



**POLITECNICO
DI MILANO**

MICROFORESTS AS A TOOL FOR URBAN RESILIENCE IN THE CITY OF GUADALAJARA

BETWEEN FOREST AND CITY: RESHAPING THE URBAN LANDSCAPE

MICROFORESTS AS A TOOL FOR URBAN RESILIENCE IN THE CITY OF GUADALAJARA

BETWEEN FOREST AND CITY: RESHAPING THE URBAN LANDSCAPE

Thesis by Rayza Pérez
Supervisor Prof. Alessandra M. Pandolfi
Co-supervisor Prof. Yara Valverde
March, 2025

POLITECNICO DI MILANO
MASTER OF SUSTAINABLE ARCHITECTURE AND LANDSCAPE



POLITECNICO
DI MILANO

INDEX

1. Acknowledgements	05
2. Abstract	07
3. Chapter 01	08
3.1 Introduction	09
3.2 The city	10
3.3 Urban and environmental context	12
3.4 The Primavera Forest	15
3.5 Threats	19
3.6 Problematic	23
4. Chapter 02	24
4.1 Nature in the city.	25
4.2 Urban resilience.	26
4.3 Need for green spaces.	27
4.4 Forest and the city.	29
4.5 Biomes in the Primavera Forest.	32
4.6 Vegetation dynamics.	34

5. Chapter 03	37
5.1 Methodology.	38
5.2 Strategy.	40
5.3 Pocket Forests.	41
5.4 Case studies.	44
5.5 Landscape principles.	46
 6. Chapter 04	 48
6.1 Analysis.	49
6.2 Connectivity.	54
6.3 Vegetation.	57
6.4 Stepping stones.	65
6.5 Design Proposal.	69
6.6 Expected Impacts.	73
6.7 Performance indicators.	74
6.8 Conclusion.	75
6.9 Bibliography.	76

ACKNOWLEDGEMENTS

I would like to thank Professor Alessandra Pandolfi and Professor Yara Valverde, as without their patience, kindness, guidance, and encouragement, I would not have arrived at this result and would not have enjoyed this process and learning as much.

Also, I want to thank my family, who have shown their love and support even from afar, for believing in me and for showing me I can achieve my dreams. Thank you for this opportunity of growth, even if it meant being far from each other.

Last but not least, to my dear friends, Pepe, Mafe, Caro, Jose, and Julia, who have shown me their support and comfort since day one. Truly I am grateful for your companionship and care.

ABSTRACT

The rapid and unorganized growth of the cities currently has caused several problematics; from climate-related challenges to the displacement of people, which have resulted in one of the most critical challenges contemporary cities are facing nowadays.

The accelerated urbanization of the city of Guadalajara has been increasing in the past years causing pressure on the Primavera Forest which has contributed to the rising temperatures, ecological fragmentation, and the loss of green areas in the city. These conditions highlight the need for design-driven strategies that enhance urban resilience through ecological integration.

This thesis explores microforests as a nature-based design strategy to strengthen urban resilience in the metropolitan area of Guadalajara. Microforests are a small-scale, densely planted ecosystems composed of native species that promote biodiversity, microclimate regulation, and ecological connectivity.

Through an analysis of urban and environmental conditions, site-specific factors, and landscape design principles, the research proposes a microforest-based intervention that operates at the intersection of architecture, landscape, and urbanism.

The project evaluates the potential environmental, social, and climatic impacts of microforests, including temperature reduction, water infiltration, habitat creation, and community engagement. By positioning microforests as elements of green infrastructure, the thesis demonstrates how small-scale landscape interventions can contribute to larger ecological networks and improve the adaptability of urban environments.

The findings suggest that microforests offer a replicable and effective design approach for enhancing resilience in rapidly expanding cities such as Guadalajara.

CHAPTER 01

INTRODUCTION

INTRODUCTION

Contemporary cities nowadays are being shaped by the rapid growth of the urban sprawl and the impacts caused by it, conditions that have intensified environmental, social, and spatial vulnerabilities within urban environments.

This thesis aims to create a solution to the current problematics that exist in the city of Guadalajara, due to challenges like increasing temperatures, loss of biodiversity and green areas, air pollution, along with the fragmentation that the city currently faces, green spaces have emerged as **crucial infrastructure for regulating climate and enhancing urban resilience**.

In Guadalajara, as the urban expansion continues to trespass upon natural landscapes, the lack of ecological continuity between the city and the surrounding ecosystems has caused an increase in the existing environmental stress, contributing to heat island effects, the reduction of green coverage, and weakened the connectivity between them which highlights **the need for strategies that mitigates the pressures on the forest** whilst restoring and reconnecting urban spaces.

Within this framework, microforests emerge as a promising nature-based design approach and methodology, as it offers an effective solution to regenerate sites, improve microclimates, and strengthen ecological connections. This approach acts as an infrastructure network of green nodes which when is implemented in strategically planned and interconnected systems of natural and semi-natural spaces, provides environmental, economic, and social benefits, resulting in urban resilience.

This research explores the potential of microforests, as a tool for adaptation while integrating architectural, landscape, and urban design principles to create a more resilient and livable city.

The research proposes an intervention that addresses the ecological fragmentation, by positioning microforests as a transition area for the city and the forest, this study seeks to demonstrate how small-scale, **design-driven interventions can support broader urban sustainability and resilience goals**.

THE CITY

Over the last decade, the Guadalajara Metropolitan Area has experienced sustained growth in both population and territorial expansion leading to a reduction in green spaces in the city. The population of the metropolitan area has increased by an annual growth rate close to 1.29%, which has resulted in a higher demand for housing, services, and infrastructure; leading to a greater urban pressure on the Guadalajara Metropolitan Area.

The growth of the city was not limited to the central municipality which has caused the urban sprawl to extend to a point that much of it has gone into other municipalities causing fragmentation and suburbanization, increasing the amount of paved surface area invading on peri-urban land. Consequently, the urban footprint has grown significantly, occupying land that was previously rural or natural, creating an increasing pressure on the metropolitan territory and leading to a reduction and division in green spaces in the city.

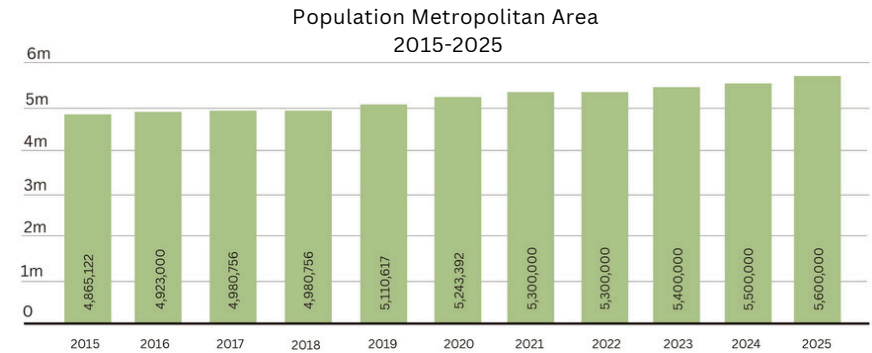


Figure 01

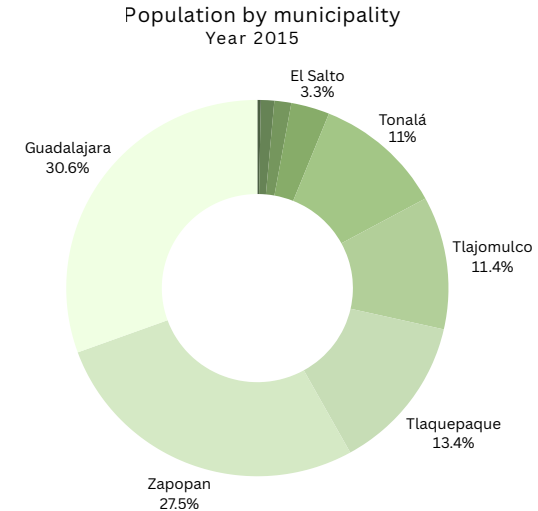


Figure 02

Figure 01 & 02: population growth in GMA (Guadalajara Metropolitan Area) Drawn by author.

GROWTH OF THE CITY

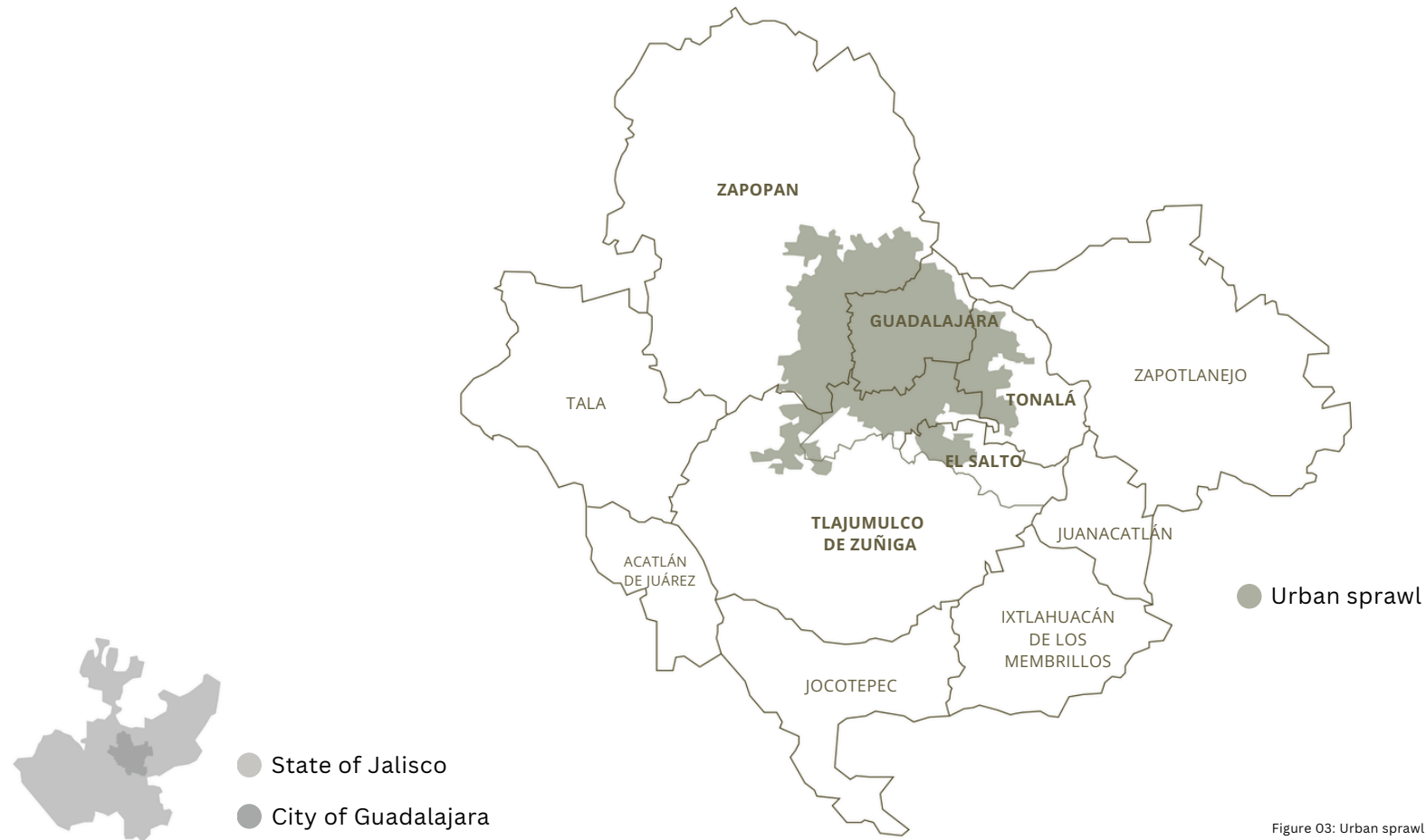


Figure 03: Urban sprawl GMA
(Guadalajara Metropolitan Area) Drawn by author.

URBAN AND ENVIRONMENTAL CONTEXT

The city of Guadalajara, displays a complex urban and environmental context shaped by rapid metropolitan expansion and significant ecological constraints.

Over the past decades, urban growth has followed a predominantly horizontal and dispersed pattern, increasing land consumption, infrastructure demands, and pressure on peri-urban ecosystems. This expansion has contributed to the loss and fragmentation of vegetation cover, higher levels of surface impermeability, and the intensification of environmental risks such as urban heat islands, air pollution, and pluvial flooding.

The Primavera Forest, located on the west side of the city that functions as a critical environmental buffer and as a key ecological component for the metropolitan system, providing ecosystem services for the city, including climate regulation, groundwater recharge, carbon sequestration, and biodiversity conservation.

However, the continued urban expansion, infrastructure development, and land-use change along its boundaries signify ongoing threats to its ecological integrity, highlighting the urgent need for a integrated metropolitan planning that aligns urban development with environmental conservation.



Picture 01: Guadalajara Historic City Center. From: Shutterstock.

GREEN AND GREY INFRASTRUCTURE

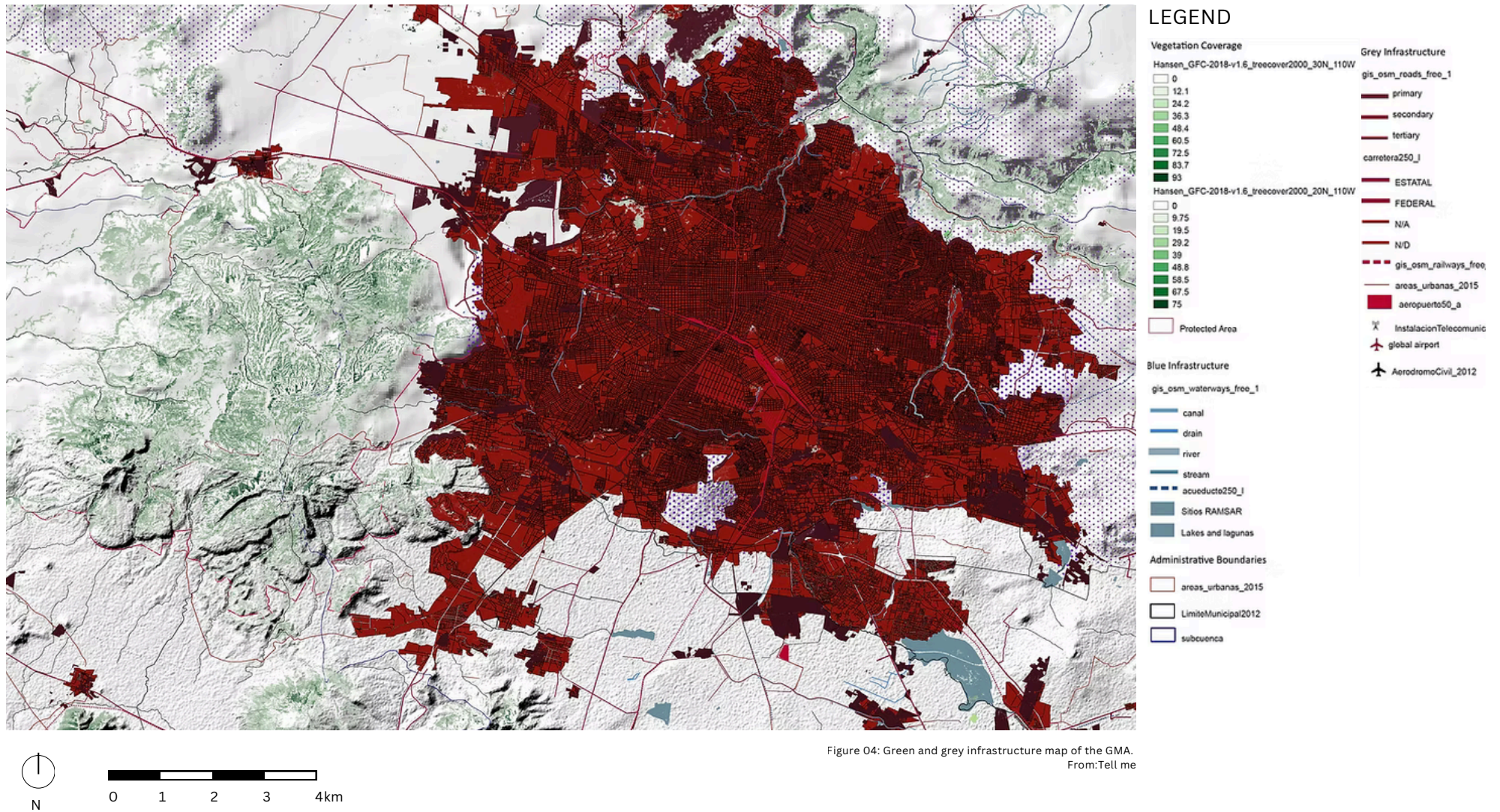


Figure 04: Green and grey infrastructure map of the GMA.
From: Tell me

LAND USE

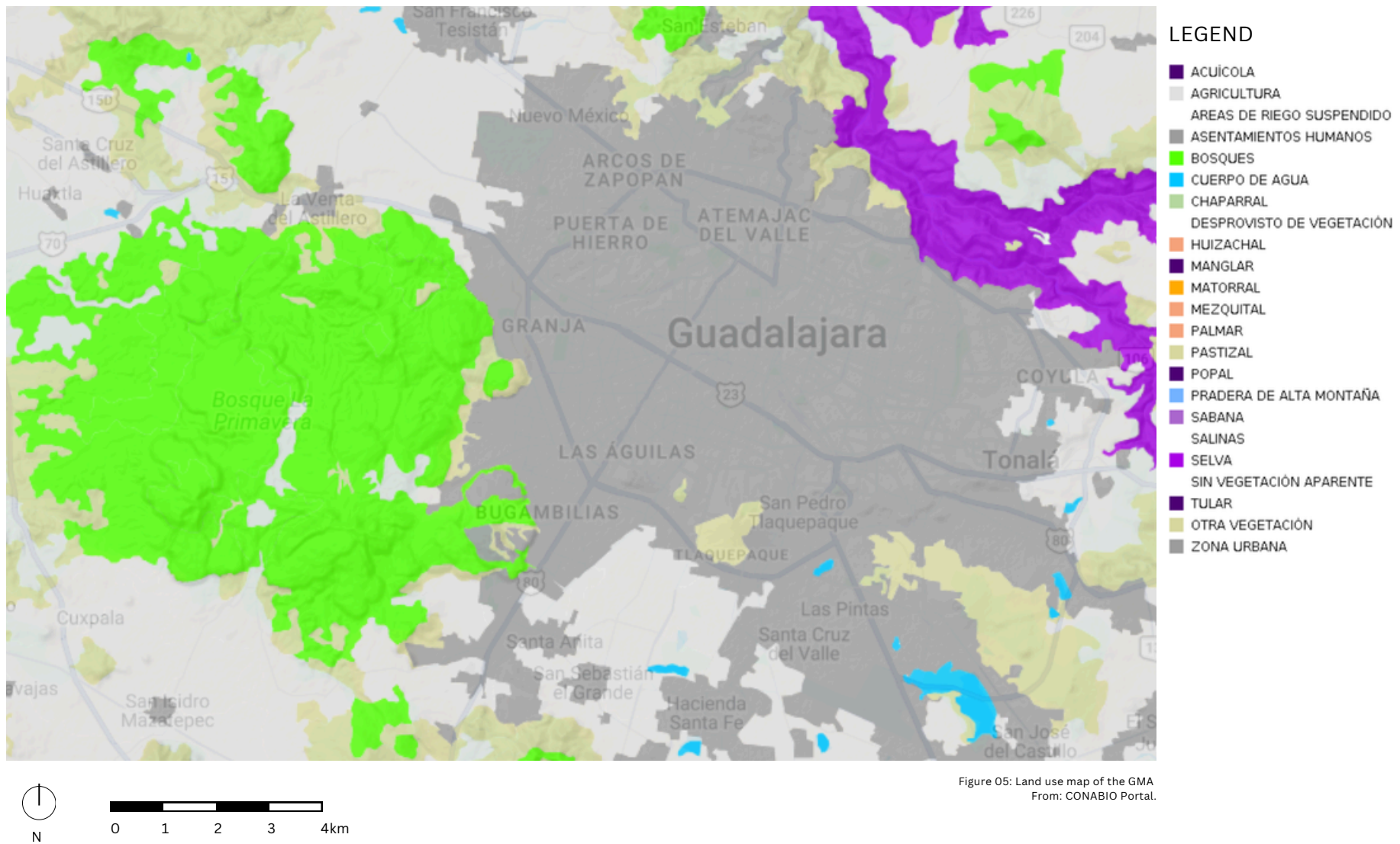


Figure 05: Land use map of the GMA
From: CONABIO Portal.

THE PRIMAVERA FOREST

The Primavera Forest is a protected natural area located west of the Guadalajara Metropolitan Area and is one of the most important ecosystems in the region and one of the main green spaces of the city, it stands out for its rich biodiversity, as it fulfills key environmental functions and provides multiple environmental services that benefit the inhabitants of Guadalajara and nearby communities; as it plays a vital role as an environmental regulator.

The forest ecosystem helps improve the air quality of the city by absorbing large quantities of carbon dioxide, as well as acting as a natural barrier that mitigates high urban temperatures. It also contributes to the recharge of aquifers that supply water to the region and serves as a habitat for a wide variety of flora and fauna, which are endemic to the area.

In addition, it serves as a space for recreation and environmental education for the population, making its conservation essential for ecological balance and the well-being of present and future generations. Its preservation and care is essential for maintaining ecological balance, protecting biodiversity, and ensuring a healthier environment for the inhabitants of the metropolitan area.

The forest is a fragile ecosystem, threatened by the voracious urban sprawl of Guadalajara. It is one of our largest green spaces, and the one we neglect the most. (El informador, 2024) The protection and conservation of this area is key to limit the urban expansion, control land use, and reduce human activities that could damage it.

The Primavera Forest is officially designated as a protected natural area, which means it is legally recognized and managed to conserve its ecosystems, biodiversity, and environmental services as the forest is home for more than 700 flora species and 300 fauna species.



Picture 02: Primavera Forest. From: Author.

A PROTECTED NATURAL AREA

The Bosque de la Primavera is characterized by a high level of biological diversity, making it a key area for conservation in western Mexico. Floristic studies have documented more than 700 flora species, dominated by pine-oak forests and tropical deciduous vegetation, which form complex habitats essential for ecological stability.

In terms of fauna, the protected area supports around 200 bird species, 59 mammal species, 49 reptile species, 20 amphibian species, and 7 fish species, reflecting its role as an important refuge for terrestrial and aquatic wildlife. Additionally, the forest contains several endemic species, particularly among its flora, whose restricted geographic distribution increases their vulnerability. The richness in species composition plays a vital role in preserving native plants and animal species, maintaining ecological balance, highlighting its ecological significance and reinforcing the need for strict protection and sustainable management strategies to take care of it.



Picture 03: Primavera Forest from above. From: Freepik

The Primavera Forest protected area is located within an approximate area of 30,500 hectares in the municipalities of Zapopan, Tlajomulco de Zúñiga, Tala and El Arenal; Jalisco.

THE ECOLOGICAL FUNCTION OF THE FOREST

The Primavera Forest constitutes one of the most ecologically significant areas in western Mexico and functions as a critical environmental system for the Guadalajara Metropolitan Area. Located in between rapidly expanding urban development and regional natural landscapes, the forest performs multiple ecological functions that operate at a regional and local scale.

In addition, the Primavera Forest contributes to biodiversity conservation, climate regulation, hydrological processes, and plays as a key complex ecological system that provides essential ecosystem services at local, metropolitan, and regional scales.

Its connectivity with ravines, natural corridors, and peri-urban vegetation patches enables an ecological flow, including the movement of different species, nutrient cycling, and disturbance recovery. Maintaining this connectivity is essential for preserving regional ecological resilience.

At the regional scale, the Primavera Forest functions as a vital habitat and genetic reservoir within the western Mexico area. Its diversified vegetation matrix supports high levels of species richness as a transition zone. The forest's spatial extent and ecological health enables the maintenance of fauna and flora populations as it helps the population dynamics; allowing the movement of flora and fauna into the surrounding peri-urban and rural ecosystems.

From a landscape ecology perspective, these functions emerge from the interaction of the vegetation structure, the disturbance patterns, geomorphology, and biological processes.

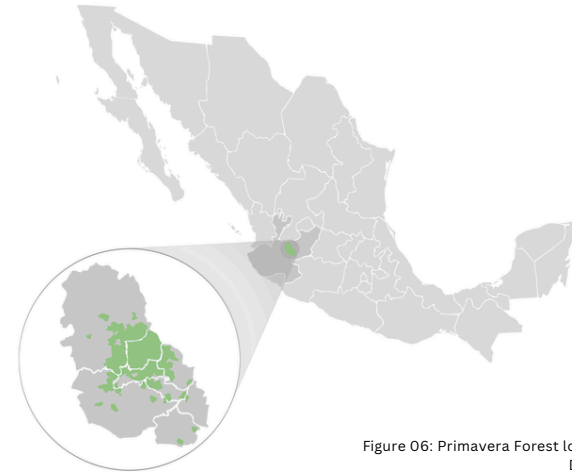


Figure 06: Primavera Forest located in Mexico.
Drawn by author.

At the local scale, forest vegetation significantly influences microclimatic conditions through shading, evapotranspiration, and wind regulation. The canopy cover layer reduces surface and near-ground air temperatures, minimizes daily temperature variations, and boosts relative humidity. These impacts reach into nearby urban regions, helping to reduce the intensity of urban heat islands in those areas.

Furthermore, the forest supports soil formation and stability through litter deposition, root reinforcement, and microbial activity. Organic matter accumulation enhances soil structure, increases nutrient availability, and promotes water retention. These processes reduce erosion on steep slopes and support long-term ecosystem productivity, particularly in areas with shallow volcanic soils.

Understanding the multi-scale ecological functions of the Primavera Forest impacts directly urban and regional planning

Conservation strategies must prioritize the maintenance of forest structure, connectivity, and disturbance-adapted dynamics while integrating complementary nature-based solutions within the urban matrix. Interventions such as pocket forests, ecological corridors, and native vegetation restoration can extend local ecological functions into the city, reinforcing regional resilience and reducing pressure on the protected area.



Picture 04: Primavera Forest. From: Author.

THREATS TO THE FOREST

The pressures and threats that the Primavera Forest faces are multifactorial; urban growth, wildfires, illegal logging, and alterations in land use are some. Additional threats involve the isolation of the forest from other green spaces in the city caused by urban expansion.

One of the most significant threats is urban expansion, which leads to land-use change, habitat fragmentation, and increased pollution along the forest's boundaries. Forest fires, many of which are linked to human activities, pose a serious risk by degrading vegetation, altering soil properties, and reducing biodiversity. Additionally, illegal logging, unregulated tourism, and the introduction of invasive species disrupt ecological processes and weaken native ecosystems. The lack of adequate buffer zones further intensifies these impacts by allowing direct interaction between urban areas and the protected forest. Together, these threats compromise the forest's ecological integrity and highlight the urgent need for effective management, enforcement, and long-term conservation strategies.

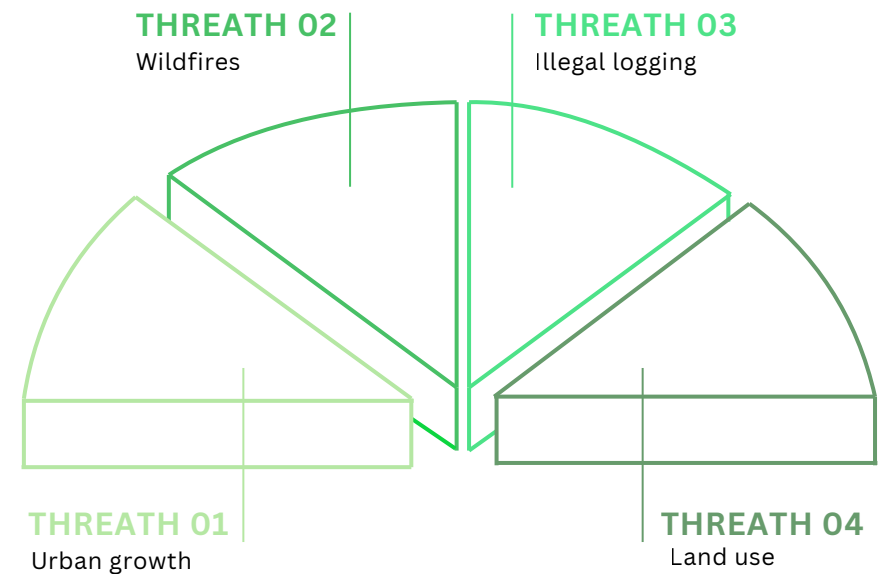


Figure 07: Main threats of the Primavera Forest
Drawn by author.

URBAN SPRAWL & LAND USE

As the expansion of the Guadalajara Metropolitan Area has increasingly enclosed upon its boundaries the change of land use of the surrounding natural land to the forest into residential developments, roads, and commercial infrastructure resulted in the modification of how the network of the forest operates, which directly lead to habitat loss and fragmentation. These changes disrupt the ecological connectivity, limit the wildlife movement, and has reduce the availability of resources for native species dependent on the forest.

There are numerous illegal subdivisions and constructions in the surroundings of the Primavera Forest, representing a persistent threat to this protected natural area. Authorities have identified dozens of these irregular settlements. Additionally, incompatible land uses such as agriculture, quarrying, and recreational developments near or within the forest perimeter has increase soil erosion, water contamination, and the risk for forest fires.



Figure 08: Guadalajara Urban sprawl. Drawn by author.

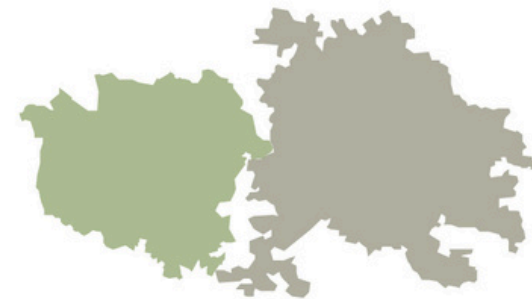


Figure 09: Graphic of the Primavera Forest compare to the growing urban sprawl of Guadalajara. Drawn by author.

WILDFIRES

Wildfires represent a major threat to the conservation of the B Primavera Forest due to their frequency, intensity, and long-term ecological impacts. Although fire is a natural component of some forest ecosystems, in this area many wildfires are caused or intensified by human activities, such as agricultural burning, unattended campfires, and the expansion of urban areas near the forest. Recurrent fires damage vegetation cover, reduce soil fertility, and increase erosion, which affects water infiltration and groundwater recharge. Wildfires also lead to habitat loss and mortality of wildlife, particularly for species with limited mobility, and can facilitate the spread of invasive species. When fires occur too frequently, they disrupt natural regeneration processes, weakening the forest's resilience and threatening its biodiversity and ecological stability.

So far in 2025, 49 fires have been recorded in the forest, with an affected area of around 1,933 hectares. The fires damage flora and fauna which causes a disruption in the ecological functions such as seed dispersal and pest control. It is estimated that shrub vegetation can take up to a year to regenerate, and the tree layer up to two years in the affected areas.



Picture 05: Wildfire in the Primavera Forest. From: Milenio Digital.



Picture 06: Burnt area of the Primavera Forest. From: Author.

ILLEGAL LOGGING

Illegal logging poses a significant threat to the Bosque de la Primavera by directly degrading its forest structure and ecological integrity. This activity typically occurs through the unauthorized extraction of timber for commercial use, fuelwood, or land clearing, often taking advantage of limited surveillance and access points near urban and rural boundaries.

The removal of trees reduces forest cover, disrupts habitat continuity, and alters microclimatic conditions essential for many plant and animal species. In addition, illegal logging increases soil erosion and decreases the forest's capacity to retain water, which negatively affects groundwater recharge. The creation of informal access routes for logging also facilitates further human intrusion, increasing the risk of wildfires and additional land-use change. As a result, illegal logging undermines conservation efforts and accelerates ecosystem degradation within the protected area.



Picture 07: Illegal logging Primavera Forest. From: María Ramírez Blanco.



Picture 08: Illegal logging Primavera Forest. From: María Ramírez Blanco.

PROBLEMATIC

The absence of transition areas and buffer zones around the Primavera Forest represents significant risks for both the ecosystem and the city. Without these zones, the forest is directly exposed to urban expansion, increasing pressure from real estate development, roads, and land-use changes. This leads to habitat fragmentation, negatively affecting species that depend on continuous natural areas to survive.

The lack of these protective areas also reduces the forest's ability to regulate the local climate, protect groundwater recharge zones, and conserve biodiversity. These risks can result in accelerated ecosystem degradation and the loss of the environmental services that the forest provides to the Guadalajara metropolitan area.

Additionally, without buffer zones to reduce human impact, problems such as forest fires, pollution, littering, the introduction of domestic animals, and illegal activities increase. As a result, uncontrolled urban growth and inappropriate land use significantly undermine the forest's ecological functions and long-term conservation.

Also, the introduction of invasive species disrupt ecological processes and weaken native ecosystems. The lack of adequate buffer zones further intensifies these impacts therefore zoning is required for the management of the territorial development whilst it reducing pressure on natural green areas with the intention on preserving the biological diversity of the Primavera Forest and other important reserve natural areas of the city.



Picture 09: View of the city from the Primavera Forest. From: Author.

CHAPTER 02

FROM THE CITY TO THE FOREST

NATURE IN THE CITY

Accelerated urban growth in the GMA has had a negative impact on green areas and vegetation cover across the city. In the past years a reduction and fragmentation of urban vegetation has been noticed, as well as an unequal distribution of parks and green spaces, limiting access for large segments of the population.

In addition, there is a significant deficit of urban trees, particularly in areas such as the eastern part of the city, the historic center, and the industrial zone, which has reduced key ecosystem services provided by trees, including shade, temperature regulation, and rainwater absorption.

Beyond these ecological services, access to nature in cities has been shown to enhance physical and mental health, foster social cohesion, and strengthen residents sense of place and identity.

In Guadalajara, green areas hold both environmental and cultural significance. Green areas such as the Primavera Forest, urban parks, and ravines are deeply embedded in the collective identity of the city and function as key spaces for recreation, environmental education, and cultural practices. For Guadalajara's residents, these landscapes represent not only ecological infrastructure but also symbols of regional heritage and connection to the territory.



Picture 10: View from the Historic City Center of Guadalajara.
From: Wes Ciecwa.



Picture 11: Renovated pedestrian walk in city center.
From: Fernández Arquitectos.



Picture 12: View of the city center.
From: Michelle Vázquez in "El Diario".

URBAN RESILIENCE

Urban resilience refers to the capacity of cities to adapt and recover from environmental, social, and climatic stresses while maintaining their essential functions and identity.

In this context, nature-based solutions play a crucial role by working with ecological processes rather than against them, enhancing the ability of urban systems to respond to disturbances such as climate change, biodiversity loss, and extreme weather events.

By integrating natural elements such as vegetation, soils, and water systems—into urban environments, cities can improve ecosystem services including temperature regulation, stormwater management, air purification, and habitat provision. An ecological approach to urban resilience emphasizes the interdependence between human and natural systems, recognizing that healthy, biodiverse ecosystems strengthen adaptive capacity, reduce vulnerability, and support long-term sustainability.

As a result, nature-based and ecologically driven strategies are increasingly seen as essential components of resilient urban planning and design.

As cities face increasing pressures from climate change, population growth, and land-use intensification, integrating natural elements into the urban fabric has become a critical strategy for enhancing urban resilience and quality of life.



Figure 10: Urban resilience main principles based in nature based solutions.
Drawn by author.

NEED FOR GREEN SPACES

In contemporary cities, green areas have evolved from simple recreational spaces into essential infrastructure that sustains the ecological, social, and climatic functioning of urban life. Beyond their landscape value, green systems like parks, ecological corridors, neighborhood gardens, and microforests function as environmental networks capable of regulating microclimates, promoting ecology services as shade, water infiltration, capturing carbon, and mitigating the urban heat island effect.

In the face of challenges such as rising temperatures, biodiversity loss, air pollution, and territorial fragmentation, green areas have become an essential infrastructure for climate regulation and urban resilience.



Picture 13: View from above of the city of Guadalajara. From: Overview.

Within the context of Guadalajara, it faces a particularly intense challenge due to its rapid growth and its complex relationship with the Primavera Forest, one of the most significant ecosystems in the region.

The existing public green spaces in the city of Guadalajara are insufficient and poorly distributed with no connection between them, which results in a cutback in ecosystem services. Even though these few green spaces represent a future potentiator for strengthening and creating biological nodes which translates into the regulation of microclimates, as the presence of green areas contributes to public health, environmental awareness, and social well-being, while also reinforcing cultural values linked to landscape, tradition, and community.

Preserving and expanding urban nature in the city of Guadalajara is therefore essential not only for ecological resilience but also for maintaining the cultural and social fabric that defines the city. These ecosystems are embedded in local traditions, recreational practices, and environmental awareness, shaping how residents perceive and interact with their territory.

EXISTING GREEN AREAS IN THE METROPOLITAN AREA

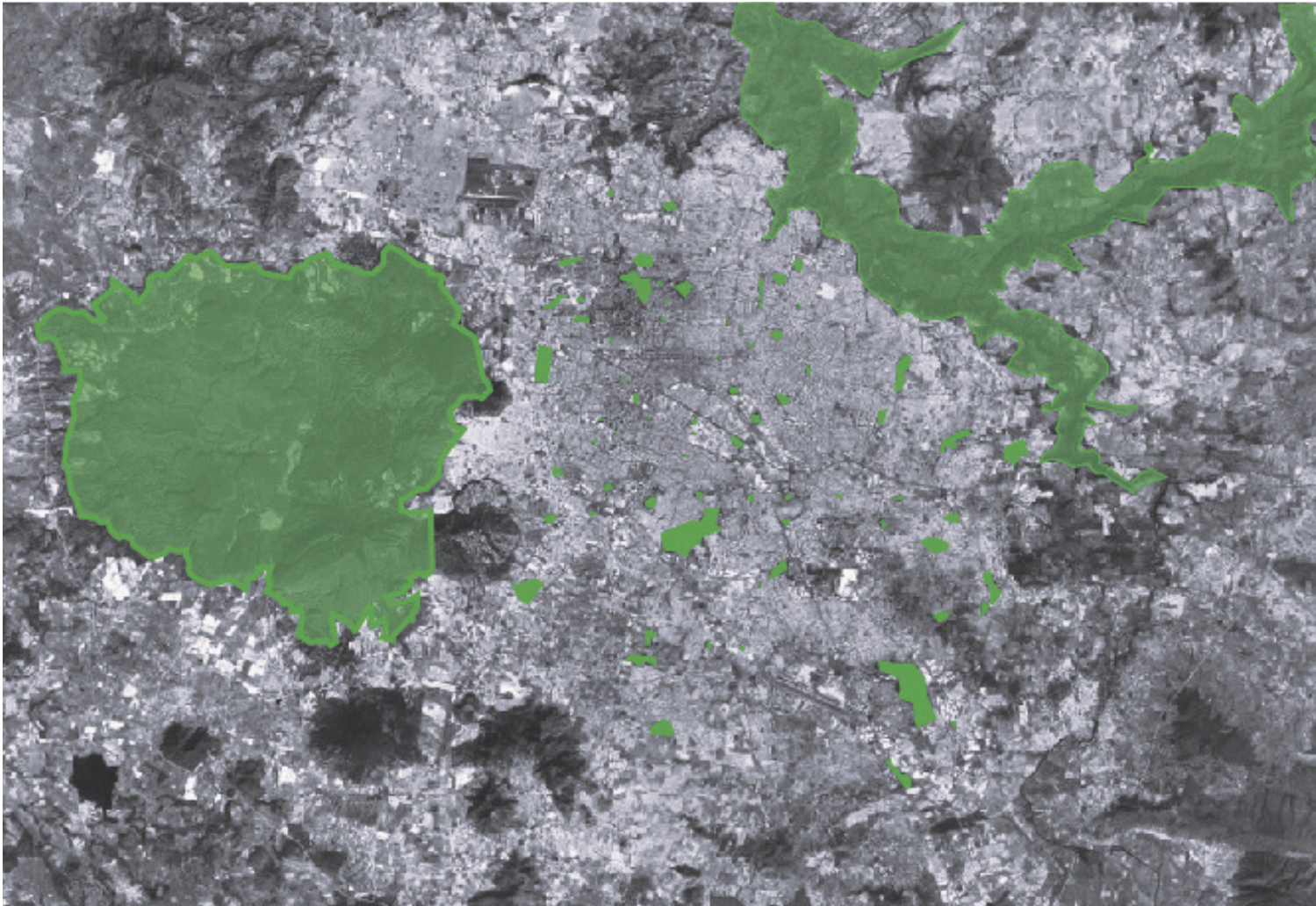
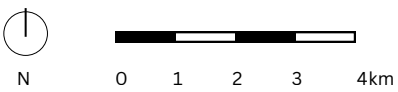


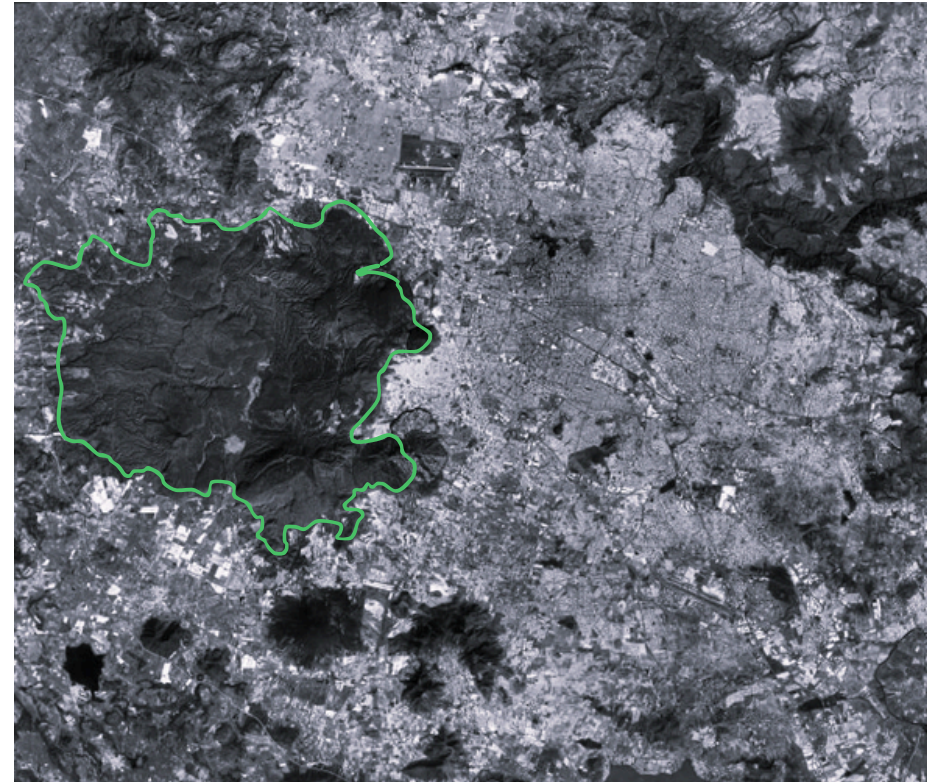
Figure 11: Existing green areas of the GMA
Base from CONABIO Portal, drawn by author.



FOREST & THE CITY

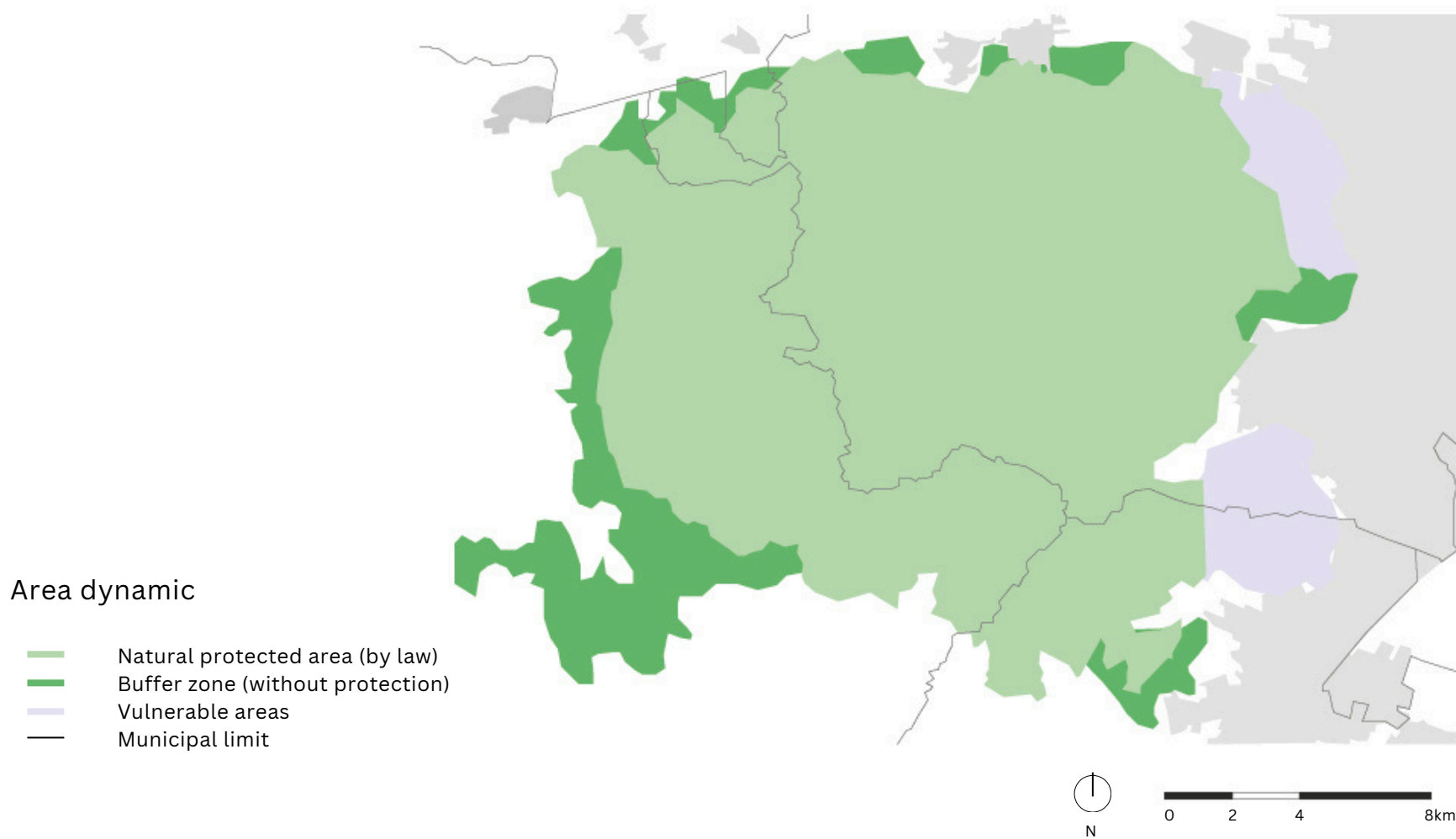
The interface “between forest and city” constitutes a critical territory where urban pressure threatens ecological continuity, while simultaneously offering opportunities to implement new strategies for restoration and environmental connectivity. Among these strategies, microforests and pocket-forests emerge as tools capable of regenerating degraded spaces, increasing neighborhood adaptive capacity, and strengthening ecological links between the forest and the metropolitan area.

Therefore, understanding the importance of green areas in the cities for urban resilience involves not only recognizing their environmental benefits, but also acknowledging their role as a ecological, social, educational, and community infrastructure. This research explores how the creation of microforests in the metropolitan region of Guadalajara can contribute to building a more livable, ecologically connected city that is better prepared to face climate change.



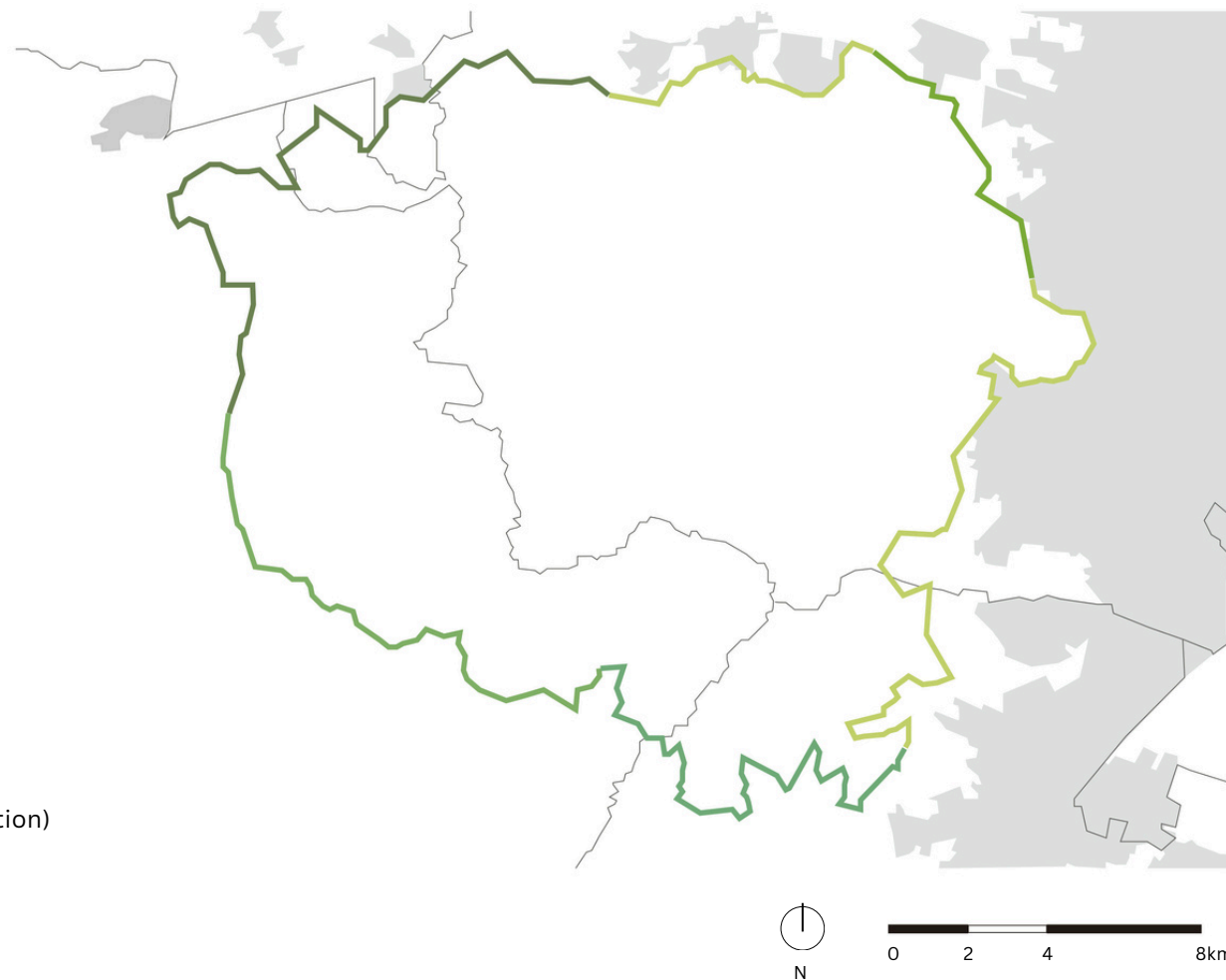
Picture 13: Aerial view of the city and the Primavera Forest perimeter.
Base:google maps. Drawn by Author.

DYMANICS OF THE PRIMAVERA FOREST



Perimeter dynamic

-  Rural agriculture
-  Agriculture
-  Connectivity (natural vegetation)
-  Urban
-  Semi-urban
-  Municipal limit



BIOMES IN THE PRIMAVERA FOREST

The temperate forest biome is one of the most ecologically significant biomes in the region and is primarily represented by pine-oak forests.

These forests are dominant in higher elevation areas, particularly within Primavera Forest and surrounding mountainous zones. Pine-oak forests are easily adapted to volcanic soils and seasonal drought and are shaped by natural disturbance regimes, especially by fire (Rodríguez-Trejo & Fulé, 2003).

This biome plays a critical role in carbon sequestration, climate regulation, groundwater recharge, and biodiversity conservation. It also functions as a regional ecological anchor for western Mexico.

Understanding the distribution and dynamics of biomes and ecosystems in Guadalajara is fundamental for informing sustainable urban planning, conservation strategies, and resilience-oriented landscape interventions.



Picture 13: Primavera Forest.
From: Author.

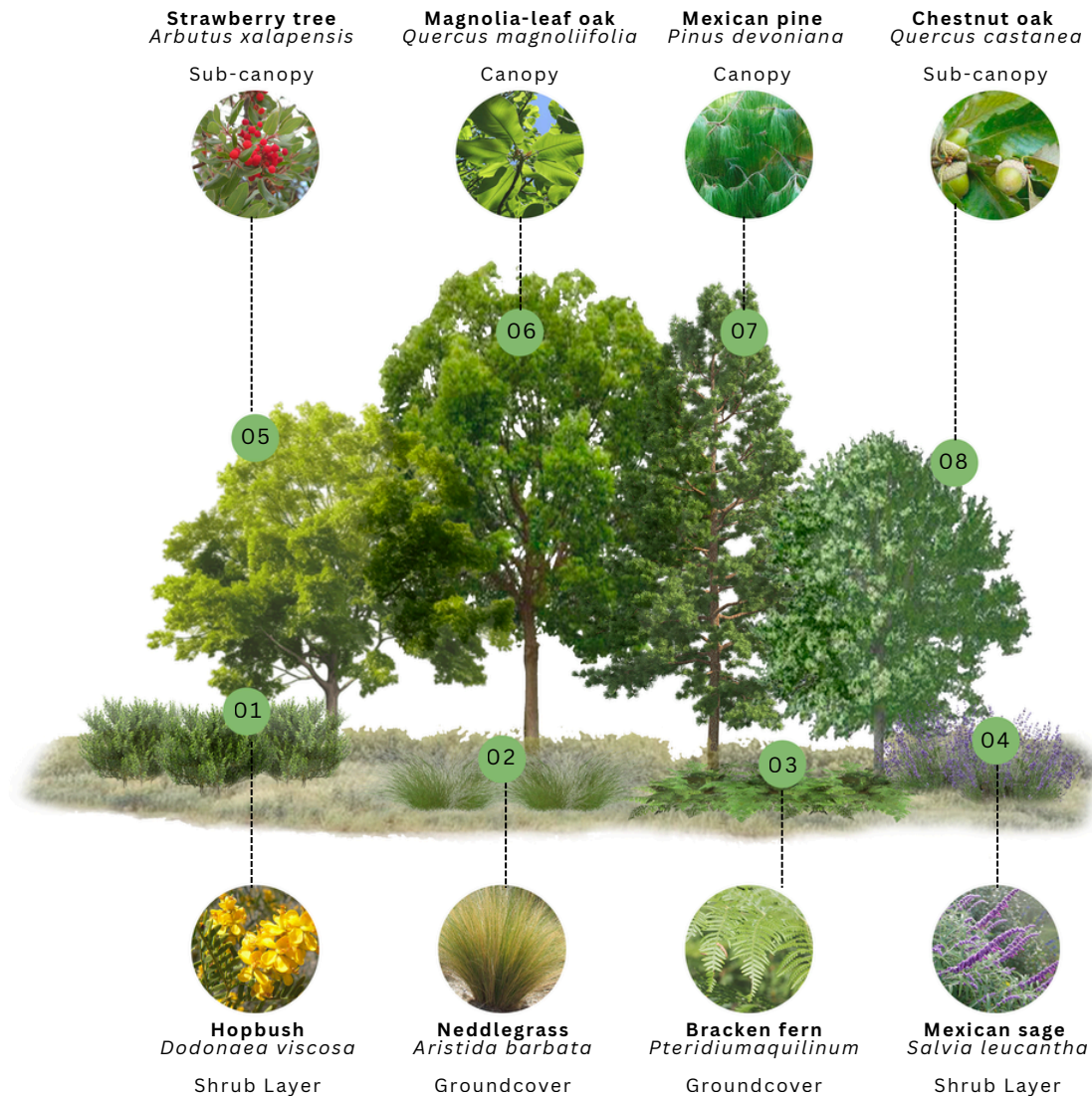


Picture 14: Primavera Forest.
From: Author.



Picture 15: Primavera Forest.
From: Aurther.

PRIMAVERA FOREST BIOME



VEGETATION DYNAMICS



Picture 16: Primavera Forest. From: Author.



Picture 17: Primavera Forest. From: Author.

Regional Scale

At the regional scale, the Primavera Forest functions as a key ecological node within western Mexico's landscape. Its vegetation plays a critical role in climate regulation, carbon sequestration, and hydrological processes that extend beyond the forest boundaries.

Endemic and native vegetation also support regional biodiversity conservation by acting as a source population for surrounding ecosystems. The forest acts as a genetic reservoir, facilitating species dispersal and recolonization across fragmented habitats. This regional function is especially relevant in the context of rapid urban expansion, which increasingly isolates natural areas and disrupts ecological connectivity.

Local Scale

The complex mosaic of the primavera forest consists on native and endemic vegetation, primarily composed of pine-oak forest, tropical deciduous forest, and secondary shrubland communities.

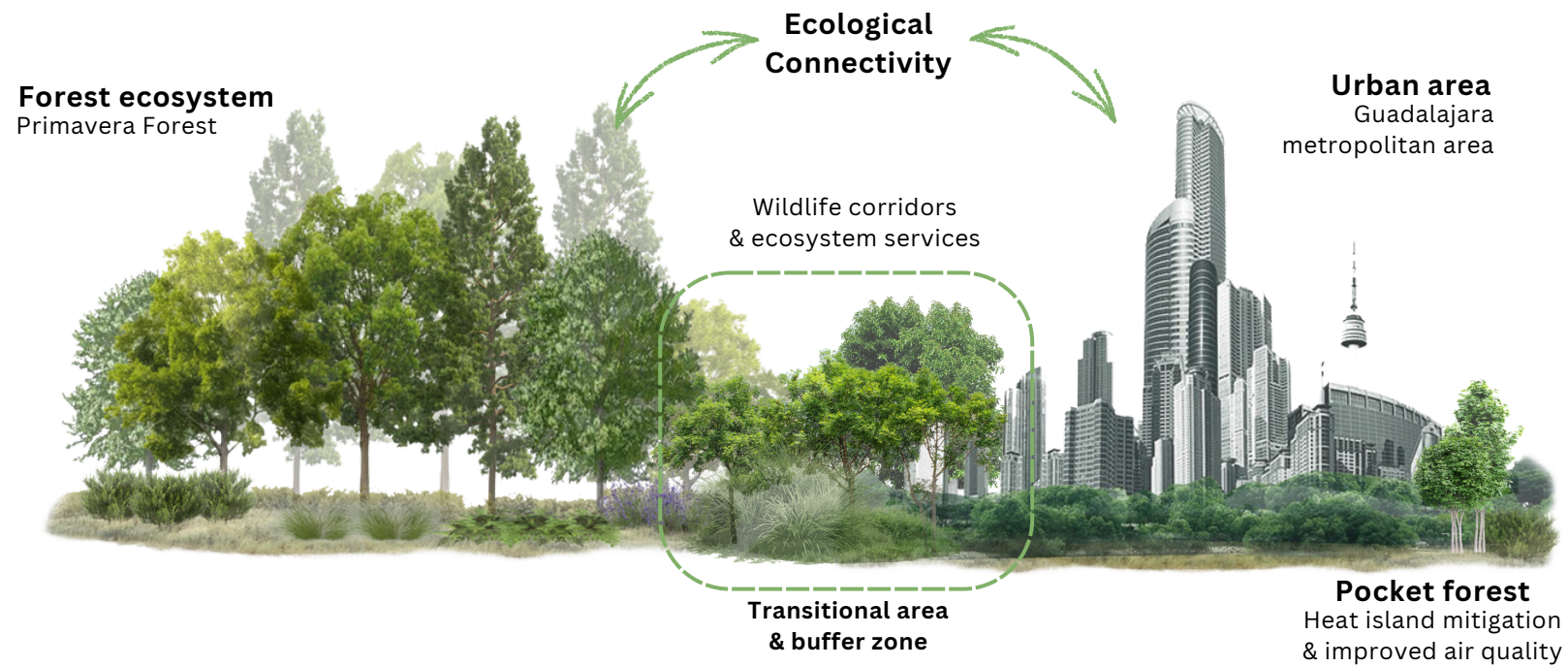
Vegetation dynamics within the forest are driven by species interactions, and natural disturbances. Pioneer species, including fire-resilient shrubs and grasses, play a crucial role in post-disturbance recovery by stabilizing soils and facilitating the establishment of later successional tree species.

At a local scale, endemic and native vegetation contributes directly to regulating microclimatic conditions within and around the forest. It reduces surface temperatures, moderates humidity levels, and limits soil desiccation during dry seasons.



Picture 18 & 19: Primavera Forest. From: Author.

VEGETATION DYNAMICS AND ITS LINK TO THE CITY



CHAPTER 03

METHODOLOGY, CONCEPTS, AND DESIGN PRINCIPLES

METHODOLOGY

This thesis adopts a multi-scalar methodological approach grounded in landscape ecology, ecosystem services, ecological connectivity and spatial analysis to address the urban development and how it affects ecological systems.

It begins with a comprehensive review of academic literature on landscape ecology, ecosystem services, ecological connectivity, spatial analysis, and urban resilience taking into consideration nature-based solutions, with particular emphasis on pocket forests as an emerging ecological strategy establishing the conceptual framework for the research.

In addition, this study examines regional ecological research related to endemic vegetation and ecosystem dynamics in western Mexico followed by an ecological and territorial diagnosis of the study area, focusing on biomes, vegetation dynamics, ecological functions, and environmental pressures affecting the Primavera Forest and the Guadalajara Metropolitan Area.

The research focuses on the Primavera Forests and its interaction with the Guadalajara Metropolitan Area, framing the forest as a regional ecological anchor affected by urban pressures. The methodology combines theoretical research, ecological diagnosis, and GIS-based spatial analysis, allowing the study to address environmental processes at both local and regional scales. This interdisciplinary approach ensures that ecological theory is translated into spatially explicit and operational planning criteria.

Collectively, these establish the conceptual foundation of the research which subsequently guide the selection of analytical tools, spatial criteria, and strategic decisions throughout the study.

This review establishes key concepts such as resilience, ecological function, connectivity, and multi-scale analysis, which guide subsequent methodological decisions.



Figure 12: Urban resilience infographic methodology.
Drawn by author.

STRATEGY

The strategy of this thesis is based on the premise that urban resilience and ecological conservation must be addressed simultaneously. Rather than treating protected natural areas and cities as separate systems, the strategy emphasizes their functional interdependence.

Focus on the forest-city interconnection, where the main goal is to create buffer zones and ecological transitional areas for the Primavera Forest in the Guadalajara metropolitan area, whilst promoting the linkage forest-city, enhancing land management, ecological conservation and urban resilience.

Micro forests and pocket forests are proposed as a nature-based solution that strengthens the ecological relationship between the city and the Primavera Forest. The pocket forests and micro forests are conceived not as isolated green space, but as ecological infrastructure embedded within the urban fabric. Strategically distributed across the city in key areas, they function as biodiversity support systems, microclimate regulators, and ecological stepping stones enhancing connectivity.

Their small scale allows for flexible implementation in vacant or underused urban spaces, while their cumulative impact contributes to a multi-scalar resilience.

At the local scale, pocket forests improve thermal comfort, air quality, and access to nature, enhancing environmental quality and social well-being for residents. Furthermore, at a urban scale a network of pocket forests would strengthen green infrastructure plus reducing the existing fragmentation of the city enhancing the urban ecosystems, and mitigating climate-related risks such as heat stress. Also, at the regional scale pocket forests function as connectivity elements that reduce pressure on the Primavera Forest and reinforce regional ecological networks.

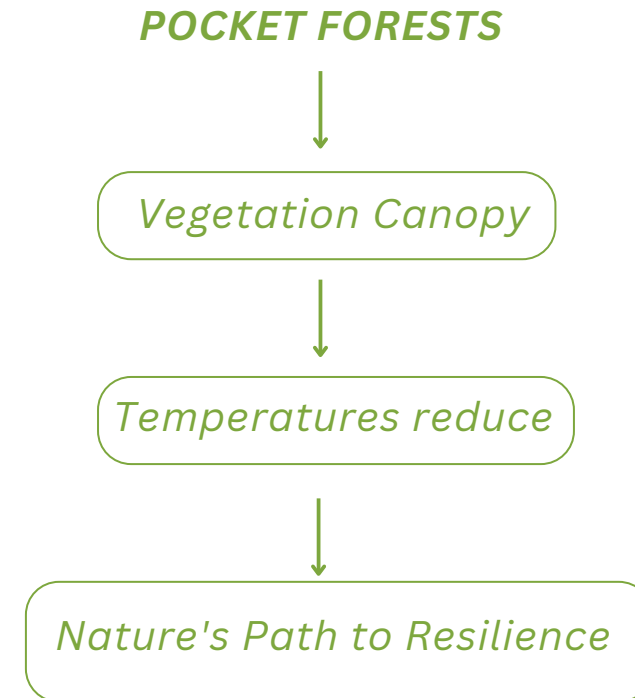
By integrating pocket forests into urban planning, the strategy enhances the adaptive capacity of Guadalajara to climate change and environmental stressors. The approach supports a shift from reactive environmental management to proactive, ecosystem-based planning.

POCKET FORESTS

A pocket forest, also known as a microforest, is a small but densely planted forest designed to create a fully functioning forest ecosystem in a limited space. These forests use a high diversity of native trees, shrubs, and groundcover plants planted close together in multiple layers to mimic how natural forests grow.

Despite their small size, pocket forests and microforests provide significant environmental benefits, including improved air quality, wildlife habitat, carbon storage, stormwater absorption, and urban cooling.

Additionally, pocket forests are designed as a nature-based solution that focus on heat-vulnerable areas to boost the health and livability of urban and suburban neighborhoods.



MAIN POINTS FOR A POCKET FOREST

- **High-Density Planting:** Saplings are planted very closely together, typically 3 to 5 plants per square meter which causes them to compete for sunlight and grow upwards rapidly, rather than outwards.
- **Native Species Selection:** The technique relies exclusively on species that are native and endemic to the area, this ensures that the plants are already adapted to local climate conditions and other stressor factors.
- **High Biodiversity:** A successful pocket forest includes a diverse mix of trees, shrubs, and understory plants, taking into consideration the different vegetation layers to create a more resilient, multi-layered ecosystem.
- **Soil Preparation:** Before planting, the soil needs to be prepared often with compost and other organic materials to improve its fertility and water retention, which is crucial for quick establishment and growth.



Picture 25: Community Forest design.
From: SuGi Project.

BENEFITS

Pocket forests method is characterized by rapid ecological establishment and high functional efficiency compared to conventional urban tree plantings. One of their most notable attributes is their accelerated growth rate, because native species are planted densely and in carefully prepared soils rich in organic matter, pocket forests can grow up to ten times faster than traditional reforestation projects.

This rapid development allows the vegetation to establish a closed canopy within a relatively short period, often within three to five years, significantly speeding up the ecological maturation of the site.

Additionally, pocket forests are planted at very high densities typically three to five saplings per square meter which creates a highly competitive yet cooperative environment among the plants.

As a result, these forests can be up to thirty times denser than conventional urban tree plantings and support substantially greater biodiversity.

Another important characteristic of pocket forests is their capacity to become self-sustaining after a short establishment period.

During the first two to three years, careful maintenance is required to manage weeds, ensure adequate watering, and allow the vegetation to develop strong root systems. After this, the forest structure becomes sufficiently stable to regulate itself, requiring minimal human intervention as natural ecological processes such as nutrient cycling, shade regulation, and soil enrichment take over. Their dense vegetation captures and stores atmospheric carbon, helping mitigate climate change, while the layered canopy structure contributes to reducing urban heat island effects through shading and evapotranspiration.

Finally, by introducing diverse native vegetation into urban environments, pocket forests create critical habitat patches that support wildlife, contributing to the restoration of urban biodiversity and ecological connectivity.

FOREST ECOSYSTEM LAYERS

Forest ecosystems are structured vertically into distinct layers that together form a complex ecological system capable of sustaining high levels of biodiversity and ecosystem functionality.

The vertical stratification of each layer results from the variation of the light availability, soil moisture, temperature, and the species adaptation, allowing different organisms to occupy the space. The layered structure of the forests is fundamental to their ability to regulate climate, support wildlife, maintain soil fertility, and stabilize hydrological processes. Understanding the ecological roles of each of these layers is particularly relevant in the design of microforests, as replicating the natural ecosystem forest stratification enhances the ecological performance even within small urban green spaces.

The canopy layer forms the primary structural continuous cover of the forest. This layer intercepts the majority of incoming sunlight and rainfall, regulating the microclimate of the forest interior.

The sub-canopy layer is consists of smaller trees located beneath the canopy layer, is essential for forest regeneration, as it contains juvenile trees that may eventually replace older trees. This layer receives filtered sunlight and maintains a more stable microclimate compared to the upper layers.

The shrub layer provides critical habitat for insects, pollinators, and small vertebrates, and plays an important role in maintaining ecological interactions such as pollination and seed dispersal.

The herbaceous layer plays a crucial role in nutrient cycling and soil health, it contributes organic matter to the soil through leaf litter and decomposition, supporting microbial activity and maintaining soil fertility.

The groundcover consists of decomposing organic material, it supports a vast community of microorganisms, it also enhances soil structure, water retention, and carbon storage, making it a critical component of long-term ecological stability.

Canopy

The canopy layer regulates microclimate, provides shade, and supports carbon sequestration, forming the structural foundation of the pocket forest.

Sub-canopy

The sub-canopy layer enhances vertical diversity, supports regeneration, and provides habitat for birds and insects.

Shrubs

The shrub layer increases biodiversity, protects the soil, and creates shelter while buffering the forest from surrounding urban activity.

Soil

This layer drives nutrient cycling, enhances soil fertility, and provides habitat essential for long-term forest resilience.

Groundcover

The groundcover layer reduces erosion, improves water infiltration, and supports soil health through organic matter accumulation.

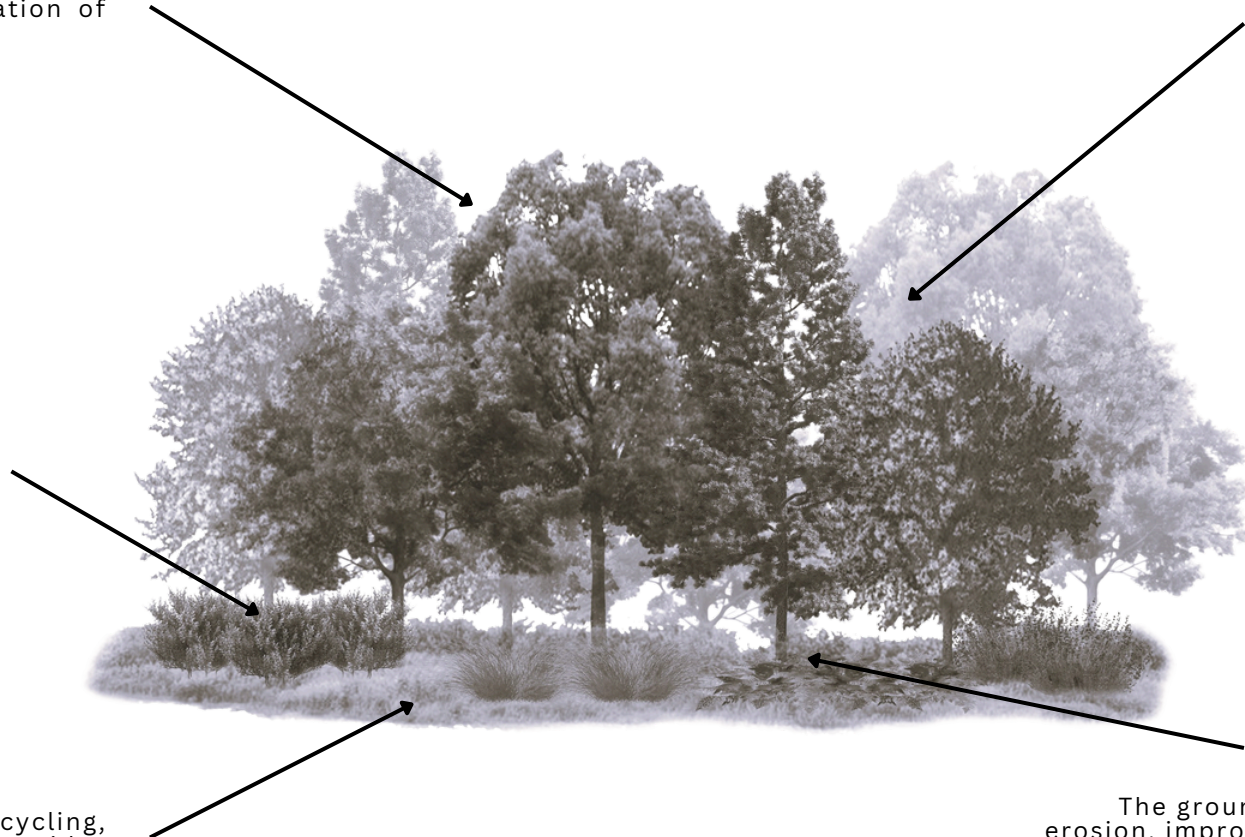


Figure 13: Forest layers, base from regenerative design group.
Drawn by author.

URBAN REFORESTATION

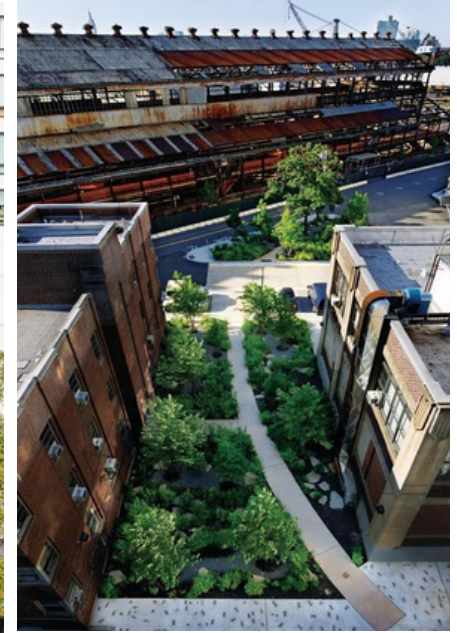
Urban resilience is a key factor for creating sustainable development in the city of Guadalajara, as it enables the city to adapt to environmental stresses while minimizing the pressure and threats on the Primavera Forest.

The microforest and pocket-forest strategy improves the quality of life, biodiversity, and mitigates the effects of the city, such as high temperatures, water absorption and quality of air and seeks to establish biological connections between the city and the forest in order to preserve biodiversity and improve the quality of life of the surrounding communities.

This strategy aims to reduce the impact of deforestation, degradation, fragmentation and loss of green spaces in the urban areas through the implementation of vegetation barriers and buffer zones in key areas such as abandoned spaces or underused areas whilst building biodiversity, climate resilience and better quality of life in communities.



Picture 20: High Line in New York. From: Adobe Stock.



Picture 21: Pocket Forest in Brooklyn. From: Chuck Choi.

Pocket Forest
=
Urban
Reforestation
↓
Urban Resilience

URBAN ECOSYSTEM SERVICES

Urbanization has significantly altered natural landscapes, often reducing vegetation cover and disrupting ecological processes.

As cities expand, the loss of natural ecosystems diminishes the capacity of urban areas to provide essential environmental functions. In response, nature-based solutions such as pocket forests have emerged as innovative strategies to reintroduce ecological processes within dense urban environments.

Despite their limited spatial extent, these systems can generate a wide range of ecosystem services that contribute to environmental quality, biodiversity conservation, and urban resilience.

One of the most significant ecosystem services provided by pocket forests is the regulation of urban microclimates. They help mitigate the heat island effect through shading and evapotranspiration processes. Vegetation intercepts solar radiation and cools the surrounding air by releasing water vapor through plant transpiration.

This dense vegetation space also provides important habitat for urban biodiversity. Urban landscapes are often highly fragmented, limiting the movement and survival of many species. By introducing dense clusters of native vegetation, pocket forests create small habitat patches that support insects, birds, pollinators, and other urban wildlife. These patches can function as ecological stepping stones that facilitate species movement between larger natural areas, contributing to greater ecological connectivity within the urban matrix.

Furthermore, they play an important role in improving air quality by capturing airborne pollutants. Although the scale of pocket forests is small, their cumulative effect can contribute to improved air quality when implemented as a distributed network throughout the city.

Finally, pocket forests also provide significant social and cultural benefits, as they can transform underutilized urban spaces into areas for environmental education, community engagement, and recreation.

CASE STUDIES

The Pocket Forests movement, which applies the Miyawaki method to create ultra-dense, biodiverse small forests in cities around the world, do not require a huge amount of space you can plant them almost anywhere, in sites as small as three 3 square meters.

These pocket forests are perfect for the fast regeneration of urban areas, this method has transformed school playgrounds, city parks, and urban rivers from grey to green.

“Bosque de Neza” in Mexico city represents one of the first pocket forests implemented in Mexico using the Miyawaki method.

In a previously barren area near the Nezahualcóyotl University, around 1,500 trees of 36 native species were planted in 600 square meters to help combat the heat island effect, improve infiltration and soil quality, increase biodiversity, and enhance local resilience to climate stressors. This part of the city suffers from a shortage of green spaces and is one of the most affected by the city’s heat island effect.

The proposed design for the pocket forest envisions a circular green space strategically located in an underutilized and arid area, adjacent to a sports field and the university campus. By incorporating 25 native species tolerant of salinity, the design improves soil quality and promotes biodiversity under high-salinity conditions.

It will create a self-sustaining ecosystem that supports local wildlife, provides a vital green refuge for the community, and mitigates the urban heat island effect. This natural “lung” also improves air quality and promotes the overall well-being of the community.



Picture 22 & 23: Sugi Forest in Mexico city location and design.
From: SuGi Project.

The Queanbeyan Community Forest is a project in New South Wales that demonstrates how grassroots activism can solve complex urban environmental issues. Located in the suburb of Karabar, this project was born from a direct need to protect the community against heat island effects, where hard surfaces like asphalt and roofs trap heat, making the neighborhood significantly hotter than surrounding rural areas.

The community decided to start a crowdfunding campaign to develop a community forest for the neighborhood, which consisted in transforming a 526 m² underutilized plot into a resilient environment to reduce the heat island effect in an area. as it was facing extreme temperatures.



Picture 24: Community Forest in Australia.
From: SuGi Project.

By planting 1,500 native species, the project acts as a natural air conditioner, reducing ground temperature and enhancing urban biodiversity by attracting native wildlife. It also offers a space for recreation and environmental education, serving as a model of participatory restoration funded and executed by the community.

This project serves as a blueprint for other Australian suburbs, proving that even a small, neglected plot of land can be transformed into a high-functioning ecosystem that improves public health and restores nature.



Picture 25: Community Forest design.
From: SuGi Project.

LANDSCAPE PRINCIPLES

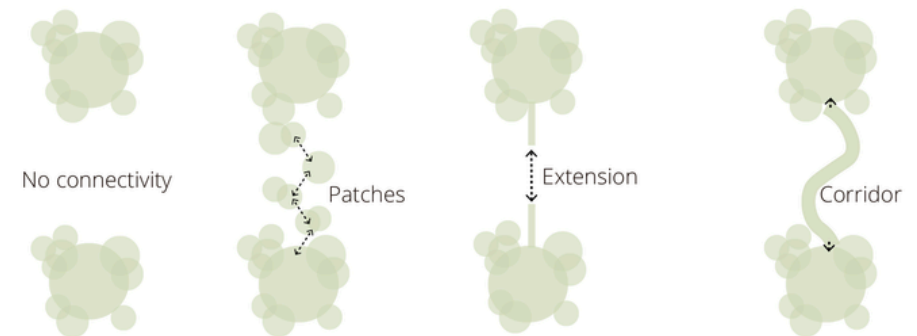
Landscape principles describe the fundamental patterns and relationships that shape how land is organized and how ecosystems function, including elements such as mosaics, matrices, patches, edges, and corridors.

These principles help us understand how natural and human-designed landscapes are structured, how different areas interact, and how plants, animals, water, and energy move across space. Understanding landscape principles is important because it allows planners, designers, and ecologists to create and manage landscapes that are healthier, more resilient, and more functional.

By applying these principles, we can improve biodiversity, reduce environmental impacts, support wildlife movement, manage resources more effectively, and design spaces that balance ecological health with human needs.

Ecological Strategies

Figure 14



Patch-corridor-matrix connectivity

Figure 15

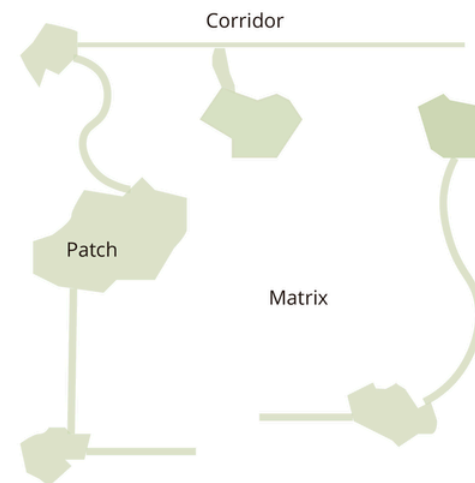


Figure 13 & 14: Landscape Principles.
Drawn by author.

01

Mosaics



A landscape's overall structural and functional integrity, it can be understood and evaluated depending on its scale as well as its pattern.

02

Matrix



Different elements designed to emulate the look and function of a natural ecosystem found in the wild. They can be single or subdivided, variegated or homogenous, continuous or perforated.

03

Patches



An area that differs greatly from its surrounding environment in terms of structure and function. They can be large or small, round or elongated, few or numerous, dispersed or clustered.

04

Edges



The outer portion of a patch where the environment and structure varies significantly from the interior. Its composition, abundance, and condition in species differs. They can be curvilinear or straight.

05

Corridors



The interconnection with one or more patches to create networks, enclosing other landscape elements. They can be narrow or wide, straight or curvy, continuous or disconnected.

CHAPTER 04

THE PROJECT: ANALYSIS AND DESIGN IMPLEMENTATION

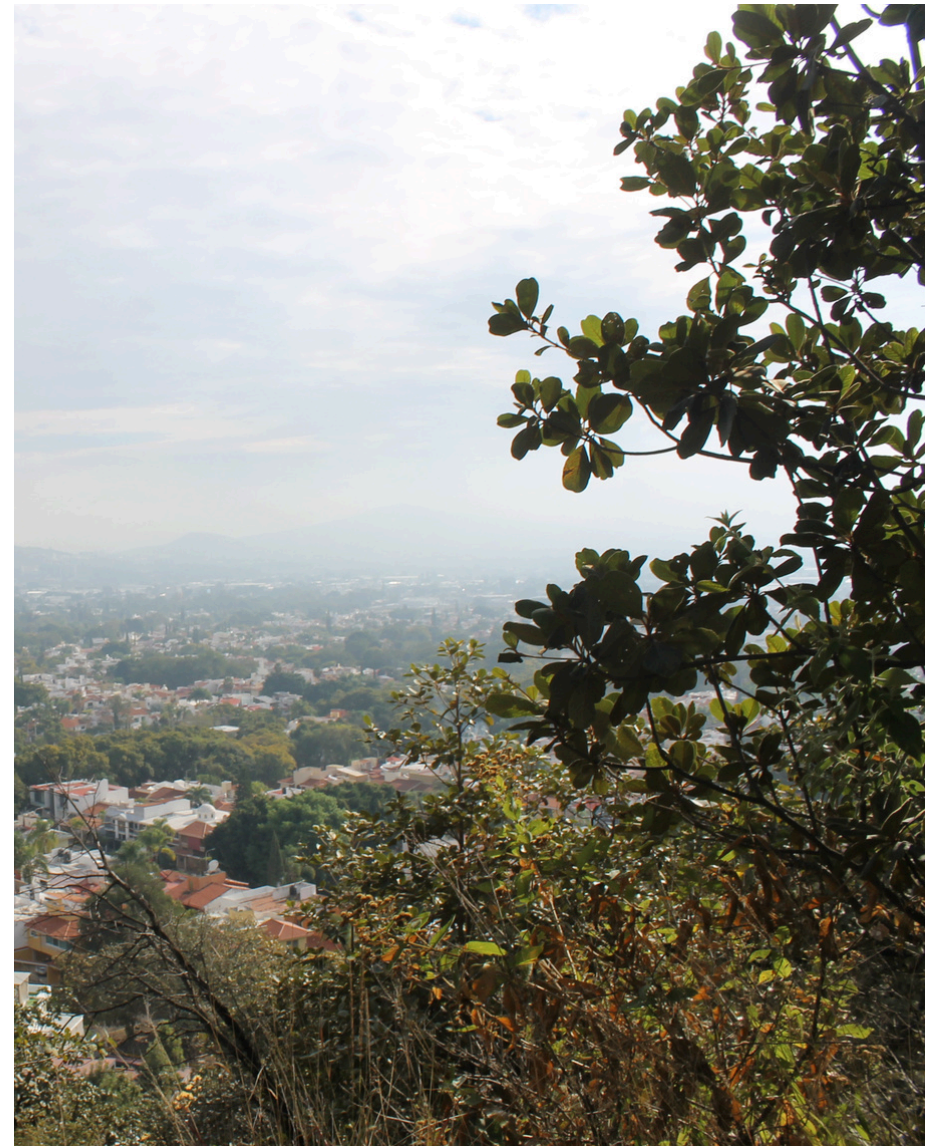
SITE SELECTION CRITERIA

The selection of the site is a critical component of the proposed methodology. Pocket forests should be strategically located around the site to maximize ecological and resilience benefits.

The site selection criteria includes:

- Proximity to existing green spaces
- Location within urban heat islands
- Availability of underutilized or vacant land
- Proximity to the Primavera Forest
- Potential to function as ecological stepping stones in the area.

This strategy helps and supports the development of green network that helps and potentializes a buffer and transitional area for the Primavera Forest.



Picture 28: View to the city from the Primavera Forest.
From: Author.

POSSIBLE SCENARIOS

Public spaces



Underused areas



STRATEGIC AREA

A highly suitable area for implementing the pocket forest methodology is the western part of the city particularly along the urban-forest edge adjacent to the Primavera Forest. This zone represents a critical transition area where urban expansion, fragmented green spaces, and residual natural elements intersect, creating both ecological pressure and opportunity.

The western peri-urban interface of the Guadalajara Metropolitan Area was selected as a priority zone for pocket forest implementation due to its proximity to Primavera Forest, and to existing isolated green infrastructure, and its potential to function as a buffer and connectivity zone within a regional ecological network.



Picture 26: Ciudad Granja neighborhood.
From: Más por más.

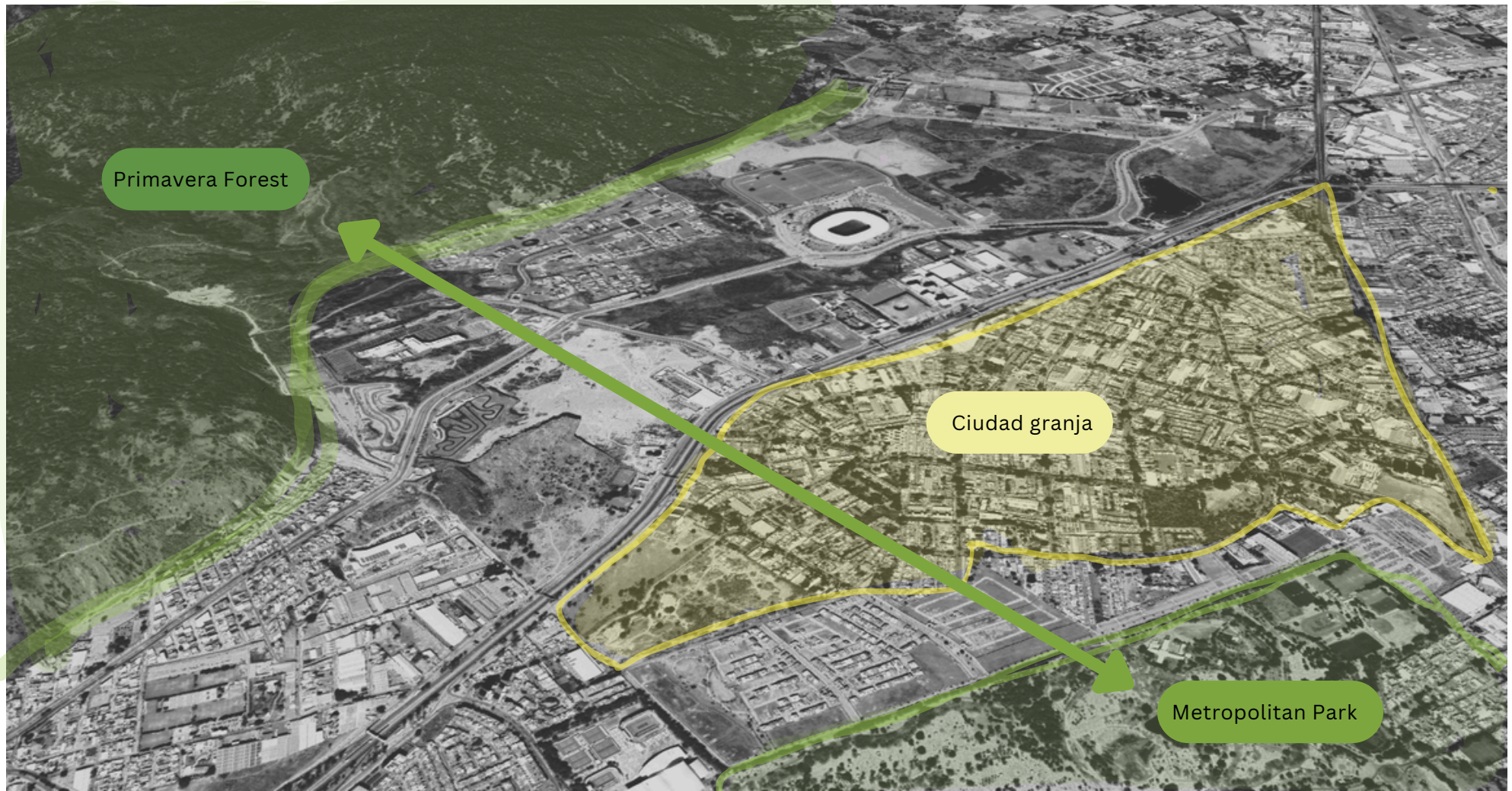
Furthermore, a priority area for the pocket forest implementation was identified in the western sector of Zapopan, particularly within the neighborhood of Ciudad Granja along with potential avenues that may work as major corridors such as Avenida Vallarta, Avenida Aviación, Mariano Otero, and Anillo Periférico Poniente.

These areas were selected due to their proximity to the Primavera Forest and the presence of fragmented and isolated green spaces which have a potential environmental impact to function as ecological stepping stones within the metropolitan area.



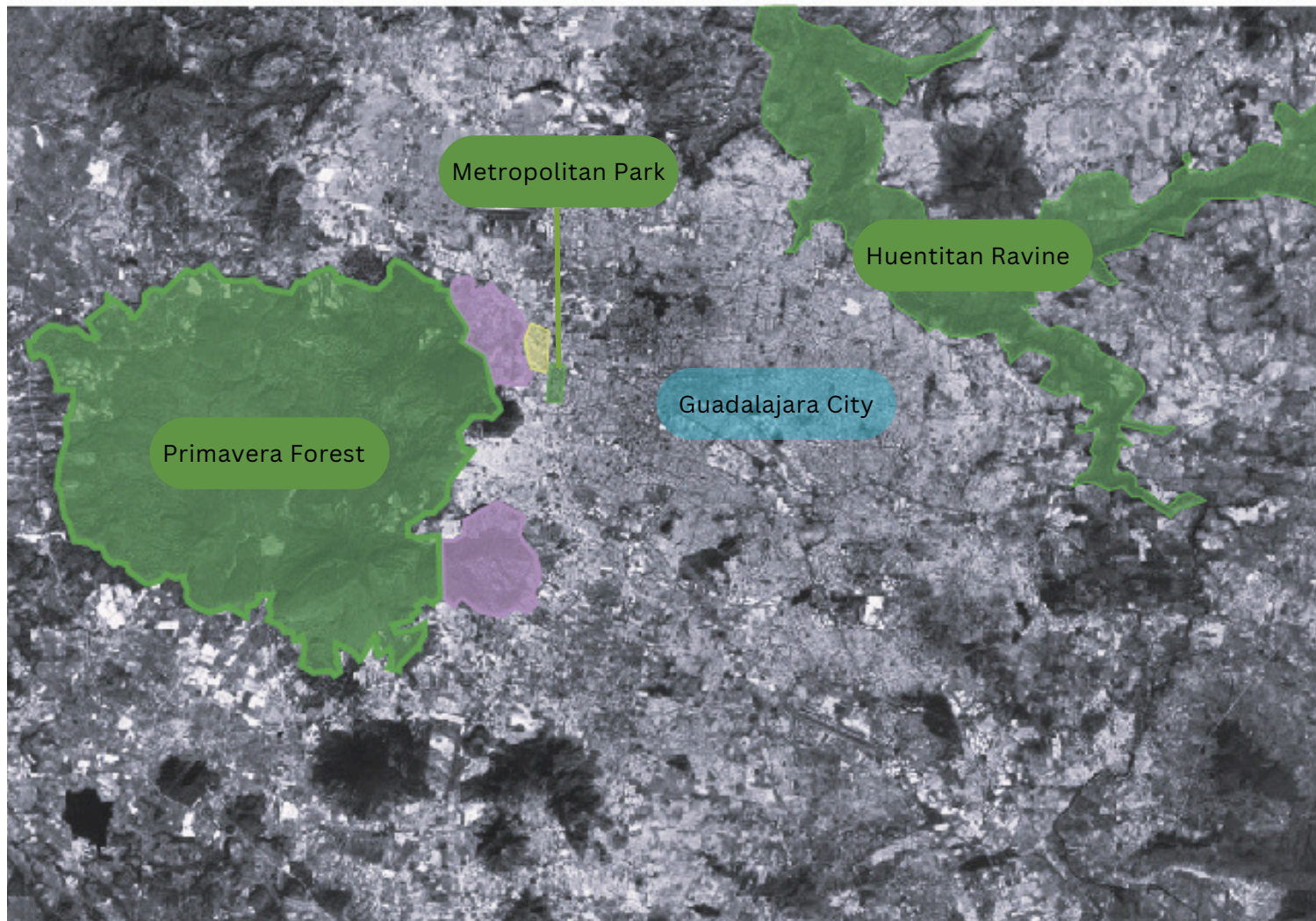
Picture 27: Metropolitan Park view from above.
From: Visita GDL.

TRANSITIONING POINT



The ciudad granja neighborhood is situated in a area where the Metropolitan Park can act as a potential stepping stone for the Primavera Forest.

ANALYSIS



LEGEND

- Vulnerable area
(perimeter of the forest)
- Ciudad Granja neighborhood
(Area of interest)

The study area includes the Guadalajara Metropolitan Area, with particular emphasis on the western and peri-urban zones that interface with the Primavera Forest. This area is characterized by rapid urban expansion, fragmented green spaces, and increasing exposure to environmental stressors.

The selected area is located in a key part of the city with a proximity to the Primavera Forest and next to one of the most important public parks of the city.

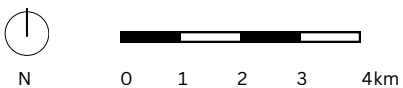
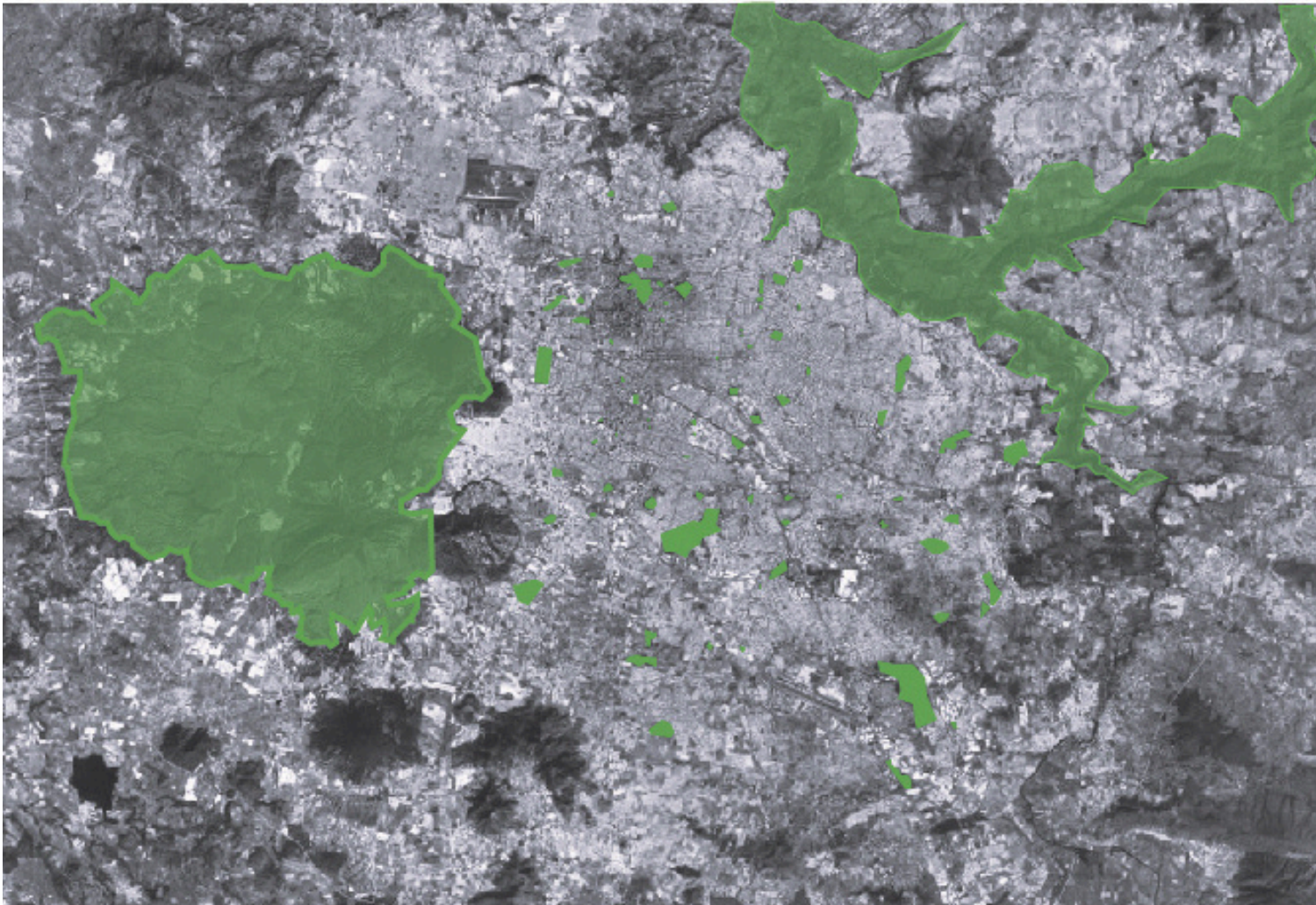


Figure 16: Context of the site area
Drawn by author.

EXISTING GREEN AREAS



N



0 1 2 3 4km

Figure 17: Existing green areas of the GMA
Base from CONABIO Portal, drawn by author.

LAND USE

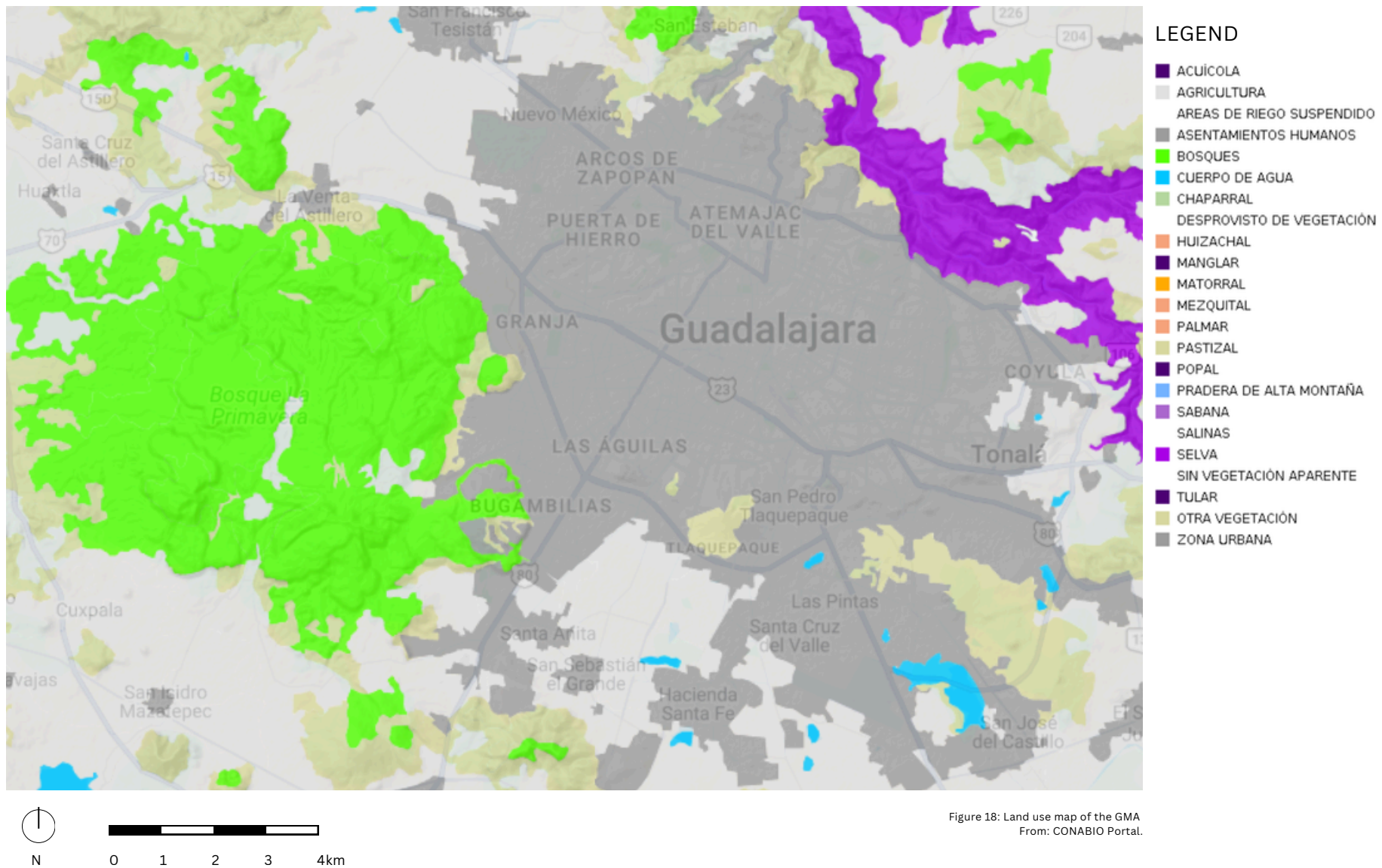
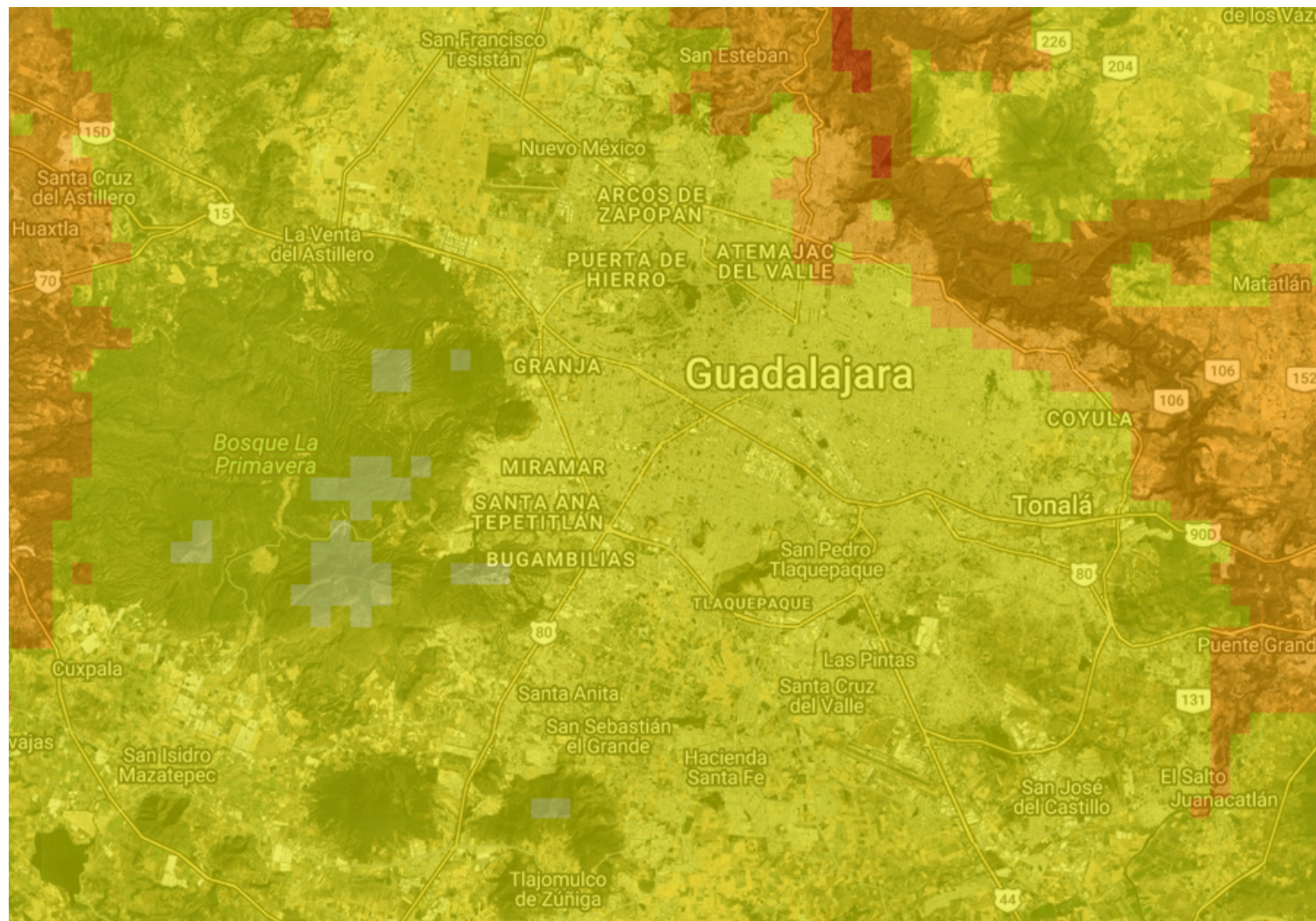


Figure 18: Land use map of the GMA
From: CONABIO Portal.

TEMPERATURE



LEGEND

Average maximum temperature

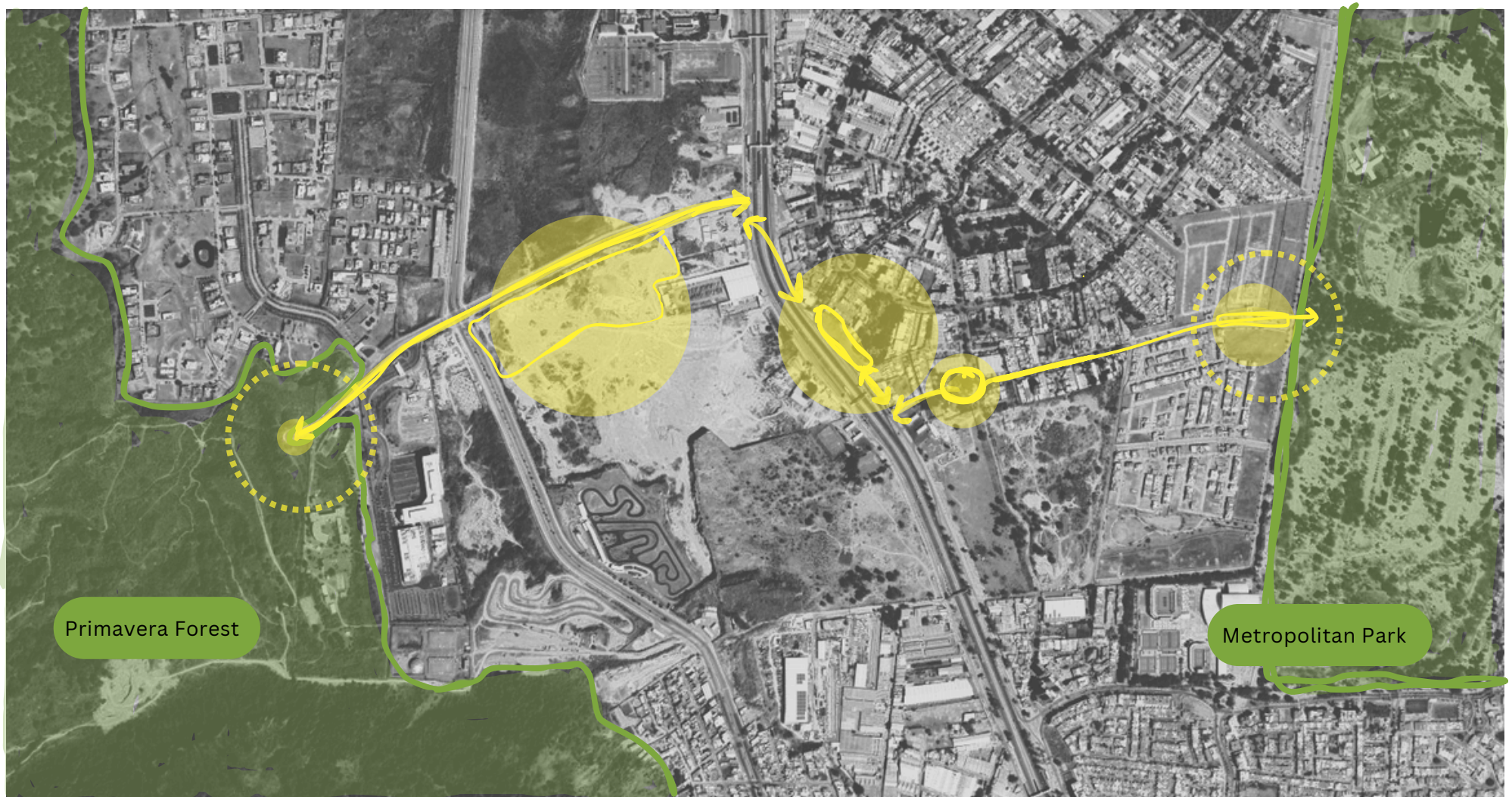
- 20 - 24
- 24 - 28
- 28 - 32
- 32 - 36
- 36 - 40

As seen in the map, Guadalajara suffers from the heat island effect, and the temperature seems to be rising with each year.



Figure 19: Average temperature of the GMA map.
From: CONABIO Portal.

CONNECTIVITY



Different underused or green spaces were chosen in the neighborhood of Ciudad Granja or next to it to work as connecting extensions.

GREEN NETWORK



POCKET FORESTS FOR RESILIENCE



Picture 29: Pocket Forest. From: SuGi Project.



Picture 30: Pocket Forest. From: SuGi Project.

Minimal size for pocket forest self-sustained

100 m² is the minimum size for a pocket forest to establish, survive, and self-sustain.

It can be smaller but it has to have a careful species selection, soil preparation, and maintenance, especially in harsh urban conditions. Smaller patches are more vulnerable to stress, drought, and human disturbance.

Optimal size pocket forest for RESILIENCE

200+ m² is the minimum size for a pocket forest to establish, survive, and self-sustain.

From 200+ m² a microforest strats to:

- Create own microclimate
- Reduce heat, wind, noise
- Support groundcover
- Maintain higher soil moisture and biodiversity
- Become self-maintaining after 2–3 years

VEGETATION STRATEGY

The vegetation selection prioritizes native and endemic species associated with the Primavera Forest and the western Mexico region. This strategy enhances ecological compatibility, supports local biodiversity, and reinforces the forest's role as a genetic and ecological reference system.

- Regional ecological reference: Primavera Forest

The goal is to replicate ecological functions, not recreate the forest exactly.

Key vegetation types:

- Native to western region of Mexico
- Present in the Primavera Forest
- Adapted to urban context
- High ecological value



Picture 31: Pocket Forest. From: SuGi Project.

Pocket forests should select species adapted to the regional climate, soils, and disturbance regimes.

VEGETATION SELECTION

The selection of the vegetation for pocket forests was guided by the ecological characteristics of the Primavera Forest as a regional reference system, prioritizing native and endemic species adapted to the climate and the existing disturbance conditions of the city of Guadalajara.

Different species were selected taking in to consideration the multiple vertical strata and functional roles, ensuring ecological resilience, low maintenance requirements, and compatibility with urban environments.

For the selection of the vegetation it was take into consideration different species that were adapted to the regional climate, soils, and disturbance regimes, especially drought and fire which are some of the main stressors that the vegetation of the city faces. The main goal is to replicate the ecological functions of the forest, not to recreate the forest exactly.

The Primavera Forest was taken as a reference for the ecological system.

Key vegetation types in La Primavera:

- Pine-oak forest
- Tropical deciduous forest
- Secondary forest and shrubland

Also, for the vegetation selection it was consider various factors of the region, such as:

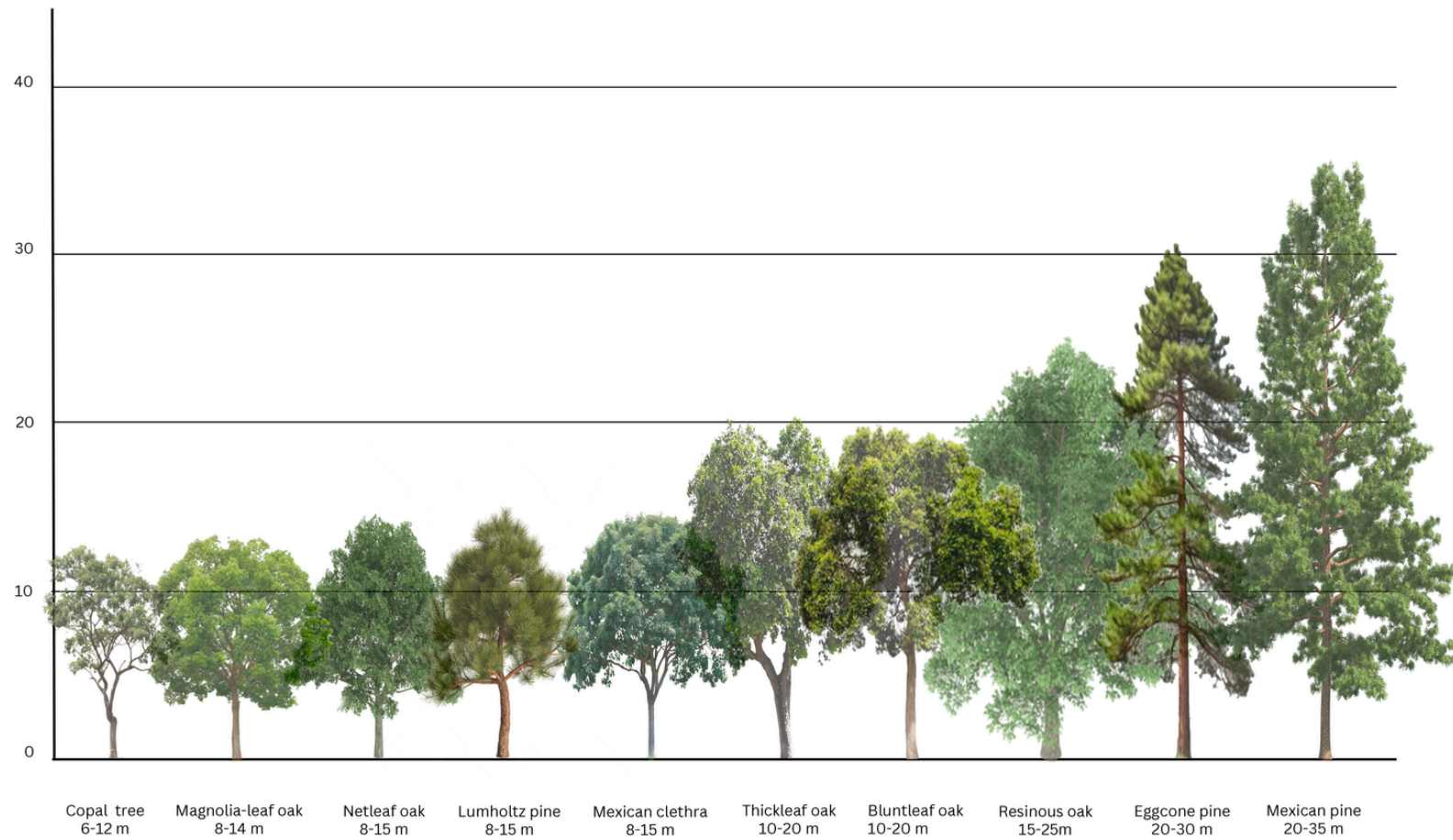
- Soil type (volcanic, compacted, shallow)
- Sun exposure
- Water availability
- Fire resistant species
- Drought-tolerant species
- Avoid species requiring deep soils or permanent moisture

VEGETATION LAYERS

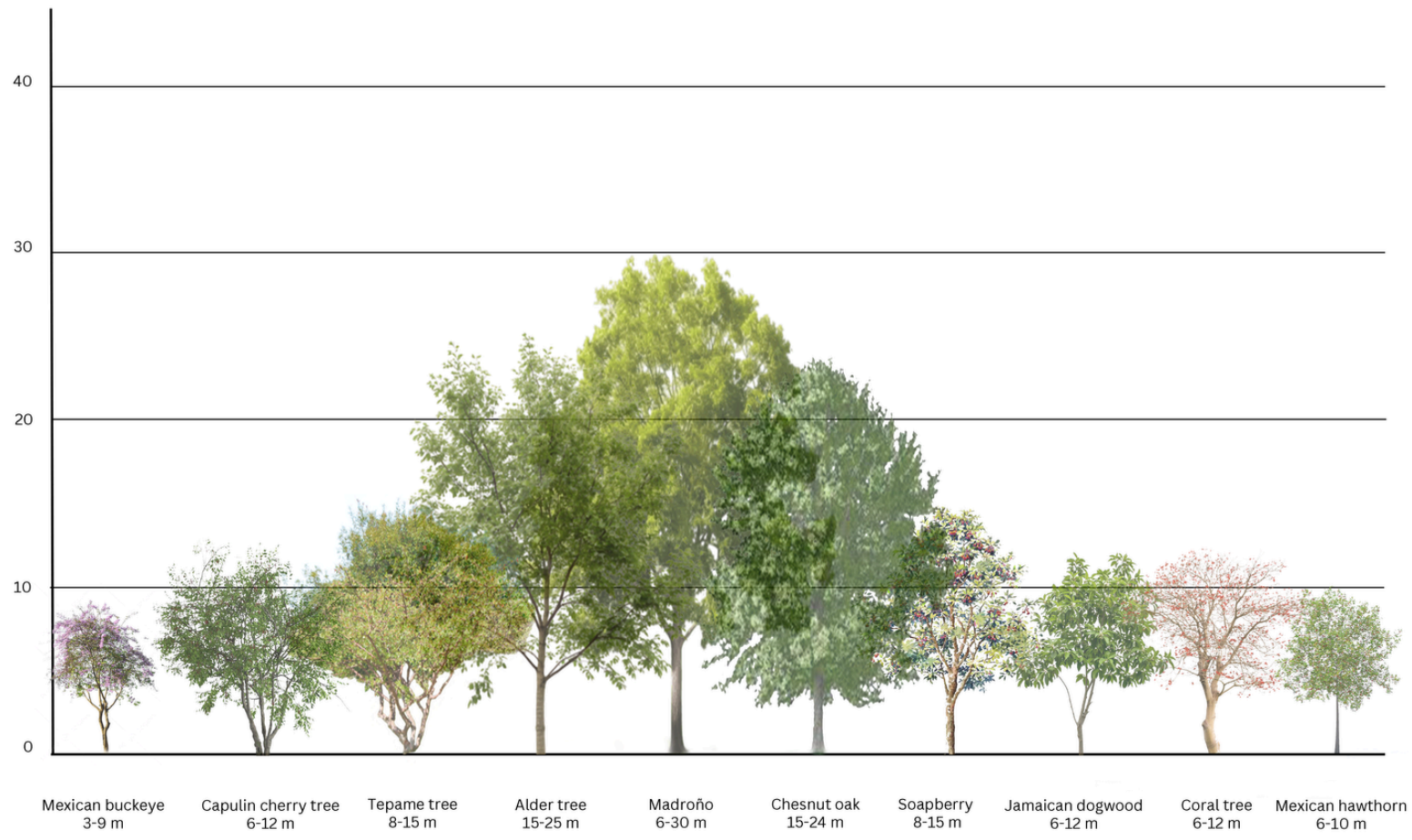


VEGETATION CATALOG

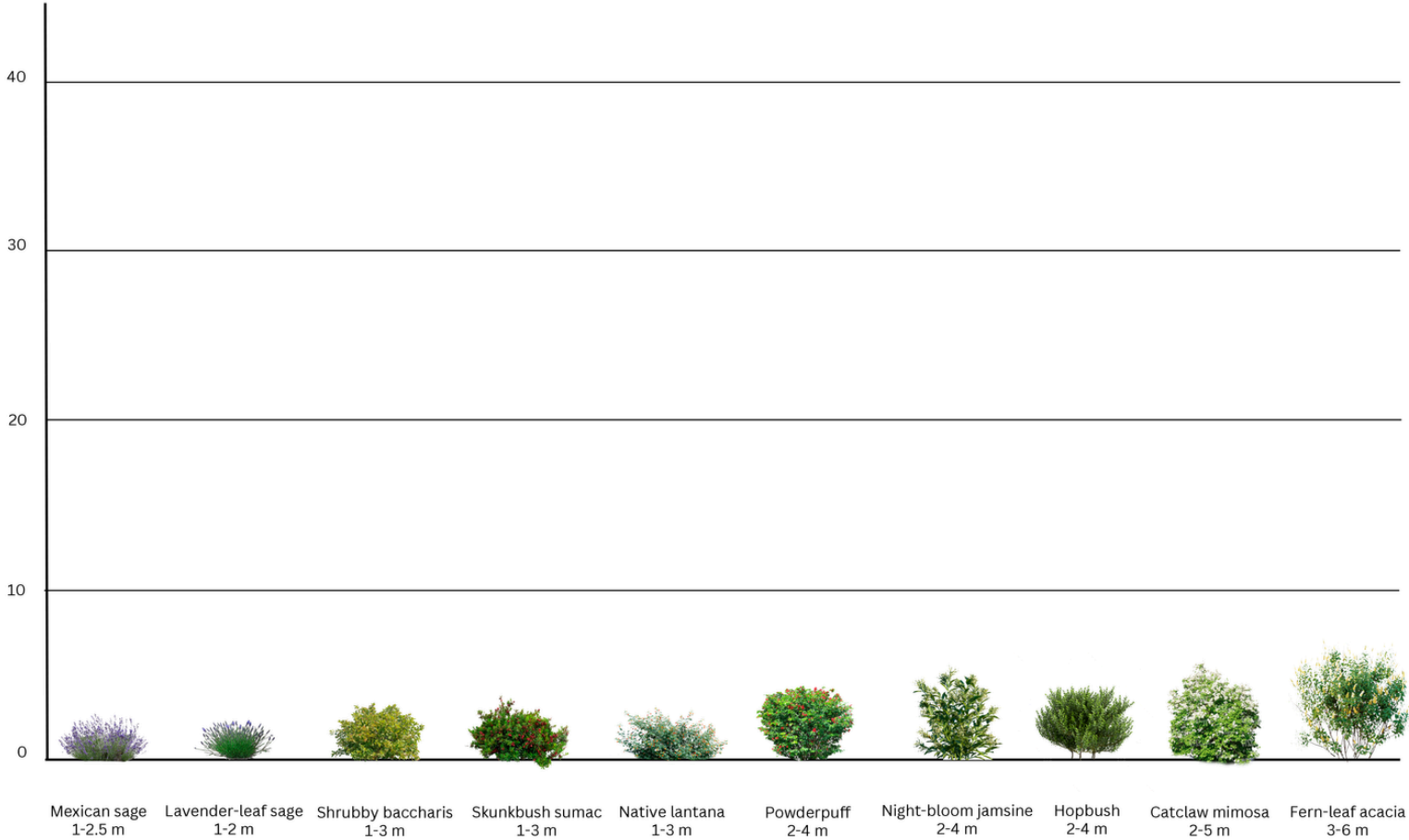
Canopy Layer- Dominant trees



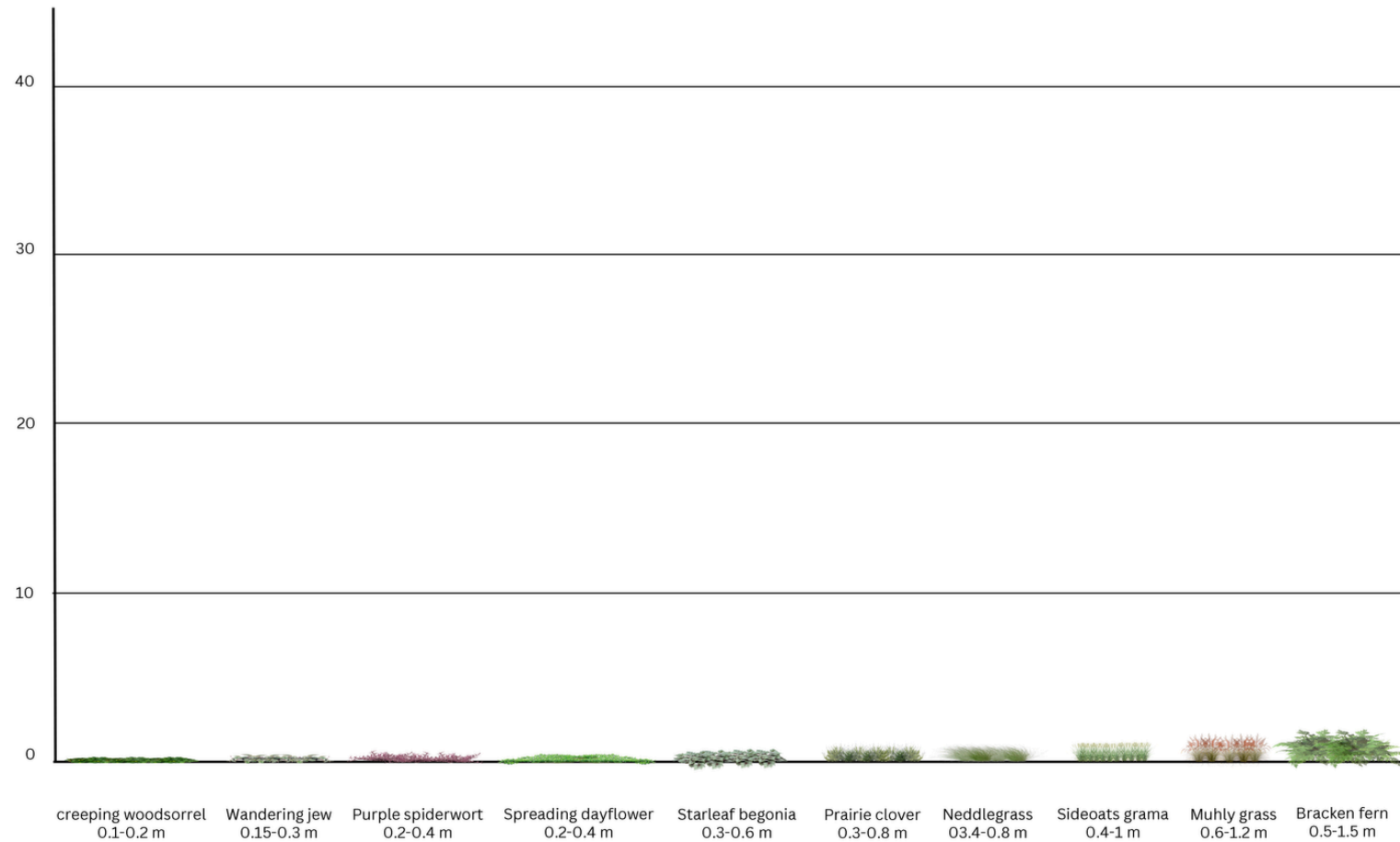
Sub-canopy Layer: Midstory tress



Shrub Layer



Groundcover Layer: (herbaceous plants, grasses, ferns)



VEGETATION CHOICE

Canopy layer

- Resinous oak- *Quercus resinosa*
- Mexican red oak- *Quercus castanea*
- Mexican yellow pine- *Pinus oocarpa*

Sub-canopy / small trees

- Strawberry tree- *Arbutus xalapensis*
- Tepame- *Lysiloma acapulcense*
- Mexican hawthorn- *Crataegus mexicana*

Shrub layer

- Mexican salvia- *Salvia leucantha*
- Hopseed Bush- *Dodonaea viscosa*
- Sensitive plant- *Mimosa pudica*

Groundcover / herbaceous

- Sideoats grama- *Bouteloua curtipendula*
- Needlegrass- *Aristida barbata*
- Bracken fern- *Pteridium aquilinum*

This vegetation was chosen because its low maintenance, tolerance to urban stressors, and high ecological value.



Picture 32,33,34, 35 & 36: Vegetation choice. From: Adobe Stock.

ECOSYSTEM NETWORKS

Ecosystem networks refer to spatially connected systems of natural and semi-natural areas that function collectively to sustain ecological processes, biodiversity, and ecosystem services across landscapes. Rooted in landscape ecology theory, ecosystem networks emphasize the importance of connectivity between habitat patches, corridors, and matrix elements to counteract the negative effects of habitat fragmentation. Rather than viewing ecosystems as isolated units, this approach recognizes landscapes as dynamic mosaics.

In urban and peri-urban contexts, ecosystem networks are particularly relevant due to the high degree of land-use fragmentation and ecological disruption caused by the dense development of the city, which has led into the importance of establishing functional ecological networks within cities for maintaining biodiversity, ecosystem services, and enhancing urban resilience due to the different environmental stressors and climate change.

The base of ecosystem networks lies in the conservation of existing high-value ecosystems. Protected natural areas, forests, wetlands, and recharge zones must be preserved and effectively managed to maintain their ecological integrity. In regional systems, these key areas act as biodiversity reservoirs and sources of ecological processes that extend beyond their boundaries.

In dense urban fabrics where large corridors are not possible, small-scale interventions play a crucial role. Pocket forests, urban parks, green roofs, and community gardens can function as stepping stones that reduce isolation between habitat patches and can make a huge impact on specific areas in a smaller scale. Although individually limited in size, their strategic distribution significantly improves landscape permeability and supports species movement, pollination, and seed dispersal.

POCKET FORESTS AS POTENTIATORS

Microforests can act as functional nodes in green networks, they function primarily as ecological nodes or stepping stones. When strategically located, they enhance landscape permeability by reducing distances between larger green spaces, such as urban parks, green corridors, and protected natural areas.

By increasing functional connectivity, microforests help transform fragmented urban green spaces into cohesive ecological networks. This network-based configuration is essential for maintaining ecological processes across different scales and for sustaining biodiversity within urban regions.

Through green network environmental conditions within the urban fabric can improve and help to reduce the impact of indirect pressures on the Primavera Forest, such as recreational overuse, land-use change, and ecological isolation.

Furthermore, pocket forests can function as conservation and buffer zones for the regional ecosystems, promoting ecological awareness and reinforcing local identity tied to the forest. This multi-scale approach positions the Primavera Forest as a key conservation area supported by a network of smaller ecological systems interventions throughout the metropolitan area.

CONTRIBUTION TO URBAN RESILIENCE

From an urban resilience perspective, pocket forests contribute to Guadalajara's adaptive capacity by:

- Reducing local temperatures and mitigating heat island effects.
- Improving air quality and carbon sequestration.
- Enhancing stormwater management and soil infiltration.
- Supporting urban biodiversity and habitat connectivity.
- Distributing ecological functions across the city, reducing reliance on a single protected area.

These benefits directly complement the ecosystem services provided by the Primavera Forest, reinforcing its role within a regional ecological network.

The dynamic interaction between endemic vegetation and environmental processes in the Primavera Forest highlights the importance of integrating ecological knowledge into urban planning. By maintaining functional vegetation systems at both local and regional scales, cities like Guadalajara can enhance resilience to climate change, reduce environmental risks, and support long-term biodiversity conservation.



Picture 37: Pocket Forest installation in Italy.
From: Jacopo Gennari.

DESIGN PROPOSAL

From an urban resilience perspective, pocket forests contribute to Guadalajara's adaptive capacity by:

- Reducing local temperatures and mitigating heat island effects.
- Improving air quality and carbon sequestration.
- Enhancing stormwater management and soil infiltration.
- Supporting urban biodiversity and habitat connectivity.
- Distributing ecological functions across the city, reducing reliance on a single protected area.

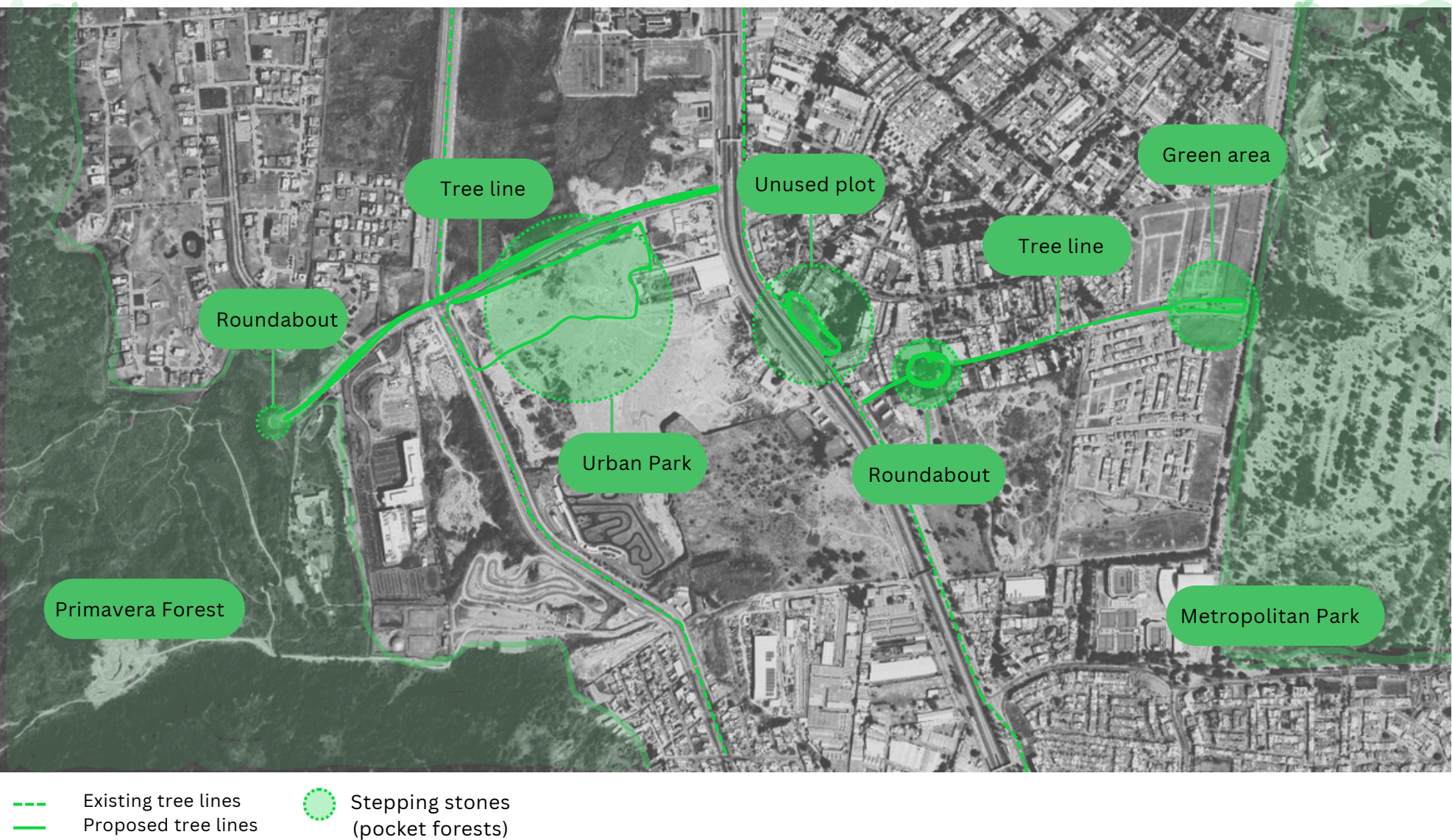
These benefits directly complement the ecosystem services provided by the Primavera Forest, reinforcing its role within a regional ecological network.

The dynamic interaction between endemic vegetation and environmental processes in the Primavera Forest highlights the importance of integrating ecological knowledge into urban planning. By maintaining functional vegetation systems at both local and regional scales, cities like Guadalajara can enhance resilience to climate change, reduce environmental risks, and support long-term biodiversity conservation.



Picture 37: Pocket Forest installation in Paris.
From: Sfera project.

STEPPING STONES



POCKET FORESTS CASE 01



- Existing tree lines
- Proposed tree lines
- Pocket forest



Collage roundabout pocket forest



Floor Plan pocket forest and tree line

POCKET FORESTS CASE 02



- Existing tree lines
- Proposed tree lines

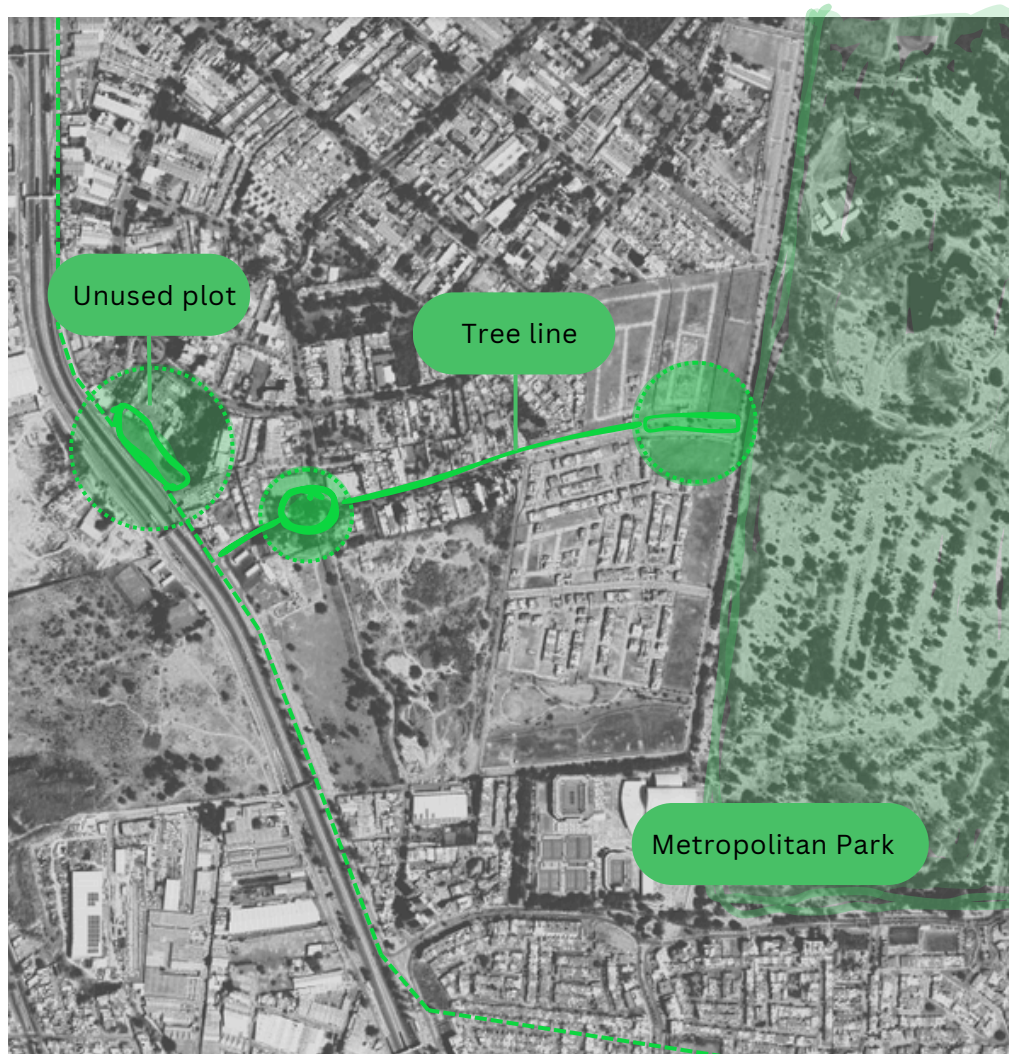


Collage Urban park view



Floor plan urban park

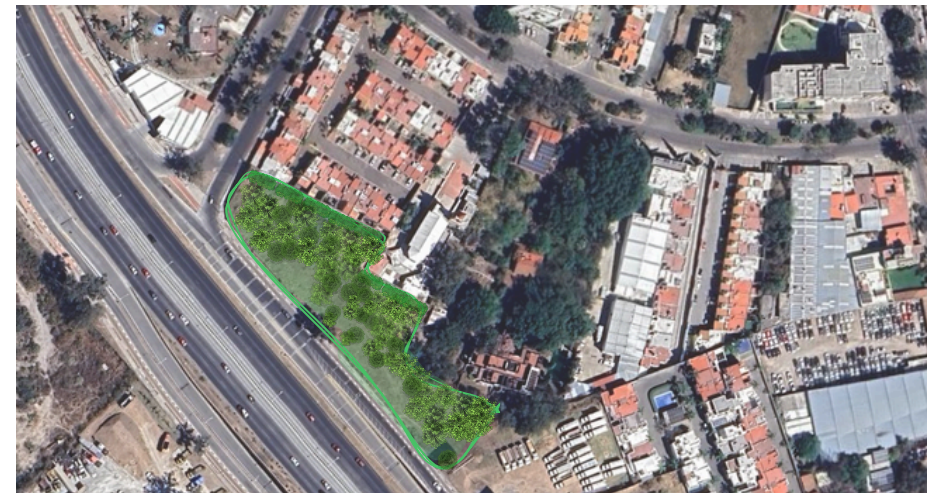
POCKET FORESTS CASE 03



- Existing tree lines
- Proposed tree lines
- Stepping stones (pocket forests)

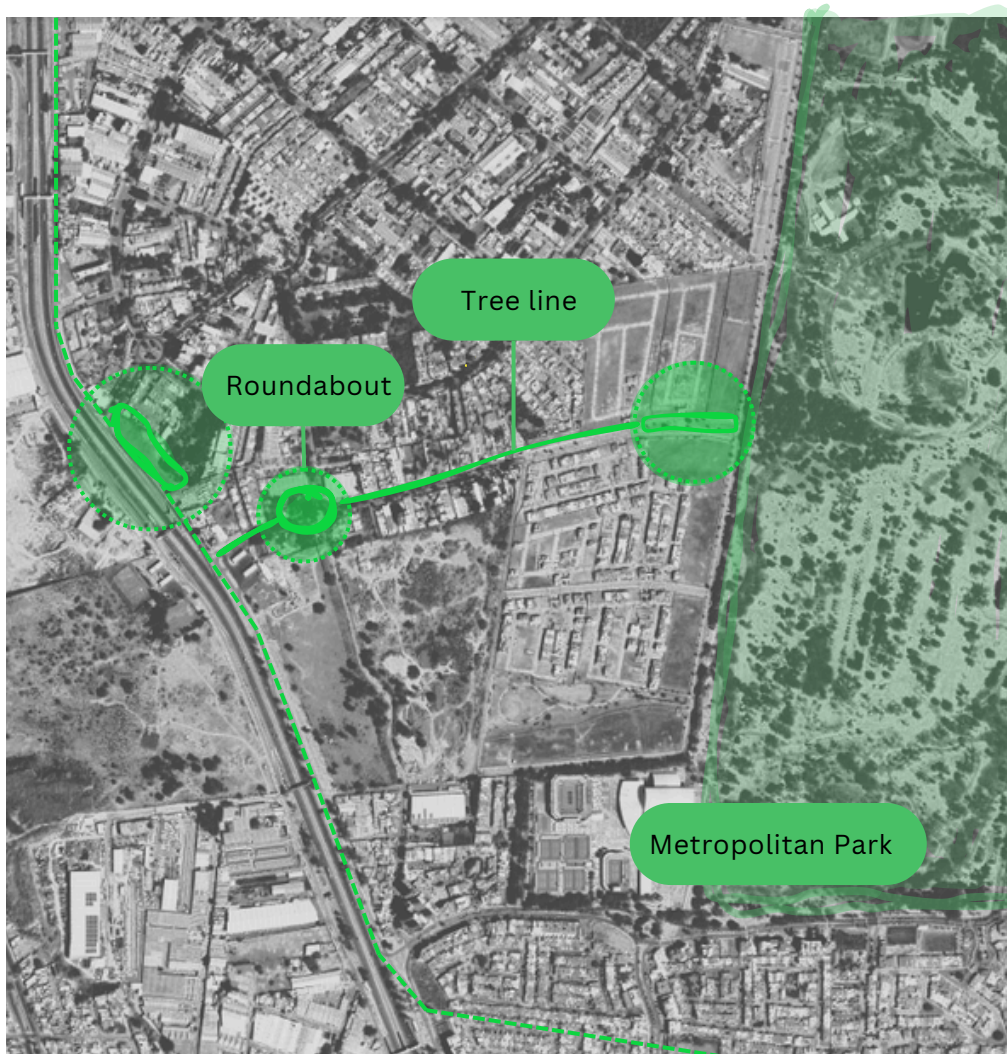


Unused plot collage view



Floor plan unused plot

POCKET FORESTS CASE 04



- Existing tree lines
- Proposed tree lines
- Stepping stones (pocket forests)

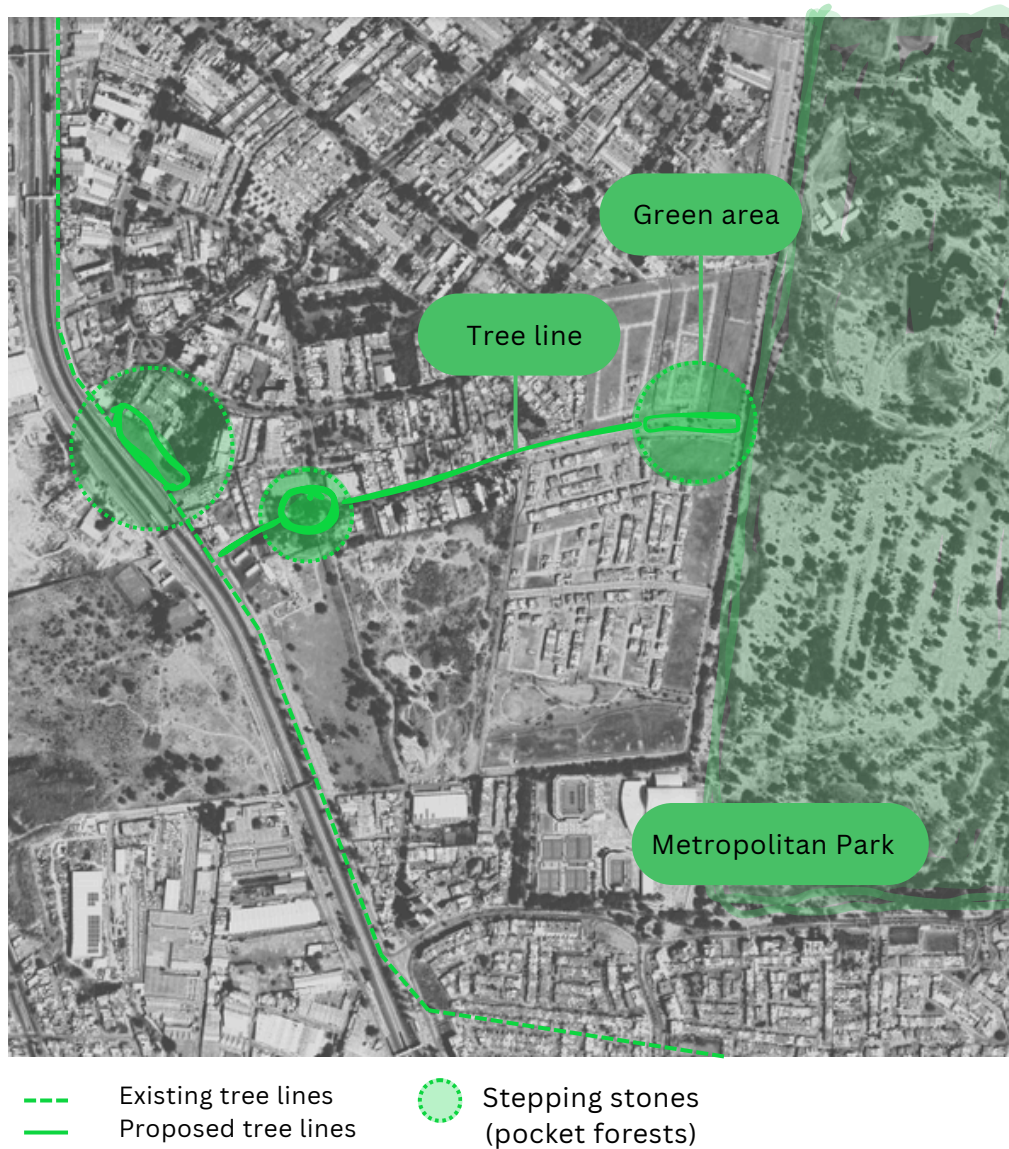


Collage roundabout pocket forest



Floor Plan pocket forest and tree line

POCKET FORESTS CASE 05



Collage green area pocket forest



Floor Plan pocket forest

TREE LINE CASE 06



- Existing tree lines
- Proposed tree lines
-



Collage tree line view



Floor plan tree line

EXPECTED IMPACTS

The implementation of microforests in the Guadalajara metropolitan area is expected to generate ecological, climatic, and social impacts that collectively contribute to urban resilience.

Due to their dense vegetation structure and strategic placement within the urban fabric, microforests function as high-efficiency nature-based solution capable of delivering ecosystem services at a local scale while reinforcing green networks at a regional scale.

From an ecological perspective, microforests are expected to increase urban biodiversity by providing habitat and food resources for various fauna and flora species. The use of native and regional vegetation helps pollinators, birds, and small fauna, contributing to the local species presence and ecological interactions within fragmented urban environments. These impacts can be assessed through indicators such as changes in species richness and abundance.

Microforests are also expected to play a significant role in urban climate regulation, particularly in mitigating urban heat island effects. Through shading and reducing temperatures, these densely vegetated patches can lower ambient and surface temperatures in their immediate surroundings. Indicators for this impact include measured temperature differentials between microforest sites and adjacent built areas.

Beyond ecological and physical processes, microforests generate important social benefits by increasing access to nature within residential neighborhoods. Proximity to green spaces has been associated with improved mental well-being, stress reduction, and enhanced quality of life. Microforests also support community engagement and environmental awareness by serving as visible, participatory green interventions.

PERFORMANCE INDICATORS

While pocket forests offer significant benefits, some of the indicators of success can be reflected in the integration of nature into peri-urban environment, the strengthening of existing ecosystem services, connectivity improvement and the reduction of vulnerability to fires, climate change, urbanization and other stressors.

Some of the ecological indicators include changes in species richness and abundance, habitat complexity. In the climatic performance can be measured through the reductions in air temperatures, increased relative humidity, and localized mitigation of urban heat island effects.

Social impacts may be evaluated through indicators of access to green space and usage frequency.

At a general level, the urban resilience can be assessed through indicators of green network connectivity, node density, ecosystem service coverage, and redundancy within the urban green infrastructure network.



Picture 38: Metropolitan park.
Author: Hotel lindo.

CONCLUSION

The implementation of pocket forests as a methodological proposal represents a viable and strategic approach to enhancing urban resilience and biodiversity within the dense urban environment of the city of Guadalajara while supporting the long-term preservation of the Primavera Forest.

As demonstrated throughout this research, these small but structurally complex vegetation patches can function as ecological stepping stones that contribute to the restoration of fragmented urban ecosystems. By integrating dense, native-species micro-forests into the urban landscape, it can strengthen ecological connectivity, distribute ecosystem services, and build adaptive capacity in the face of environmental change.

This methodology demonstrates how small-scale interventions can contribute meaningfully to regional ecological sustainability when embedded within a comprehensive planning framework.

By replicating the structure of the forest and utilizing native vegetation, pocket forests provide habitat for urban fauna, enhance ecosystem services, and improve environmental conditions within cities.

However, while the pocket forest technique offers a valuable tool for urban ecological restoration, it should take into consideration the broader strategy aimed at improving urban ecological connectivity. One of the main limitations of pocket forests lies in their small scale. Although they support biodiversity and facilitate species movement across fragmented landscapes, their ecological impact becomes significantly greater when integrated into a larger network of green infrastructure.

For this reason, urban resilience strategies should also incorporate complementary landscape interventions that strengthen connectivity at multiple spatial scales.

Another opportunity for improvement involves the restoration and protection of existing natural features within the Guadalajara metropolitan area. Vegetation patches often function as hidden ecological corridors within cities but are frequently degraded or disconnected due to the ongoing urban growth of the city.

Furthermore, strengthening these systems through ecological restoration, soil rehabilitation, and vegetation management can significantly enhance urban ecological networks.

In the case of Guadalajara, protecting and restoring natural corridors that connect with the Primavera Forest would be particularly important for maintaining regional ecological connectivity and biodiversity.

Urban planning policies also represent a critical area for improving ecological connectivity. Land-use regulations that prioritize green infrastructure, limit urban sprawl near protected natural areas, and encourage the integration of vegetation into peri-urban and urban areas can help reinforce ecological services in the city.

Planning instruments that incorporate ecological networks into urban development strategies can help ensure that green spaces function as interconnected systems rather than isolated patches.

Finally, the long-term success of ecological interventions depends not only on design strategies but also on governance and community participation. Encouraging citizen involvement can foster environmental awareness and promote stewardship of local ecosystems.

In conclusion, while pocket forests provide a powerful and innovative approach to restoring ecological functions within cities, their greatest potential lies in their integration within a broader urban ecological network. If the microforest intervention lacks of connectivity with other green areas its adaptive strategy will face more challenges to succeed and can eventually end in an failure. The main goal is to create a resilient green network of ecosystems capable of supporting both, biodiversity and human well-being.

BIBLIOGRAPHY

Bonan, G. B. (2008). Forests and climate change: Forcings, feedbacks, and the climate benefits of forests. *Science*, 320(5882), 1444–1449. <https://doi.org/10.1126/science.1155121>

CEA Jalisco. (2018). Programa hídrico del estado de Jalisco. Comisión Estatal del Agua, Gobierno del Estado de Jalisco.

Kabisch, N., Korn, H., Stadler, J., & Bonn, A. (2017). Nature-based solutions to climate change adaptation in urban areas. Springer.

Rzedowski, J. (2006). Vegetación de México. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO).

Alberti, M. (2015). Eco-evolutionary dynamics in an urbanizing planet. *Trends in Ecology & Evolution*, 30(2), 114–126.

Ahern, J. (2011). From fail-safe to safe-to-fail: Sustainability and resilience in the new urban world. *Landscape and Urban Planning*, 100(4), 341–343.

Meerow, S., Newell, J. P., & Stults, M. (2016). Defining urban resilience: A review. *Landscape and Urban Planning*, 147, 38–49.

Forman, R. T. T. (1995). Land mosaics: The ecology of landscapes and regions. Cambridge University Press.

Turner, M. G., Gardner, R. H., & O'Neill, R. V. (2001). Landscape ecology in theory and practice. Springer.

Dramstad, W. E., Olson, J. D., & Forman, R. T. T. (1996). Landscape ecology principles in landscape architecture and land-use planning. Harvard University Press.

Benedict, M. A., & McMahon, E. T. (2006). Green infrastructure: Linking landscapes and communities. Island Press.

cONANP (Comisión Nacional de Áreas Naturales Protegidas). (2018). Áreas Naturales Protegidas y servicios ecosistémicos en México.

Aguilar, A. G., Ward, P. M., & Smith Sr., C. (2003). Globalization, regional development, and mega-city expansion in Latin America. *Cities*, 20(1), 3–21.

REFERENCES

<http://geoportal.conabio.gob.mx>

https://iteso.mx/en/web/general/detalle?group_id=3136222

https://es.wri.org/sites/default/files/pocket_parks.pdf

<https://carbonpositiveaustralia.org.au/blog/why-community-pocket-forests-matter/?srsltid=AfmBOoojJU3lQdoFEseAuefHwEC4Y0ML98bVCV6JaHVKEssLLpLzerx>

<https://climateresilient.wixsite.com/ayerdevens/copy-of-project-recommendations>

<https://labcsa.org/2022/01/14/la-primavera-un-bosque-en-riesgo-inminente/>

<https://cdmxsecretaria.com/en/neza-forest-sugi-project/>

https://www.ntrguadalajara.com/post.php?id_nota=219083

<https://bosqueurbanoextra.org.mx/2025/09/10/distribucion-de-areas-verdes-en-el-area-metropolitana-de-guadalajara/>

<https://tooledesign.com/project/boston-complete-streets-manual/>