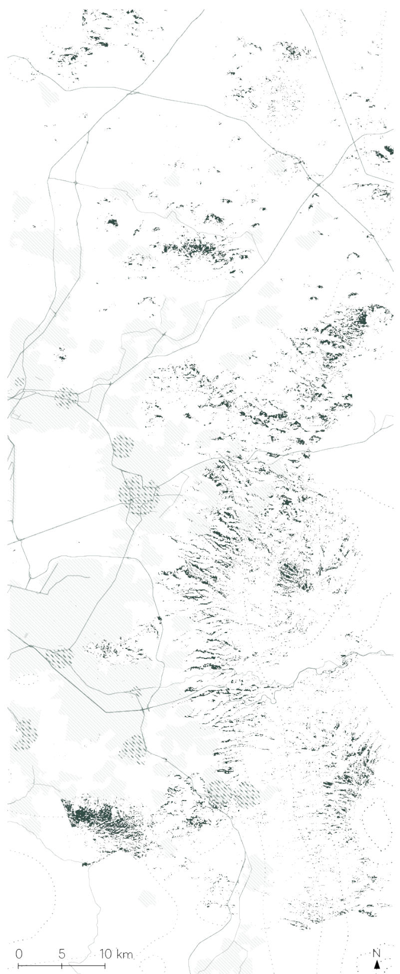
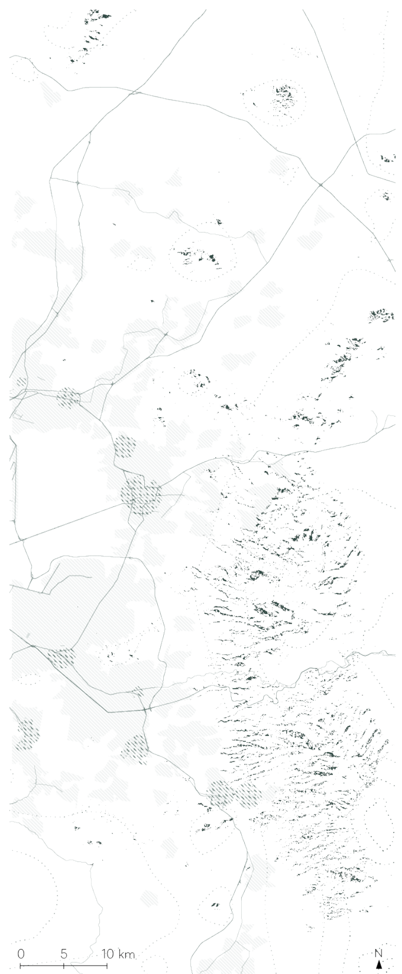

	

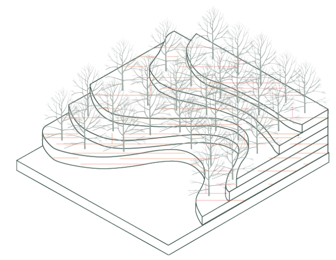
Figure 7.63	Figure 7.64

Low slopes	High slopes
Description:	Description:
Social performance: 0	Social performance: 0
Ecological performance: Cuautitlán Pachuca: 0.62 Texcoco: 1.66 Chalco: 2.65	Ecological performance: Cuautitlán Pachuca: 0.13 Texcoco: 0.79 Chalco:1.45
Economic performance: 290,048,979 MXN	Economic performance: 1117,513,154 MXN
Time of deployment: 5 years	Time of deployment: 5 years
Possible stakeholders' involvement: SEMARNAT/SEDEMA SEDATUSEDUVYM CONAGUA/CAEM	Possible stakeholders' involvement: SEMARNAT/SEDEMA SEDATUSEDUVYM CONAGUA/CAEM

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

Water infiltration with increased vegetation and terracing on the hillsides



This intervention decreases the runoff on the hillsides with the use of vegetation and terracing.

It is divided in two zones of intervention: the areas with low slope and the areas with high slope.

Low slopes	High slopes

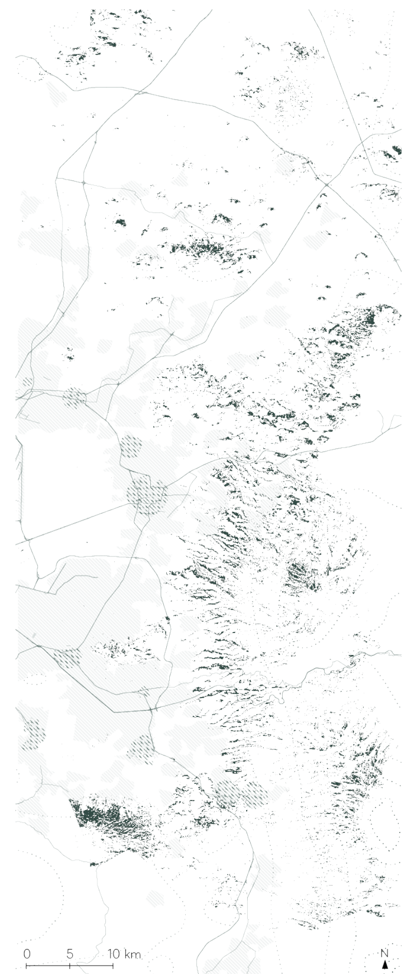
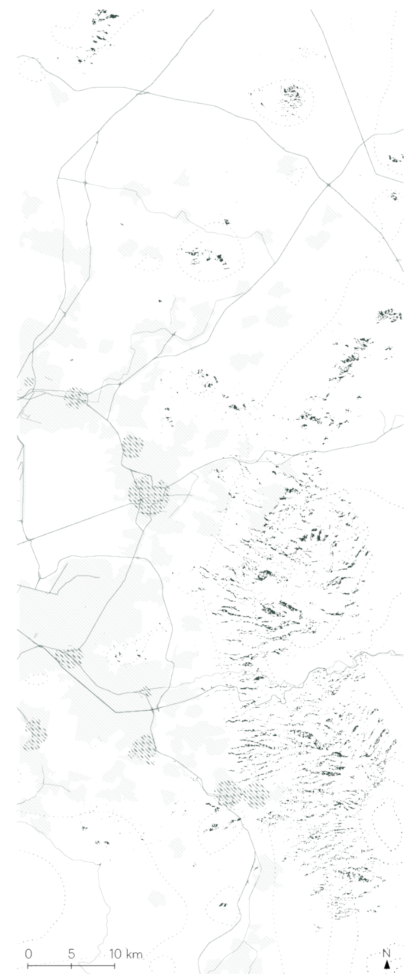

	

Figure 7.65	Figure 7.66

Low slopes	High slopes
Description:	Description:
Social performance: 0	Social performance: 0
Ecological performance: Cuautitlán Pachuca: 1.15 Texcoco: 3.06 Chalco: 4.88	Ecological performance: Cuautitlán Pachuca: 0.25 Texcoco: 1.37 Chalco: 2.67
Economic performance: 1,534,479,000 MXN	Economic performance: 621,693,154 MXN
Time of deployment: 5 years	Time of deployment: 5 years
Possible stakeholders' involvement: SEMARNAT/SEDEMA SEDATUSEDUVYM CONAGUA/CAEM	Possible stakeholders' involvement: SEMARNAT/SEDEMA SEDATUSEDUVYM CONAGUA/CAEM

Urban water system

- Future housing development
- WTP
- Extraction wells
- Infiltration areas
- Employment centers
- Built environment
- Primary street network

8. Researcher's development of the Process, Evaluation, Change, and Impact Models *Modelling II*

This chapter presents the second sub-iteration of the Modelling Iteration. In this sub-iteration the researcher realised the first part of the mixed-anticipatory-agent based modelling method by developing the Process and the Change Models and assessing them with the Evaluation and Impact Models accordingly.

The Process Model evaluated the Meso-scale based on its social-ecological performance and on its governance performance over the Macro-scale, while the Change Model evaluated the Meso-scale based on its social-ecological, governance and regenerative performance.

In an analogue way, as in the previous chapter, each of the methods that assisted to develop the models appears with their corresponding results, therefore in this Chapter the method used for defining and modelling the three mentioned indicator performances is explained prior to the presentation of the results.

Defining the performance indicators

This section presents the performance indicators used to assess the Meso-scale. Overall, assessing the regenerative performance of a region in question is the main objective. The main indicator of regenerative performance is in turn made up of the social, the ecological and the governance performance indicators. Figure 8.1 gives an overview of the breakdown of the indicators and their corresponding formulas , while the subsequent sections will elaborate on the definition of the individual indicators and their computation.

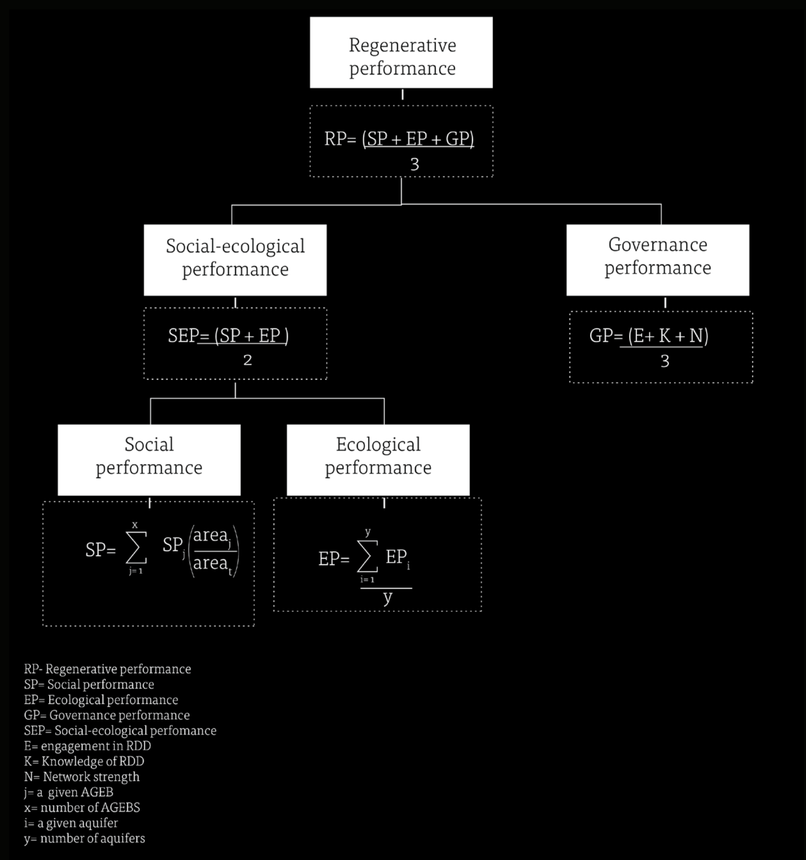


Figure 8.1 Overview of the regenerative perfomance indicators

Defining the regenerative performance

The regenerative performance of the area is the number one criterion that was assessed. It is a function of the social performance (SP), the ecological performance (EP) and the governance performance (GP), defined as the sum of individual performances, divided by the number of indicators, hence:

$$RP = \frac{(SP + EP + GP)}{3}$$

Formula 8.1 Regenerative performance of the Meso-scale

Defining thegovernance performance of the Meso-scale

Similarly, to the definition of the regenerative performance, the governance performance is made up from 3 factors. It is given by the mean value of the engagement of the stakeholders engagement in regeneration, their knowledge on regeneration, and lastly the strength in their network.The values for each of the variables ae given as a qualittaitve ranking assessed by th researcher and the stakeholders on a scale form 1 to 5.

$$GP = \frac{(E + K + N)}{3}$$

Formula 8.2 Governance performance of the Meso-scale

Defining the ecological performance of the Meso-scale

Chapter 7 presented the defining and modelling method to assess the performance of each intervention per aquifer. This section presents the defining and modelling method to assess the performance of the Meso-scale, once a set of interventions is given as a development strategy. The total ecological performance, indicating the performance of all the aquifers in the assessed scale, is then calculated by summing each individual aquifer performance for a given set of interventions. Repeating this process for alternative intervention scenarios, then allows for comparing the ecological performance of current to potential interventions.

$$EP = \frac{\sum_{i=1}^{y} EP_i}{y}$$

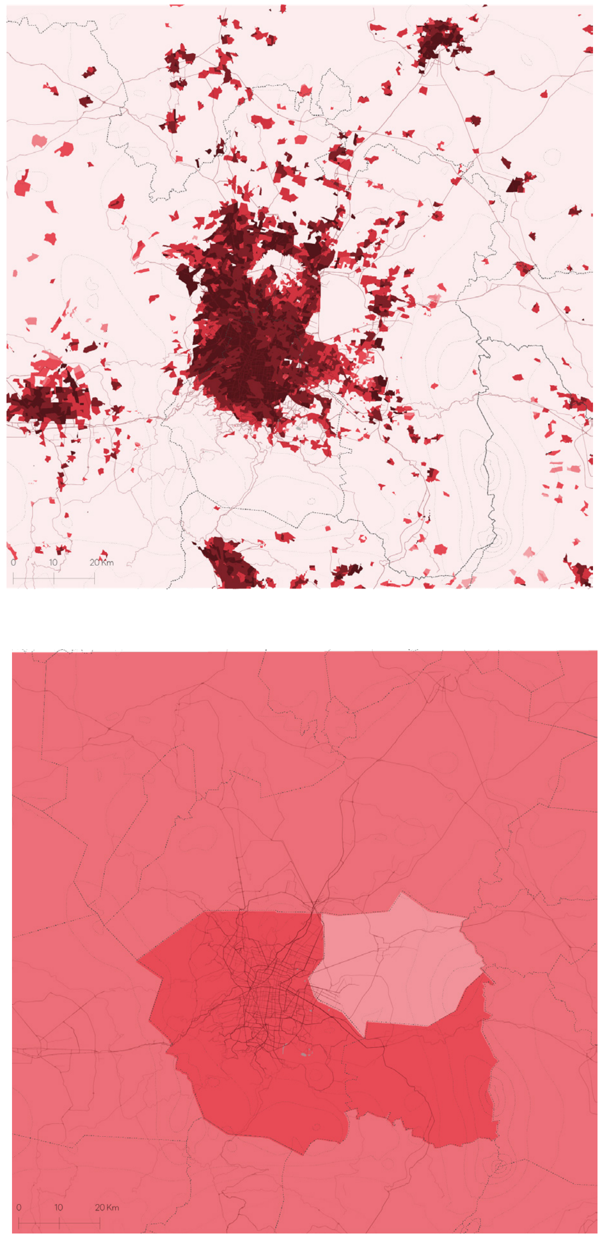
Formula 8.3 Ecological performance of the Meso-scale

Defining the ecological performance of the Meso-scale

Analogously, as with the ecological performance, Chapter 7 presented the defining and modelling method to assess the performance of each intervention per AGEB. This section presents the defining and modelling method to assess the social- performance of the Meso-scale, once a set of interventions is given as a development strategy. The total social performance, thus, indicates the performance of all the AGEBS and future development areas in the assessed scale. It is then calculated by summing each of the individual AGEB relative performance (according to their area within the total area of the MAVM) as indicated on Formula 8.4.

$$SP = \sum_{j=1}^{x} SP_j \left(\frac{area_j}{area_t}\right)$$

Formula 8.4 Social performance of the Meso-scale

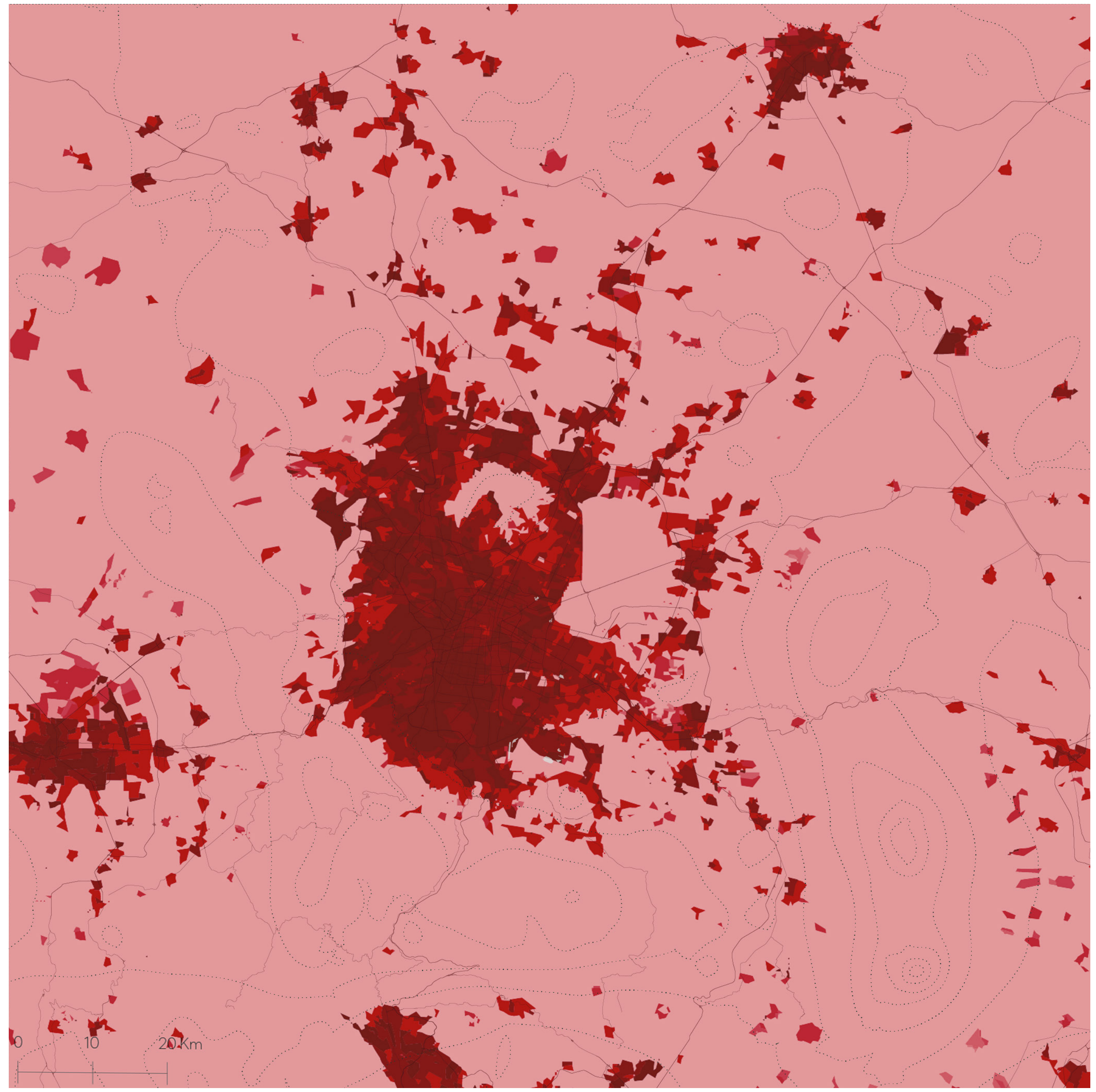


Social-ecological performance

10

1

Figure 8.2 The maps show the social (top) and the ecological (bottom) evaluation of the of the MAVM (Elaborated with data from INEGI, 2010 and CONAGUA 2019.)



Social-ecological performance

10

1

Figure 8.3 The map show the social-ecological evaluation of the of the MAVM (Elaborated with data from INEGI, 2010 and CONAGUA 2019.)

8.1 Researcher's Process and Evaluation Model

This section presents the selection of the interventions that the researcher considered, based on experience and gathered knowledge, that the stakeholders would invest on, as well as their resulting social-ecological and governance performance in the Meso-scale.

Figures 8.4 and 8.5 presents the set of interventions that would take place under a Business-as-Usual Scenario. Housing would be developed in areas distant from any employment centers (Zone 3). The existing water treatment plants would be used at their current capacity, although probably some others might be developed by the CAEM, therefore the addition of 2 new ones was considered. The extraction of groundwater would be incremented, and the increment of wastewater discharge as well.

Researcher's Business as-Usual-Development

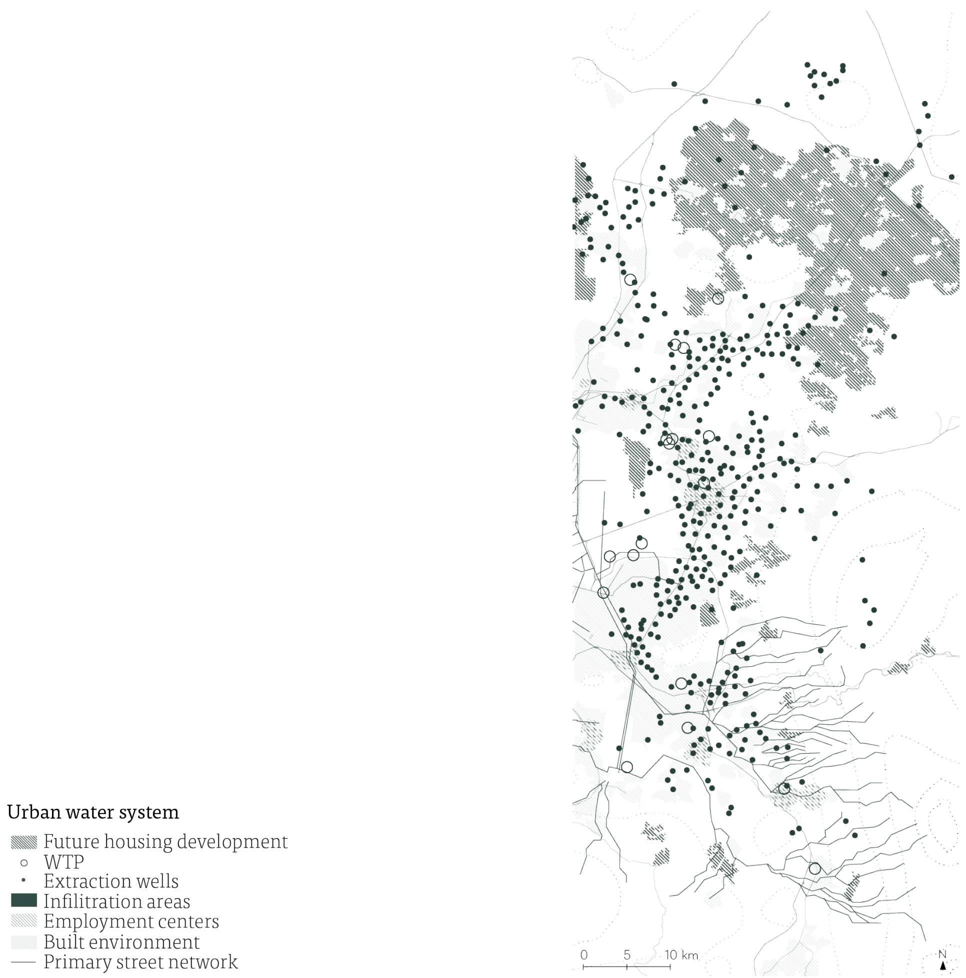


Figure 8.4 Spatial dimension of the Business-As-Usual scenario developedby the researcher

Figure 8.5 Investments that of each of the stakeholders would have over the interactions as foreseen by the researcher. The coloured circles indicate physical interventions that primary stakeholders would invest on, while the contoured circles indicate policies that secondary stakeholders would promote. A green line indicates if there would be any type of collaboration amongst the stakeholders when doing the investments.

Social-ecological evaluation of the Researcher's Business-as-Usual development

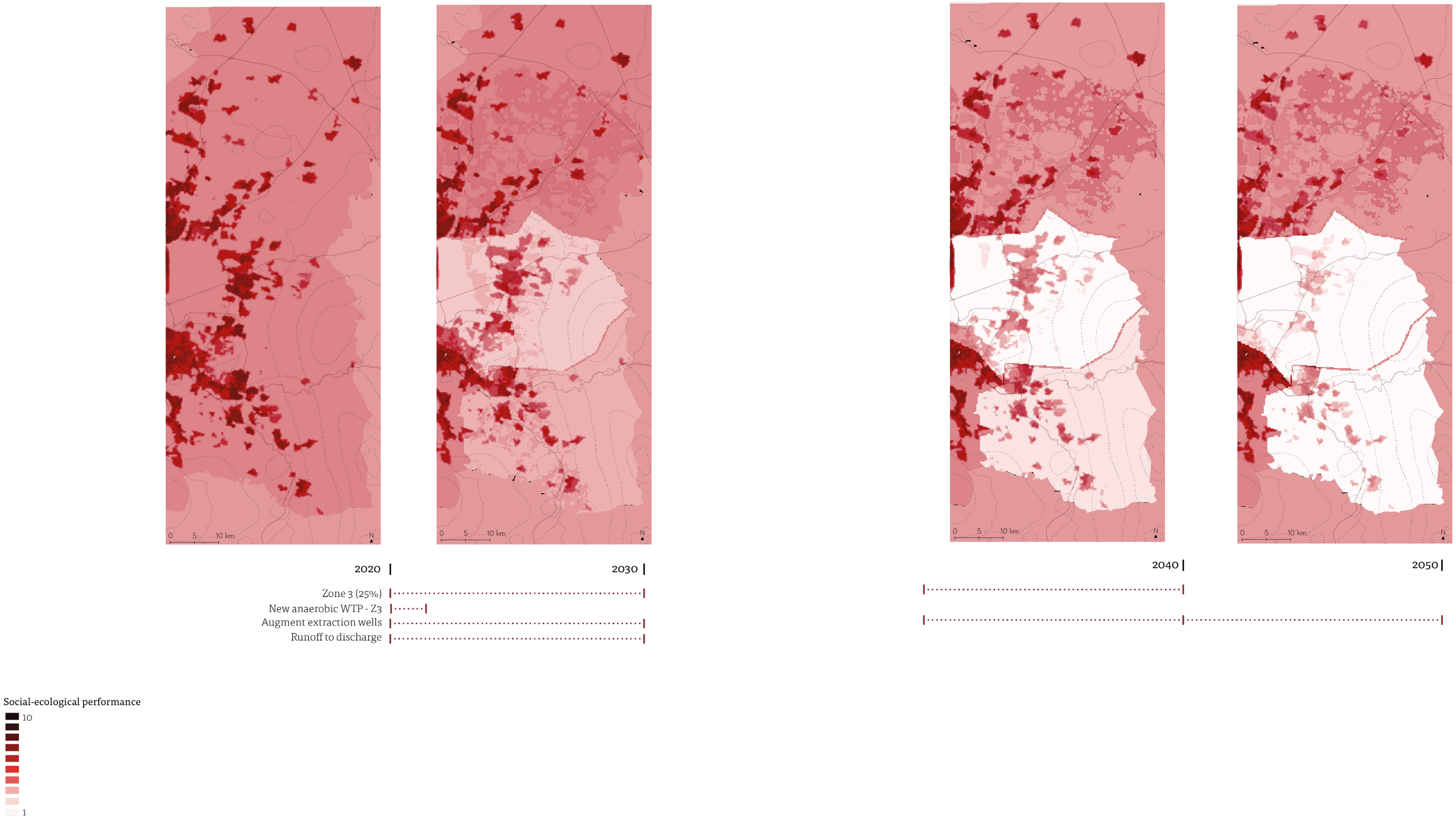


Figure 8.6 Social-ecological evaluation of the investments over time, according to their time of deployment. The development of social housing in Zone 3, increments the accesibility to infrastructure and services in the rural areas where they are deployed, however it does so with a very minimal increment, as the assessment of the performance takes into account that the developers will not fully provide such infrastructure, and that the areas are relatively far away from any subcentrality. (...)

(...) On the other hand, the investment in the new added water treatment plants also increments the social-ecological performance, however the increment of the extraction of the groundwater causes the overall decrement of the performance over time.

Governance evaluation of the Researcher's Business-as-Usual development

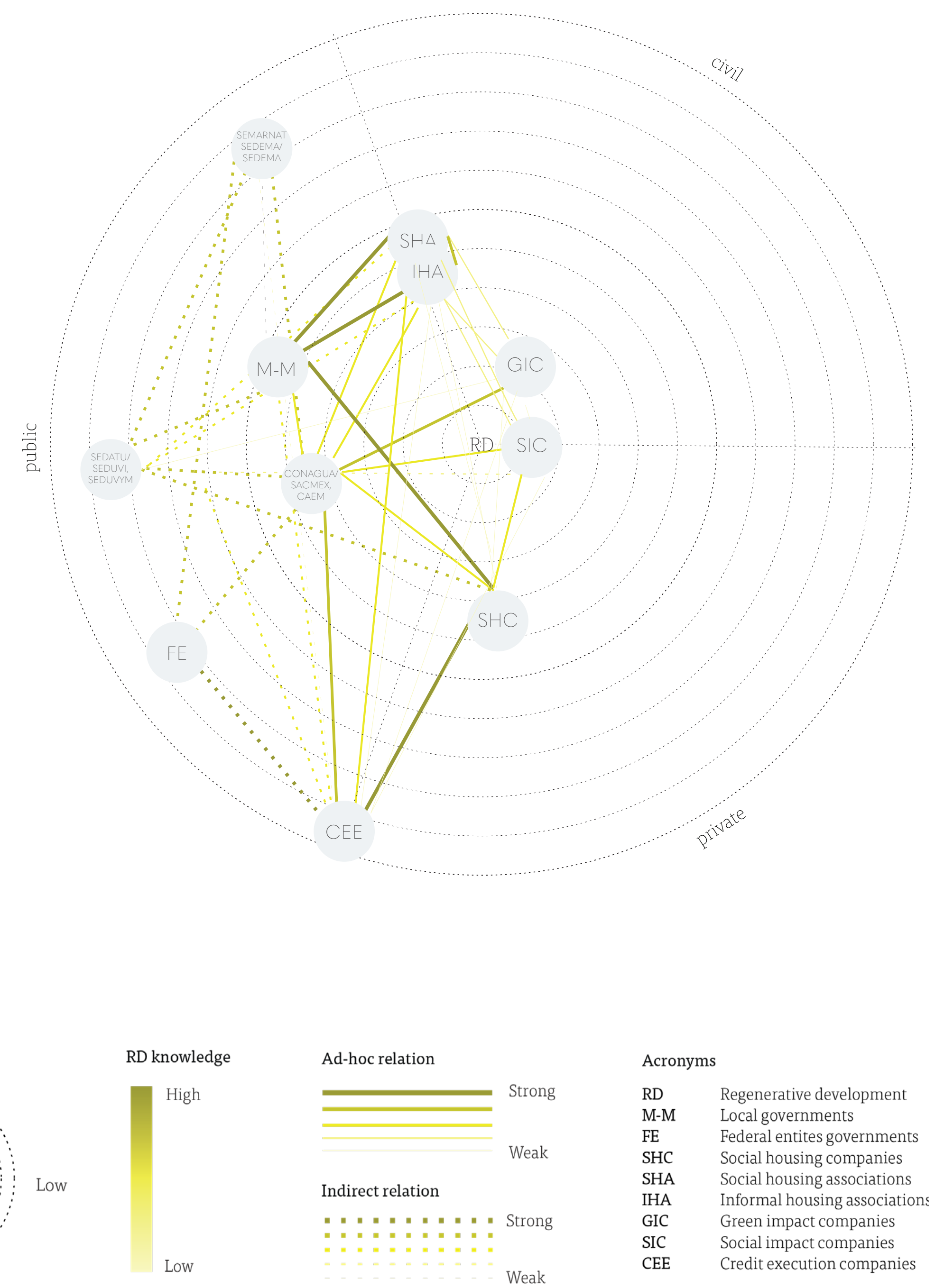


Figure 8.7 Onion scheme depicting the stakeholder's engagement in regenerative approaches and the strength of their network[15], based on the researcher's analysis of literature review and interviews.

15. Refer to Appendix 12 for a detailed information on the stakeholder's associatedness ranking.

The diagram on Figure 8.7, indicates the knowledge that the stakeholders have over regenerative development, their engagement in the topic, and their network strength. As mentioned previously in the chapter, the governance performance of the developed Process and Change Models is the mean function of the three mentioned aspects. The governance performance is expressed in this section and in further sections, in the form of a diagram which was adapted from Czischke's (2018) own adaptation of Sudiyono's diagram (2013), and Alexander & Robertson's (2004).

The original stakeholder onion diagram was developed by Alexander & Robertson in 2004 (Czischke, 2017) to visualize the relationships of the stakeholders towards a project goal. Further on, Sudiyono and Czischke have adapted it by 1) distingushing three different domains to which the stakeholders belong to, either the civil, the public, or the private spheres, by 2) categorising the stakeholders in three different levels of roles, and by 3) establishing three different types of relationships amongst the stakeholders (Czischke, 2017).

The stakeholders are categorised according to their roles based on their legitimacy, their control over essential resources, and whether they have a veto over the project or not. The resulting categories are as follows. The primary stakeholders hold a significant influence in the project, with strong legitimacy and/ or control over the essential resources, and a veto. They are most of the times, the users of the project who are involved in the day-to-day operations of the interventions, in this project specifically they are the social and informal housing developers and civil associations, the green-impact or social-impact companies, CONAGUA/CAEM, and the municipalities and mayoralties. The secondary stakeholders hold a relative influence in the project, but are not involved in day-to-day operations. These are are the regulatroy authories like SEMARNAT/SEDEMA, SEDATU/SEDUVI, the federal entities governments and the credit exectuion companies. [16]. Lastly, the wider environment are stakeholders with individuals or organisations that are indirectly affected by the project. They have minimal legitimacy or control over the resources, and no veto whatsoever. These are suppliers, the media, or financial beneficiaries. In the case of the research, the diagram only considers the first two different types of roles, as no stakeholders from the wider environment were included in the study. Further, the type of relationships amongst the actors can be either strong, ad-hoc, or indirect.A strong collaboration indicates constant and interdependent operational aspects of the project. An ad-hoc collaboration indicates a relation based on technical matters such as financing or the provision of services. An indirect relationship indicates a legal or regulatory relation.

The diagram served as a perfect basis for representing the strength of the network amongst the actors, as it represents which actors have a regulatory role, and which ones are involved in an operational way to the project, and because it also depitcts what type of relationships are held amongst them. It was, then, further enhanced, so that the lines that indicate the relationships would also indicate how strong those relationships are. Therefore, the thicker and darker the line, the stronger the relationship is. The diagram was also modified so it could indicate within their roles, how engaged each of the actors are to regenerative development. For this each of the rings was divided in 5 sub-rings, the closer the stakeholder is positioned to the center within each ring, the more engaged it is with regenerative approaches. Lastly, one last modification was realised so that the diagram could also express how much knowledge about regeneration, does the stakeholder have. For such, the darker the color of their icon, the more the knowledge they have. In the case of the diagrams for the Process and the Change Models in this chapter, the icons have no color as the researcher could not judge previouly to developing surveys how much knowledge did the actors have about regenerative development.

16 Regulatory institutions were included as secondary stakeholders, even though Czichske classifies as them as the wider environment. More over, the mayoralties and muncipalities would be normally be considered secondary stakeholders, however in the research they are considered as primary actors, because they are in charge of the provision of water and sewage infrastructure.

8.2 Researcher's Change and Impact Model

This section presents the selection of the interventions that the researcher considered, based on experience and gathered knowledge, the stakeholders should invest on to achieve a regenerative development, as well as their resulting social-ecological and governance performance in the Meso-scale.

Figures 8.8 and 8.9 presents the set of interventions that would take place under a Regenerative Development Scenario. Housing would be developed in areas close to employment centers (Zone 1) and investments on rainwater catchment systems and source separation would be realised in new and previous developments. Water treatment plants would be turned into anaerobic, and blackwater and greywater would be treated in the anaerobic WTP and in wetlands respectively. More investmenes would be realised over infiltration lagoons, and to increase the vegetation and terracing on the hillsides. Overall, more collaboration amongst the stakeholders is expected to take place in this scenario.

Stakeholder's Regenerative-Strategy

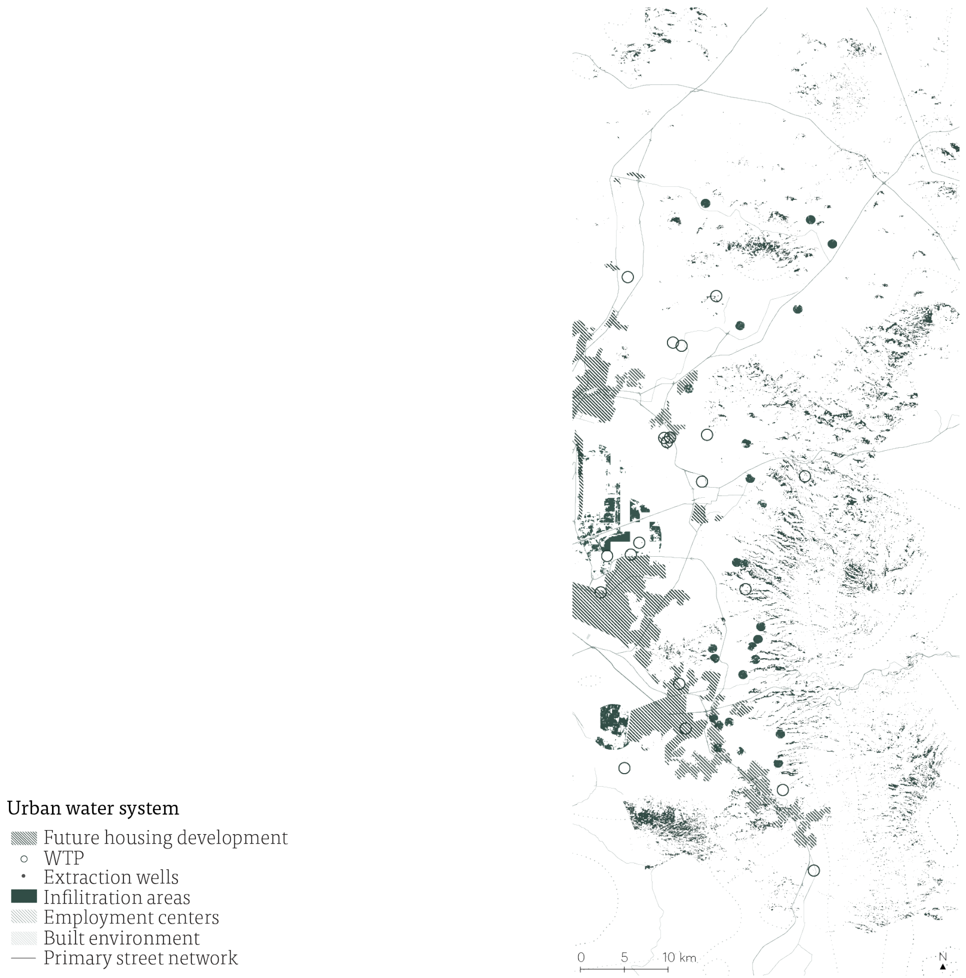


Figure 8.8 Spatial dimension of the Regenerative Development scenario developed by the researcher

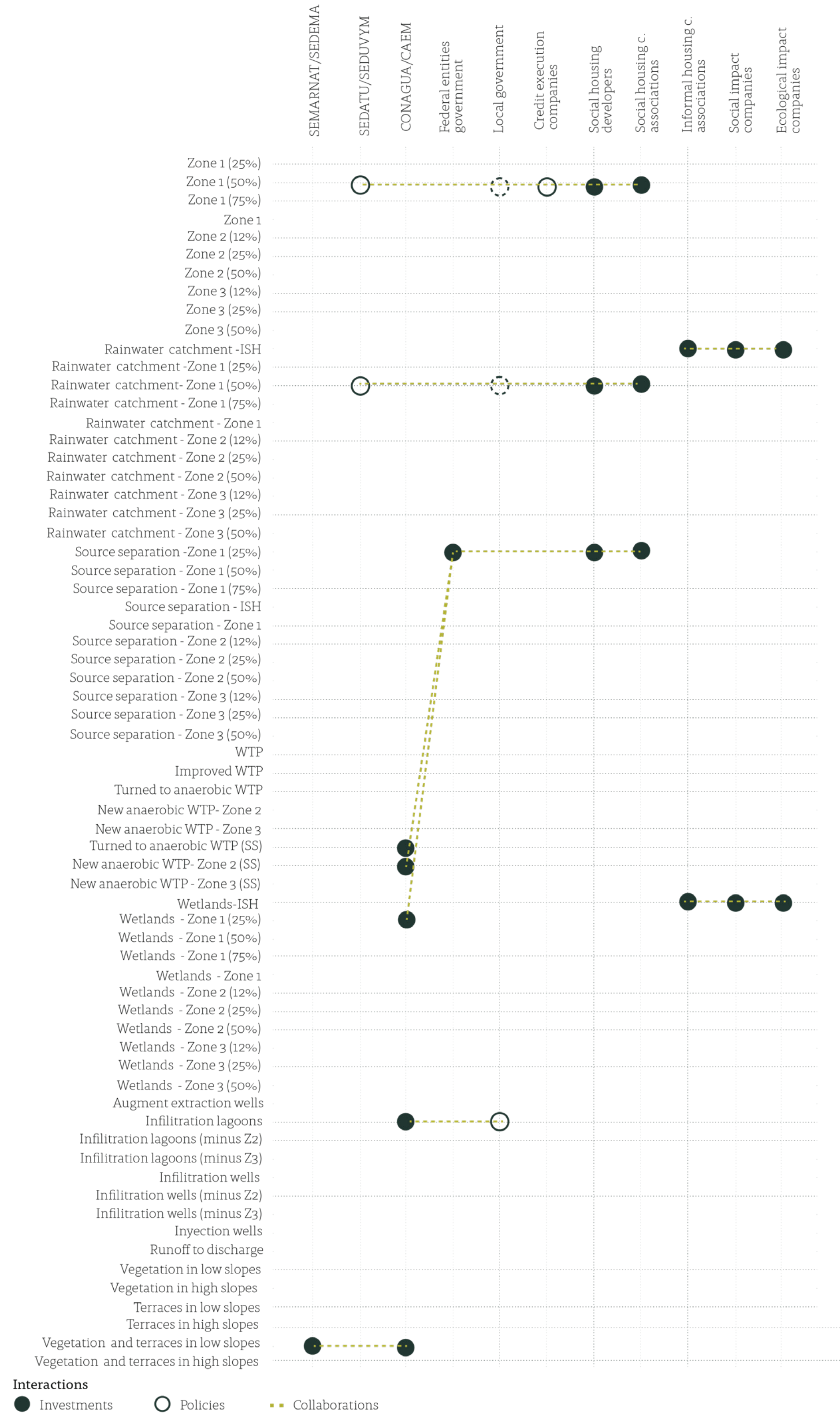
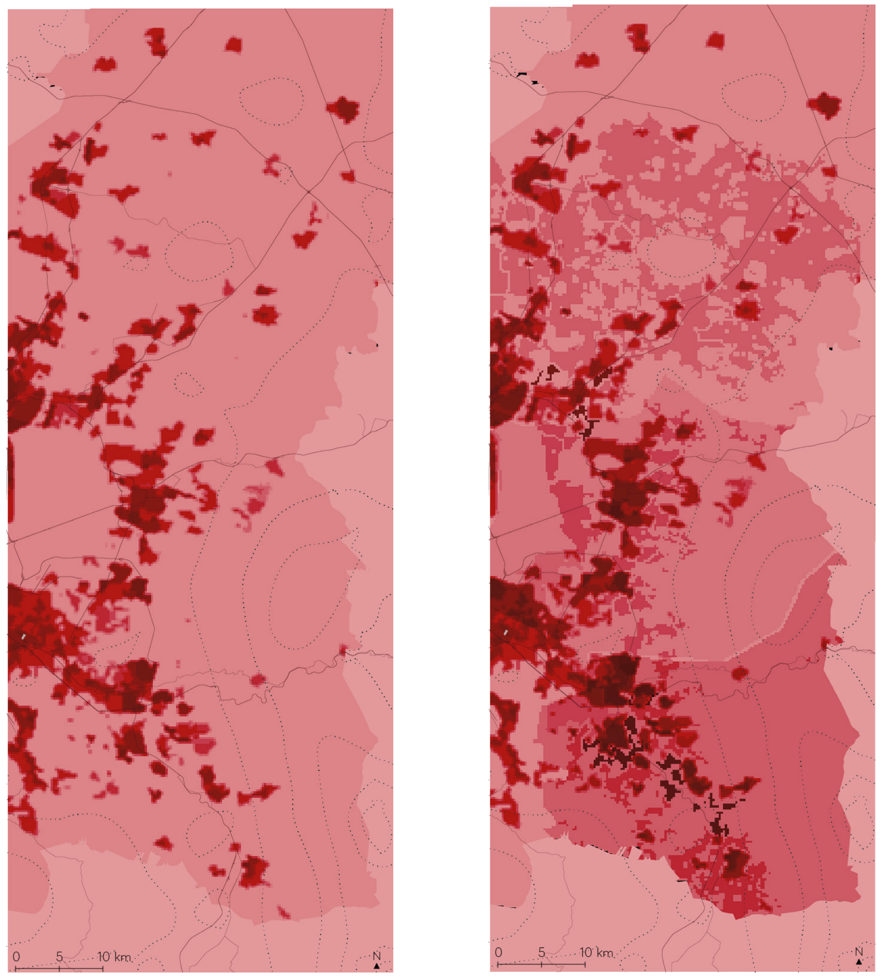


Figure 8.9 Investments that of each of the stakeholders would have over the interactions as foreseen by the researcher. The coloured circles indicate physical interventions that primary stakeholders would invest on, while the contoured circles indicate policies that secondary stakeholders would promote. A green line indicates if there would be any type of collaboration amongst the stakeholders when doing the investments.



2020 | 2030 |

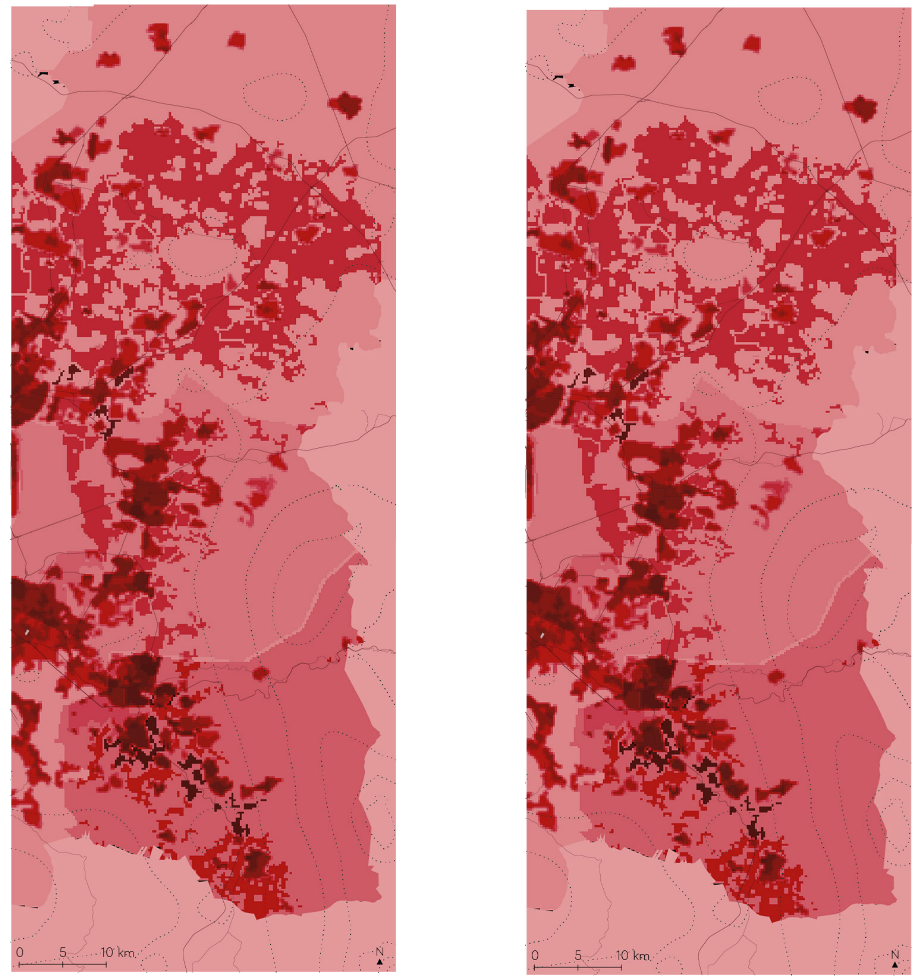
Zone 1 (50%)
RW catchment -ISH
R1 catchment- Z1 (50%)
Source separation - ISH
WTP turned anerobic (SS)
New anaerobic WTP-Z2 (SS)
Vegetation and terraces in low slopes

Social-ecological performance

10

1

Figure 8.10 Social-ecological evaluation of the investments over time with a regenerative strategy, according to their time of deployment. The development of social housing in Zone 1, has a positive impact on the areas where they are developed as they are close to services centers. The investmens in rainwater catchment systems and in the treatment of their black and greywater in anaerobic plants and in the wetlands, increment the accesibility to infrastructure both in the new and in the old developments. (...)



2040 | 2050 |

(...) Further, the social-ecological performance improves slighly more in the next ten years as the time of deployment of the newly cnverted anaerobic WTP extends till 2040. From the year 240 to 2050 there are no further changes in the performance.

Governance evaluation of the researcher's Regenerative Strategy

Figure 8.11 Onion scheme depicting the stakeholder's engagement in regenerative approaches and the strength of their network[17], based on the researcher's analysis of literature review and interviews.

17. Refer to Appendix 12 for a detailed information on the stakeholder's associatedness ranking.

Regenerative performance of the researcher's strategy for a Regenerative Development over a Business-As-Usual Development

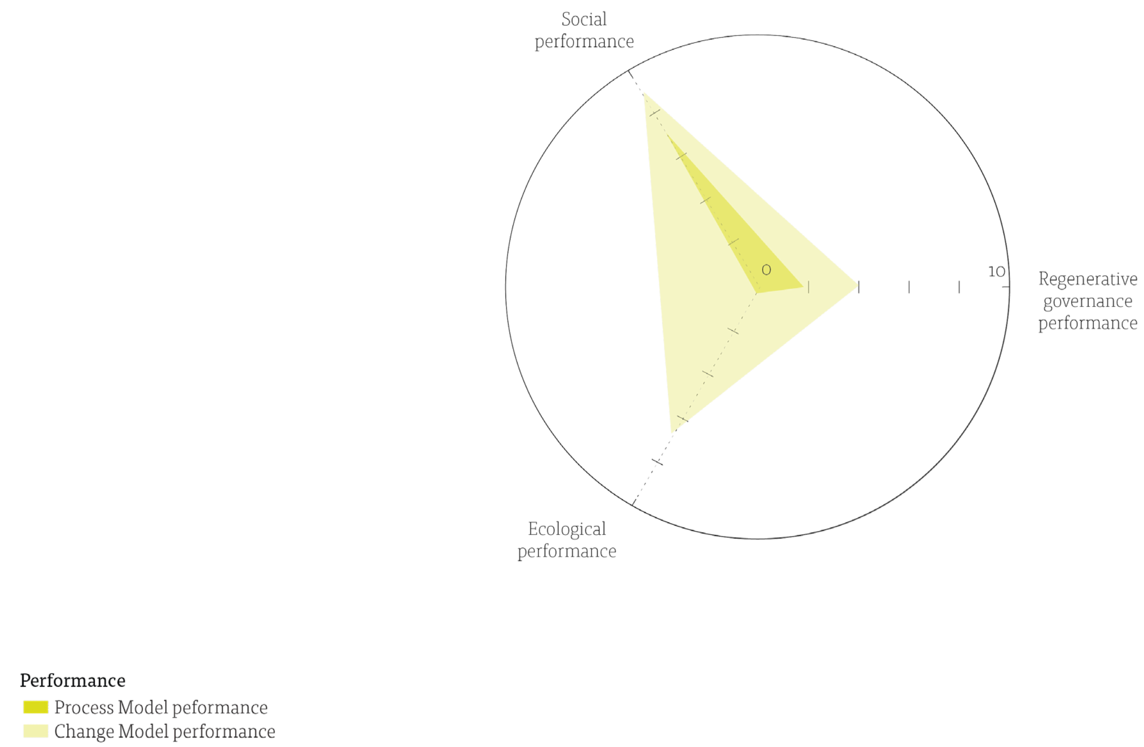


Figure 8.12 Improvement from key performance indicators from the Process to the Change Model , as developed by the researcher

The report shows how use the Process Model to evaluate how much regenerative capacity does the Change Model has over the current way of developing.

When comparing both Models, the social ecological performance increased from 66 to 99 in a scale of 100, the ecological performance increased from 0 to 67 in the same scale, and the governance performance increased from 20 to 40[18]

The previous means that the regenerative performance of the Regenerative Development scenario over a Business-as-Usual scenario has a value of 66 over 23 in a scale of 100, improving by 288%.

18 It is important to note that the assessment of the governance performance had very high, if not impossible values to achieve, as a 100 would mean that every stakeholder has the strongest relationship every other stakeholder. In order, to read more about this, refer to the Conclusions Chapter in the report.

9. Stakeholder's development of the Process, Evaluation, Change, and Impact Models; *Modelling III*

This chapter presents the second sub-iteration of the Modelling Iteration. In this sub-iteration the stakeholders realised, with the spatial-decision support tool, the Process, the Evaluation, the Change, and the Impact Models in a workshop in Mexico City.

The Process Model evaluated the Meso-scale based on its social-ecological performance and on its governance performance over the Macro-scale, while the Change Model evaluated the Meso-scale based on its social-ecological, governance and regenerative performance.

In an analogue way as in the previous chapter, each of the methods that assisted to develop the models appears with their corresponding results, therefore in this Chapter the workshop is explained as themethod used to develop this specific sub-iteration. The methods to evaluate the performance indicators have already been explained in the previous chapter.

Workshop:

Objective

The workshop aimed to bring the stakeholders involved in the development and/or regulation of selected interactions in the project, in order to evidentiate their agencies, interests, and possible and potential collaborative paths amongst them. It worth reminding that planning in the MAVM is sectoral, and therefore, these kind of events are rare. However, the engagement of the stakeholders, as well as the enhancement of their systemic thinking capacities, is of utmost importance to ensure a regenerative development in the MAVM.

Planning & Preparation

During the months prior to the workshop, the stakeholders to be invited to attend were identified. The Decision Model developed at the beginning of the framework, analysed the stakeholders with agencies over the development of the social-ecological systems in question in the research. The analyses presented the involved stakeholders, their functions, their capacities, and their interests; all these are shown in Chapter 6.

Once the stakeholders were identified, extensive research was developed to find out who could be the representatives from the institutions, organisations, and companies to be contacted. Once a solid network of potential participants was built, each one of them was invited over the phone or via email to participate in the workshop. A concise description of the thesis highlighting the issues concerning linear and intra-sectoral planning in the MAVM and an alternative scenario for its development, as well as the objective and prospects of the workshop was needed to clarify the intentions of the meeting and to attract well-suited people. In this process, it was crucial to plan well in advance respecting the long lead times and the solidly booked schedules from some of the representatives. In fact, some of the stakeholders who wanted to attend but whose schedule prohibited them to do so offered to have a representative of their own representation to attend. Figure 9.1 a list of the stakeholders that were invited and highlights the ones that actually attended.

Most of the stakeholders were able to attend or to send someone representing their interests. The only ones that were not even contacted were SEMARNAT/SEDEMA, the local governments, the federal entities governments and CONAGUA/CAEM. As no representative of CONAGUA nor CAEM was able to be contacted and as their role was considered crucial in the workshop, a fellow colleague with extensive knowledge on the topic of water management role-played the participation of CONAGUA/ CAEM. For future situations, it would be highly recommended to also role-play the representation of the local government(s), as their agency was constantly coming up in the workshop and it would have been interesting to know their take on the topics covered.

Figure 9.1 Current interactions in the social and the ecological systems

Completion

This section guides the reader through the development of the workshop, discusses the steps taken in the process and serves as a guideline for how to conduct it again if ever needed.

Phase 1 – Welcome & Introduction

At the beginning of the workshop the participants were welcomed. A short round of individual introductions followed to familiarize the stakeholders amongst each other. Thereby their respective agencies and their relation to the problem at hand were clarified. Further, the round of introduction eased up the communication and enhancedd the mutual understanding via a common language amongst the participants.

Then, the research problem was presented to the stakeholders in a 10 minutes presentation. Special attention was brought to the concept of regenerative development and the importance of the co-engagement of the stakeholders with the topic.

After stating the problem field, each of the stakeholders received a set of cards which contained similar information to the one presented in the catalogue in Chapter 7.

Phase 2 –Business-As-Usual Scenario

During the next phase the workshop participants developed the Process Model of the sub-iteration. They were asked to select the interventions that they (and their institution) would likely or typically invest on. In this process, no additional care was taken to encourage the stakeholders to collaborate or exchange information; however the interaction between stakeholders was also not prohibited.

The results of this set of interventions, as well as their evaluation, is shown further in this Chapter.

Phase 3 – Regenerative Development Scenario

During the next phase of the workshop, the stakeholders developed the Change Model of the framwork's sub-iteration. The researcher, playing the role of the moderator, encouraged the stakeholders to work in an integrated manner in order to co-design a future regenerative development. This exercise, stimulated joint decision making, which is currently not typical in MAMV's planning efforts. The results of this phase are also presented further in the Chapter.

Phase 4 – Discussion and concluding remarks

"...Whoever thinks that they are going to do urbanism, by being an only architect, or an engineer, or an ecologist, or only an economist, or only a sociologist is completely wrong. This is a multidispclinary topic. All the involved parts need to be in agreement so everybody can participiate"

- Marco Figuera, 2019

The second phase of the workshop gave rise to a long conversation which grasped everybody's interest. The conversation stirred into the direction of how the collaboration amongst stakeholders is of vital importance in the Metropolitna Area of th Valley of Mexico in order to do urban planning.

The results of the workshop wee promising and the feedback from the stakeholders was very positive. It is exciting to say that as of today, I know that three prospective collaborations amongst them have emerged since the workshop took place

9.1 Stakeholder's Process and Evaluation Model

This section presents the selection of the interventions that the stakeholders selected to invest on in the workshop in a Business-As-Usual scenario, as well as their resulting social-ecological and governance performance in the Meso-scale.

Figures 9.2 and 9.3 present the set of interventions that each of the stakeholders selected. Housing would be developed in areas distant from any employment centers (Zone 3) by the social housing developers and the civil associations. Interestignly, the both actors expressed an interest in investing in rainwater catchment systems and source separation. Unfortunately separating wastewater was pointless, since CONAGUA only invested in improving the WTP and not in converting them to anaerobic plants. Lastly, CONAGUA was also interested in infiltrating runoff water with wells.SEDATU was invested in promoting regenerative interventions, however the lack of communication between this regulatory institution and the operational actors made SEDATU's suggestions to go unheard.

Stakeholder's Business as-Usual-Development

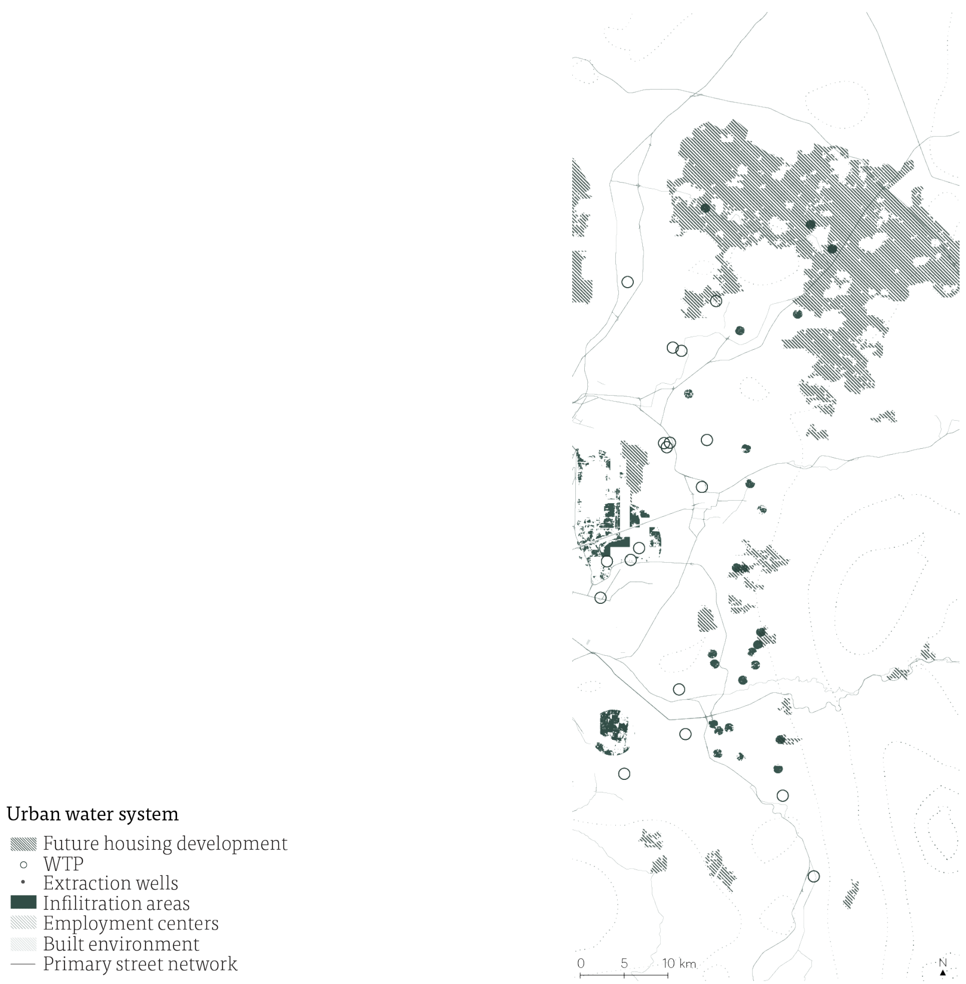


Figure 9.2 Spatial dimension of the Business-As-Usual scenario developed by the stakeholder

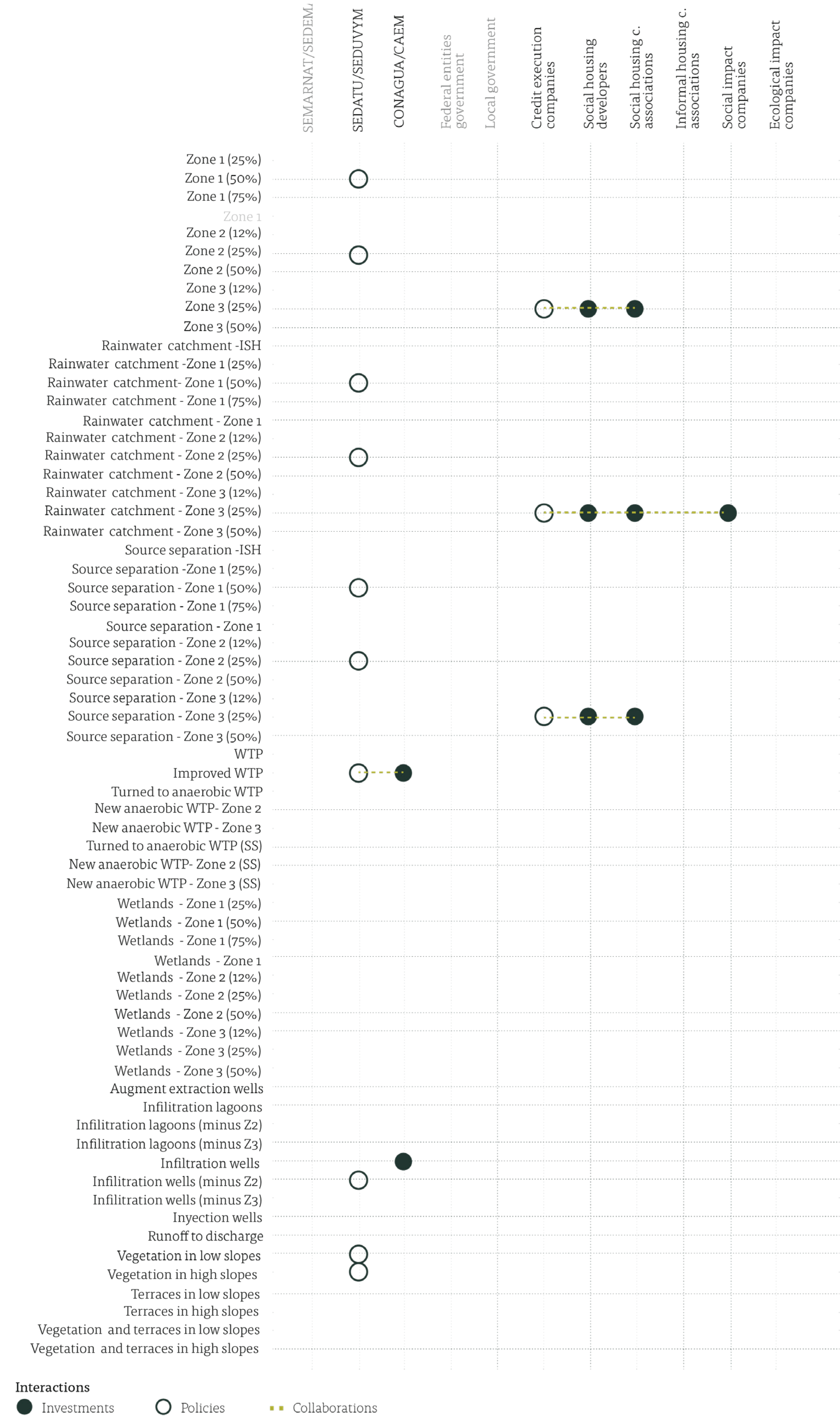


Figure 9.3 Investments that of each of the stakeholders had over the interactions. The coloured circles indicate physical interventions that primary stakeholders would invest on, while the contoured circles indicate policies that secondary stakeholders would promote. A green line indicates if there was any type of collaboration amongst the stakeholders when doing the investments.

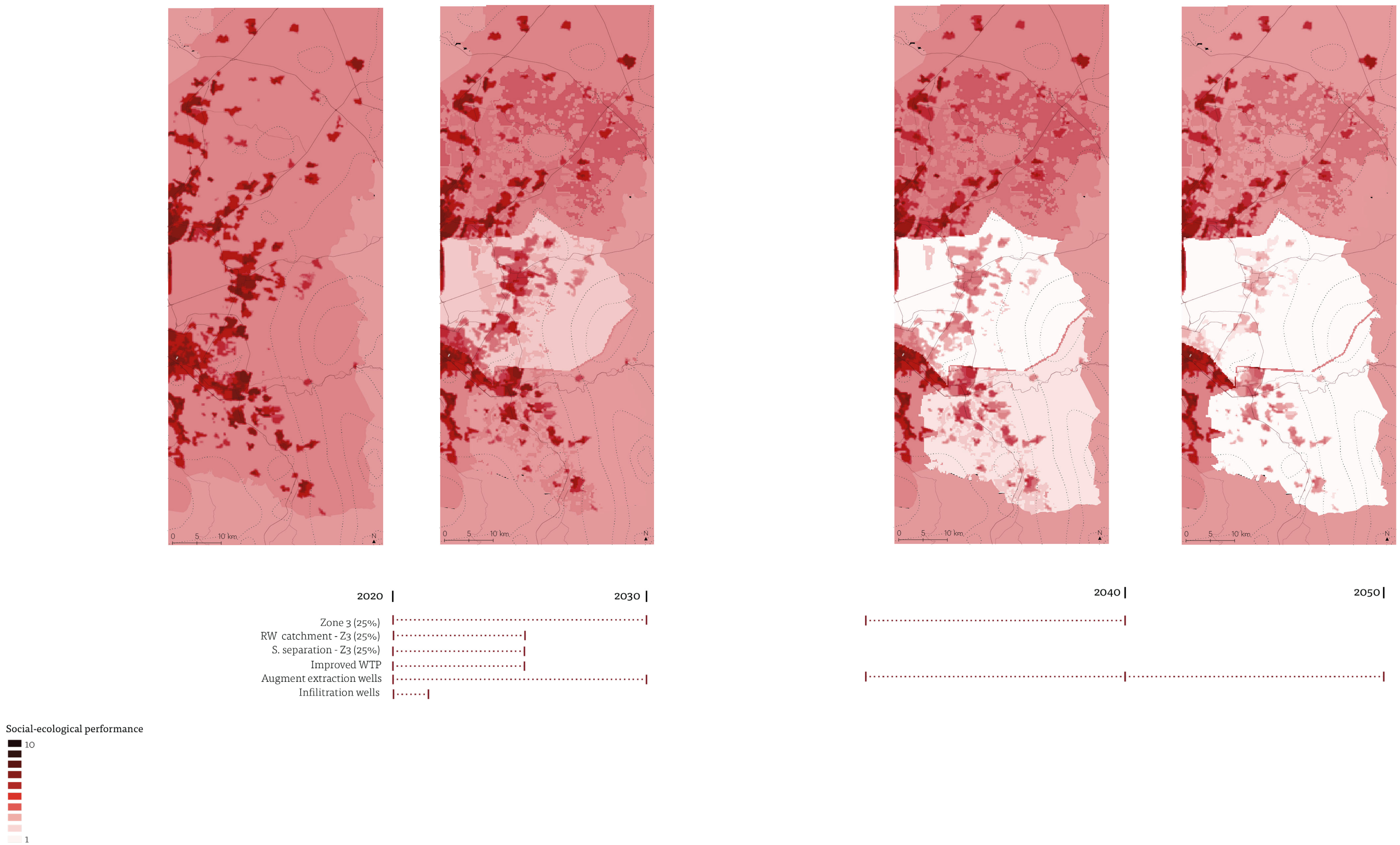


Figure 9.4 Social-ecological evaluation of the investments over time in a Business-As-Usual scenario, according to their time of deployment. The development of social housing in Zone 3 and the provision of rainfall catchment systems, increments the accesibility to infrastructure and services in the rural areas where they are deployed . The intention of investing in source separation is useless, becasue there are no investments in any anaerobic treatment. (....)

(...) On the other hand, the increment of the extraction of the groundwater causes the overall decrement of the performance over time.

Governance evaluation of the Stakeholders' Business-as-Usual Development

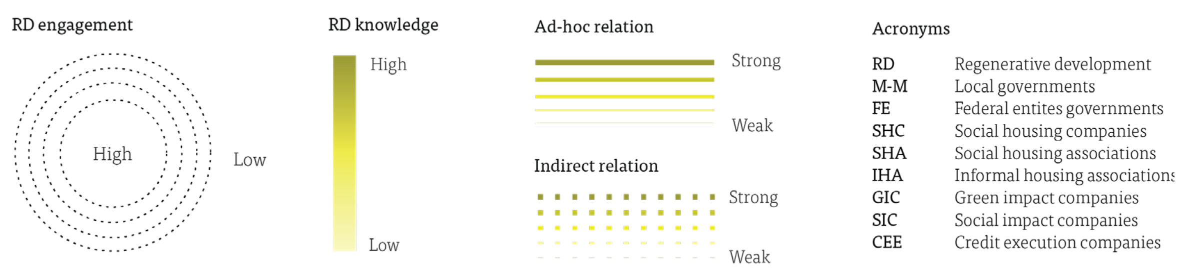


Figure 9.5 Onion scheme depicting the stakeholder's engagement in a Business-A-Usual and the strength of their network, based on the surveys realised at the workshop. [19]

19. Refer to Appendix 12 for a detailed information on the stakeholder's associatedness ranking, and to Appendix 13 for the surveys results.

Same as in the previous chapter, the diagram on Figure 9.5, indicates the knowledge that the stakeholders have over regenerative development, their engagement in the topic, and their network strength. As mentioned previously, the governance performance of the developed Process and Change Models is the mean function of the three mentioned aspects. The governance performance is expressed in this section and in other sections, in the form of a diagram which was adapted from Czischke's (2018) own adaptation of Sudiyono's diagram (2013), and Alexander & Robertson's (2004)[20].

The stakeholders are categorised in the same way as in the previous versions of the diagram,in two types of roles: the primary stakeholders and the secondary stakeholders.The primary stakeholders have a day-to-day perational role in the project, such as the social housing developers, the social housing cicivl associations, the informal housing civil associations, CONAGUA/CAEM, the mincipalities and the mayoralities, and the green and social-impact companies. The secondary stakeholders's role is to provide regulations, or services to the projet, such as SEMARNAT/SEDEMA, SEDATU/SEDUVI, or the credit execution companies.

The types of relationships are also categorised in the same way, a continuous line indiciates that the relationship is strong, with a constant and interdependent relation, and a dashed lines indicates an ad-hoc ollaboration, based on technical matters, or the provision of financing or services.

The diagram on the left, then, served as a perfect basis for representing the strength of the network amongst the actors, as it represents which actors have a regulatory role, and which ones are involved in an operational way to the project, and because it also depitcts what type of relationships are held amongst them. The lines that indicate the relationships would also indicate how strong those relationships are. Therefore, the thicker and darker the line, the stronger the relationship is. The diagram was also modified so it could indicate within their roles, how engaged each of the actors are to regenerative development. For this each of the rings was divided in 5 sub-rings, the closer the stakeholder is positioned to the center within each ring, the more engaged it is with regenerative approaches. The diagram also expresses how much knowledge about regeneration, does the stakeholder have. For such, the darker the color of their icon, the more the knowledge they have.

20 For a detailed explanation, refer to Chapter 8.

9.2 Change and Impact Model

This section presents the selection of the interventions that the stakeholders invested on, as well as their resulting social-ecological and governance performance in the Meso-scale.

Figures 9.6 and 9.7 presents the set of interventions that would take place under a Regenerative Development Scenario. Housing would be developed in areas relatively close to employment centers (Zone 2) and investments on rainwater catchment systems and source separation would be realised in the new developments. The involved actors in all of the previous range from SEDATU who promoted the interventions, the credit execution companies that provided the financial approval, the municipalities that allowed to use the land and the private companies and the associations who develop the social housing. The capacity of the water treatment plants would be increased, and blackwater and greywater would be treated in the WTP and in wetlands respectively. More investments would be realised by CONAGUA on over infiltration wells, and to increase the vegetation in high slopes on the hillsides.

Stakeholder's Regenerative Strategy

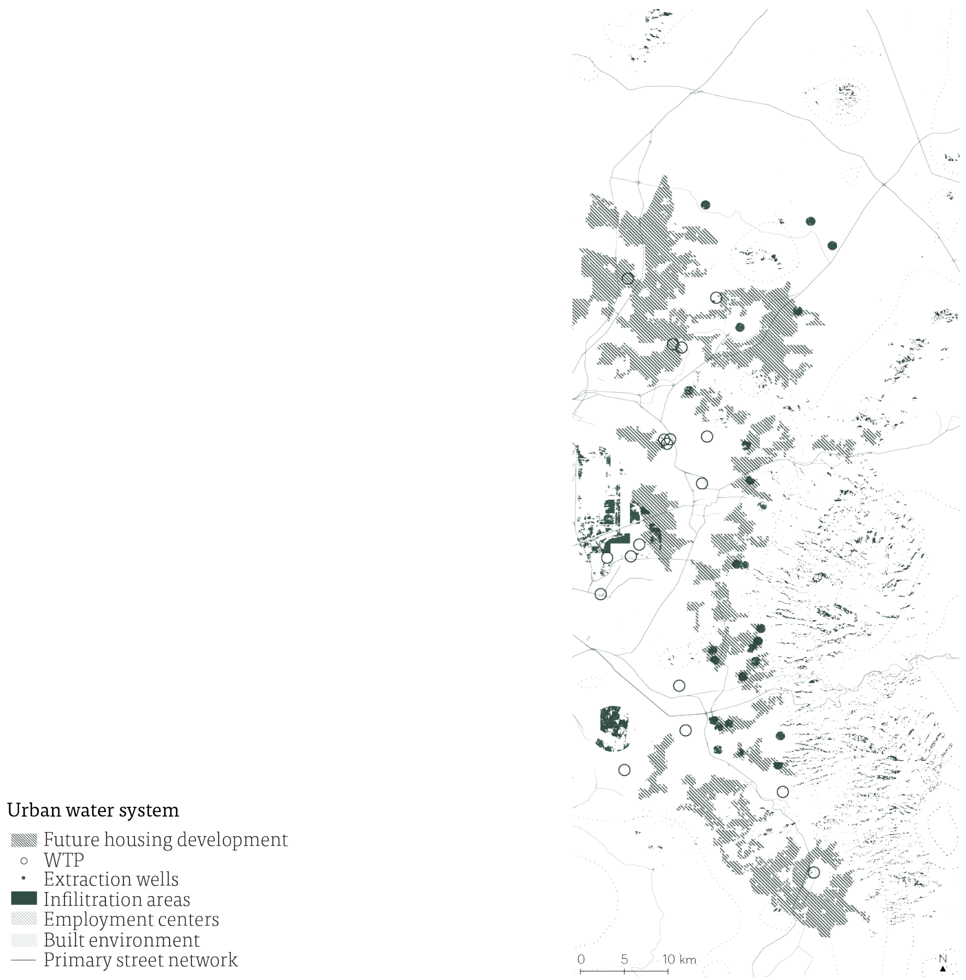


Figure 9.6 Spatial dimension of the Business-As-Usual scenario developed by the stakeholders

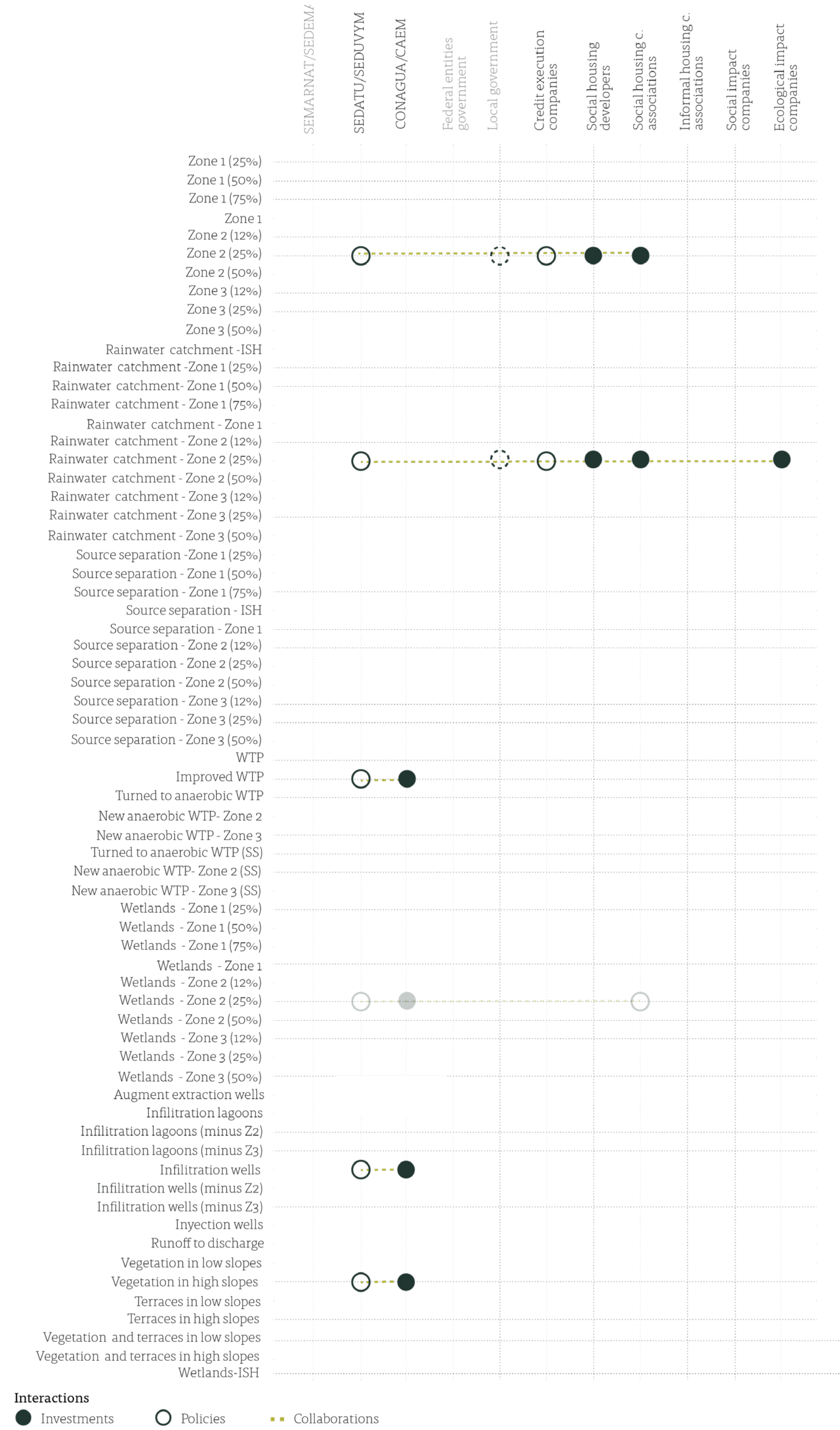
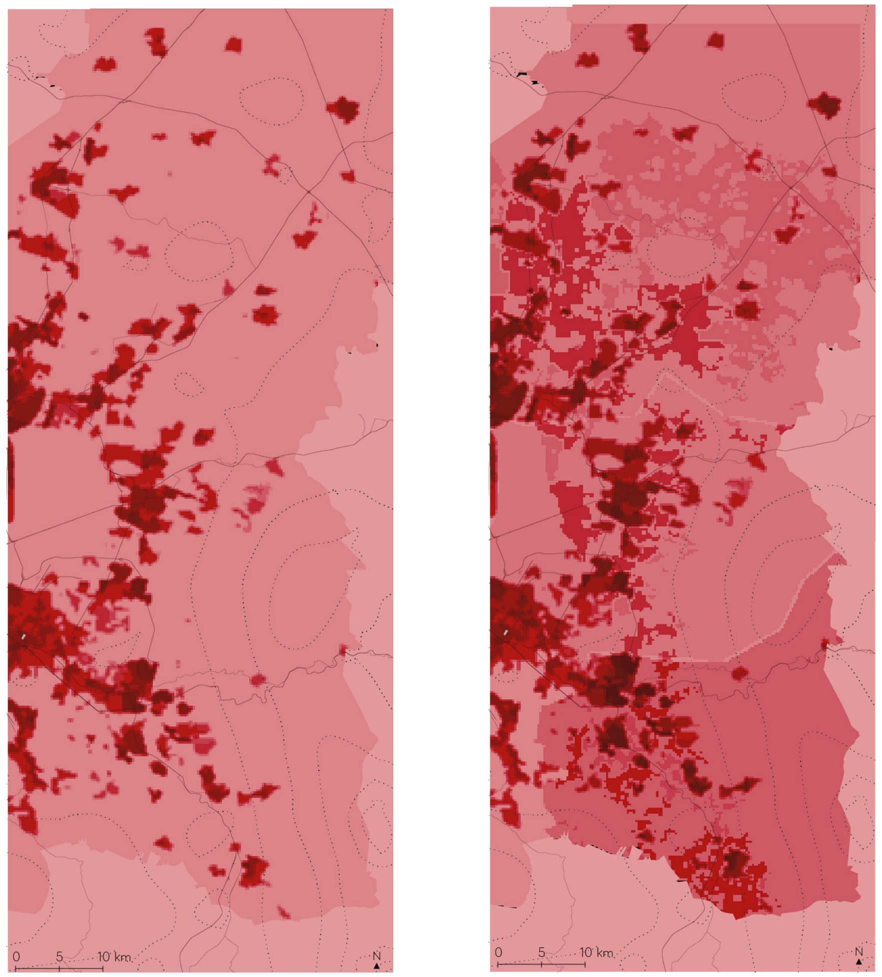


Figure 9.7 Investments that of each of the stakeholders had over the interactions. The coloured circles indicate physical interventions that primary stakeholders would invest on, while the contoured circles indicate policies that secondary stakeholders would promote. A green line indicates if there was any type of collaboration amongst the stakeholders when doing the investments.



2020 | 2030 |

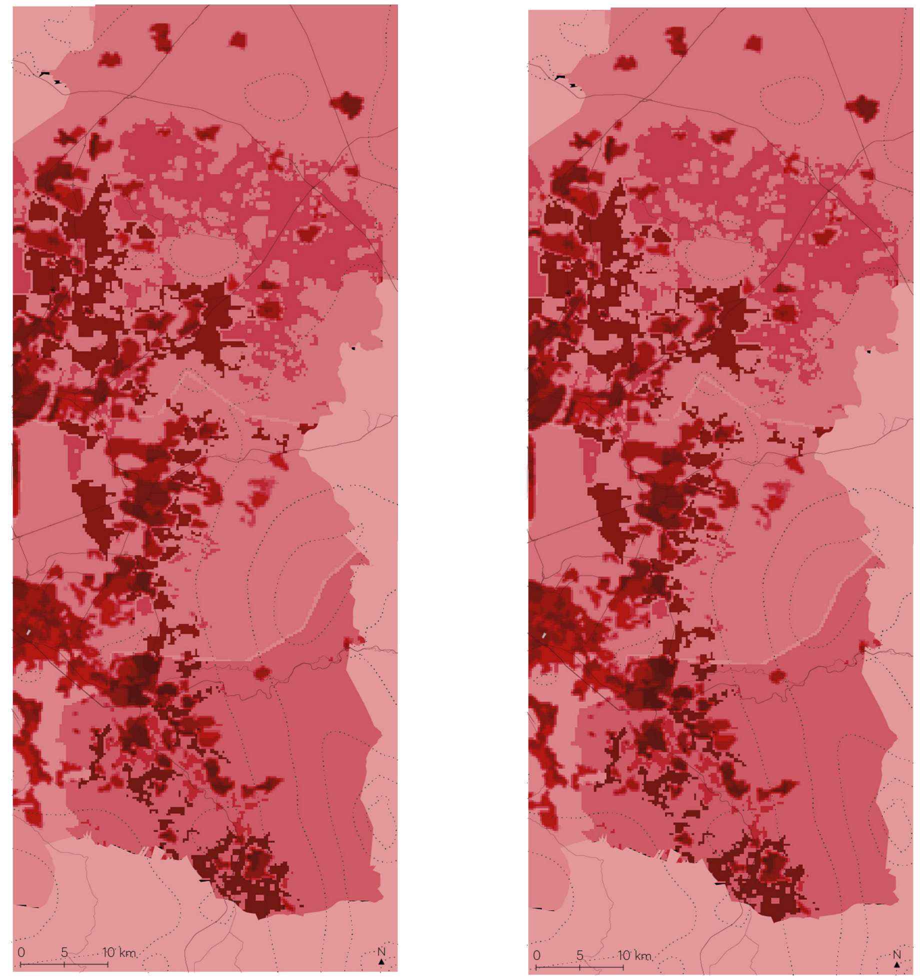
Zone 2 (25%)
RW catchment - Z2 (25%)
Improved WTP
Wetlands - Z2 (25%)
Infiltration wells
Vegetation in high slopes

Social-ecological performance

10

1

Figure 9.8 Social-ecological evaluation of the investments over time in a Regenerative Development scenario, according to their time of deployment. The development of social housing in Zone 2 increments the accesibility to services in the rural areas where they are deployed. On the other hand, the improvement of WTP, and the construction of wetlands, and rainwater catchment systems increments the accesibility of those areas to infrastructure and imprves the water balance of the aquifers.



2040 | 2050 |

(...) Further more, the deployment of the Zone 2 and its rainwater catchment systems, as well as the improvement of the WTPs extends till the year 2040.

Governance performance of the of the Stakeholder's Regenerative Strategy

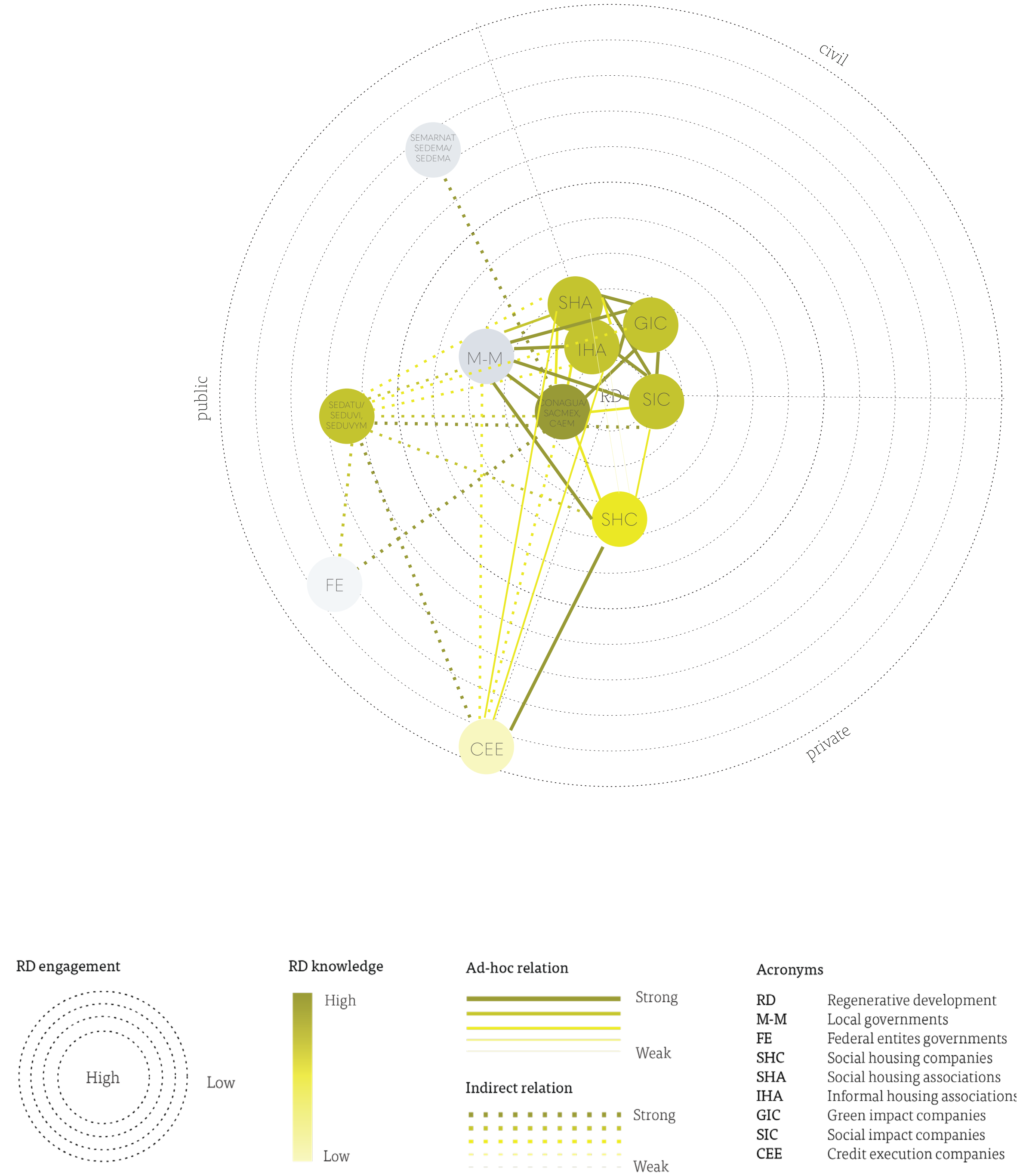


Figure 9.9 Onion scheme depicting the stakeholder's engagement in regenerative approaches and the strength of their network[21], based on the surveys realised in the workshop

21. Refer to Appendix 12 for a detailed information on the stakeholder's associatedness ranking.

Regenerative evaluation of the Researcher's Regenerative Strategy

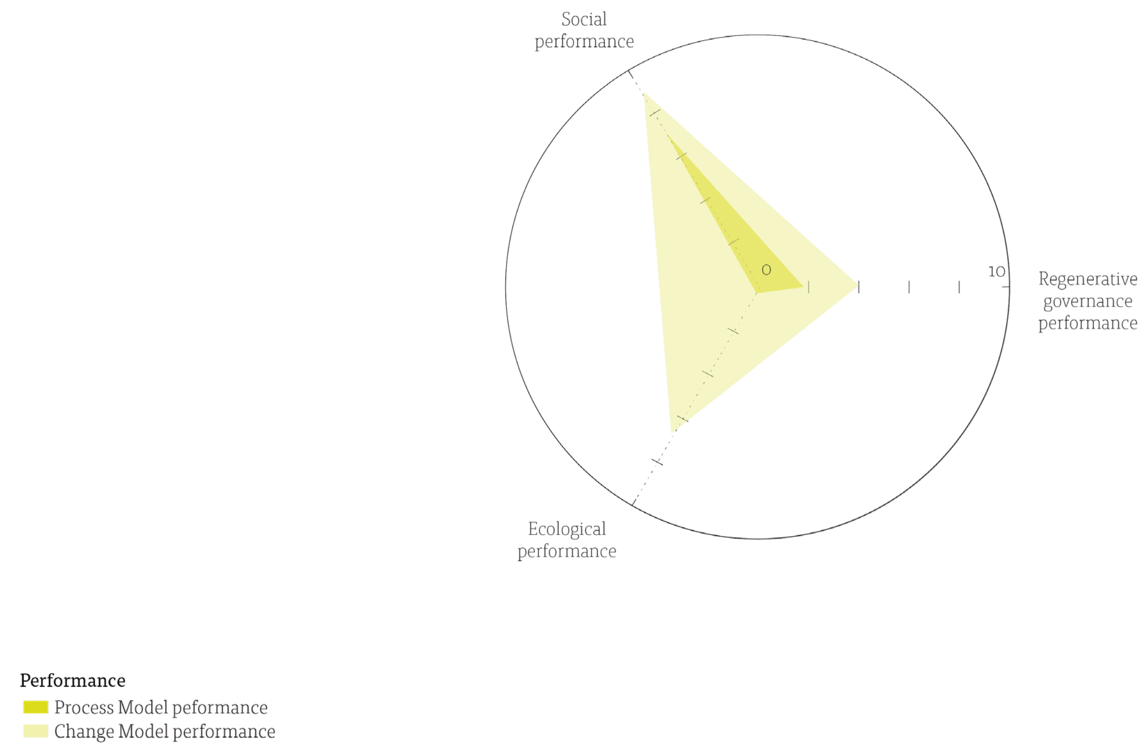


Figure 9.10 Improvement from key performance indicators from the Process to the Change Model , as developed by the stakeholders

The report shows how use the Process Model to evaluate how much regenerative capacity does the Change Model has over the current way of developing.

When comparing both Models, the social performance increased from 85 to 99 in a scale of 100, the ecological performance increased from 55 to 57 in the same scale, and the governance performance increased from 18 to 39.[22]

The previous means that the regenerative performance of the Regenerative Development scenario over a Business-as-Usual scenario has a value of 53 over 66 in a scale of 100, improving by 120%.

22 It is important to note that the assessment of the governance performance had very high, if not impossible values to achieve, as a 100 would mean that every stakeholder has the strongest relationship every other stakeholder. In order, to read more about this, refer to the Conclusions Chapter in the report.

10. Integrated development of the Change and Impact Models *Modelling IV*

This chapter presents the last sub-iteration of the Modelling Iteration. In this sub-iteration the researcher integrates the Change Models developed in the first and the second sub-iterations.

The chapter then shows the method of how these two were integrated in order to develop potential regenerative pathways of accordance with the stakeholders, as well as with the researcher. Further, the chapter presents the results the co-planned regenerative strategy, its implementation and deployment times, and its outcomes.

Lastly the chapter presents the regenerative outcomes in the entire MAVM, and not only in the Meso-scale.

Integrating the researcher's and the stakeholder's strategies

In order to develop the last sub-iteration, the results from the Change Models of the researcher and the stakeholders we combined. The comparison of the two models for change indicated that the researcher's strategy for regenerative development had a higher social-ecological and a higher regenerative performance than the stakeholders strategy.

Therefore, the onion scheme was used to visualise which collaborations amongst actors in the staekholders strategy could further be enhanced. Next, the strategies that were proposed in the previous subiterations were overlayed. The results are shown in the next table taking into account the conclusions of the workshop and the links that the researcher thought should definitely be enhanced .

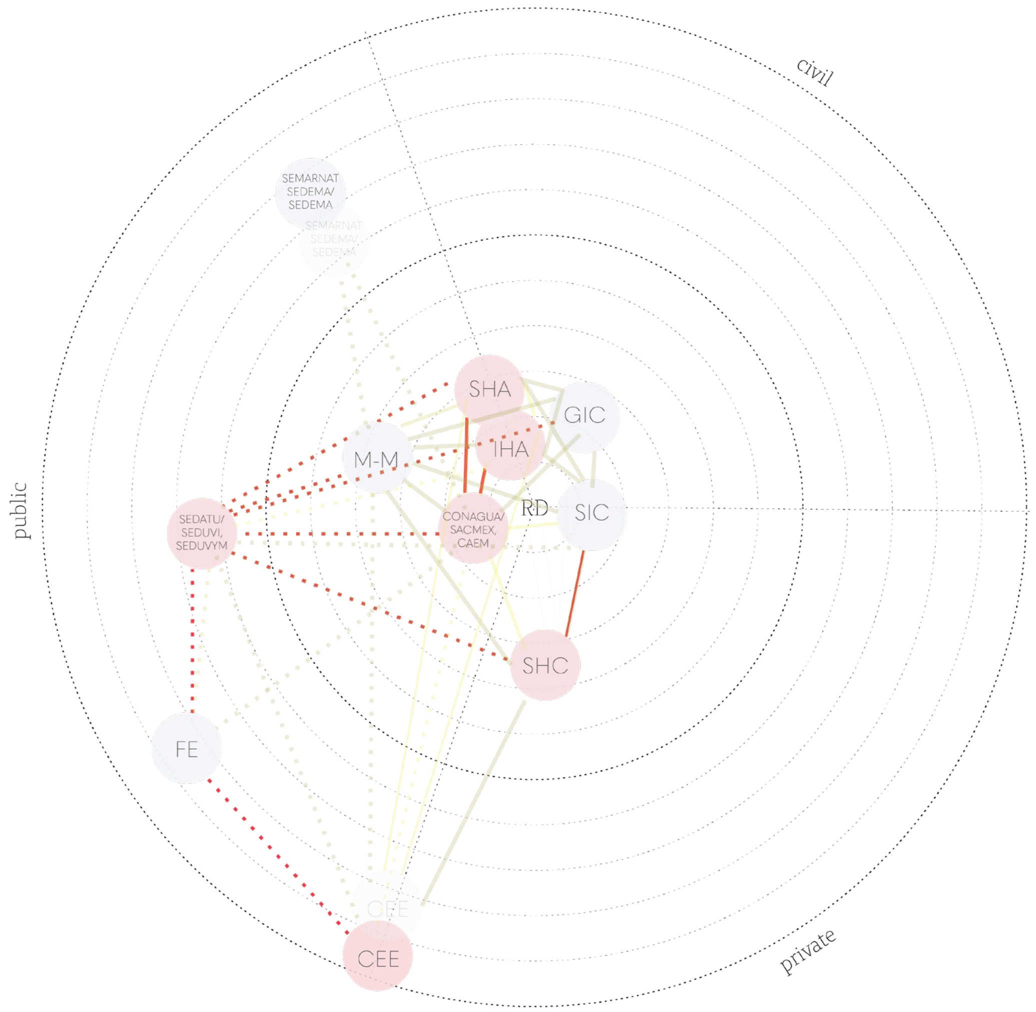


Figure 10.1 Weak collaboration link highlighted in red

The following collaborations prevailed weak in the stakeholder regenerative strategy, and if enhanced more regenerative capacity could be ensured:

- the collaboration between SEDATU/SEDUVI, the housing developers and CONAGUA/CAEM
- the collaboration between CONAGUA/CAEM and the housing developers either private or from civil associations
- the collaboration between SEDATU/SEDUVI, the federal entities and the credit execution companies
- the collaboration between the social housing private developers and social impact companies

The integration of the strategies was further developed taking into account the notes above and other comments recovered from the worksop. The results are presented in Table 10.1 and illustrated in Figure 10.3

Annotation	*Description*
1 2	SEDATU should collaborate more closely with the credit execution companies, and the local governments so that joint programmes could be institutionalised to have more sustainable wyas of developing housing. The credit execution companies already have programmes to give better financing to projects with those characteristics however, SEDATU could further reinforce their promotion.
3 4	The provision of source separation in the new social housing areas, provided by the developers, and in existing social and informal housing areas by companies aiming to have social and ecological impact can only word if the Federa entities governments provide the source separation infrastructure in the streets. Better collaboratins should exist between the Federal Entities governments with SEDATU and the credit execution companies in case the state does not have enough resources or technical capacity to do such thing. The water treatment either in water treatment plants or wetlands required for the wastewater to be separarted in black and greywater, and therefore all the previous collaborations above.
5	The development of infiltration lagoons could be achieved with less resistant from the civil associations that develop formal and informal housing if they would be benefited from such. SEDATU and the local governments need to have more open conversation with the mentioned actors then.
6	The stakeholders suggested to invest in vegetation rather than vegetation and terracing because it is less pricey, which was chosen in this strategy as the difference in the cost/benefit indeed indicates that it is not worth to invest on terracting as well. They also suggested to invest in high slopes preventing the low slopes might be areas for future rural developments.
7	Finally, the stakeholders suggested that it is better to invest in future conditions rather than the existing decaying ones. Even though this was controversial idea for the researcher, it was respected as there was a unilateral agreement from the practice side. The interventions in such areas were then suggested to have an implementation time further on in the future.

Table 10.1 Integratin of the researcher and the stakeholders' Change Models

10.1 Process and Evaluation Model

This section presents the selection of the integrated interventions, based on table presented above.

Co-designed Regenerative Strategy

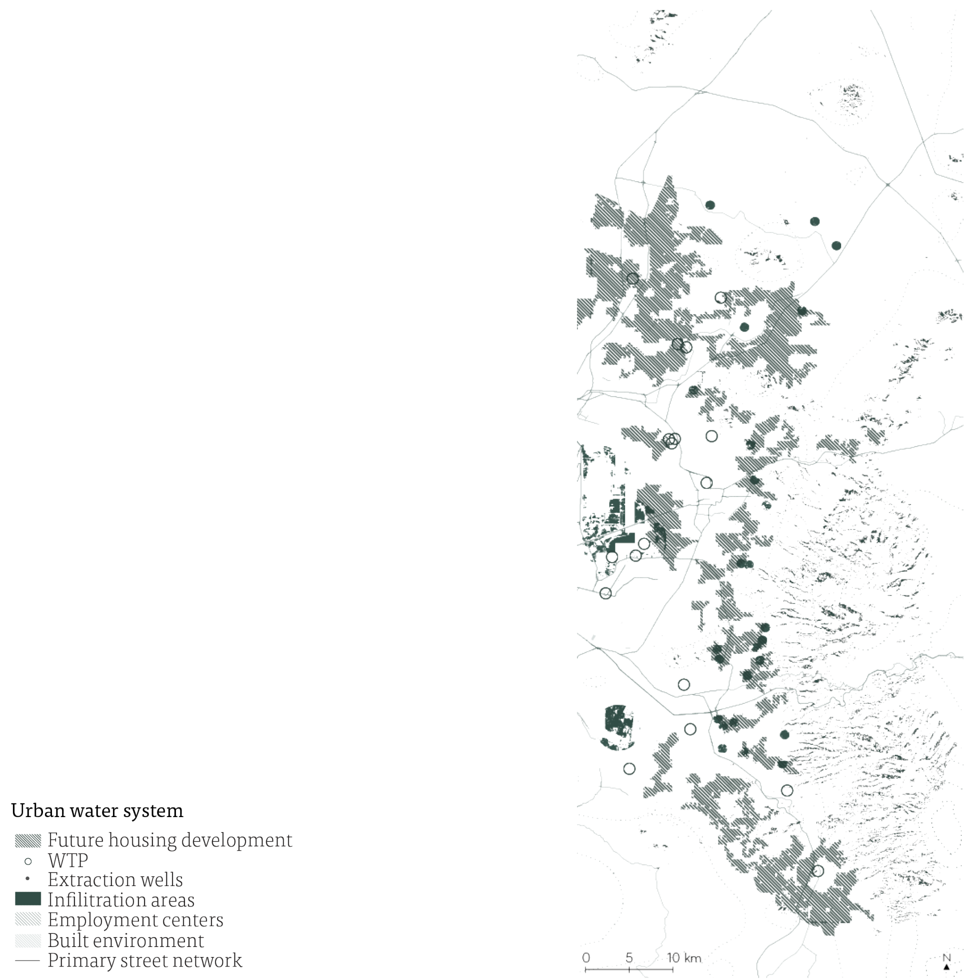


Figure 10.2 Spatial dimension of the co-designed regenerative strategy

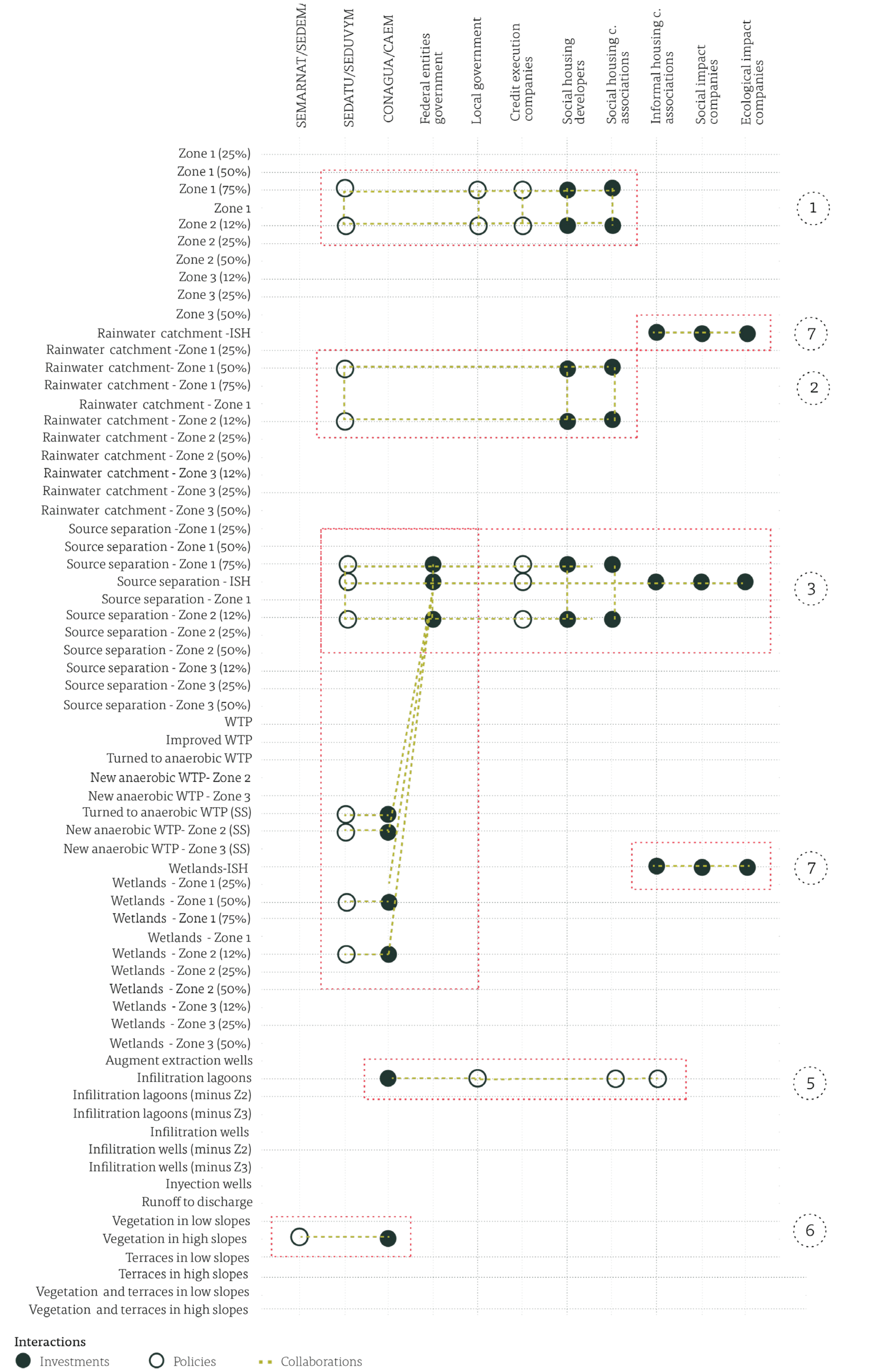


Figure 10.3 Investments over the interactions. The coloured circles indicate physical interventions that primary stakeholders would invest on, while the contoured circles indicate policies that secondary stakeholders would promote. A green line indicates if there was any type of collaboration amongst the stakeholders when doing the investments.

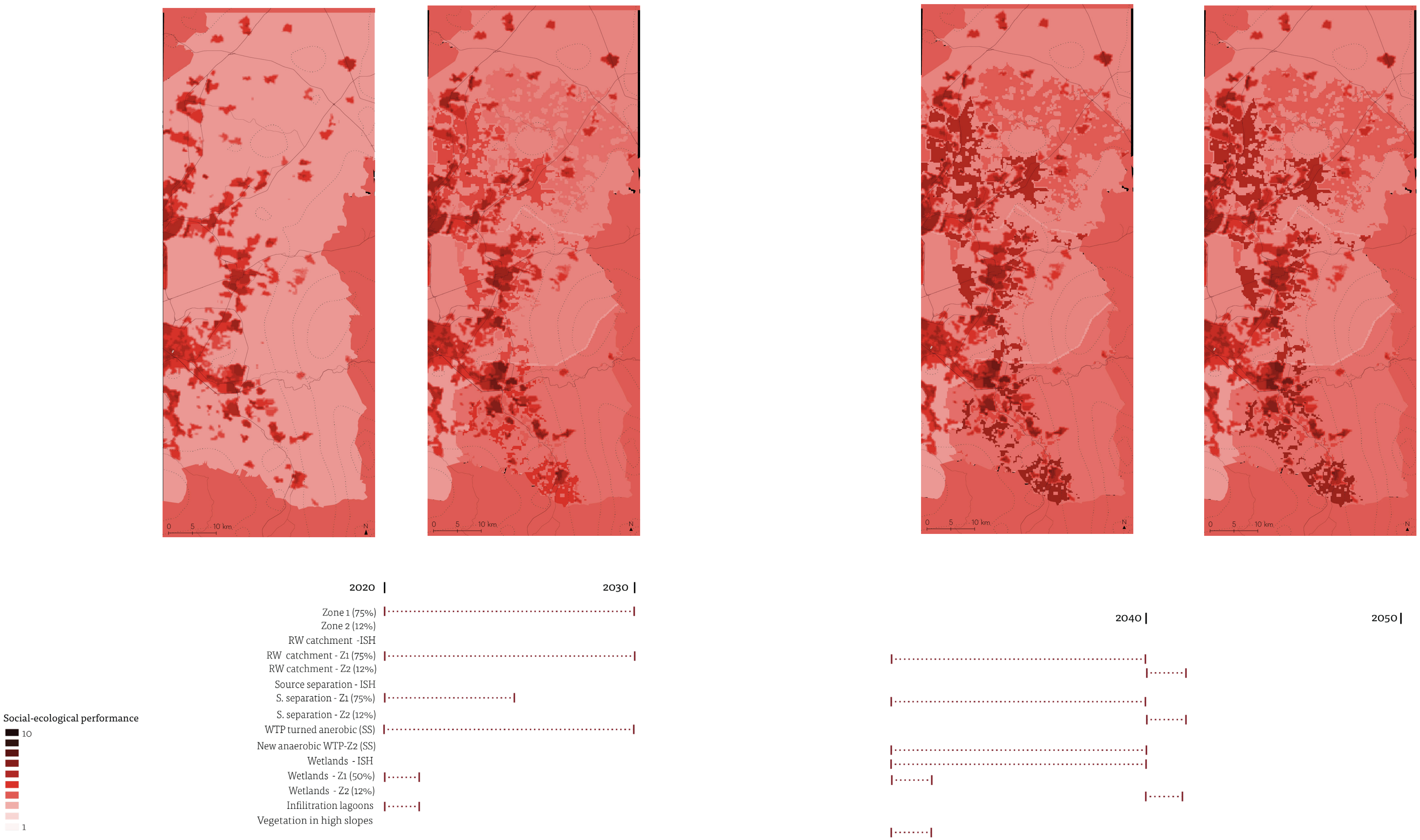


Figure 10.4 The figure above shows the evolution of the outcomes throughout, time . Underneath, the image indicates what is the time of deplyoment and of implementation of each interventions, which ultimately affects the evolution of the system.

Governance performance of the of the *Stakeholder's Regenerative Strategy*

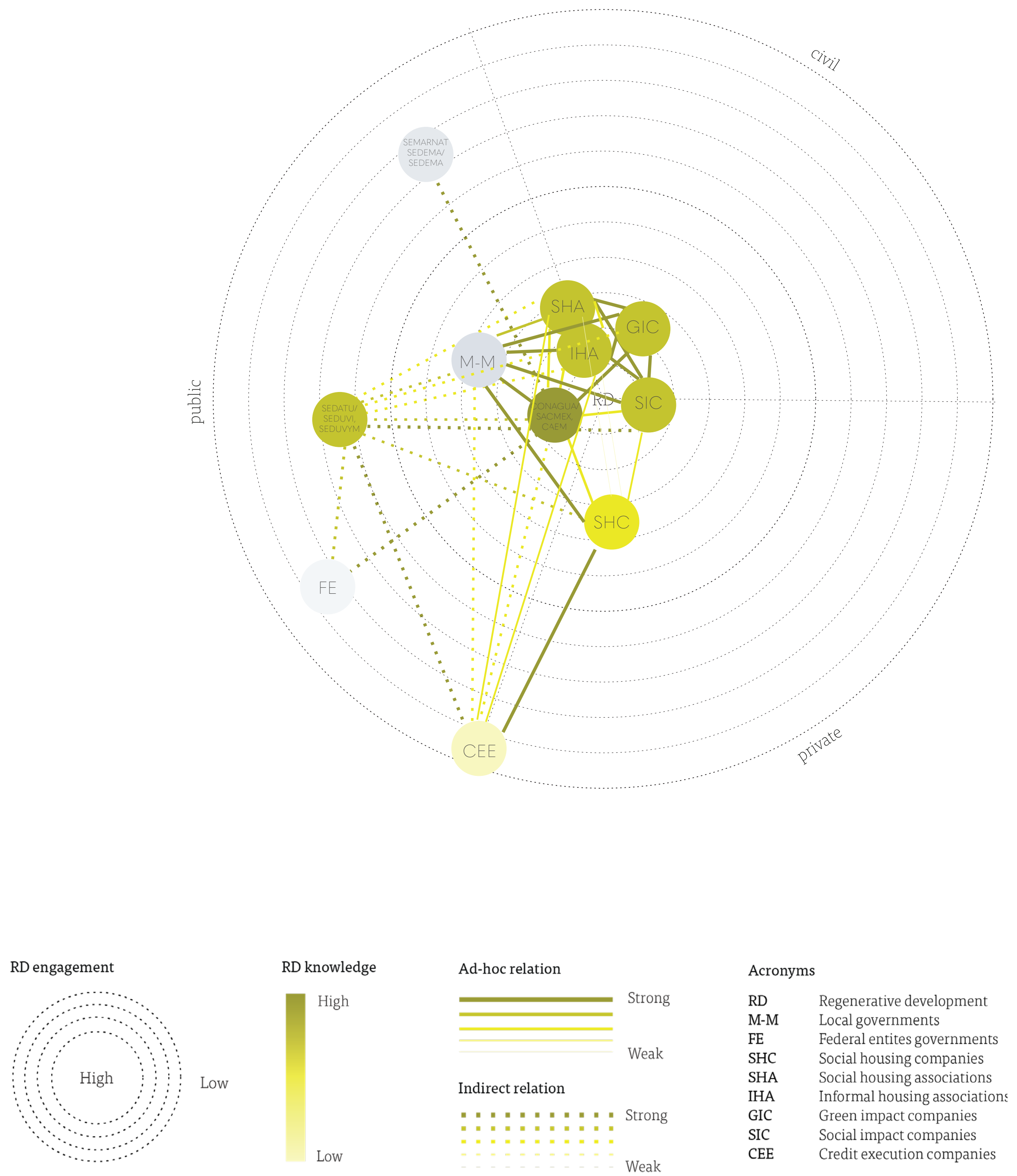


Figure 10.5 Onion scheme depicting the stakeholder's engagement in regenerative approaches and the strength of their network[23], based on the improvements suggested by the researcher

23. Refer to Appendix 12 for a detailed information on the stakeholder's associatedness ranking.

Regenrative evaluation of the Researcher's Regenerative Strategy

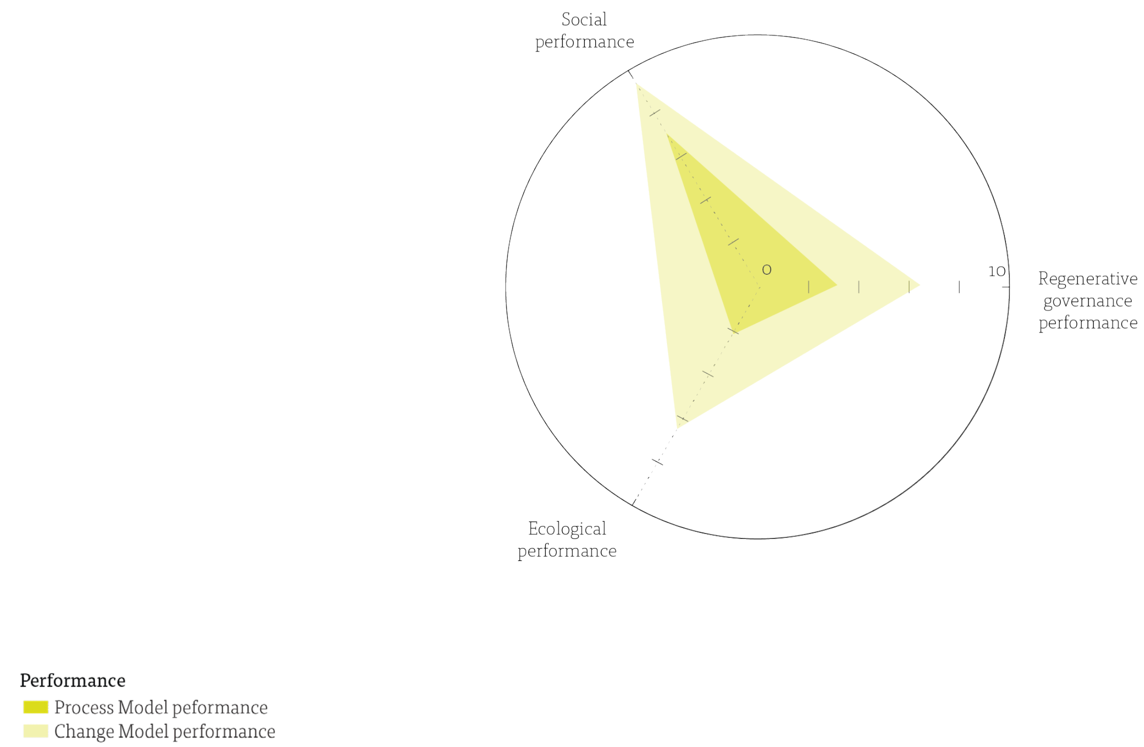


Figure 10.6 Improvement from key performance indicators from the Process to the Change Model , as developed by the stakeholders

The report shows how use the Process Model to evaluate how much regenerative capacity does the Change Model has over the current way of developing.

When comparing both Models[24], the social performance increased from 76 to 98 in a scale of 100, the ecological performance increased from 20 to 66 in the same scale, and the governance performance increased from 18 to 64.[25]

The previous means that the regenerative performance of the Regenerative Development scenario over a Business-as-Usual scenario has a value of 38 over 76 in a scale of 100, improving by 200%.

24 The average value of the stakeholders and the researchers models were used to calcute the Process Model.

25 It is important to note that the assessment of the governance performance had very high, if not impossible values to achieve, as a 100 would mean that every stakeholder has the strongest relationship every other stakeholder. In order, to read more about this, refer to the Conclusions and Reflection Chapter in the report.

11. Conclusion

The thesis departed from the problem that is the lack of integration between theories like Regenerative Development and Design (RDD) and planning practices. Theories like RDD take a systematic approach towards bringing sustainable and adaptable solutions to the built environment. Theories like this are highly relevant because they embrace cities as the complex systems that they are. The thesis used the case study of the Metropolitan Area to answer to the question of how to integrate then, regenerative development and planning practices. It used the working hypothesis that by integrating the geodesign framework as a methodological basis and the Social-Ecological Systems Framework (SESF) as a theoretical/analytical basis, the previous could be achieved.

Five sub-research questions were used to answer the how to integrate RDD and planning practices. The first sub-research question addressed how can geodesign be adapted to be integrated with the Social-Ecological Systems Framework. In order to answer the question, SESF was used to address the use of social-ecological systems , governance framework,s and multiscalarity, while the geodesign framework was mostly used to achieve transdisciplinarity. The integrated framework was further enhanced to use multiple scales and to allow for co-designing.

Firstly, it was decided that the geodesign framework would use the seven SESF variables to give answers to each of its models. The Representation Model is supposed to describe the study area in relation to its spatial context, so, accordingly, the Setting, the Resource System, and the Resource Units were used to describe the model. he Interactions variables were used to answer the questions of how the study area operate (Process Model); and the Outcomes variables were used to assess if it is working properly (Evaluation Model). The Interactions were used as well as to answer the questions of what differences might take place (Change Model), and Outcomes to answer what changes that that cause (Impact Model) in the system;Finally, the Governance System and the Actors variables were used to describe what should be considered when taking the final design decision (Decision Model).

Further, the research found that the newly integrated framework did not actually use multiple scales and that transdisciplinarity in the geodesign framework could be further enhanced. Therefore, the newly integrated framework suffered four main adaptations. Three of them were developed in order to enhance the use of multiple scales and transdiscplinary approaches. The first modification improved the use of multiscalarity in the adapted framework by 1.1) dividing the Resource System in two different types of scales: into system and subsystems, and into an assessment and designing area, and by 1.2) developing the selection of the criteria, the methods to model and the modelling of the Macro-scale of the Resource System before than the rest of the framework The second and third modifications aimed to enhance the use of transdiscplinarity by enhancing the co-designing amongst the stakeholders and between the stakeholders and the designers by 2) using an anticipatory-agent based modelling method in the Process Model and by integrating the Change Models of the stakeholders and geodesign team rather than selecting from them. The last adaptation was developed as a response to the constraint of not having a geodesign team but rather only one designer developing the study, which is not suggested to be followed unless there is also a lack of other geodesign team members.

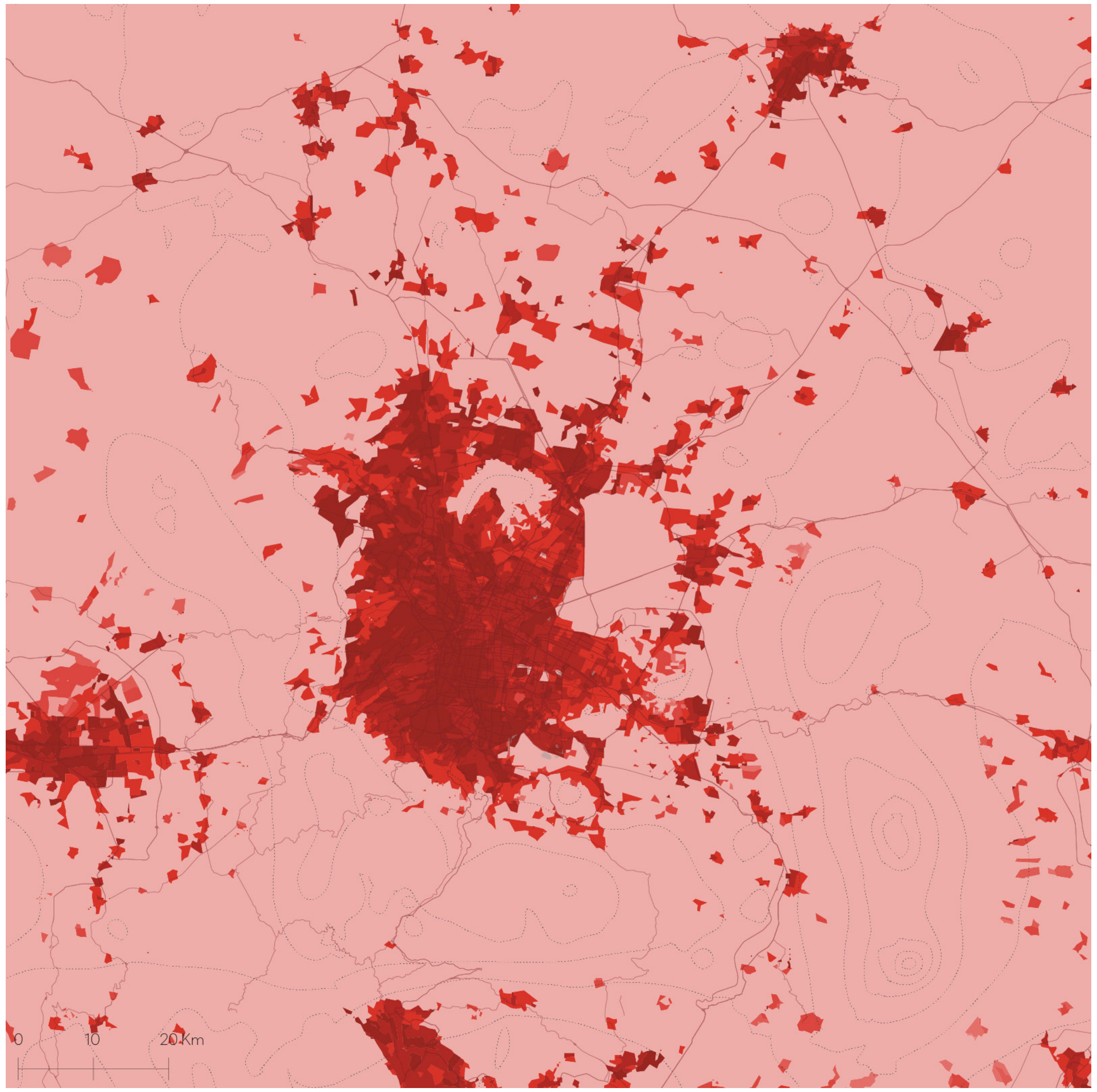
The next sub-research question asked what characteristics from the social and ecological system could be identified in the MAVM that could function as value generating capacities. One of the premises of regenerative development and design is that the use of technologies and strategies which, focus on the value generating capacities of the system can generate a systemic understanding of place and develop the strategic systemic thinking capacities of the designer and the stakeholders. The iteration zero, was used to select the criteria to study, the methods to model, and to model Representation Model with the Setting, the Resource System, and the Resource Units variables. As mentioned before, the Representation Model studied the assessment area or Macro-scale, its resource systems and its subsystems to understand the spatial context of the study and furthermore, to select the area that was used to design within the next steps of the framework. The selection of the design took into account that the location of the greater concentration of value-generating capacities, which were identified as: areas with existing social and informal housing were future developments would likely take place, areas with low slopes and low land price, areas with better soil permeability, with the most water treatment plants, the most rainfall, and the most runoff.

The third sub-research question addressed how the value generating capacities of the social-ecological system could be turned into regenerative strategies. The identification of the mentioned capacities permitted to identify the regenerative interactions and current outcomes that could possibly take place in the selected Meso-scale, besides the interactions that are currently taking place. After such interactions were identified, they were operationalised as physical interventions with specific locations, social and ecological performances, times of deployment, monetary costs, and plausible stakeholder agencies. This last step was developed as part of the second and the third iterations of the geodesign framework. The aim of operationalising all the interactions was to have a catalogue that could be embedded in a spatial decision support tool which was used to develop the agent-based modelling. The regenerative strategies were then formed by the researcher and the stakeholders by selecting a set of interventions that would simulate the investments/decisions that the stakeholder would have/take.

The fourth sub-research question asked how did the MAVM function perform as a social-ecological system. In order to answer the question, the researcher developed a method for defining and modelling a set of performance indicators in the Macro and in the Meso-scale. The report presents how the regenerative, the social, the ecological, and the governance performance were obtained. They were used to assess the overall social-ecological performance of the MAVM as of today (Figure 11.1) and further on they were also used to assess the social-ecological performance of the Meso-scale in the next 30 years according to the interventions that the researcher and the stakeholders considered would take place, respectively.

Lastly, the fifth sub-research question asked what strategy or strategies promote regenerative development in the MAVM. It is important to say, there were three strategies developed for such purpose. The researcher developed the first one, representing the usual geodesign team, the stakeholders then developed the second strategy, and lastly the researcher integrated the previous to into a co-designed strategy in which the lessons from previous sub-iterations were applied. Technically, when the researcher's strategy only simulated the decisions that the stakeholders would have aiming for a regenerative development, which means that the stakeholder were actually not involved in such strategy. In order to achieve a regenerative development the engagement and the development of the systemic thinking capacities of the actors in necessary, which means that the first developed 'regenerative strategy' did not promote the regenerative development of the MAVM. The previous was known since the thesis was being developed, however it was necessary to develop this step so further on, the integration of the researcher's knowledge and the stakeholders' could be achieved. The second strategy promoted regenerative development at a minor degree as the improvement from the social, the ecological and the governance performance indicators in the Meso-scale was of only 120%. Lastly, the third co-designed strategy actually promoted a regenerative development in the MAVM. It was clearly promoting the regenerative development of the MAVM as it involved a transdisciplinary approach in which the designer's (the researcher's) knowledge and the stakeholders' capacities and interests were taken into account. With such strategy, the improvement in the Meso-scale was of 200%. Due to time constraints it was not calculated what would be the precise increment in the performance of the MAVM and not only of the Meso-scale, however, Figure 10.2 clearly shows that the social-ecological performance of the MAVM improves with the co-designed strategy.

Overall it can be said that the methodology used in the thesis to which was explored in the case study of the MAVM successfully bridged the gap between Regenerative Development and Design theory and the planning practices in the MAVM. The thesis proposed a system of technologies and strategies which, by focusing on the value generating capacities of the system, generated the systemic understanding of place and developed the strategic systemic thinking capacities of the designer and the stakeholders. The goal of regenerative development could be understood as to catalyse the transformation of the biophysical and governance components of the social-ecological systems across scales into regeneratively sustainable states (Gibbons et al., 2018). The systemic understanding of the place and the development of strategic thinking capacities in the project, catalysed or laid the ground to shift worldviews, to add value across scales and to create mutual beneficial, co-evolving relationships.



Social-ecological performance

10

1

Figure 11.1 The map show the social-ecological evaluation of the state-of-the-art of the MAVM (Elaborated with data from INEGI, 2010)

Social-ecological performance

10

1

Figure 11.2 The map show the social-ecological evaluation of a regenerative MAVM by 2050

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Reflection

Small summary of the results

The thesis departed from the problem that is the lack of integration between theories like Regenerative Development and Design (RDD) and planning practices. Theories like RDD take a systematic approach towards bringing sustainable and adaptable solutions to the built environment. Theories like this are highly relevant because they embrace cities as the complex systems that they are.

The thesis used the case study of the Metropolitan Area to answer to the question of how to integrate then, regenerative development and planning practices. It used the working hypothesis that by integrating the geodesign framework as a methodological basis and the Social-Ecological Systems Framework (SESF) as a theoretical/analytical basis, the previous could be achieved. The SESF was used to address the use of social-ecological systems, governance, and multiscalarity, while the geodesign framework was mostly used to achieve transdisciplinarity. The integrated framework was further enhanced to use multiple scales and to allow for co-designing.

The report then presented the methodology that was used to explore such issue, followed by the results of the explorations of the meth-odology in the case study of the MAVM. The thesis proposed a system of technologies and strategies which, by focusing on the value generating capacities of the system, generated the systemic understanding of place and developed the strategic systemic thinking capacities of the designer and the stakeholders. The goal of regenerative development could be understood as to catalyse the transformation of the biophysical and governance components of the social-ecological systems across scales into regeneratively sustainable states (Gib-bons et al., 2018). The systemic understanding of the place and the development of strategic thinking capacities in the project, catalysed or laid the ground to shift worldviews, to add value across scales and to create mutual beneficial, co-evolving relationships.

Reflection on a wider social, professional and scientific framework

The use of an adapted geodesign framework as a methodology to integrate the theory of Regenerative Development and Design and plan-ning, which, as mentioned before, is still a gap in the current spatial planning panorama, provides enough flexibility to be adapted to other projects. Even more, the use of the developed framework can be used not only to bridge regenerative development but also other sustainability approaches such as co-evolutionary planning (Boelens and de Roo, 2014), landscape sustainability (Gibbons et Al., 2018) or circular economy (Van der Leer et al. , 2018; Williams, 2019). The four principles that the methodological framework is based on : social-ecological systems frameworks, governance frameworks, multiscalarity, and trandisciplinarity are principles which were obtained from a thorough research of previous approaches to bridge similar theories and planning practices (Picket et Al. ,2003, Scott et Al. ,2003, Aalto et Al., 2018), van der Leer et Al. , 2018), and Boelens and de Roo, 2014). The outcome of integrating all the studied approaches possess the potential to ultimately further enhance said approaches.

Interestingly, one of the studied cases, uses regeneration as one of the actions needed to ensure circularity in cities. This approach was obviously not used in the research as it uses regeneration which was the actual research subject. However, it serves as a fine example to evidentiate the potential of the adapted geodesign framework developed in this thesis. Wil-liams (2018) proposes to bridge circular economy and urbanism with two principles and three actions. The principles embrace preserving natural capital and optimising resource units, and the actions to achieve such principles are closing resource loops, planning for adaptation (rather in a technical way with adaptable buildings infrastructure), and by regenerating the natural and social capital. The perspective from which Williams tackles such actions, is rather from a biophysical level, without taking much consideration of the governance matters involved. She even suggest that further research is needed in regards of the key actors required to achieve such actions (Williams, 2018). Even more, I find that her actions are also in need of formal methodologies to be achieved. The framework towards regenera-tion proposed in this thesis could be the first step her research could take into achieving one of her three actions, and to properly include a governance framework to her studies.

Further, the definition and the modelling of the performance indictors in a continuous loop for designing and assessingprovided the possibility to run many iterations of the case study in order to reach a co-designed and agreed-upon regenerative strategy. This ultimately, provides a more informed and transparent evaluation of regenerative strategies, that can ultimately improve the values system of the involved actors. This is important, especially in an area where decisions are mainly done in a linear and short-sighted manner. Even more, a regenerative approach not only brings ecological enhancement but also socioeconomical ones, and this method allowed for the stakeholders to notice that.. Such enhancements could provide for a better quality of life for existing and future housing developments.

Lastly, the methodology of the proposed thesis supports the research by design approach that characterises TU Delft's Urbanism research programme. It further focuses on combining the knowledge of urban design, spatial planning, landscape architecture andenvironmental technology. However, while the proposed thesis touches on all the previous topics from the Urban Metabolism perspective, it probably does so more on environmental technology and spatial planning than on urban design and landscape architecture. The research agenda of TU Delft also focuses on more sustaina-ble and fairer environments, which this research elaborated on for Mexico's central basin.

Reflection on the work

I am satisfied with the results of the thesis. When the academic year started I knew it would be a challenge to develop a methodology that would aim to integrate regenerative development with planning practices. I strongly thought that I would have to go beyond paper and screen to achieve such, and to actually co-design in place with the stakeholders involved in the project that are rather used to developing in sectoral and fragmented ways. Even more so, I knew it would be a challenge to develop the necessary knowledge and technical capaci-ties to achieve my research aims. mn the end, I was able to develop, along with the stakeholders, potential regenerative pathways of ac-cordance from the spatial and governance perspectives that went from an sectoral to an integral way, which I am proud of.

Overall, the workshop was perceived by me as a very important moment for the thesis. As I mention, in my report, one of the aims of the thesis is to catalyse a regenerative development in the MAVM, and this was the moment in which I could take this goal beyond paper.

There is, of course, room for much more improvement both in regards to the methodology proposed and in regards to the details of the design.

In regards to the methods

The current assessment of the accessibility to services takes into account how accessible are the newly developed areas to employment center, independently of which kind of employment centers they area. In the future it would be interesting to also develop more the assessment to take into account, for instance, if the employment center has an agro-industrial character, merely an industrial, or if it is more focused on commerce and services. When developing the thesis, I always had in mind, that my strategy should be developed close to the current Agrico-industrial areas in the MAVM: Taxco and Chalco, which were included in Zone 1, but there was no way of highlighting it within the methodology.

Regarding the social performance of the areas where nothing is built or developed yet, the report considered that the areas have low accessibility to services and infrastructure. However, a more precise method to assess this is necessary as in reality, these areas they do not actually need to have infrastructure and services. The current assessment currently adds a value of either 33, 66 or 100 depending on how accessible the areas are to employment centers, taking into account that the value of the areas where they are developed is 0. The modification would indicate that in reality, the development areas should probably subtract the values of 33, 66 and 100 to the areas where originally there was no need for infrastructure or services, and with the layout of housing, the need is created.

In the report, it was also mentioned that the maximum governance performance was set to a very highly, if not even impossible value to achieve. This is due to the fact that the maximum value of the strength of the network depends on having all the stakeholder having strong collaboration with every other, which ultimately is impossible and not even desirable. This, I believe, translated into having rather low governance performance values that did not match the comments and the attitude from the actors after the workshop.

The method to integrate the stakeholders and the researcher's regenerative strategies should further be repeated, as it was only developed once, and it a more qualitative steps which could more easily make it vary.

Lastly, at the beginning, the project aimed to calculate how much water was being prevented from being discharged to the Tula basin at the north of the MAVM, however the scope and time limitations prohibited to do it , but overall it is known that the more water is treated, the less water is being discharged to an external basin.

In regards to the workshop

If I would organise this event again, I would probably send out a Doodle form so that the stakeholders would be able to choose which date fits them the most. On a personal level, I was initially very intimidated with the whole organisation of the event and the reaching out to people. The idea of not having anyone answering this call scared me at first. However, I definitely overcame that, but it inhibited me still of proposing a longer duration of the workshop. With more anticipation doing the previous, I would suggest a more extended workshop, of at least half the day of duration. Due to the limited time of the workshop and the number of interventions to look at the decision support tool that I realised was not able to be used iteratively with the stakeholders, but rather as an evaluation tool in the end. Having iteratively used the tool with the actors could have been very interesting. I am still curious if their reactions towards the interventions or strategies could have changed their choices. However, taking into account that they were satisfied with their final strategy, I could imagine that it most likely would not have been the case.

In regards to the spatial-decision support tool

In regards to the tool, it could also definitely be improved further, as of the moment, it only takes into account the already preselected locations. The previous limits the possibility for the stakeholders to select the areas that they might desire. The issue found with selecting the sites within the tool is that, besides it being extremely time-consuming, the tool would have to have feedback on the evaluation of such locations already.

In regards to the future research

For future research, it would be interesting to study what are the effects of the water balance and the conditions of the land and the strategies on the floodings, draughts, and subsidence rates in the region, and to include those aspects in the social performance evaluation. The accessibility to public spaces is another aspect that could be further studied; however, it could prove to be very challenging to assess the quality of the public spaces in peripheral areas.

The exploration of the use of renewable energy is very closely related to the thesis, as it was considered one of the aspects that would improve social performance, which, unfortunately, due to the scope of the project, was barely touched.

Appendix 1
Agent-based modelling code for NetLogo

```
extensions [ gis ]

globals [socioeco-dataset
     aquifer1-dataset
     aquifer2-dataset
     aquifer3-dataset
     ish-dataset
     z1-dataset
     z2-dataset
     z3-dataset
     socioeco2-dataset
     social-dataset
     ecological-dataset
     boundaries-dataset
      elevation-dataset
      landprice-dataset]

breed [ socioeco-vertices socioeco-vertex]
breed [ aquifer1-vertices aquifer1-vertex]
breed [ aquifer2-vertices aquifer2-vertex]
breed [ aquifer3-vertices aquifer3-vertex]
breed [ ish-vertices ish-vertex]
breed [ z1-vertices z1-vertex]
breed [ z2-vertices z2-vertex]
breed [ z3-vertices z3-vertex]
breed [ social-vertices social-vertex]
breed [ ecological-vertices ecological-vertex]
breed [ landprice-labels landprice-label ]
breed [ boundaries-labels boundaries-label ]
breed [ boundaries-vertices boundaries-vertex]

patches-own [i8t socioeco aquifer1 aquifer2 aquifer3 ish z1 z2 z3 socioeco2 social ecological landprice elevation boundaries]

to setup
 ca
 ;set x-dataset gis:load-dataset "data/x.shp"
 set socioeco-dataset gis:load-dataset "data/N_socialeco.asc"
 set aquifer1-dataset gis:load-dataset "data/N_aa1.asc"
 set aquifer2-dataset gis:load-dataset "data/N_aa2.asc"
 set aquifer3-dataset gis:load-dataset "data/N_aa3.asc"
  set ish-dataset gis:load-dataset "data/N_ISHa.asc"
  set z1-dataset gis:load-dataset "data/N_Z1a.asc"
  set z2-dataset gis:load-dataset "data/N_Z2a.asc"
  set z3-dataset gis:load-dataset "data/N_Z3a.asc"
 set i8t-dataset gis:load-dataset "data/i8_t.asc"
 set ecological-dataset gis:load-dataset "data/ecologicalresilience.asc"
 set elevation-dataset gis:load-dataset "data/slopemaybe.asc"
 set landprice-dataset gis:load-dataset "data/landprice_raster.asc"
 set boundaries-dataset gis:load-dataset "data/statesmaybe.shp"
 ; Set the world envelope to the union of all of our dataset's envelopes
 gis:set-world-envelope (gis:envelope-union-of (gis:envelope-of socioeco-dataset)
```

```
                        (gis:envelope-of aquifer1-dataset)
                        (gis:envelope-of aquifer2-dataset)
                        (gis:envelope-of aquifer3-dataset)
                        (gis:envelope-of ish-dataset)
                        (gis:envelope-of z1-dataset)
                        (gis:envelope-of z2-dataset)
                        (gis:envelope-of z3-dataset)
                        (gis:envelope-of ecological-dataset)
                        (gis:envelope-of landprice-dataset)
                        (gis:envelope-of boundaries-dataset))
end

; TO TRANSFORM RASTER INTO PATCHES
to sample-socioeco-with-patches
 let min-socioeco gis:minimum-of socioeco-dataset
 let max-socioeco gis:maximum-of socioeco-dataset
 ask patches
 [ set socioeco gis:raster-sample socioeco-dataset self]
end

to sample-aquifer1-with-patches
 let min-aquifer1 gis:minimum-of aquifer1-dataset
 let max-aquifer1 gis:maximum-of aquifer1-dataset
 ask patches
 [ set aquifer1 gis:raster-sample aquifer1-dataset self]
end

to sample-aquifer2-with-patches
 let min-aquifer2 gis:minimum-of aquifer2-dataset
 let max-aquifer2 gis:maximum-of aquifer2-dataset
 ask patches
 [ set aquifer2 gis:raster-sample aquifer2-dataset self]
end

to sample-aquifer3-with-patches
 let min-aquifer3 gis:minimum-of aquifer3-dataset
 let max-aquifer3 gis:maximum-of aquifer3-dataset
 ask patches
 [ set aquifer3 gis:raster-sample aquifer3-dataset self]
end

to sample-ish-with-patches
 let min-ish gis:minimum-of ish-dataset
 let max-ish gis:maximum-of ish-dataset
 ask patches
 [ set ish gis:raster-sample ish-dataset self]
end

to sample-z1-with-patches
 let min-z1 gis:minimum-of z1-dataset
 let max-z1 gis:maximum-of z1-dataset
 ask patches
```



```
 [ set z1 gis:raster-sample z1-dataset self]
end

to sample-z2-with-patches
 let min-z2 gis:minimum-of z2-dataset
 let max-z2 gis:maximum-of z2-dataset
 ask patches
 [ set z2 gis:raster-sample z2-dataset self]
end

to sample-z3-with-patches
 let min-z3 gis:minimum-of z3-dataset
 let max-z3 gis:maximum-of z3-dataset
 ask patches
 [ set z3 gis:raster-sample z3-dataset self]
end

; TO INTERVENTIONS
to evaluate
if socioeco  <= 10 [set pcolor pink + 4]
if socioeco > 10 and socioeco <= 20 [set pcolor pink + 3.5]
if socioeco > 20 and socioeco <= 30 [set pcolor red + 3]
if socioeco > 30 and socioeco <= 40 [set pcolor red + 2]
if socioeco > 40 and socioeco <= 50 [set pcolor red]
if socioeco > 50 and socioeco <= 60 [set pcolor red]
if socioeco > 60 and socioeco <= 70 [set pcolor red - 1.5]
if socioeco > 70 and socioeco <= 80 [set pcolor red - 2]
if socioeco > 80 and socioeco <= 90 [set pcolor red - 3]
if socioeco > 90 and socioeco <= 100 [set pcolor red - 4]
end

to z1-h
 ask patches with [z1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 25]
end

to z2-h
 ask patches with [z2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 16.5]
end

to z3-h
 ask patches with [z3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 8.25]
end

to z1-25-Rainfall
 ask patches with [z1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 4.12 ]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.085]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.045]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.205]
end

to z1-50-Rainfall
 ask patches with [z1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 4.12 ]
```

```
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.17]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.095]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 2.41]
end

to z1-75-Rainfall
 ask patches with [z1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 4.12 ]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.25]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.14]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 3.615]
end

to z1-100-Rainfall
 ask patches with [z1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 4.12 ]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.34]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.19]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 4.82]
end

to z2-12-Rainfall
 ask patches with [z2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 4.12 ]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.31]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.165]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.185]
end

to z2-25-Rainfall
 ask patches with [z2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 4.12 ]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.62]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.33]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.37]
end

to z2-50-Rainfall
 ask patches with [z2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 4.12 ]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.24]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.66]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.74]
end

to z3-12-Rainfall
 ask patches with [z3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 4.12 ]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.615]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.045]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.025]
end

to z3-25-Rainfall
 ask patches with [z3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 4.12 ]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.235]
```



```
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.09]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.05]
end

to z3-50-Rainfall
 ask patches with [z3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 4.12 ]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 2.475]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.18]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.10]
end

to wtp-i
 ask patches with [z1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 9.68 ]
 ask patches with [z2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 9.68 ]
 ask patches with [z3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 9.68 ]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.64]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 2.84]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 2.86]
end

to wtp-a
 ask patches with [z1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 16.13 ]
 ask patches with [z2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 16.13]
 ask patches with [z3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 16.13]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.45]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 6.42]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 6.44]
end

to wtp-a2
 ask patches with [z1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 2.68 ]
 ask patches with [z2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 2.68]
 ask patches with [z3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 2.68]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 2.37]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0]
end

to wtp-a3
 ask patches with [z1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.785 ]
 ask patches with [z2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.785]
 ask patches with [z3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.785]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.805]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0]
end

to wtp-a-ss
 ask patches with [z1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 13.745 ]
 ask patches with [z2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 13.745]
```

```
 ask patches with [z3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 13.745]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.375]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.66]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.675]
end

to wtp-a2-ss
 ask patches with [z1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 2.285]
 ask patches with [z2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 2.285]
 ask patches with [z3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 2.285]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.615]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0]
end

to wtp-a3-ss
 ask patches with [z1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.565]
 ask patches with [z2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.565]
 ask patches with [z3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.565]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.47]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0]
end

to wetland-z1-25
 ask patches with [z1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 3.05]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.013]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.007]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.17]
end

to wetland-z1-50
 ask patches with [z1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 3.05]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.025]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.15]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.38]
end

to wetland-z1-75
 ask patches with [z1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 3.05]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.05]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.025]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.765]
end

to wetland-z1
 ask patches with [z1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 3.05]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.1]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.45]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.5]
```



```
end

to wetland-z2-12
 ask patches with [z2 = 2 and socioeco <= 100 ] [set socioeco socioeco + 3.05]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.135]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.155]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.29]
end

to wetland-z2-25
 ask patches with [z2 = 2 and socioeco <= 100 ] [set socioeco socioeco + 3.05]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.275]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.29]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 058.]
end

to wetland-z2-50
 ask patches with [z2 = 2 and socioeco <= 100 ] [set socioeco socioeco + 3.05]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.55]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.55]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.15]
end

to wetland-z3-12
 ask patches with [z3 = 3 and socioeco <= 100 ] [set socioeco socioeco + 3.05]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.27]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.035]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.02]
end

to wetland-z3-25
 ask patches with [z3 = 3 and socioeco <= 100 ] [set socioeco socioeco + 3.05]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.54]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.07]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.04]
end

to wetland-z3-50
 ask patches with [z3 = 3 and socioeco <= 100 ] [set socioeco socioeco + 3.05]
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.095]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.14]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.125]
end

to wells-increase
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco - 9.212]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco - 47.07]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco - 36.845]
end
```

```
to lagoon
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.025]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 2.985]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 4.345]
end

to lagoon-z2
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.75]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 12.65]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 3.04]
end

to lagoon-z3
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.445]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 16.3]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 5.915]
end

to well
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 2.21]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 2.21]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 2.21]
end

to well-z2
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 2.21]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 2.21]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 2.21]
end

to well-z3
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 2.21]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 2.21]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 2.21]
end

to inyection
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.115]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.34]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.445]
end

to vegetation_low
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.44]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.17]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.87]
end

to vegetation_high
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.095]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.525]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.025]
```



```
end

to terracing_low
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.31]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.83]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.325]
end

to terracing_high
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.065]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.395]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.725]
end

to vegetationterracing_low
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.575]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.53]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 2.44]
end

to vegetationterracing_high
 ask patches with [aquifer1 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.125]
 ask patches with [aquifer2 = 1 and socioeco <= 100 ] [set socioeco socioeco + 0.685]
 ask patches with [aquifer3 = 1 and socioeco <= 100 ] [set socioeco socioeco + 1.335]
end

; TO WORK WITH NEIGHBOURING CELLS
to regeneration-10
if (z1 = 1) and (socioeco >= 25)
 [ask neighbors [set pcolor magenta]]
end

to regeneration-20
if ( pcolor = magenta) and (socioeco >= 25)
 [ask neighbors [set pcolor magenta]]
end

to regeneration-30
if ( pcolor = magenta) and (socioeco >= 25)
 [ask neighbors [set pcolor magenta]]
end

; TO STORE!
to store
 let patches_out nobody
 ask one-of patches [
  set patches_out gis:patch-dataset pcolor
 ]
 gis:store-dataset patches_out "R_socialeco_try.asc"
end
```

Appendix 2
Supporting calculations and data

Intervention	Density	Hab/Ha	Area Cuautitlan	Area Texcoco	Area Chalco	Area total	Habitants	lps per Ha	m3/s per Ha	Black water disposal	Only Black water disposal	Grey water disposal	Grey water disposal Cuatutiltan	Grey water disposal Texcoco	Grey water disposal Chalco
Other built area			61628				800,000.00	0.08	0.00008	4.93024	1.281862	3.648378			
Informal housing			17826					0.08	0.00008	1.42608	0.370781	1.055299			
Social housing			1528					0.08	0.00008	0.12224	0.031782	0.090458			
Zone 1	25%	22.50	1021	290	4043	5354	120,465.00	0.015	0.000015	0.08031	0.020881	0.059429	0.0113331	0.003219	0.044877
Zone 1	50%	45.00	1021	290	4043	5354	240,930.00	0.03	0.00003	0.16062	0.041761	0.118859	0.0226662	0.006438	0.089755
Zone 1	75%	67.50	1021	290	4043	5354	361,395.00	0.06	0.00006	0.32124	0.083522	0.237718	0.0453324	0.012876	0.179509
Zone 1	100%	90.00	1021	290	4043	5354	481,860.00	0.12	0.00012	0.64248	0.167045	0.475435	0.0906648	0.025752	0.359018
Zone 2	12.5	11.25	20722	11082	12379	44183	497,058.75	0.0075	0.0000075	0.331373	0.086157	0.245216	0.1150071	0.061505	0.068703
Zone 2	25%	22.50	20722	11082	12379	44183	994,117.50	0.015	0.000015	0.662745	0.172314	0.490431	0.2300142	0.12301	0.137407
Zone 2	50%	45.00	20722	11082	12379	44183	1,988,235.00	0.03	0.00003	1.32549	0.344627	0.980863	0.4600284	0.24602	0.274814
Zone 2	75%	67.50	44199				-	0.06	0.00006	0	0	0	1.9624356	0	0
Zone 3	100%	90.00	44199				-	0.12	0.00012	0	0	0	3.9248712	0	0
Zone 3	12.5	11.25	41349	3081	1797	46227	520,053.75	0.0075	0.0000075	0.346703	0.090143	0.25656	0.22948695	0.0171	0.009973
Zone 3	25%	22.50	41349	3081	1797	46227	1,040,107.50	0.015	0.000015	0.693405	0.180285	0.51312	0.4589739	0.034199	0.019947
Zone 3	50%	45.00	41349	3081	1797	46227	2,080,215.00	0.03	0.00003	1.38681	0.360571	1.026239	0.9179478	0.068398	0.039893
Zone 3	75%	67.50	46227				-	1.03	0.00103	0	0	0	35.2342194	0	0
Zone 3	100%	90.00	46227				-	2.03	0.00203	0	0	0	69.4421994	0	0

Figure App.1.1 Calculations of the density, areas, population, water consumption, and water disposal of the differnt interventions related to the social system (Elaborated with data from Redacción (2015).)

Aq.	Intervention	m3/s
CUAUTITLA	Current extraction	13.16
TEXCOCO	Current extraction	7.82
CHALCO	Current extraction	3.1
CUAUTITLA	Augmented extraction	7.57
TEXCOCO	Augmented extraction	19.82
CHALCO	Augmented extraction	8.57

Aquifer	Intervention	Area (Ha)	Area (m2) 60%	Amount of rainwater m3/s per m2	Cost per m2	Total caught rainwater	Total cost	Household cost
CUAUTITLA	Rainwater catchment- Informal and s	3246.42	25971360	0.000000035	4,332.00	0.90	112,507,931,520.000	151,620.00
TEXCOCO		7025.37	56202960	0.000000035	4,332.00	1.95	243,471,222,720.000	151,620.00
CHALCO		3841.17	30729360	0.000000035	4,332.00	1.07	133,119,587,520.000	151,620.00
CUATITLAN	Rainwater catchment- Social housing	301.58	2412640	0.000000035	4,332.00	0.08	10,451,556,480.000	151,620.00
TEXCOCO		652.63	5221040	0.000000035	4,332.00	0.18	22,617,545,280.000	151,620.00
CHALCO		356.83	2854640	0.000000035	4,332.00	0.10	12,366,300,480.000	151,620.00
CUAUTITLA	Rainwater catchment- Zone 1.25	255.25	2042000	0.000000035	4,332.00	0.07	8,845,944,000.000	151,620.00
TEXCOCO		72.5	580000	0.000000035	4,332.00	0.02	2,512,560,000.000	151,620.00
CHALCO		1010.75	8086000	0.000000035	4,332.00	0.28	35,028,552,000.000	151,620.00
CUAUTITLA	Rainwater catchment- Zone 1.50	510.5	4084000	0.000000035	4,332.00	0.14	17,691,888,000.000	151,620.00
TEXCOCO		145	1160000	0.000000035	4,332.00	0.04	5,025,120,000.000	151,620.00
CHALCO		2021.5	16172000	0.000000035	4,332.00	0.56	70,057,104,000.000	151,620.00
CUAUTITLA	Rainwater catchment- Zone 1.75	765.75	6126000	0.000000035	4,332.00	0.21	26,537,832,000.000	151,620.00
TEXCOCO		217.5	1740000	0.000000035	4,332.00	0.06	7,537,680,000.000	151,620.00
CHALCO		3032.25	24258000	0.000000035	4,332.00	0.84	105,085,656,000.000	151,620.00
CUAUTITLA	Rainwater catchment- Zone 1	1021	8168000	0.000000035	4,332.00	0.28	35,383,776,000.000	151,620.00
TEXCOCO		290	2320000	0.000000035	4,332.00	0.08	10,050,240,000.000	151,620.00
CHALCO		4043	32344000	0.000000035	4,332.00	1.12	140,114,208,000.000	151,620.00
CUAUTITLA	Rainwater catchment- Zone 2.25	5180.5	41444000	0.000000035	4,332.00	1.44	179,535,408,000.000	151,620.00
TEXCOCO		2770.5	22164000	0.000000035	4,332.00	0.77	96,014,448,000.000	151,620.00
CHALCO		3094.75	24758000	0.000000035	4,332.00	0.86	107,251,656,000.000	151,620.00
CUAUTITLA	Rainwater catchment- Zone 2.5	10361	82888000	0.000000035	4,332.00	2.88	359,070,816,000.000	151,620.00
TEXCOCO		5541	44328000	0.000000035	4,332.00	1.54	192,028,896,000.000	151,620.00
CHALCO		6189.5	49516000	0.000000035	4,332.00	1.72	214,503,312,000.000	151,620.00
CUAUTITLA	Rainwater catchment- Zone 3.25	10337.25	82698000	0.000000035	4,332.00	2.87	358,247,736,000.000	151,620.00
TEXCOCO		770.25	6162000	0.000000035	4,332.00	0.21	26,693,784,000.000	151,620.00
CHALCO		449.25	3594000	0.000000035	4,332.00	0.12	15,569,208,000.000	151,620.00
CUAUTITLA	Rainwater catchment- Zone 3.50	20674.5	165396000	0.000000035	4,332.00	5.74	716,495,472,000.000	151,620.00
TEXCOCO		1540.5	12324000	0.000000035	4,332.00	0.43	53,387,568,000.000	151,620.00
CHALCO		898.5	7188000	0.000000035	4,332.00	0.25	31,138,416,000.000	151,620.00
CUAUTITLA	Rainwater catchment- Zone 4.25	255.25	2042000	0.000000035	4,332.00	0.07	8,845,944,000.000	151,620.00

Figure App.1.2 Calculations of the data related to the rainwater caachment (Elaborated with data from Isla Urbana (2019)

Aq.	Intervention	Number of WTP	Quantity of treated water	Cots of improvement per m3/s	Cost per new WTP	Cost of gasoelectric	Infrastructure network length (average)	Netowork cost	Total cost of network	Cost of purification plant	Total cost	Total cost for only remodeling the necessary amount
CUAT	Current water	4	0.66666667									
TEXC	Current water	9	1.5									
CHAL	Current water	*5*	0.83333333									
ALL		*18*	3									
CUAT	Extra improve	4	0.53333333	200000000							106,666,666.67	
TEXC	Extra improve	9	1.2	200000000							240,000,000.00	
CHAL	Extra improve	*5*	0.66666667	200000000							133,333,333.33	
ALL		*18*	2.4								480,000,000.00	
CUAT	Turn to anaer	4	1.2	800000000							960,000,000.00	
TEXC	Turn to anaer	9	2.7	800000000							2,160,000,000.00	540,000,000.00
CHAL	Turn to anaer	*5*	1.5	800000000							1,200,000,000.00	300,000,000.00
ALL		*18*	5.4	4.5							4,320,000,000.00	
TEXC	Extra anaerob	2	1		570000000	70000000	6	1500000	9000000	220000000	869,000,000.00	
CUAU	Extra anaerob	3	1.5		570000000	70000000	6	1500000	9000000	220000000	1,299,000,000.00	
CUAT	Turn to anaer	4	0.45066667	800000000							360,533,333.33	90,133,333.33
TEXC	Turn to anaer	9	1.014	800000000							811,200,000.00	202,800,000.00
CHAL	Turn to anaer	*5*	0.56333333	800000000							450,666,666.67	112,666,666.67
ALL		*18*	5.4	4.5							1,622,400,000.00	
TEXC	Extra anaerob	2	0.26		570000000	70000000	6	1500000	9000000	220000000	225,940,000.00	
CUAU	Extra anaerob	3	0.39		570000000	70000000	6	1500000	9000000	220000000	337,740,000.00	

Figure App.1.3 Calculations of the data related to water treatment of wastewater(Elaborated with data from CONAGUA (2017) and Redacción (2015).)

Aq	Intervention	Quantity of treated water	Water treatment per Ha of wetland	Cost per Ha of wetland	Total amount of Ha of wetland needed	Total cost of intervention
CUAUTITLAN	Wetlands zone 1.25	0.011	0.1	17629	*0.11*	1,939.19
TEXOCO	Wetlands zone 1.25	0.003	0.1	17629	*0.03*	528.87
CHALCO	Wetlands zone 1.25	0.04	0.1	17629	*0.4*	7,051.60
						9,519.66
						-
CUAUTITLAN	Wetlands zone 1.5	0.022	0.1	17629	*0.22*	3,878.38
TEXOCO	Wetlands zone 1.5	0.0064	0.1	17629	*0.064*	1,128.26
CHALCO	Wetlands zone 1.5	0.089	0.1	17629	*0.89*	15,689.81
						20,696.45
						-
CUAUTITLAN	Wetlands zone 1.75	0.045	0.1	17629	*0.45*	7,933.05
TEXOCO	Wetlands zone 1.75	0.012	0.1	17629	*0.12*	2,115.48
CHALCO	Wetlands zone 1.75	0.179	0.1	17629	*1.79*	31,555.91
						41,604.44
						-
CUAUTITLAN	Wetlands zone 1	0.09	0.1	17629	*0.9*	15,866.10
TEXOCO	Wetlands zone 1	0.02	0.1	17629	*0.2*	3,525.80
CHALCO	Wetlands zone 1	0.35	0.1	17629	*3.5*	61,701.50
						81,093.40
						-
CUAUTITLAN	Wetlands zone 2.25	0.23	0.1	17629	*2.3*	40,546.70
TEXOCO	Wetlands zone 2.25	0.123	0.1	17629	*1.23*	21,683.67
CHALCO	Wetlands zone 2.25	0.137	0.1	17629	*1.37*	24,151.73
						86,382.10
						-
CUAUTITLAN	Wetlands zone 2.50	0.46	0.1	17629	*4.6*	81,093.40
TEXOCO	Wetlands zone 2.50	0.24	0.1	17629	*2.4*	42,309.60
CHALCO	Wetlands zone 2.50	0.27	0.1	17629	*2.7*	47,598.30
						171,001.30
						-
CUAUTITLAN	Wetlands zone 3.25	0.45	0.1	17629	*4.5*	79,330.50
TEXOCO	Wetlands zone 3.25	0.03	0.1	17629	*0.3*	5,288.70
CHALCO	Wetlands zone 3.25	0.01	0.1	17629	*0.1*	1,762.90
						86,382.10
						-
CUAUTITLAN	Wetlands 3.50	0.91	0.1	17629	*9.1*	160,423.90
TEXOCO	Wetlands 3.50	0.06	0.1	17629	*0.6*	10,577.40
CHALCO	Wetlands 3.50	0.03	0.1	17629	*0.3*	5,288.70
						176,290.00

Figure App.1.4 Calculations of the data related to water treatment with wetlands (Elaborated with data from Comisión de Cuenca De Los Ríos Amecameca Y La Compañía (2009), and Redacción (2015).)

Aq.	Intervention	m3/S
CUAUTITLAN	Current infiltration	11.31
TEXOCO	Current infiltration	4.93
CHALCO	Current infiltration	2.62

Aquifer	Intervention	Area/ quantity	Infiltrated water per Ha of lagoon	Cost	Infiltrated water per infiltration unit	Cost	Total new infiltration	Total cost
CUAUTITLAN	Infiltration lagoons	*3.79*	0.23	15,400,000.00			0.8717	58,366,000.00
TEXCOCO		*21.67*	0.23	15,400,000.00			4.9841	333,718,000.00
CHALCO		*5.67*	0.23	15,400,000.00			1.3041	87,318,000.00
CUAUTITLAN	Infiltration lagoons - zone 1	*3.79*	0.23	15,400,000.00			0.8717	58,366,000.00
TEXCOCO		*21.67*	0.23	15,400,000.00			4.9841	333,718,000.00
CHALCO		*5.67*	0.23	15,400,000.00			1.3041	87,318,000.00
CUAUTITLAN	Infiltration lagoons - zone 2	*2.94*	0.23	15,400,000.00			0.6762	45,276,000.00
TEXCOCO		*16.06*	0.23	15,400,000.00			3.6938	247,324,000.00
CHALCO		*2.65*	0.23	15,400,000.00			0.6095	40,810,000.00
CUAUTITLAN	Infiltration lagoons - zone 3	*1.62*	0.23	15,400,000.00			0.3726	24,948,000.00
TEXCOCO		*20.7*	0.23	15,400,000.00			4.761	318,780,000.00
CHALCO		*5.15*	0.23	15,400,000.00			1.1845	79,310,000.00
CUAUTITLAN	Infiltration wells	*32*			0.06	11948	1.92	382,336.00
TEXCOCO		*32*						
CHALCO		*32*						
CUAUTITLAN	Infiltration wells - zone 1	*32*			0.06	11948	1.92	382,336.00
TEXCOCO		*32*						
CHALCO		*32*						
CUAUTITLAN	Infiltration wells - zone 2	*32*			0.06	11948	1.92	382,336.00
TEXCOCO		*32*						
CHALCO		*32*						
CUAUTITLAN	Infiltration wells - zone 3	*32*			0.06	11948	1.92	382,336.00
TEXCOCO		*32*						
CHALCO		*32*						
CUAUTITLAN	Inyection wells	*1*			0.1	11948	0.1	11,948.00
TEXCOCO	Inyection wells	*1*			0.1	11948	0.1	11,948.00
CHALCO	Inyection wells	*1*			0.1	11948	0.1	11,948.00

Figure App.1.5 Calculations of the data related to the artifical infiltration of runoff (Elaborated with data from Burns, E. (2009), and Comisión de Cuenca De Los Ríos Amecameca Y La Compañía (2009))

Aq.	Intervention		Area	Extra infiltration	Cost	Total improveme nt infiltration	Total cost
CUAUTITLAN	Vegteation in low slope	4731	4731	0.000079	90,000.00	0.373749	425,790,000.00
TEXCOCO		4341	4341	0.000079	90,000.00	0.342939	390,690,000.00
CHALCO		4755	4755	0.000079	90,000.00	0.375645	427,950,000.00
CUAUTITLAN	Vegetation in high slope	1045	1045	0.000079	90,000.00	0.082555	94,050,000.00
TEXCOCO		1954	1954	0.000079	90,000.00	0.154366	175,860,000.00
CHALCO		2603	2603	0.000079	90,000.00	0.205637	234,270,000.00
CUAUTITLAN	Terraces in low slope	4731	4731	0.000056	20,977.00	0.264936	99,242,187.00
TEXCOCO		4341	4341	0.000056	20,977.00	0.243096	91,061,157.00
CHALCO		4755	4755	0.000056	20,977.00	0.26628	99,745,635.00
CUAUTITLAN	Terraces in high slope	1045	1045	0.000056	20,977.00	0.05852	21,920,965.00
TEXCOCO		1954	1954	0.000056	20,977.00	0.109424	40,989,058.00
CHALCO		2603	2603	0.000056	20,977.00	0.145768	54,603,131.00
CUAUTITLAN	Vegetation and terraces in	4731	4731	0.000103	110,977.00	0.487293	525,032,187.00
TEXCOCO		4341	4341	0.000103	110,977.00	0.447123	481,751,157.00
CHALCO		4755	4755	0.000103	110,977.00	0.489765	527,695,635.00
CUAUTITLAN	Vegetation and terraces in	1045	1045	0.000103	110,977.00	0.107635	115,970,965.00
TEXCOCO		1954	1954	0.000103	110,977.00	0.201262	216,849,058.00
CHALCO		2603	2603	0.000103	110,977.00	0.268109	288,873,131.00

Intervention	Total cost
Current discharge	**0**
Augmented discharge	18,000,000,000.00

Intervention	Total cost
External supply	**0**
Augmented external suppl	**0**

Figure App.1.6 Calculations of the data related to the delayment of runoff f (Elaborated with data from Burns, E. (2009), and Comisión de Cuenca De Los Ríos Amecameca Y La Compañía (2009))

	SEMARNAT	SEDEMA/SEDEMA	CONAGUA	SACMEX/CAEM	SEDATU	SEDUVI/SEDUVYM	Gobierno estatal	Gobierno local	Entidades financieras	Desarrolladores de vivienda social	Asociaciones civiles de desarrollo de vivienda social	Asociaciones civiles de desarrollo de vivienda informal	Compañías de impacto ambiental	Compañías de impacto social
SEMARNAT														
SEDEMA/SEDEMA														
CONAGUA														
SACMEX/CAEM	4	4	4		3	3	4	3	2	3	2	2	3	4
SEDATU	5	3	5	3		3	5	3	2	3	3	3	2	2
SEDUVI/SEDUVYM														
Gobierno estatal														
Gobierno local	3	4	4	5	3	4	3		1	5	5	5	2	2
Entidades financieras	5	5	5	5	5	5	5	5		5	3	3	5	5
Desarrolladores de vivienda social	3	5	3	5	4	5	5	5	5		1	1	1	3
Asociaciones civiles de desarrollo de vivienda social	3	4	4	4	4	5	5	5	4	1		5	5	5
Asociaciones civiles de desarrollo de vivienda informal	3	3	4	5	3	5	5	5	2	2	3		4	4
Compañías de impacto ambiental									1					
Compañías de impacto social	4	1	5	3	4	4	3	2	1	3	1	1	1	

Figure App.1.7 Matrix of how the integration amongst the stakeholder prior to the workshop (Elaborated with data from the Interviews in Appendix 3)

	SEMARNAT	SEDEMA/SEDEMA	CONAGUA	SACMEX/CAEM	SEDATU	SEDUVI/SEDUVYM	Gobierno estatal	Gobierno local	Entidades financieras	Desarrolladores de vivienda social	Asociaciones civiles de desarrollo de vivienda social	Asociaciones civiles de desarrollo de vivienda informal	Compañías de impacto ambiental	Compañías de impacto social
SEMARNAT														
SEDEMA/SEDEMA														
CONAGUA	5	4		4	5	5	5	5	3	3	3	3	3	5
SACMEX/CAEM														
SEDATU	5	4	5	4		4	4	3	3	3	3	3	3	3
SEDUVI/SEDUVYM														
Gobierno estatal														
Gobierno local	4	5	4	5	5	5		3	3	5	5	5	5	5
Entidades financieras	5	5	5	5	5	5	5	3		5	3	3	5	5
Desarrolladores de vivienda social	3	5	3	5	4	5	5	5	5		1	1	1	3
Asociaciones civiles de desarrollo de vivienda social	2	4	2	4	2	4	4	4	3	1		5	5	5
Asociaciones civiles de desarrollo de vivienda informal	4	5	4	5	4	5	4	5	3	3	3		5	4
Compañías de impacto ambiental														
Compañias de impacto social (ambiental)	5	4	5	4	5	5	4	5	4	3	5	5		5

Figure App.1.8 Matrix of the integration amongst the stakeholder prior to the workshop (Elaborated with data from the Interviews in Appendix 3)

Appendix 3
Surveys

Rol: Entidad Financiero

Encuesta 1

1= Muy alto	2= Alto	3= Regular	4= Bajo	5= Muy bajo

¿Cómo evaluaría el interés en el desempeño ecológico desde su rol?

1 2 3 4 **5**

¿Cómo evaluaría el interés en el desempeño social desde su rol?

1 2 3 4 **5**

¿Cómo evaluaría el interés en el rendimiento económico de sus acciones desde su rol?

1 2 3 4 **5**

¿Cómo evaluaría que tan estrecha es su relación/colaboración desde su rol con los siguientes actores?

SEMARNAT	1	2	3	4	**5**
SEDEMA/SEDEMA	1	2	3	4	**5**
CONAGUA	1	2	3	4	**5**
SACMEX/CAEM	1	2	3	4	**5**
SEDATU	1	2	3	4	**5**
SEDUVI/SEDUVYM	1	2	3	4	**5**
Gobierno estatal	1	2	3	4	**5**
Gobierno local	1	2	3	4	**5**
Entidades financieras	1	2	3	4	**5**
Desarrolladores de vivienda social	1	2	3	4	**5**
Asociaciones civiles de desarrollo de vivienda social	1	2	**3**	4	5
Asociaciones civiles de desarrollo de vivienda informal	1	2	**3**	4	5
Compañías de impacto social	1	2	3	4	**5**
Compañías de impacto ambiental	1	2	3	4	**5**
Habitantes de vivienda social	1	2	3	4	**5**
Habitantes de vivienda informal	1	2	3	4	**5**

¿Cómo evaluaría el conocimiento que tiene desde su rol acerca del desarrollo regenerativo?

1 2 3 4 **5**

Si tiene conocimiento acerca del desarrollo regenerativo, ¿cómo evaluaría su interés en tal?

1 2 3 4 5

Rol: Representante de asosiación formal para desarrollo de vivienda Encuesta 1

1= Muy alto	2= Alto	3= Regular	4= Bajo	5= Muy bajo

¿Cómo evaluaría el interés en el desempeño ecológico desde su rol?

1 2 3 4 5

¿Cómo evaluaría el interés en el desempeño social desde su rol?

1 2 3 4 5

¿Cómo evaluaría el interés en el rendimiento económico de sus acciones desde su rol?

1 **2** 3 4 5

¿Cómo evaluaría que tan estrecha es su relación/colaboración desde su rol con los siguientes actores?

SEMARNAT	1	2	**3**	4	5
SEDEMA/SEDEMA	1	**2**	3	4	5
CONAGUA	1	**2**	3	4	5
SACMEX/CAEM	1	**2**	3	4	5
SEDATU	1	2	**3**	4	5
SEDUVI/SEDUVYM	**1**	2	3	4	5
Gobierno estatal	**1**	2	3	4	5
Gobierno local	**1**	2	3	4	5
Entidades financieras	1	**2**	3	4	5
Desarrolladores de vivienda social	**1**	2	3	4	5
Asociaciones civiles de desarrollo de vivienda social	**1**	2	3	4	5
Asociaciones civiles de desarrollo de vivienda informal	**1**	2	3	4	5
Compañías de impacto social	**1**	2	3	4	5
Compañías de impacto ambiental	1	2	3	4	5
Habitantes de vivienda social	**1**	2	3	4	5
Habitantes de vivienda informal	**1**	2	3	4	5

¿Cómo evaluaría el conocimiento que tiene desde su rol acerca del desarrollo regenerativo?

1 2 3 **4** 5

Si tiene conocimiento acerca del desarrollo regenerativo, ¿cómo evaluaría su interés en tal?

1 2 3 4 5

Rol: Representante SACMEX Encuesta 1

1= Muy alto	2= Alto	3= Regular	4= Bajo	5= Muy bajo

¿Cómo evaluaría el interés en el desempeño ecológico desde su rol?

1 **2** 3 4 5

¿Cómo evaluaría el interés en el desempeño social desde su rol?

1 2 **3** 4 5

¿Cómo evaluaría el interés en el rendimiento económico de sus acciones desde su rol?

1 2 3 **4** 5

¿Cómo evaluaría que tan estrecha es su relación/colaboración desde su rol con los siguientes actores?

SEMARNAT	1	**2**	3	4	5
SEDEMA/SEDEMA	1	**2**	3	4	5
CONAGUA	1	**2**	3	4	5
SACMEX/CAEM	**1**	2	3	4	5
SEDATU	1	2	**3**	4	5
SEDUVI/SEDUVYM	1	2	**3**	4	5
Gobierno estatal	1	**2**	3	4	5
Gobierno local	1	2	**3**	4	5
Entidades financieras	1	2	3	**4**	5
Desarrolladores de vivienda social	1	2	**3**	4	5
Asociaciones civiles de desarrollo de vivienda social	1	2	3	**4**	5
Asociaciones civiles de desarrollo de vivienda informal	1	2	3	**4**	5
Compañías de impacto social	1	2	**3**	4	5
Compañías de impacto ambiental	1	**2**	3	4	5
Habitantes de vivienda social	1	2	**3**	4	5
Habitantes de vivienda informal	1	2	**3**	4	5

¿Cómo evaluaría el conocimiento que tiene desde su rol acerca del desarrollo regenerativo?

1 2 **3** 4 5

Si tiene conocimiento acerca del desarrollo regenerativo, ¿cómo evaluaría su interés en tal?

1 2 **3** 4 5

Rol: Desarrolador de Viviande

Encuesta 1

1= Muy alto 2= Alto 3= Regular 4= Bajo 5= Muy bajo

¿Cómo evaluaría el interés en el desempeño ecológico desde su rol?

1 **2** 3 4 5

¿Cómo evaluaría el interés en el desempeño social desde su rol?

1 2 **3** 4 5

¿Cómo evaluaría el interés en el rendimiento económico de sus acciones desde su rol?

1 2 **3** 4 5

¿Cómo evaluaría que tan estrecha es su relación/colaboración desde su rol con los siguientes actores?

SEMARNAT	1	2	**3**	4	5
SEDEMA/SEDEMA	**1**	2	3	4	5
CONAGUA	1	2	**3**	4	5
SACMEX/CAEM	**1**	2	3	4	5
SEDATU	1	**2**	3	4	5
SEDUVI/SEDUVYM	**1**	2	3	4	5
Gobierno estatal	**1**	2	3	4	5
Gobierno local	**1**	2	3	4	5
Entidades financieras	**1**	2	3	4	5
Desarrolladores de vivienda social	1	2	3	4	5
Asociaciones civiles de desarrollo de vivienda social	1	2	3	4	**5**
Asociaciones civiles de desarrollo de vivienda informal	1	2	3	4	**5**
Compañías de impacto social	1	2	3	4	**5**
Compañías de impacto ambiental	1	2	**3**	4	5
Habitantes de vivienda social	1	2	**3**	4	5
Habitantes de vivienda informal	1	2	3	4	**5**

¿Cómo evaluaría el conocimiento que tiene desde su rol acerca del desarrollo regenerativo?

1 2 **3** 4 5

Si tiene conocimiento acerca del desarrollo regenerativo, ¿cómo evaluaría su interés en tal?

1 **2** 3 4 5

Rol: SEDATU

Encuesta 1

1= Muy alto 2= Alto 3= Regular 4= Bajo 5= Muy bajo

¿Cómo evaluaría el interés en el desempeño ecológico desde su rol?

1 2 3 4 **5**

¿Cómo evaluaría el interés en el desempeño social desde su rol?

1 2 3 4 **5**

¿Cómo evaluaría el interés en el rendimiento económico de sus acciones desde su rol?

1 2 3 4 **5**

¿Cómo evaluaría que tan estrecha es su relación/colaboración desde su rol con los siguientes actores?

SEMARNAT	1	2	3	4	**5**
SEDEMA/SEDEMA	1	2	**3**	4	5
CONAGUA	1	2	3	4	**5**
SACMEX/CAEM	1	2	**3**	4	5
SEDATU	1	2	3	4	**5**
SEDUVI/SEDUVYM	1	2	**3**	4	5
Gobierno estatal	1	2	3	4	**5**
Gobierno local	1	2	**3**	4	5
Entidades financieras	1	**2**	3	4	5
Desarrolladores de vivienda social	1	2	**3**	4	5
Asociaciones civiles de desarrollo de vivienda social	1	2	**3**	4	5
Asociaciones civiles de desarrollo de vivienda informal	1	2	**3**	4	5
Compañías de impacto social	1	**2**	3	4	5
Compañías de impacto ambiental	1	**2**	3	4	5
Habitantes de vivienda social	1	2	**3**	4	5
Habitantes de vivienda informal	1	2	**3**	4	5

¿Cómo evaluaría el conocimiento que tiene desde su rol acerca del desarrollo regenerativo?

1 2 **3** 4 5

Si tiene conocimiento acerca del desarrollo regenerativo, ¿cómo evaluaría su interés en tal?

1 2 3 **4** 5

Rol: Asociacones des cules des desarrollo de vivienda informal — Encuesta 1

1= Muy alto	2= Alto	3= Regular	4= Bajo	5= Muy bajo

¿Cómo evaluaría el interés en el desempeño ecológico desde su rol?

1 **2** 3 4 5

¿Cómo evaluaría el interés en el desempeño social desde su rol?

1 2 3 4 5

¿Cómo evaluaría el interés en el rendimiento económico de sus acciones desde su rol?

1 2 **3** 4 5

¿Cómo evaluaría que tan estrecha es su relación/colaboración desde su rol con los siguientes actores?

SEMARNAT	1	2	**3**	4	5
SEDEMA/SEDEMA	1	2	**3**	4	5
CONAGUA	1	**2**	3	4	5
SACMEX/CAEM	**1**	2	3	4	5
SEDATU	1	2	**3**	4	5
SEDUVI/SEDUVYM	**1**	2	3	4	5
Gobierno estatal	**1**	2	3	4	5
Gobierno local	**1**	2	3	4	5
Entidades financieras	1	2	3	**4**	5
Desarrolladores de vivienda social	1	2	3	**4**	5
Asociaciones civiles de desarrollo de vivienda social	1	2	**3**	4	5
Asociaciones civiles de desarrollo de vivienda informal	1	2	3	4	5
Compañías de impacto social	1	**2**	3	4	5
Compañías de impacto ambiental	1	**2**	3	4	5
Habitantes de vivienda social	1	2	3	**4**	5
Habitantes de vivienda informal	**1**	2	3	4	5

¿Cómo evaluaría el conocimiento que tiene desde su rol acerca del desarrollo regenerativo?

1 2 3 **4** 5

Si tiene conocimiento acerca del desarrollo regenerativo, ¿cómo evaluaría su interés en tal?

1 **2** 3 4 5

Rol: — Encuesta 1

1= Muy alto	2= Alto	3= Regular	4= Bajo	5= Muy bajo

¿Cómo evaluaría el interés en el desempeño ecológico desde su rol?

1 2 3 4 5

¿Cómo evaluaría el interés en el desempeño social desde su rol?

1 2 3 4 5

¿Cómo evaluaría el interés en el rendimiento económico de sus acciones desde su rol?

1 2 3 4 5

¿Cómo evaluaría que tan estrecha es su relación/colaboración desde su rol con los siguientes actores?

SEMARNAT	1	**2**	3	4	5
SEDEMA/SEDEMA	1	2	3	**4**	5
CONAGUA	**1**	2	3	4	5
SACMEX/CAEM	1	2	**3**	4	5
SEDATU	1	**2**	3	4	5
SEDUVI/SEDUVYM	**1**	2	3	4	5
Gobierno estatal	1	2	**3**	4	5
Gobierno local	**1**	2	3	4	5
Entidades financieras	1	2	**3**	4	5
Desarrolladores de vivienda social	**1**	2	3	4	5
Asociaciones civiles de desarrollo de vivienda social	**1**	2	3	4	**5**
Asociaciones civiles de desarrollo de vivienda informal	**1**	2	3	4	**5**
Compañías de impacto social	**1**	2	3	4	**5**
Compañías de impacto ambiental	**1**	2	**3**	4	5
Habitantes de vivienda social	**1**	2	**3**	4	5
Habitantes de vivienda informal	**1**	2	3	4	**5**

¿Cómo evaluaría el conocimiento que tiene desde su rol acerca del desarrollo regenerativo?

1 2 **3** 4 5

Si tiene conocimiento acerca del desarrollo regenerativo, ¿cómo evaluaría su interés en tal?

1 2 3 4 **5**

Rol: SEDATU

Encuesta 2

1= Muy alto 2= Alto 3= Regular 4= Bajo 5= Muy bajo

¿Cómo evaluaría el interés en el desempeño ecológico desde su rol?

1 2 3 4 **5**

¿Cómo evaluaría el interés en el desempeño social desde su rol?

1 2 3 4 **5**

¿Cómo evaluaría el interés en el rendimiento económico de sus acciones desde su rol?

1 **2** 3 4 5

¿Cómo evaluaría que tan estrecha es su relación/colaboración desde su rol con los siguientes actores?

SEMARNAT	1	2	3	4	**5**
SEDEMA/SEDEMA	1	2	3	**4**	5
CONAGUA	1	2	3	4	**5**
SACMEX/CAEM	1	2	3	**4**	5
SEDATU	1	2	3	4	5
SEDUVI/SEDUVYM	1	2	3	**4**	5
Gobierno estatal	1	2	3	**4**	5
Gobierno local	1	2	**3**	4	5
Entidades financieras	1	2	**3**	4	5
Desarrolladores de vivienda social	1	2	**3**	4	5
Asociaciones civiles de desarrollo de vivienda social	1	2	**3**	4	5
Asociaciones civiles de desarrollo de vivienda informal	1	2	**3**	4	5
Compañías de impacto social	1	2	**3**	4	5
Compañías de impacto ambiental	1	2	**3**	4	5
Habitantes de vivienda social	1	2	**3**	4	5
Habitantes de vivienda informal	1	2	**3**	4	5

¿Cómo evaluaría el conocimiento que tiene desde su rol acerca del desarrollo regenerativo?

1 2 3 **4** 5

Si tiene conocimiento acerca del desarrollo regenerativo, ¿cómo evaluaría su interés en tal?

1 2 3 **4** 5

Rol:

Encuesta 2

1= Muy alto 2= Alto 3= Regular 4= Bajo 5= Muy bajo

¿Cómo evaluaría el interés en el desempeño ecológico desde su rol?

1 2 3 4 5

¿Cómo evaluaría el interés en el desempeño social desde su rol?

1 2 3 4 5

¿Cómo evaluaría el interés en el rendimiento económico de sus acciones desde su rol?

1 2 3 4 5

¿Cómo evaluaría que tan estrecha es su relación/colaboración desde su rol con los siguientes actores?

SEMARNAT	1	2	3	4	5
SEDEMA/SEDEMA	1	2	3	4	5
CONAGUA	1	2	3	4	5
SACMEX/CAEM	1	2	3	4	5
SEDATU	1	2	3	4	5
SEDUVI/SEDUVYM	1	2	3	4	5
Gobierno estatal	1	2	3	4	5
Gobierno local	1	2	3	4	5
Entidades financieras	1	2	3	4	5
Desarrolladores de vivienda social	1	2	3	4	5
Asociaciones civiles de desarrollo de vivienda social	1	2	3	4	5
Asociaciones civiles de desarrollo de vivienda informal	1	2	3	4	5
Compañías de impacto social	1	2	3	4	5
Compañías de impacto ambiental	1	2	3	4	5
Habitantes de vivienda social	1	2	3	4	5
Habitantes de vivienda informal	1	2	3	4	5

¿Cómo evaluaría el conocimiento que tiene desde su rol acerca del desarrollo regenerativo?

1 2 3 4 5

Si tiene conocimiento acerca del desarrollo regenerativo, ¿cómo evaluaría su interés en tal?

1 2 3 4 5

Rol: SACMEX

Encuesta 2

1= Muy alto 2= Alto 3= Regular 4= Bajo 5= Muy bajo

¿Cómo evaluaría el interés en el desempeño ecológico desde su rol?

1	2	3	4	5

¿Cómo evaluaría el interés en el desempeño social desde su rol?

1	**2**	3	4	5

¿Cómo evaluaría el interés en el rendimiento económico de sus acciones desde su rol?

1	2	3	4	5

¿Cómo evaluaría que tan estrecha es su relación/colaboración desde su rol con los siguientes actores?

SEMARNAT	**1**	2	3	4	5
SEDEMA/SEDEMA	**1**	2	3	4	5
CONAGUA	1	2	3	4	5
SACMEX/CAEM	**1**	2	3	4	5
SEDATU	**1**	2	3	4	5
SEDUVI/SEDUVYM	**1**	2	3	4	5
Gobierno estatal	**1**	2	3	4	5
Gobierno local	**1**	2	3	4	5
Entidades financieras	1	2	**3**	4	5
Desarrolladores de vivienda social	1	2	**3**	4	5
Asociaciones civiles de desarrollo de vivienda social	1	2	**3**	4	5
Asociaciones civiles de desarrollo de vivienda informal	1	2	**3**	4	5
Compañías de impacto social	1	2	**3**	4	5
Compañías de impacto ambiental	**1**	2	3	4	5
Habitantes de vivienda social	1	2	3	4	5
Habitantes de vivienda informal	1	2	3	4	5

¿Cómo evaluaría el conocimiento que tiene desde su rol acerca del desarrollo regenerativo?

1	2	3	4	5

Si tiene conocimiento acerca del desarrollo regenerativo, ¿cómo evaluaría su interés en tal?

1	2	3	4	5

Appendix 4

Theory paper

Social-ecological systems as dynamic explorative tools

Assessment of the analytical frameworks of social-ecological systems from the perspective of urban planning

Theories of urban planning and design

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Abstract – The term social-ecological system has emerged to address the complex interface of ecological and social systems. The concept of social-ecological systems (SES) has become relevant in the field of spatial planning with the understanding of the urban realm as a complex system. Social-ecological systems, are complex adaptive systems, and as such, offer the potential to integrate the biophysical and social cultures in a multi-scalar and interdisciplinary way. The understanding of such systems, however, remains vague, specially in relation to spatial planning. Even more, the explorations of the socio-ecological interactions fall short with the lack of proper frameworks for their analysis and model development. This paper reviews literature regarding the different definitions, analytical frameworks and modelling approaches of social-ecological systems and assesses them in relation to the practice of urban planning and design. Furthermore, this paper aims to contribute to the understanding of how the proper framing of SES can better integrate these systems and urban planning through their dynamic modelling.

Key words – Social-ecological systems, complex adaptive systems, urban planning, analytical framework, dynamic modelling

Introduction

The concept of social-ecological systems has become relevant in the field of spatial planning with the need to more accurately and realistically capture and conceptualise complex urban processes (Marcus et al, 2018).

> The experiences of various scholars have led to the insight that these complex problems cannot be analysed with disciplinary approaches alone. They have to be dealt with in an integrative, interdisciplinary way that considered the interaction between social and ecological systems. (Binder et al., 2013).

The need to integrate planning either with social-ecological systems or to sustainability theories and methods has been researched by authors like Picket et al. (2003), Scott et al. (2013), Marcus et al. (2018), and van der Leer et al. (2018) (Table 1). Picket and collaborators (2003) specifically research how to improve the link in amongst the ecological, socio-economic, and planning realms, through the use of socio-ecological resilience. Scott and collaborators (2013), research three methods on how to bridge the Ecosystems Approach and the Spatial Planning frameworks through better planning processes across the natural and built environments. Marcus and collaborators (2018) target the gaps in between the socioecological knowledge and urban planning and design. While, van der Leer et al. (2018), research the integration of Circular Economy to Urban Planning through horizontal and vertical systems. One of their concluding remarks points out to the need to investigate how the understanding of socio-ecological-technical-systems can improve the integration of urban planning and CE.

All of the mentioned research depart from different aims, however the lack of understanding and even more, of integration of the social and ecological systems prevails in all of them. Throughout the past decades, the concept of SES has evolved from being applied in the sole study of animal behaviour to being used to address complex environmental issues (Binder et al, 2013), and with that, its definition, approaches and relations to different disciplines as well. A better understanding of the dynamics of between and within the social and the ecological systems is still lacking. (Shlüter, 2014). Even more, frameworks that can support the modelling of such dynamics are imminent for their integration in urban planning. Frameworks provide the basic set of variables and terms used to construct causal explanations expected from a reality (Binder et al., 2014, Ostrom, 2005). While a model constitutes a more detailed manifestation of reality in terms of the functional relationships among the independent and dependent variables important in a particular setting (Binder et al., 2014). Model development of the social-ecological dynamics is particularly interesting for urban planning as it allows to explore different possible design and planned scenarios. Therefore, it is necessary to elaborate frameworks that can support a systemic and transparent processes of model development which can better integrate the SES into urban planning.

Authors	Theory	Integrative approach	Practice
Picket et al. (2003)	Ecology, socialecology	Socioecological resilience metaphor	Urban planning and design
Scott et al. (2013)	Ecosystems Approach	Multi-scalar and sectoral approach with a governance framework	Spatial Planning frameworks
Marcus et al. (2018)	Socioecological knowledge	Transdisciplinary frameworks	Urban planning and design
Van der Leer et al. (2018)	Circular economy	Socio-ecological-technical systems	Urban planning

Table 1. Social-ecological systems and urban planning gap

Methodology

The research comprises two main phases: a literature review and the assessment of the findings of such review. The literature review was realised in order to find the existing definitions of SES, the existing analytical frameworks of SES, and the existing methods to process changes in the interactions of the SES. Four packages of searches were made, consisting of a two-steps search, starting with review papers, followed by all other types of documents. The search was realised with help of the search engine 'Web of Science', always limiting the papers to the categories of 'environmental studies', 'environmental sciences', 'ecology', 'geography', 'planning development', 'multidisciplinary sciences', engineering environmental', and 'urban studies'. The first package looked for the initial terms: 'socio-ecological systems' and 'social-ecological systems'; the second package, looked for the same terms plus 'analytical framework'; the third package, looked for the initial terms plus 'modelling''; the last package, looked for the initial terms plus 'cellular automata' and 'agent-based modelling'.

In the second phase of the research, the findings of the literature review were assessed in order to suggest which frameworks are best to integrate social-ecological systems with urban planning.

Conceptualisation of SES

In order to define proper framework for the understanding of SES, it is important to reach to a common definition of what SES actually are. The term 'social-ecological system' was first published by Crook et al. and Emory and Harris in 1976 while studying animal behaviour (Herrero-Jauregui, 2018). Ever since, the usage of the term (and other similar terms as 'socio-ecological systems' and 'socio-ecosystem') has been divided in four different consecutive and overlapping stages of time identified by Herrero-Jauregui and collaborators (2018). The first phase compiles the years in between 1976-1999, the second; the years 2000, 2005; the third, the years 2006-2011; and lastly, the fourth, the years in between 2013-2016.

The first stage is characterised by a time in which the researchers did not have a common understanding of what the term meant, however they would use it to refer to social-ecological relationships when the matter of study was not included in the concept of an ecosystem. The second phase was probably triggered by the formation of the Resilience Alliance in 1999 and the formalisation of the term by authors like Berkes & Folke & Simon Levin. Berkes & Folke (1998) began approaching the SES as an integrated approach for having humans in nature, instead of humans outside of nature, and further drew on the SES multi-scalar and hierarchical properties. They provide the definition: '*SES are nested multilevel systems that provide essential services to society such as the supply of food, fiber, energy, [and] drinking water'*. Simon Levin (1998) was the first author to pin the concept (previously developed by Holland) of complex adaptive systems to describe the SES as hierarchical and dynamic systems. The second phase is then characterised by the use of the term linked to complex adaptive systems.

In the third phase, the SES were linked to the concept of resilience, specially embraced by the Stockholm Resilience Centre in 2007. Socio-ecological resilience was adopted as the "*capacity to adapt or transform in the face of change in SESs, particulary unexpectaded change, in ways that continue to support human-well being*" (Folke et al., 2016). In this phase, publications which aimed to develop methods to integrate the socio and biophysical realms were introduced, however it was not till the fourth phase that they actually took off.

In between the third and the fourth phases, Ostrom and collaborators (2009) proposed the most complete framework to analyse SES defining the values in each subsystem to be studied. The fourth phase was probably triggered by the introduction of the concept of SES as part of the Sustainable Development Goals. The fourth phase was also preceded by the linkage of the SES to governance systems, introduced by Glaser and collaborators (2008), which provide one of the most complete and actual definitions for social-ecological systems. The fourth phase is further then characterised by the linkage to governance systems, and also by the aim to develop intradisciplinary methods for studying the SES. Many of the latest publications have been focused on land management and decision-making.

They are described by Glaser et al. (2008) (and later on other similar definitions from the Stockholm Resilience Alliance) as a "*bio-geo-physical unit and its associated social actors and institutions.* Even though this definition departs from an Anthorpocentric point of view, which Binder and collaborators have proved not to be the sole one anymore, it defines one of the main aspects of SES: the governance associated to a socioecological system. Further on, Glaser and collaborators also define the social-ecological systems as *"complex and adaptive [systems] and delimited by spatial or functional boundaries surrounding particular ecosystems and their problem context*" (Glaser et al., 2018). As complex systems, they have non-linear, hierarchical, emergent and self-organised behaviours, and they are also strongly linked to their context and history (Glaser et al, 2018). Finally as adaptive systems, they present resilience in a sustained manner.

Shlüter et and collaborators also provide another definition of the SES describing them as "*dynamic systems that continuously change in response to internal or external pressures*" and mentioning that "*SES coevolve through interactions between actors, institutions, and resources constrained and shaped by a given setting"* (Shlüter et al., 2014).

From the previous definitions, three main aspects of the SES are suggested to be taken into account for developing a framework that can support model development. Social-ecological systems are systems consisting of social and ecological variables, the dynamic relations between them and the borders which delimit them.

Analytical frameworks of SES

As mentioned before frameworks provide set of assumptions, concepts, values and practices which help to conceive specific realities (Binder et al, 2014). They have been useful in the study of social-ecological systems as they provide a common language for different disciplines and backgrounds to build and compare theories (Hinkel et al, 2014). Binder et al (2013) provide a comparison of 10 established frameworks for analysing SES (Table 2).

The Driver, Pressure, State, Impact, Response (DPSIR) framework focuses on developing 'an improved understanding of indicators ad response to impacts of human activities on the environment (Binder et al., 2014). The Ecosystem Services framework aims to understand the interactions of biotic and abiotic components of an ecosystem in relation to which services they can provide to support life on Earth (Binder et al., 2014). The Human-Environment Systems framework provides a methodological tool to understanding the structure of SES, and the processes and dynamics between the social and ecological systems (Binder et al., 2014). Picket and collaborators (2003) make use of the HES framework to study the link in between urban planning, social and ecological systems. The concluding remarks point out to importance of the linkage of science (ecology) and planning through a better understanding of resilience. The Material and Energy Flow Analysis (MEFA) quantifies the material and energy flows representing the biophysical metabolism of different scales. (Binder et al., 2014). The Management and Transition Framework (MTF) supports the understanding of water systems, management regimes, and transition processes towards their more adaptive management (Bindet et al., 2014). The Social-ecological Framework provides a common language for case comparison for organising in four main tiers the many variables relevant in the analysis of SES (Ostrom, 2009). The Sustainable Livelihood Apprach (SLA) analyses which combination of livelihood permits which combination of livelihood strategies with sustainable outcomes (Binder et al., 2014). The Natural Step framework provides constitutional principles, outcomes and processes to reach sustainability (Binder et al. 2014). Lastly, the Vulnerability Framework analyses what can be done to reduce the environmental and human vulnerabilities (Binder et al. 2014).

The research realised by Binder and collaborators which resulted in a decision tree which can be used when selecting which framework to use. The criteria they used for such decision-making is based on three main aspects: whether the relationship in between the social and ecological systems presented by the framework is uni- or bi-directional; whether the perspective the framework takes on the ecological systems is anthropocentric or ecocentric; and whether the framework is action-oriented or analysis oriented. Besides these criteria, the comparison also elaborates approach to the social and ecological dynamics and scales of the systems.

This research considers the relation between the social and ecological systems extremely relevant as the SES are supposed to consider humans in nature, instead of outside of nature (Berkes & Folke, 1998). However, the anthropocentric /ecocentric perspective and the action/analysis oriented approaches are not considered relevant as they do not affect the definition nor dynamism of the SES in any sort of way.

Instead, this research assesses the frameworks presented by Binder et al., according to how the dynamics or changes in between and within the social and ecological systems are conceived. High emphasis is placed on the social-ecological dynamics as this research aims to determine how SES can be better integrated with urban planning.

As mentioned, the relation of the social and ecological systems is extremely important in the conception of SES. Table 2 shows how seven out ten of the frameworks do not conceive a bidirectional relation between the two systems, only the HES, the MTF and the SESF frameworks do so.. Consequentially, this means that HES, MTF and SESF frameworks are the only ones that can support the modelling of dynamics between the social and the ecological systems.

In terms of social dynamics, the TNS, the HES, the MTF and the SESF conceive the changes in the social system mostly in relation to learning processes and decision making. These four (and the SLA framework) are also the frameworks that conceive social changes across scales. The HES MTF and SESF frameworks specifically, take into account the feedback loops between both levels.

In terms of ecological dynamics, six out of ten of the frameworks (ESA, MEFA, DPSIR, HES, MTF,

Framework	Phase	Authors and year	Social-ecological relation	Social dynamics	Social dynamic across scales	Ecological dynamics	Ecological dynamics across scales
Sustainable Livelihood Approach (SLA)	1st phase	Ashley and Carney 1999, Scoones 1998	S←E	None	Macro-→ micro	None	No interaction
Earth Systems Analysis (ESA)	1st phase, 2nd phase	Schellnhuber 1998, 1999, Schellnhuber et al. 2005	S→E	None	Macro level	Feedbacks in flow of energy or matter between scales	No interaction
Ecosystem Services (ES)	1st phase, 2nd phase	Costanza et al. 1997, Daily 1997, de Groot et al. 2002, Limburg et al. 2002	S→E	None	Macro level	No	No interaction
Material and Energy Flow Analysis (MEFA)	1st phase, 2nd phase	Ayres 1978, Baccini and Bader 1996, Haberl et al. 2004, Brunner and Rechberger 2005	S→E	None	Macro level	Feedbacks in form of stocks and flows	No interaction
Vulnerability Framework (TVUL)	2nd phase	Turner et al. 2003*a,b*	S←E	None	Macro-→ micro	No	No interaction
The Natural Step (TNS)	1st phase, 2nd phase, 3rd phase	Burns and Katz 1997, Robèrt 2000, Upham 2000, Missimer et al. 2010	S→E	Scenario/visioning and backward planning processes	Macro-→ micro	No	Partial interaction
Driver, Pressure, State, Impact, Response (DPSIR)	1st phase, 3rd phase	Eurostat 1999, Carr et al. 2007, Svarstad et al. 2008	S→E	None	Macro level	Measurements of the state of the environment	No interaction
Human Environment Systems Framework (HES)	2nd phase, 3rd phase	Scholz and Binder 2004, Scholz et al. 2011*a*	S←→E	Learning processes and interferences	Micro ←→ macro	Feedbacks in form of stocks and flows	Possible interaction
Management and Transition Framework (MTF)	3rd phase	Pahl-Wostl 2009, Knieper et al. 2010, Pahl-Wostl and Kranz 2010	S←→E	Decision making and learning processes , negotiation and policy development	Micro ←→ macro	Considers variables related to resource government and management	Interaction between scales
Social-Ecological Systems Framework (SESF)	3rd phase, 4th phase	Ostrom 2007, 2009, 2014	S←→E	Defined variables as 'information sharing', 'self-organising activities'	Micro ←→ macro	Feedback of variables	Possible interaction

Table 2. Assessment of frameworks presented by Herrero-Jauregui (2014)

and SESF) do engage in feedback loops of stocks and flows or managing of the ecosystem whereas out of those six, only the HES, the MTF and the SESF conceive the dynamics across scales.

These results show that the HES, the MTF ad the SESF are the better suited frameworks to integrate SES into urban planning. As Table 2 also shows, these three frameworks are also the latest ones to be developed which is probably the reason why they have the most updated conception of considering humans next to nature instead of outside of nature.

Dynamic modelling of SES

Models are simplifications of real world systems which can be subjected to tests and simulations of the reactions of the real system caused by changes in their state and function (Clarke, 2014). Models are considered to be valuable based on their calibration, their design, their tractability, their performance and their validity. Agent-based models (ABM) and cellular automata (CA) are both modelling approaches to complex systems and both have proven to succeed in the previously mentioned criteria (Clarke, 2014). Both CA and ABM focus on simulating microscale elemental agents and actions that overtime and space, result in aggregate forms of behaviour, which for the case of SES would not only allow to simulate the changes in the system but also the emergent properties of the system.

Cellular models are usually preferred when geographic space is in form of a grid such as cells in a raster GIS or when the states are and the probabilities of the states are known and stable (Clarke, 2014). Examples of their usage are land use change models and urban growth models.

CA was conceived by Stainslaw Ulam in 1940's . It is composed of four elements: a gird of cells, each cell being able to assume a finite number of states a neighbourhood the most usual one the 8-cell Moore neighbourhood; a set of initial conditions, a set of initial state for each and every cell in the system; and one or more rules that are applied to change the states of the cells. (Clarke, 2014).

Agent based models, are used when the basis of the model is rather a behavioural unit with a relation to space: a pedestrian, a household, a business, etc. and when the modelled process consists of interactions overtime among one or more types of agents which end producing a spatial pattern, namely land use or a habitat type. ABMs consist of agents specified at specific model scales and types; decision n-making heuristics; learning or adaptive rules procedure for agent engagement; an environment that can both influence and be impacted by the agents.

The main difference between the two is that in the CA approach, the agents are bound to stay in place and interact only with the neighbours.

It has been mentioned before how the conceptualisation of socioecological systems has evolved over time. For its latest phase, which takes into account governance and management processes, it seems that the ABM is better suited rather than the CA.

Few research has been done focused on the modelling of SES with CA or ABM. CA has been used in the research of Engelen et al. (1995) and other like Clarke et al., Wu and Webster, and Sante et al. (Clarke, 2014) . While ABM has merely been used by authors like Murray-Rust et al. (2009). However, these models offer great potential to integrate SES to urban planning.

Recently authors like Schlüter et al (2014) have engaged in the study of such, proposing a framework which supports the integration of the analytical framework of the SES and their modelling (Figure 1).

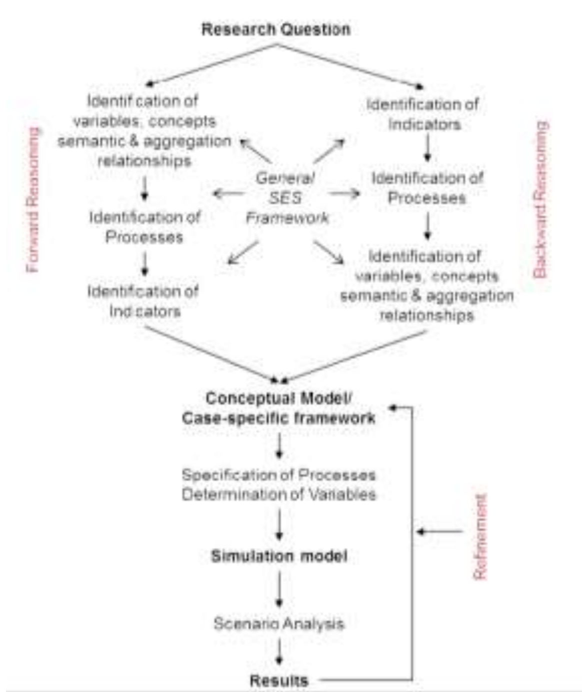

Figure 1. Framework supporting modelling for SES (Schlüter et al., 2014)

Levin and collaborators (2013) also have engaged in the discussion of four different aspects to take into consideration when modelling SES.

Ignoring nonlinear dynamics can potentially lead to errors. Socioecological systems have non-stead-state and a steady-state analysis is therefore not enough. The optimal regulation of the system can probably depend on past actions for which taking a time variable into account is important

Taking into account nonlinearity by default takes into account a time dependence on the SES. The time scaling of the subsystems may be different amongst each other. The dynamics may be slow, constant or fast, depending on the subsystem. In the analysis and modelling it is important to take into account slow and fast terms. Scale issues are also found is space and organisational complexity. It is important to regulate part of a system always with regards to feedback to other scales of the system. Heterogeneity can refer to spatial patterns, genetic matters or diversity in norms, institutions, laws, incentive structures and behavioural practices. As well heterogeneity should be considered not only on an individual basis but also on a systems basis, for which the matter of scale is reinforced here. Risk and uncertainty request to accept that the perfect understanding of the ecosystem's functional dynamics or the perfect modelling is impossible to achieve for which sensitivity, robustness and resilience issues are to be taken into consideration. Strategies to deal with such threshold are therefore needed. (Levin et al., 2013)

Conclusions

This paper reviewed and assessed the literature regarding the different definitions, analytical frameworks and modelling approaches of social-ecological systems in relation to the practice of urban planning and design.

A gap in between the framing of the social-ecological systems and the practice of planning was identified. The dynamic properties of the social-ecological systems offer the potential of using the SES as tools that can enable a better integration of the social, ecological and planning realms.

Proper frameworks that can support the modelling of the SES are necessary to complete this integration. The Management and Transition Framework, the Human-Environment Framework and the Socio-Ecological Framework are all analytical frameworks that integrate the aspects of the latest definitions of social-ecological systems. Cellular automata and agent based modelling are approaches which can take into consideration the relations in between the ecological and the social in space as well as the interactions throughout space.

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