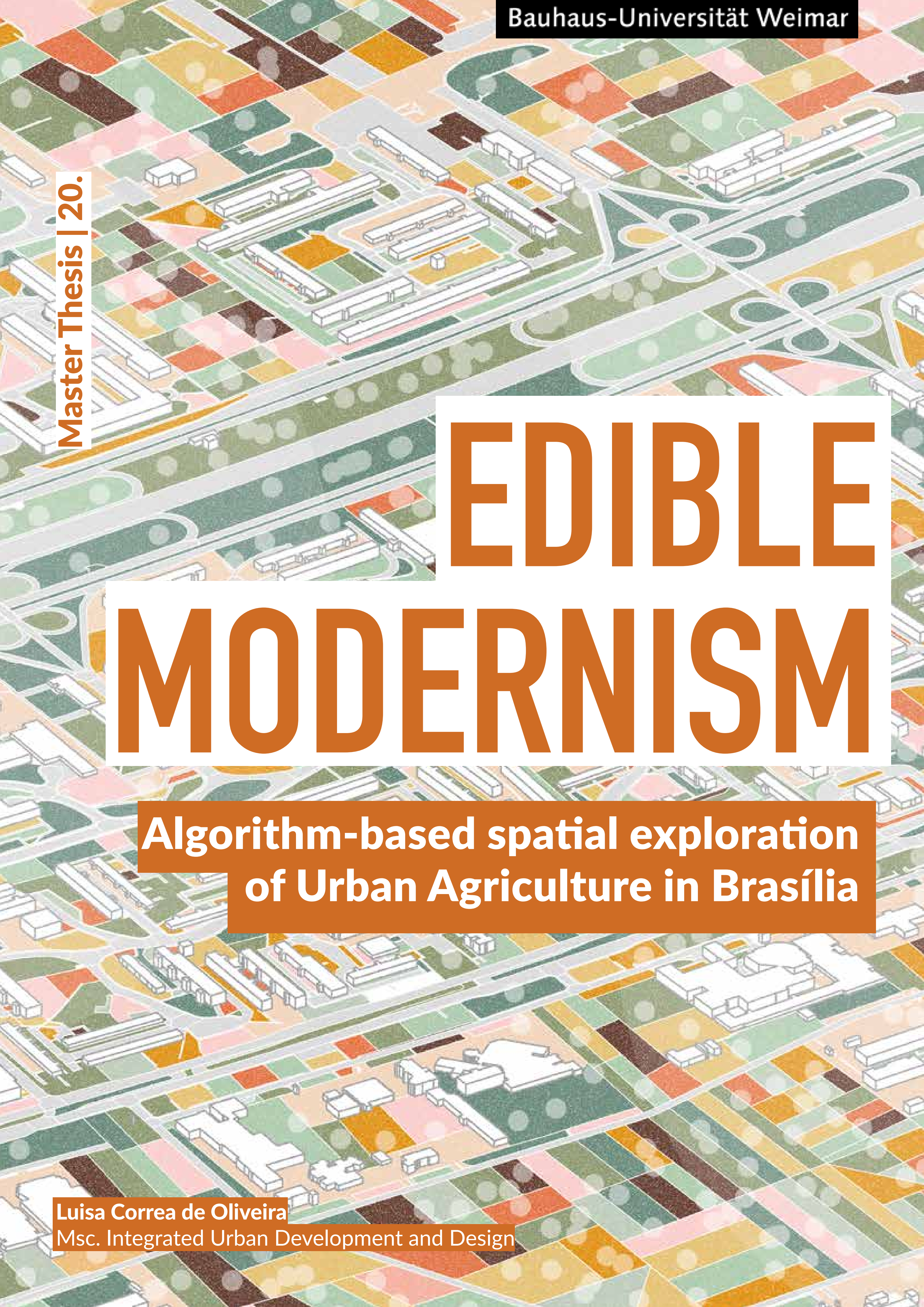

Bauhaus-Universität Weimar

Master Thesis | 20.

EDIBLE MODERNISM

Algorithm-based spatial exploration of Urban Agriculture in Brasília

Luisa Correa de Oliveira
Msc. Integrated Urban Development and Design

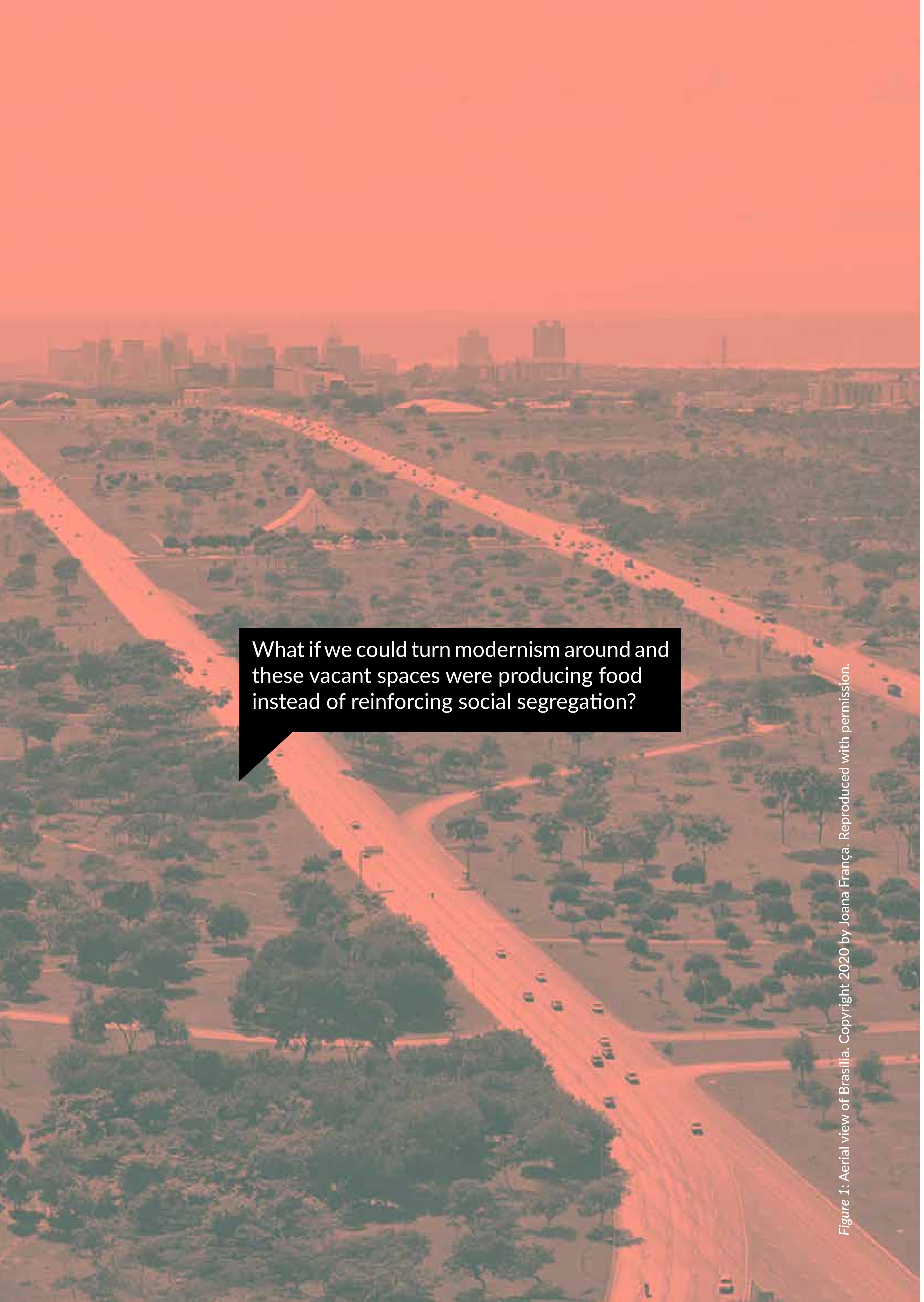

Figure 1: Aerial view of Brasília. Copyright 2020 by Joana França. Reproduced with permission.

Weimar, August 2020.

Edible Modernism: Algorithm-based spatial exploration of Urban Agriculture in Brasília.

Keywords: food systems, urban agriculture, urban metabolism, spatial justice, parametric urban design, urban modelling and simulation.

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Foreword

This Master Thesis is the end product of my two-year Master's Degree within the Integrated Urban Development and Design (IUDD) program at Bauhaus Universität Weimar. This is a Research-Based Design work, which means that it is a scientific application of knowledge to inform decisions and that the process is more important than a final result.

As a thesis in the IUDD program should be, the main topics explored in our degree are developed here: urban metabolism-based strategies, computational design methods, and urban modeling and simulation applied in a broad and holistic approach towards urban planning.

I hope this work contributes to the academic knowledge, as well as public and private sectors discussions in Brazil, and Germany regarding the topics it explores.

The development of this research was supported and sponsored by the DAAD STIBET Graduation Scholarship and by the Women's Promotion Fund (Frauenförderfonds) of the Equal Opportunities Office (Gleichstellungsbüro) at Bauhaus Universität Weimar.

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Abstract

Historically, food provision was in the core of the reasoning for human settlement decisions, and the evolution of the patterns of food production, processing, commercialization, and consumption fundamentally shaped the contemporary morphology of our cities. During past industrialization processes, what were once intertwined systems, urban and rural realities became exponentially more separated amidst a significant shift in settlement standards, as most of the population migrated to cities. The result is a continuous reality of increasing urban sprawl and an agricultural production driven away from its consumers, ultimately creating fundamental social, economic, and environmental challenges, from the commodification of food production to monocultures and deforestation. Urban Agriculture is therefore seen as a possible solution for some of these issues, for connecting people to food systems allows more efficient use and reuse of resources, more sustainable consumption patterns, and a strategic urban metabolism-based future.

In this light, how could we adapt existing vacant spaces in a city, transforming them into food production units? How would Urban Agriculture support existing waste and water management systems? How could this new sustainable strategy be spatially organized within the existing infrastructure in the city? Investigating these questions, this Master Thesis presents an algorithm-based spatial exploration for the organization of Urban Agriculture elements in the city of Brasília.

Designed with modernistic urbanism standards, the city has abundant public spaces and large vacant areas by default, making it an interesting case study. Additionally, Brazil plays a significant role in global food production and in terms of natural resources reserves. Therefore, a substantial Brazilian Urban Agriculture experiment has a significant and scalable impact beyond the local level.

The research methodology consists of a literature review on the aspects of Urban Agriculture regarding Urban Planning and case studies on other cities where the practice was already applied. The next step is a local analysis of the urban conditions in Brasília, supported by GIS data, concerning the topic and how the current food system works. Next, all these ingredients are woven together in a systematic strategy relating the necessary Urban Agriculture aspects to the opportunities the modernist urban form suggests. Finally, the strategy is spatially operationalized with a series of computational urban analysis. The first iteration tests the land accessibility for two distinct urban agriculture typologies based on proximity to pertinent urban features. The result is visualized in a heatmap, which ultimately informs where the best locations for each typology are. The second iteration tests water accessibility from water harvesting systems in a zoomed-in scale. Lastly, the third iteration analyzes solar radiation and its implication on the location of composting elements related to Urban Agriculture.

Conclusively, when overlapping these results, the outcome is a possible spatial organization for Urban Agriculture, accounting for its impacts on resources derived from the previously described research methodology. It is not intended as a unique possible solution but rather a suggestion out of many on how the subject could be addressed in Brasília. The results could be used in informed policy-making decisions, public debates, and raising collective awareness of alternative food production models. Hopefully, the contribution is also a valid experiment in the contemporary sustainability debate and the validation of computational methods as an alternative for integrated simulations and design.

Abstract // Português

Historicamente, a provisão de alimentos sempre esteve no centro das decisões de assentamentos humanos, e a evolução de padrões de produção, processamento, comercialização e consumo fundamentalmente influenciaram a morfologia das nossas cidades. Durante o processo de industrialização, realidades urbanas e rurais, antes interligadas, se tornaram exponencialmente mais distantes em meio a uma mudança significativa nos padrões de habitação, com a maioria da população migrando para cidades. O resultado é uma contínua realidade de espraiamento urbano e uma produção rural afastada dos consumidores, criando desafios socio-econômicos e ambientais fundamentais, desde a comodificação da produção de alimentos até crises de desmatamento. A Agricultura Urbana é vista como uma possível solução para alguns desses problemas, pois conectando pessoas com sistemas alimentares permite-se um uso e reuso de recursos mais eficiente, padrões de consumo mais sustentáveis e um planejamento urbano baseado em processos de metabolismo.

Nesse sentido, como poderíamos adaptar espaços vazios em uma cidade, transformando-os em unidades de produção de alimentos? Como a Agricultura Urbana apoiaria sistemas existentes de manejo da água e do lixo? Como essa nova estratégia sustentável poderia ser espacialmente organizada junto à uma infraestrutura existente? Investigando essas questões, esta pesquisa apresenta uma exploração espacial paramétrica para a organização de elementos de Agricultura Urbana na cidade de Brasília.

Planejada sob princípios do Urbanismo Moderno, a cidade possui abundantes espaços públicos e enormes áreas vazias, fazendo com que seja um estudo de caso interessante. Adicionalmente, o Brasil tem um papel significativo na produção mundial de alimentos e em termos de reservas naturais. Portanto, um experimento substancial de Agricultura Urbana no Brasil tem um impacto notável tanto em nível local como internacional.

A metodologia consiste de pesquisa conceitual acerca dos aspectos de Agricultura Urbana no que diz respeito à Planejamento Urbano e estudos de caso em outras cidades onde a prática já foi aplicada. O passo seguinte é uma análise das condições urbanas de Brasília e do sistema local de produção de alimentos através de dados georreferenciados. Depois, esses elementos são estrategicamente interconectados, relacionando-se os aspectos necessários para Agricultura Urbana com as oportunidades que a cidade modernista oferece. Por último, a estratégia é operacionalizada espacialmente através de uma série de simulações utilizando ferramentas de desenho urbano paramétrico. A primeira iteração testa o acesso à lotes para duas tipologias de Agricultura Urbana baseadas na proximidade de estruturas urbanas relevantes. O resultado é visualizado em um “mapa de calor” informando as melhores localizações para cada tipologia. A segunda iteração testa o acesso à água por meio de sistemas de captação de chuva, e a terceira testa a melhor localização para unidades de compostagem com base na incidência solar necessária.

Conclusivamente, sobrepondo esses resultados, o produto final é uma possível organização espacial para Agricultura Urbana, levando-se em consideração o impacto nos recursos naturais. O resultado não deve ser entendido como uma resposta final, mas sim como uma possibilidade em meio a tantas outras. As resoluções podem ser usadas para assistir políticas urbanas e interação entre atores urbanos, sensibilizando sobre a importância de modelos alternativos de produção de alimentos. A contribuição também é válida na validação de métodos computacionais em Planejamento Urbano como uma alternativa para integração de simulações e design.

Acknowledgements

While I sit down to write this part, I stare at my computer, utterly unable to believe this rollercoaster journey is already at the end. My two years at Bauhaus brought me much more than I ever dreamed or expected. This time permanently changed my life personally and professionally in deep and meaningful ways, however mellow may sound to you, dear reader.

First of all, thank you to the one person who was the most crucial pivotal node in my life, way before Bauhaus happened, but that literally brought me here. You were light from the second we met and continues to be, until the end of time. There will never be enough grateful words in any language for what you represent. Thank you for showing me who I am and for the sun kissed roads I had the honor to have walked by your side.

Mamãe e Diogo, thank you for being the most unconditionally loving and supporting family a person can have. I love you to the moon and back countless times. Thank you for financially and emotionally allowing me to be here right now, and for everything that came before to pave this way. I know how incredibly hard it is and has been. Still, I hope I succeeded in making you proud of me, even though you never demanded anything but my happiness.

My dearest and profoundly loved friends in Brazil. Thank you for supporting and believing in me for so many years, you are also my family. Thank you for being my lighthouse, my port, and support through everything for so long. Thank you for loving me even when there was an ocean in between us. I love you always, through space and time.

My IUDD bubble, my international family, my adventure partners. Without you, none of this would have been possible, at least not with the same colors, glittering happiness, and glasses of wine. Thank you for showing me your worlds, and therefore making me question everything I thought I knew about mine. Thank you for all the love, trust, and treasured moments we shared and the strong life-lasting friendships we managed to build in this time. It was the greatest pleasure to walk this path with you. Thank you for holding my hand while we were at it. I cannot wait to see what life brings us now, but know each of you carries a piece of my heart wherever you are on this planet.

MVRDV, thank you for having me for six intense, beautiful, and life-changing months during this journey. My time in the office brought so.much.more. than I could ever expect. Thank you for the beautiful and inspiring souls I met along the way and for the dear friends I now cherish. Thank you to my dear ones who were there with me every step of the way, for living a shared dream. And thank you universe for bringing me out of those dutch bike paths in one piece!

Thank you, universe, to everything that ever happened in my life, the happiness and the sorrow, for all the pieces brought me here right now. I proudly finish this chapter and welcome whatever comes next with nothing but gratitude. Let's rock and roll!

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Figure 2: Detail of The Allegory of Good Government: A glimpse on a peaceful existence of city and country. Ambrogio Lorenzetti/Public Domain.

1 Introduction

Research Background
Global Food Paradigm

The world is currently undergoing an unprecedented rural-urban migration, and it is expected that by 2050, two-thirds of the world's population will live in cities (United Nations Environment Programme [UNEP], 2017). The complex problems that originate from urbanization processes encompass environmental, social, and economic challenges for achieving a sustainable future. The necessary land for food production, water supply, and energy never seem enough to feed our modern lifestyles. Urban settlements currently consume 75% of earth's natural resources, meaning that unless the current patterns change, we would need 1.6 planets to accommodate the expected population growth (UNEP, 2017).

"The sustainable and efficient management of natural resources is now imperative for the achievement of all 17 United Nations Sustainable Development Goals (SDGs)."
(UNEP, 2016)

Therefore it is clear that in order to sustainably develop, cities need to achieve more, using less. It means we have to continue to supply our services in ways that are more resource-efficient, climate-friendly, resilient, and equitable (UNEP, 2017). Additionally, in a hyper globalized world, where decentralized economies and interdependency of resources and supply chains are the rules, any drastic environmental or economic change on one end disrupts the whole system. So now, more than ever, sustainability is truly a global agenda. Additionally, by the time this thesis is being written, the world is undergoing a Pandemic due to the novel virus COVID-19, and it has been one of the biggest challenges of our time. As a significant part of the world is on lockdown, economies are derailing all around the globe as countries resilience, social cohesion, and the ability to provide for themselves are put to test.

The food sector is globally a dominant user of a very significant part of the planet's resources: land, soil, water, terrestrial and marine biodiversity, minerals, and fossil fuels are all consumed in the food production (UNEP, 2016). That is the case because the resources are consumed not only in the production phase but throughout the whole chain of packaging, transportation, processing, and storing necessary to keep cities literally alive. Not to mention that in such a long chain of processes lies many opportunities for losses, complications, and a very complex management situation.

Figure 3: Food Systems waste. The current Food Systems allow for a huge amount of food waste throughout the production chain. That accounts for lost resources and food insecurity. Copyright 2020 by naranjasdelcarmen.com. No copyright infringement intended.

The current mainstream agriculture system relies mostly on intensive monoculture and heavy pesticides, causing deforestation, soil degradation, and large amounts of water go for irrigation. The same system also goes far beyond solely the environmental sphere. Worldwide monopolies often control the whole chain of production and distribution of food, leading to a concentration of resources and wealth, perpetuating an uneven distribution of land, compromising food security, and contributing to social inequality patterns.
It is also fundamental to state that even though there is a global demand around the topic and an overarching common agenda, specific conditions and challenges apply in national, regional, and local levels of urban and rural areas worldwide.

For instance, Brazil, the topic of this Master Thesis research, is regarded as a country where there is a bounty of natural resources and diversity of food production. The country is the 4th largest food exporter in the world (Confederação da Agricultura e Pecuária do Brasil, 2020), has nearly 20% of the planet's water reserves (World Bank Group, 2016), and 58.93% of the country's land is covered by forests (World Bank Group, 2016). However, this reality does not reflect in wealth for a significant part of the Brazilian population, and even this tremendous amount of natural resources is under serious threat. According to the Food and Agriculture Organization of the United Nations (FAO), 5.2 million people suffer from hunger in Brazil (FAO, 2018), only 62,1% of the population has access to both clean water and sanitation (World Bank Group, 2016) while alarming 70% of the country's water consumption goes to agricultural irrigation (Agência Nacional de Águas, 2019), and approximately 1.7 million hectares of the Amazonian rainforest is lost to farmlands every year (Santos and Glass, 2018).

Such disparity in resources distribution and poor infrastructure draws back from the historical circumstances and colonial geopolitical configurations that left Latin America with the worst land distribution in the whole world: In Brazil, 51,19% of all agricultural lands are concentrated on the hands of 1% of the rural owners, according to Oxfam International (Santos and Glass, 2018), making it the 5th place in the world ranking of land access inequality according to data from the same institution. Brazil has 45% of its productive land concentrated in properties with more than 1.000 hectares, which are 0.91% of the rural properties (Santos and Glass, 2018). These farms are so big that, if all of them formed a country, it would be the 12º largest territory on the planet, with 2,3 million km², an area bigger than Saudi Arabia (Santos and Glass, 2018).

This massive agrarian inequality is reflected in strong monopolies in the food production business, in a reality driven by profit and high productivity, neglecting ecosystem's ecologies and inclusive labor market opportunities.

The interrelation of all these numbers is a symptom that, among other problems, the current food production model is a failing system with disconnected social, economic, and environmental flows. It threatens entire ecosystems, social cohesion, and overall resilience, limiting the path for sustainable growth.

Figure 4: Deforestation in the Amazon rainforest in August 2019. Copyright CC-BY by Mayke Toscano/Getty Images.

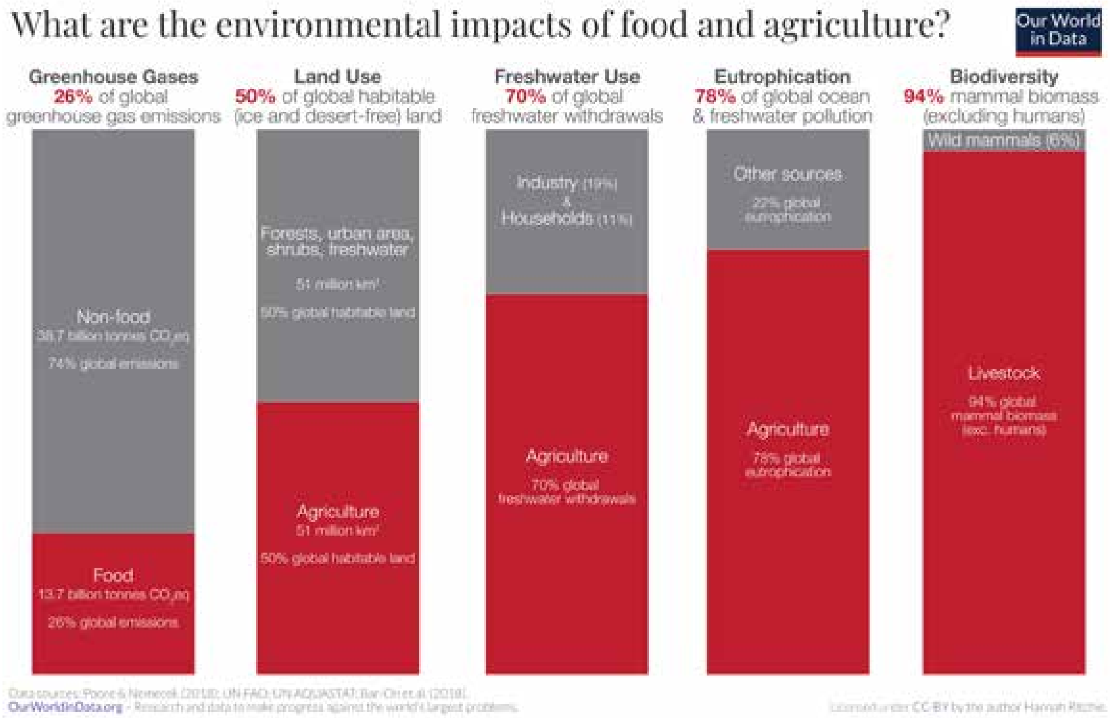


Figure 5: What are the environmental impacts of food and agriculture? : Agriculture as the major driver for land and freshwater consumption. Copyright CC-BY by Hannah Ritchie/ ourworldindata.org

Given the complexity of the global food provision situation and its interrelated political and cultural processes, it is clear that the topic should be addressed systematically, across disciplines, countries, and scales.

"Food systems will play a central role in delivering the sustainable development agenda" (FAO, 2018).

Therefore, Food Security is also part of the global Urban Planning agenda. As stated by the Food and Agriculture Organization of the United Nations (FAO) in the "Framework for the Urban Food Agenda" (FAO,2019), "Focusing on the urban landscape does not imply a simple orientation towards food in cities, but instead draws attention to the (re)connections, (dis)locations and (in)justices that can be reworked." According to the American Planning Association (APA), a pioneering institution in bridging Urban Planning and food systems, the urban practitioners can "help build stronger, sustainable and more self-reliant community and regional food systems" (APA, 2007). Therefore the importance and relevance of this Master Thesis topic in the contemporary Urban Planning education, practice, and research.

On that note, the conceptual framework for investigating the previously described background touches the domains of food production, ecology, resources management, and land distribution, specifically spatial justice. The current literature review on operationalizing these topics in an Urban Planning perspective orbits around key concepts such as urban metabolism, urban and peri-urban agriculture, and continuous productive urban landscapes, which will be specified in the upcoming pages.

Ultimately, in order to investigate the possible impact of a system supported by the concepts above in the previously explained environment, this Master Thesis explores a resource-efficient spatial organization of Urban Agriculture elements in Brasília, capital of Brazil. The research is intended as a valuable case study which can trigger similar analysis in cities elsewhere in the country.

Problem Statement

Towards an Urban Agriculture exploration in Brasília

Brasília is a particularly interesting case study because since it has just recently turned 60 years of existence, it is still going through major urbanization processes and their complexities, being a live laboratory of the conditions stated in the previous pages. Beyond that, its unique condition of being a realized modernist utopia, a city designed from scratch in the heart of a continental country, exposes the perpetuation of strong spatial segregation and mismanagement of natural resources.

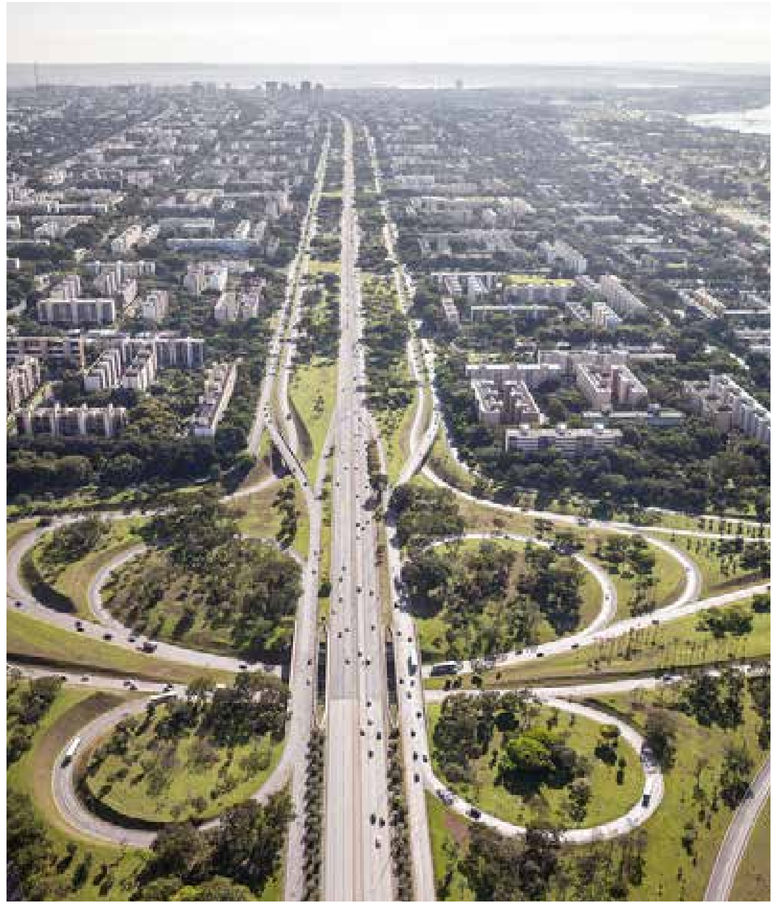


Figure 6: Aerial view of one of Brasilia's major mobility axis and the residential neighborhoods amidst green spaces. Copyright 2020 by Joana França. Reproduced with permission.

Its monumental architecture structured around enormous open green spaces cut by wide highways is a patch of built and unbuilt human-made landscapes. Such a choice of vast open spaces in the core of the capital comes at the expense of an extensive urban sprawl that consumes native ecosystems outside of the city and pushes socially vulnerable groups to the fringes. Adding to that, the city is characterized by the modernistic monofunctional landuse distribution, in which industry and any heavy production and processing activity is driven away from the urban center, making any logistics integration a challenge.

The farmlands fall in the same rule and are scattered in many different sizes, and production types in different places outside of the modernistic and heritage protected urban core. Brasilia is one of the very few capitals in the world that still has farmlands (Agência Brasília, 2016). And on one hand, this existing agriculture system is a remarkable success. It provides a great amount of fresh, nutritious food to the people who can afford it and have access to fresh food markets, and employs a fair number of people. In fact, in 2017, Brasilia's farms were among the most productive corn producers in the country, for example (Agência Brasília, 2016).

What is, however, not so great is that the original plan for the city failed to foresee its success and the unprecedented amount of rural-urban migration to the capital. A city initially planned for 500.000 inhabitants now has 3.3 million people (Instituto Brasileiro de Geografia e Estatística [IBGE], 2019). That, and the artificial landscape the city was built on, strain the management of the interconnected water and waste systems that keep the modernist machine working. A high amount of the city's water is currently destined to the farmlands irrigation (Brasília Capital, 2016), the past deforestation of the original vegetation and poorly designed sewage infrastructure contributed to the most significant water crisis in the place's history, with a prolonged shortage in between 2016 and 2018. Adding to that, the lack of a proper destination for waste and its treatment contributed to the biggest landfill of Latin America - a shocking achievement for a city of roughly 60 years of existence. All of that comes as a desolating future in a country so rich in natural resources. The young city also did not go through a significant agrarian reform since the decision to settle in the region, which means that a majority of the farmlands are oversized properties focusing on a hyper-productive business. At the same time, displaced jobless families live crammed in informal settlements, barely affording any food for each day.

Figure 7: The biggest landfill of Latin America in a 25 min drive from the Presidential Palace. Copyright by D Alves/CB/D.A Press. No Copyright infringement intended.

It becomes clear that, despite the best intentions behind its plan, the current spatial organization of Brasília's landscapes is culminating in neglected ecologies and social segregation, threatening the sustainability of natural resources, food security, and the local social cohesion in the long run. The current reality shows an urban metabolism with open loops and lacking a strategy that integrates the natural vegetation and water infrastructures.

There are currently great initiatives contributing to these issues, such as composting startups, permaculture centers, ecological farmers associations, Zero Waste conferences, and efforts from different ends of the Public Sector.

However, what lacks so far is a cohesive overall planning approach that coordinates the existing efforts, legitimating the problems and the need to address them, purposefully enhancing the existing structures and regenerating the urban-rural social and natural ecosystems. Therefore, believing in the environmental, social, and economic valuable impacts this sustainable agenda brings, this Master Thesis intends to contribute in that direction with a spatial exploration of Urban Agriculture as a possible start of future strategic discussions.

Research aim & questions

Building upon the previously mentioned productive, ecological, and social challenges, the goal of this thesis is, supported by computational design methods, to explore a potential organization of Urban Agriculture elements in Brasilia. The core principles are the social-spatial inclusiveness through a better spatial distribution for land access, integration with water and waste flows, integration with existing mobility and landuse structures, and small scale food production.

Such a choice of a computational design approach allows for the development of a system based on rules between the variables. It permits the visualization of their dynamics in different scenarios and the impacts each part has on the ecosystem as a whole. The conclusions drawn from these analyses can be used to inform Urban Planning and policy-making decisions.

The investigation aims to obtain clarity on the following research questions:

Main Question:

What is a potential spatial organization of Urban Agriculture elements in Brasília?

Follow up Questions:

What is important for Urban Agriculture to thrive, in an Urban Planning perspective?

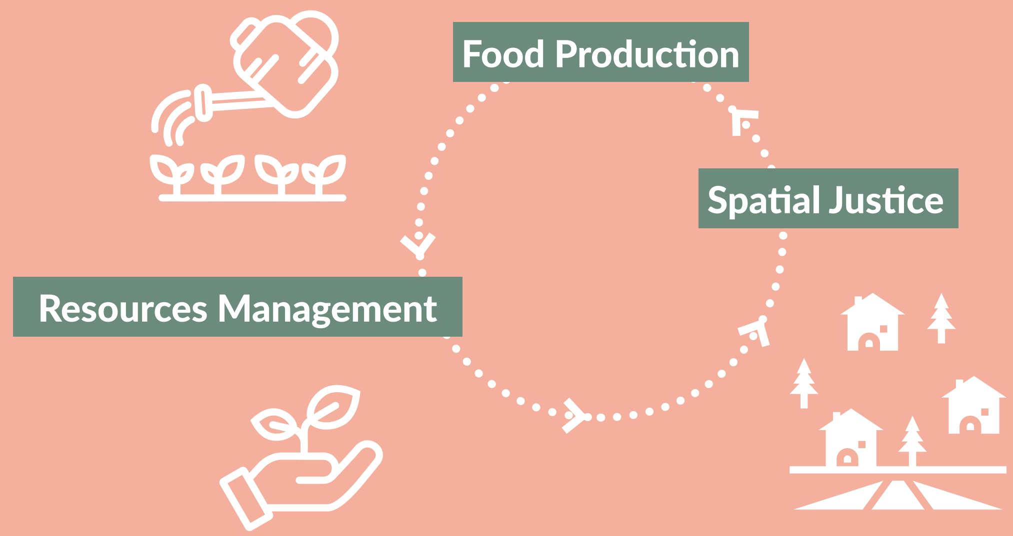
How are these features interconnected with existing Urban Planning layers?

How can Urban Agriculture connect to existing water and waste management?

How is Urban Agriculture inserted in the existing local food system considering commercial and logistics operations?

How can Urban Agriculture successfully be integrated in the urban landscape and be accepted by the people?

Therefore, the research aim revolves around 3 main overarching subjects:



Methodology

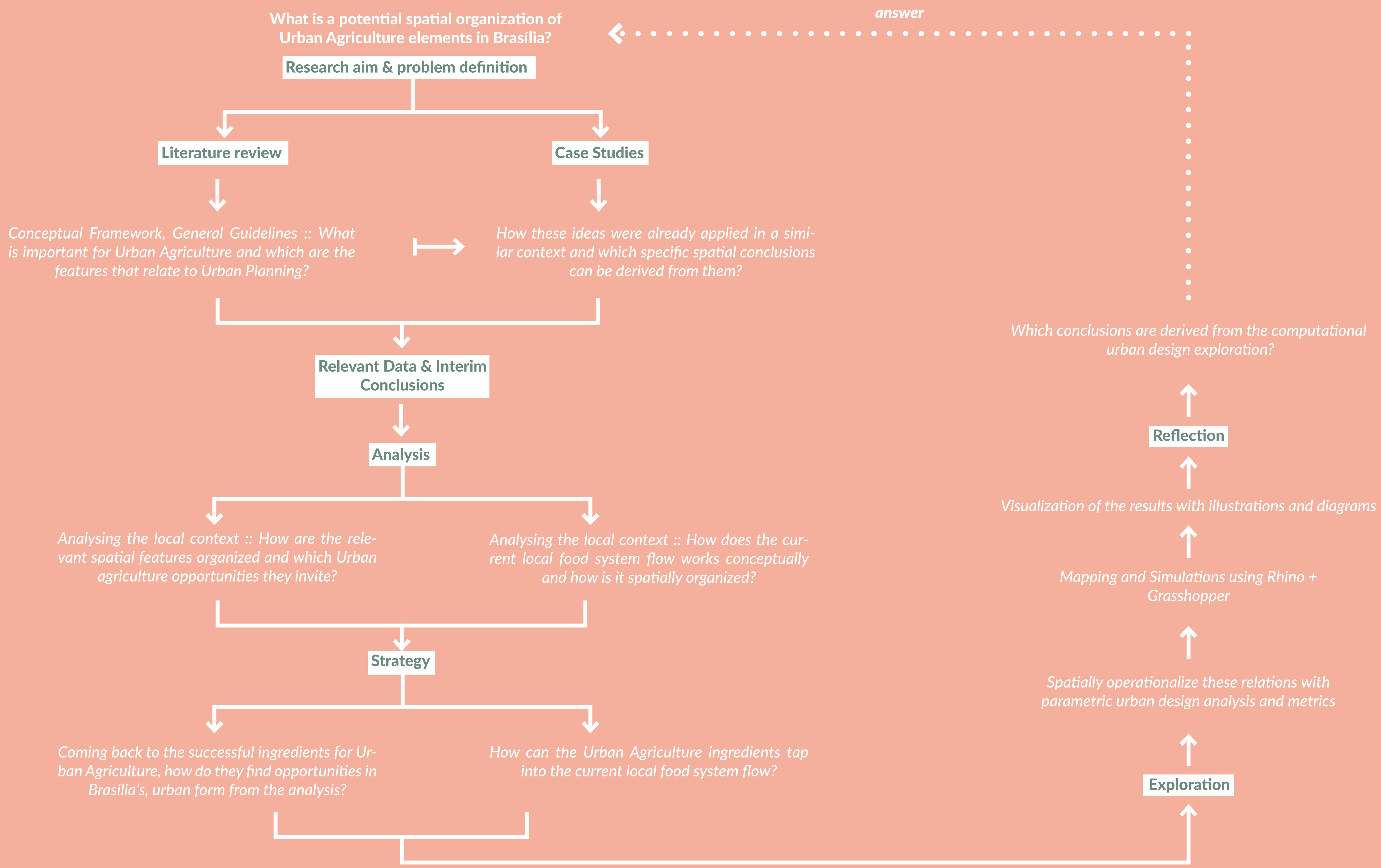


Figure 8: Urban Agriculture. Copyright CC-BY by Markus Spiske/unsplash.com

2 Literature Review

Conceptual Framework
Key research terms and theoretical foundation

The Urban Planning approach towards food systems planning and the three previously mentioned overarching subjects allow for conceptual framework support for the spatial exploration development. After an extensive literature review on the topic, selected theories that foster the project's goals are presented here alongside the definition of some important key terms for the research.

Brasília

The definition of the boundaries of what is considered the city of Brasília is a topic of perpetuating discussions, confusion, and polemics. Some consider Brasília as only the core modernistic original masterplan conceived by the architect Lúcio Costa, the so-called Plano Piloto, an area of 412km^2 and 215.000 inhabitants (IBGE, 2019). Another definition is Brasília being the whole metropolitan region, with 31 so-called "Administrative Regions," Plano Piloto, for instance, being only one of them, and a total area of 5.778 km^2 and 3.3 million inhabitants (IBGE, 2019).

Due to feasibility constraints time-wise, despite understanding and respecting the area as a whole ecosystem with the sum of its parts, and aware of the delicate spatial segregation in the region, this Master Thesis will investigate only the modernist part of Brasília. It will, therefore, explore specifically the significant amount of unused spaces in that location and check how an Urban Agriculture approach in them could have a regional impact. Hopefully, it can trigger awareness and future research for the metropolitan area, starting from the core.

Food Systems

"Food systems encompass the entire range of activities involved in the production, processing, marketing, consumption and disposal of goods that originate from agriculture, forestry or fisheries, including the inputs needed and the outputs generated at each of these steps. Food systems also involve the people and institutions that initiate or inhibit change in the systems as well as the socio-political, economic and technological environment in which these activities take place." (FAO, 2013)

Figure 9: The closed loop of an ideal sustainable local food system (Chicago Metropolitan Agency for Planning, 2012). No copyright infringement intended.

Food Systems Planning

According to the activities by the Growing Food Connections Institution, lead by the

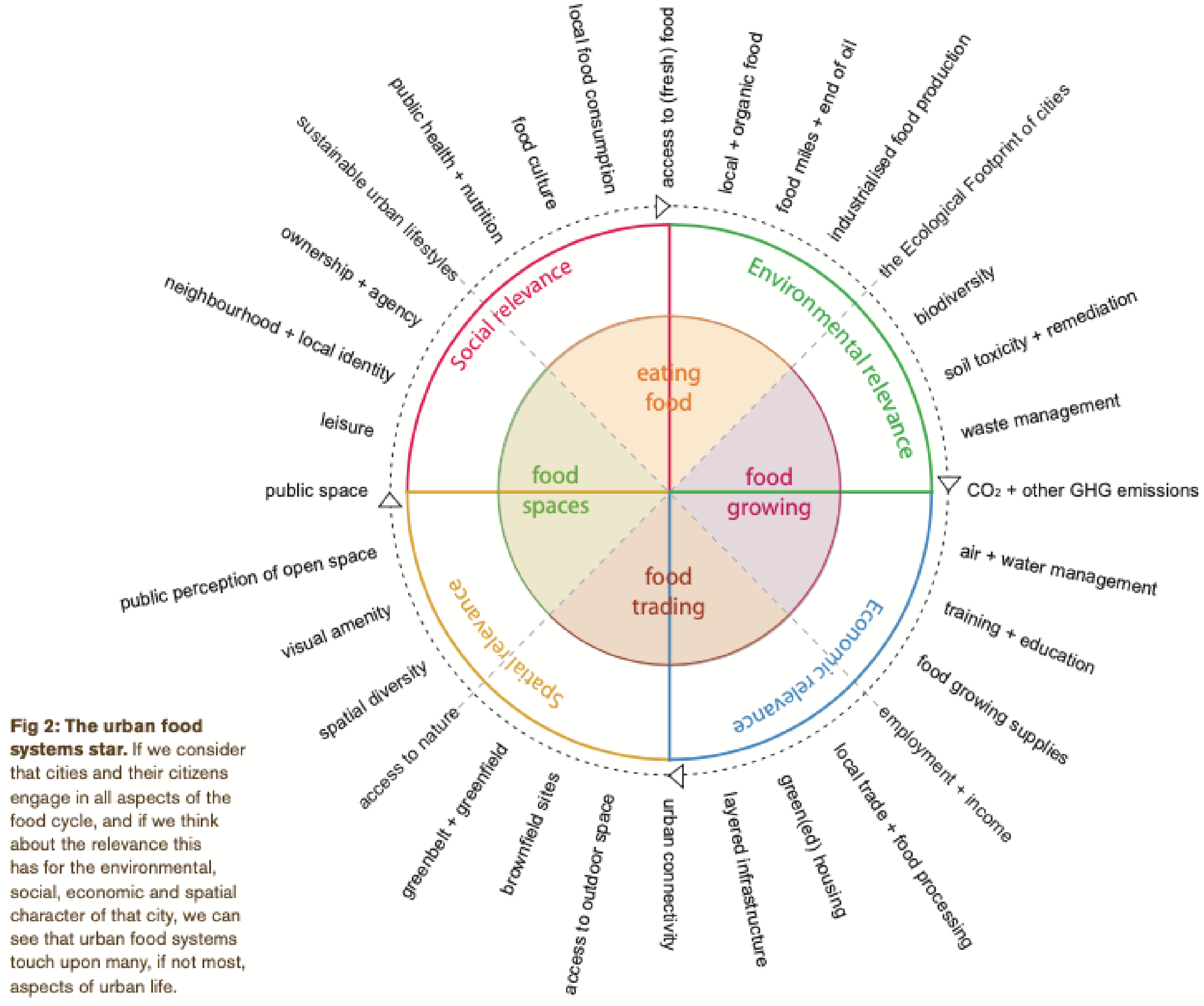


Figure 10: The Urban Food Systems star. (Viljoen and Bohn, 2014). No copyright infringement intended.

University at Buffalo, Food Systems Planning is "a set of interconnected, forward-thinking activities that strengthen a community's food system through the creation and implementation of plans and policies". (Growing Food Connections, n.d.)

"Food Systems Planning should suggest ways the industrial food system may interact with communities and regions to enhance benefits such as economic vitality, public health, ecological sustainability, social equity, and cultural diversity." (APA, 2007)

Food security

"A situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 1996).

Based on this definition, four food security pillars can be identified: food availability, economic and physical access to food, food utilisation and stability over time (FAO, 2008).

Environmentally-sustainable Food Systems

The definition according to the United Nations Environment Programme: "Food Systems in which the environmental bases to deliver food security for future generations is not compromised. Three main principles must be followed to transition towards a re-

source-smart food system:
1. Sustainable use of renewable resources, implying no degradation or depletion of resources, such as land and soils, water and biodiversity.
2. Efficient use of all resources.
3. Low environmental impacts from food system activities. Resource-smart food systems are not only about sustainable and efficient food production; the key challenge is to be effective in terms of overall food security, livelihoods and human health while protecting essential natural resources." (UNEP, 2016)

Land & Landscape

Land itself is a finite resource, and as such, it is affected by degradation all the time, and ecosystem services are lost as a result (European Comission, 2020). Therefore particular attention should be paid to how we can use this valuable and non-renewable element that benefits society as a whole. In that sense, it is essential to understand that landscapes are public goods (Lefebvre et al., 2014). Which means that they are non-rival, if the good is consumed by one person, it does not reduce the benefit available to others, and it is non-excludable, meaning that if the good is available to one person, other people cannot be excluded from enjoying its benefits (Agriculture and Rural Development European Commission, 2011). Moreover, since agriculture production occupies a significant amount of the available land, it plays an essential role in the provision of a whole range of public goods such as high-quality air, soil, and water, as well as providing the resilience of land to natural disasters such as fire and flooding (Agriculture and Rural Development European Commission, 2011). However, at the same time, of course, farmlands operate to provide also private goods, such as food itself, so it means these different interests compete for productive resources such as land and labor (Agriculture and Rural Development European Commission, 2011). It implies that to achieve sustainable development, a multi-level planning strategy is needed to secure food production and economic development without compromising land as a resource, and all the derived public benefits the population is entitled to. This understanding is particularly interesting for agriculture in urban areas, as this interaction is much more evident.

Spatial Justice

In this Master Thesis, the concept of Spatial Justice is used to tackle the fair distribution of the previously qualified landscape qualities in a system. Spatial justice bridges social justice and space. It is the "fair and equitable distribution in the space of socially valued resources and opportunities to use them" (Soja, 2009). This understanding is spatially translated into segregation, exclusion, and inequality.

The concept is valuable for understanding landscapes as public goods and, therefore, the need for their fair distribution. This perspective does not imply that farmers should share their land, but that they should bring values to society, and those should be fairly distributed. Specifically for Brasília, this reinforces that the existing empty spaces should be giving something back to the people, regardless of any social conditions.

Urban Agriculture

"Urban agriculture is an industry located within (intra- urban) or on the fringe (peri-urban) of a town, a city or a metropolis, which grows and raises, processes and distributes a diversity of food and non-food products, (re-) using largely human and material resources, products and services found in and around that urban area, and in turn supplying human and material resources, products and services largely to that urban area." (Mougeot, as cited in Viljoen and Bohn, 2014)

Continuous Productive Landscapes

"Overlaying the sustainable concept of Productive Urban Landscapes with the spatial concept of Continuous Landscapes proposes a new urban design strategy which would change the appearance of contemporary cities towards an unprecedented naturalism. Continuous Productive Urban Landscapes (CPULs) will be open landscapes productive in economical and sociological and environmental terms.

"CPULs will be productive in various ways, offering space for leisure and recreational activities, access routes, urban green lungs, etc. But most uniquely, they will be productive by providing open space for urban agriculture, for the inner-urban and peri-urban growing of food." (Viljoen, 2005).

"Producing food where one wants to eat it, or consuming food where it has just grown, establishes a healthy and sustainable balance of production and consumption. It is an effective and practical, but at the same time self-beneficial way of reducing the energy embodied in contemporary Western food production." (Viljoen, 2005).

Urban Metabolism

"The multiple socio-technical processes by which cities or regions gather, transform, and use biotic and abiotic resources, and expel waste, to ensure their functioning". (Galan and Perrotti, 2019)

Agroecological agriculture

"Agroecological agriculture (of which organic is one system) supports small farms that are diverse, integrated and use low levels of input to ensure the long-term balance between food production and the sustainability of natural resources" (Eldridge, 2018).

Parametric urban design

As mentioned before in the methodological description of this thesis, the chosen approach for the spatial exploration is supported by computational design methods, or in other words, parametric urban design. As supported by the literature excerpts below, Parametric urban design allows for the integration of data as input for a design/modeling/visualization outcome. That is what this thesis aims as a result: Urban Agriculture-related rules and parameters informing a spatial organization for it.

"Parametric design tools accept variable input data, establish mathematical relationships and produce further data, including geometric information" (Steinø and Veirum, as cited in, Richthofen, Knecht, Miao, and König, 2018).

"With advances in computing power and the growing availability of data, parametric systems can now be employed to deal with complex urban phenomena on a multi-scalar and multi-dimensional level. In comparison to conventional design methods, parametric urban design uses rule sets as the basis for the configuration of 3D urban models" (Abdelsalam, as cited in, Richthofen, Knecht, Miao, and König, 2018).

"In short, parametric urban design can be used to model alternative scenarios, visualisations and quantification all in one – a key advantage over conventional design methods" (Richthofen, Knecht, Miao, and König, 2018).

Urban Agriculture
and its key features

Building upon the definition of Urban Agriculture, we now explore the features that make food production in cities possible. According to the United States Department of Agriculture (USDA) "Urban Agriculture Toolkit" (USDA, 2016), there are seven key resources for developing thriving Urban Agriculture. They are:

Business planning, land access, soil quality, water access/use, capital and financing, infrastructure, and market development.

This Master Thesis understands that land access, water access, infrastructure, and market development are subjects in the scope of Urban Planning and will focus on them as the design drivers. It is essential to state that the many and fundamental urban policies associated with the access of these features, however extremely relevant are not in the scope of this thesis.

1. Land Access

Access to land in urban areas can be particularly challenging. Even though it is not the case in Brasília, empty spaces suitable for farming are not common in most cities. In any case, the definition and tailoring of the different types of landuse for Urban Agriculture are important so they can be officially incorporated into zoning laws and municipal plans. Although there is not one recipe that can be applied everywhere, according to the ChangeLab Solutions' "Seeding the City: Land Use Policies to Promote Urban Agriculture" (ChangeLab Solutions, 2012) publication, a basic typological definition can be as such:

Home Garden, Community Garden and Urban Farm.

And the key considerations for their distribution, according to the same source, are:

The size of the land area;
The location of the area;
The number of users of the property (and possibly the generated traffic);
The purpose of the operation (e.g., private or commercial).

Furthermore, different uses are defined as:

Home Garden: "A home garden shall mean the property of a single-family or multifamily residence used for the cultivation of fruits, vegetables, plants flowers, or herbs by the residents of the property, guests or a gardening business hired by the property owner. This includes the rooftop, courtyards and balconies" (ChangeLab Solutions, 2012).

Community Garden: "Privately or publicly owned land used for the cultivation of fruits, vegetables, plants, flowers, or herbs by multiple users. Community gardens may be divided into separate plots for cultivation by one or more individuals or may be farmed collectively by members of the group and may include common areas maintained or used by group members" (ChangeLab Solutions, 2012).

Urban Farm: "Privately or publicly owned land used for cultivation of fruits, vegetables, plants, flowers, or herbs, (and/ or for animal products, livestock production, or value increase) by an individual, organization, or business with the primary purpose of growing food for sale" (ChangeLab Solutions, 2012).

When it comes to size limits, it varies from city to city, and it is up to the local conditions to regulate it. For instance, Home Gardens

literature review

require no regulations (ChangeLab Solutions, 2012), while the size limits for the other two categories will be derived from the case studies in other cities that will follow in the next pages.

The compatibility with the existing landuses defines that Home Gardens are a permitted use in all residential districts; Community Gardens are allowed in residential, multifamily, mixed-use, open space and industrial zones, subject to regulation; Urban Farms shall be a conditional use in residential districts and subject to regulations in all districts. (ChangeLab Solutions, 2012). These definitions are essential for coupling these requirements of the plots to the existing landuses in the city fabric.

2. Water Access

Water accessibility is of extreme importance, demanding sustainable use avoiding overloading the existing network in the city. The standard means for water supply require specific supporting urban policies that allow the farmers to tap into the nearest hydrant, for example, or in a regular network outlet. However, locally adapted small scale irrigation and plant production methods and schemes are possible solutions to save water. Low-cost water-saving technologies such as underground and drip irrigation can increase water efficiency and allow safe use of low-quality water resources (FAO, 2020). Systems of water harvesting through roofs and catchment ponds, for example, are sustainable solutions that, with accurate dimensioning, it is possible to pair the amount of water harvested to the number of productive plots that can be sustainably watered in a network in the urban scale.

3. Infrastructure Access

The access to infrastructure relates to all the necessary equipment for Urban Agriculture, in many scales, since flowerbeds to machinery and, for example, access to energy, composting material, and a direct connection to the agroindusty commercial activities (USDA, 2016). In that sense, from an Urban Planning perspective, it is compelling to couple the productive plots with a more comprehensive system of organic waste recycling from residences and allocating specific landuses for agroindustry plots on the proximities of Urban Agriculture sources. Other related uses that complement this primary infrastructure are, for example, centers to foster Urban Agriculture innovation and training, as well as community restaurants. Altogether these structures build a more robust network and identity, making Urban Agriculture an integrated feature of the existing urban life.

4. Market Development

The possibility of successfully selling the products is vital for the success of Urban Agriculture (USDA, 2016). For truly bridging farmers, consumers, generating jobs and income leads to, social sustainability and inclusiveness. The market development is, of course, in a commercial and economic domain, but the Urban Planning sphere can contribute legitimizing market points in the most convenient locations, supplementing the existing ones and decentralizing the distribution of food. The market development is intrinsically related to the infrastructure access, as they are connected in the productive chain. Just so as infrastructure should be connected to the productive farms, the market should also be accessible to the agroindustry products directly from the farmers and, naturally, to the consumers. It also contributes to creating the previously mentioned Urban Agriculture identity and the integration of this culture in urban life.

The more comprehensive the landuse distribution of these elements are, the better they will work as an ecosystem with the existing infrastructure, just as a different and complementing layer of the urban realm.

Urban landscapes for food security

Urban Agriculture in Cuba

Since the Urban Agriculture movement started in Cuba about three decades ago, the country has become a reference in the field due to the success of its implementation and the positive socio-economic unfoldings from it. Cuba has been a global leader in the policy, science, and practice of Urban Agriculture based on agroecological principles (Fernandez, 2017), promoting essential innovations in the field.

The context that originated the movement was that of the fall of the Socialist Bloc in the early 1990s and the United States trade embargo, leading to an "era of severe food and fuel shortages" (Fernandez, 2017), as 80% of the Cuban imports at the time came from the bloc (Fernandez, 2017). This abrupt transition forced the shift of a "centrally-planned, large-scale, high external input, capital intensive monocultural system to a decentralized, small-scale, low external input, diversified, knowledge-intensive system" (Fernandez, 2017). The transition required a structuring and decentralization of land tenure and management, food distribution, technical assistance, and knowledge exchange" (Fernandez, 2017). Particularly in the capital Havana, citizens started to farm in whatever space they had available. And over time, with strong government support, the country's Urban Agriculture was "rapidly transformed from a spontaneous response to food insecurity to a national priority" (FAO, 2014).

One of their most significant contributions to Urban Agriculture was the invention of the so-called "organopónicos". It is an intensive production system in raised beds that uses drip irrigation, compost, and agroecological management practices such as the use of well-adapted varieties, mixed cropping, crop rotation, and integrated pest management (FAO, 2014). The system can produce vegetables all year round and achieve an impressive yield of up to 20kg per m^2 (FAO, 2014). It is also remarkable that agrochemical techniques in the gardens are forbidden by law.

Figure 11: Organoponico plaza in Havana, Cuba. Copyright by James Pagram/ https://www.theguardian.com/environment/2008/apr/04/organics.food. No copyright infringement intended.

The city of Havana has around 35.900ha (FAO, 2014) under agriculture production and that encompasses typologies such as agricultural enterprises, cattle farms, tree production units, pig and livestock production, agricultural cooperatives and also backyards plots utilized by families to grow fruits, vegetables, condiments, and small animals.

The commercialization of this production is mainly with the direct exchange between the producer and the consumer. The fresh produce can be sold in many different points, usually located within 5km of the production units, within the city's neighborhoods (FAO, 2014). Special subsidized programs facilitate the selling for schools, hospitals, and retirement homes.

This system's success comes from the high cooperation between all the actors involved in the process and stable government policies as backbone support. For instance, the agricultural production in Havana is implemented under two national programs, one for urban and one for peri-urban areas. Both programs aim at "achieving local food self-sufficiency through food production in the neighborhood for the neighborhood" (FAO, 2014). Their basic principles are agroecological production, local-level sustainability, continuous technological innovation, and producers' ownership of what they produce (FAO, 2014). They are expected to use simple technologies and minimal resources to increase food production and reduce dependence on food imports. A decentralized system with minimal inputs and a high degree of food autonomy have been the key to long-lasting food security, environmental preservation, and resilience on the island.

Reported benefits from Urban Agriculture recognized by both the government and society are, for example, the creation of more than 300.000 jobs, the reduction of children malnutrition, community strengthening, and solidarity (Fernandez, 2017). Also, the many educational programs derived from the technical agricultural knowledge and the inherent importance of preserving these achievements for further generations.

A very interesting feature of the Cuban case study is that it is the first country to face a dramatic peak oil crisis in the contemporary age forced to make a drastic supply transition in such a big scale. That points out the near future for all of us and sustainable, viable solutions that should be implemented elsewhere regardless of the imminent threat of a crisis, but because it is the only way to live in a more environmental and socially-just planet.

To systematically apply this knowledge to this thesis, a more specific take on the spatial organization of these structures is needed. On that note, the book "Continuous Productive Urban Landscapes : Designing urban agriculture for sustainable cities" (Viljoen, 2005), brings an exciting DNA of the characteristics of the many facets of Urban Agriculture in Cuba and the typologies on which they could be clustered, showcasing productive sizes and derived yields. The result is as follows:

1. State farms for producers' consumption, cultivated by workers. Size: more than 1ha; yield: 0.6kg/m^2.yr;

2. Community Gardens, cultivated by families. Size: less than 1000m^2; yield: 8-12kg/m^2.yr;

3. Intensive cultivation gardens, cultivated by several families. Size: Between 1000m^2 and 3000m^2; yield: 8-12kg/m^2.yr;

4. Urban community garden, cultivated by collectives. Size: Between 2000m^2 and 5000m^2; yield: 20kg/m^2.yr;

5. High yield urban gardens, cultivated by co-operatives. Size: over 10000m^2; yield: 25kg/m^2.yr;

Given the similarities in technological resources and cultural backgrounds within Latin America and the proven success derived from these standards, this Master Thesis will use the Cuban precedent numbers as a stepping stone for the follow up spatial explorations presented here.

Cities without hunger
Urban Agriculture NGO in São Paulo

“Cities without hunger” is today a leading NGO promoting Urban Agriculture, mainly in São Paulo, Brazil. Their work operates in a unique system and focuses on benefiting and employing socially vulnerable groups, especially unemployed women and migrants.

The NGO works mainly in two different branches. The first one searches for idle and vacant plots in the city, manages the negotiation with the owner to use that land for urban agriculture and through sponsorship from private companies, they set up the arable land, irrigation systems, warehouses, bathrooms, kitchens, rest areas and provide equipment. People living in proximity to the gardens can apply to work and go through the NGO's urban farming training process. The selling of products happens like in most cities: either on the location or in markets. The NGO manages and monitors the gardening activities, considering the inputs, production, sales, income generation, and consumption. The intention is that after a while of the functioning garden, the farmers are capable of sustaining themselves without the help of the sponsorship (Cities Without Hunger NGO, personal communication, June 15, 2020)

The second track of work is with gardens for schools. A school with an available space would request the work from the NGO, and, also with the support of sponsorship, set up the land and provide the adequate training so that the students and teachers themselves can care for the garden. In this way, they are provided with fresh, healthy food in school meals and snacks. In addition to the food itself, students have access to science, environment, and nutrition classes, an impact that extends from school to family and public health in the long term (Cities Without Hunger NGO, personal communication, June 15, 2020).

The NGO's work is fully aligned with broader overarching goals such as the United Nations' Sustainable Development Goals (United Nations, n.d.). The production focuses on organic products, responsible use of water, exclusively applying dripping irrigation and rainwater harvesting, not using the water from the municipal network, nourished land via composting, commercialization of food at fair prices and income generation for a more inclusive society (Cities Without Hunger NGO, personal communication, June 15, 2020). The salaries of the works are equally paid and obey the minimum wages of the country. Additionally, the farmers are provided with infrastructure, such as bathrooms and kitchens, on-site, to work with dignity (Cities Without Hunger NGO, personal communication, June 15, 2020). Since 2004, the NGO built 27 urban gardens, employed 411 farmers, produced 732 tons of food, and built 51 school gardens, serving almost 30.000 students monthly (Cities Without Hunger NGO, personal communication, June 15, 2020).

In the coming years, the goals for the NGO are to expand their activities to other areas, consolidate their data monitoring systems, improve water collection and distribution systems, and develop more partnerships to foster local consumption and circular economy (Cities Without Hunger NGO, personal communication, June 15, 2020).

With this case study, it is clear how significant Urban Agriculture's impact can be and that such a model is feasible, especially if it had the local authorities' support, which is the case of the next case study in another city in Brazil.

literature review

Legitimating Urban Agriculture
The Food System Program in Belo Horizonte

Belo Horizonte is Brazil's sixth-largest city with an estimated population of 2.5 million (IBGE, 2019), and it is a remarkable example of the pioneering implementation of Brazilian Zero Hunger programs that started in the 1990s and continue until this present day. Therefore, the city has become a valuable case study on how far Urban Agriculture and local food systems can go when combined with well-designed public policies and their environmental and socioeconomic benefits.

Like other Brazilian cities, Belo Horizonte suffered high rates of poverty and hunger in the last decades. It was estimated that 38% of the people in the metropolitan region lived under the poverty line, and 18% of the children aged less than three years old were malnourished. (FAO, 2014).

Responding to these challenges, the municipality created a leading supply agency, which has evolved to today's Secretariat for Nutrition and Food Security (SMASAN). With the institutionalized power from the municipality and its agenda and budget, the agency “develops actions for food education and nutrition, through mobilizing and dynamic strategies aiming at promoting a dialogue with the local community about the importance of healthy food access” (Secretaria Municipal Adjunta de Segurança Alimentar e Nutricional, 2019).

These actions focus on socially vulnerable groups and work in cooperation with other municipal programs, notably on schools, childcare homes, and centers for the elderly and healthcare. The strategy encompasses an extensive set of tools among subsidized food sales and school meals, free food distributions, affordable community restaurants, regulation of prices in food markets, and agricultural production in rural and urban areas (FAO, 2014).

Alongside the political will, a crescent civic engagement over the years pushed for the legitimization of urban agriculture as a landuse in the city. The municipality now sees it as “contributing to the full development of the city's social functions” (FAO, 2014). Currently, urban farming is recognized as an economic activity and “urban farmer” as a legit professional category. Recognizing this importance boosts other related fields and the expansion of local and public education programs on gastronomy and social services. Adding to that, on the municipality's website, the location of the more of 200 gardens spread around the city is available, organized in between institutional and agroecological family productive units. Likewise, a facilitated system directly connects institutions or individuals who wish to donate food to people in need. The fact that all these pieces of information are publicly available reinforces the normalization of this system and its integration on people's lives, with the official support of the local government.

The programs' implementation relies heavily on the active participation of the community, as the local people are managing the plots. The process is that a group must apply for the lease of the land of one of the selected vacant plots, and once approved, SMASAN provides the necessary support and training to ensure the quality of the products under their guidelines (FAO, 2014). For example, pesticides are prohibited, and the irrigation comes from the city's network, as currently, there is no other option available. The commercialization of the products is mainly to schools for student meals, food markets, and directly to the consumers (FAO, 2014).

In fact, the coupling of Urban Agriculture and schools has proven to be a great success in the local context. It is one of the most effective ways to promote the practice, where children are invited to attend workshops on micro gardening, and they spend around 1 hour per day caring for the plants. This strategy reaches around 96 000 pupils (FAO, 2014). The municipality also relies on the children's education to bring the changes and awareness to their homes, expanding the food education network in a natural process, hence the success.

Besides working with schools, another source of promotion of Urban Agriculture is the centers for agroecological living. They are located mainly in peri-urban areas and are also managed by civil society groups. They offer courses on organic production, recycling, nutrition, and ecology. (FAO, 2014)

The results of all these years of the programs are that the vegetable consumption has increased among families and students and an estimated 9 000 city residents have access to pesticide-free produce at a reasonable price, (FAO, 2014).

The municipality plans for the upcoming future are to facilitate access to Urban Agriculture plots in urban centers and longer leases, therefore lowering the competition with land for real estate development. The municipality also intends to implement rainwater harvesting systems and better integration with solid waste management to use local compost (FAO, 2014). The idea is that facilitating and improving urban agriculture infrastructure more young people would be interested in the activities, therefore leading to the perpetuation of the programs.

Interim conclusions
& Selected Data

After the literature review and the case studies, notable takeaways will be applied in the thesis further development:

1- Considering Land Access, Water Access, Infrastructure, and Market Development as the **four main features that contribute to the best performance of Urban Agriculture** concearning Urban Planning. These will be the features explored in the computational simulations;

2- The Land Access also encompasses a **division in typologies** and their compatibility with existing landuses. For instance, the thesis will adopt the simplified division in **Home Gardens, Community Gardens, and Urban Farms** as derived from the "Seeding the City: Land Use Policies to Promote Urban Agriculture" (ChangeLab Solutions, 2012) publication;

3- For the sake of the simulations and the development of guidelines, this thesis will, therefore, consider the following **productive land sizes**: Home Gardens will not have a size restriction, Community Gardens, shall be plots up to 1ha and Urban Farms shall be plots from 1ha to 3ha, as derived from the Cuban example;

4- The **landuse compatibility** will also follow the "Seeding the City: Land Use Policies to Promote Urban Agriculture" (ChangeLab Solutions, 2012) publication, being as such: Home Gardens are a permitted use in all residential districts; Community Gardens are allowed in residential, multifamily, mixed-use, open space and industrial zones, subject to regulation; Urban Farms shall be a conditional use in residential districts and subject to regulations in all districts;

5- As seen in the Brazilian case studies, Urban Agriculture has its **best performance when coupled with schools** and supplemented by **additional infrastructure such as community restaurants** boosting access to food. The plots should also be somehow accessible for the workers either within a catchment area from their own homes or to a public transportation point.

6- The **drip irrigation through water harvesting systems** is already an applied technology, hence presenting the significant potential to be scaled up to an institutionalized strategy on a larger scale;

7- The use of composting material in the gardens is desired but still considered expensive and hard to access. Therefore a strategy that **fosters the management of the organic waste** from households to composting units and finally the gardens in a local level is highly beneficial;

8- When designing an Urban Agriculture strategy in Brazil, it must be evident that the priority is to **benefit socially vulnerable groups.** Therefore the landuse definition and accessibility rules must be aiming at reaching people in need;

9- The understanding of **land and landscapes as public goods**, and therefore their responsibility on providing and being accessible for the whole population, must be in the core of the implementation of land distribution plans, and this case for urban agriculture. Such an exercise has to be seen as an opportunity for **fighting social inequality and spatial segregation** through spatial justice and the socio-economic opportunities it unfolds;

In a more specific note, the following data will be considered as the base for the future calculations and simulations, complementing the previous research:

// **The necessary area to feed one person:** 0.23 ha (FAO, 2011).

// **Average yield of Urban Agriculture:** 6-8kg/m^2.yr (McDougall, Kristiansen and Rader, 2019).

// **One of the most common crops produced in the region of the study:** Corn (Agência Brasília, 2016)

// **The necessary amount of water for corn irrigation:** 3-6mm per day :: 350-500mm for the whole cultivation (Agência Embrapa de Informação Tecnológica, n.d.).

// **Average amount of fertilizer needed:** 400kg/ha (Braga, 2012).

// **Average amount of organic waste produced in a household in Brasília:** 650gr (Imbelloni, 2007).

// **Minimum average solar radiation required to grow the crops**: 500MJ (Yang, Xu, Hou, et al, 2019).

// **Average annual precipitation in Brasília:** 1668mm (Climate Data, n.d.).

// **Average temperature in Brasília:** 21.1°C (Climate Data, n.d.).

// **Walkability standards to reach amenities:** amenities in a 5min walk :: 400m (Morphocode, n.d.)

// **Walkability standards for taking the public transport:** average of 580m, maximum of 800m (WYG, 2015).

// **Maximum distance people walk before deciding to use a car for shopping:** in between 1.000 and 1.200m (WYG, 2015).

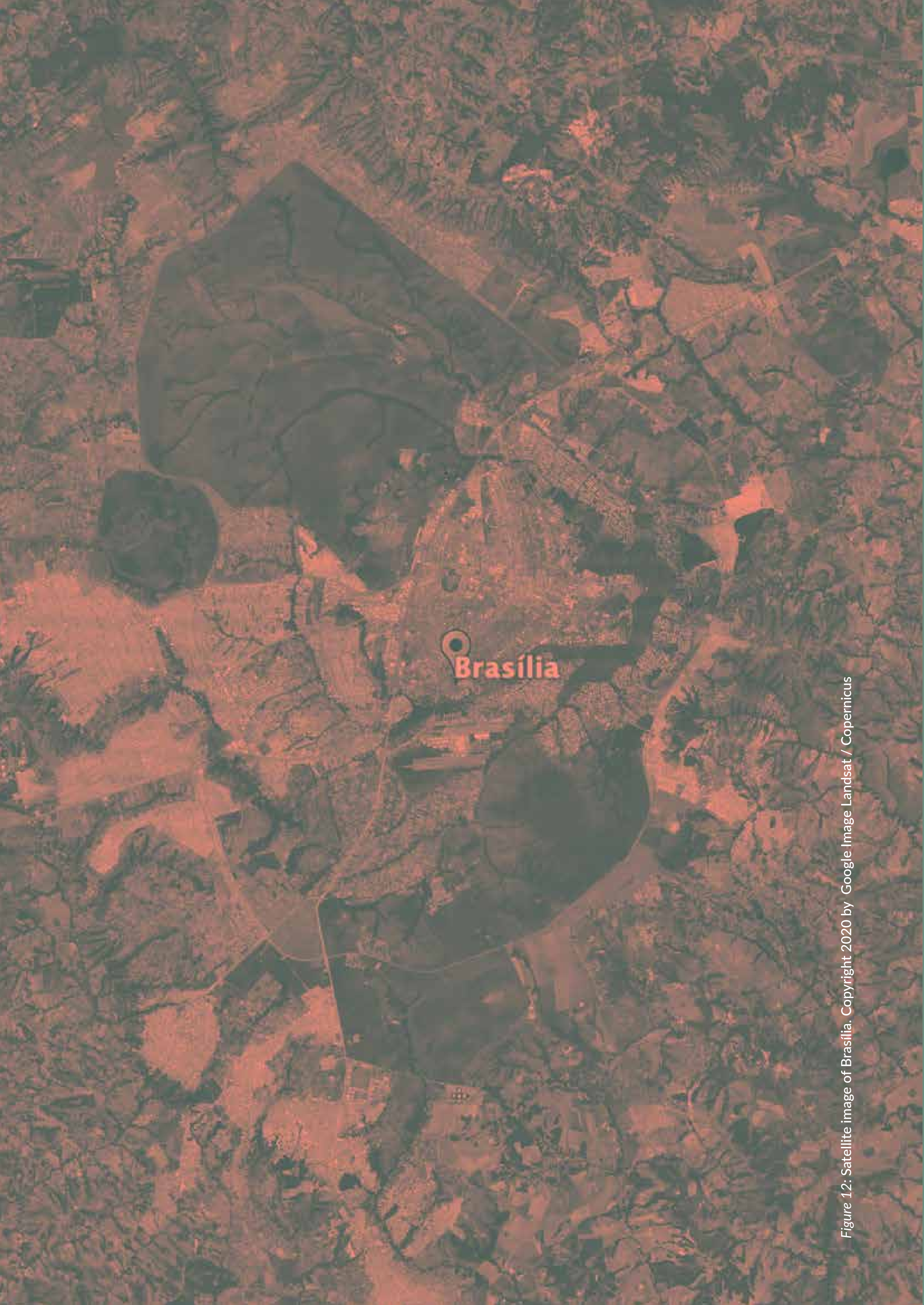


Figure 12: Satellite image of Brasília. Copyright 2020 by Google Image Landsat / Copernicus

3 Local Analysis

Situating Brasília

The modernist urban form and its derived opportunities

As mentioned before, the delimitation of Brasília can be understood as the whole metropolitan region or only the modernist core, as shown in the diagram. Despite understanding the importance of the whole region as a connected ecosystem and that the most significant urban challenges fall exactly there, due to feasibility constraints and the unique character of the modernist urban form, the thesis focuses on a spatial investigation of that part only. Hopefully, the lessons learned here have the potential to be replicated in the other areas or simply to inspire similar future research.

Brasília is a result of a design competition aimed at finding the best project for Brazil's future capital in 1956. The intention behind moving the capital from Rio de Janeiro to somewhere in the country was to boost and anchor the development of that area, which was far behind the coast at that time.

The importance of the new capital's accession inspired the symbolism of the plan of the winning proposal, by the urbanist Lucio Costa, with later architecture landmarks by Oscar Niemeyer. The uniqueness and recognized importance of its modernist design were celebrated with the title of a UNESCO World Heritage Site (UNESCO, n.d.) - which yes also means that everything is frozen in time and cannot change, for better or worse.

"In Costa's view, a modern city needed to be deliberate, orderly, rational, and systematic. —the opposite of messy, over-crowded cities that grew and developed organically over time" (Budds, 2019). The plan has two main components, the Monumental Axis (east to west) and the Residential Axis (north to south), connecting a patch of scattered open

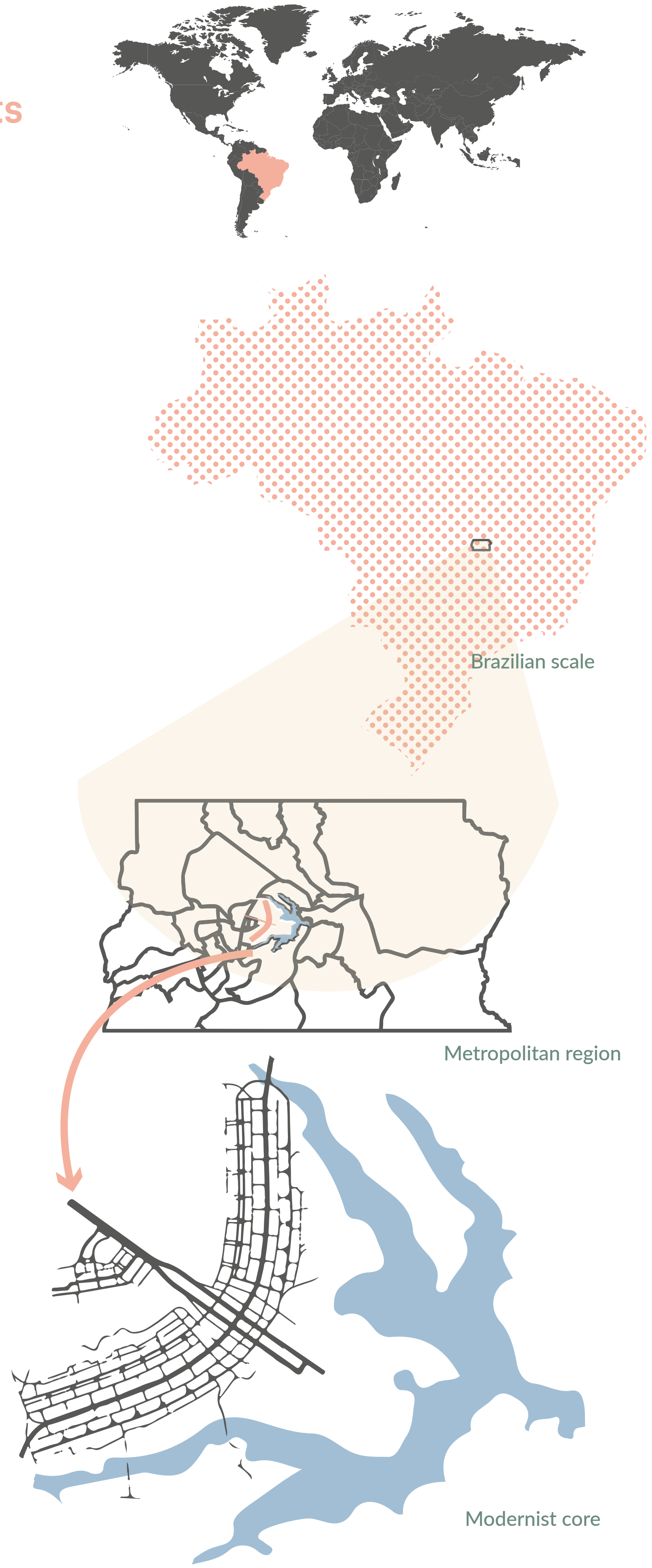


Figure 13: Situating Brasília in different scales. Own design.

local analysis

spaces and buildings. Following a sectorized landuse distribution, the Monumental Axis was assigned political and administrative activities and is considered the city's body with the style and simplicity of its buildings, oversized scales, and broad vistas and heights producing the idea of Monumentality. This axis includes the various ministries, national congress, presidential palace, supreme court building, and the television and radio tower (Wong, 1989).

Figure 14: The monumental axis: political and administrative buildings, open spaces and highways. Copyright 2020 by Joana França. Reproduced with permission.

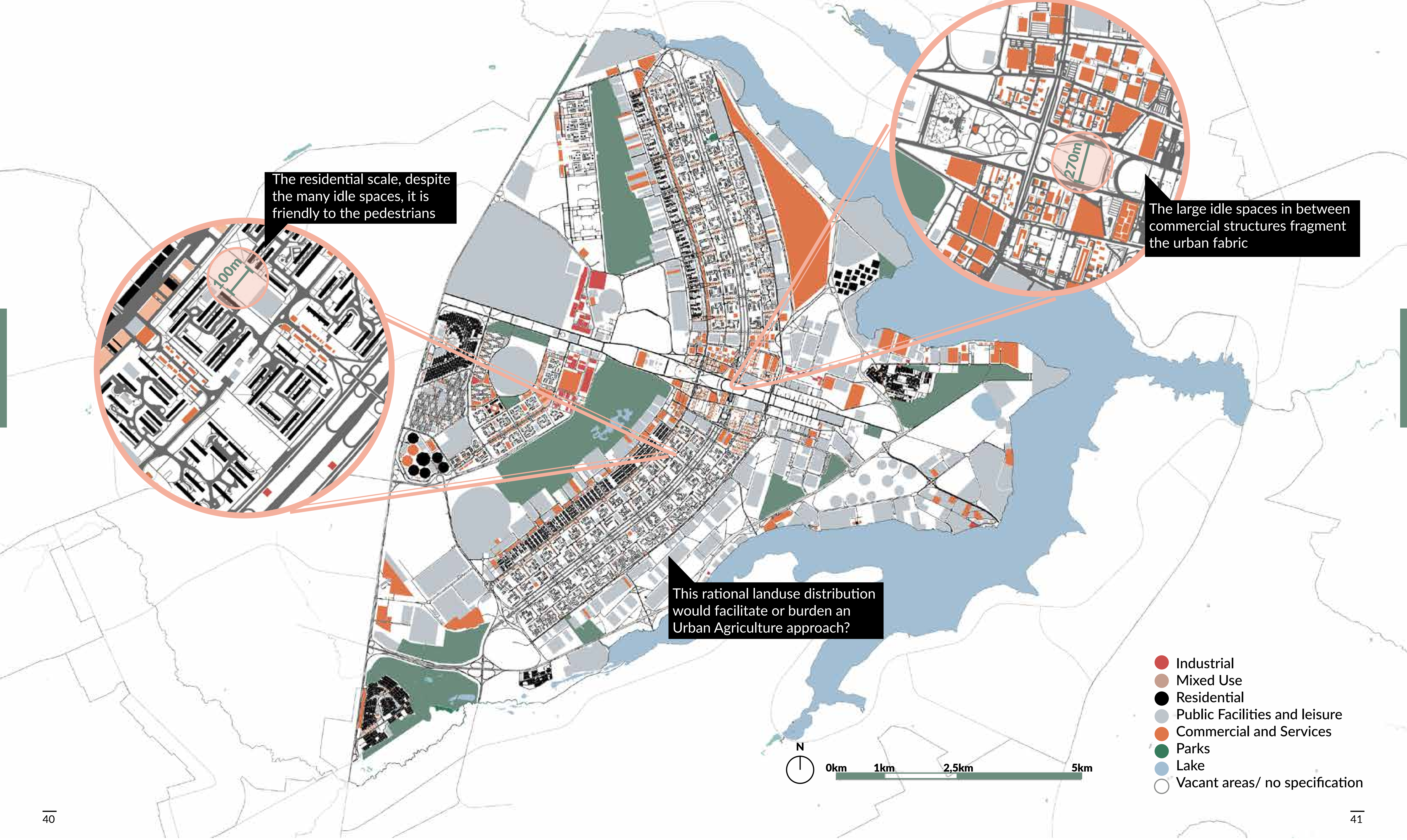
The Residential Axis was intended to contain intimate character areas and is considered the most important achievement of the plan. It was designed for housing and associated functions such as local commerce, schools, cinemas, and churches, composed of 96 superblocks, the so-called "Superquadras" (280x280m each), limited to six-story height buildings and 12 additional superblocks limited to three-story buildings. The buildings' architecture has a purity of form, with flat roofs, orthogonal façades, and a public groundfloor, since they are elevated by pilotis, which is a privilege in the Brazilian reality where housing is usually fenced off and gated.

Figure 15: The special charachter of the buildings. Copyright 2020 by Joana França. Reproduced with permission.

Figure 16: The superblocks are placed in between green spaces, like a park city. Copyright 2020 by Joana França. Reproduced with permission.

The intention behind the superblocks was to have small, self-contained and self-sufficient neighborhoods providing a walking distance

Mapping Brasília: Modernist landuse distribution and street network



from daily amenities and uniform buildings placed amidst green spaces, as in a park, with apartments of two or three different categories, where the vision of the integration of upper and middle classes sharing the same residential area could flourish (Wong, 1989).

The plan of Brasília also envisioned to allow free flow of automobile traffic, as in that time cars were the symbol of modernity. Moreover, until this date, even though Brazil has continental dimensions, there is not a railway network in the country, so all the movement of people and goods rely heavily on automobile mobility. The result of this choice in Brasília is a city-scale strange for pedestrians, with long distances without many attractions in-between spaces.

It is essential to highlight the tabula rasa approach that took place in the construction of the city. The native vegetation in the region was mostly cleared out, offering space for the urban core built from scratch in 5 years. Therefore all the nature that one can see in the pictures was actually artificially placed there.

Lastly, the city was conceived mainly to prioritize the aesthetic and functional forms, neglecting other sides of the urban ecosystem, such as the management of waste and water flows. As already mentioned before, there was no planning for solid waste, culminating today in the biggest landfill of Latin America. The design of the street network favoring automobile flows' efficiency, with their orthogonal shapes, challenges the capacity of rainwater drainage as it overlooks the morphology of the rainfall in the terrain.

All together, these features naturally result in many specificities, and whether Brasilia's modernist experiment is considered a success is an endless debate, and it falls outside the scope of this work. Therefore only a critical outlook on the features revolving Urban Agriculture potentials will be reviewed and

Figure 17: Flooding in one of the Superblocks in 2019. Copyright by André Borges/ https://www.metropoles.com/distrito-federal/brasilia-desaba-em-chuva-forte-veja-fotos-e-videos . No copyright infringement intended.

further integrated in the strategy into the next chapter.

As a start, the idle open areas though intended as urban quality, turned out to be a collection of hyper underutilized public spaces, resulting in immense voids of precious land in the middle of the city, which are simply very costly to maintain by the public funds. Furthermore, that happens at the same time that 13,26% (Companhia de Planejamento do DF - Codeplan, 2018) of the regional population does not have access to housing, for example. And the people who do manage to access a home are pushed away to land-consuming-urban-sprawling new satellite cities and informal settlements. This situation mirrors the Brazilian society, characterized by enormous social inequality, and the uneven access to natural resources.

These public spaces without qualification end up not being attractive or safe for leisure activities and also do not quite work as green infrastructure for rainwater drainage, for example, since the original vegetation was completely cleared out. They are spaces mainly covered by grass (but also many times concrete and long asphalt roads), which often become mud during the rainy season and dirt in the dry season. As already mentioned before, all these features combined with poor water and waste management pile up culminating in floods and water shortages. The nonexistence of public ownership concerning these spaces also contributes to urban violence problems due to the lack of urban activity throughout the city.

Figure 18: The dimension of the open spaces on eye level in the Monumental Axis. Copyright 2020 by Google.

Figure 19: The dimension of the open spaces on eye level in one of the Superblocks. Copyright 2020 by Google.

In the residential scale, this scenario is slightly different. The Superblocks scale allows for unique pedestrian mobility in Brasília, and the particularities of the architecture of the buildings, such as the freed-up groundfloor, connects the surrounding landscape in a continuous permeable path. This clear visibility brings safety, dynamicity to space, and promotes a greater sense of community.

The question that arises is whether all these green spaces could nevertheless be more useful beyond contemplation and fruit trees. All this public space availability heavily contrasts with the reality of most of the residential areas surrounding the modernist core, where access to green spaces is scarce. Therefore, since nothing can be built on them in any case, due to the Heritage title, how can these spaces serve a broader public good? And how can the other characteristics of the architecture, such as flat roofs, be more useful hosting urban gardens, urban bees, or rainwater harvesting, for example? Can a new organized way of implementing a different layer of green infrastructure be benefitial? In which ways? And how?

Moreover, do these places have the right conditions for that? What if these spaces were utilized for a suitable type of Urban Agriculture for instance? How many people could benefit from them? How could they be integrated into the urban landscape? How could all this land serve the social value intended in its conception?

In sum, the idea of modernity in Brasília was the materialization of the dream of a country that moved forward, which boosted industrialization and urbanization, released from its agrarian past and colonial history. However, what if today, modernity and contemporaneity mean precisely coming back to that, due to the current urban challenges? What if Brasília could again be a bold symbol of courage and forward-thinking agency by prioritizing food sovereignty and urban resilience, transforming its criticized empty public spaces into Urban Agriculture, becoming a living lab of how a city can adapt its existing infrastructure for fighting poverty, hunger and social inequality in Brazil.

To apply any change in that sense, it is first necessary to continue this local analysis moving forward to understanding the current food supply conditions in the city.

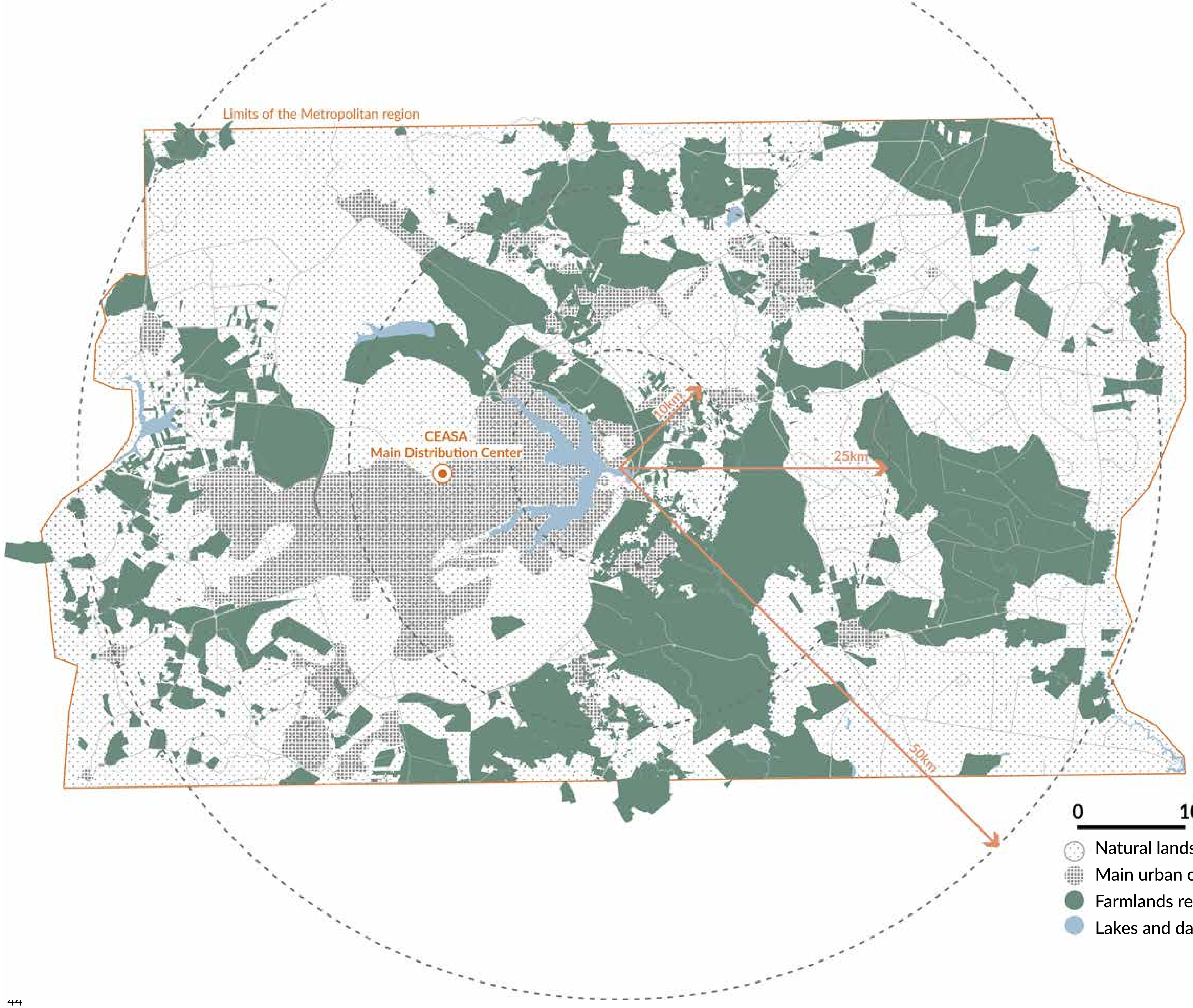
The local food system

And the opportunities it unfolds

As already mentioned in the background section of this work, the farmlands that supply Brasília's metropolitan cluster lie just outside

local analysis

The local food system's spatial features:



75%

of the production is supplied by small scale farmers

(Agência Brasília, 2019)

46%

of the rural plots correspond to small scale agriculture

(Agência Brasília, 2019)

70%

of the metropolitan area corresponds to rural zones

(Agência Brasília, 2019)

there are currently around

19.000

rural properties in the metropolitan area

(Agência Brasília, 2019)

small scale farmers are plots up to

20.000m²

(Agência Brasília, 2019)

The Local Food Supply

How the local food reaches the table of consumers in Brasília

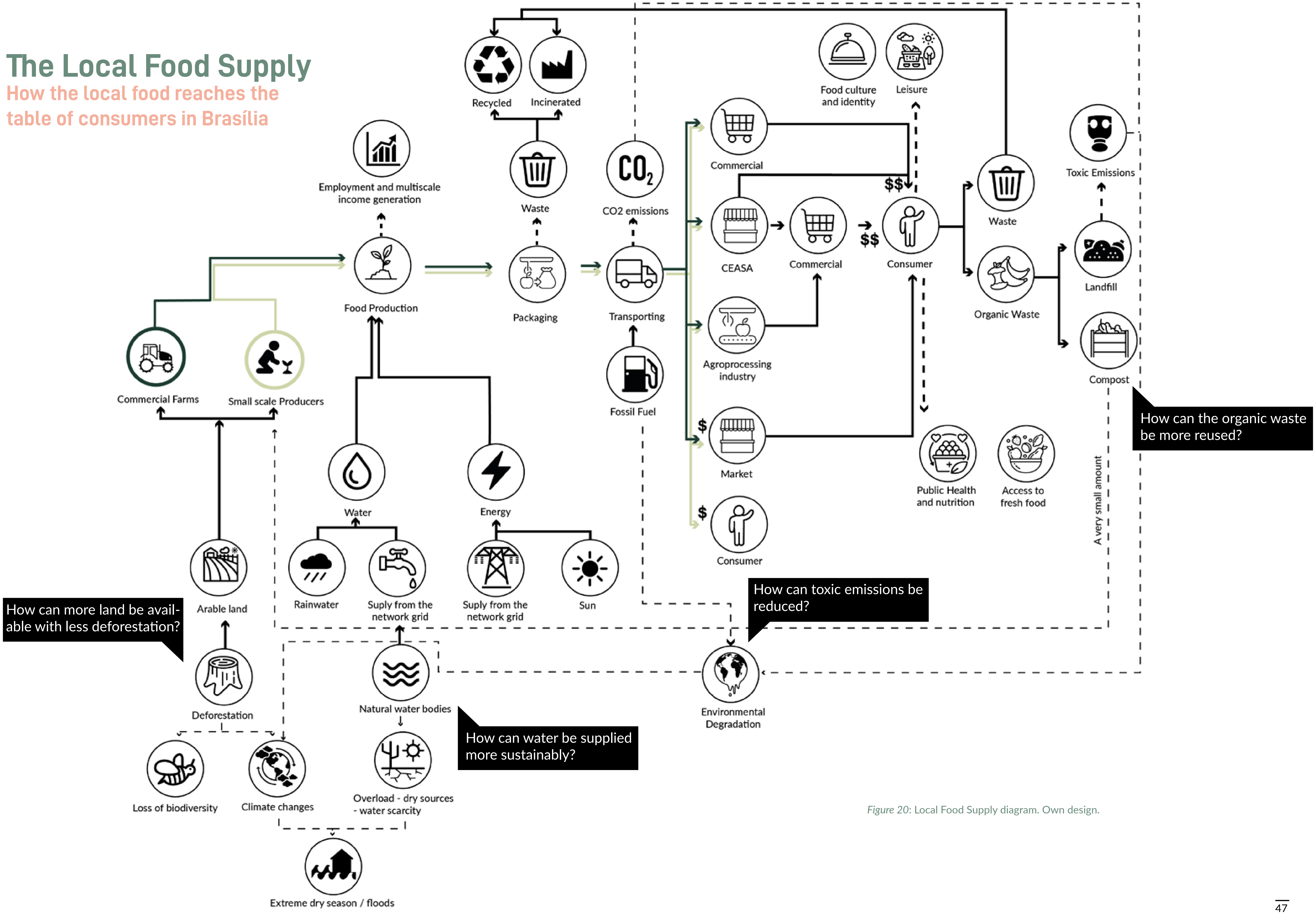


Figure 20: Local Food Supply diagram. Own design.

of the main urban areas and are fairly productive, substantially supplying the local population and playing a very significant role in the national exports as well. That means that in average, the supply and consumer sources lie in a 50km catchment area as shown in the map in the past pages. The main produces of the area are grains, such as soybeans, corn, sorghum, beans, wheat, peppers, tomatoes, strawberries, guava, jiló, okra and zucchini (Agência Brasília, 2019).

The main challenges that arise from the current spatial organization are the concentration of wealth and land in large-sized commercial farms, straining the opportunities for familiar, small scale, and ecological production. The commercial farms usually heavily apply chemical fertilizers, therefore not offering organic and healthy products, and consume a very significant amount of the regional water for irrigation (Brasília Capital, 2016). Additionally, the current food system has an open end, as the waste becomes a landfill far away from the productive lands, instead of returning as compost material. This production chain was shown in the flow chart on the past page.

Therefore, even though the agriculture system is considered reasonably good because it accomplishes its primary duty of supplying most people with food, when considering the land potential inside the city of Brasília, a lot can still be improved by merging the urban and the rural realities and decentralizing the system. A decentralized system opens room for possibilities for smaller-scale enterprises, job opportunities, and income generation at the local level for more people. Meaning the revenue of the products remains, employs, and feeds the local population. Additionally, the necessary infrastructure for the production can benefit from the existing water and waste loops already inside the city.

In the socio-economic sphere, even though there is a solid local production, fresh products do not equally reach the population (Jornal de Brasília, 2019), and there are still often logistic challenges for the family farmers to reach distribution points (Canal Rural, 2018). As shown in the diagrams, the produce from the commercial farms goes to a centralized distribution center, called CEASA, from where people can go shopping either for commercial use, such as restaurant owners, or also for personal consumption. The other option is for the farmers to sell the products directly to the supermarket chains, send them elsewhere in the country or to international export. This whole process is well regulated by local governmental authorities, managing and supporting the farmers, organizing the distribution, and checking for hygienic and related regulations.

Figure 21: Inside the CEASA (Center of Distribution of Production) the local producers have their stands. 55% of the people selling there are family farmers (Agência Brasília, 2019). Copyright by Lúcio Bernardo Jr. / Agência Brasília.

The small producers can also sell their goods in smaller markets scattered around the urban areas. Some of them are institutionalized in given spaces others are self-initiated and organized by the producers themselves. However, the farmers often have to drive to the city center and from there walk from door-to-door to sell their goods or in the traffic lights when the cars stop. It means that they need to organize, pack, and bring the goods from a distant farm and carry them back if not everything is sold every day. This process can be arduous, as, beyond the logistics barriers, the producer still has to search for the costumers actively. Many of them choose to do so despite the difficulties, as they can earn more selling directly to people. If they could produce already where they sell it, the process could be simplified, reducing the packaging, the CO_2 emissions on transportation, and the physical and emotional distress of the farmer.

One more important feature is that the local population has a significant tendency to buy processed goods such as already cut vegetables and fresh juice (Canal Rural, 2018). Therefore, the local agroindustry is rising and currently processes around 90ton (Canal Rural, 2018) of food per month, generating many jobs opportunities and strengthening the relationship with the local farmers. They usually partner with small scale producers and collect the goods directly from them, facilitating transportation, usually a challenge from the farmer's side. Therefore, supporting this already existing relation is a positive strategy that should be taken into consideration when planning commercial and industrial activities in the city's strategy.

The last layer on the overview of the local food production is not anymore analyzing how the system is organized today, but rather how diverse initiatives are already planning to change it.

Existing initiatives
A selection

Urban Agriculture in Brasília is not exactly an innovative idea, as the will of growing local food or simply attempting on a more off-grid lifestyle was already in the radar for some citizens and enterprises.

Notably, the pioneers of civic engagement in the city, the "Nossa Brasília Movement" has been taking actions on the implementation of community gardens in Brasília. The movement from the civil society is articulated as a network of people, initiatives, communitary organizations and social movements that share the same vision for the right to the city and human rights with a critic and collective perspective. (Movimento Nossa Brasília, n.d.). The group organizes political participation in varied areas such as Culture, Gender Issues, Solid Waste Sustainable Management, Urban Mobility and last but not least, Urban Agriculture.

The group joined forces with interested people and volunteers to build community gardens in public spaces aiming on promoting the agroecological practice in the city, supporting local actions and legal frameworks for the promotion of related public policies with the production of healthy food.

Figure 22: Group of volunteers from the Nossa Brasília Movement working on one of the community gardens. Copyright by Movimento Nossa Brasília/ http://www.movimentonossabrasilia.org.br/abraco-em-solidariedade-as-hortas-comunitarias-de-brasilia/. No copyright infringement intended.

After setting up some of the gardens, the group faced many challenges for keeping them. First of all, since it is still an innovative practice, many people simply stole the food that was growing there or vandalized the spaces. A second challenge was the recurrent interruption of the water supply from the city's agency (Movimento Nossa Brasília, 2017). These problems probably arouse mainly because there is not yet a legitimation of Urban Agriculture, meaning that the majority of the population does not understand the boundaries and rules around it. Likewise, it is unclear how the integration with the other supply services should work. Once again, it shows that a centralized institutionalized strategy is imperative for its success.

A second strategy to be mentioned is a celebrated local startup called "Projeto Compostar", which works bridging organic waste, compost, local producers, and fresh food. The process is that for a monthly fee, weekly, the organic waste is collected from the subscriber's household, transformed into compost at the company's facilities, and you receive in exchange one herb or plant that was fertilized with that compost (Projeto Compostar, n.d.).

Figure 23: Composting process in the windrows. Copyright 2020 by Projeto Compostar. Reproduced with permission.

Another branch of their work is supplying the compost to local farmers and selling their products for the people. It works in the same way as a subscription, in which, for a weekly fee, the person receives a box with the local harvest of a specific small scale producer. It supports the local farmers and expands access to healthy and nutritious food and the direct management of organic waste (Projeto Compostar, n.d.).

Lastly, a current effort from the government is also worth mentioning. In 2018 the municipality developed the "District Plan of Integrated Solid Waste Management" (Governo de Brasília, 2018), defining goals and guidelines to be achieved in the next 20 years. This action is part of a broader strategy at the national level to finally coordinate the actions on waste management in the country.

The program's main goals involve the non-generation of waste, the reduction of its production, the reutilization of materials, recycling, treatment, and final destination. The program characterized the waste according to its origin and the responsibility on the management depends on that classification (VG Resíduos, 2018).

For example, it means that restaurants are now responsible for the destination of their organic waste, the factories that produce packages are responsible for the destination of their share, and so on. This brings an exciting perspective as it opens up opportunities for innovative approaches and synergies between public and private sectors and new employment opportunities and environmental relief. In the prospect of this thesis, it confirms that the integration of organic waste for composting is a coherent need that is aligned with the current expectations of the public agenda.

Interim conclusions

At the end of this Local Analysis section, essential conclusions should be highlighted and carried on to the upcoming strategy:

1- The main aspects of Brasilia's urban form related to Urban Agriculture are the **extensive availability of land inherent to the modernist Urban Planning** and the orthogonal architecture of the buildings in which flat roofs can also be used as gardens;

2- **The classification of Brasília as a World Heritage Site implies that nothing can be built on its empty spaces.** It means that since those spaces could never become housing for the future population growth for example, maybe they can become productive fields, according to the perspective of this work;

3- The city's **flood challenges call for a solution on the water management**, at the same time that the **current irrigation system in the local farms contributes to the problem**, straining the local network capacity;

4- The current food production system works favoring large commercial farms and their profit, while small scale organic producers struggle to carve their way. Therefore, **an Urban Agriculture approach should prioritize activities on the small scale, in other words, family farmers**;

5- The **local agroindustry is already a strong business** that could be boosted with a facilitated integration with small scale local producers;

6- **Urban Agriculture is already being tried in Brasília by civil society movements**. However, the **acceptance of it by the general public is still troubled**. From the knowledge acquired during the research of this thesis, it is believed that this can be reversed once **an institutional strategy is created and well communicated to the public.** As well as the collective benefits that arise from the practice;

7- **Connecting households' organic waste, composting and food production is already being implemented** by private sector initiatives in the city and having a significant positive acceptance from the people, meaning it potentially could be scaled up;

8- Adding to the last point, now on the public side of waste management, **a new municipal program decentralizes the responsibility for the treatment of generated waste**, which means that commercial services that produce it should find the correct destination. That opens up enormous possibilities, such as the composting initiative, in an institutionalized city scale. **It means that the solution of directly using the organic waste in near composting stations within urban agriculture elements could become a legit approach in the city.**

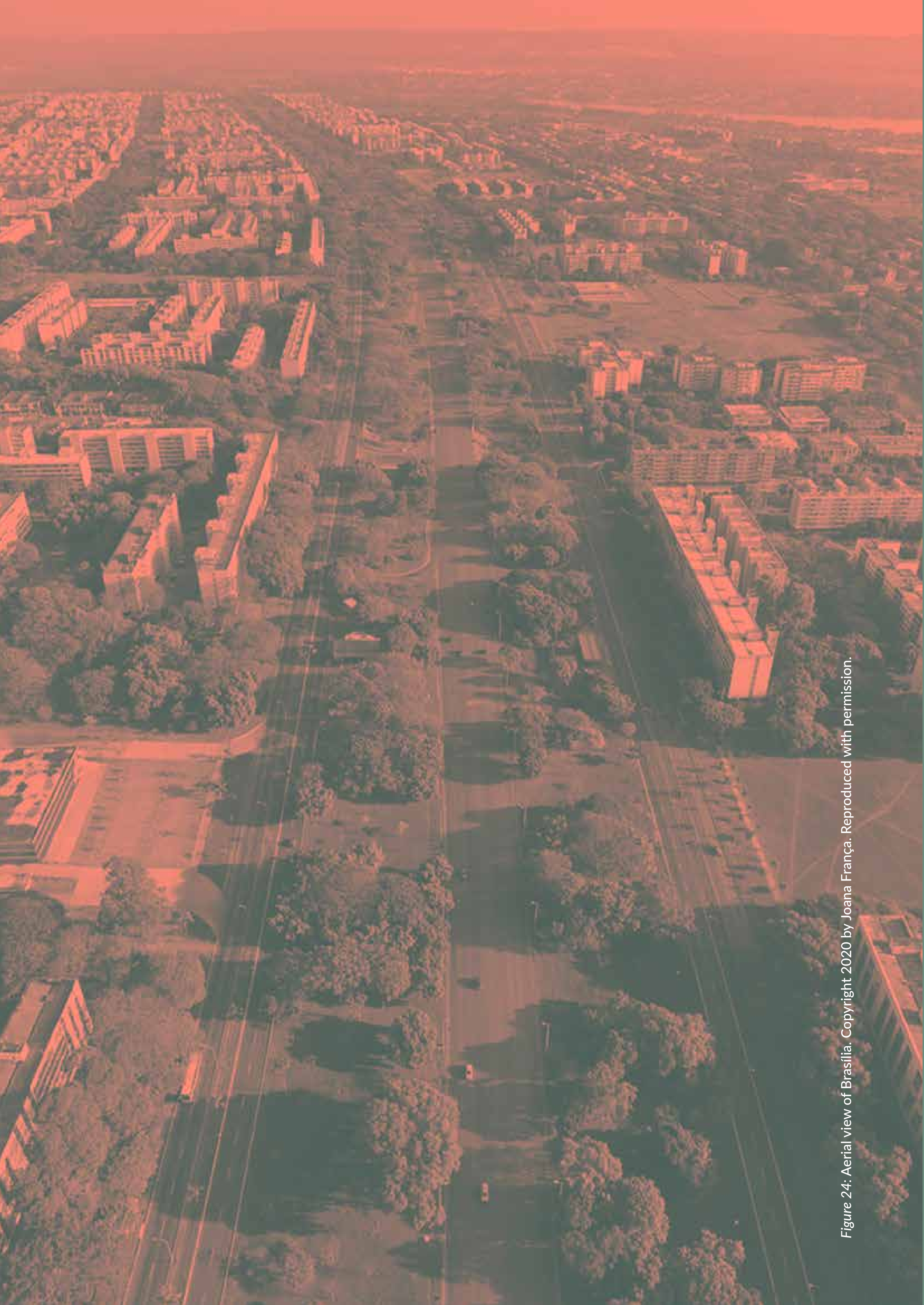


Figure 24: Aerial view of Brasília. Copyright 2020 by Joana França. Reproduced with permission.

4 Strategy

Summary of findings
and derived spatial guidelines

After investigating the opportunities for Urban Agriculture that linger in Brasilia's urban form and in the current local food supply chain, understanding how and what can be done based on literature review it's time to tie it all together in a systematic approach.

From the literature review section, derived that **Urban Agriculture needs** mainly four features that relate to Urban Planning:

1- Land Access

2- Water Access

3- Infrastructure

4- Market Development

In parallel, the analysis of Brasília's urban form brings the following **opportunities** that can accommodate the Urban Agriculture inherent needs:

1- Many **empty spaces** in the urban scale due to the modernist urban design;

2- Most of the buildings follow a modernistic architecture design, meaning most of them have **large flat roofs**, a potential for Urban Agriculture;

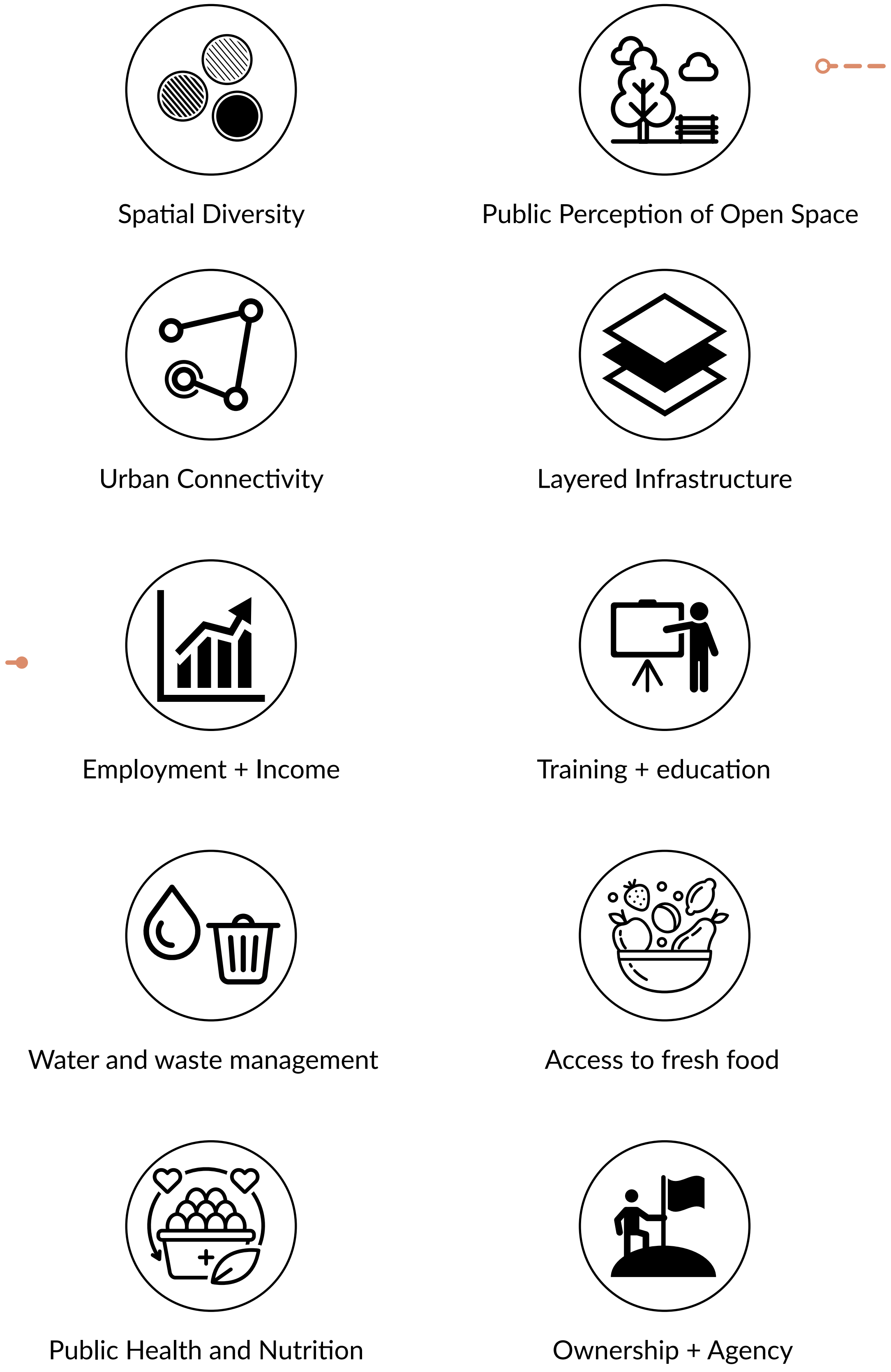
3- Points of flooding present potential for an **integrated water harvesting system** for Urban Agriculture irrigation;

4- The city can provide the necessary support for Urban Agriculture such as **available commercial plots for new industries**;

5- The city already has many **existing market points** where the products can be sold.

strategy

Relevant socio-spacial aspects of Urban Agriculture (Viljoen and Bohn, 2014):



These added aspects can aid the current socio-economic, environmental and mobility-related challenges in the city.

strategy

Operationalizing the concepts

Transforming concepts into Urban Planning measures

Finally, how can these concepts and relations become a systematic approach in Urban Planning? First of all, the previously mentioned features must be scientifically qualified and quantified to be spatially analyzed, replicated elsewhere, and therefore create a framework for spatial planning aided by Computational Design. Therefore, from the literature review chapter, the following measures were derived as a way of operationalizing the previously mentioned relations in between urban form and Urban Agriculture:

Urban Scale:

Land Access

1. Map built/unbuilt potential. How much of the total vacant land could be farmed, and how could it be organized? In which typologies could the plots be divided?

Typology 1: **Community Gardens**
Plots < 1ha

Typology 2: **Urban Farms**
1ha < Plots < 3ha

these constraints relate to:

Market Development

1. Mapping of the existing market locations and their catchment areas

+

Infrastructure

Amenities

1. Landuse mapping of residences and schools and their catchment areas;
2. Mapping of bus stops and their catchment areas;
3. Street Network centrality analysis;
4. Mapping of commercial plots sorted by size;

Market and Infrastructure mapping inform the distribution of each typology

Ideally located:
- In the catchment area of residences and schools;
- In the catchment area of bus stops;
- In the catchment area of Markets;
- Closer to smaller commercial plots that could host small processing facilities.

Ideally located:
- In the catchment area of bus stops;
- In the catchment area of Markets;
- Alongside the streets with the heaviest traffic flows;
- Closer to larger commercial plots that could host heavier processing facilities.

store values

Built/Unbuilt mapping

Street Network Centrality

Catchment area based on landuse

weights and visualizes values

Heatmap visualization

The heatmap is a final visualization of where each typology would be best located given the constraints of their related complements.

Compost

continues on the next page

Neighborhood Scale:

Heatmap visualization

Zoom in the heatmap for detailing water access and compost units

Water Access

1. Map where the water naturally flows during rainfall events;

2. Map and visualize water accumulation points and therefore where rainwater harvesting catchment could be implemented for irrigation.

Rainrunoff simulation

Compost

1. Map of the solar and shadow local conditions for best location of composting windrows.

Solar Radiation and Shadows analysis

Overview of constraints in the neighborhood scale

Overall conclusion:

Heatmap visualization in the urban scale

Overview of constraints in the neighborhood scale

Overview of a comprehensive spatial organization for Urban Agriculture elements given their complementary features.

strategy

Proposed flow chart

Implementing the strategy, how the local food system could be enhanced:

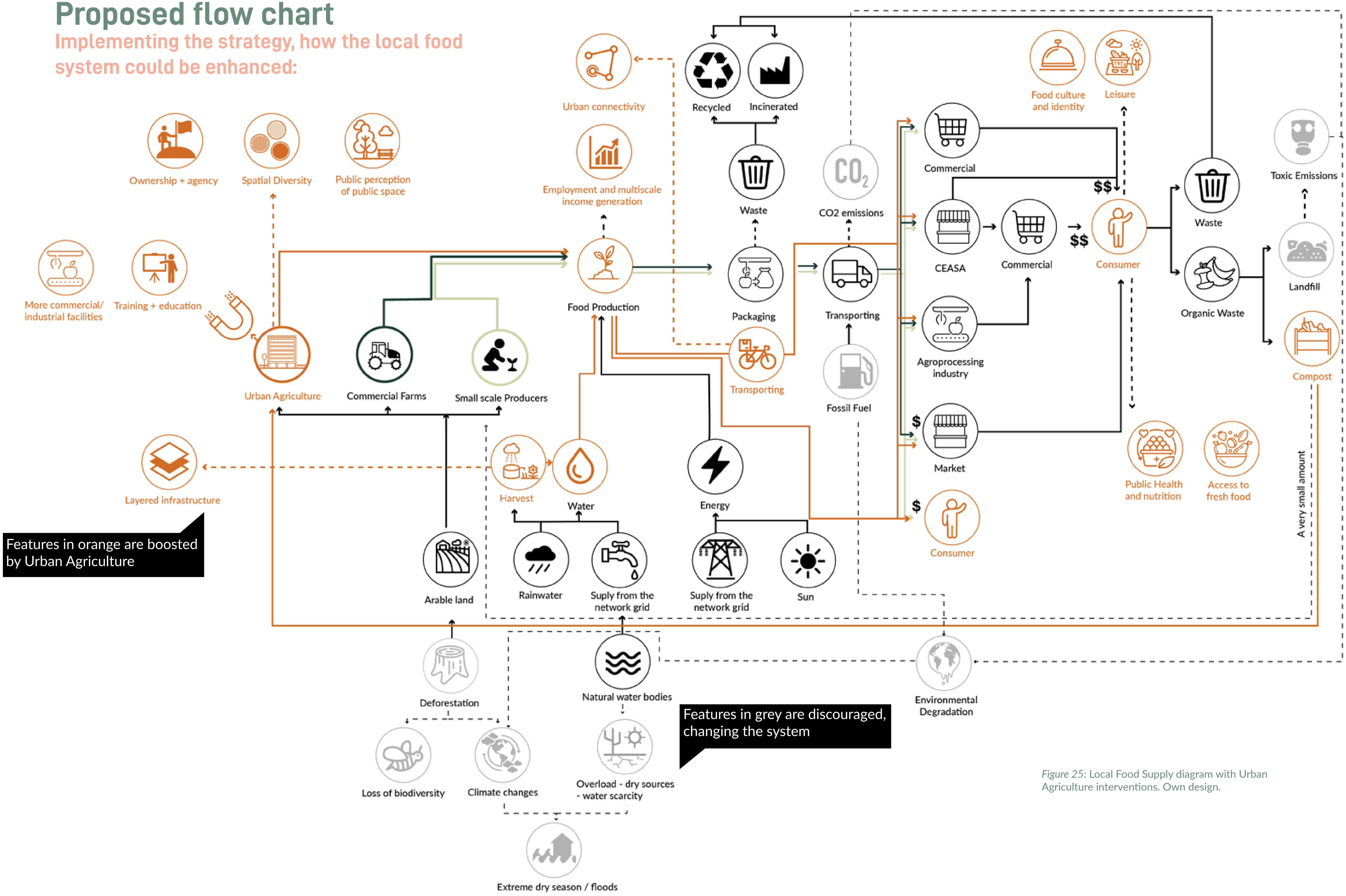


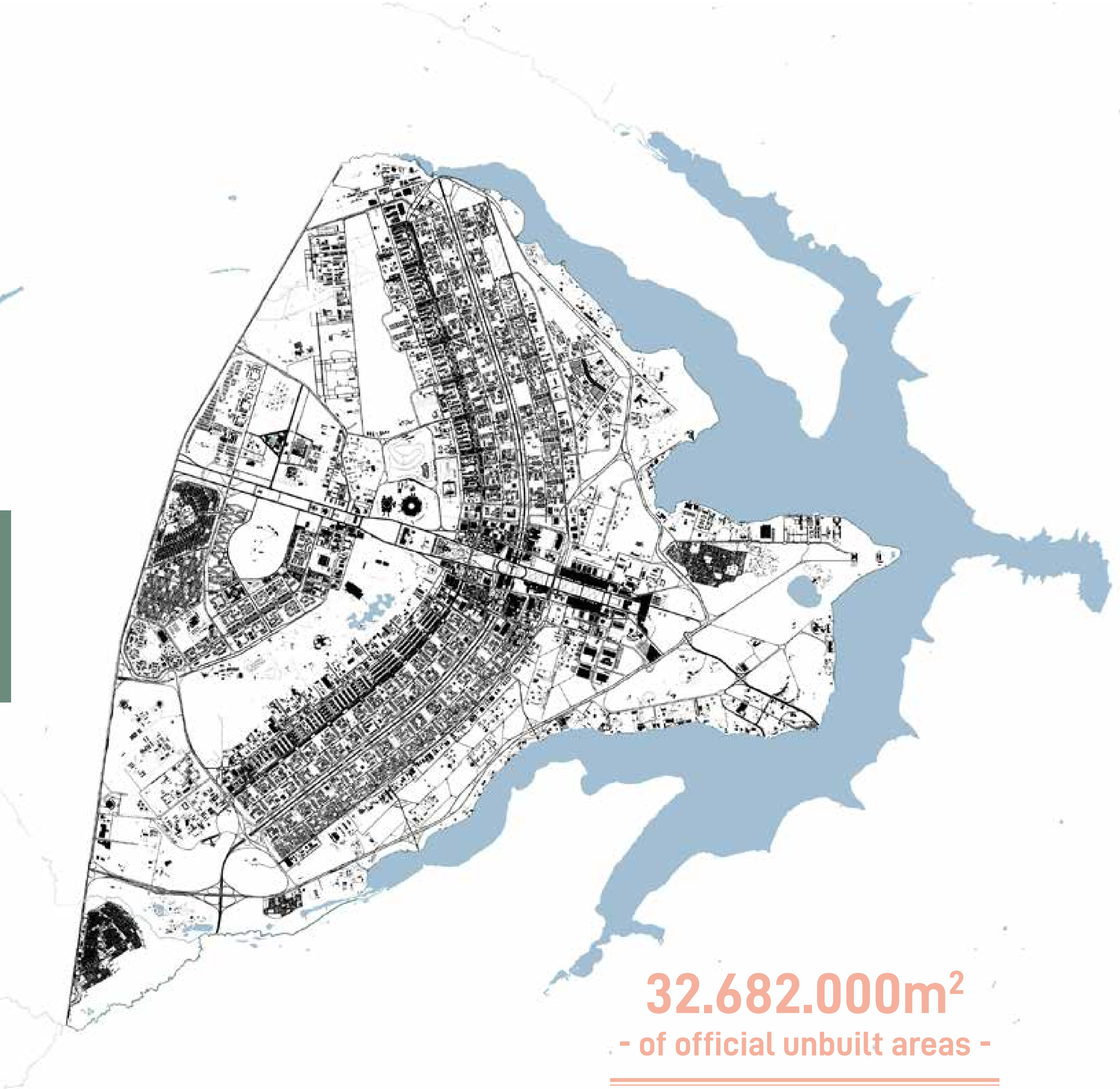
Figure 25: Local Food Supply diagram with Urban Agriculture interventions. Own design.

Figure 26: Aerial view of Brasília. Copyright 2020 by Joana França. Reproduced with permission.

5 Computational Exploration

1.1- Land access_Mapping the potential

Built/Unbuilt map



32.682.000m²

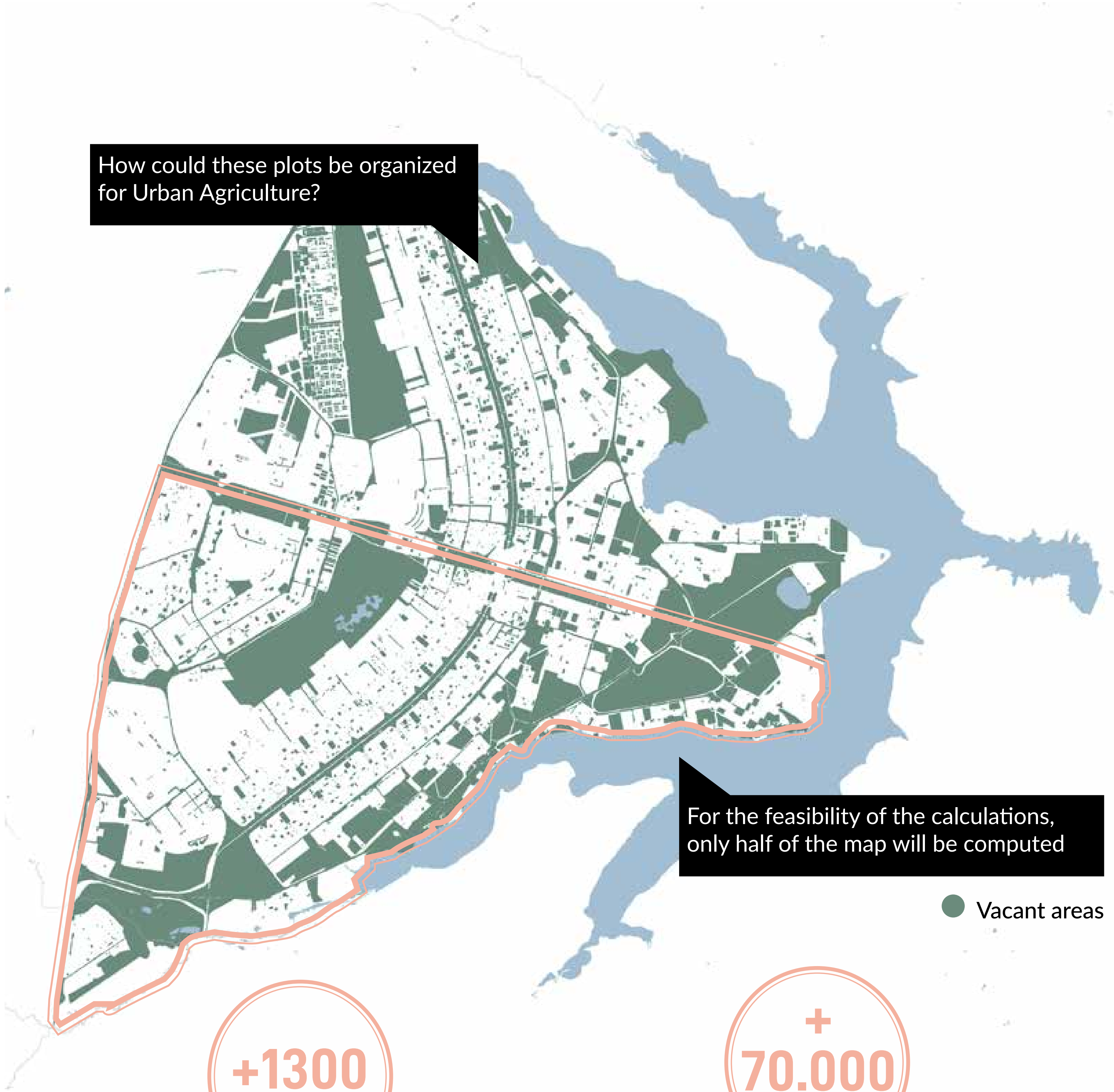
- of official unbuilt areas -

+ smaller green spaces and roofs that can significantly increase this number

N

2km 5km 10km

exploration | urban scale



+1300

people could be fed using only the official unbuilt area as productive units

+ 70.000

families in Brasília live under poverty and have a hard access to food

(Companhia de Planejamento do Distrito Federal, 2015)

1.2- Inputs_Existing Infrastructure

Residences and schools, bus stops, streets, market locations and commercial plots

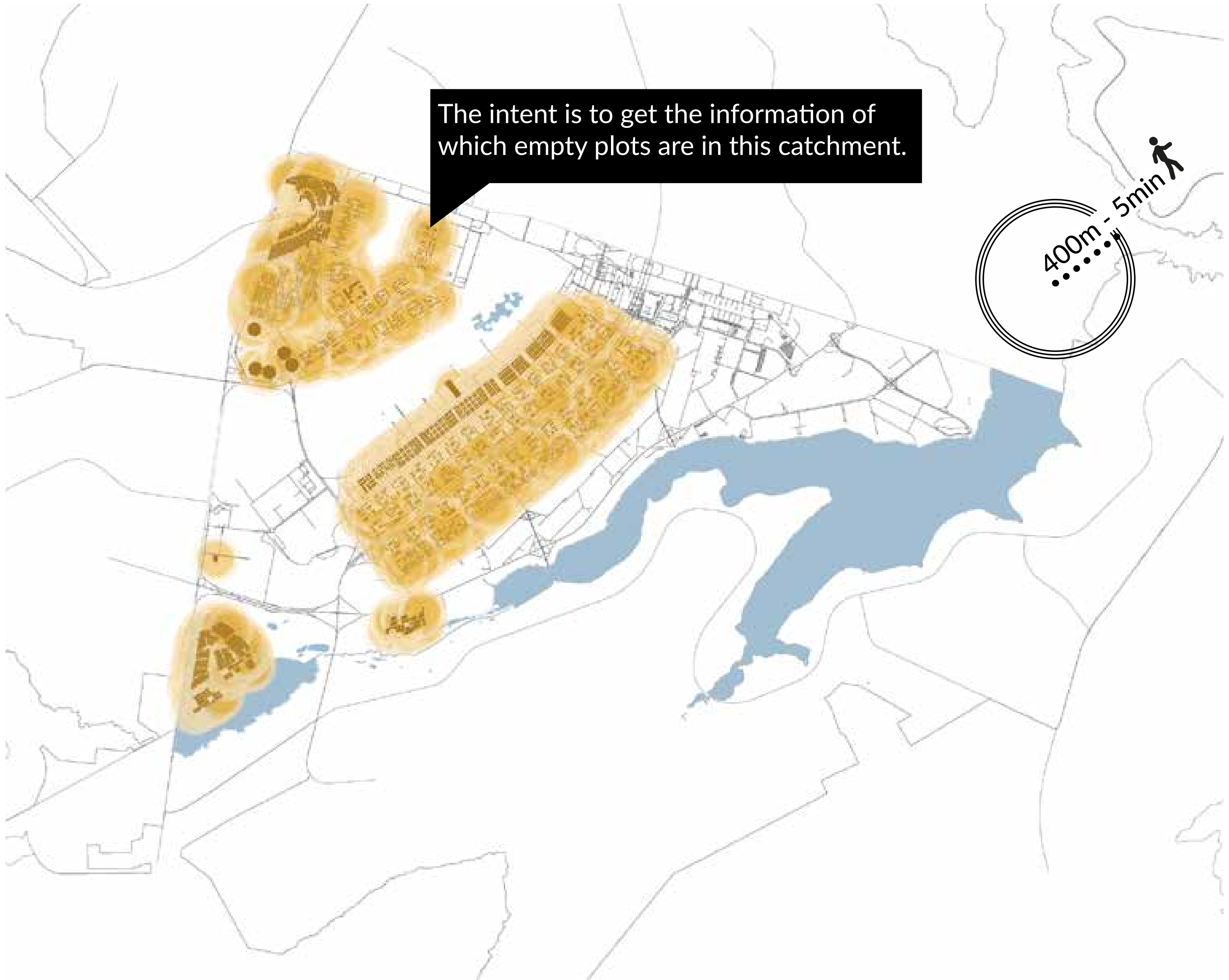
The relationship in between existing landuse and mobility structures informs the organization of the Urban Agriculture typologies distribution

vacant plot sizes vary from as little as $4m^2$ to as much as $3.975.300m^2$ (.ca 400ha)

exploration | urban scale

1.3- Explorations_ Accessibility and catchment areas

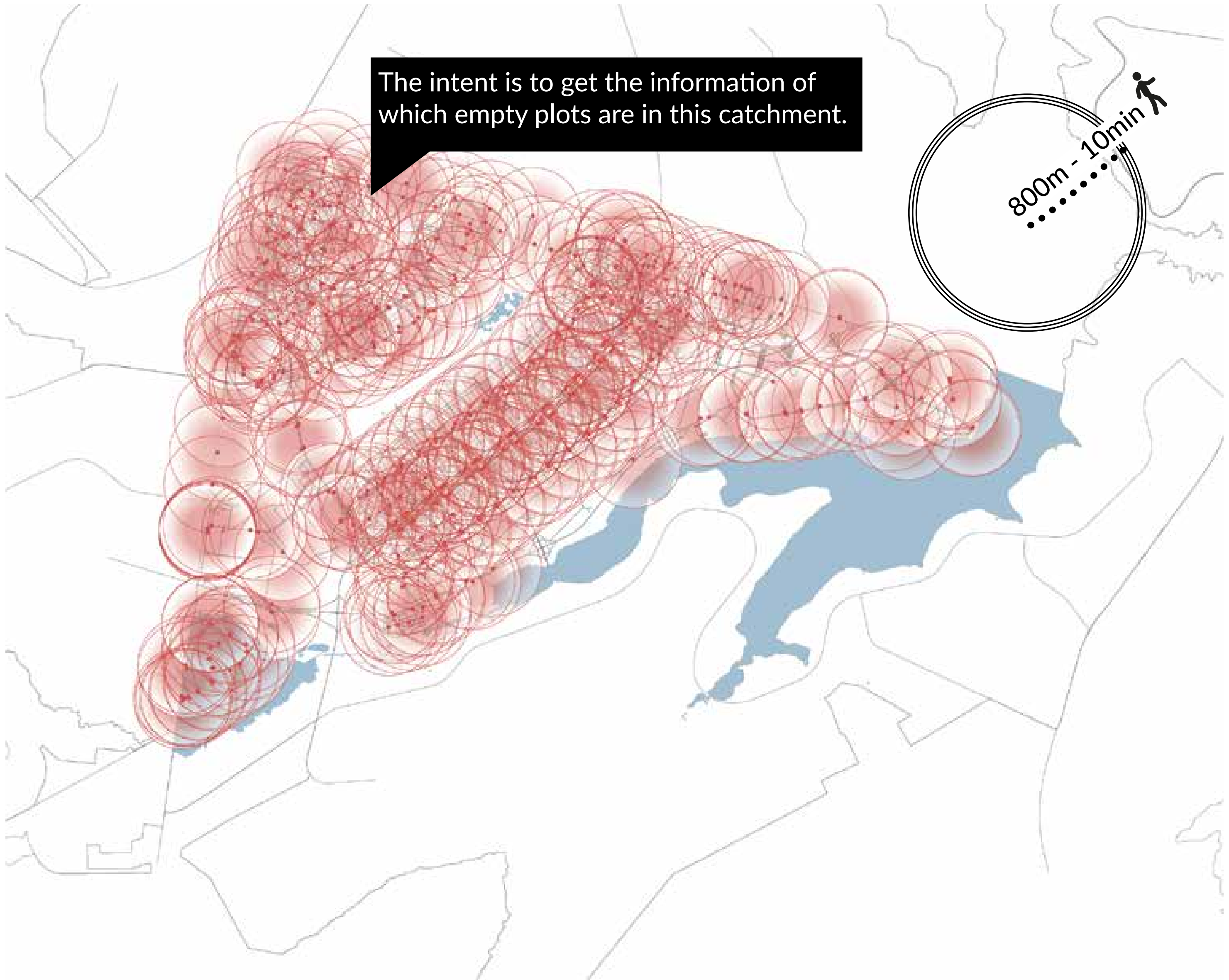
Check where are the plots more accessible to residents and schools, accessible by public transport, accessed in the most connected streets by car and the closest plots to markets



Map of the catchment area of a 5min walking distance from all residences center points. The walkability standards for amenities were derived from Morphocode (n.d.). as seen in Chapter 2.

Map of the catchment area of a 5min walking distance from all schools center points. The walkability standards for amenities were derived from Morphocode (n.d.). as seen in Chapter 2.

exploration | urban scale

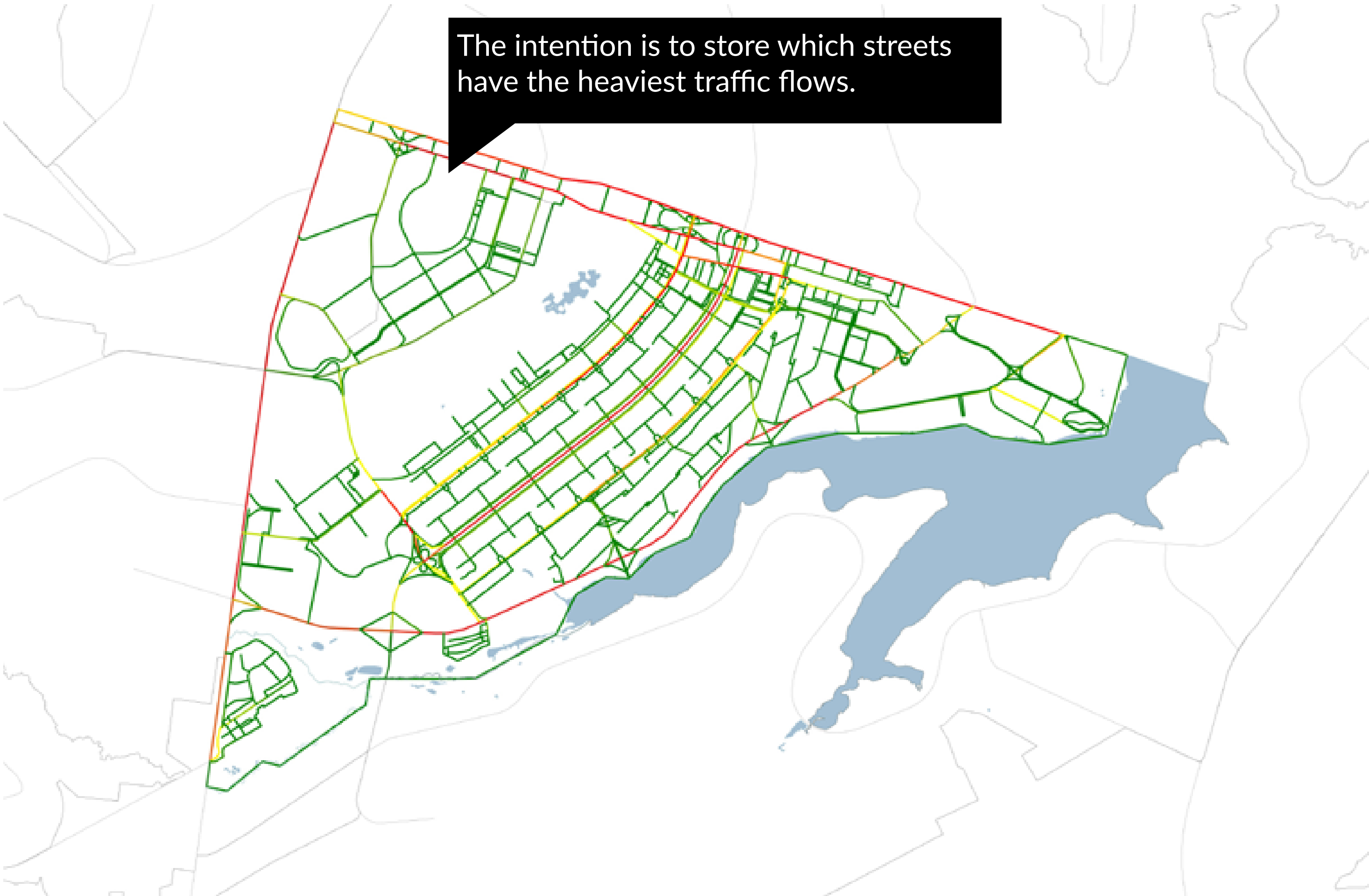


Map of the catchment area of a 10min walking distance from all bus stops. The catchment of bus stops was derived from WYG (2015) as seen in Chapter 2.

Map of the catchment area of a 1km distance from all open markets that sell organic products. The catchment area was derived from WYG (2015) as the average maximum distance people walk before deciding to take a car for shopping, as seen in Chapter 2.

Map of commercial plots sorted by size. 7500m^2 was chosen as the split area because it's the half of the largest area.

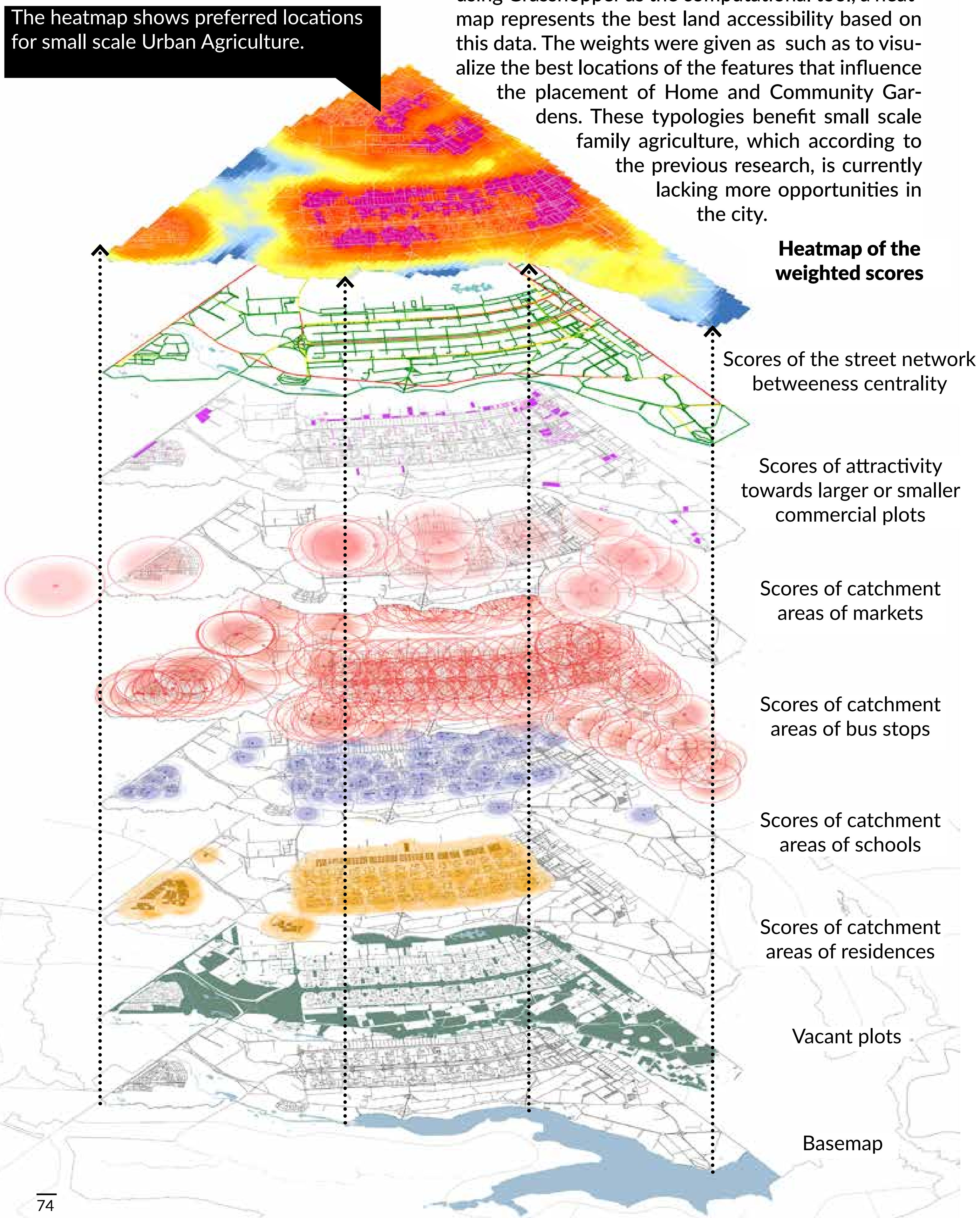
- Commercial areas up to 7500m^2
- Commercial areas from 7500m^2 to 15500m^2



Street network betweeness centrality analysis: how many times a node acts as a bridge in between two other nodes. It was generated in Grasshopper and represents how are the movement flows when everybody is travelling everywhere.

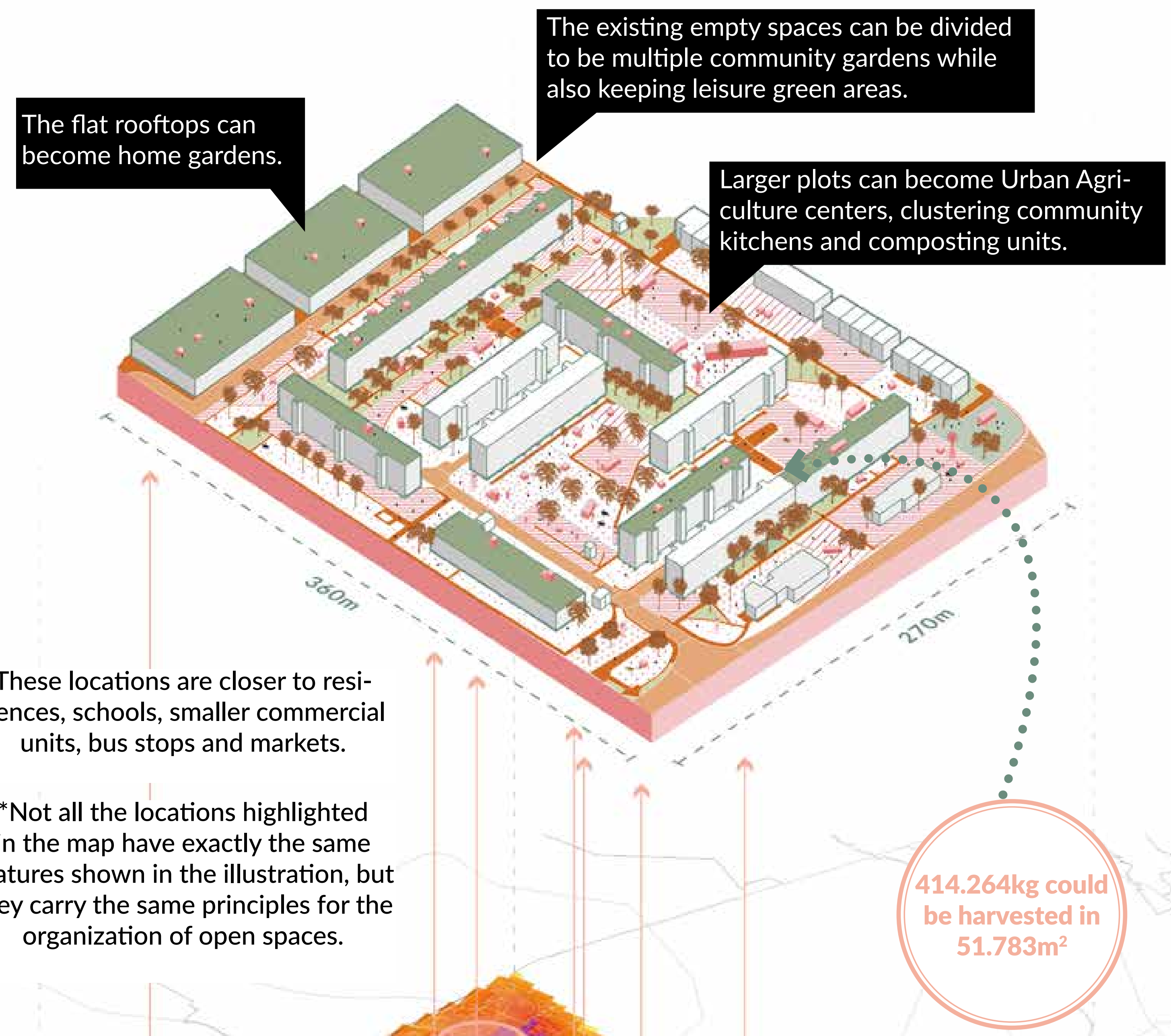
Streets with higher centrality values — Streets with lower centrality values

Overlaying the maps information and their scores using Grasshopper as the computational tool, a heatmap represents the best land accessibility based on this data. The weights were given as such as to visualize the best locations of the features that influence the placement of Home and Community Gardens. These typologies benefit small scale family agriculture, which according to the previous research, is currently lacking more opportunities in the city.



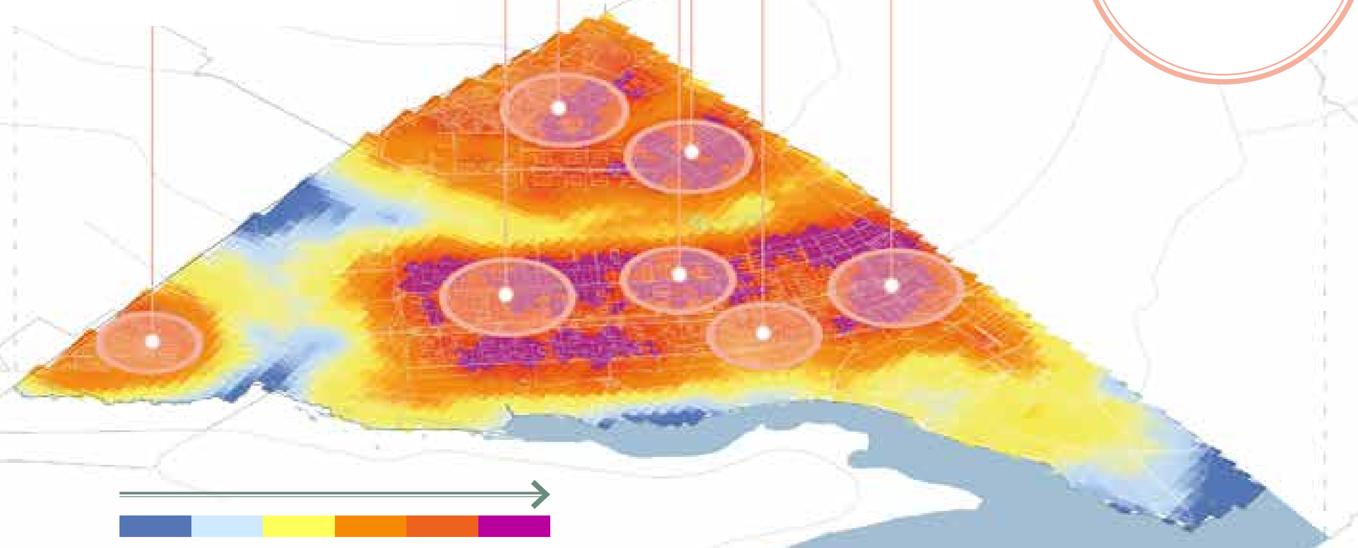
exploration | urban scale

A possible spatial organization for Home and Community Gardens typologies zoomed in:



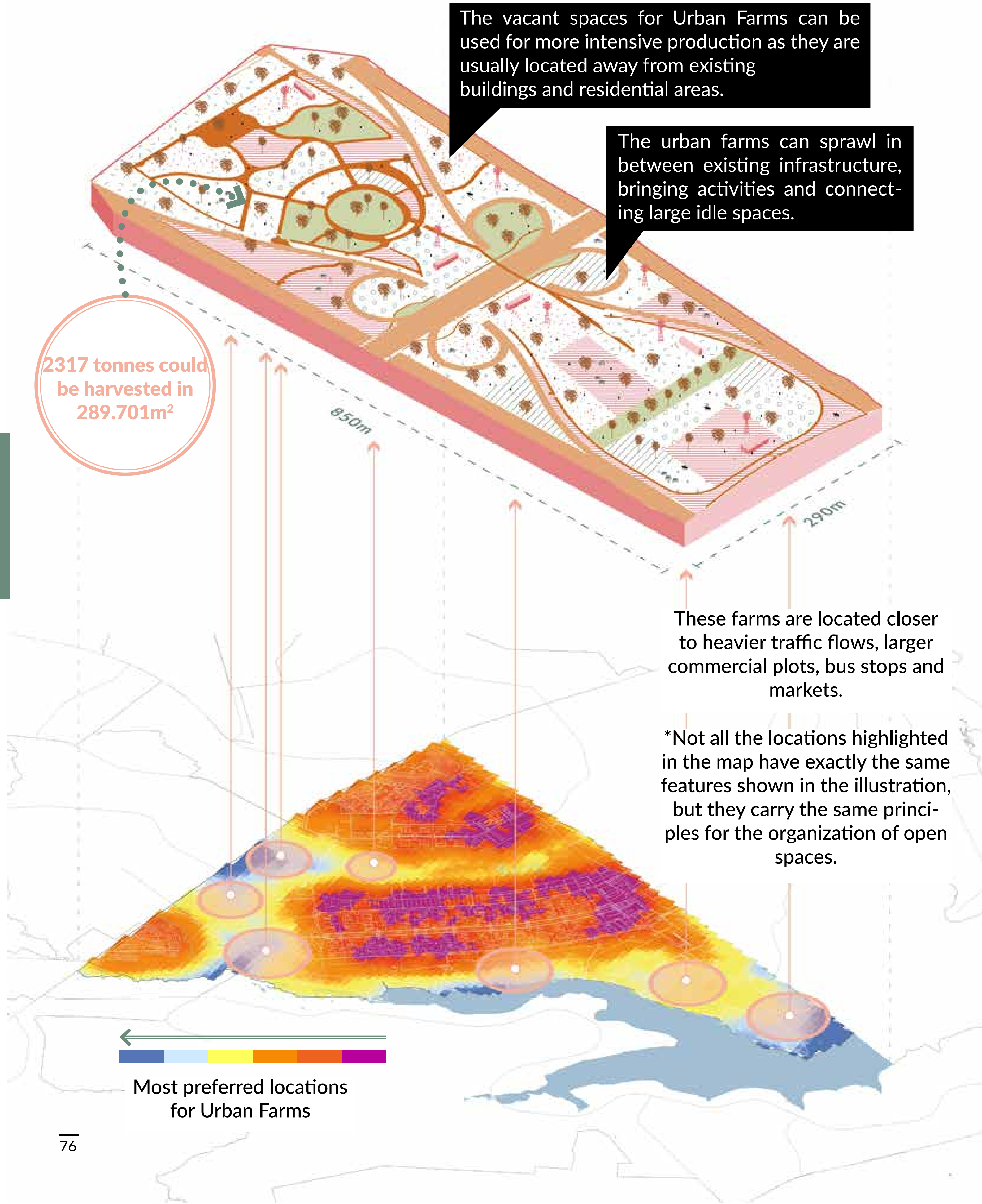
These locations are closer to residences, schools, smaller commercial units, bus stops and markets.

*Not all the locations highlighted in the map have exactly the same features shown in the illustration, but they carry the same principles for the organization of open spaces.



Most preferred locations for Home Gardens and Community Gardens

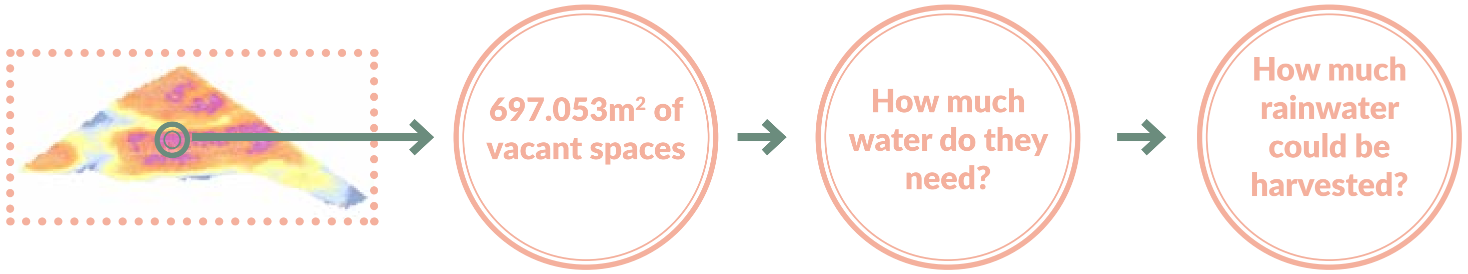
A possible spatial organization for Urban Farms typologies zoomed in:



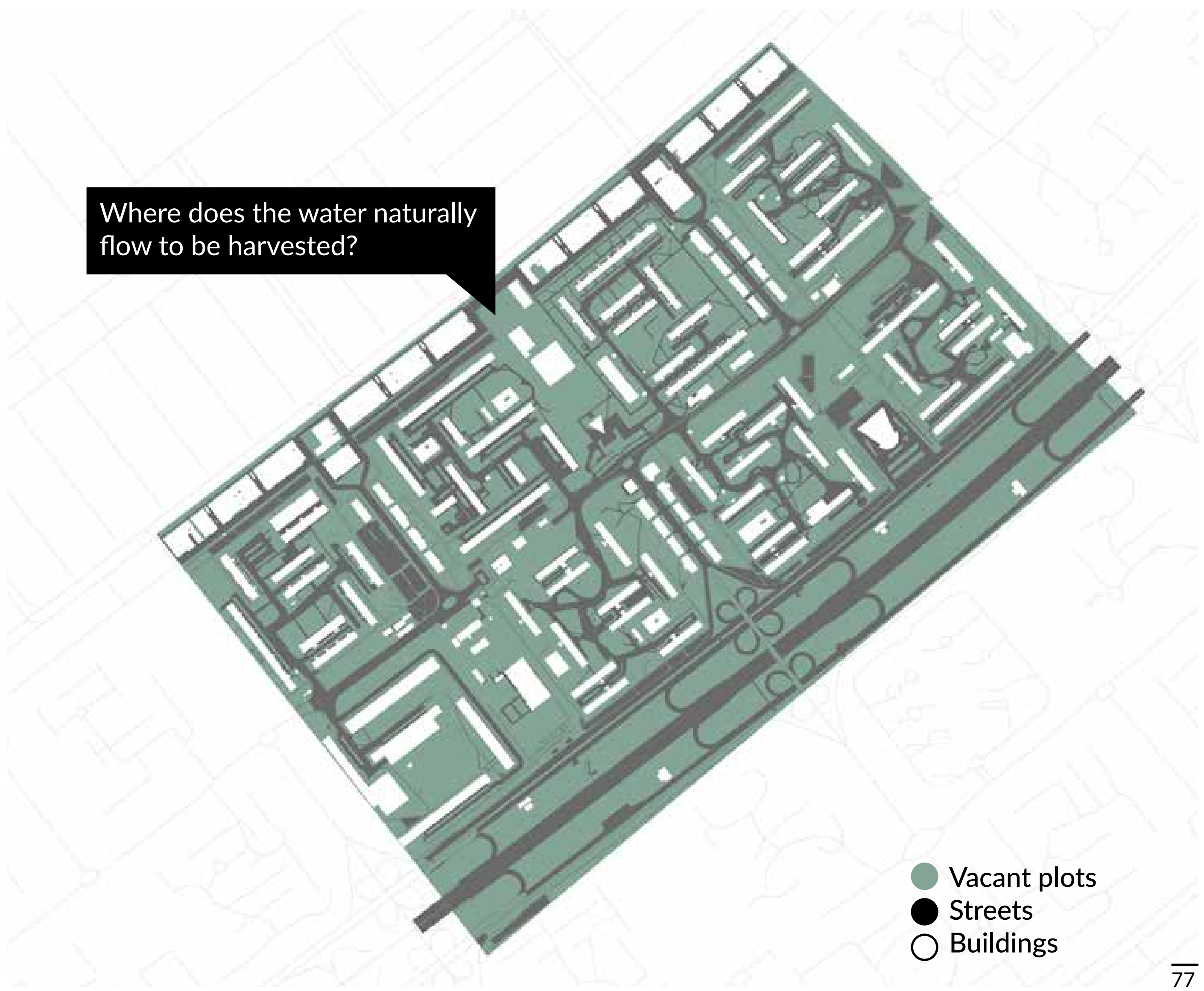
2.1- Water access_Mapping the potential

Vacant plots in detail

The analysis in the neighborhood scale allows for a more detailed mapping of the vacant spaces available. It is possible to carefully consider all the idle spaces between pedestrian paths and not only the official vacant plots. When it comes to water supply, how much of the total area available could be watered with rain harvesting? And how and where?

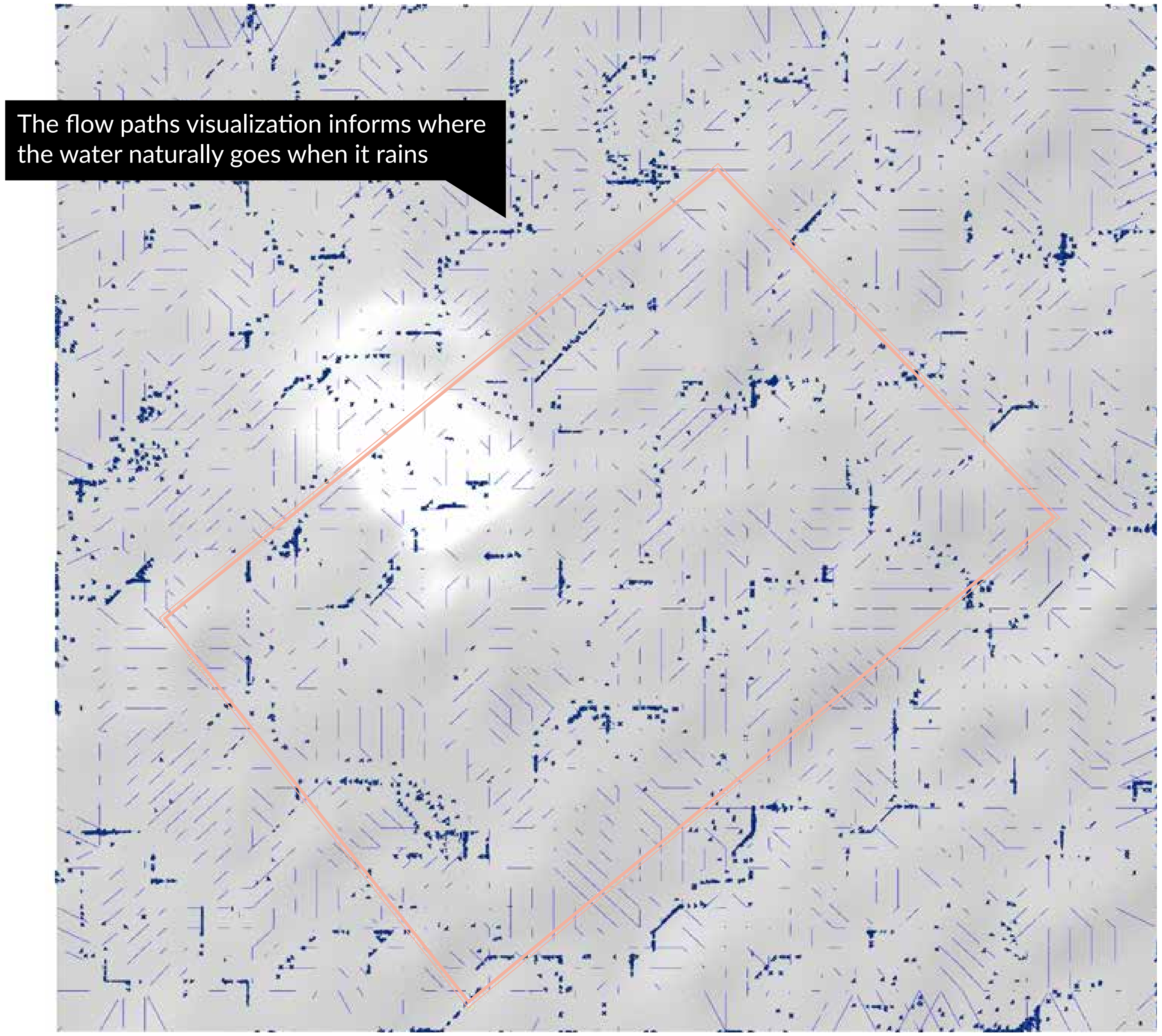


This section of the neighborhood exploration is a zoom in one of the most preferred locations for small scale Urban Agriculture and will be used to analyse the water access potential:



2.2- Inputs_Mapping the potential

Environmental conditions: rainwater flow paths

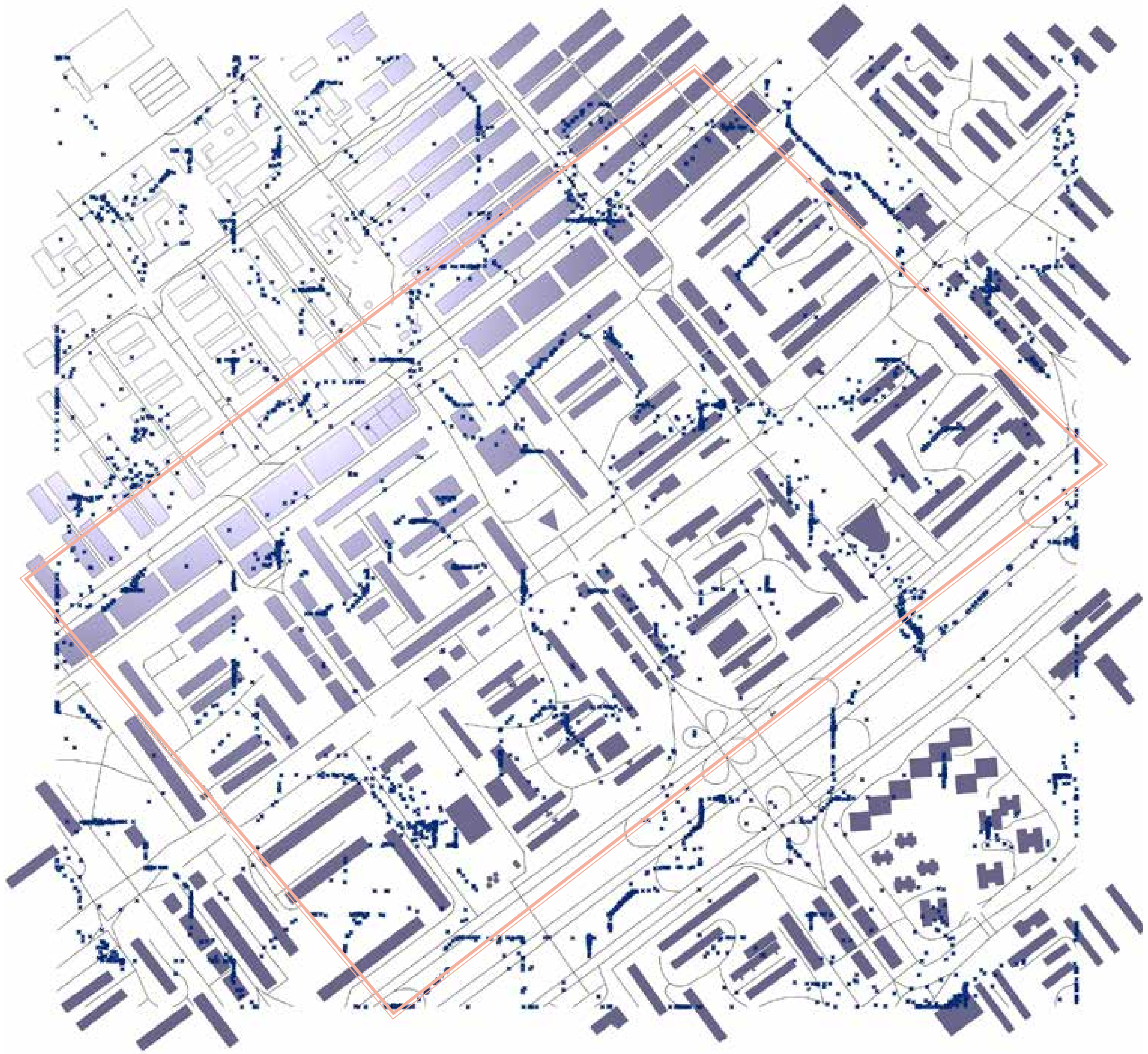


Map of the terrain and the flow paths from the rainfall generated with Grasshopper through a definition by Julius Morschek (Morschek, 2020).

Analysis boundary

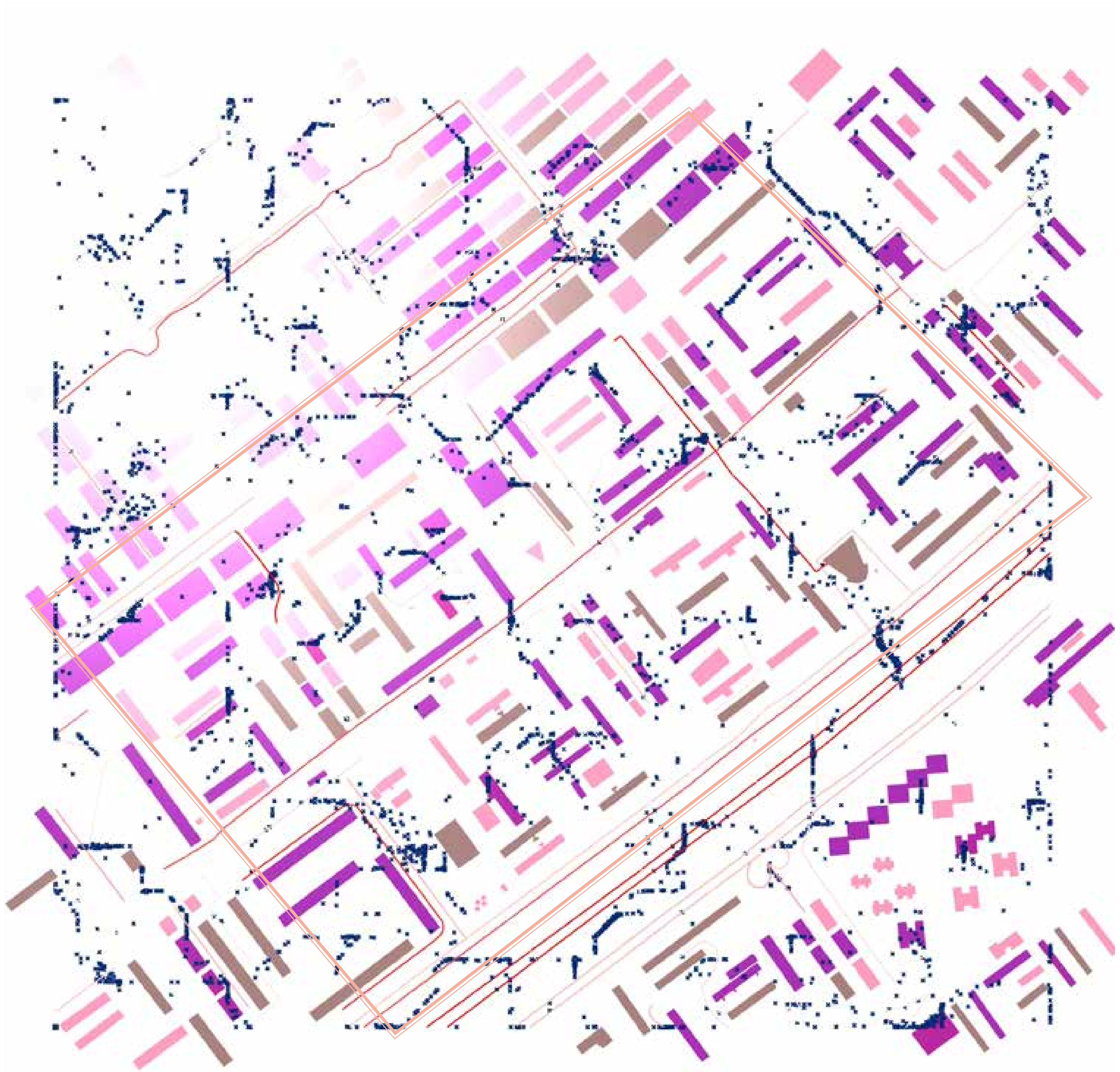
2.3- Exploration_the impact of flowpaths

Relations in between the rainwater accumulation points and the built environment



Visualization of the accumulation points from the flow paths generated with Grasshopper through a definition by Julius Morschek (Morschek, 2020).

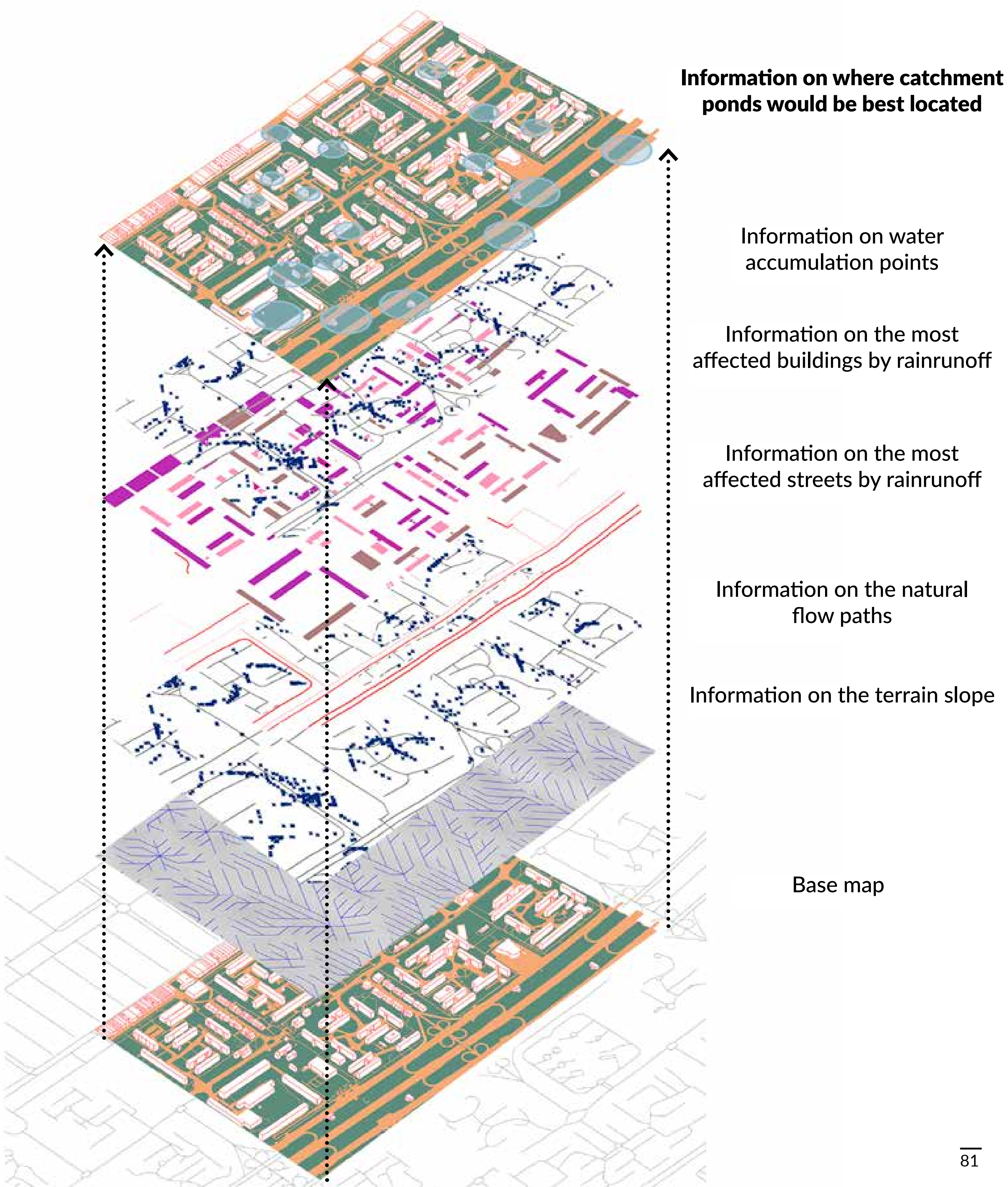
Analysis boundary



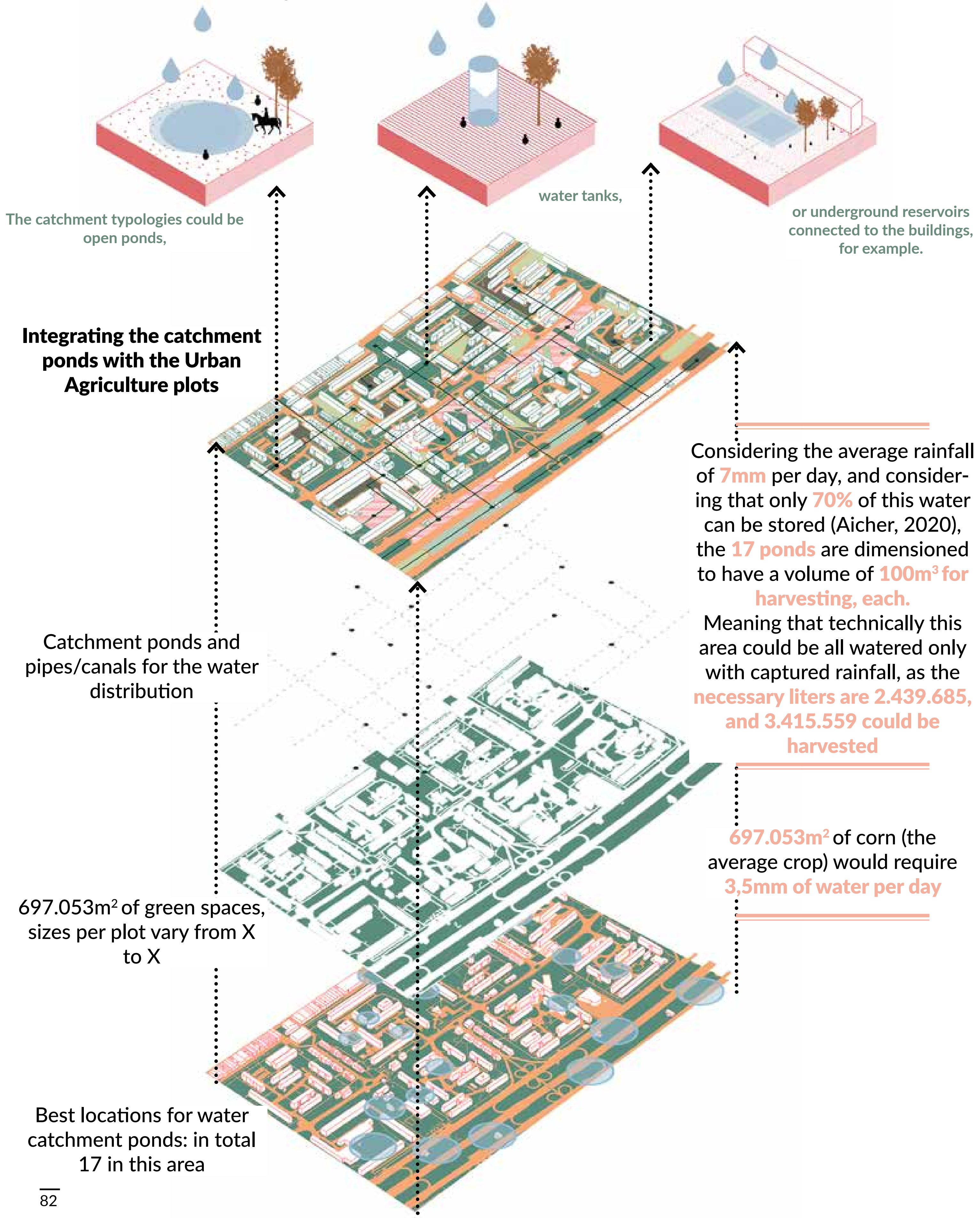
The impact of the accumulation points in the built environment generated with Grasshopper through a definition by Julius Morschek (Morschek, 2020).
Darker colors of buildings: most affected. Red streets: more prone to flooding.

Analysis boundary

Overlaying this data, it is possible to visualize where natural catchment ponds are formed. The water could, therefore, be stored there and used for urban agriculture irrigation. The reserved water would grant irrigation access without overloading the already strained city network and improve the resilience to flooding events as capturing the water prevents the rain runoff from being on the streets.



The catchment ponds could have varied morphologies while having the same harvesting capacity of 100m^3. A deeper analysis is however necessary to determine the best stuitable one for the local conditions, specially taking into consideration the dry season and the water evaporation.

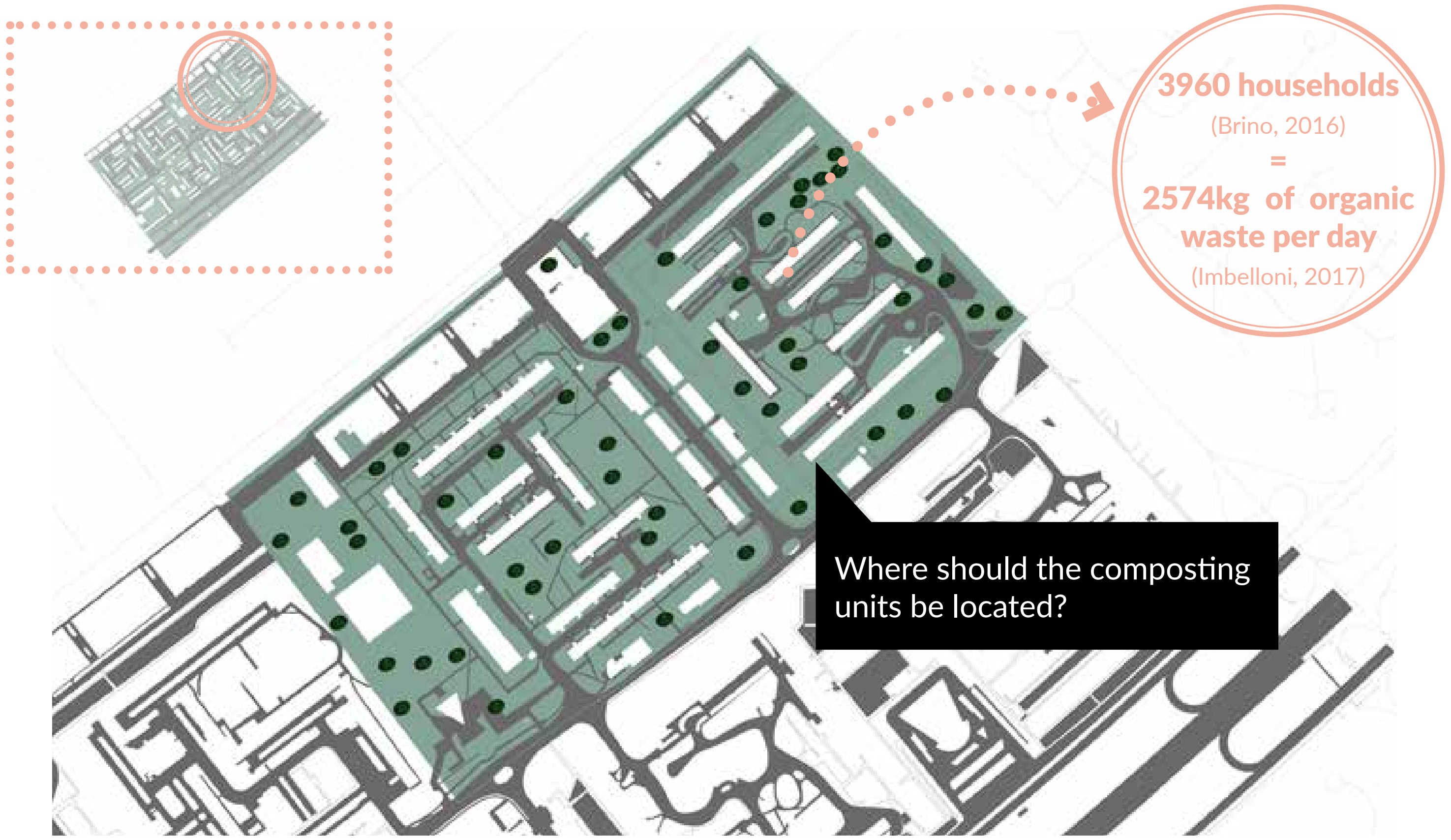


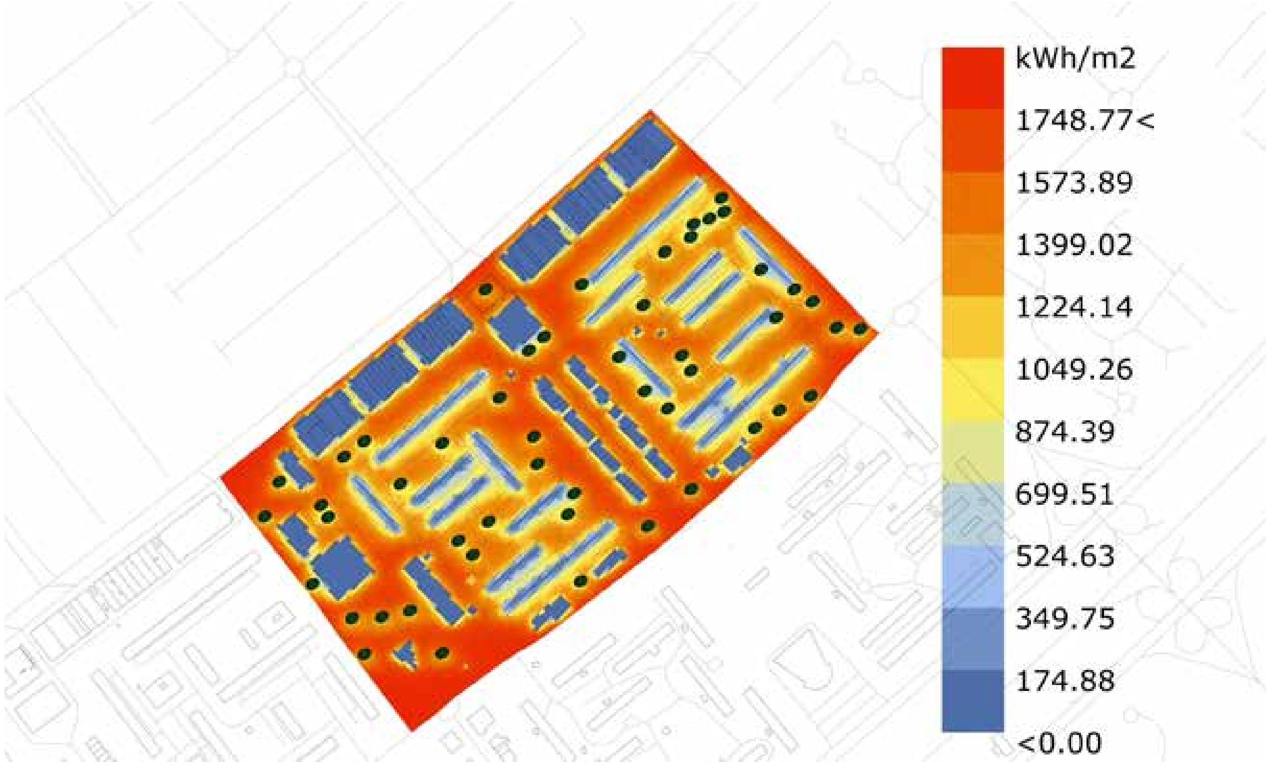
3.1- Infrastructure_Mapping the potential

Solar radiation and shadow analysis for composting units location

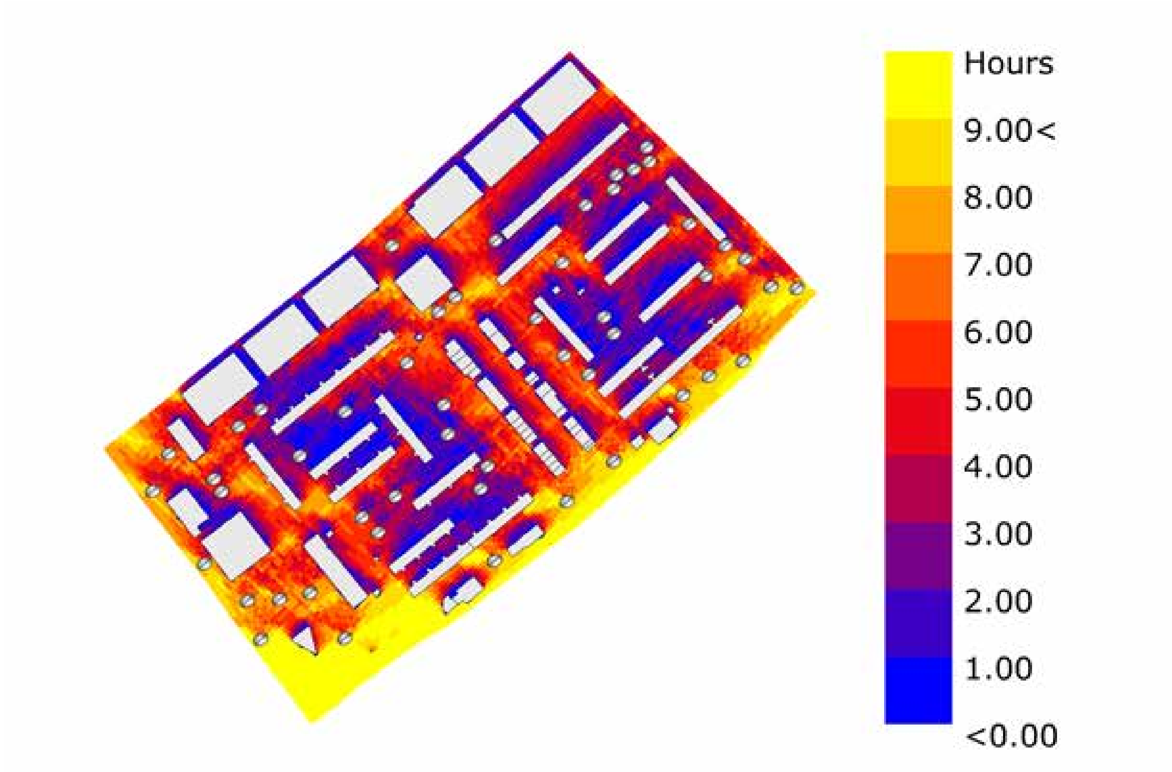
In this last iteration for analyzing the best locations for Urban Agriculture elements, potential places for composting units, and related supporting infrastructure such as sustainable dry toilets are checked. The choice for dry toilets as infrastructure comes from the limitations for constructing permanent standard structures in Brasília due to the Heritage Protection regulations. Additionally, it is another urban layer that produces compost, and their location can be used to anchor a local community space for Urban Agriculture in each neighborhood. This designated space could store collective equipment, facilitate knowledge exchange, and a be laboratory promoting sustainable living for the general public.

For choosing the best location for the composting units, the sun has to be taken into consideration as the correct amount of radiation plays a fundamental role in the biological process of the transformation of the organic matter into compost (Washington State University, n.d.). This analysis considers the windrow composting technique, as, according to the research, it is a recommended type for larger-scale composting. Windrow composting is the production of compost by piling organic matter or biodegradable waste, such as animal manure and crop residues, in long rows ("Windrow Composting", n.d.). These rows have to be turned to guarantee the right oxygen content, remove or add moisture, and redistribute the pile's hotter and hotter portions. The temperature of the windrows has to be continuously measured, and it's one of the essential factors on the time and success of the compost production. There is no standard for how much sun would be needed as it depends a lot on the material being decomposed and in the local climate conditions. However, a steady condition of sun and shadow seems to be the most indicated. On the contrary, the composting technique for sustainable dry toilets requires as much sun as possible to process the humanure to happen inside the chamber of the toilet (Biletska, 2018).

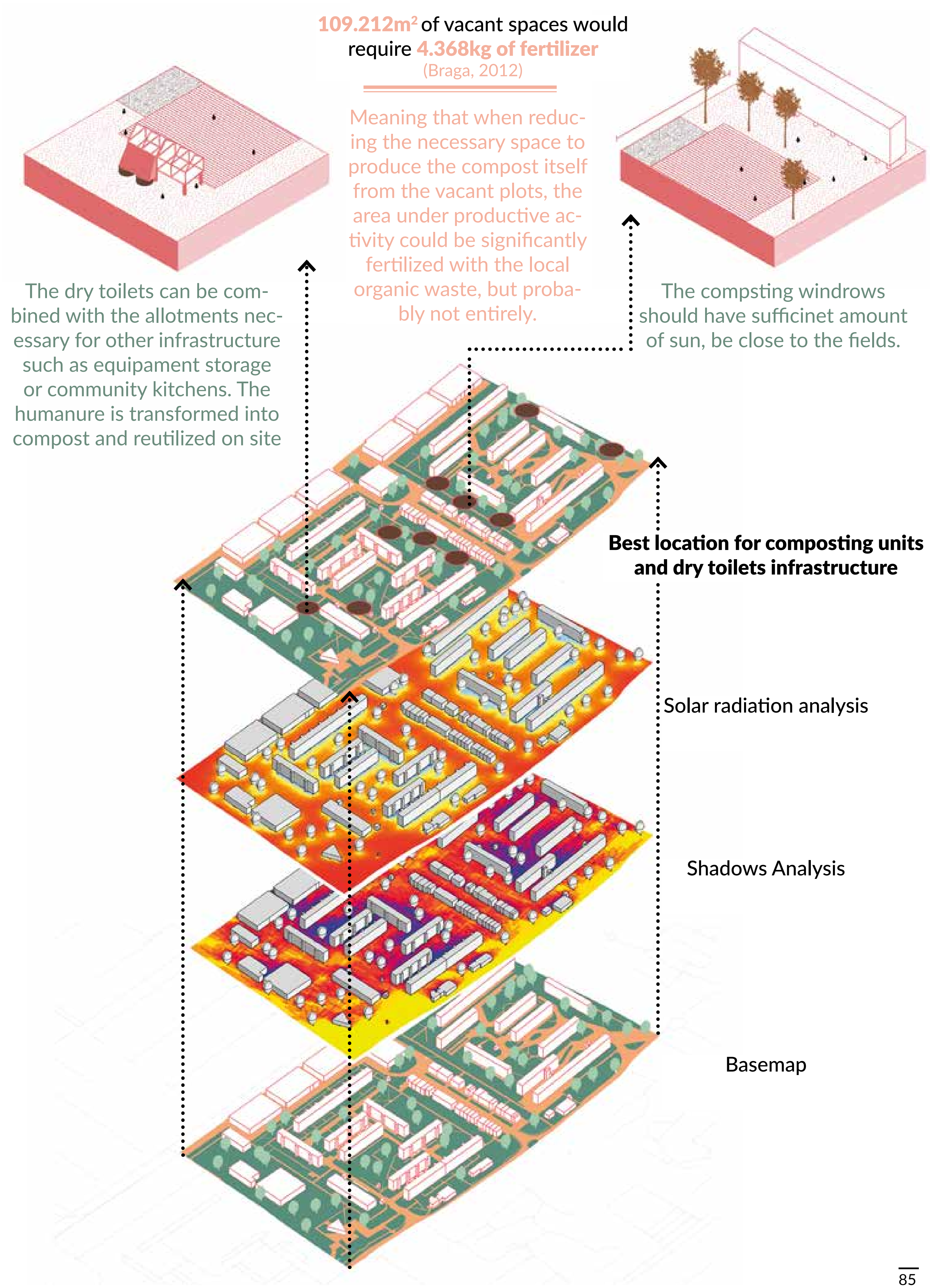




The solar radiation simulation shows the amount of sun that reaches the surface. It demonstrates as expected that the minimum amount of sun of 500MJ (= 138, 89KWh) for growing the crops (as shown in Chapter 2) is covered and also that it would be enough to reach the necessary temperatures for the composting biological reactions.



The shadows analysis show that mild conditions, better suited for the composting activities would happen in the red colored areas, which is ideal since it's not directly close to the residences.



Bringing the elements together:

A final summary of findings

Taking into consideration all the simulation results for a possible spatial distribution of Urban Agriculture elements in Brasília, this diagram is a final visualization of how the concepts spatially relate to each other. This is not at all intended as a design proposal, but rather as an abstraction.

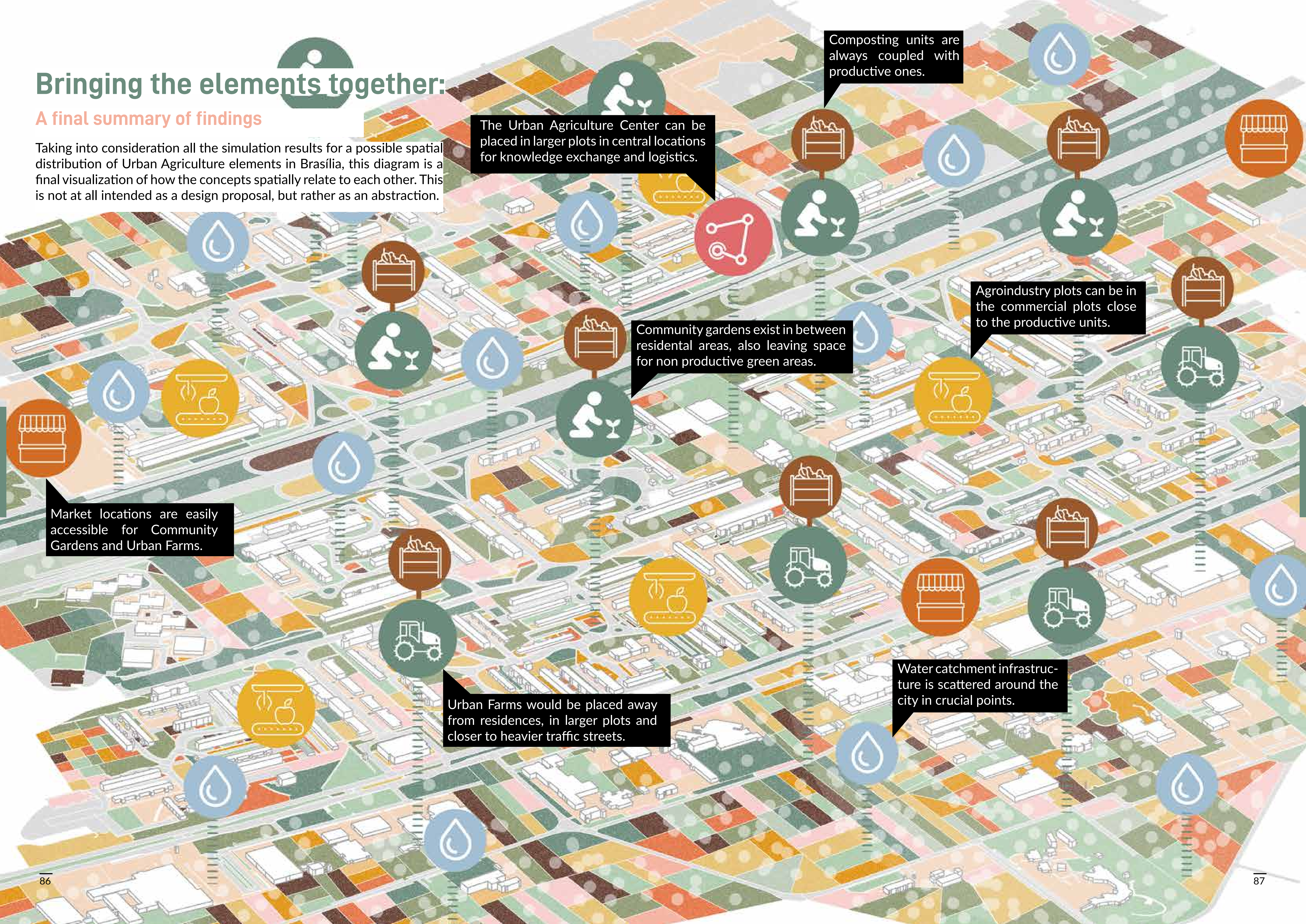


Figure 27: Aerial view of Brasília. Copyright 2020 by Joana França. Reproduced with permission.

6 Reflection

Conclusions

The idea for developing this Master Thesis topic sparkled last year while doing our Design Studio at the IUDD Master Program on Rural Development under an Urban Metabolism framework for the settlement of Wurer in Ethiopia. It was the first time I worked with such a conceptual framework as an urban planner. Moreover, the whole experience resonated with everything I believe in as a person, as a professional, and with my hopes for this planet as a human being, so working with resources is something I wanted to explore further.

I was born and raised in Brasília and lived there all my life. Hence the empty spaces described in the thesis were (and are) a significant part of my memories. Furthermore, while growing up around them and becoming an architect, I always questioned what all of them meant, how those spaces could be different, the relationship between landscape and us, how they could be improved, maintaining the qualities of the original plan for this supposedly garden city.

Therefore, when choosing the master thesis topic, it was evident that I would be extremely interested in bridging my past Brazilian reality with the recently explored knowledge. Accordingly, it began the exploration of how Urban Agriculture in those empty spaces in Brasília could look like, and which impacts that could have. Also, during my Master studies, alongside the focus on urban metabolism, we learned parametric urban design tools, which was entirely new for me, and now I cannot imagine a world anymore in which design is not done with the support of data and simulations as a first step. Personally, that was a big realization during this individual process that I would like to register here.

My research began with a comprehensive exploration of the topic, and so many new concepts appeared along the way, and for me, the hardest part of this whole process was framing the work and reducing the subject to something feasible for our three months' research time. Therefore, my study area had to be condensed in only areas of the modernist part of Brasília, and the understanding of Urban Agriculture remained very straightforward, without deepening into specifications such as agroecological production and other possible variations. It was also imperative to keep a boundary in between what I was actually proposing - research to inform a future design - instead of detailing and creating a design itself. That was hard for me as my background is very design-oriented, so this scientific framework greatly enriched my professional experience.

Beyond personal notes, I return to my research questions and how they were ultimately answered during this process:

What is a potential spatial configuration of Urban Agriculture elements in Brasília?

The question was answered through the construction of a strategic framework based on extensive research to inform decisions. This framework was spatially operationalized with computational simulation and design tools that could ultimately enable the visualization of the expected urban configuration. For the feasibility of the computations, this process was done in different urban scales.

Specifically, it was imperative to first know what influenced Urban Agriculture elements and their placement in a given urban context and how they relate to the existing infrastructure in the city. As demonstrated before, the four main features adopted in this thesis were land and water access, infrastructure, and market development. The first iteration, based on GIS mapping of relevant elements related to infrastructure and market development, generates a series of computational simulations and analysis mainly based on proximity and attractivity relations. When overlapping these results, a heatmap allows the visualization of the preferred locations, in other words, land accessibility, of two different Urban Agriculture typologies.

The second iteration investigates the potential locations of water harvesting systems for the field irrigation based on rainfall and flow paths analysis. The third and last iteration investigates possible locations for supporting infrastructure, specifically composting units, through sun and shadow analysis, important elements for the biological composting processes to happen. Finally, what remains a result is a comprehensive understanding of where all these elements could be located in the city based on their constraints and the impacts of these choices. This outcome is, of course, only one out of many other possible solutions for Urban Agriculture distribution.

It is interesting to mention that knowing the city's existing organization reasonably well, the result of the heatmap was quite predictable. However, it does not decrease its value, as a data-based solution is always much more reliable and precise than just assumptions. It is an extra tool for possible stakeholder interactions and planning discussions. The heatmap also shows that the organization of the two typologies are very clearly divided just like the existing infrastructure that influence them, following the existing principles of a rational modernist urban plan.

Ideally, the water and infrastructure analysis results should also be integrated into the heatmap visualization, although that was not feasible for the timeframe of this thesis. Therefore, the separation in two different scales and understanding the results as accuracy for the whole city is a limitation.

The other follow up questions from the main research question were also answered along the way:

What is important for urban agriculture to thrive, in an Urban Planning perspective?

This was imperative for the development of the whole strategy, and as already mentioned many times, the considered aspects were land and water accessibility, infrastructure, and market development.

How are these features interconnected with existing Urban Planning layers?

These features have a compatibility range with landuse and other Urban Planning elements, as demonstrated in the strategy framework. For instance, housing and schools attract the location of community gardens for the facility of management and for allowing a direct channel for selling the products; existing commercial plots can play a role supporting the necessary infrastructure for the businesses; the vacant plots closer to streets with more substantial traffic flows attract commercial farms for facilitating the transport with trucks; bus stops and existing market points attract both typologies for mobility and commercial logistics. In this regard, the features that are important to Urban Agriculture are already existing inside the city. They simply can have an optimized spatial distribution to boost productivity and full integration in the urban fabric.

How can Urban Agriculture connect to existing waste and water management?

As seen throughout the research, urban agriculture can be a catalyst and support for implementing solid waste management strategies. More specifically, the productive fields become a direct destination for transforming organic waste into composting material and reused as fertilizer. Regarding the water, as seen as a result of the computational simulation with rainfall, the necessary water for irrigation could come almost entirely from rainwater harvesting structures. Therefore food could be produced without overloading the city supply, and the capture of the rain runoff can help to prevent severe flood events.

How is Urban Agriculture inserted in the existing local food system considering commercial and logistics operations?

As visualized in the food flow chart, Urban Agriculture becomes a new source of food production, supports the local small scale system, and opens up opportunities for farmers who did not have land before. The commercialization of the products can be performed directly to the customers or through the current markets and commercial channels. The difference is that since the distances are shorter, they do not require the farmer to own a car. The distribution can be done by bike, or since it is close, the commercial establishments can pick up the products and not the opposite, once again facilitating the farmer's production.

How can Urban Agriculture successfully be integrated in the urban landscape and be accepted by the people?

This thesis's scope did not directly measure the social dimension of the impacts, but it is worth mentioning the expectations from the spatial organization implementation. In Brasília, the hope is that having the empty spaces being used could literally wake people for their surroundings and trigger more civic engagement and ownership for that land. It can bring awareness that space is a public good and must be enjoyed, and everyone should care about it and benefit from it.

The direct conclusions from the simulations show that, in the urban scale of the study:

+1300

people could be fed from the Urban Agriculture fields only with vacant public spaces on the analyzed area in the urban scale

+2900

new direct jobs could be generated in that analyzed area based on the number of vacant spaces

+ 155.000 tonnes

of food could be produced in the analyzed urban scale area

+3M liters

of water could be harvested in the analyzed area in the neighborhood scale, meaning all the fields in that area could be irrigated with a proper infrastructure for harvesting and distribution

2574 kg

of organic waste could be transformed into compost instead of ending up in a landfill everyday in the selected analyzed area

Finally, and the main takeaway of this work is the understanding that inserting Urban Agriculture in the landuse discussion in contemporary cities is not only possible but should become an imperative for the upcoming years given the benefits and challenges it can address. After my research and the experience during the current COVID-19 pandemic, it is also clear to me the essential role and urgent demand of solid resilience strategies on local, regional, and national levels in all planning topics, in this specific case, regarding innovative decentralized and sustainable food production systems.

During my investigation, it was made evident that a fundamental part of the implementation of any strategy, as such must be a very thoughtful and meaningful public participation process. As the productive fields can primarily be placed in public areas and most likely be self-regulated by the civic society, comprehensive and sensitive cooperation between stakeholders must be designed. It is a process that must also be widely clearly communicated to the local population as so to avoid any misinterpretation on how this land is intended to be used for a collective purpose.

Limitations

The research naturally also has a few limitations. First of all, it is important to state again that this work was written during the COVID-19 pandemic, and an initially panned field trip to Brasília was not possible. Therefore, the local context's visual documentation is limited as well as a more precise delimitation of vacant plots on the neighborhood scale. Additionaly, realizing an extensive work as such while the world was undergoing such a delicate time was not simple, and many personal and logistics challenges emerged from that.

Conceptually, despite the research on the literature review and the Brazilian case studies, it is essential to highlight that it is not a guarantee that those parameters would directly serve for Brasília or any other city, for instance. The propositions here should be understood as an initial step, as they are intended. If such a strategy were to be implemented, some details would probably have to be adapted to a more specific reality.

Another significant limitation of the work is the scale of the exploration. Ideally, the study should have been done for the whole metropolitan region, especially considering that the main argumentation point was precisely the integration of it, and the possibility of expanded income generation for vulnerable groups. When it comes to the analysis as such, since the water study is in a limited area, even though it gives a good insight in the neighborhood scale, an extensive investigation for other points in the city would support a better perception of the broader context and a more systematic recommendation. Adding to that, the presented results for the water analysis should be better detailed, as the location for harvesting points would also depend on other factors and the feasibility of the infrastructure to successfully distribute the water through the urban agriculture fields, completing the idea of the rain harvesting for irrigation. It is nevertheless informative as a base for their location on the desired study level for this thesis, and the detailing of it remains a further step in future research.

A constraint in the research was also the availability of GIS data regarding water and waste infrastructures. The primary urban data, such as landuse, was reasonably complete, but the integration with the other government agencies databases is still not available for the other services in the city. With more precise data of the waste collection routes and destinations, for example, new elements could have been added to the heatmap visualization. Nevertheless, overall, the amount of data available was sufficient to explain the strategy of the thesis and its central points.

Final Statement

As a final statement, the literature review, case studies, and local urban analysis made possible the development of a strategic framework spatially translated through computational design and analysis tools to explore a possible spatial organization of urban agriculture elements in Brasília. The results were visualized as maps and diagrams, and they can be used for kickstarting a more detailed investigation, bringing awareness to the subject, or reinforcing that resources management and food security are topics of the Urban Planning agenda. The study can maybe inspire future works, especially in the local context, where such approach is currently limited.

The methodology and the results, as intended since the beginning, demonstrate how to integrate computational design methods and analysis to support future design decisions. Even though it was a modest exploration, I hope that the idea and intention behind it remain and further push the integration of such methods.

Outlook for further research

As future analysis recommendations, drawn back from the limitations statements, similar research on the metropolitan area would be of great value. Likewise, on the opposite scale, it would be interesting to detail the food production spaces to be able to recommend which crops could thrive according to the specific local constraints.

Furthermore, from a computational simulation perspective, a growth model of this situation would be extremely valuable. As the research now shows how Urban Agriculture could be implemented precisely at this moment in time with the current population and resources, the same rules and parameters could be used to feed an extended model to assist future planning. The model could demonstrate how a future landuse distribution could happen when the city expands, aiming to keep the same favorable conditions for each Urban Agriculture typology and the balance of resource availability.

In any case, future research should continue to consider the core principles of supporting small scale producers and the benefits that land and landscapes serve as public goods.

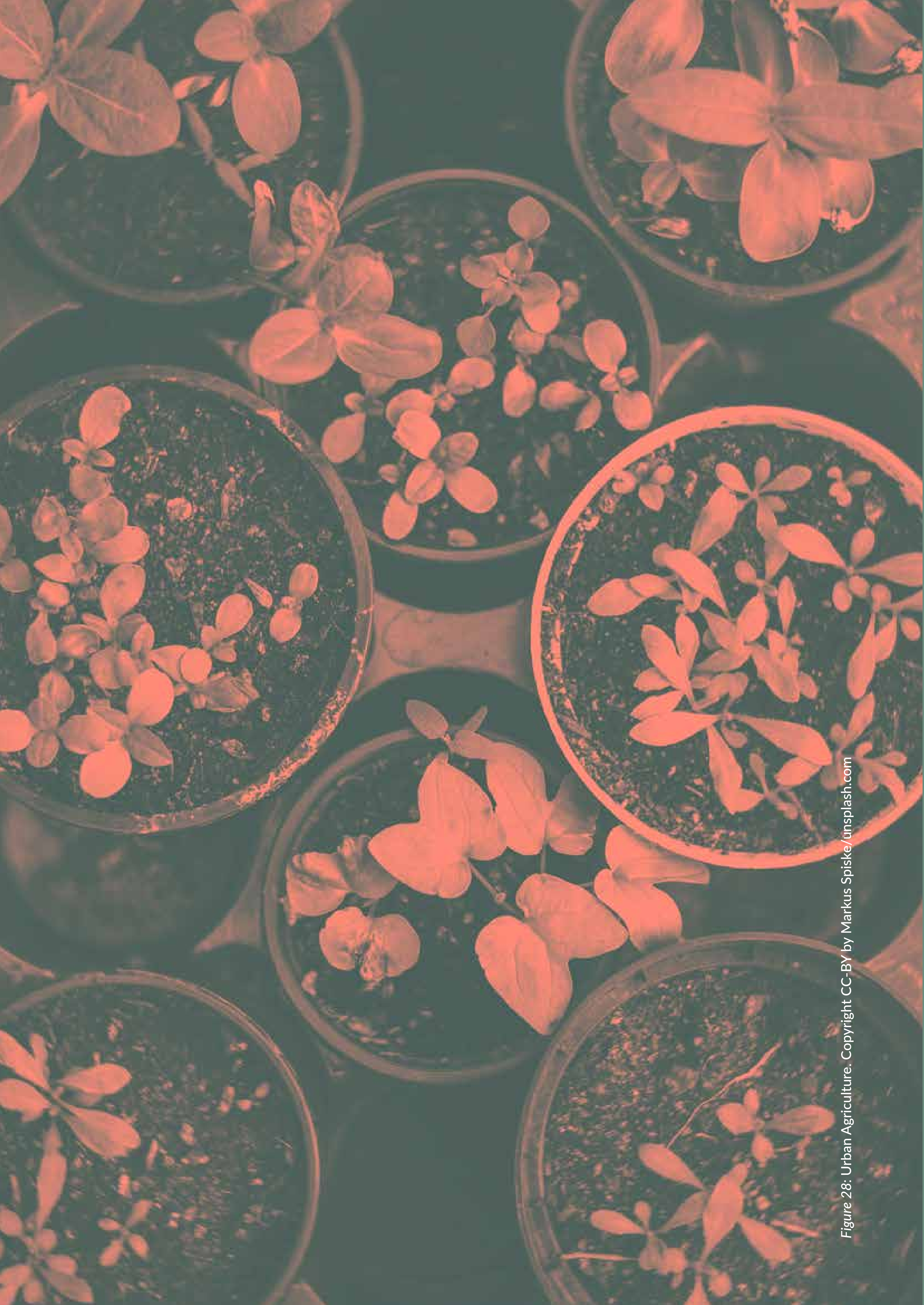


Figure 28: Urban Agriculture. Copyright CC-BY by Markus Spiske/unsplash.com

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The world is currently undergoing an unprecedented rural-urban migration, meaning that in the next decades, the environmental, social, and economic challenges that originate from urbanization processes will be aggravated. A pressing point is that our modern urban lifestyles consume more resources than the planet can accommodate, especially with the expected population growth.

Food production, for instance, is one of the activities that consume reserves the most. The current long chain of production, packaging, transportation, and distribution touches all domains of our existence and a significant part of the planet's terrestrial and marine supplies. This system is intrinsically related to monopolies, deforestation, and the commodification of food production, creating urgent socio-economic, and environmental challenges.

Urban Agriculture is seen as a possible solution for some of these issues, for connecting people to food systems allows more efficient use and reuse of resources, more sustainable consumption patterns, and a decentralized economic model, in which inclusive and broader income opportunities can arise.

In this light, how could we adapt existing vacant spaces in a city, transforming them into food production units? How would Urban Agriculture support waste and water management systems? How could this new sustainable strategy be spatially organized within a current urban infrastructure?

Investigating these questions, this Master Thesis, supported by a comprehensive conceptual framework, presents an algorithm-based spatial exploration for the organization of Urban Agriculture elements in the city of Brasília. Brasília is an unique opportunity, since it has a Modernistic urban design, vast vacant public spaces are there by default. The methodology encompasses analysis and mapping of relevant Urban Agriculture features and the related infrastructure in the city. And, through computational design tools, simulate and visualize a possible spatial distribution based on proximities and attractivity relations of the pertinent features.

The results could be used in informed policy-making decisions and varied stakeholder interactions, raising collective awareness for alternative food production models. Hopefully, the contribution is a valid experiment in the contemporary sustainability debate and the validation of computational methods as an alternative for integrated simulations and design.

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