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Understanding of Green Infrastructure and implications for urban planning in the Mexican city of Culiacán

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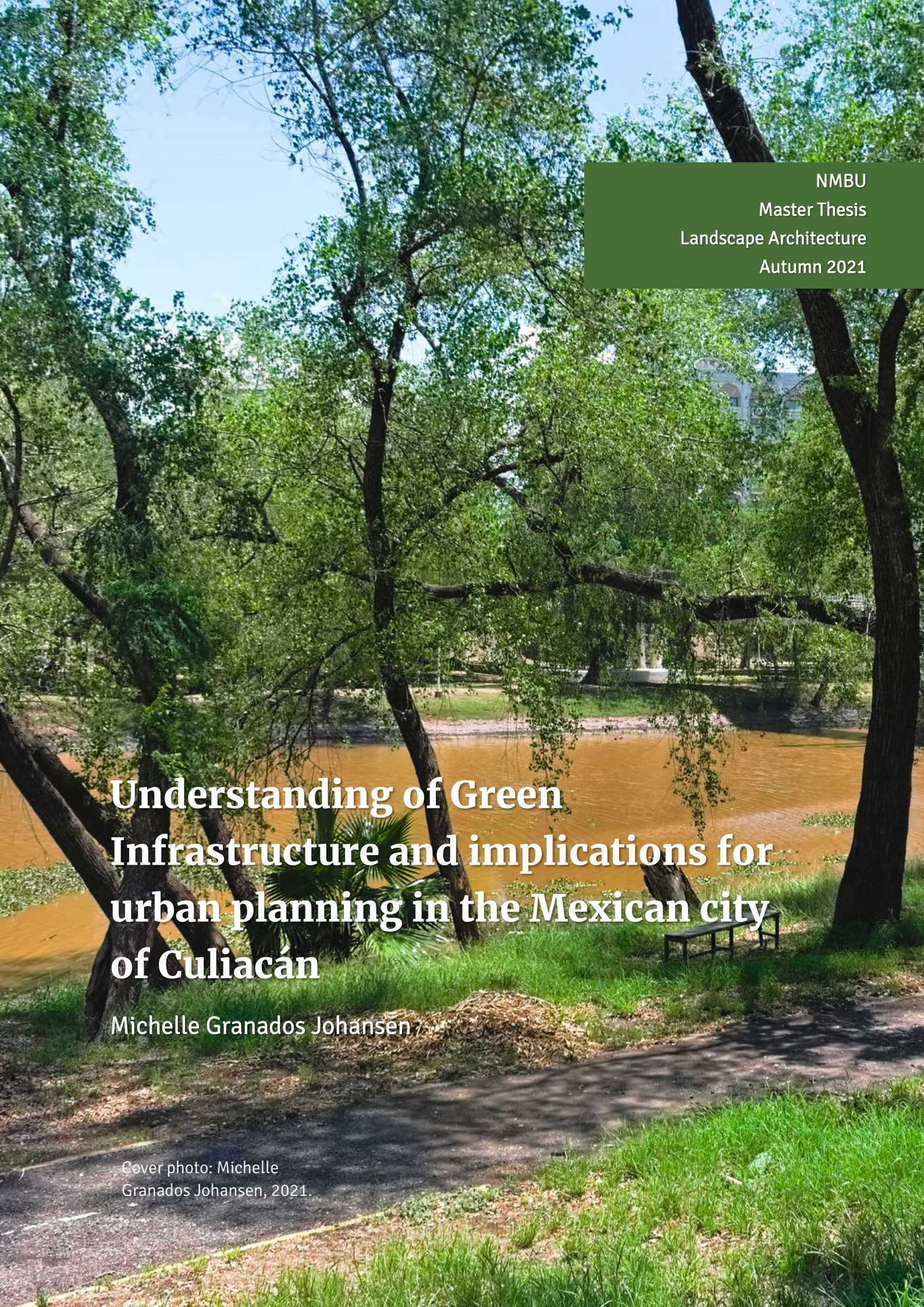
Master in Landscape Architecture



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Abstract

Green Infrastructure (GI) means an interconnected network of natural, semi-natural and artificial elements for the associated ecosystem services it provides to the population. The city of Culiacán currently does not have a plan for Green Infrastructure, or even green spaces in general. Without a unified vision, independent interventions behave like islands. Therefore, it was an objective for this master thesis to provide a knowledge-based framework for future landscape architecture interventions in the city. This study aims to integrate the qualities of existing Urban Green Spaces (UGS) and the vision for improvement into a unified Green Infrastructure plan. For this, it was necessary to find out where the potential for the city to incorporate GI strategies is. Cartographic and documental information was used to provide a panorama of the situation, to diagnose where the main issues are. Multiple methods to process the information included remote sensing, spatial analyses, and an in-depth interview. The results suggest that existing Urban Green Spaces are scattered and isolated, that only 5% of the city's total surface area is destined to recreational green spaces, and that 48% of the population do not have access to high quality UGS by walking distance (300 m). Similar to other Latin American cities, an unequal distribution of UGS favoring those of highest income was observed throughout the study. Moreover, the results on the spatial analysis confirmed a relation between the lack of vegetation and the extreme warm temperatures. The use of exotic species, vulnerability to flooding, and the degradation of the river were the most recurrent environmental problems. At the end, a strategic Green Infrastructure proposal was made to reduce issues related to environmental inequality and to increase urban resilience. It is ultimately the vision for this proposal to become a planning tool to bring Culiacán closer to reaching the Sustainable Development Goal 11 by contributing to a more inclusive, safe, resilient, and sustainable city.

Keywords: Green Infrastructure, Ecosystem Services, Urban Planning, Nature-Based Solutions, Urban Green Spaces, Sustainable Cities

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Glossary of recurrent terms

ES – Ecosystem Services

GHG – Greenhouse gas

GI – Green Infrastructure

IMPLAN – Instituto Municipal de Planeación Urbana

LST – Land Surface Temperature

NDVI – Normalized Index Vegetation Index

NPA – Natural Protected Area

SDG – Sustainable Development Goals

SUDS – Sustainable Urban Drainage Systems

UGS – Urban Green Spaces

UHI – Urban Heat Island

Introduction

Green infrastructure can be described as a network of natural and natural-inspired multifunctional systems that provide ecosystem services –such as water management, wildlife habitat, public health, aesthetic qualities, and others –for the benefit of human settlements (Benedict & McMahon, 2006). Green infrastructure is a topic with a growing relevance and studies. Most of these studies are done in highly developed countries (Retno et al., 2020), but we cannot simply export solutions from the "Western world" into developing countries because they have unique social challenges (De Block, 2015). These issues inequality, social exclusion, informal settlements, and weak cooperation between authorities and local communities (Breen et al., 2020; Vásquez et al., 2019).

The study focuses on a Mexican city, Culiacán. This city is the capital of the state of Sinaloa, located in the northwestern part of Mexico. It has 808 416 inhabitants and occupies a territory of 65 km^2 (INEGI, 2021a). In the summer of 2021, this city had the worst drought in 58 years (Varela, 2021), while historically, Culiacán is constantly exposed to extreme flooding during the wet season (GEOLMEX, 2020). This city is affected by a culture of fear to crime, which greatly influences how public spaces are designed manners (Ibarra & Ceballos, 2018). There is a general disconnection from nature, and inequality in access to high quality green spaces (ibid.). It is a priority for the regional authorities to preserve and restore the ecological equilibrium, to allow for a healthy environment, to protect biodiversity, and to provide the adequate infrastructure for the well-being of the people (Ordaz Coppel, 2017). Moreover, there is an expressed commitment to direct urban development towards the Sustainable Development Goals and the New Urban Agenda 2030 (Medrano-Contreras, 2021). Green Infrastructure can contribute to the achievement of this vision through the provision of ecosystem services, as it has been described the use of Green Infrastructure's principles in urban planning is "the most cost-effective method of achieving a desired urban or societal goal" (Beatly, 2016).

Already in other Mexican cities, green infrastructure is implemented as a new approach to target ecosystem services, for example to increase rainwater infiltration, reduce the extreme warm temperatures in the urban centers, improve air and water quality, and decrease flooding risk (Giner et al., 2019; Quiroz Benitez, 2018). Also, there are several studies that support the idea that green spaces can have a positive impact in improving perceived safety in public spaces (Beatly, 2016; Ceccato et al., 2020; Pima County, 2015), as well as providing physical and psychological health benefits (Beatly, 2016; Fongar, 2015; Kaczynski, 2008). In addition, there is evidence that green infrastructure can provide economic growth for the city and its population (Beatly, 2016; Jennings & Bamkole, 2019; Natural England, 2019). For example, by attracting investment (Beatly, 2016), increasing the value of urban space and housing (Cicea & Marinescu, 2011), inviting for tourism (ibid.), and providing food and other natural resources to the people (Adegun, 2019). Considering the potential for green infrastructure to face local challenges through ecosystem services, there is an urgent need to examine the possibilities for a green infrastructure plan in Culiacán.

My aim for this dissertation paper is (1) to make a general diagnostic on the existing urban green areas in Culiacán, and (2) to make a strategic proposal of a green infrastructure plan according to the needs and opportunities of the city.

To meet the objective, I will answer the following research questions:

1. How does the current state of the existing urban green in Culiacán relate to the city's landscape issues?
2. Which green infrastructure strategies can be implemented on a city planning level to fill the gap between the needs of the city and the current state of the urban green?

The answers to these questions will provide insights on the existing conditions of the green areas of Culiacán, the desired outcome, and the way to reach it.

Chapter 1. Literature review

1.1 What is Green Infrastructure?

1.1.1 Historical background

Green infrastructure is a recent term, but it is not a new idea, as humans have always been dependent on the conditions of the landscape to create their cities. Since the beginnings of civilization, man and nature have been closely related. Humans began by finding shelter in caves. Then they stepped outside when they started to understand how to control fire. Larger communities began to emerge, and they worked together to shape their environments, to create stone monuments and gather resources from the land. Some communities evolved to be the first great civilizations near water sources. The first cities in Mesopotamia, Egypt, Greece and Rome were built in a close integration of architecture and nature. From the hanging gardens of Babylon to the parks and orchards in Athens, ancient cities were always interlinked with the potential of the natural landscape. This shows that the natural environment and the richness of its green and blue elements are a requirement for the creation of a city (Stankovic & Maksimovic, 2019).

It was first in the 19th century that the natural landscape in the form of park systems was understood as an integral part of the urban environment, not only for its aesthetics and cultural significance, but also for its technical benefits. The American landscape architect Frederick Law Olmsted promoted the idea of the park as a technical object to provide the inhabitants of metropolises the benefits of nature in the form of fresh air, light, vegetation and beautiful scenery (Czechowski & Hauck, 2015). He translates the ideas of beauty and cultural enlightenment from 18th century landscape gardening to a matter of human health and wellbeing. This came as a result of the rapid urbanization that was producing cramped, dark and polluted environments for people in the cities. He established the functionalistic principles of what a park should be, following the liberal ideas of equal rights and freedom (ibid.).

Olmsted's principles consist of free movement, accessibility for all classes of society, and open spaces to gather for people's needs (Eisenman, 2013). He stated that for urban green spaces to have an impact in the health of the population, a park should be of sufficient size to provide clean air, sunlight, and vegetation; wide open lawns would permit an adequate lighting and air circulation; easy accessibility to all levels of the population is essential. His proposal for parkways systems meant to bring people closer to previously isolated green areas and consequently improve accessibility and the associated benefits of nature. Olmsted advocated for the inclusion of natural scenery in cities because he understood the link between nature and human well-being. This understanding is the foundation of what we call today Ecosystem Services (ibid.).

Olmsted's ideas influenced many scholars and landscape architects and led to different versions of *greenways (Jongman et al., 2004)*. Little (1995) defines Greenways as ***"linear open space established along either a natural corridor, such as a riverfront, stream valley, or ridgeline, or overland along a railroad right-of-way converted to recreational use, a canal, a scenic road, or other route"***, while other scholars define similar concepts with terms like ecological networks (Forman & Godron, 1981), habitat corridors (Noss, 1987), and environmental networks (McHarg, 1969). Since the 90's, the discourse about greenways has evolved into a wider understanding of the role of nature in urban planning (Forman, 2014). The contemporary understanding of Green Infrastructure is a holistic one. Benedict and McMahon (2006) define it as:

"an interconnected green space network that is planned and managed for its natural resource values and for the associated benefits it confers to human populations".

This includes natural areas such as rivers, forests, deserts, and coastal areas, as well as public and private conservation lands, working lands with conservation values, and other protected open space. It also includes man-made systems such as parks, street trees, canals, private gardens, corporate and industrial properties, military installations, golf courses, railroad corridors, agricultural areas, and many others (Benedict & McMahon, 2006).

1.1.2 Green infrastructure and ecosystem services

Green Infrastructure can provide a framework for future development and land conservation based on two fundamental concepts:

(1) protect and link urban green spaces for the benefit of the people,
(2) preserve and connect natural areas for the benefit of biodiversity.

A Green Infrastructure network is based on a system of hubs, links and sites (see Figure 1) that support both ecological and social benefits (Benedict & McMahon, 2006).

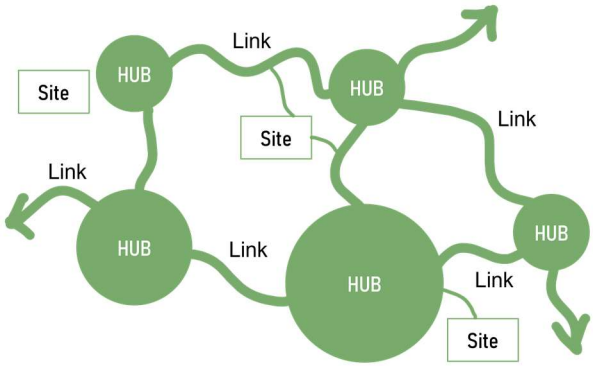


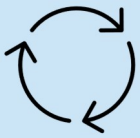
Figure 1. Conceptual Green Infrastructure network. Made by the author based on Benedict and McMahon (2006).

When we talk about the benefits provided by Green Infrastructure, we are talking about Ecosystem Services. These all the direct and indirect benefits that humans can receive from an ecosystem. An ecosystem includes a complex interconnection of plants, animals, microorganisms and the non-living environment, as well as all the processes and relationships between each other (Millenium Ecosystem Assessment, 2005). Another way to understand ecosystem services is to recognize that humans are also part of the ecosystem, and so we depend on them for our health and well-being. Ecosystem services can then describe the way humankind connects and relies on nature. The report to the European Environment Agency from Haines-Young and Potschin (2013) establishes that there are three categories for ecosystem services, depending on their broad functions (See Table 1). These services are not independent from each other. For example, for the ecosystem to be able to produce food (provisioning service), the soil needs to have enough nutrients (supporting service), and the climate and water availability should be suitable for the type of crops (regulating services).

Ecosystems provide functions that have nothing to do with anthropogenic purposes. What we call 'services' are those functions that people value and use (Termorshuizen & Opdam, 2009). For example, plant roots fulfill the function of retaining soil structure and nutrients. It becomes a service when we realize that this function is useful for us, for example when we use this land for agricultural production. Like other functionalistic approaches, there is also a criticism to ecosystem services for reducing nature to the benefits it provides to humanity. Ecosystems have an intrinsic value for themselves, independent of the benefits they provide to people and their potential to be exploited for economic development (Zari, 2018). Nevertheless, valuing ecosystems in

terms of their usefulness to our cities can be an essential tool for working towards a more sustainable built environment (ibid.). The Millenium Ecosystem Assessment (2005) estimates that over 60% of the global ecosystem services have been degraded by recent human activities. Consequently, there is an urgent need to acknowledge the potential in our urban environments to gain back the provision of these services.

Table 1. Categories of Ecosystem Services. Made by the author with information from Haines-Young and Potschin (2013).

Service type	Description
Provisioning services 	These include goods that humans can get directly from nature in the form of nutrition, materials, or energy. For example, water, biomass, wood, fuel, fiber, medicines and food
Regulation and maintenance 	These refer to the regulation of living organisms and complex systems like the water cycle, waste removal, pest regulation, mitigation of natural hazards, and climate regulation. They also include the necessary services to support the rest of the ecosystem services, such as pollination, nutrient cycle, soil formation, habitat provision, amongst others.
Cultural services 	All the non-material values that human receive in the form of recreation, physical and mental health, spiritual needs, and aesthetic inspiration.

1.1.3 Ecosystem disservices

Despite of all the positive effects of green infrastructure, there is also potential for negative aspects to impact human quality. These negative effects can be called Urban Ecosystem Disservices (Von Döhren & Haase, 2015). The concept of ecosystem disservices is not yet fully developed as systematically as ecosystems services. Nevertheless, they can be categorized in five types for research purposes: ecological, economic, health, psychological, and general impact on human well-being (ibid.). The descriptions and examples of these effects can be found in Table 2.

There are several issues defining ecosystem disservices. First of all, the fact that there is little agreement on their classification makes it hard to integrate them in planning processes. This problem gets accentuated by the fact that there is little inventory on the characteristics of natural green spaces to give enough information for an integrated analysis on ecosystem disservices (Von Döhren & Haase, 2015). Furthermore, the perception of what makes an effect "negative" is very subjective. What may seem like an attractive quality for one person might be negative for another one. For example, an overgrown riverbank may have positive qualities for biodiversity, while some people might consider these spaces as a waste of land (Schneider et al., 2020). These definitions for what is a "service" and what is a "disservice" may vary according to cultural background, economic situation, gender, age, and health status of the affected people (Von Döhren & Haase, 2015).

Table 2. Urban Ecosystem Disservices. Sources: (Escobedo et al., 2011; Haddad et al., 2014; Lõhmus & Balbus, 2015; Montes-Pulido & Forero, 2021; Schneider et al., 2020; Von Döhren & Haase, 2015).

Description	Examples
Ecological impact	
Negative effects on ecosystem services, ecosystem structures and/or processes.	Increased water consumption and emission of volatile organic compounds (VOC) by street trees. Emission of GHG by constructed stormwater wetlands. The spread of invasive species displacing native species. Negative effects of edge creation. Expansion of unwanted disturbances: fire, predators, etc. Air pollution emissions from maintenance activities.
Economic impact	
Those effects that negatively impact socioeconomic structures and processes.	Infrastructure damage done by plant growth and microbial activity. Maintenance costs for urban vegetation relater to pruning, planting, irrigation, pest-control, etc. Increased energy use due to blocking of sunlight by vegetation surrounding buildings.
Health impact	
Effects that have negative consequences in human health and well-being.	Exposure to allergens caused by urban trees. Vector-spread diseases by animals such as mosquitoes and rats. Attacks by wild animals. Injuries in natural green areas.
Psychological impact	
Feelings of anxiety and discomfort	Disgust caused by animal and plant waste. Fear of danger in densely vegetated areas. Criminal activities in green spaces. Sounds from animals may be annoying to some people. Human fear or phobias to certain species like snakes and spiders. Obscured views and unpleasant aesthetics.

Recognizing the presence of Urban Ecosystem Disservices can provide useful for decision-makers in planning projects to assess the overall impact of an area and to evaluate mitigation alternatives. For example, a study in Oslo suggests that limited visibility and concealment by vegetation in urban green spaces can have a negative effect on perceived safety, especially among female users (Evensen et al., 2021). The experience can be easily improved by designing and maintaining vegetation in a way that there is full visibility along paths. Another study in Colombia, revealed feelings of insecurity in isolated areas of a park, mostly due to the presence of occasional drug users and absence of security guards (Montes-Pulido & Forero, 2021). This also points to the need for increased visibility in public spaces. Ecological disservices such by the edges can be mitigated by creating wider corridors and reducing the contrast between corridor and surrounding matrix (Haddad et al., 2014). Other negative effects like allergenic pollen produced by trees, risk of injuries, and vector-transmitted diseases can be managed by proper plant choice, design and maintenance of green spaces (Lõhmus & Balbus, 2015). In many cases, it has been concluded that the benefits of Green Infrastructure far outweigh the possible disservices, either social (Escobedo et al., 2011; Montes-Pulido & Forero, 2021) or ecological (Haddad et al., 2014), so the knowledge on possible negative effects can only add to the quality of interventions and decision-making.

1.1.4 Green Infrastructure's role for sustainability

In the history of the world, there has never been more people than today. Between 1950 and 2014 the global population living in cities went from 746 million to 3.9 billion people, and it is forecasted that by 20150 this number will increase to 6.4 billion (United Nations Department of Economic and Social Affairs, 2014). This has mainly been driven by industrialization and economic growth. But this rapid urbanization has come with great challenges, and the paradigm for how we design cities has changed from pushing industrial development to solving the environmental and social problems of this century. Inequality is more predominant in cities than rural areas, where hundreds of millions of people living in cities live in sub-standard conditions. In many cities, the uncontrolled urban expansion has brought problems like pollution and environmental degradation (ibid.). Urban growth and the degradation of biodiversity has led to the loss of ecosystems and the natural benefits that humans and all other organisms rely on (Millenium Ecosystem Assessment, 2005). Under this new paradigm, there is an urgent need to change the way we build our cities and the way we think about urban development.

To be able to cope with the global environmental changes, cities need nature more than ever. Green Infrastructure has been identified as a strategy to reach a sustainable community development (Williamson, 2003). Sustainability has been defined by the UN as:

> ***"meeting the needs of the present without compromising the ability of future generations to meet their own needs."*** (United Nations, n.d.).

It has been widely accepted that sustainability is based on three pillars or dimensions: Social, Environmental and Economic (see Figure 2) (Barbier, 1987). Furthermore, in 2015, the 17 Sustainable Development Goals were adopted by the UN as part of the 2030 Agenda for Sustainable Development (United Nations, n.d.).

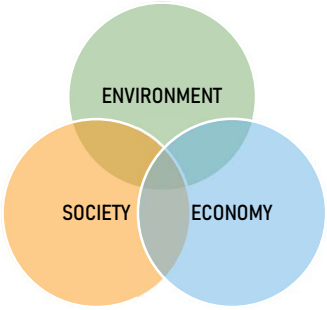


Figure 2. Pillars for sustainable development (Barbier, 1987).

Already in 1999, Green Infrastructure was identified as a key strategy to achieve a sustainable development because it contributes to the conservation of natural ecosystem, our life support (Williamson, 2003). The influence of GI is especially important for Goal 11, Sustainable Cities and Communities (see Figure 3). According to Project Everyone and the Global Goals Campaign (n.d.),

"we need new, intelligent urban planning that creates safe, affordable and resilient cities with green and culturally inspiring living conditions".

Borelli et al. (2014) suggests green spaces can contribute to improving the living conditions in cities, boost a green economy model, increase community cohesion, improve human wellness and health, thus promoting a sustainable development. Table 3 presents an overview on how GI can contribute to reaching the specific targets of Goal 11.

Moreover, Green Infrastructure can contribute to getting closer to the other SDGs. For example, the use of urban vegetation can contribute to passive climate regulation reducing the need for artificial cooling (Bass & Baskaran, 2003) (goal 7), working as an adaptation strategy to climate change (Gill et al., 2007) (goal 13), and reducing the impacts that excess of heat can have on human health (goal 3). The creation of accessible urban green spaces also contributes to social sustainability by providing ecosystem services to people regardless of socioeconomic status (goal 1), by creating job opportunities related to forest managing, landscaping, gardening, cleaning and maintenance, and others (Adegun, 2019) (goal 8), and by improving urban image and consequently perceived safety (Ceccato et al., 2020) (goal 16). The environmental benefits of Green Infrastructure include stormwater management (Stankovic & Maksimovic, 2019) (goal 6), protection of biodiversity and natural habitats (Beck, 2013; Benedict & McMahon, 2006) (goal 15), and contributing to regulation services like pollination and nutrient cycle (Beck, 2013) that make possible food production (goal 2).

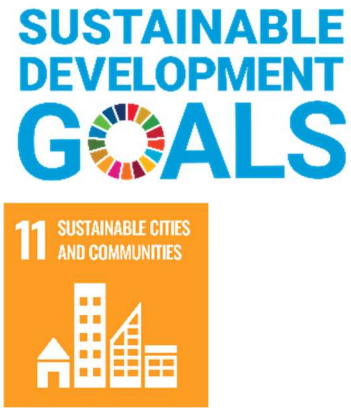


Figure 3. SDG logo and Goal 11. United Nations.

Table 3. Green Infrastructure's contribution to reaching Goal 11 Sustainable Cities and Communities: Make cities and human settlements inclusive, safe, resilient, and sustainable (Project Everyone and the Global Goals Campaign, n.d.).

	Target	Role of Green Infrastructure
	**11.2 Affordable and sustainable transport systems**	Streets that favor sustainable mobility, accessible to everyone (Natural England, 2010). Improved safety and comfort for pedestrians using street vegetation (McHarg, 1969).
	**11.3 Inclusive and sustainable urbanization**	Green spaces improve social cohesion and community involvement (Jennings, 2019). A greener environment is also a healthier environment for everyone (WHO Regional Office for Europe, 2016). Smart growth by establishing green boundaries (Benedict & McMahon, 2006).
	**11.4 Protect the world's cultural and natural heritage**	Conservation of natural resources and biodiversity (Beck, 2013; Benedict & McMahon, 2006). Recognition of the role of the landscape as a cultural identity (Rosenzweig, 2003). Prevent soil degradation (Shipek et al., 2016).
	**11.5 Reduce the adverse effects of the natural disasters**	Mitigating measures against the effects of flooding (Stankovic & Maksimovic, 2019; Watson & Adams, 2011), drought (Weinstein, 1999), erosion (Shipek et al., 2016), heat (Gill et al., 2007), and others.
	**11.6 Reduce the environmental impact of cities**	Compensate for the CO2 emitted in cities with the use of vegetation. Reduce air and water pollution. Mitigate the urban heat island effect (Gunawardena et al., 2017; Taha, 1997; Weng et al., 2004).
	**11.7 Provide access to safe and inclusive green and public spaces**	Good offer of high quality, multifunctional urban green areas, accessible for all (Braubach et al., 2017). Use of vegetation to improve the quality of public spaces and perceived safety (Beatly, 2016; Ceccato et al., 2020).
	**11.A Strong natural and regional development planning**	Ecological connectivity at urban and regional scales (Beck, 2013; Benedict & McMahon, 2006).
	**11.B Implement policies for inclusion, resource efficiency and disaster risk reduction**	Climate change adaptation and mitigation strategies (Quiroz Benitez, 2018). Protect ecosystems and their natural resources (Natural England, 2019). Plans for no-development of risk areas and enhance ecosystem services instead (Benedict & McMahon, 2006).

1.2 Urban Green infrastructure planning

Green infrastructure is a broad term that includes different strategies that come as a response to different functions in an urban environment with the use of vegetation and water. Czechowski and Hauck (2015) suggest that **Green Infrastructure planning is based on identifying the ecosystem services provided by a defined area, and then ensuring and maximizing their provision through a network of interconnected natural, semi-natural and artificial elements**. Then the key concepts that come up when talking about green infrastructure are 'network', 'nature' and 'ecosystem services'.

The role of applying ecological principles into urban design had been recognized as ***"the most cost-effective method of achieving a desired urban or societal goal"*** (Beatly, 2016). Planning with this perspective can help achieve many goals for urban development. For example, by creating high quality environments which are attractive for investors and businesses, green infrastructure can contribute to building a

stronger and more competitive economy (ibid.). Well-designed spaces reinforce the character and sense of place, which helps build a stronger identity for the locals (Jennings & Bamkole, 2019). Green infrastructure also promotes healthy and safe communities by offering opportunities for recreation, exercise, social interaction, contact with nature, community food-growing, and gardening (WHO Regional Office for Europe, 2016). It not only benefits communities, but it also contributes to the natural environment by enhancing ecological connectivity and conservation of biodiversity, as well as providing protection for water and other natural resources (Benedict & McMahon, 2006). In addition, green infrastructure can help planners mitigate the effects of climate change such as flooding and extreme temperatures (Natural England, 2019).

To ensure a good balance between economic growth and environmental protection, there is a need to assign equal validity to implementation of both financial and ecological policies, management, and investment (Young, 2002). In other words, economic development must be seen in conjunction with supporting a healthy environment. Green infrastructure planning provides the opportunity to integrate these two goals, by providing functional solutions for urban development, while also providing a wider range of environmental and social benefits.

For a successful planning, GI efforts need an establishment of priorities custom-made according to the characteristics of the site (Benedict & McMahon, 2006). It is a long-term commitment that require the coordination of many people from all sectors of the community, including public and private actors. It does not dictate urban growth, but it establishes limits and patterns of land use. It helps identifying areas where not to develop to prevent natural hazards and biodiversity loss (ibid.). In this way, green infrastructure is a tool that can empower urban planners to achieve a smarter and more sustainable urban development while also contributing to other important objectives.

Green planning has been the result of three factors: (1) the demand for strategic development plans on a metropolitan or regional scale (Czechowski & Hauck, 2015), (2) a focus on ecological network planning in conjunction with the built environment (Schweiger, 2015), and (3) the concept of ecosystem services as a way to provide “hard”, quantifiable justification for green infrastructure (Millenium Ecosystem Assessment, 2005).

The European Green Surge guide establishes that Green Infrastructure planning is based on four core principles (Hansen et al., 2017):

(1) integration between the green and the gray,
(2) connectivity,
(3) multifunctionality,
(4) and social inclusion.

When it comes to planning, these four principles allow us to decompose the spatial structure of a city into factors that we can observe, measure and intervene.

The strategies that apply to GI planning depend on the setting in which the area takes place. In rural areas, a GI network can contribute to the protection of natural areas and agricultural land while directing development towards areas best for human use. While in an urban context, GI can include public and private green areas, street trees, and rivers. It can also set aside buffers to natural areas and floodplains to protect both people and ecosystems (Benedict & McMahon, 2006). Moreover, strategies will differ depending on the scale at which planning is implemented. At parcel scale, the idea is to integrate the green and the buildings. At a community scale, a GI network can connect people to green areas using

greenways/ parkways. At a regional level, GI can mean the protection and linkage of large natural areas like forests and prairies (ibid.).

A classic example of Green Infrastructure planning is Boston's Emerald Necklace, by Olmsted. This is one of the earliest examples of a mini-regional scale GI system in 1887, linking parks and natural areas through a series of parkways (Coolidge, 1972). Initially, this project was meant to restore the contaminated bay and turn it into a stormwater basin, but later its purpose was expanded to include recreational qualities (ibid.). Later in the 1930's, planners like Benton MacKaye began to think of green systems as a way to establish boundaries between community growth and natural or agricultural areas. Several "greenbelt" communities were established, using walkways, forest buffers and green corridors around neighborhoods to offer easy access to nature (Benedict & McMahon, 2006).

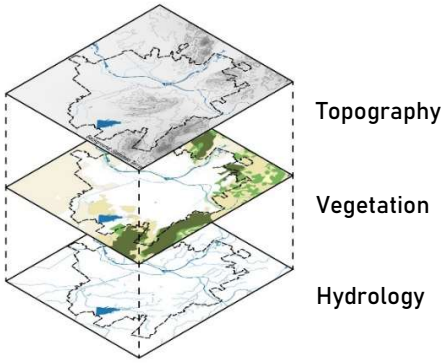


Figure 4. Interpretation of McHarg's layered approach. Made by the author based on McHarg, 1969.

It was until the 1960's that the principles of ecology would be applied to urban planning and landscape architecture. Ian McHarg, in his book *Design with Nature*, introduced the method of map overlays (see Figure 4) as a mean to quantify and display information about the natural environment to approach land use decisions (McHarg, 1969). His method is the basis of what we know today as Geographic Information Systems.

1.2.1 Planning tools

Classifying Urban Green Spaces (UGS)

According to the WHO Regional Office for Europe (2016), urban green spaces can be analyzed in function of their physical characteristics linked to the health benefits they produce in specific population groups. Summarizing from available literature, they have concluded the following key aspects to determine the social qualities of green spaces: Size, land cover type, presence of water, recreational types, environmental qualities, amenities, accessibility (proximity, public access and points of access), and usage (frequency, duration of visits, activities, etc.).

There is no universal indicator to measure the quality of green spaces (Badiu et al., 2016). However, many countries have used different criteria as guides to evaluate and plan for green areas. One way to classify Urban Green Spaces (UGS) is by the benefits they provide. For example, parks provide cultural ecosystem services, street trees improve air quality and improve urban biodiversity, urban forests provide habitat for wildlife, and other spaces like schools, public institutions, private gardens, cemeteries, sports grounds, and squares can contribute with stormwater and temperature regulation (Badiu et al., 2016 refers to Bolund and Hunhammar, 1999, DeGraaf and Wentworth, 1986, De Ridder et al., 2004, and Hobbs, 1988). Another way to classify them is by making a distinction between public and private spaces as a way to measure the provision of cultural ecosystem services (Feltynowski et al., 2018). Measuring canopy cover and species composition could improve ecological analysis and climate adaptation plans (ibid.), as well as provision of health benefits associated with the presence of vegetation (WHO Regional Office for Europe, 2016). Measuring accessibility to UGS

Different countries have their own indicators to evaluate accessibility to green spaces in a city or community level according to size and distance. Table 4 presents an overview on criteria used by different governments and researchers.

Table 4. Green spaces accessibility indicators across different countries.

Country	Indicators
United States (The Trust for Public Land, 2018)	The ParkScore® index evaluates how well the largest 100 cities in the US are meeting the needs for urban green spaces. Some of the physical characteristics they assess include: • Size: measures percentage of city area, variable • Amenities: Basketball hoops, off-leash dog parks, playgrounds, recreation and senior centers, restrooms, splashpads and playgrounds. • Access: 10-minute walk, half-mile barrier-free routes. • Inclusion: Parks of open public access. These do not include parks in gated communities, private golf courses, private cemeteries, school parks of restricted access, zoos, museums and professional sports stadiums.
Colombia (Hernández, 2020)	A Colombian study evaluated the provision of ecosystem services within the basin of the Fucha River, in the city of Bogotá. To do this, an analysis of the accessibility to urban green spaces was determined following these values: • 200 m buffer to green areas between 1000 and 5000 m^2. • 750 m buffer to green areas between 5000 m^2 and 1 ha. • 2 km buffer to green areas greater than 1 ha. • 4 km buffer to natural protected areas.
England (Natural England, 2010)	The Accessible Natural Greenspace Standard recommends that everyone, wherever they live, should have an accessible green space of high quality, free of charge: • Less than 300 m (5 min walk) to a natural green space of at least 2 hectares (Neighborhood-scale provision) • Less than 2 km from home to a 20-hectare natural green space (District-scale provision) • Less than 5 km from housing areas to an accessible green space of at least 100 ha (City-scale open space) • Less than 10 km from housing areas to an accessible green space of at least 500 ha • A minimum of one ha of statutory Local Nature Reserves per thousand population.
Norway (Miljødirektoratet, 2014a)	The Environmental Department in Norway suggest the following classification of recreational green spaces: • Big areas: Natural green spaces, often a part of a greater green corridor, important for physical activity and contact with nature. Recommended 500-1000 m from housing areas. • Small areas: Parks in proximity to housing areas, social meeting places and recreation for adults and children. Inside built areas, maximum 200 m from houses, minimum 5000 m^2 of surface area. • Green corridors: Forms part of the "soft" mobility network. Link together big and small green areas in a hiking route. Maximum of 500 m from housing areas. Ideally 30 to 50 m wide, with few exceptions.

Blue-Green Factor (BGF)

Among the tools used in the countries listed in Table 4, Norway has developed a tool inspired by the German model *Biotopflächenfaktor* (BFF) and a Swedish adaptation to it (Aamlid et al., 2018). The Blue-Green Factor is a tool used by municipalities to incentivize the adoption of blue-green infrastructure in construction and urban development projects (Standard, 2020). This is a quantitative tool that assign different values to green infrastructure interventions in a site level (see Figure 5 and Table 5), then those values are summed up and divided by the total lot area. These values are then compared with a targeted BGF, that for dense urban areas it is a minimum of 0.7 and for open areas it is 0.8 (ibid.). The purpose is to reduce the damage from rainfall events, support the use of sustainable water management practices, promote soil regeneration and local biodiversity, and improve the local environment regarding climate, water and air quality (ibid.)

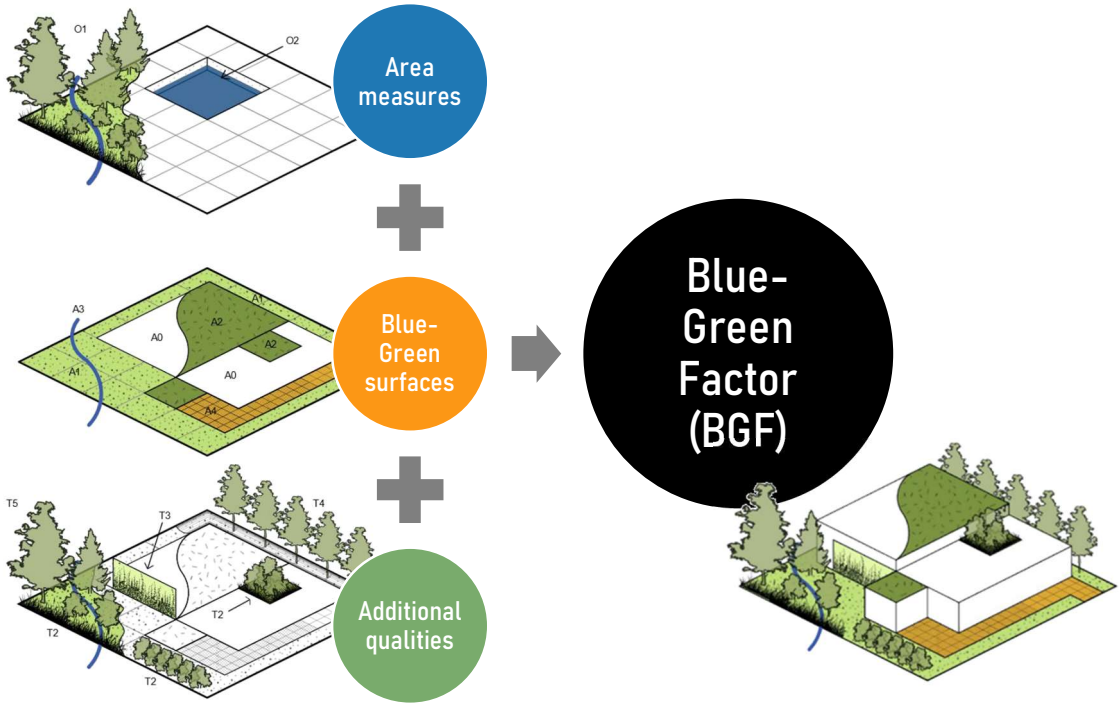
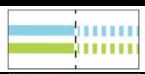
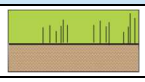
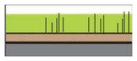
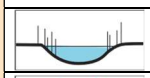
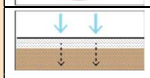
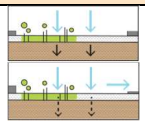
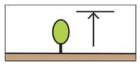
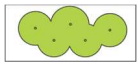
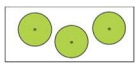


Figure 5. Principles of Blue-Green Factor. Adapted from NS 3845:2020 (Standard, 2020).

Table 5. Strategies evaluated by the Blue-Green Factor (BGF). Adapted and translated from NS 3845:2020 (Standard, 2020).

Categories		Type		Factor value	Amount	Unit	Score
Area measures (01-02)		01 Connection to existing Blue-Green structures		0.05		unit	
		02 Collection of surface water for irrigation		0.05		unit	
		Sum of BGF for area measures					
Blue-Green surfaces (A0-A5)		A1, Green surfaces on terrain		1		m^2	
		A2, Green surfaces on construction:					
		A2.1, Growing medium with depth 0-3 cm		0.2		m^2	
		A2.2, Growing medium with depth 3-20 cm		0.4		m^2	
		A2.3, Growing medium with depth 20-60 cm		0.7		m^2	
		A2.4, Growing medium with depth > 60 cm		0.9		m^2	
		A3, Permanent water bodies and open watercourses		2		m^2	
		A4, Permeable surfaces		0.3		m^2	
		A5, Impermeable surfaces with runoff to open surface water measures		0.2		m^2	
		A0, Other surfaces		0		m^2	
		Sum of project area / Sum of BGF for Blue-Green surfaces					
Additional qualities (T1-T5)		T1, Terrain depressions					
		T1.1, Infiltration as main function		1		m^2	
		T1.2, Retention as main function		0.5		m^2	
		T2, Plant fields and existing vegetation types		0.5		m^2	
		T3, Green walls		0.4		m^2	
		T4, Newly planted trees	Est. m^2				
		T4.1, expected to grow <10 m (calculated as 25 m^2 tree crown area)	25	1		unit	
		T4.2, expected to grow >10 m (calculated as 50 m^2 tree crown area)	50	1		unit	
		T5, Existing trees	Est. m^2				
		T5.1, Actual tree crown area (without overlap)		1		m^2	
		T5.2, stem circumference < 90 cm (calculated as 50 m^2 crown area)	50	1		unit	
		T5.3, stem circumference > 90 cm (calculated as 100 m^2 crown area)	100	1		unit	
		Sum of BGF for additional qualities					
		Sum of BGF					

1.2.2 Challenges in urban green infrastructure planning: a focus in Latin America

Since there is not a universal definition of green infrastructure and what it means for urban planning, there are different approaches for how GI is applied in practice, and how its value is understood across different cities. It is important to notice also that discourses change with time, and as ecosystem services are better understood, the way they are implemented also changes.

The available research on green infrastructure is biased by the countries that publish such research papers. In this case, there is a disproportioned amount of publication that are published in the USA compared to other countries (Retno et al., 2020). Followed by this, the next most productive countries in GI publications are the UK, China, Italy, Australia and Germany. Even though there exist publications in countries such as Colombia, Turkey and South Africa, there is a clear tendency that most of the scientific knowledge we have on GI comes from highly developed countries. As Retno et al. (2020) acknowledges, the benefits of green infrastructure are independent on how developed a country is, and developing countries are aware of the potential benefits GI can provide for their economical, social and environmental challenges, but we cannot simply export solutions from the 'Western World' into developing countries because they have unique social and political conditions (De Block, 2015).

Green infrastructure strategies are applied differently according to factors like climate, social needs, culture, and different environmental challenges. **In the United States, Green Infrastructure has been recognized since the 90's mainly as a way to deal with stormwater management and resilience against extreme events**, leaving other ecosystem services to a lesser attention (Hansen et al., 2015; Rouse & Bunster-Ossa, 2013). **In Europe, the approach covers topics like conservation of biodiversity, interconnectivity, and provision of ecosystem services**, but there is little attention from the financial, social services and health sectors (Slätmo et al., 2019). Meanwhile **in Latin America, the discussion around Green Infrastructure is relatively new**. It has been vaguely adopted in a few policies, mainly with the purposes of dealing with pollution and mitigating natural hazards like flooding, water scarcity, and heat islands. However, there has been little integration between GI planning and other aspects such as climate change mitigation, social integration, and sustainable mobility (Giannotti et al., 2021).

A research study found a total of 47 publications about Green Infrastructure in Latin American countries (Breen et al., 2020). These studies are fairly recent, most of them published from 2015 to 2020, and most of them are done in Brazil (29.8%), Mexico (19.1%) and Colombia (17%), followed by small number of publications in Chile, Argentina and other countries. In general, these studies show a lack of cooperation between governments and local communities. The lack of representation from indigenous communities, academics and local residents often leads to conflicts of interests and loss of opportunities for social infrastructure. In these studies, **the four most common issues for Urban Green Infrastructure planning in Latin America are weak local government, informal settlements, pronounced socioeconomic inequalities, and clashes with indigenous community practices** (ibid.). Further research in Latin America could potentially help increase the understanding of how these issues influence the way urban green infrastructure is implemented and managed, and how it differs to other regions of the world.

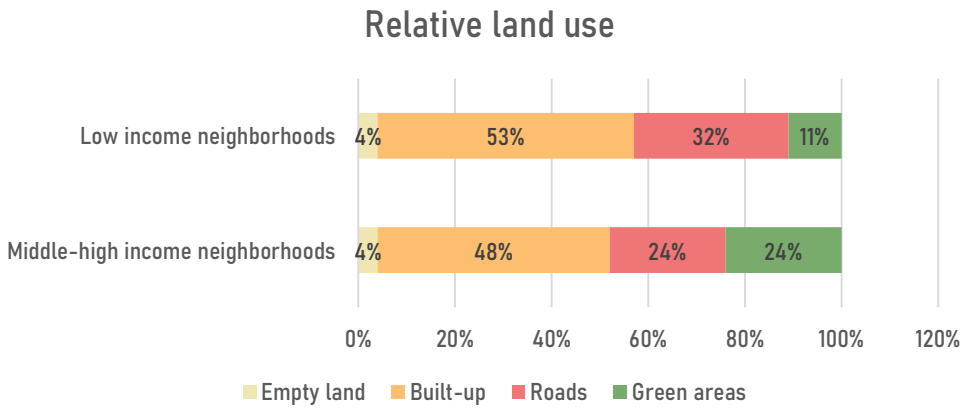


Figure 6. Comparison of land use between neighborhoods of low and high income in Mexico (SEDESOL, 2012a).

In Latin America, there is little appreciation of the urgency to deal with climate change (Giannotti, 2020), there is confusion on the benefits of GI, and little innovation in planning methods to include it (Matthews et al., 2015). The role of Green Infrastructure in dealing with social and climatic issues is often underappreciated (Vásquez et al., 2019). Social issues like inequality, social exclusion, segregation, and centralization accentuate the consequences of natural disasters and climate change. This is what is known as environmental inequality (ibid.). For example, people living in slums are more vulnerable to natural and human-induced hazards because they are often built upon sensitive land such as landfills and steep hills (Vásquez et al., 2017). Unequal access to public services also means more risk for water scarcity, a lack of access to green spaces to mitigate heat islands, and a lack of recognition in plans and programs. In Chile, for instance, there are studies indicating that there may be a relationship between the access to green areas and the socio-economic status of the region. This is especially notorious in arid and semi-arid regions because it is evident to see where the budget covers the irrigation and maintenance of public green spaces (ibid.). The same phenomenon can be observed in Mexico (SEDESOL, 2012a). Mexican statistics reveal that in neighborhoods of middle-high incomes there is an average of 24% of land use destinated for green areas, while in areas of low income this number is reduced to 11% (see Figure 6).

In Mexico, the demands of the most marginalized communities are often overlooked, and added with the deficit of basic public infrastructure, it means that there is a very limited capacity for the government to handle the challenges of climate change (SEDESOL, 2012a). Moreover, the lack of coordination between different sectors of governance and the general population makes it difficult to turn programs into effective action (ibid.). In addition, there is little follow up on the existing GI projects and their efficacy to provide their initially intended ecosystem services (Pickett et al. 2011b, as referenced by Felson, 2013). This lack of understanding in the way projects perform can have economic and ecological consequences. Felson (2013) proposes that a closer cooperation between urban designers and ecologists can significantly improve the provision of ecosystem services in GI plans.

Informal settlements present additional challenges because they often lack even basic infrastructure and equipment (Vásquez et al., 2017). In the absence of state interventions, self-help initiatives can provide some improvements for urban greening. However, the limited resources of

the resident of low-income communities make these initiatives very difficult, and could benefit from support and collaboration with state and non-governmental organizations (Adegun, 2019). Moreover, they are often located in areas of ecological significance, environmental vulnerability, or agricultural cultivation (Adegun, 2017). This means that informal settlements are more vulnerable to natural hazards and climate change, they pose risks for conservation efforts, and they are in most need for affordable solutions (ibid.

Green Infrastructure planning is not an easy task, and it requires the collaboration of many actors in a wide range of disciplines (Benedict & McMahon, 2006). This is a challenge in itself. To ensure the success of any GI plan, there has to be an active and early dialogue between urban planners, architects, landscape architects, ecologists, engineers, politicians, and representants of the population, each of them with their own interests and perspectives (McHarg, 1969). A successful GI planning depends on sharing plans with different stakeholders, including those who may be in opposition (ibid.). However, there is little literature on collaborative efforts to apply ecosystem services on landscape development (Termorshuizen, J. W. & Opdam, P. (2009), which adds up to the barriers on the implementation of GI.

1.3 Green Infrastructure's influence on cities and human life

1.3.1 Green infrastructure and water management

After the 19th century, the topic of stormwater management has been mostly addressed by civil and hydraulic engineers. However, the relationship between water and soil has implications that involve social, economic, political, and ecological levels (Di Carlo et al., 2020). Because of this, there is a need for greater integration between water management and urban planning, in which water is no longer seen exclusively as a functional and sanitary concern, but also as potential for aesthetic, social and environmental qualities of the landscape.

In the past, the paradigm for water management was based on connecting the hydraulic supply as much as possible, and then evacuating wastewater through drainage systems as fast as possible (Bertrand-Krajewksi, 2021). The problem with this approach is that it does not consider the natural water cycle and the importance of surface water infiltration on-site. This problem is exacerbated by the increased urbanization and constant expansion of cities at the expense of green areas, thus reducing possibilities for water to naturally infiltrate into the soil and instead end up as increased runoff into the drainage systems. In addition, the burden of climate change on increased rainfall puts an extra pressure on the already saturated drainage systems (Stankovic & Maksimovic, 2019). Not only this increases flood risk in urban areas, but it also raises the probabilities for drought because there is little recharge of the water table, it increases water pollution and soil erosion, and it adds up to the urban heat island effect.

Traditionally, stormwater control has focused on large, infrequent storm events. **But 90% of rainfall events are smaller in volume and intensity, and most of existing infrastructure and regulations do not account for them.** These "smaller" events also have the capacity to generate runoff, and because it is unmanaged it creates a lot of flooding problems in urbanized areas. Rainfall that would naturally be absorbed by the soil and vegetation, instead accumulates into artificial systems that send an increased

runoff downstream. This results in flooding, water pollution, erosion, and shortages in water recharge. Instead, capturing runoff from an early stage makes it more effective to artificial systems to manage excessive amounts of water during heavy storms (Watson & Adams, 2011).

Building and developing land without taking in consideration the water balance results in inefficient water dynamic that increases the frequency and severity of flooding. Large impervious surfaces like asphalt and concrete generate runoff almost immediately. In contrast, vegetated landscapes are very effective at cleaning and intercepting rainwater, and consequently reducing runoff for most off rainfall events. (Watson & Adams, 2011). Table 6 shows a comparison of how different types of vegetation cover influence in rainfall interception. It is evident that adding variation in the urban vegetation including trees and prairie grass is more effective than just having a uniform lawn cover at intercepting rainwater. Furthermore, **the replacement of native vegetation with nonnative species that lack the capacity to absorb rainfall effectively results in an increased demand for supplemental irrigation and a reduction in the landscape's capacity to cope with flooding**. Urban trees do not provide the benefits of trees in a natural forest either. Street trees often grown under less-than-ideal conditions such as compacted soils, very limited area, pollution, neglectful maintenance, or lack soil volume. The combined result is a shorter life span and limited growth, and therefore urban trees hold less capabilities for groundwater recharge and flood reduction (ibid.).

Table 6. Approximate maximum rainfall interception by vegetation type. Source: (Watson & Adams, 2011).

Vegetation type	mm
Deciduous forest	35.6
Big bluestem prairie grass	25.9
Urban deciduous tree	14.2
Corn	3
Turf grass	2

Natural systems provide effective solutions to deal with excess to water and minimize flooding (McHarg, 1969, p.65-69). Forests help reduce the amount of runoff and its impact, leaves on the ground reduce raindrop impact and thus prevents soil erosion, vegetated areas absorb greater amounts of water than paved ground, wetlands store water during heavy rains and slow down runoff, and floodplains carry excess water during periods of heavy rain. Trees also improve the quality and quantity of water, they absorb water from the soil, and reduce the movement of sediment that would otherwise end up clogging nearby streams (ibid.).

When it comes to flooding, **we can replicate the natural systems' response to rainfall by planning for different stages of rainfall events**. In principle, it is recommended to follow a three-level strategy for managing surface runoff divided it in three stages (Miljødirektoratet, 2014b; Statens Vegvesen, 2020):

(1) infiltration,
(2) retention,
(3) and safe drainage.

First, rainfall from small events should be captured and infiltrated on-site to reduce the amount of runoff sent downstream. Secondly, during modest rainfall events, runoff can be captured and delayed through retentive grading in places that can be allowed to flood at times. Finally, greater rainfall can be led away by superficial floodways (Miljødirektoratet, 2014b; Watson & Adams, 2011). In addition, floodplains, wetlands, and buffers that prevent damage to private property during heavy rainfall events should be protected and restored so that they are capable to control the damage during extreme events. According to Watson and Adams (2011), most rainfall events, regardless of location, produce less than 13

mm of precipitation. Capturing rainfall during these small events reduces the total runoff that ends up in larger drainage systems, and therefore becomes critical at mitigating the amount of damage caused during extreme events (ibid.). These alternative ways of thinking about surface water management are examples of nature-based design for resilience.

Photo 1. Example of Sustainable Urban Drainage System in Oslo. Photo: Michelle G. Johansen, 2020.

There are several ways governments have been trying to integrate natural elements into water management practices. One of these initiatives is **Sustainable Urban Drainage Systems** (SUDS). SUDS represent an alternative to the traditional systems to efficiently manage drainage and stormwater in urban environments (Stankovic & Maksimovic, 2019). They can improve the conditions of the built environment by reducing the risk of flooding and other harms caused by the traditional drainage systems. They also create opportunities to preserve habitats for urban wildlife, to recharge natural groundwater, and to enhance evapotranspiration from vegetation and surface water (ibid). **SUDS aim to control the volumes of runoff and reduce water pollution before recharge**. This involves mimicking the natural catchment process by the use of green roofs, soak ways, rain gardens and permeable pavements to prevent an excess of runoff (see Photo 1).

Water Sensitive Urban Design (WSUD) is a more holistic approach that welcomes water inside cities, instead on just focusing on how to take it out. SUDS tend to refer only to surface water runoff, while **WSUD integrate all the stages of the water cycle, incorporating water supply and demand, wastewater, rainfall and its runoff, stormwater and ground management** (Stankovic & Maksimovic, 2019). WSUD can be applied to different scales, from home design to urban planning. In addition to the measures used in SUDS, WSUD can be applied by controlling and reusing grey water, directing runoff to street trees, and establishing open spaces near water to minimize flood damage.

A similar approach is the Chinese concept of **Sponge Cities**. It encourages the use of vegetation and permeable surfaces to capture every single rain drop. The term Sponge City was introduced by the Chinese government in 2014 with the purpose of dealing with stormwater challenges, such as pluvial flooding, water pollution, and water scarcity. **The goal is that cities will manage most of their stormwater on-site through natural storage, infiltration and purification** (MHRUD, 2014). This new approach calls for the use of slower, more natural processes such as soil and vegetation to manage stormwater. The principle behind this is that impervious areas are those that do not absorb water into the soil and in turn create runoff after a rainfall event, while soil in natural areas absorb water like a sponge. Through a system of vegetation, soil, stream networks and natural features, the natural landscape ensures an effective response to long-term rainfall patterns (Watson & Adams, 2011).

Green Infrastructure involves the use of both vegetation and water components, such as rivers and lakes, as an interconnected network. It also contributes to the efficiency

of artificial drainage systems and reduces our dependence to them. Some concrete examples of Green Infrastructure with a focus on water management include the use of runoff diversion strategies, rainwater harvesting systems, rain gardens, planter boxes, bioswales, permeable pavements, green streets and alleys, green parking, green roofs, urban trees, and natural land conservation (Stankovic & Maksimovic, 2019). **By combining man-made drainage systems with natural and semi-natural elements there is a higher potential for reducing the amount of runoff and thus the risk of flooding in cities.**

We can prevent flooding by using green infrastructure following these principles (Watson & Adams, 2011):

- **Protect and restore natural systems** such as wetlands, floodplains, sand dunes, mangroves, and vegetation buffers.
- **Plan for different levels of rainfall** through interception, retention, and slow release of runoff.
- **Increase the amount of vegetation and permeable soil** to allow for water to convey deep into the soil and avoid water damage.
- **Capture and reuse water** through cisterns.
- **Protect the hydrological systems** of connected streams and tributaries.
- **Leave space for rivers** to meander naturally so that there is enough area to store and slow down waterflow.
- **Design areas** such as parking lots, sports fields, parks, and other public gathering spaces **to detain water** during storm events temporarily.
- **Combine gray infrastructure** such as canals and sewers **with green infrastructure** such as swales and greenways to distribute water away from built areas.

1.3.2 Green infrastructure and urban ecology

The greatest threat to biodiversity worldwide is the rapid loss, fragmentation and degradation of habitat due to human activities (Millenium Ecosystem Assessment, 2005). Other causes for loss of biodiversity include climate change, spread of invasive species, and pollution, which are also results of human activities, mainly agricultural and urban expansion (ibid.). Species diversity provides people with food, medicine and natural resources that contribute to economic development and human well-being (McHarg, 1969). For instance, studies reveal that a healthy environment is one covered with trees with at least 40% of the total area (McHarg, 1969). Therefore, a highly vegetated area will not only provide habitat for many species but will also benefit human health (WHO Regional Office for Europe, 2016). Moreover, **"biodiversity has cultural values, because many people ascribe intrinsic value to biodiversity, and because it represents unexplored options for the future (option values)." (Millenium Ecosystem Assessment, 2005).** Biodiversity loss is therefore a major concern for human development, and the role that human activities have on this problem should be taken seriously.

Urbanization alters species biodiversity in at least three ways (Grimm et al., 2008). First, **as humans dictate the types of vegetation we want in our cities, we directly control plant richness, evenness, and density**. Second, **by altering the species compositions, biological communities are also affected**. While some species become well-adapted to our imposed changes, indigenous species often become displaced by exotic species introduced by humans. Some species even thrive because they outmatch their natural enemies in adapting to the urban conditions. Finally, the urban environment not only changes species diversity and interactions, but **it also alters**

species behaviors, psychologies, and morphologies of city-dwelling organisms. We act as a selective force by changing the physical environment, for example by building structures and modifying and fragmenting habitats, and the indirect effects of our cities, such as temperature changes, light, noise and pollution. In the long term, the influence cities have on biodiversity can lead to the loss of species and to evolutionary changes in entire species communities (ibid.).

Despite the well-known negative effects that urbanization has for biodiversity loss, studies reveal that **urban environments are actually home to the majority of birds and plant species** (Aronson et al., 2014). The population density of species in cities is currently in decline (ibid.), while urban expansion is projected to increase significantly in the coming decades (United Nations Department of Economic and Social Affairs, 2014). The classic approach to maintaining biodiversity and their associated ecosystem services is the conservation of existing natural and semi-natural habitats (Rosenzweig, 2003). The restoration and reconstruction of habitats is another way to compensate for the biological changes of the altered urban landscape. The problem with these two alternatives is that cities often have shortage of available land for either conservation or restoration (ibid.). Reconciliation ecology proposes a compromise between conservation and urban development. As Rosenzweig (2003) defines it, reconciliation ecology is "**the science of inventing, establishing, and maintaining new habitats to conserve species diversity in places where people live, work, or play**", and to be able to create inviting habitats we need to learn what species need to survive and to thrive. It is therefore important to direct conservation efforts beyond creating natural reserves and incorporate the role that cities have for the preservation of native and endemic species (Aronson et al., 2014).

Nature and human environments are no longer seen as separate entities. Urban ecology understands cities as heterogeneous ecosystems, composed of changing landscapes and complex social systems (Grimm et al., 2008). Green Infrastructure offers solutions for the protection of biodiversity while also providing social and economic benefits to human settlements (McHarg, 1969). For example, GI planning can provide a framework to direct urban growth away from important habitats and conservation areas. It can also provide pathways for wildlife to improve their habitat conditions. Many ecologists suggest that as urban populations expand, and their associated environmental problems become more evident, our creativity and commitment to take responsibility for our actions should

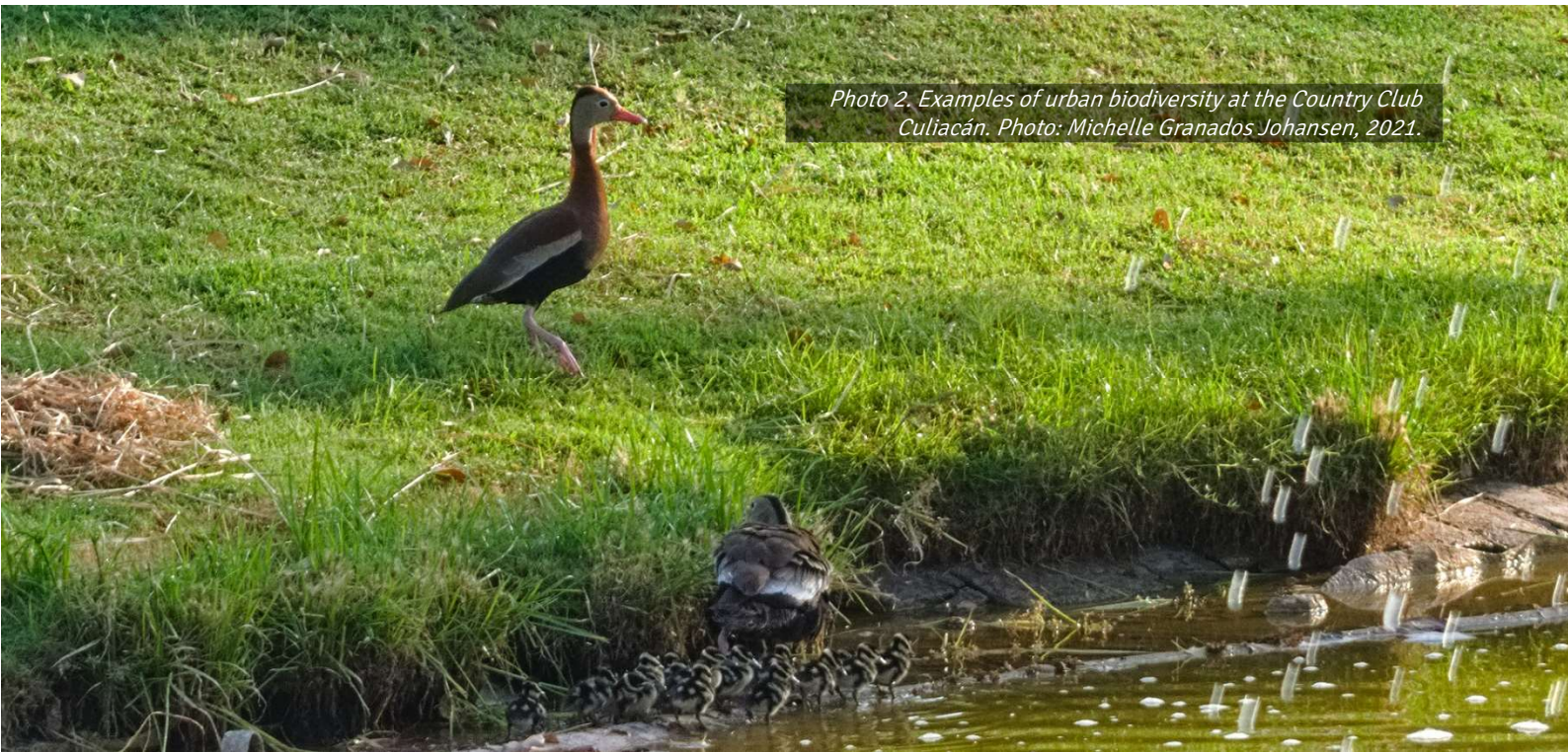


Photo 2. Examples of urban biodiversity at the Country Club Culiacán. Photo: Michelle Granados Johansen, 2021.

also increase. In this way, urban ecology will become essential if we want a more sustainable future (Grimm et al., 2008).

Much of what is known about landscape and urban ecology is based on the principles of island biogeography theory (MacArthur & Wilson, 1967), in which species number and dynamics could be described by the characteristics of their habitats. Their theory recognizes three fundamental patterns:

(1) larger areas tend to support more species number and diversity,
(2) remote islands tend to support fewer species and increase the likeliness for extinction,
(3) species numbers are always shifting according to changes in rates of extinction and immigration.

Their studies suggest that there is a limited number of individual species that an island can support. When a new species migrates to the island, there is a possibility that it will either not prevail against existing competitors, or it will adapt and maybe displace local species. Interconnected habitats tend to have a higher relative diversity in the species that succeed in dispersal. Even small intermediate islands (steppingstones) can significantly enhance biotic exchange. Dispersal can create an initial unbalance in the absolute species number, but in the long term it leads to an increase relative species diversity. The theory of island biogeography is often applied to natural reserves. However, MacArthur and Wilson (1967) make a distinction between islands and other types of isolated habitats. Terrestrial 'habitat islands', or patches, differ from real island in which the surrounding conditions make migration, disturbances, and influences from the exterior more likely. Thus, more factors influence the total number of species and their population dynamics than just size and proximity. According to Bastin and Thomas (2004), it appears that the most effective conservation measure of terrestrial plant species in urban environments is to preserve and connect large, high quality habitats.

Altered habitats can be designed and spatially arranged for human benefit in a way that maximizes urban biodiversity and their consequent ecosystem services (Rosenzweig, 2003). **The single most significant landscape determinant for urban species richness is patch size** (Beninde et al., 2015). There is not a single ideal patch size for maintaining high levels of urban biodiversity, as the ideal size would depend on specific factors of the region and the prioritized species. However, there has been shown results that **for patches below 27 ha, species richness declines rapidly** (ibid.). For smaller habitat patches, 4.4 ha have been considered sufficient to minimize the loss of urban-adapted species (Drinnan, 2005; Germaine et al., 1998). Greater areas are also necessary for the conservation of species that avoid urban environments. An average of 53.3 ha has been determined as a standard threshold (Drinnan, 2005).

The next most important factor is connectivity (Beninde et al., 2015). It has been shown that the presence of green corridors between patches is much more effective than having patches at close distance from each other, or in other words, **corridors are more effective than steppingstones at promoting species dispersal**. For example, studies demonstrates that there is a positive correlation between birds, frogs, and plant populations with the presence of corridors, and can partly compensate for long distances between suitable patches in urban settings (Drinnan, 2005). On the contrary, isolated populations in fragmented urban landscapes may act as islands. In addition, the benefits that green corridors provide goes beyond wildlife connectivity. They also provide buffers for flooding and pollution (McHarg, 1969, p. 44), and they can be a useful tool to establish urban development boundaries and buffers

against vulnerable zones while also providing opportunities for recreation and soft mobility (Benedict & McMahon, 2006). Despite all the benefits, corridors can also facilitate the spread of unwanted pathogens, fires or invasive species (Haddad et al., 2014). It is therefore important to plan carefully which patches are to be connected to each other, depending on their characteristics and the purpose of the intervention. Overall, research suggest that the benefits of providing corridors to improve ecological connectivity far outweigh the possible negative effects and are therefore an important tool for species conservation (ibid.).

Other positive factors for species richness include the presence of water, management intensity, vegetation density and vegetation structure (Beninde et al., 2015). The proportion of vegetation cover compared to the area of a city can be determinant in maintaining urban species richness. There has been found that a vegetation cover of less than 10% to 30% of the landscape would mean a rapid decline in species richness (Radford et al., 2005), while some authors suggest that the threshold of 20-30% should be established to prevent the further effects of habitat loss combined with habitat fragmentation (Andrén, 1994). However, the amount of area covered with vegetation is not enough to guarantee high levels of biodiversity. A heterogenous vegetation structure that includes herbs, shrubs and trees provides more benefits than tree density alone (Beninde et al., 2015). Nevertheless, each species has different dispersal capabilities, so to have an effective corridor or patch, selected species should be prioritized to provide the right habitat requirements (Bastin & Thomas, 2004).

The shape of patches and corridors will differ depending on the purpose we want to achieve (Beck, 2013). A compact, round patch will have more core area and more stable microclimatic conditions, while an elongated patch will be almost all edge and will encourage movement. A convoluted patch encourages animal movement and genetic diversity. Species interactions and exchanges of materials increase in patches that are convoluted and have multiple lobes. According to Dramstad et al. (1996), the ideal patch shape is a 'spaceship' form that combines the benefits of a stable core area and the interactions with the surrounding landscape that the lobes provide (see Figure 7).

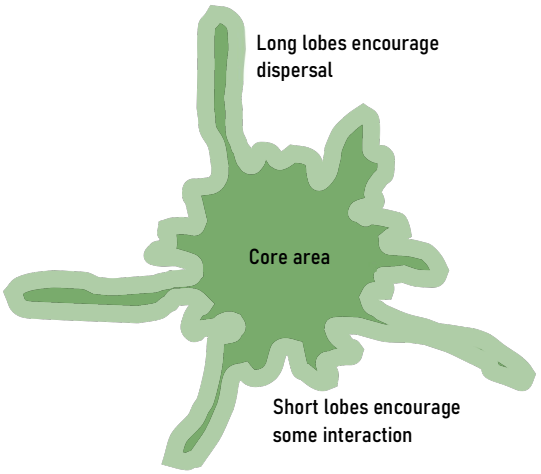


Figure 7. Ideal spaceship shaped patch. Adapted from Dramstad et al. (1996).

Summarizing the previous information, for a patch or a corridor to be considered suitable habitat it needs to be big enough and of good quality, by providing a diverse vegetation and in some cases access to water, and it should also be connected to suitable habitat to ensure species interactions and genetical diversity. Unfortunately, the creation of ecological patches and corridors within urban environments is often limited by the lack of available space and conflicting land uses (Bastin & Thomas, 2004). Narrow corridors do not provide for forest core, and as Bastin and Thomas (2004) explain it,

"there is a potential conflict in planning between narrow green corridors, which have important social benefits, and broad, but quite localized corridors, which might actually benefit more restricted types of wildlife".

Moreover, the creation of new habitats and the restoration of degraded land are far more expensive than protecting undeveloped land (McHarg, 1969, p. 41). Hence the importance of identifying ecological hubs before they are developed and protect them before they come in conflict with other land uses.

1.3.3 Green infrastructure and health benefits

An urban environment that has nature as the driver for design has multiple physical and mental health benefits. Several studies lead to the conclusion that there is a link between the presence of urban green spaces and a range of health and well-being outcomes, such as increased walking (Sarkar et al., 2015); less children's obesity (Bell et al., 2008); lower rates of depression, anxiety and stress (Beyer et al., 2014); and lower mortality due to causes such as respiratory diseases and cardiovascular disease (Villeneuve et al., 2012).

Exposure to natural environments has also been linked to an **improvement in the immune system** (Kuo, 2015 as referenced by Braubach et al., 2017). For example, a study by (Li et al., 2008) shows associations between visiting forests and the presence of anti-cancer proteins (Braubach et al., 2017). Other studies have demonstrated that greater exposure to the natural environment and the microorganisms present in biodiverse environments may be correlated with a reduced risk of developing allergies, especially from early exposure (Hanski et al., 2012; Kondrashova et al., 2013; Ruokolainen et al., 2015) with some exceptions (Fuertes et al., 2016).

Moreover, the presence of trees in residential areas can be linked to lower asthma incidence (Lovasi et al., 2008). There is also evidence that green roofs and walls can improve the air quality and temperature of buildings, filtering the amount of air pollutants and thus providing a healthier environment for people inside buildings (Bass & Baskaran, 2003).

A study in Scotland found a link between higher levels of neighborhood green spaces **and lower stress levels** for both men and women (Roe et al., 2013). Stress has been proven to be the cause of many health problems, such as cancer, depression, dementia, and cardiovascular problems (Beatly, 2016, p. 85). Cities like Birmingham, in the UK, have taken this seriously. They have identified the areas of the city where there is an overlap between declining health conditions and depravations of the environment, in order to create a coordinated greening plan to increase the amount of trees, green roofs, and green trails for pedestrians and cyclists (City of Birmingham, 2013, p. 16).

It has been suggested that the presence of high quality green spaces increase **physical activity** of near residents (Bedimo-Rung et al., 2005). Physical activity is highly regarded as means to improve human health. It has been linked to an improvement in cardiovascular and mental health, neurocognitive development, and general well-being, as well as preventing obesity, cancer and osteoporosis (Owen et al., 2010). Moreover, a study from Kaczynski et al. (2008) showed that there is a connection between the characteristics of parks and physical activity. This study concludes that both size and proximity are significant for the frequency and choice of green spaces. But even more significant is the presence of facilities (like walking trails, water areas, wooded areas, meadows, playgrounds and sports fields), and support amenities like restrooms, benches,

attractive landscaping, lighting, drinking fountains, picnic areas, parking lots, bike racks, signs and multiple entrances. The study concludes that an interconnected network of parks that provide trails and a variety of facilities may be effective at encouraging physical activity in adults (ibid.).

There are some lessons that we can learn from what has been seen during the covid-19 pandemic and the role of Urban Green Spaces. Because the lockdown measures reduced physical activity of individuals, neighborhood green spaces took a more important role in providing conditions for outdoor activities (Ahmadpoor & Shahab, 2021). People living in areas far from green spaces lack the benefits that these spaces provide. Traveling restrictions only enhance the disparity of who has access to green spaces. This can lead to isolation and negative health effects of sedentarism, as well as mental effects like stress and anxiety. This means that accessibility and quality of urban green spaces can have important influence on the physical and mental health of communities during the lockdown (ibid.).

1.3.4 Green infrastructure and social benefits

Besides the influence on psychological and physical health, it is hard to argue against the benefits that green spaces provide to a population regarding recreation, creativity, and spirituality. The Attention Restoration Theory, as explained in the early works of Kaplan and Kaplan (1989), underlines the significant role that nature has in recovering from stress and improving cognitive performance. Other studies conclude that connection with nature encourages generous behavior (Weinstein et al., 2009), cooperation (Zelenski et al., 2015) and creativity (Lichtenfeld et al., 2012). These factors put together mean that people who is exposed together are also more apt to learning and working, which eventually translates to economic benefits (Beatly, 2016).

Human beings evolved in a natural environment. It has been only in the last centuries that we have adapted our lives to indoors, but our nature is still the same (Rosenzweig, 2003). A study from the ecologist Gordon Orians and the psychologist Judith Heerwagen suggest that **the human species have never outgrown the desire to live in close relationship to nature** (Heerwagen & Orians, 1986 as interpreted by Rosenzweig, 2003). Their study revealed that people get satisfaction from looking at open landscapes with a few trees, and prefer trees with several trunks topped by a wide branching structure. Men prefer more open vistas of the savannah, while women prefer a more sheltered, lightly wooded corner. Both men and women appreciate the presence of water, grazing animals, flowers, fruiting plants, and vantage views to the horizon in at least one direction (ibid.). Thus, we can say that we all have a need for nature, and what we define as a "beautiful landscape" reflects this need.

A study made by Roe and Aspinall (2011), shows that there is a visible influence that connection with nature has on **children's development**. In their study, they saw the positive impacts for adolescents that spend time outside the classroom, in contact with nature. They showed an improved mood and more effectiveness in reaching personal goals. For children with behavioral problems, the benefits were even more significant, as time spent in nature proved to reduce the symptoms of ADHD and contributes to treat autism. Disconnection from nature, on the other hand, leads to fear to nature and of the outside world (Louv, 2008, as referenced by Beatly, 2016).

Studies in Turkey (Kalayci Önaç et al., 2021) and New York (Lopez et al., 2021) suggest that people tend to use green spaces and connect to nature no matter how crowded the city. Residents in New York continued to use UGS during the covid-19 pandemic, but factors like concerns about safety (regarding

virus transmission), lack of access, and lack of desired features like restrooms and playgrounds discouraged people from using green spaces (ibid.). In Turkey, the use of UGS changed during lockdown measures. People began to shift their transportation modes to those of individual character, such as walking and cycling, and open areas gained a more important role for recreation, working, resting, and eating, rather than the traditional uses like walking or sports (Kalayci Önaç et al., 2021).

Accessibility to green spaces is also a topic relevant for **social equity**. People in marginalized communities often lack availability to good quality green spaces and all the associated ecosystem services related to them (Allen & Balfour, 2014, as referenced by Braubach et al., 2017). Because the presence of urban greenery has an impact on human health, improving the availability of good quality green in disadvantaged neighborhoods contributes to reducing health inequality (ibid.). This puts more responsibility on those who design public spaces to provide for different needs, to provide enough space for everyone, and to improve equitable access so that all people can benefit from the health benefits that green spaces provide, even during times of crisis.

Green spaces can play an important role for improving **social cohesion and sense of community**. Parks offer opportunities for people to gather in social activities and recreational purposes. Activities like barbeques, cycling and excercise can stimulate social interactions that would not occur in other settings (Jennings & Bamkole, 2019). Some studies have concluded that volunteering experiences like green space maintenance and sports participation correlate to stronger bonds within the community and increased solidarity among residents (Jennings, 2019). A case study of an informal settlement in Johannesburg suggested that self-sustained green areas in such challenging neighborhoods can improve the living conditions of the residents (Adegun, 2019). For example, gardens can contribute to psychological well-being and a sense of attachment because of the aesthetics; trees can improve air quality and temperature regulation, thus increasing comfort for the residents; communal gardens and urban farming can support low-income families by providing food and job opportunities, while also enhancing social capital; and natural green areas can provide natural resources such as water, firewood and construction materials, in addition to recreation and contact with nature (ibid.).

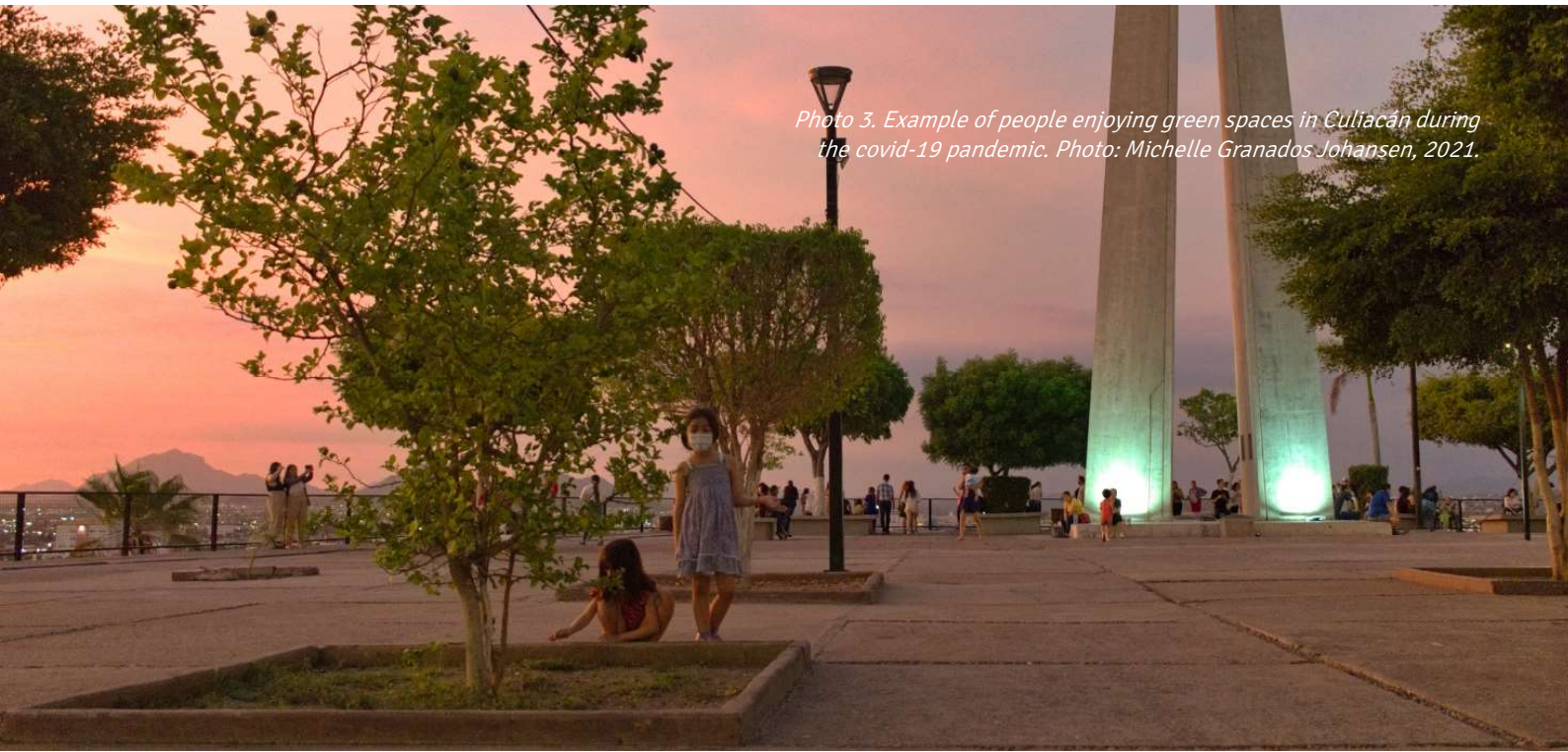


Photo 3. Example of people enjoying green spaces in Culiacán during the covid-19 pandemic. Photo: Michelle Granados Johansen, 2021.

Studies show that the presence of green spaces can have an impact on the **perceived safety of an area**. For example, one study suggest that a 10% increase in tree cover in vacant lots could be linked to a 11.8% decrease in crime rate, all else equal (Troy, Grove, and O'Neil-Dunne, 2012, as referenced by Beatly, 2016). Thus, we can say that urban vegetation is not only a topic for public health, but also for public safety. Other studies reveal an association between abundance of vegetation and lower rates of assault, robbery, and burglary (Ceccato et al., 2020). Even in low-income neighborhoods residents perceived parks as safe. The vast majority of research support the idea that green areas have a positive impact in the perceived safety and the actual crime rates in residential areas (ibid.).

On the other hand, some studies reveal that areas with dense vegetation can actually increase crime. An important remark of these studies is that **maintenance plays an important role for crime**. Vacant lots that are well managed and maintained have less crime and vandalism than neglected sties (Branas et al., 2011; Heinze et al., 2018; as referenced by Ceccato et al., 2020). It is important to note that perceptions of safety vary a lot depending on culture, income levels, political context, climate, and urban planning traditions. Meaning that the local context of a city should be thoroughly considered before drawing conclusions.

Safety can also be increased by incorporating vegetated traffic-calming features like medians and roundabouts to protect pedestrians from vehicles (Pima County, 2015). Narrower streets can have the effect of reducing traffic speeds, while also giving more space for pedestrians, cyclists and street trees (ibid.). In addition, the presence of street trees near the road edges can have a calming effect for car drivers, thus reducing the probabilities for traffic accidents (Fitzpatrick et al., 2016).

1.3.5 Green infrastructure and temperature regulation

Rising temperatures in cities have become a serious problem in the recent decades and will only increase in the years to come. Urbanized and built cities are significantly warmer than their surrounding rural areas. This is what is known as the Urban Heat Island (UHI) phenomenon. As Bass and Baskaran (2003) explain, "the UHI effect not only causes thermal discomfort, but it increases the formation of smog and leads to respiratory problems and heat stress". The main reason for this phenomenon is the large amount of heat produced by human activities and the built environment, mainly because cities tend to be built with non-reflective materials, impermeable surfaces and with a lack of vegetated areas (Shishegar, 2014).

Research shows that some measures to mitigate the UHI phenomenon include the use of highly reflective surfaces, the use of water bodies, and bioclimatic design that takes in count the shapes of buildings to direct wind flow. But the most effective of all measures is to add vegetation. This is because vegetation influences air temperature through evapotranspiration, in which plants lose water in the form of vapor released into the air. In ideal conditions, evapotranspiration could reduce temperatures by 2-8°C compared to surrounding areas (Taha, 1997). Secondly, tree canopy produces shade, which blocks sunlight from reaching surfaces underneath and therefore less solar energy is converted to heat (Shishegar, 2014). And finally, vegetation can shape the movement of air flow, channelizing air movement by placing trees, shrubs and grass strategically (Bonan, 1997). Because of these three factors, **the use of vegetation is the most effective measure to mitigate the Urban Heat Island effect**. However, this is a challenging task because the urban design principles that apply to temperate climates are not the same as those of warm, tropical cities. For example, in cities

like Singapore or Hong Kong it is desirable to have city blocks close together to provide shade, while in colder cities it is preferred to leave enough room between the buildings to welcome sunlight to the road level (Lehmann, 2007).

The effectiveness of the urban green for temperature regulation has been studied in many cities around the world. A study in Manchester suggests that a 10% increase in vegetation cover could compensate for the increasing temperatures in dense urban areas (Gill et al., 2007). While a decline of 4 to 15% vegetation cover would have the opposite effect, rising temperatures by 5.6 to 9.2°C (Carter et al., 2015). Studies in Taipei and Mexico City (Barradas, 1991; Chang et al., 2007) conclude that big parks are cooler than smaller parks. This is especially important in cities that experience extreme warm temperatures. A study in Tel-Aviv shows that parks with more trees tend to be cooler than parks with fewer trees, but an excess of trees could also block desired wind and have a negative effect on human comfort. Contrastingly, parks covered only with grass can be even warmer and more humid that its surrounding built areas during the day. Hence, tall trees with wide canopies are the best option for cooling in a coastal Mediterranean area (Potchter et al., 2006). A study carried out in Athens by Tsiros (2010), shows that streets with dense tree cover and minimal traffic load can be up to 2.2°C cooler than treeless streets, and another pilot study suggests that shade provided by mature trees can reduce surface temperatures up to 15.6°C (Gill et al., 2007). Therefore, **adding green to cities is an effective way to mitigate the rising temperatures** observed in contemporary cities.

Not only can parks help cool the air in the summer, but in some cases they can also be warmer than their surroundings during the winter (Chang et al., 2007). An example of this is a large urban park in the city of Nagoya, Japan. During the summer months, researchers found that the air temperature of the park was 1.9°C cooler than its surroundings, while it was 0.3°C warmer during the winter (Hamada & Ohta, 2010).

A common problem is that cities often lack the space for new parks and street trees, yet we have space for green roofs and vertical gardens. By removing heat from air due to evapotranspiration, green roofs can add to passive cooling strategies and contribute on mitigation of the Urban Heat Island Effect. In addition to the potential for outdoor temperature regulation, green roofs also provide cooling inside buildings, reducing the need for the use of air conditioning and thus the extra heat and emissions of CO_2 that comes from HVAC systems (Shishegar, 2014). In Toronto, a study revealed that the implementation of green roofs could lead to a reduction in energy consumption of 6% for cooling and 10% for heating, while the use of vertical gardens can reduce the need for air conditioning by at least 23% (Bass & Baskaran, 2003). Similar results were found in studies in Vancouver, Montreal and Santa Barbara (ibid.).

In summary, the most effective strategy to mitigate the heat produced by urban structures is to improve the amount of vegetation cover in urban areas. Vegetation reduces temperatures through evapotranspiration, shading, and air flow (Shishegar, 2014). Therefore, it is of outmost important to increase urban green areas such as parks, street trees, short vegetation cover, and green roofs and walls if we want temperatures to cool down in cities.

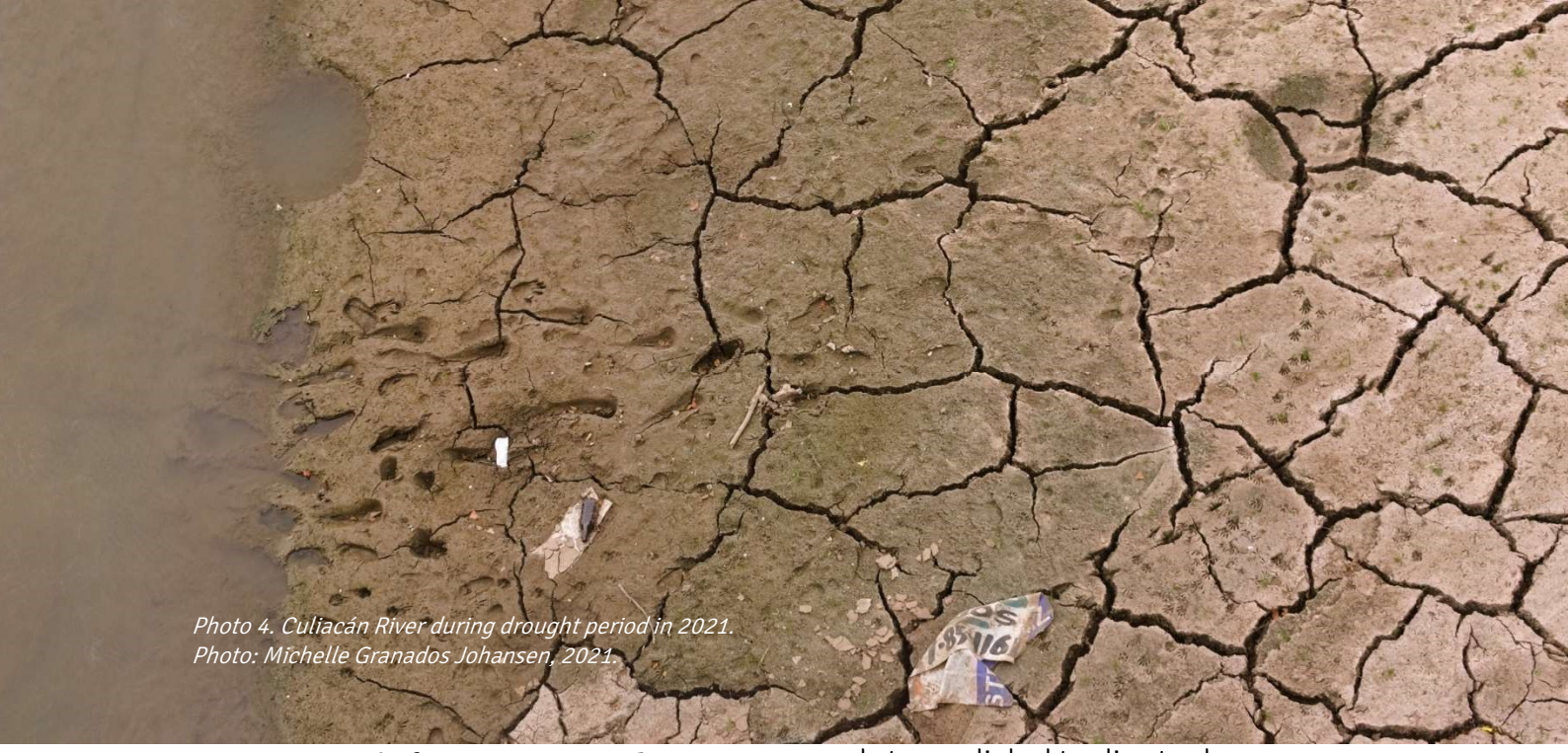


Photo 4. Culiacán River during drought period in 2021.
Photo: Michelle Granados Johansen, 2021.

1.3.6 Green infrastructure and climate change

Over the last century, global average surface temperatures have increased by about 0.6°C, and it has accelerated so that it is projected up to 5.8°C increase in the next hundred years (IPCC, 2021). Even an increase of 2°C means a pressing threat from heatwaves, droughts, floods, more severe storms, ice sheet melting, and an increment of the sea level that will leave many cities under water (ibid.). It is estimated that cities account for 70 to 80% of all greenhouse gas (GHG) emissions, even though it is only 50% of the world's population that live in urban areas (IPCC, 2014). In Latin America, it is 80% of the population that lives in cities, and this number is expected to rise to 85% by 2040 (United Nations Department of Economic and Social Affairs, 2014). GHG emissions in cities come mostly from fossil fuel combustion and industrial processes, and they will likely continue to grow as long as they are the means for economic growth (IPCC, 2014).

If we continue in this path, we are going to face unprecedented catastrophes in cities all around the world. Therefore, we need to create strategies to mitigate the causes of climate change, but we also need to learn how to adapt to the inevitable changes that are coming. According to IPCC (2014), **mitigation** consists of both the reduction of substances linked to climate change sources and the boosting of GHGs sinks (p. 1266), while **adaptation** is "the process of adjustment to actual or expected climate and its effects" (IPCC, 2014, p. 1251). Under a changing climate, the urban green has an important role to play for adaptation and mitigation strategies in our cities. As the landscape architect Travis Beck states,

> ***"our greatest chance of success is to learn from the evolving natural systems that have survived on this planet through far greater upheavals"*** (Beck, 2013, p. 258).

With rising temperatures worldwide, **the Urban Heat Island effect will be accentuated**. Thus, it is necessary to find passive design strategies that contribute to reducing temperatures in cities. As mentioned before, there is a correlation between the amount and density of green areas compared to surface temperatures (Barradas, 1991; Bonan, 1997; Chang et al., 2007; Gill et al., 2007; Potchter et al., 2006; Shishegar, 2014; Taha, 1997). Therefore, **an adaptation strategy to increasing temperatures is to add more vegetation wherever possible**. Cities that are already highly built-up present the challenge of lack of space for new green areas. In these cases, we must creatively find opportunities to increase vegetation cover,

for example through green roofs and vertical gardens, unused railway lines, street vegetation, private gardens, brownfields (Kazmierczak, 2016), parking lots, and the creation of greenways where the space allows for it (Gill et al., 2007).

Another foreseen effect of climate change is **the increase and severity of droughts**. One way to adapt with the use of green infrastructure is to use **plant species that are drought tolerant** (Gill et al., 2007). Landscaping design choosing plants according to their water needs in relation to the local climate and landscape is known as xeriscaping (Weinstein, 1999). This practice reduces the need for artificial irrigation while still allow for evapotranspiration and water infiltration. We can learn from the experience of desertic regions and the strategies they use to capture as much water as possible and make sure it reaches down to the aquifers (underground reservoirs). In Mexican and American cities within the desert of Sonora, mulch is recommended to keep moisture in the soil, to reduce soil temperature, and to reduce erosion (Shipek et al., 2016). Concrete strategies to allow **for water infiltration in urban areas** include the use of bioretention basins and swales in street curbs, medians, traffic circles, and parking lots (ibid.). The use of pervious pavement (for example porous asphalt or concrete, structural grid systems, and permeable pavers) is also encouraged (ibid.). These strategies help **reduce the loss of water that goes through surface runoff and unnecessary irrigation**.

Temperatures and extreme events are expected to increase in the coming years, and the sectors of the population that are most vulnerable to the impacts of climate change should be prioritized (SEDESOL, 2012a). One of the biggest problems will be the excess of water from **changing rain patterns, rising sea level, and more severe storms and hurricanes** (IPCC, 2021). Upon this challenge, cities must learn how to deal with the excess of water in smart ways, for instance, by leaving buffer zones from coastlines and floodplains, protecting and restoring natural systems such as wetlands, mangroves and sand dunes, increasing water absorption in urban areas by using permeable surfaces and vegetation, incorporating green infrastructure to make engineered water systems more efficient, and applying the principles of rainfall interception, infiltration, retention, and slow release (Watson & Adams, 2011).

If we are to reduce the carbon emissions that cities produce, there is an increasing need for architects, planners and landscape architects to include the scientific knowledge we have on energy efficiency into the built environment (Lehmann, 2007). This goes beyond the scale individual buildings, we need more strategies for energy-efficient cities that are also resilient to the changes to come in the future. As Gaiser and Hardy (2006) describe it, "Architecture could lose or give up its responsibility to perform if we no longer have environmental achievement 'per form', but only 'per system'." It requires that we reduce the need for motorized transportation, and for artificial cooling, heating, and lighting with the use passive strategies adapted to the different types of climates and urban contexts (ibid.). For example, the demand for motorized transport can be reduced by providing greenways that make more attractive the use of sustainable mobility like cycling and walking and by promoting a compact city growth, thus reducing the emission of greenhouse gases and air pollutants from vehicles (Natural England, 2010). The use of passive strategies like tree coverage, green roofs and green walls can increase thermal comfort in buildings, and so reduce the energy demand for HVAC systems and their CO_2 emissions (Shishegar, 2014). Moreover, urban trees and green roofs have been promoted for their potential for carbon sequestration (Beck, 2013). Trees are very reliable at storing

carbon during a stable climate, but during drought periods, grasslands can fix carbon into the soil more effectively (Dass et al., 2018). This means that carbon emissions in cities can be mitigated by using street tress, green walls, green roofs, urban forests, and grasslands.

Green infrastructure present opportunities to both mitigate some of the causes of climate change and to adapt to a more unpredictable climate in the future (Quiroz Benitez, 2018). Table 7 provides an overview on specific green infrastructure strategies that contribute to adaptation and mitigation efforts as recommended in Mexican climate action plans.

Table 7. Green Infrastructure potential for adaptation and mitigation of climate change. Source: made by the author based on Quiroz Benitez, (2018).

Green Infrastructure element	Benefits	M	A
Street trees	Comfort, shade, temperature regulation, reduction of pollutants, carbon sequestration, reduction of erosion, water conservation.	X	X
Residual areas	Depends on the specific characteristics of the site.	X	X
Urban forest	Production of oxygen, absorption of CO_2, aquifer recharge, runoff control, temperature regulation, mitigation of sound pollution.	X	X
Green belt	Absorption of CO_2, reduce erosion and flood risk in coastal areas, runoff delay, soil stabilization, refugee for wildlife and protection of biodiversity.	X	
Rainwater cisterns	Possibility to keep water for dry seasons, reduction of the demand on public water supply, better water quality for human use.		X
Swales	Capture and control the volume of runoff, reduce urban pollutants, delay runoff.		X
Fluvial drainage	Reduce flooding.		X
Roof water capture	Minimize water pollution, capture, conduct, intercept, and store rainwater.		X
Rain gardens	Capture and improve water quality before infiltration		X
Green walls	Provide thermic isolation to buildings, which reduces energy demand and expenses, contribute to mitigate urban heat island effect, increase comfort and bring opportunities for food production and aesthetic qualities.	X	X
Parks	Comfort, shade, recreation.		X
Permeable pavement	Water infiltration, passive irrigation to surrounding vegetation, reduce the volume of runoff.		X
Infiltration well / dry well	Water capture, can be used to penetrate layers of impermeable soil.		X
Dams and dikes	Contribute to regenerate the water table in water basins, soil regeneration, reduce the erosion caused by runoff.		X
Green roofs	Can contribute to increase the overall urban vegetation cover and mitigate urban heat island effect, provide thermal isolation to buildings and therefore reduce energy demands and costs, reduce damage to roof constructions by reducing exposure to the elements and sun radiation.	X	X
Berm and basin	Water capture, useful in programs of hillside restoration.		X
French drain / infiltration trench	Protect buildings from humidity, extend the capture capacity of other strategies when space is limited.		X

Chapter 2. Methods

2.1 Documentation of the study area
2.2 In-depth interview
2.3 Spatial analysis

To answer the research questions, this master thesis follows multiple methods. The **documentation of the study area** and the **in-depth interview** have the purpose of presenting the qualitative data about the environmental characteristics of the city of Culiacán, the social dynamics involving the use and perceptions on green spaces, the main ecological issues, and the plans and visions for the future of the city. The **spatial analyses** are the author's contribution to the knowledge on existing green spaces, including qualitative and quantitative data on size, vegetation, function, and other characteristics. Finally, the findings of these methods lead to a **Green Infrastructure proposal** consisting of planning principles and a spatial distribution of GI strategies.

The data acquired through these three methods answer to the first question: **How does the current state of the existing urban green in Culiacán relate to the city's landscape issues?,**

and the strategic proposal that aims to answer the second question: **Which green infrastructure strategies can be implemented on a city planning level to fill the gap between the needs of the city and the current state of the urban green?**

The main objective of this study is to identify potential Green Infrastructure solutions for the city of Culiacán to get closer to Goal 11 of the Sustainable Development Goals: Sustainable Cities and Communities, make cities and human settlements inclusive, safe, resilient, and sustainable.

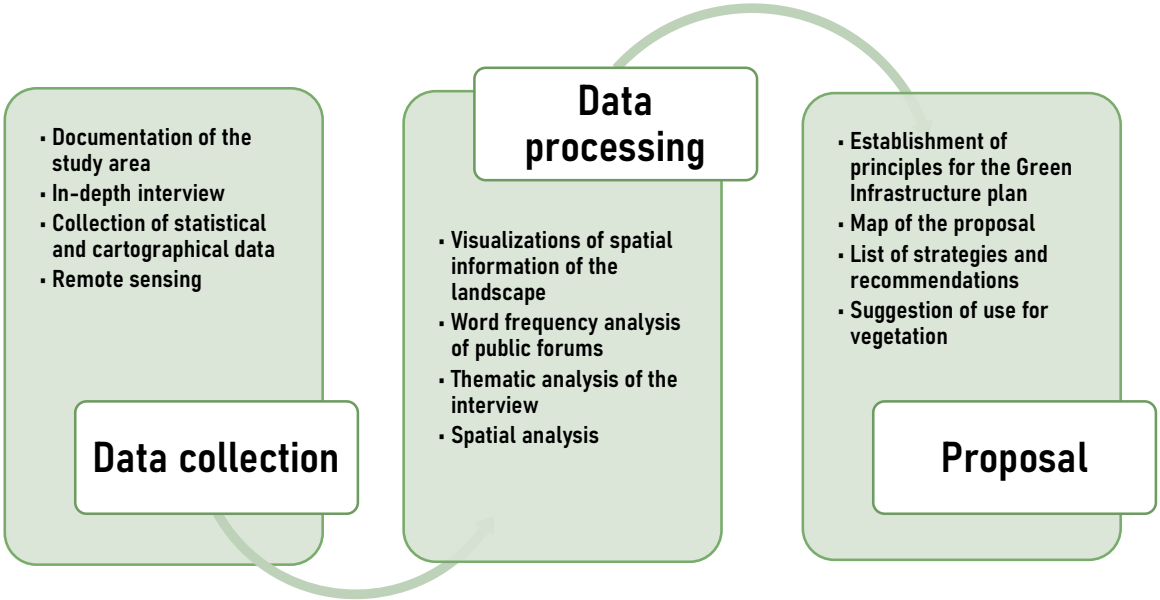


Figure 8. Diagram of multiple methods.

2.1 Documentation of the study area

This was an exploratory stage of the process. Information was gathered from various sources like planning documents, government reports, official statistics, scientific research, articles in newspapers, and cartographic publications. Revision of these documents provided an overview of the main characteristics of the city, including environmental and social aspects. In addition, a summary of the vision of the authorities for future development was provided.

2.2 In-depth interview

An unstructured in-depth interview was conducted with a key-informant to get first-hand information about the ecology of the city. This method was selected because it allows for extracting detailed information and getting a deeper understanding of a topic than through questionaries or surveys (Showkat & Parveen, 2017).

The purpose of this interview was to collect data about important species, implementation challenges, experiences with the local population, and opportunities for improvement. This information complemented and expanded the limited available scientific data about the ecology of the city of Culiacán.

The topics covered in the interview include:

- Firsthand knowledge on the local biodiversity.
- Species of interest: endangered, invasive, protected, endemic and exotic. Pollinators and keystone species. Commercially available.
- The biologist's perspective on areas of potential for recreation, ecological connectivity, conservation and development, and areas of conflict.

The person interviewed is a biologist and professor at the Faculty of Biology in the Autonomous University of Sinaloa. He has a master's degree in Natural Resources and a Science Doctorate in Biotechnology. His field experience with vegetation from the local dry forest and the city of Culiacán provides reliable information about the current status of the local ecology.

The duration of the interview was of 120 minutes and was done through the digital platform Zoom. The interview was recorded to allow for further transcription and revision.

After conducting the interview, the transcript was coded for further thematic analysis. The frequency of these codes was quantified to identify the prevalent themes and patterns during the interview. The proximity of these codes was also quantified to provide an overview on how the topics relate to each other. These analyses were done in the programs QDA Miner Lite and Microsoft Excel.

2.3 Spatial analysis

Description of the process

The purpose of the spatial analysis was to gather, process and generate quantifiable data on the existing conditions of existing Urban Green Spaces in Culiacán. The cartographic data was classified and processed following conclusions from the literature review (see sections below). The results of these analyses were then compared with goals described in the planning documents, information gathered on the city's landscapes issues and conclusions from the

literature review to determine problems and opportunities of improvement. The general processed in described in Figure 9.

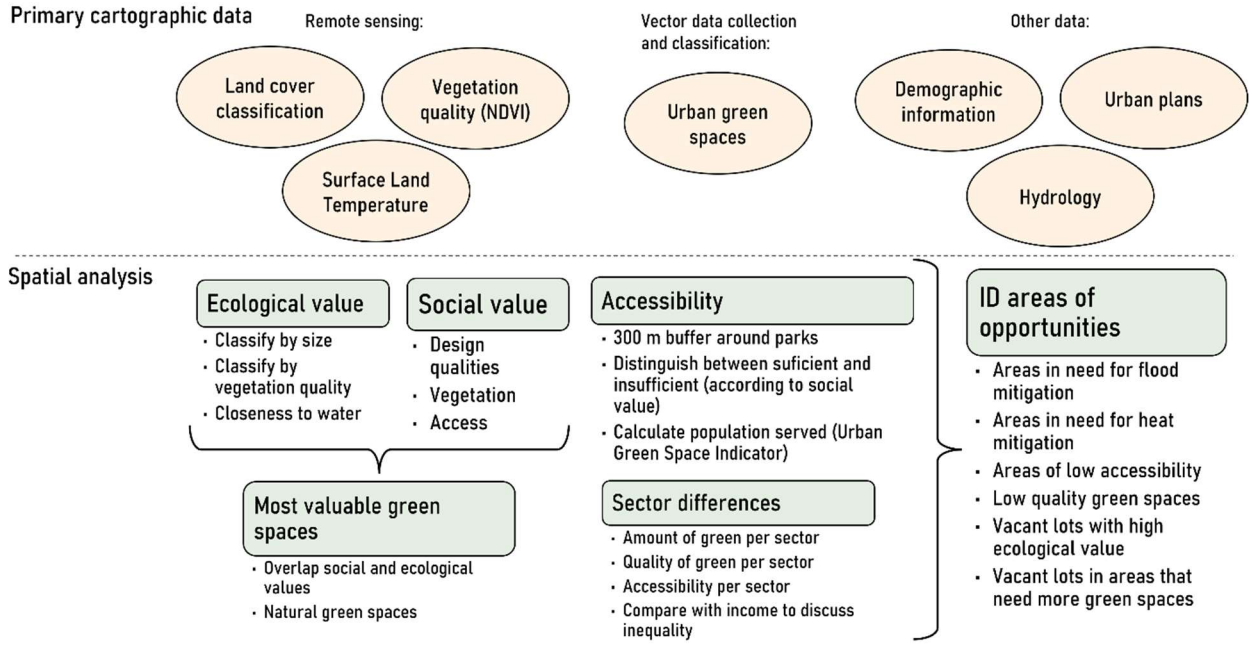


Figure 9. Main steps of spatial analysis.

Data sources

The National System of Statistical and Geographical Information (INEGI) has open GIS data that form the cartographical basis for further spatial analysis. This includes information on vegetation cover, topography, hydrology and demographics.

The Culiacan Municipal Planning Institute (IMPLAN) has cartographical information and studies on several topics that provide more accurate insights for the assessment of the spatial analysis. These information includes road systems, development plans, infrastructure and equipment, risk zones, sectors of the city, amongst others.

The Risk Atlas of the municipality of Culiacan, generated by Acierto Consultores in 2015, provides additional information on environmental risks like flooding, drought, and extreme temperatures.

Additional sources and details are provided in Table 8. All the map data is openly available.

The source maps were corrected and refined by the author by comparing discrepancies between different datasets and satellite images.

Table 8. Cartographic data sources.

Type of information	Data collected	Sources
Satellite bandsets for remote sensing	LC08_L1TP_032043_20200821_20200905_01_T1 (Band set)	https://earthexplorer.usgs.gov/scene/metadata/full/5e83d0b656b77cf3/LC80320432020234LGN00/ Author: USGS Satellite: Landsat 8 Acquisition date: 2020-08-21
Satellite image of Culiacán	Google Satellite WMS	

Urban Green Spaces in Culiacán	Parques alegres.kmz	https://www.google.com/maps/d/viewer?mid=1clQ6L-n8LyU5baHbzOBOOVuW1JlzVM6v&ll=24.794749540040485%2C-107.40814211985418&z=13 Author: Parques Alegres Entity: Culiacan, Sinaloa Published date: June 2019
	Ins_diversa50_a.shp Ins_deportiv50_a.shp Cementerio50_a.shp Area_ver_ur50_a.shp	https://www.inegi.org.mx/app/biblioteca/ficha.html?upc=889463830580 Author: INEGI Published date: 2019 Entity: Culiacan, Sinaloa
Demographic information (statistical and cartographical)	Census 2020	Author: INEGI Published date: 2020 Entity: State of Sinaloa
Hydrology	Conjuntos de datos vectoriales de información topográfica digital, por Entidad Federativa. Escala 1:250 000. Serie IV	https://www.inegi.org.mx/contenidos/masiva/indicadores/inv/25_SCINCE_zip.zip Author: INEGI Published date: 2016 Entity: State of Sinaloa
	Existing channels and streams	IMPLAN
Urban plans	Land use plan 2010 Strategic projects Road structure	IMPLAN
Natural protected areas	Anpest20gw.shp	http://geoportal.conabio.gob.mx/metadatos/doc/html/anpest20gw.html Author: CONABIO Published date: 2020-06-01 Entity: Mexico
Land use and vegetation		INEGI

2.3.1 Remote sensing

Remote sensing consists of gathering land information from remote sources such as aircrafts, drones or satellites (Coops & Tooke, 2017). In this case remote sensing was executed in the program QGIS version 3.4.15 through the Semi-Automatic Classification plug-in. The band set used for these analyses came from the satellite Landsat 8 with a resolution of 30x30 m.

Land cover classification

The semi-automatic or supervised classification enables the identification of different surfaces of a satellite image according to their spectral signatures (Congedo, 2014). For this study, 6 macro classes were identified: Water bodies, Agriculture, Vegetation, Dense vegetation, Built-up, and Bare soil, in addition to Unclassified. The intention for this method was to measure the land use of the city to provide an initial panorama of the landscape.

Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) is a spectral index that automatically outlines the greenness, or relative density and health of vegetation, present in a satellite image (USGS, n.d.). This indicator uses the reflectance values from the red and the near-infrared bands from satellite sources, such as Landsat 8. The red band senses the light absorption region of chlorophyll, which indicates a healthy vegetation. While the near infra-red band strongly reflects the cellular structure of the leaves in different canopy levels. Combined, these two bands detect different levels of vegetation canopies and provide an accurate representation of healthy, green vegetation. It is also a good indicator for naturally fertile zones.

NDVI measurements are widely used in remote sensing for identifying vegetation globally because it helps to compensate for changes in lighting conditions, surface slope, exposure and other external factors (USGS, n.d.). The World Health Organization recommends the use of the NDVI, or "greenness", to identify high quality green spaces. Several studies have found a positive link between high NDVI values and benefits like increased physical activity, psychological well-being, lower mortality rates due to respiratory and cardiovasculary diseases, and environmental benefits like urban heat island mitigation (WHO Regional Office for Europe, 2016).

NDVI is calculated based on the following formula (Congedo, 2012-2016):

Equation 1. Normalized Difference Vegetation Index (NDVI).

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

NIR = Near infra-red band
RED = Red band

The NDVI values range from -1 to 1. Negative values mainly represent clouds, water and snow. Values close to zero indicate mostly rocks, snow, or bare soil, in other words absence of vegetation. Medium values ranging from 0.2 to 0.5 usually represent shrubs, grassland, or senescing crops, while values from 0.6 to 0.9 correspond to dense vegetation such as in forests or crops at their peak stage (USGS, n.d.).

To correctly interpret the resulting values of this index, it is necessary to take in count the context of the local environment. The city of Culiacán has a native vegetation corresponding to tropical dry deciduous forest. In this type of climate there is a dry and a wet period, which significantly changes the amount of green vegetation throughout the year (Murphy & Lugo, 1986). For the purposes of this study, satellite data from the wet period will be taken in count because it is then that vegetation is at its highest quality.

Land Surface Temperature

The Land Surface Temperature was measured by remote sensing using thermal infrared (TIR) data. This map will be generated by measuring Land Surface Temperature (LST). The map result from the land cover classification was used as basis for this analysis. The original macro land classes were reclassified to the following emissivity values (Brown et al., 2007; Congedo, 2012-2016; Jin & Liang, 2006):

Original value	Concept	Reclassified emissivity values
1	Water	0.97
2	Agriculture	0.95
3	Vegetation	0.96
4	Built-up	0.94
5	Bare soil	0.93
6	Dense vegetation	0.97

The map was then processed using the Raster Calculator and applying the following formula (Weng et al., 2004):

Equation 2. Land Surface Temperature (LST).

$$LST = \frac{TB}{\left[1 + \left(w * \frac{TB}{14388}\right) * ln\varepsilon\right]}$$

TB = Thermal Infrared band

w = Wavelength of emitted radiance

ε = Emissivity

2.3.2 Classification of the urban green

Before analyzing the existing Urban Green Spaces (UGS) of Culiacán, it was necessary to gather all the available data and classify it for further processing.

Because the definition of what is an urban green space varies a lot depending on who executes the study (Badiu et al., 2016), different sources have been selected to cover the majority of existing green spaces in Culiacán. Table 8 shows an overview of all data sources used in the spatial analysis. Of these sources, the ones used for identifying UGS were INEGI, Open Street Map, Parques Alegres, IMPLAN, and visual imagery from Google Satellite.

Based on recommendations from the European Office of the WHO and the comparison of measurements from different countries, the following criteria was used to classify urban green spaces in the city of Culiacán:

By type:

For the purposes of this study, areas defined as Urban Green Spaces (UGS) include all parks, outdoor sports fields, outdoor recreational centers, street vegetation like medians and roundabouts, cemeteries, and private lots with considerable green areas such as institutions, government buildings and the airport. Table 9 gives a detailed description of all the types of UGS considered in this paper. These categories are based on the author's criteria after comparing similar categorizations from other research papaers (Badiu et al., 2016; Calderón-Contreras & Rosas, 2017; Feltynowski et al., 2018; Zinia & McShane, 2021). Vacant lots and other residual areas are considered a separate category and used for analysis that account for the ecological value of their vegetation, but not for those that involve social aspects.

Table 9. Classification of UGS by type of use.

General types	Included areas
Functional green areas	Street vegetation: curbs, roundabouts, medians Burial grounds
Recreational green areas	Parks and playgrounds Linear parks City squares Zoo Botanical garden
Sports and recreation	Dedicated sports fields Mixed sports units Stadiums Athletic swimming pools Golf courses
Institutions and equipment (with significant green areas)	Educational equipment: schools, museums, libraries, university campus Medical institutions Government buildings Transportation equipment: bus terminal, airport
Natural green areas	Tropical dry deciduous forest Riverbanks
Residual green areas	Vacant lots Vegetation along streams and canals Railways Abandoned areas Other

By size

The ability of a site to provide ecosystem services increases at greater surface areas. European sources consider 5000 m^2 as the minimum size of a park to have good quality recreational values. (Miljødirektoratet, 2014a). According to a review made by Beninde et al. (2015), the minimum threshold to avoid the losses of urban-adapted species is 4.4 ha, or 44 000 m^2. A greater threshold of 27 ha would be the target if the aim is not only survival, but urban species richness. If urban-avoider and threatened species are to be considered, then an average of 53.3 ha (533 000 m^2) can be considered as minimum patch area for conservation value (Drinnan, 2005; Germaine et al., 1998). Values lower than these ones have very little impact in species conservation. Table 10 shows an overview of the different size classes applied to the Urban Green Spaces (UGS) in this study.

Table 10. Classification of UGS by size.

Surface area	Description
Less than 400 m^2	Pocket park
400 – 5 000 m^2	Small park
5 000 – 44 000 m^2	Urban park: Minimum for recreational qualities
44 000 – 270 000 m^2	Urban biodiversity: Minimum size for urban-adapted species
270 000 – 533 000 m^2	Urban species richness
533 000 m^2 or more	Suitable for ecological conservation of urban-avoider species

By vegetation quality

This analysis consisted in extracting the data from the NDVI results into the existing Urban Green Spaces. This was done by applying the Zonal Statistics tool in QGIS and choosing the mean values for each polygon. To classify the vegetation, threshold values shown in Table 11 were used (USGS, n.d.).

Table 11. Classification by vegetation quality.

NDVI values	Description
0 – 0.10	Little to absent vegetation
0.10 – 0.30	Low quality
0.30 – 0.50	Average quality
0.50 – 0.70	High quality
0.70 – 1	Very high quality

By access:

There is not an official source of information on the accessibility of UGS in Culiacan. Determining this information was important to analyze accessibility, hence the need for the author to verify the access for all green areas. This was done by empirical knowledge of the city and visual assessment on satellite imagery. Two categories were established based on the literature (Feltynowski et al., 2018), as shown in Table 12.

Table 12. Classification of UGS by access.

Concept	Description
Open access	Public green areas, parks with no entrance fees, open for everyone.
Exclusive access	Public areas with entrance fees, limited access hours. Parks in gated communities, private sports fields, country clubs and similar, green areas in institutional grounds.

By equipment and amenities

This was a visual assessment on satellite images to determine the landscape qualities of individual UGS.

Table 13. Classification of UGS by equipment and amenities.

Value	Description
0	No amenities and equipment.
1	Minimum equipment.
2	Visible walking trails, amenities, playgrounds, sports fields, and similar.
3	High quality landscaping design, visible structures like gazebos, agoras or swimming pools, high quality sports equipment.

2.3.3 Ecological value

Table 14. Classification of UGS by ecological value.

Ecoological value	Description
Limited ecological value	Green areas with NDVI values greater than 0.30.
Potential habitat for urban adapted species	Vegetated areas greater than 44 000 m^2 of surface area.
Highest ecological value	Areas with water bodies within their borders, or closer than 100 m from a water body or stream.
Residual spaces with high ecological value	Existing spaces of high ecological value that are considered residual areas such as vacant lots and unclassified, contiguous vegetated areas.

The ecological value of existing green spaces was determined by a series of filters (see Table 14). All green areas were considered, including vacant lots, natural areas, parks, institutions, and street vegetation. These were first filtered by the relative vegetation cover based on NDVI values greater than 0.30. This value indicates the presence of vegetation, with shrubs or grassland at their minimum. Followed by this, the green spaces were filtered by surface area greater than 44 000 m^2, or 4.4 Ha. This surface area has been considered the minimum to mitigate the loss of urban-adapted species (Beninde, 2015). In addition, the closeness to water has been considered as relevant for species richness (ibid.). Therefore, the highest ecological value corresponds to green spaces with presence of vegetation and water, and with a surface area big enough to support urban-adapted species.

Moreover, a distinction was made between spaces that are considered as Urban Green Spaces and those that are residual areas. This is to specify which vacant lots have the highest potential for becoming ecological hubs.

2.3.4 Social value

Table 15. Classification of UGS by social value.

Social value	Description
1	Low quality recreational green areas.
2	Green areas with either good quality vegetation or existing amenities.
3	Green areas with both good quality vegetation and amenities.
4	High quality green areas of open access.

To determine the social value of existing urban green spaces, a subjective assessment was necessary. This was divided in four value levels, as summarized in Table 15. The first one indicates green spaces designated as recreational green areas, such as sports fields, playgrounds, and different types of parks, but without any physical elements that support those functions or any significant vegetation .

The second level describes those recreational areas that either have good quality vegetation (NDVI values above 0.30) or some recreational equipment (benches, children's playgrounds, sports related elements, walking paths, and similar). The NDVI value was considered because of the links found between the amount of vegetation and the physical and mental well-being of the population(WHO Regional Office for Europe, 2016). The presence of recreational equipment was determined by the use of satellite images and registrations from Parques Alegres (2019).

The third level considers green areas with elements from the previous categories but in a higher quality and visible maintenance. These are spaces where landscape design was implemented more carefully and that contain more than one type of amenities and vegetation, but that have some limitation in who can access, for example by the use of fees or restricted admission.

The highest level of social value includes the same qualities as the third level except that there are no restrictions for who can enter the place. This means that urban green spaces with the highest social value are those with good quality vegetation, recreational equipment and amenities, and that are open for everyone, without any fees or reserved admission.

These levels were determined based on the available information on the existing green and the conclusions from the literature review. For example, it has been concluded that the presence of vegetation has several benefits for human health and general well-being (Ahmadpoor & Shahab, 2021; Braubach et al., 2017; Roe et al., 2013; WHO Regional Office for Europe, 2016), that the presence of amenities and equipment determine the use of the spaces (Kaczynski et al., 2008; Lopez et al., 2021), that design and maintenance has an important role for perceived safety (Ceccato et al., 2020; Evensen et al., 2021), and that free, open access to urban green spaces improve social equity (Braubach et al., 2017; Vásquez et al., 2017; WHO Regional Office for Europe, 2016).

The purpose of this analysis is to understand which urban green spaces have a higher value for recreational activities, and which ones need improvement.

2.3.5 Accessibility

To evaluate the access people have to green areas, a buffer zone of 300 m was be created around urban green spaces to compare it to the amount of the population served in nearby residential zones. 300 m is the maximum walking distance that WHO recommends for the provision of health and recreation of the urban green. This is to give insights on which sectors of the city have good cover of green spaces and which ones need improvement.

The indicator defines the percentage of an urban population living within 300 m from public green spaces, according to the following formula (WHO Regional Office for Europe, 2016):

Equation 3. Urban Green Space Indicator (UGSI).

$$Urban\ Green\ Space\ Indicator = \frac{N}{Nt} \times 100$$

Notes:

N = Number of inhabitants living within 300 m from nearest urban green space of specified size and quality.

Nt = Total number of inhabitants within the area of interest.

In this case, it is not only important to determine the accessibility to existing green areas, but also to understand who has access to areas of high social value and who does not. For that reason, four levels of accessibility are determined. Similarly to how social value was determined, the first level corresponds to existing green areas that are officially designated as recreational. The second level indicates those areas that in addition have a vegetation cover that ranges from average to very high. To do this, values from the NDVI analysis of 0.30 or higher will be taken as reference. The third level refines further the green spaces by isolating those with amenities, equipment, and landscaping. Finally, the fourth level makes a distinction between spaces of open access and

those of private or limited access. In summary, the areas or higher accessibility are those that have recreational purposes, that are covered with vegetation, that have amenities, and that are of open access for everyone. The Urban Green Space Indicator accounts for the population living within 300 m of those green areas.

The purpose of analyzing accessibility is to determine which sectors of the population need more green spaces nearby, and which ones could benefit from just improving the social value of the existing ones.

2.3.6 Urban Heat Island Effect

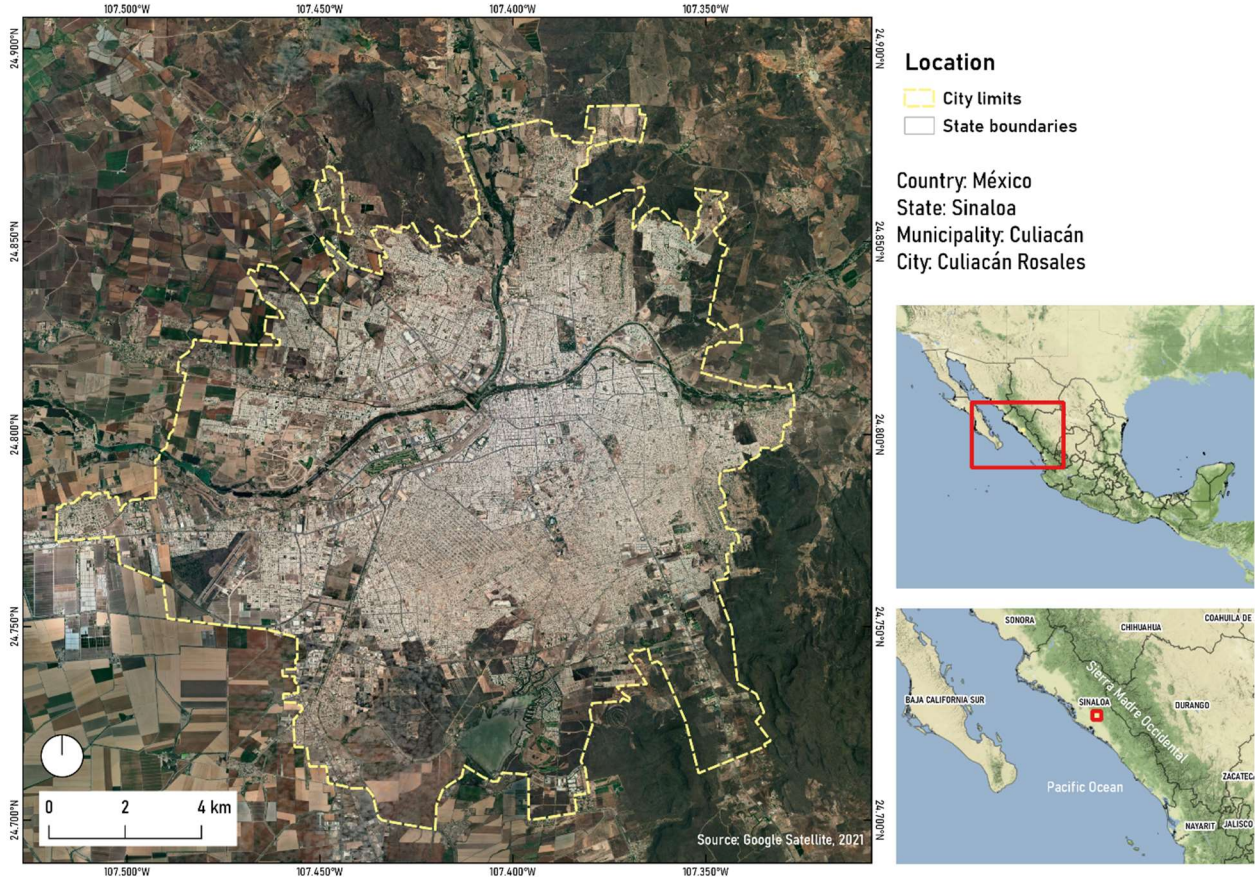
As the literature indicates, the main causes of the UHI effect include a lack of vegetation, an extensive cover of impermeable surfaces, and human activities such as excessive traffic and industries. To visualize this problem, the Land Surface Temperature map is compared with NDVI and other factors to qualitatively assess their influence on the UHI effect.

The goal for this assessment is to see the relation between spatial characteristics, such as vegetation, traffic and land use, and extreme high temperatures so that a mitigation strategy can be proposed around existing hotspots.

Chapter 3. Study area: the city of Culiacán

Photo 5. Panoramic view of the city of Culiacán. Photo: Michelle Granados Johansen, 2021.

3.1 Characteristics of the city



Map 1. Location of Culiacán. Made by the author with images from Google Satellite, 2021 and Stammen Terrain by Stammen Design licensed under CC BY 3.0.

Culiacán is the capital city of the state of Sinaloa. It is located in the central area of the state (see Map 1), in the Culiacán valley between the Sierra Madre Occidental Mountain Range and the Pacific Ocean (IMPLAN, 2020). This is a very narrow valley that extends along the coast of the states of Sonora, Sinaloa, and Nayarit, and it is covered mostly by alluvial sediments that have been deposited by the rivers from the mountains in the northeast to the sea at the southwest. This makes the valley a very fertile region for agriculture, the main economic activity of Sinaloa (ibid.).

Climate

According to INEGI (2008), the city of Culiacán is located in the climate region Bs1(h')hw, which is a variation of BSh or hot semi-arid according to the Köppen–Geiger climate classification system. This type of climate is semi-dry, with a rainy period in the summer and scarce rain the rest of the year. The mean yearly temperature is 25.4°C, and the mean precipitation is of 663.3 mm per year. In Figure 10, it is clear that the rainiest months are July to September, which also correspond to the warmest months. According to records between 1951 and 2010, the warmest recorded daily temperatures exceed 40°C, and these temperatures can happen between April and November (Climate Station 0025102 Escuela de Biología UAS, 2010).

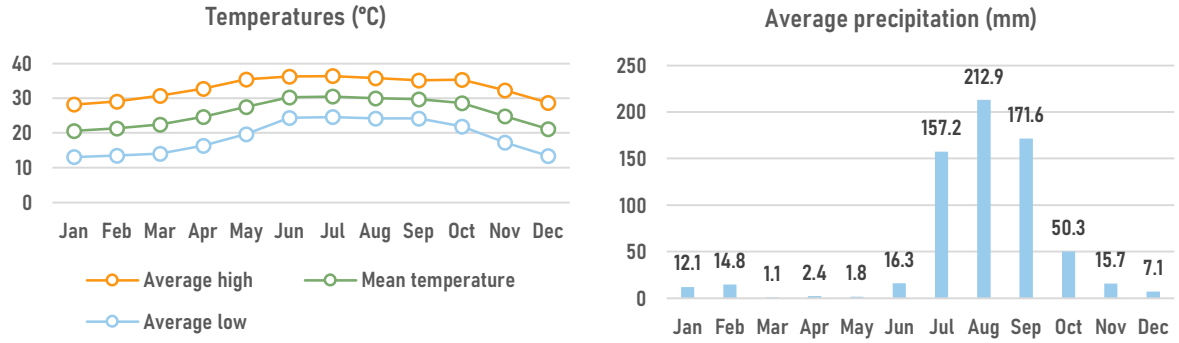
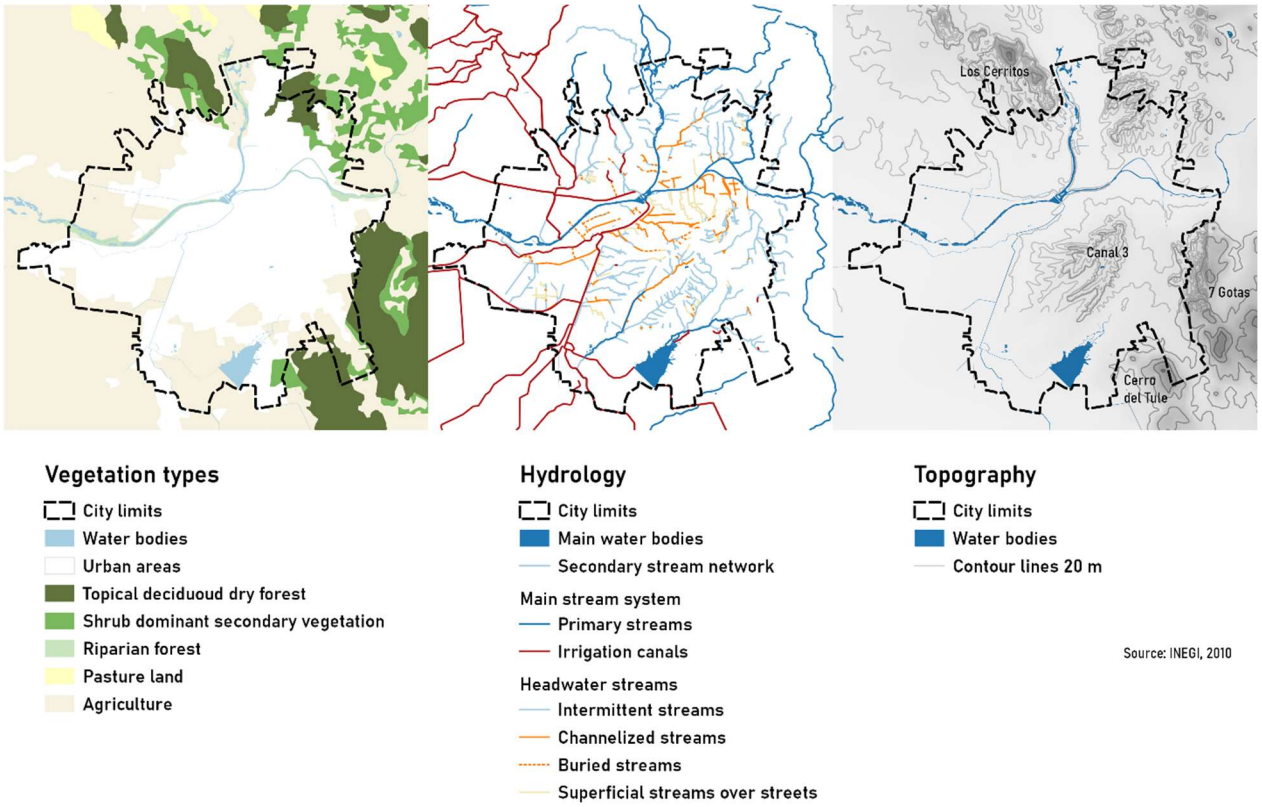


Figure 10. Climate charts. Made by the author based on data from Climate Station 0025102 Escuela de Biología UAS (2010)

3.1.1 Natural environment

The city is divided in three parts by the rivers Humaya, at the north, Tamazula, at the east, and Culiacán, which forms by the confluence of the former two (see Map 2). These rivers are the main water source for all irrigation in the Culiacán Valley, and for human needs in the city and the nearby rural communities (IMPLAN, 2020).



Map 2. Natural environment of Culiacán.

Natural vegetation

Photo 6. Aereal view of a nearby agricultural field and Culiacán in the background. Photo: Michelle Granados Johansen, 2021.

The existing vegetation surrounding the city is mostly influenced by human activities. The predominant type of vegetation is of agricultural origin. The native vegetation of the nearby forests belongs to the tropical dry deciduous forest (see Map 2). This type of forest is characterized by the distinction between dry and wet periods (Murphy & Lugo, 1986). Tropical dry forests are the most threatened tropical forests in the world, with less than a tenth of their original extent remaining (Banda-R et al., 2016). The importance of the tropical dry forest is often underappreciated. According to Murphy and Lugo (1986), this type of forest is highly resilient, fertile, rich in rare species, and has an economic significance for agricultural, medicinal and woody products. The number of endemic species in tropical dry deciduous forests is very high, this makes them very important for biodiversity, but also very vulnerable to disturbances (Beltrán, n.d.). The areas in Culiacán that remain as tropical dry deciduous forest correspond to those of highest altitude (see Map 2). It is precisely because of their steepness and difficulty to establish urban settlements that these hills have been partly preserved, but they are still at risk of disappearance because of anthropogenic activities and thus in need for environmental protection (IMPLAN, 2020).

The characteristics of this type of forest are highly variable depending on the location, the rainfall patterns, altitude, and humidity. Vegetation tends to be smaller in stature, complexity and structure compared to wet tropical forests. The dryer the climate, the less variety of species. Despite the lower biomass relative to that of wet forests, tropical dry forests store higher amounts of root biomass than rainforests (Murphy & Lugo, 1986). Because of the fluctuation between dry and wet periods, the productivity of the tropical dry forest also alternates. Consequently, most dry forests around the world are highly composed of deciduous species, which are highly dependent on humidity and the variations of rainfall throughout the years (ibid.).

Vegetation in this type of forest typically grow between 5 and 15 m tall, most commonly in a uniform canopy height. Trees tend to grow in irregular shapes, ramified from the base, and many of them have colorful, exfoliating barks. Foliage is dense and of a light green color during the wet period, and contrasts vastly against the dry, leafless, and colorless appearance during the dry period, that typically lasts for 5 to 8 months (Rzedowski, 2006). A particular feature of this forest is the contrast between the columnar and chandelier-like cactus (see Photo 7), that can reach up to 12 m tall, and the rest of the vegetation that looks gray and lifeless during the dry period. Another appealing quality is that at the end of the dry period many species are covered with beautiful flowers.

Photo 7. Tropical dry deciduous forest. Chandelier-shaped Pachycereus ssp. *Photo: Michelle Granados Johansen, 2021.*

In Sinaloa, the torchwood family, or *Burseraceae*, is of high ecological importance. This family of trees and shrubs is characterized by their aromatic, nonallergenic resins, and their flaking, aromatic bark (Stevens, PF, 2001). The species of this family represent an important economic, ethnobotanical and cultural significance. In the traditional Mexican medicine, *Bursera simaruba* (see Photo 8) is used to treat fever, physical wounds, stomachache, intestinal infections, diarrhea and kidney problems (UNAM, 2016). Other common species of tropical dry deciduous forest in this region include *Lysiloma divaricata, Conzattia sericea, Pachycereus ssp., Ipomoea ssp, Plumeria rubra* (see Photo 22)*, Ceiba acuminata, Pithecellobium dulce, Opuntia ssp., Pereskiopsis ssp.* (see Photo 9)*,* and others (ibid.). A local sampling in one of the northern forest patches of the city found examples of the threatened species *Tabebuia palmeri (Handroanthus impetiginosus)* and *Guaiacum coulteri* (Dehesa et al., 2013) (see Photo 21).

Photo 8. Bursera simaruba. Photo: Michelle Granados Johansen, 2021.

Photo 9. Pereskiopsis ssp. Photo: Michelle Granados Johansen, 2021.

Deforestation

The State of Sinaloa has suffered high deforestation since its foundation in 1531. This used to be a densely vegetated area before the Spanish came to the region. But the Spanish conquistador Nuño de Guzmán, along with his soldiers and 7000 indigenous allies, burned their way to conquest the region and then founded the Villa de San Miguel de Culiacán in the confluence of the Tamazula and Humaya rivers (Burian, 2015). After the Mexican Revolution in 1910, the hydraulic potential of the region was developed in projects that included dams and canals, and this produced to an agricultural boom. The effect of this was an accelerated growth of the population (ibid.). This uncontrolled urban growth and agricultural explosion has led to the loss of most of the natural areas in the region.

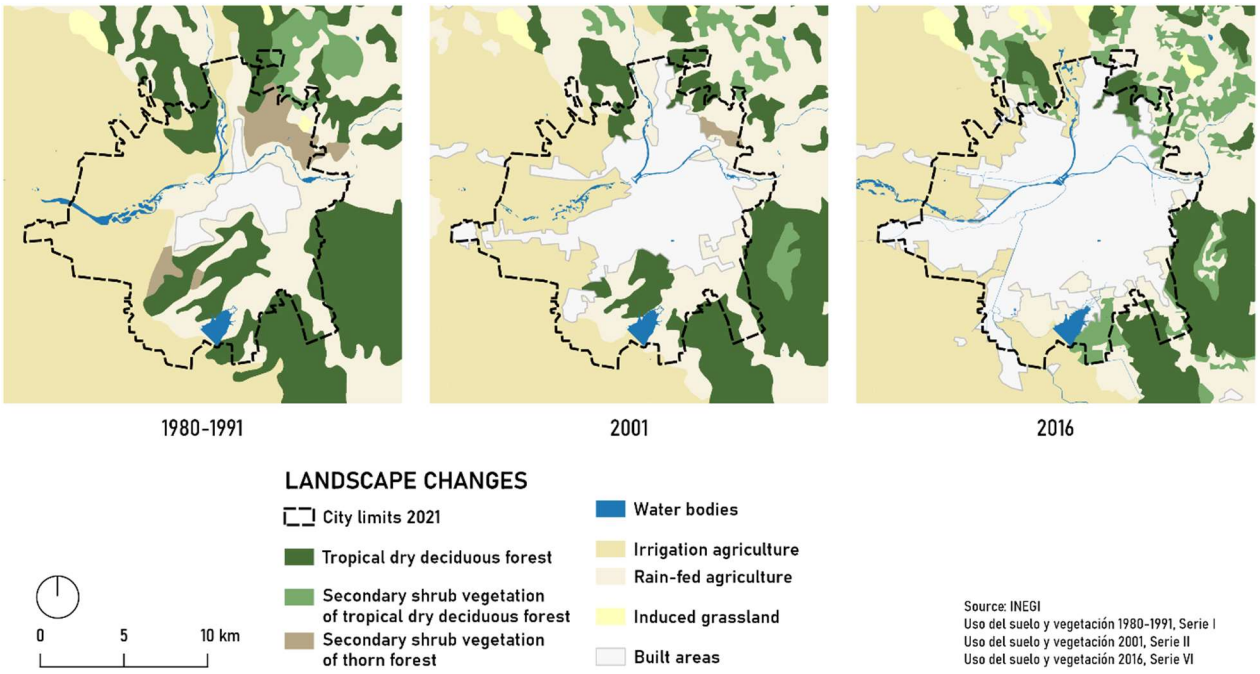


Figure 11. Landscape changes in Culiacán between 1980 and 2016.

Table 16. Landscape changes in Culiacán between 1980 and 2016.

VEGETATION TYPE	1980-1991 (m^2)	2016 (m^2)	DIFFERENCE (m^2)
INDUCED GRASSLAND	643033.21	0	-643033.21
IRRIGATION AGRICULTURE	77054415.27	24120667.80	-52933747.48
RAIN-FED AGRICULTURE	67689043.56	36711198.78	-30977844.78
SECONDARY SHRUB VEGETATION OF THORN FOREST	15048112.50	0	-15048112.50
SECONDARY SHRUB VEGETATION OF TROPICAL DRY DECIDUOUS FOREST	1470332.90	9515792.95	+8045460.05
TROPICAL DRY DECIDUOUS FOREST	39206256.97	5478278.31	-33727978.67
URBAN AREAS	20462133.54	143311407.14	+122849273.60

It has been estimated that between 1993 and 2011 Sinaloa has been losing forest at a rate of 126.50 km^2 per year (Monjardin-Armenta et al., 2017). Only inside the current city limits, more than 3000 hectares of tropical dry deciduous forest have been lost (see **Error! Reference source not found.** and Table 16). A study from Unión de Ejidos Forestales Centro Sinaloa A.C. (2010) suggested that the tropical dry forests of Sinaloa have the potential for carbon storage of 35.5 ton

of CO_2 per hectare. This means that in roughly three decades we have lost forest areas with a carbon storage of more than 100,000 ton. Moreover, the city has lost its totality of the secondary shrub vegetation of thorn forest. The main causes of deforestation in the municipality of Culiacán are urban expansion, accelerated by irregular settlements in marginalized areas, and conversion of land for agricultural use (GEOLMEX, 2020).

Since native forests in this area have been highly degraded, areas that previously have been forest have overgrown as shrub dominant secondary vegetation (see Figure 11). After some years of being cleared from vegetation, these areas have now overgrown into a secondary succession. In addition, there are a few patches of pastureland. These are areas of induced herb vegetation, mostly comprised of grasses for cattle raising (INEGI, 2017).

The river

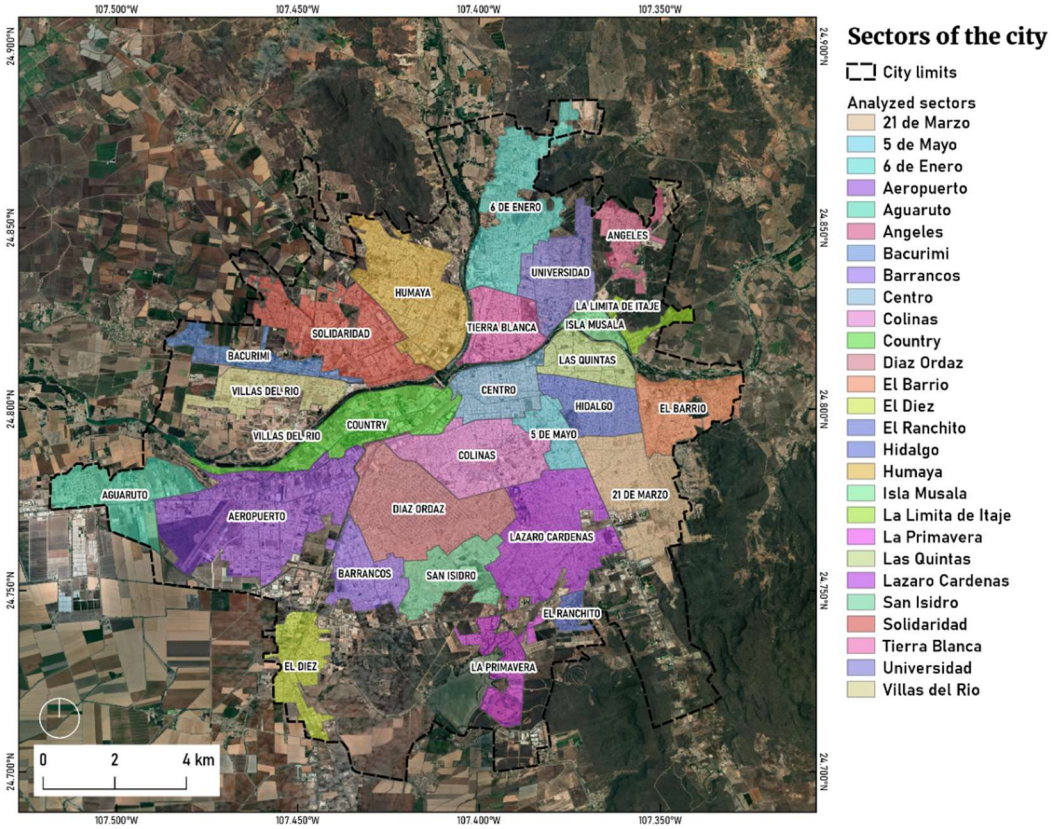
We cannot talk about the environment of the city of Culiacán without mentioning the rivers. The city is situated on the Culiacan River Basin, comprised by three rivers: Humaya and Tamazula, and their confluence forms the Culiacán River. The flow of the rivers shaped the growth of the city from the beginning, marking the northern limits for several decades, until the first bridge was erected to continue the main road of the city. But it was until 1992 that the government assigned 1413 hectares along the rivers for future urban development (Ibarra & Ceballos, 2018). The initial idea was to create natural reserves, contribute to the urban image and improve the transit of vehicles through new roads and bridges. The ambitions of the project at the end were compromised in favor of real estate development, and the initial expectations were only partly met. The unorganized urban growth has led to important damage to the flora and fauna of the rivers, and an increased risk of flooding for the population (ibid.). In addition, the hydrological structure of the city, comprised by the rivers and a series of streams, pose an environmental risk because they are transport channels for pollution (IMPLAN, 2020). This pollution comes partly from urban waste, but mostly from agrochemicals (ibid.).

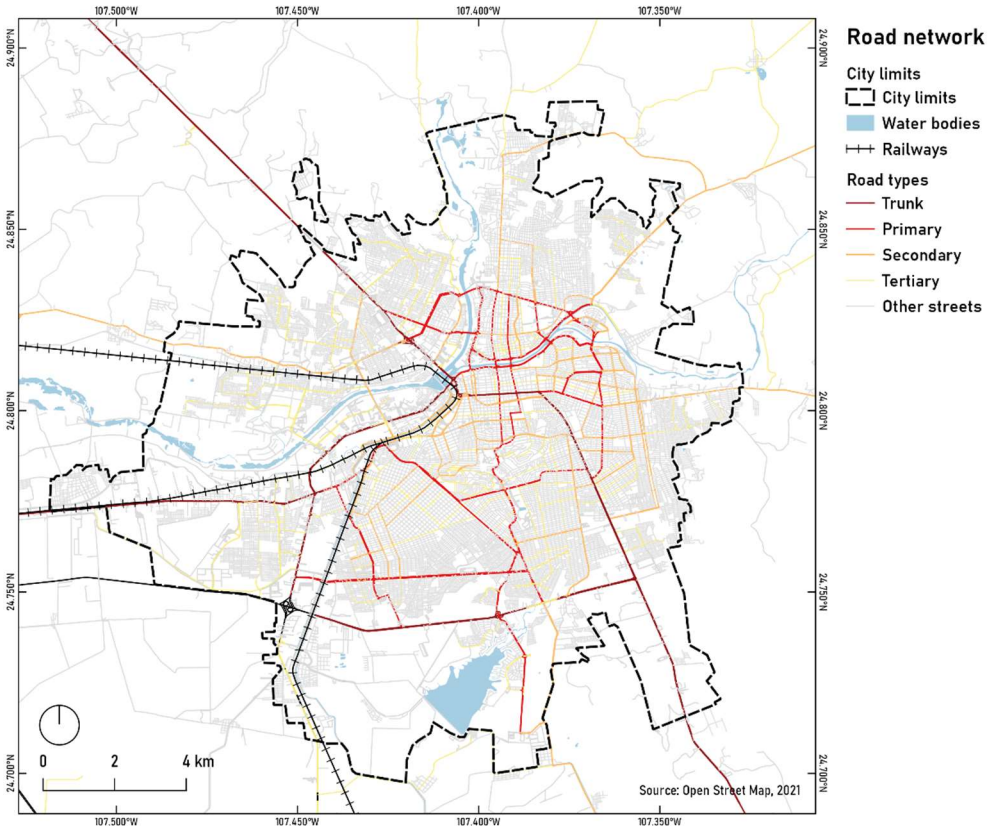
Since the creation of the Municipal Planning Institute in 2003, efforts have been made to turn the rivers into an ecological park for ecotourism. The initial proposal contemplated areas for biking, adventure sports, family recreation, water related activities, camping sites and areas for conservation. But the objectives were only partly met, and since then different groups of society and the planning institute have made further interventions to improve the state of the park. Today, the areas along the river have gone through important economic development. Along the river one can find a series of restaurants, shopping malls, companies, night clubs, casinos, and middle to high level residential areas. The rapid urbanization tightly packed along the river has blocked the river's natural flooding mechanism. The native vegetation and the natural floodplains have been almost completely removed. Consequently, the valuable real estate that is now by the edges of the river are all exposed to a permanent risk of flooding. The less dense vegetation also means that the river has less capacity to control flooding, and instead sediments are deposed on the park facilities (Ibarra & Ceballos, 2018).

Photo 10. Culiacán river during drought 2021, covered with Eichhornia crassipes*. Photo: Michelle Granados Johansen, 2021.*

An important issue with the ecology of the river is that the interventions made to transform it into a park led to the deprovision of most of its original riparian vegetation, and instead exotic vegetation has been introduced. A notably problematic species is the water hyacinth (*Eichhornia crassipes*). This is considered as one of the most invasive species in the world (Global Invasive Species Database, 2021). This plant spreads quickly over water bodies, in this case the river, and causes great environmental problems. It blocks areas of the river (see Photo 10), it impedes the sun and oxygen from reaching underwater thus harming fish populations, it fosters the breeding of mosquitoes, it deposits great amounts of organic matter accelerating the formation of sediments, and it fixates nitrogen (ibid.). On the Brightside, this plant removes pollutants from water and have ornamental flowers, but the problem is greater than its services. Removing this plant would bring benefits as its remains can be used to improve the soil and can become compost. In controlled situations, this plant can be used as means for water treatment (Fern, 2021).

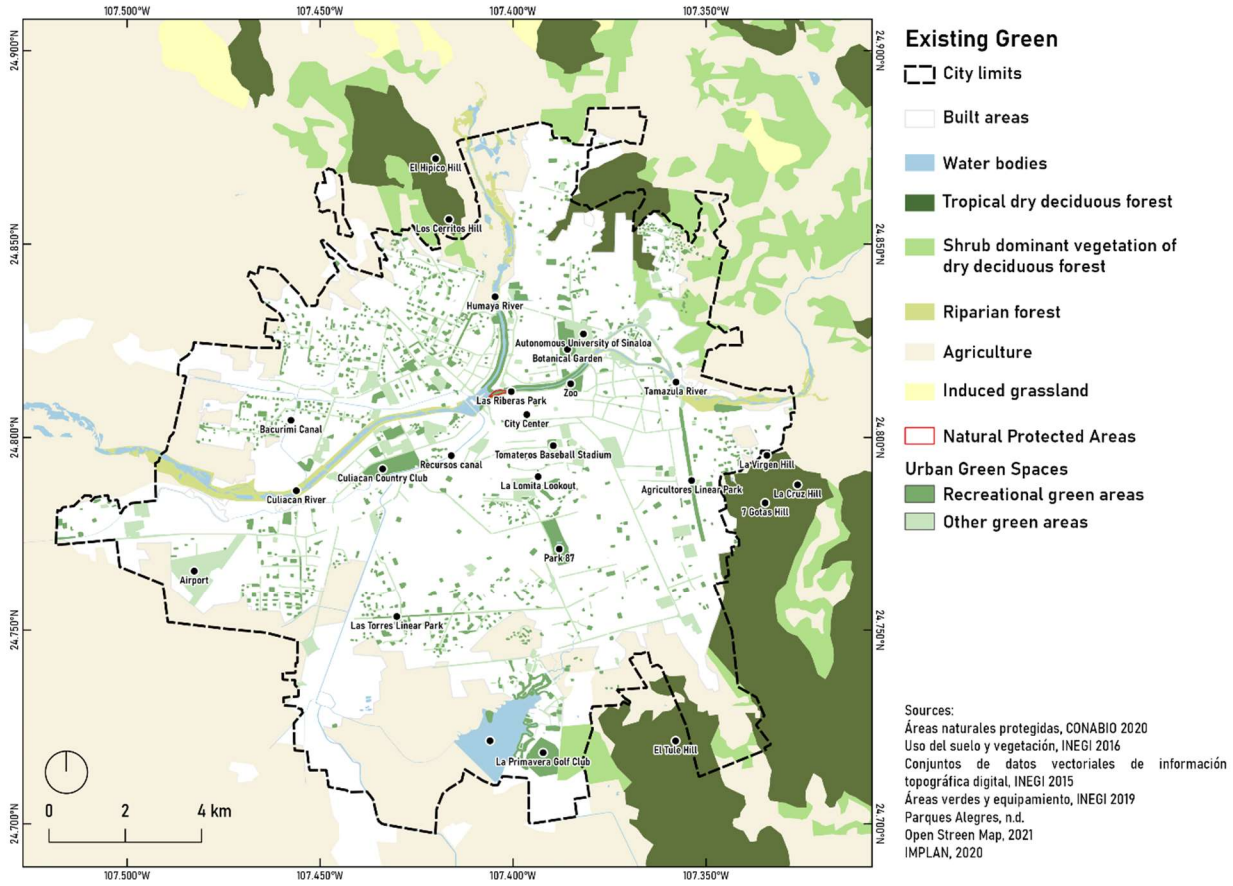
3.1.2 Urban environment





Existing Urban Green Spaces

According to the Municipal Planning Institute IMPLAN (2020), the city has 732 recreational areas. Of those, 236 are used for active recreation, mainly sports and exercise, while 496 are meant for passive recreation, such as gardens, parks, and squares. In addition, the city hosts a botanical garden and a zoo (ibid.). Map 3 shows an overview of the existing green areas in the city, highlighting the ones that are most recognizable.



Map 3. Existing green in the city of Culiacán.

The main park of the city is the one along the river, known as Parque Las Riberas. Despite all the controversy regarding the ecology of the river, we cannot deny the positive qualities that the park has in the city's population. It is a central meeting point for many. It provides many cultural activities, active and passive recreation. It contains walking and cycling trails, playgrounds, and bridges that has become icons for the city and also promotes non-motorized means of transportation (IMPLAN, 2020). The name Culiacán comes from the name Huey-Colhuacan, that means "the place of worship of the god Coltzin, or, where the two rivers meet" (Burian, 2015). Consequently, we can say that the river is the heart of city and the most important feature of the landscape.

Las Riberas Park is divided in different sections, some of them shown in Photo 12. The areas near the zoo contain a pedestrian bridge directly connecting the river on both sides to the zoo. They also contain a series of playgrounds with public bathrooms, and areas for walking and passive recreation. The mid-section is the most active one. It is linked on one side with the city center, and on the other side with the main shopping mall of the city. Recreational areas include playgrounds, bridges, bicycle-rental areas, open agoras, and a recent artistic intervention to commemorate the victims of the covid-19 pandemic (see Photo 11). By the confluence of the river, there is an open

scene that hosts a fountain show with light and music. It also contains a flagpole that crowns the area. Both sides of the river in direction north to south are surrounded by high-income residential neighborhoods. The park areas along the river in these sectors consist mainly on playgrounds, cycling paths, picnic benches, skate parks, and other areas for passive recreation. In the confluence of the river there are two islands considered as natural reserves. One of them is accessible by two bridges. This is the one names Isla de Orabá. This island has recreational equipment such as picnic benches, playgrounds, and a stage for cultural events. This is also an area dedicated to the protection of the *Iguana iguana*. The newest section of the park is the area next to the railways bridge. It is known as Parque Acuático, and it includes a series of recreational equipment under a painted bridge and a picnic area. In addition, the three bridges for pedestrians and bicycles cross the river, connecting it to the city center, shopping centers, restaurants, residential areas, university buildings, and other city parks and plazas. Along the river there are promenades that include sitting areas and artistic interventions from various artists.

Photo 11. Some attractions at Las Riberas Park. Top: Pedestrial-cycling bridge. Bottom: From left to right, paddling boats rental services, children's playground, monument to commemorate victims of covid-19. Photos: Michelle Granados Johansen, 2021.

Photo 12. From left to right, top to bottom: playground in the north-east section; view towards Isla de Orabá; playground at Isla de Orabá; iguana found at Las Riberas Park; sculpture-bench on the river promenade; view towards the Black Bridge and picnic benches at Parque Acuático; amenities under the bridge at Parque Acuatico; cyclepath and bridge connecting to the zoo. Photos: Michelle Granados Johansen, 2021.

The Culiacán Botanical Garden (see Photo 13), remodeled in 2011 by architects of international renown, is a 24.7-acre space of high cultural, social and ecological regard in the city (Burian, 2015). The areas include a museum, a library, a collection of sculptures from international artists, auditoriums, classrooms, spaces for cultural and social events, exhibitions areas, a greenhouse of unique species, and world-class botanical collections (ibid.).

Photo 13. Views of the Botanical Garden. Photos: Michelle Granados Johansen, 2021.

Other important green areas include the Constitution Civic Center (see Photo 14), located in proximity with the Culiacan Zoo and the Regional Museum of Sinaloa; the Country Club (see Photo 15) with its high-quality golf course, artificial lakes, and sports fields; the Agricultores Linear Park (see Photo 16), the first of its kind in the city; the plazas located inside the city center, the Cathedral Plaza (see Photo 23), the Revolution Park (see Photo 18), and the Plazuela Rosales (see Photo 25); the Park 87, designed to give recreational spaces to the most marginated sectors of the city at the time, with its artificial lake, diverse sports fields, swimming pools, and vegetated areas.

Photo 14. Constitución Civic Center and Zoo. Photos: Michelle Granados Johansen, 2021.

Photo 15. Country Club Culiacán, Golf Club. Photos: Michelle Granados Johansen, 2021.

Photo 16. Agricultores linear park. Photo: Michelle Granados Johansen, 2021.

Photo 17. Culiacán letters by the catherdral plaza. Photo: Michelle Granados Johansen, 2021.

Photo 18. "Parque Revolución Culiacán" by Codleex is licensed under CC BY 2.0, 2020.

In addition to public parks and the river, there are some natural areas around the city that are used for ecotourism activities, such as hiking, mountain cycling, rappelling, and mountain climbing (Hernandez, 2014). These hill areas also have a high ecological value, it is possible to find threatened species like macaws, ocelots, deer, iguanas, and pumas. They also contain beautiful waterfalls and attractive viewpoints to the city and the agricultural fields. These aeras have great potential for both recreation and ecological conservation, but to make this happen there is a need for physical installations, conservation policies, and education for the correct use of natural spaces (ibid.). Photo 19 and Photo 20 are examples of two of these hills.

Photo 19. Cerro de la Virgen. Photo: Michelle Granados Johansen, 2021.

Photo 20. El Hípico. Photo: Michelle Granados Johansen.

Urban vegetation

The urban vegetation in the city of Culiacán is mainly characterized by exotic species. As the literature suggests, this has a negative impact for biodiversity, maintenance, and climate regulation. According to a local biologist, Jair Miranda, the main risk of introducing exotic species is that is displaces native vegetation (Revista Espejo, 2019a). He mentions the examples of Neem (*Azadirachta indica*) and Olivo Negro (*Bucida buceras*), two exotic tree species that have been widely planted in streets in the city center, and recently the Kiri Tree (*Paulownia tomentosa*), a highly invasive species from Asia. In contrast, a manual made by the Botanical Society in Sinaloa (IMPLAN et al., 2018) suggests the use of native tree species for urban green. Some of these species include *Handroanthus impetiginosus, Guaiacum coulteri*, *Cordia dodecandra,* and *Pseudobombax ellipticum*, all beautiful and low maintenance species (see Photo 21). Species like *Bursera simaruba* (see Photo 8)*, Caesalpina pulcherrima* and *Plumeria rubra* (see Photo 22) are especially valuable for attracting pollinators, while *Brosimum alicantum*, *Vitex mollis* and *Coccoloba uvifera* have edible fruits for both humans and animals. The use of these and more native species instead of exotic vegetation is crucial for Culiacán to improve the status of its urban biodiversity.

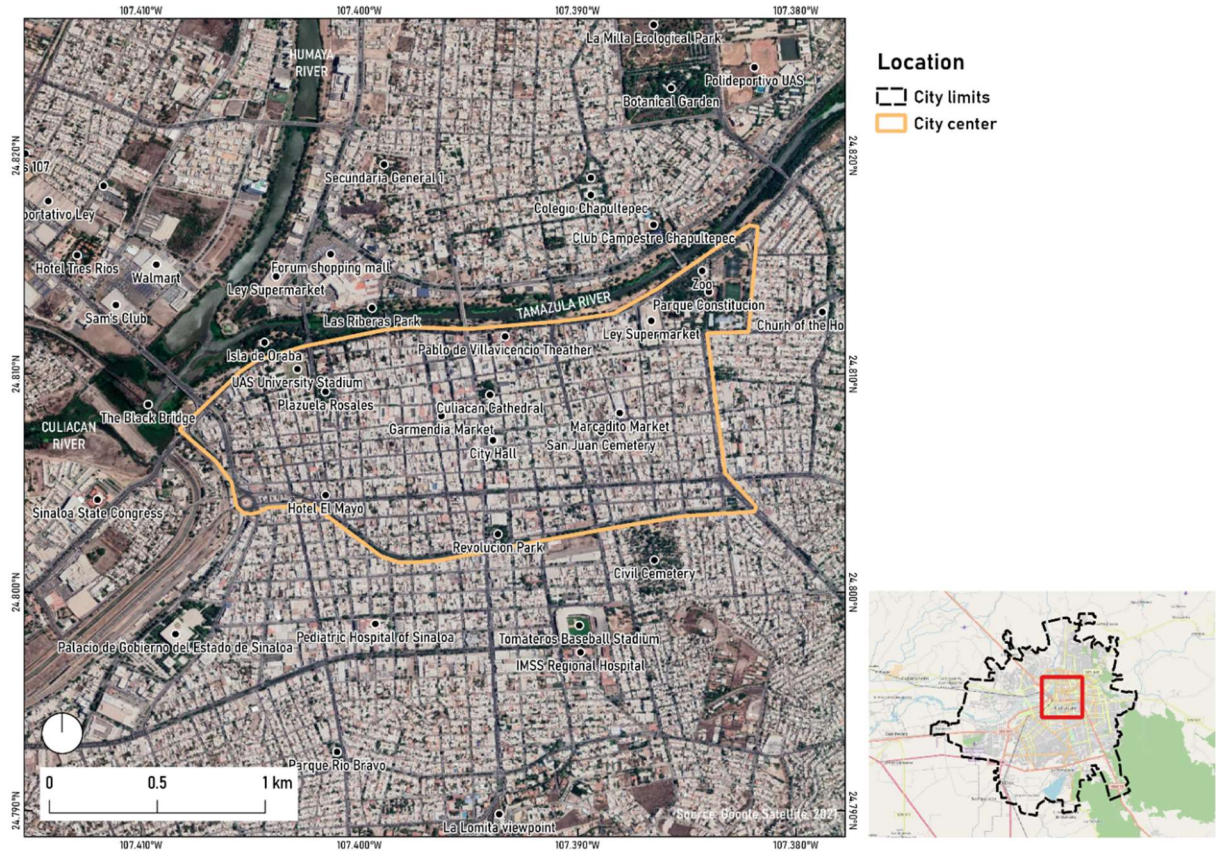
Photo 21. Attractive flowers from native trees apt for the urban environment in Culiacán. From left to right: "Handroanthus impetiginosus Ypê-roxo-bola flowers" by Mauro Halpern is licensed under CC BY 2.0. "Zygophyllaceae: Guaiacum coulteri CU" by David Bygott is licensed under CC BY-NC-SA 2.0. "Ciricote (Cordia dodecandra) orange flowers" by Bernard Dupont is licensed under CC BY-SA 2.0. "Rufous-tailed Hummingbird (Amazilia tzacatl) on Shaving brush tree - Ceibo rosado (Pseudobombax ellipticum)" by Howard Patterson is licensed under CC BY-NC-SA 2.0).

Photo 22. Plumeria rubra in the background, various cacti species in the foreground. Photo: Michelle Granados, 2021.

City center

The city center is the sector of the city with most commercial activity and intense car traffic. It also contains the most valuable properties of cultural heritage. Map 4 shows the delimitation of the city center with some of its most important locations. As of 2010, problems in this area included high levels of crime, excessive noise, deterioration of public infrastructure, visual and air pollution, flooding problems, scarcity of vegetation, and lack of permeability. According to the Planning Institute, public spaces like parks and plazas are currently underutilized and deteriorated. In addition, there is a high level of contamination from solid waste because of the insufficient cleaning services, the inefficiency of waste collection services, and mostly the lack of

ecological education of the population (IMPLAN, 2010). Because of these problems, a plan to revitalize the city center was approved in 2010. However, this plan prioritized physical projects rather than integral policies, and this has resulted in interventions that have not had the intended impact for social and economic development (IMPLAN, 2021b).



Map 4. City center. Sources: Google Satellite, 2021; Open Street Map, 2021.

Sites of cultural and historical importance

Photo 23. Culiacán Cathedral and plaza. Photo: Michelle Granados Johansen, 2021.

Culiacán emerged as the administrative and political center of the state of Sinaloa in 1823 because the nearby mountainous system provided wealth from gold and silver mines (Burian, 2015). After the decline of these mines, the banks of the rivers and streams provided fertile grounds for agriculture to flourish. The growing capital quickly developed a modern infrastructure and established important public institutions such as plazas, markets, schools, government buildings and catholic temples. Important sites from this period include the Cathedral of the city (1842-1885) (see Photo 23) along with the Plaza de Armas, the Municipal Palace (1839) with its neoclassical white facade, the Plazuela Rosales (1895) (see Photo 25) along with the Colegio Nacional Rosales (1895) that later became the heart of the Autonomous University of Sinaloa (Photo 24), the neoclassical Templo del Sagrado Corazón (1893-1908), the neoclassical City Hall (1890) that is now adapted as a museum of art, and the Garmendia Market building (1914-1917) named after a local hero killed during the Mexican revolution (ibid.). All of these buildings are located within the city center (see Map 4 and Map 5).

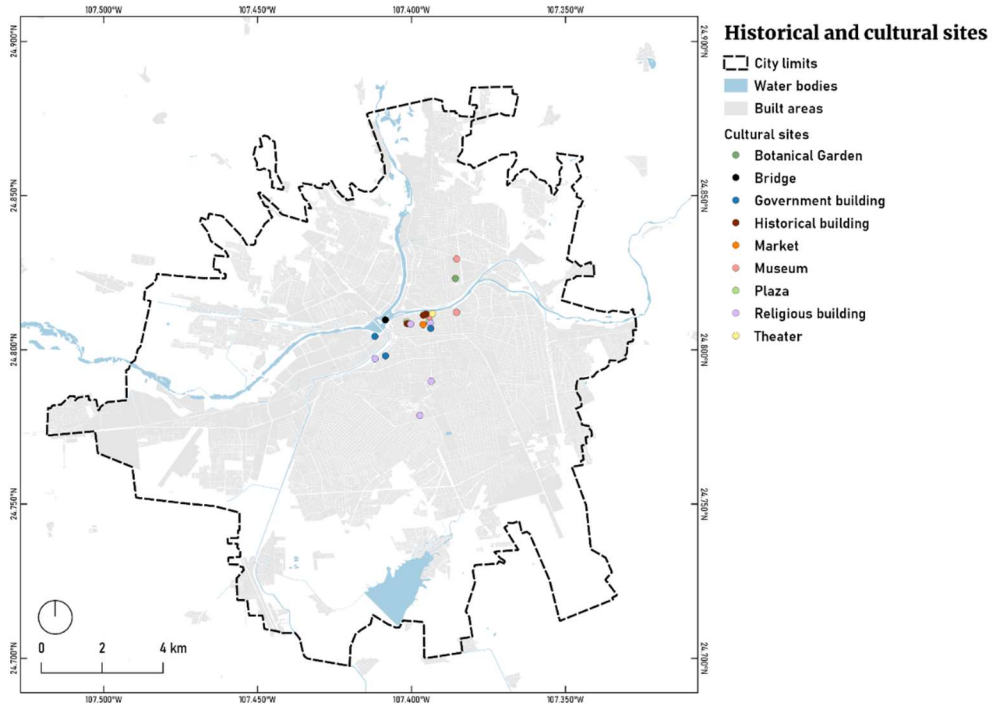
Photo 24. Central building of the Autonomous University of Sinaloa, Templo del Sagrado Corazón in the background. Photo: Michelle Granados Johansen, 2021.

Photo 25. Plazuela Rosales. Photo: Michelle Granados Johansen, 2021.

After the revolution period, more recent buildings of cultural importance have appeared. The Casino Culiacan, built in 1943, was one of the first modern buildings in the city, designed in art deco and constructed with reinforced concrete, a novelty at the time. The Santuario de

Guadalupe, also known as La Lomita, was erected in 1967 on top of a hill that crowns the main street of the city. It was built on the site of an important earlier church from 1885. This site offers panoramic views of the city, and its architecture is a great example of the early use of thin-shell concrete vaults in a parabolic geometry. A more informal cultural site is the Malverde Chapel, a small building next to the old railway tracks that commemorates Jesús Malverde, a local “robin hood” legend that has been attributed great religious importance in the city. In 1992 the State Congress was constructed. A modern courtyard with reminiscence of a classical forum frames the entrance, while it also serves as a public meeting place to meet and exchange ideas (Burian, 2015).

Photo 26. "Parroquia La Lomita" by Codleex is licensed under CC BY 2.0.



Map 5. Historical and cultural sites.

3.1.3 Social aspects

Demographics

Prior to the Spanish conquest in 1531, this region was inhabited by indigenous people as early as 8000 BC. But after the conquest, many of these people became sick and died due to the spread of European diseases. After the agricultural boom in the middle on the 20th century there was an uncontrolled increase of the population of the city. The number of inhabitants went from 30,000 in 1948, to 100,000 a decade later (Burian, 2015). According to the 2020 census of the National Institute of Statistics and Geography (INEGI), the city of Culiacán is home of 808,416 inhabitants.

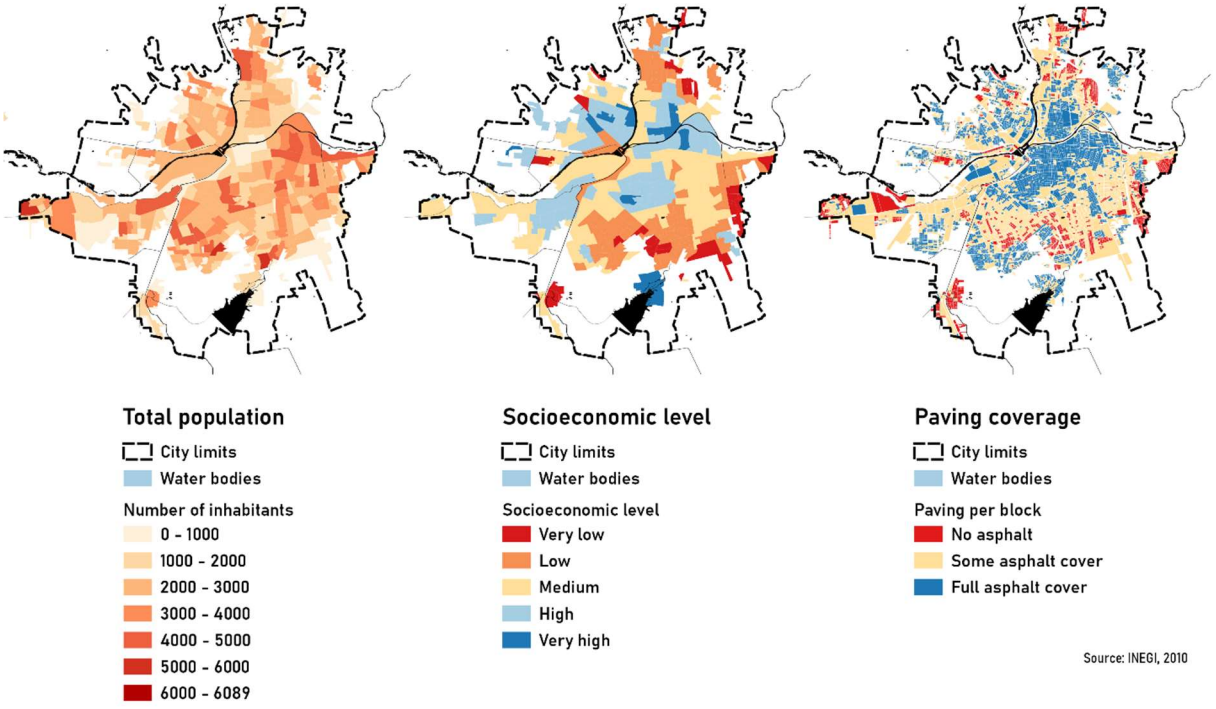


Figure 12. Demographic information in Culiacán.

Photo 27. Comparison between neighbordhoods of low and high income. From left to right: Bicentenario (low income), Tres Ríos, and Torres del Río (high income). Photos: Michelle Granados Johansen, 2018 and 2021.

Photo 28. Blvd. Emiliano Zapata, an example of car-oriented urban design. Photo: Michelle Granados Johansen.

Mobility

Transportation in the city of Culiacán is very much motor-based. Approximately 65% of the population use private cars as main means of transportation, while 35% use the public transport. The lack of preference for public transportation can be explained by the deficiencies that come as a result of a weak regulation from the government, and conflicts between the multiple concessionaries (GEOLMEX, 2020). According to Rojo-Carrascal (2018), the streets of the city center are designed to favor car traffic, while it lacks accessibility, security, comfort and attractiveness that characterize a pedestrian environment. It is a segregated space that provides poor conditions for pedestrians and cyclists. In 2019, 65% of deaths by traffic accidents in Sinaloa were pedestrians, motorcyclists, and cyclists. This points to the urgent need for urban planning and infrastructure that focus on safe mobility (CESP, 2019).

The existing cycling paths consist mostly of a recreational along Las Riberas Park, a 4km trail in the avenue Las Americas, a cycle lane around the botanical garden, a section of the Agricultores linear park, and two bridges connecting both sides of the river. According to the Planning Institute, the existing cycling paths are deteriorated for two main reasons. First, the constant flooding and the hurricane Manuel that impacted the city in 2013 have damaged the physical infrastructure. Second, there is a misuse of the cycle lanes from car users, bus drivers and motorcyclists that has resulted in the destruction of signs and bollards (IMPLAN, 2016). The studies they have made in the city show that 94% of cyclists are young men. Their studies also indicate that 78% of bicycle users are workers and 19% are students, and that 71% use it as means of transportation rather than recreation. There is a social gap in the way cycling is practiced. Most of the bicycle use as means of transportation are located in areas o the city with a low and medium average income, while its use for recreation happens mostly in areas of medium to high economic status. Their findings also show that the city center is the area of the city with most destination trips on bicycle (ibid.). Another poll published in a local newspaper showed that the main reasons people do not use the bicycle in Culiacán are the high temperatures, the lack of bicycle infrastructure, and the perceived danger from traffic (Revista Espejo, 2019b).

To improve the conditions for pedestrians and cyclists in the city center, it is necessary to address the issues of accessibility, security, comfort and attractiveness, while still allowing automobile traffic (Rojo-Carrascal, 2018). To do this, there is a need to add street trees to offer comfort and

attractiveness in the urban areas. Sidewalks should be wide enough and free of obstacles. The surface materials ought to be sufficiently uniform to allow for the movement of people with special needs. The traffic speed should be reduced to 40 km/h or less in the urban area. Undeveloped areas can be repurposed to supply enough recreational spaces in urban areas. And in general, the amount of space assigned for pedestrians and cyclists should be no less than that for automobiles.

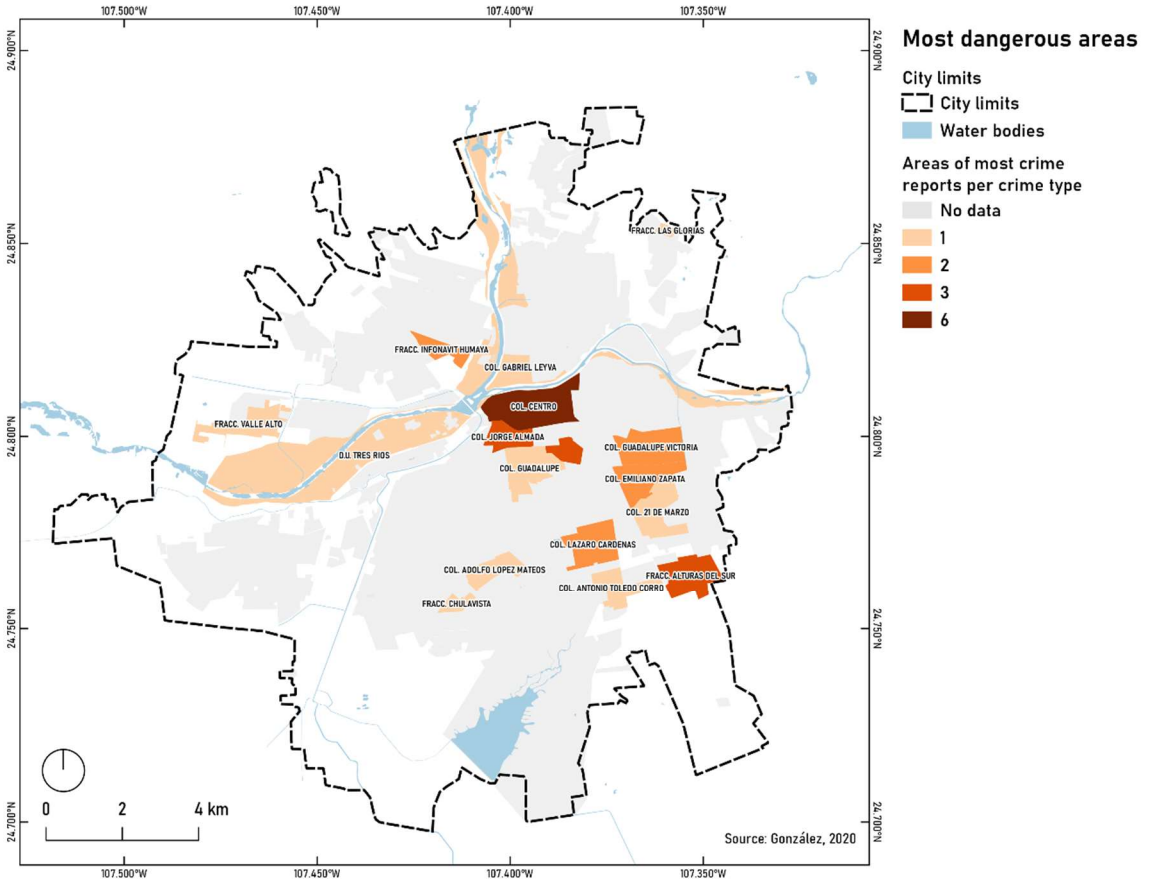
Safety and crime

Over the last ten years, crime and violence have become one of the most troubling topics in Culiacán and all the state of Sinaloa. It affects the economy, but mostly it affects the way people live in the city. According to the Security Council, Culiacán is amongst the 15 most dangerous cities in the world. People do not trust the police enforcement, they limit the time they spend outdoors, and they build their houses and businesses in fortress-like manners (Ibarra & Ceballos, 2018). People often hear stories of shootings between drug cartels in the public space and friends being assaulted in public areas. Consequently, people live in fear of outdoor spaces. The perception of violence in Culiacán affects not only the victims but also the rest of the population. Polls have revealed that, because of this generalized fear, many people have stopped doing daily activities such as letting children play outside, going out at night, going out for a walk, carrying money or jewelry, and taking the public transportation (INEGI, 2021b).

Hard facts indicate that Culiacán is in the top 10 municipalities in the country by rate of homicides, with 62.06 homicides per 100 000 inhabitants, and at least 90% of those crimes go unpunished (Ibarra & González, 2018). In addition, the city has a very high rate of robbery reports. The most frequent type of crime in the state of Sinaloa is extorsion, followed by fraud and then robbery or assault in public areas or public transportation (INEGI, 2021b). This situation not only results in economic losses, but also creates a general atmosphere of emotional and psychological violence in the population of Sinaloa. According to statistics from the National Poll of Victimization and Perceptions of Public Safety (INEGI, 2021b), it is estimated that 48.1% of the population over 18 years old in Sinaloa considers insecurity as the most important problem of the region. Furthermore, it is estimated that 22.5% of the people considers their own neighborhood to be insecure, 71.4% feels unsafe in the public space and by ATMs, 57.3% feels unsafe using public transportation, and 52% feels unsafe in the streets (ibid.).

Based on callings to the 911 emergency number, a diagnostic was made in 2019 by the Public Security Council of the State of Sinaloa, abbreviated CESP, to determine the most dangerous sectors of Culiacán according to crime type. Map 6 shows that the areas with most types of crime reports are Centro, Antonio Rosales and Alturas del Sur (CESP, 2019). These types of crime include first-degree homicide, home violence, raping, willful injuries, car robbery, business robbery and home burglary. In 2020 the number of crime reports changed, but the problematic areas remained roughly the same. Because of the covid-19 confinement, the dynamics in the public space shifted, and consequently so did the criminal activities in the city. Crimes involving robbery decreased, while those related to home violence, raping, and home burglary increased. The number of first-degree homicides in the state of Sinaloa was at its lowest since 2010. However, the cases of homicide by traffic accidents increased by 10% compared to 2019, despite the reduction in mobility due to the pandemic restrictions. Cases of home burglary also increased. Most of the victims of this type of crime were middle class workers that are away from home during working hours. Because of this, the study concludes that there is a need for more police surveillance, but also better awareness from neighbors (CESP, 2020). Moreover, according to a poll on public perception, the population of Sinaloa considers that the actions with most impact to

improve safety in the public space are improving outdoor lighting, increasing police patrolling and surveillance, and constructing and improving the conditions of parks and sports facilities (INEGI, 2021).



Map 6. Neighborhoods with most types of crimes reported to the emergency number in 2019. Made by the author with data from CESP, 2019.

As a result of fear of crime, many residential complexes in Culiacán are built as gated communities (Ibarra & Ceballos, 2018). Davis (2006) described this trend of modern cities as the *ecology of fear*. This term applies to an urban environment in which fear to crime and natural hazards, either real or imaginary, results in the segregation of the public space and a reduction of freedom to access different areas of the city. In this scenario, the mobility of pedestrians is limited, and public activity is mostly restricted to private spaces. Ibarra and Ceballos (2018) suggests that Culiacán shares many of these aspects in which there is a tendency to build residential fortresses that limit the access to public space. It is an urban paradigm obsessed with safety, controlling the mobility and access of people to different spaces, and using walls that gives its back to those walking in the street. A good example of this is the residential complex *La Primavera*. This was conceived as an enclosed housing area for the elites, enclosed by tall walls, an electric fence, and constant surveillance so that only those with permission can enter. This complex also holds one the best places to enjoy natural spaces in the city, an artificial lake, a golf course, and highly vegetated streets and parks (ibid.). The proliferation of exclusive neighborhoods and enclosed buildings results in an urban environment where fear becomes visible because it shapes how public space is designed, limiting the ability of its citizens to transit freely over the streets.

The spatial configuration of segregated space makes it difficult for pedestrians to freely move around the city. The car-oriented infrastructure makes it dangerous to choose walking or cycling as means of transportation. The fear of crime makes people choose not to be outdoors. All these factors sum to a loss of freedom and a lifestyle of being indoors most of the time. Therefore, it is of outmost importance to implement actions that turns public space into a more open, enjoyable, and safer environment. There is a need for infrastructure that protects pedestrians and cyclists, and an improved urban image and recreational spaces that contributes to public perception of safety.

3.1.4 Risk and vulnerabilities

The main phenomena that pose a risk for the municipality of Culiacán are those of hydrometeorological cause. Tropical cyclones, hurricanes, strong winds, and extreme rainfall cause flooding damage in the city every year. According to the National Risk Atlas (CNPC, 2015), the state of Sinaloa has suffered losses of 443 million USD only as a result of tropical cyclones between 2000 and 2015, and a total of 682 986 people were affected by the damages (see Figure 13), that is around ¼ of the state's total population.

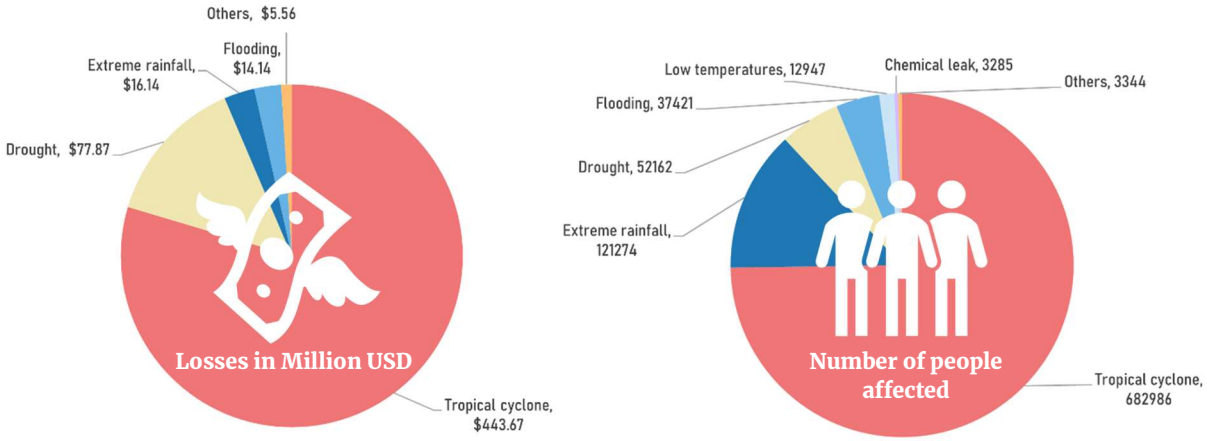


Figure 13. Cost of natural disasters in Sinaloa between 2000 and 2015. Source: Made by the author with data from CNPC, 2015.

Natural hazards exist because of the natural conditions of the region. But their effects turn them into natural disasters mainly because of the lack of control from human activities. The scarcity of monitoring, the irresponsible permissions to build in vulnerable areas, the excessive use of water and other natural resources, the lack of control on waste and pollution and the lack of protection policies against deforestation, are examples of factors that only worsen the consequences that natural disasters have on the inhabitants of Culiacán (IMPLAN, 2020). Climate change will only create more vulnerabilities for the city's population, and the worst effects will be suffered by the people with the least economic resources.

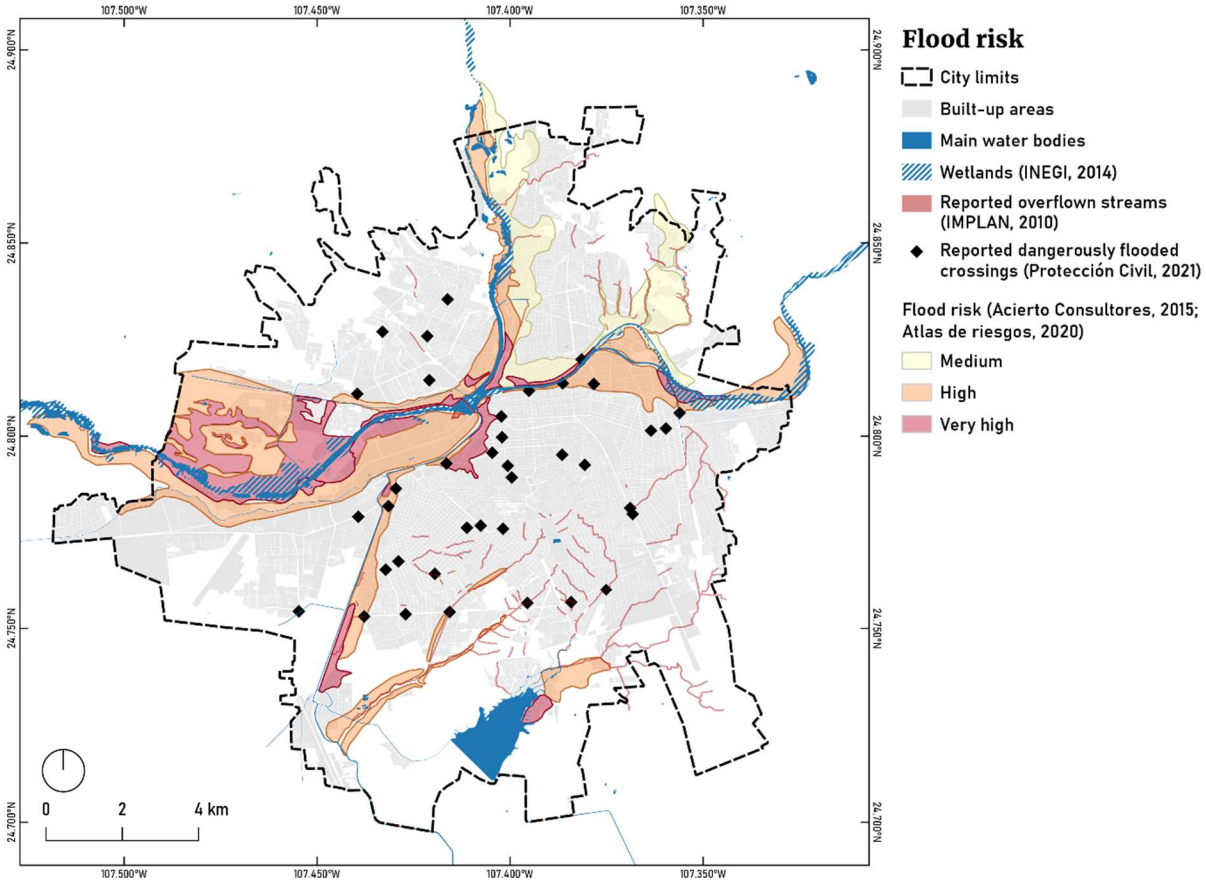
Flooding

The greatest environmental risks for the population of Culiacán are those associated with flooding (GEOLMEX, 2020). Because of its geographical location near the Tropic of Cancer and its closeness to the Pacific Ocean, Culiacán is vulnerable to tropical cyclones and hurricanes. These produce struggles every year, causing flooding, property damage, injuries, and even death (ibid.).

In this city that grows around the river, people live in fear of the next storm. In one of the most flood-vulnerable areas of the city, Valle Alto, a resident narrates how she had to carry her child in her arms to leave her home after the floodwater leaked through the windows during a storm in

2018. The water had already reached her chest by that point of the storm, and she had to pull all her strengths to walk against the current. Meanwhile, in the northern part of the city, a stream had overflown product of the extreme rainfall. The current was so intense that it was producing waves and swirls. Three women got pulled by the waters and never made it out alive. One year later, at the other side of the city, another resident was caught by floodwaters. The waters pulled her into a broken sewer that had been neglected for months, and she paid the price with her life. Events like this happen every year during the storm season in Culiacán, and because of that people live in fear (Sandoval, 2020).

According to the manager of the department of Public Infrastructure of the City Council, the hydrological network of Culiacán, comprised of three rivers and 57 streams, used to be very effective at managing stormwater. The problem began when it was decided to use vulnerable land for urban development, and so people started to build their houses in the way of streams or too close to them (Sandoval, 2020). Map 7 shows an overview of the areas of the city with risk of flooding, based on risk assessments from engineers. In addition, it shows road crossings with reports of frequent flooding that has led to accidents.



Map 7. Flood risk in Culiacán. Source: Made by the author with data from Acierto Consultores S.C., 2015; GEOLMEX, 2020; Haro, 2021 referring to the Culiacán City Council.

Drought

On the other spectrum of water problems, there has been records of drought in the area. It is assessed that light droughts, of 20-30% less rain than average, occur approximately every 6 years; moderate droughts, of 30-40% less precipitation, can happen every 25 years; and severe droughts, of 40-50% less rainfall, happen around every 50 years. These have direct economic

effects in the entire region because of its effects on agriculture, its main economic activity (IMPLAN, 2020).

Landslides

Additionally, there is a risk for landslides at the steep hills that have been previously devoid of vegetation and therefore have weakened their soil structure (IMPLAN, 2020). These are hills located in the southeast of the city, where a large irregular settlement is located. This makes these marginalized communities also the most vulnerable ones.

Extreme temperatures

Another environmental factor that poses great risk for the people of Culiacán is the extreme high temperatures that continue to increase (Acierto Consultores S.C., 2015). Exposure to excessive warm temperatures can cause health problems such as dehydration, heat strokes, multiple-organ failure, seizures, premature aging, amongst others. Intense physiological reactions can appear with temperatures higher than 37°C, not uncommon in the urban areas of Culiacán (ibid.).

The risk for cold waves in Culiacán is low (Acierto Consultores S.C., 2015). However, the consequences of this sporadic phenomenon can be significant. In 2011 more than 700 thousand hectares of crops in Sinaloa were lost in a single night, result of a cold wave that reached below 0°C (Vega, 2017). People can experience the consequences of cold waves though headaches, muscle pains, and respiratory diseases (Acierto Consultores S.C., 2015).

Earthquakes

The seismic activity in the Culiacán Municipality is moderated (GEOLMEX, 2020). Its location between three tectonic plates, Northamerican, Pacific and Rivera, in the Ring of Fire, means that there is a medium recurrency of tectonic movement. The city of Culiacán is located over 100 m from two active seismic zones, the Mesoamerican Trench and the divergence zone in the Sea of Cortes. The only registered earthquake within the limits of the municipality was in 2008, with an intensity of 3.8 Richter and 10 km of depth (Acierto Consultores S.C., 2015). Even though there are few historical records on seismic activity, the risk should not be underestimated. The soil conditions of the Culiacán valley, mostly composed of alluvial substrate, means that half of the territory is vulnerable to liquefaction (Jaimes et al., 2015, as referenced by Acierto Consultores S.C., 2015). This phenomenon would bring the effects of earthquakes from long distances closer to the city, making buildings susceptible to seismic waves (ibid.).

Climate change

Mexico is in a vulnerable position to the effects of climate change. Its geographic location between two oceans, its latitude in a tropical region, and its variated relief puts the country in the path of natural hazards (ENCC, 2013). Hurricanes, drought, extreme temperatures, and extreme rainfall events have already caused a great amount of human and economic losses between 1999 and 2011, and these events are only expected to intensify in the decades to come (INECC, 2019).

According to the National Atlas of Vulnerability to Climate Change in Mexico (INECC, 2019), the State of Sinaloa is in a vulnerable position upon flooding, landslides, transmission of Dengue, and losses in foraging and livestock productivity (see Table 17). Because of climate change, temperatures in this region are expected to increase. Heatwaves will become more extreme, and periods of drought will become more severe and frequent (Climate Analytics, n.d.). A scenario like this will not only make the region less livable, but it will also destabilize food production (Norzagaray Campos et al., 2019). Crops decline would cause major economic problems as this region's economy depends on agricultural activities. These changes are likely to happen if global

temperatures raise by 1.5°C by the next decade, which is the most optimistic predicted scenario. The most pessimistic predictions suggest that this temperature increase will happen by 2027, and temperatures will raise up to 3°C in 43 years at earliest (IPCC, 2021).

Table 17. Summary of climate change vulnerabilities in the state of Sinaloa. Source: made by the author with data from INECC (2019).

Climate change effects	Vulnerability risk
Flooding	High
Landslides	High
Potential increment in vector-transmitted disease (Dengue)	Medium
Potential losses in foraging production due to hydric stress	High
Potential losses in livestock productivity due to hydric stress	Medium
Potential losses in livestock productivity due to flooding	Low

3.2 Urban development plans in Culiacán

3.2.1 Urban Development Program for the city of Culiacán

Based on the need to integrate policies, guidelines, strategies and dispositions from the regional planning systems, an urban development program was published (IMPLAN, 2021b). This program attends problematics of the city in accordance to the General Law of Human Settlements, as well as concepts from the New Urban Agenda 2030 and the Sustainable Development Goals, mainly the Goal 11 on Sustainable Cities and Communities. During a virtual conference, the director of the Planning Institute expressed the vision for urban development in Culiacán:

"Today the city needs pertinent actions with a decided and resilient vision. The city is the habitat within a habitat, and don't lose it from sight, this is a constant of the urban and regional development that IMPLAN Culiacán seeks as a strategy" (Medrano-Contreras, 2021).

The strategies expressed in the urban development plans for the city are divided as follows:

Environment and resilience

- Environmental risk: The Municipal Risk Atlas proposes a series of prevention and mitigation actions to decrease the risk to hydrometeorological, chemical, and geological disasters in the municipality.
- Green city: Because of the rapid expansion of the city, considerable damage has been done to the natural and urban green areas. To restore the environmental qualities of the city, objectives related to the recover, self-sufficiency, and sustainability of the environment and green areas were adopted. These include the establishment of Natural Protected Areas (Sierra de las 7 Gotas, Cerro del Tule, Cerro La Guasima, and Cerro La Pithaya), and areas for conservation and protection (the riverbanks and islands near the city rivers). In addition, a system of Urban Ecological Parks was proposed. This includes development and management plans for Las Riberas Park, a natural park in Las 7 Gotas, the creation of an urban park in the existing landfill at La Pitayita, the rescuing of transitional and underutilized green areas, the rehabilitation of city parks, and the acquisition of territorial reserves for the creation of urban parks. Urban farming is also considered for its potential to address poverty issues, food security, self-esteem and public engagement, while also contributing to ecosystem services related to the increase of vegetation. Reforestation programs are prioritized in public spaces, making use of

recommended native species. There is the intention to plan for Sustainable Urban Drainage Systems through Green Infrastructure elements with a focus on flooding mitigation.

- Urban hydric system: Strategies address the problematics of water supply, sanitation, and water use efficiency. One of the objectives is to restore the stream network that has been damaged by human activities like pollution, deforestation, mining, solid waste, etc. Other objectives include the promotion of water capturing systems for home use, the evaluation and planning for residual and stormwater treatment, the restoring and construction of drainage systems, and plan for a sustainable fluvial drainage.
- Solid waste: It is estimated that the city's landfill at La Pitayita has reached the end of its capacity. This problem, combined with the fact that waste collection does not include any treatment for urban waste, means that there is a need for an integral program for solid residues. This includes the objective of improving waste collection services with full coverage in the city, the provision of modern trucks capable of separating trash, the creation of treatment plants to divide, transform and recycle waste, and the determination of a new site to dispose of solid urban waste.
- Climate change: The effects of climate change can already be seen, for example through the rising temperatures, health problems, more intense rainfalls and cyclones, and more frequency of heatwaves, cold waves and droughts. To mitigate the effects of climate change it is proposed to control the emission of air pollutants from automobiles through a system for monitoring and verification of vehicles. There is a national commitment to reduce the emission of GHG, and for this a Municipal Plan for Climate Action will be proposed. The target will be to reduce the emissions of GHG in the city of Culiacán by 15% in the long term.
- Sustainable energy: The geographic location of Culiacán brings potential for the generation of solar energy. Hence the objective of implementing infrastructure for solar panels, with a short term goal of covering 50% of the energy demand for public space and equipment, up to a 100% in the long term. Additionally, energy efficiency will be promoted by replacing conventional lighting with LED lighting.
- Sustainable buildings: Criteria for bioclimatic architecture and passive design strategies will be promoted in a manual for sustainable buildings. An additional manual for green walls is also a goal in the medium term.

Efficient land use of the territory

- Urban land use: The vision is to promote an effective use of land and mixed uses. An optimal urban density will optimize infrastructure and services, reduce transportation time, and favor non-motorized mobility with shorter distances. By providing tax incentives and flexibility of land use, the goal is to revert the depopulation trend of the inner city, while also contributing to halt the expansion of the urban footprint. To avoid fragmentation in future urban development, there will be established design guidelines in accordance with sustainable urban development. For example, new city blocks will be no longer than 150m, and bus stops will be located no farther than 300 m from each other. Undeveloped land shall be identified and updated to promote development in those located within the first priority zones and sanction the underutilized ones. In addition, urban subcenters will be established to promote a compact city development by bringing services and equipment closer to where people live.

- Partial plans: (1) City center. The intention for the city center is to promote its commercial activities and its cultural identity. A heritage conservation strategy will protect buildings of historical value while also stimulating tourism and creating housing policies to attract citizens back to the city centers. (2) Patio de maniobras. The old railway tracks will be relocated to outside the city, and the area where it is located today will be repurposed for urban regeneration.
- Housing: This strategy will promote compact urban development and vertical growth, incentives for good quality housing, financial support for housing to vulnerable groups, and tax incentives for housing projects in underutilized land. Some irregular settlements shall be integrated with planning instruments and infrastructure, while those located in areas of environmental importance or vulnerable to natural disasters will be relocated.
- Equipment: The purpose of this strategy is the implementation, recovery, maintenance and security of sports equipment, fire stations and cemeteries. This includes involvement with the community to improve the conditions and security of existing sports fields, and to localize donation lots for the creation of new cemeteries and fire stations. An important instrument is the creation of a unified GIS database with all the public equipment of the municipality.

Competitive territory

- Development of the local economy
- Logistics impulse

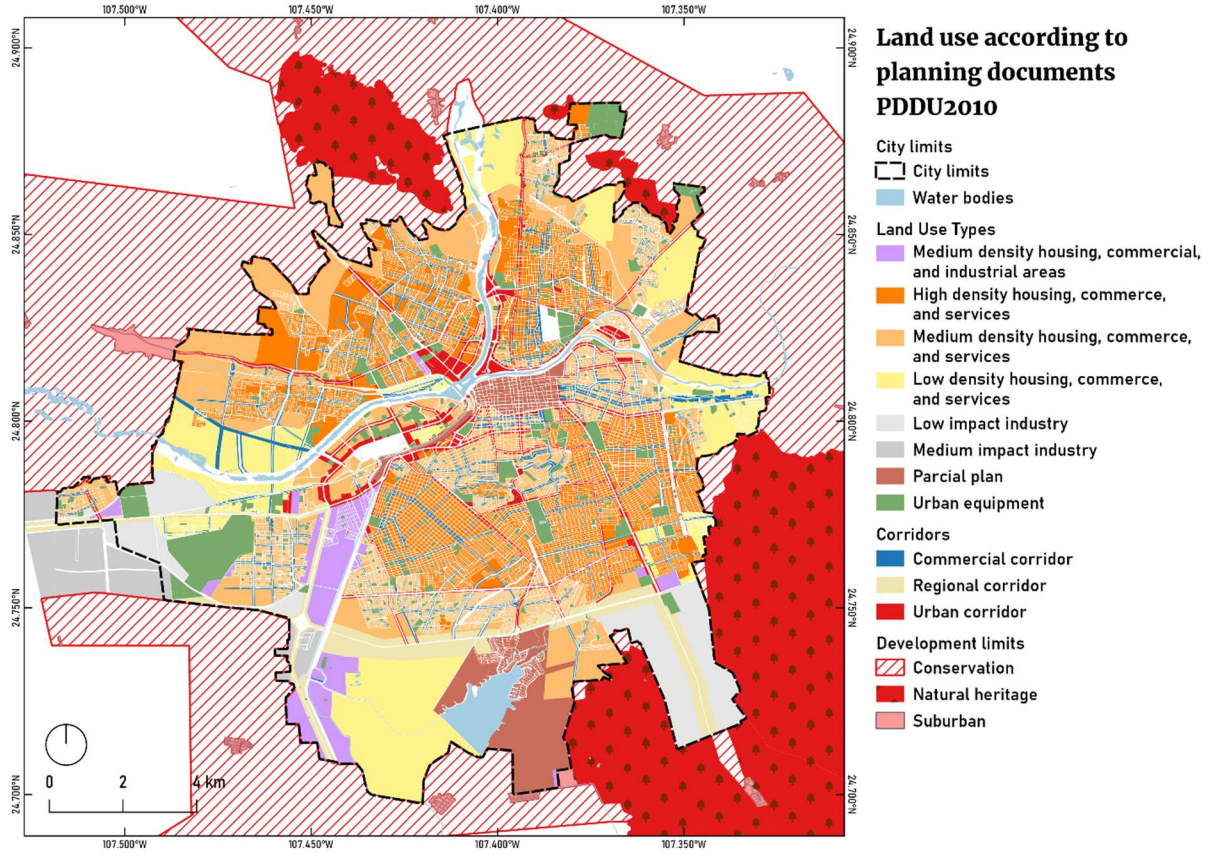
Sustainable mobility and public space

- Sustainable urban mobility
- Public transport
- Road structure
- Public space

Citizens and governance

1 Governance
2 Urban observatory
3 Institutional strengthening

3.2.2 Existing land use plans



Map 8. Land use plans 2010. Source: IMPLAN, 2010.

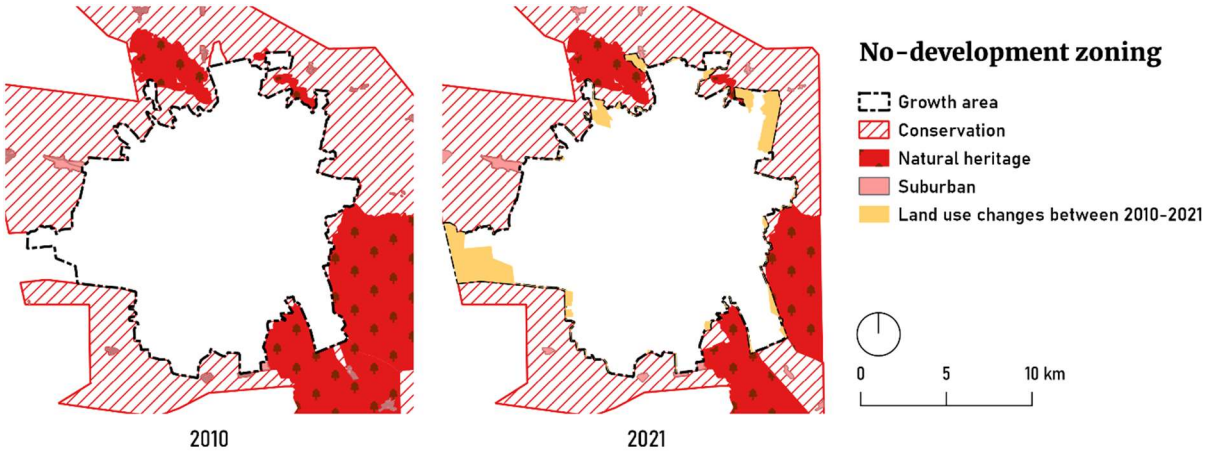


Figure 14. No development zoning 2010-2021. Sources: Made by the author with data from IMPLAN, 2010 and IMPLAN, 2021.

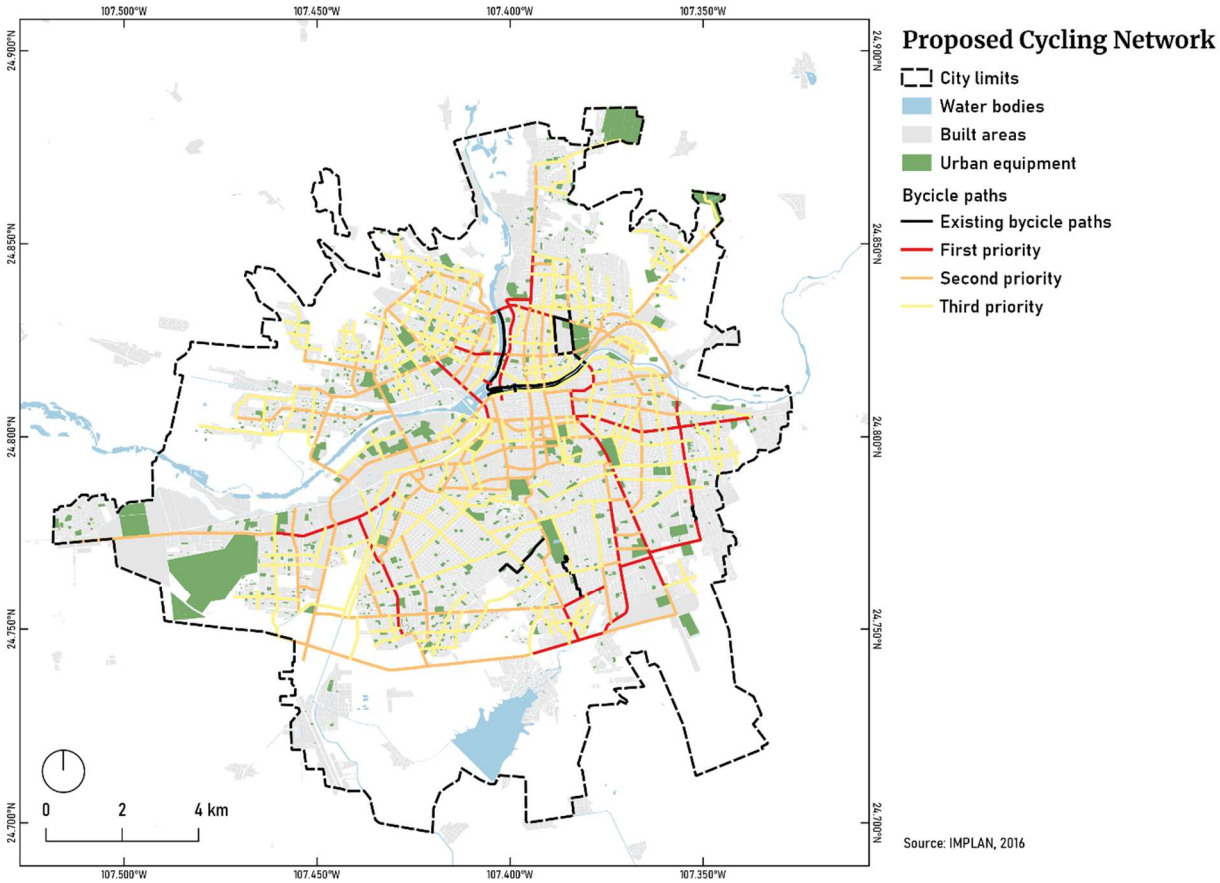
3.2.3 Plans for the City Center

The city center has special planning policies. The planning objectives for this zone include the physical restoration of public spaces like streets, plazas, and parks to improve the urban image and strengthen perceived safety. Accessibility should be prioritized through an improvement in the use of pedestrian paths, cycleways, and public transport. The building quality should also be improved, including changes in the land use to encourage more residents in the area and the

restoration of historical buildings. Reforestation with naïve vegetation should be prioritized, as well as the increment of surface area for vegetation and permeable soil. Participation from the public and private sector is encouraged, allowing the cooperation between different interested actors for the purpose of urban regeneration and appropriation. In summary, the policies for the city center aim for the increase of residents, a more dynamic use of the public space, improved accessibility for every type of mobility, the promotion of public participation, greener spaces, a healthier environment, and the regeneration of the cultural heritage (IMPLAN, 2010). This plan for the city center was published in 2009, but after 12 years it has not yet been successful. This is mainly because of the lack public participation, the lack of an organism to implement and monitor the progress, the weak institutional commitment due to the lack of personnel continuity, and the lack of innovative instruments to promote public and private investment (IMPLAN, 2021a).

3.2.4 Mobility plans

To promote the use of non-motorized means of transportation, in 2016 the Culiacán Planning Institute made a proposal of a cycling network of a total of 415 km to connect every sector of the city. Map 9 shows how this network is proposed, making a distinction from the existing pathways and the proposed ones, categorized in three levels of priority. These priorities have been the result of studies on frequency of use, destinations, and types of users in the city (IMPLAN, 2016).



Map 9. Proposed cycling network. Made by the author based on IMPLAN (2016).

3.3 Public participation

Rescuing of public spaces

In response to the crime concerns in public spaces, in 2011 an organized group of the city's inhabitants created an independent civil association to improve the quality of parks in Culiacán. This institution is called *Parques Alegres*, that in English means Happy Parks. According to its director, Carlos Aguilar Sanchez, the rehabilitation of these parks has increased the quality of life of many residents by changing the use of the space from illegal activities to culture, sports, and recreation (Hernandez, 2015).

In 2014 a similar private initiative was adopted. *Espacios Verdes Apropiados* (EVA), in English Apropriate Green Spaces, is a program created by the Chilean environmentalist Guillermo Dascal to propose new types of green areas in diverse cities in Latin America. This program has been adopted by the educational department of the Botanical Garden in Culiacán, and in conjunction with Parques Alegres they are working for the purpose of rescuing urban green spaces in state of abandonment. The program consists in four stages: (1) diagnostic, (2) sensibilization and technical training, (3) construction, and (4) activation. To do this, first they find communities that are open for change in their nearby green areas. There, inhabitants are consulted personally through interviews and workshops to figure out the need of the community. During the technical training stage, these communities learn about urban farming, compost, organic fertilizers and identification of important animal species. Once the community is organized, they work together to build their spaces with amenities, benches, shading and even reading squares. Finally, the spaces are cleaned and native vegetation is planted, and the community organizes for future maintenance, social events and future additions to the space (Piña, 2021b).

Paseos Verdes is another example of an initiative led by independent organizations to make the city greener. The asociations *Te Planto un Árbol*, *Guaiacum*, and *Más Planeta*, in cordination with the Environmental Directorate, have planted native trees in the city center. Their program includes the monitoring and involvement with the community for following up on the planted trees. During a virtual conference (Dehesa, 2021), the leader of *Guaiacum* mentioned that this program has been a successful way to improve vegetation cover in the city center, in contrast with previous efforts of planting trees without the collaboration of the community. He mentioned that in previous occasions, trees have been vandalized, sickened or stolen because of the lack of monitoring from the people living or working in their proximity. Thus he concluded that involving these people have been a key factor for this initiative.

Public opinion

There has been organized several participation forums for people to express their concerns and ideas. In 2012, the Ministry of Social Development (SEDESOL) involved the local communities in a diagnostic forum for the municipal development plans (SEDESOL, 2012b). The workshops included topics like smart growth, attention to marginated areas, environmental risks, regional competitiveness, and urban policies. Later in 2020, the Culiacan Planning Institute (IMPLAN) published the results of diverse workshops in which citizens, including children, expressed their opinions regarding their vision for the city, housing issues, environmental concerns, urban image, mobility, and safety (IMPLAN, 2020). By isolating topics about public space and natural environment it can be concluded that the main concerns of the population are as described in Table 18.

Table 18. Participation forums on topics about public space and natural environment (IMPLAN, 2020; SEDESOL, 2012b).

Participation forum	Topics and needs
Foro de Participación Ciudadana para la Presentación y Socialización del Diagnóstico del Programa Municipal de Desarrollo Urbano de Culiacán (SEDESOL, 2012b)	**Attention to marginated zones**: Problems with connectivity, flood risk, deficiency in services and basic infrastructure, need to improve educational and health equipment. **Natural environment and risks in urban development**: Lack of policies and enforcement of regulations for ecological conservation zones. Lack of a flood control program for the management of the hydrologic basins. Water pollution and lack of green areas.
Foro Ciudadano para la Integración de Propuestas (SEDESOL, 2012b)	**Smart urban development**: Densification of the city center, identification of vacant lots and their potential for housing development, reconversion of public space, declaration of green areas to conservation, creation of buffer zones between highways and housing areas, development of ecotourism projects, promotion of recreation activities to discourage illicit activities, use of the railways as urban transportation, creation of more urban green areas, implementation of planning instruments, improvements on public safety, programs for education and culture, generation of job opportunities, management of satellite cities, improvement of pluvial drainage services, improvements in urban transportation, protection of agricultural zones from urbanization. **Attention to marginated zones**: conservation of flora and fauna that favor economic activation in mountainous areas. Programs for urban trees. Mandatory environmental assessments for new urban development areas. Touristic projects in mountainous areas. **Natural environment and risks for urban development**: New conservations zones. Protect the floodplains around the river. Environmental education. Design of conservation spaces. Avoid visual contamination. Create financial programs, look for international cooperation. Create programs for management of conservation areas. Inform people of conservation areas and strengthen community participation.
Consulta infantil (IMPLAN, 2020)	**Environment**: waste, water and air pollution. **Education and culture**: good quality schools, recreational centers, promotion of values. **Public services**: safe streets, lighting, drainage, clean parks, and free sidewalks. **Equipment**: playgrounds, schools, hospitals, shopping centers and cultural centers. **Mobility**: reduce car traffic, more bicycles in the streets, free sidewalks, and good quality public transportation. **Housing**: Good quality housing, thermal comfort. **Health**: good hospitals close to housing areas.
Written proposals from citizens (IMPLAN, 2020)	**Environment and urban image**:

	1. An urban green network with hiking ways and road signs to promote the use of green areas around the city. 2. Habilitation of the riverine areas in the Villas del Rio sector for recreation. 3. Redesign as "complete street" of the main street Alvaro Obregon, between Universitarios and Blvd. Dr. Manuel Romero. 4. The creation of new public recreational spaces. **Mobility**: 1. Direct connection between Paseo Agricultores and Parque Las Riberas with universal accessibility. 2. Creation of a program for sidewalks free of obstacles. 3. Design of a program for safe crossings for pedestrians. 4. Limit the traffic speed to 30 km/hr in areas of the city center to make it safer for pedestrians, cyclists and users of public transportation. 5. Modification of laws and regulations to promote the use of non-motorized transportation. 6. Paving of a dirt road between Ejido El Quemadito and Las Beateas. 7. Rehabilitation of blvd. Enrique Sanchez Alonso for efficient traffic.
Foro-Taller técnico 2017 (IMPLAN, 2020)	**Housing and land use**: Identify vacant lots, relate economic variables and the urban context to determine which ones are feasible for housing development. **Environment and urban image**: Management of protected areas. More linear parks. Promotion of ecological activities with social value such as urban farming, orchards, or farming festivals. Updates in laws and regulations for environmental conservation. Street trees and environmental education. Training programs for maintenance of green areas. Incentivize community participation for the rescue, creation and appropriation of public spaces. **Mobility, public space and security**: Wider sidewalks and regulation of informal commerce in the public space. Implementation of a cycling network. An integral system of public transport. Programs of traffic education. Spaces for dialogue between users and providers of public transport. Increased budget in infrastructure improvements.
Foro ejecutivo 2017 (IMPLAN, 2020)	Some problematics: sound pollution, waste, cultural lag, insecurity, lack of green spaces for recreation, deficiencies in the public transport, unsafe streets because of traffic. Insufficiency of: drainage infrastructure, equipment for health, education and recreation, waste management, road infrastructure, and public transport.

People in Culiacán have expressed their perception of a lack of recreational and green areas. They have complained about the insufficiency of nonmotorized transportation alternatives, and the

inefficiency of the existing public transportation. They complain also about the flooding problems because the existing water infrastructure is uncapable to deal with extreme rainfall events. The city's inhabitants recognize that there are several environmental problems such as water pollution, urban waste, lack of conservation areas, and lack of environmental education from the general population. In addition, other concerns included lack of health infrastructure, low quality housing, and safety issues. All of these concerns are summarized after word frequency in Figure 15.

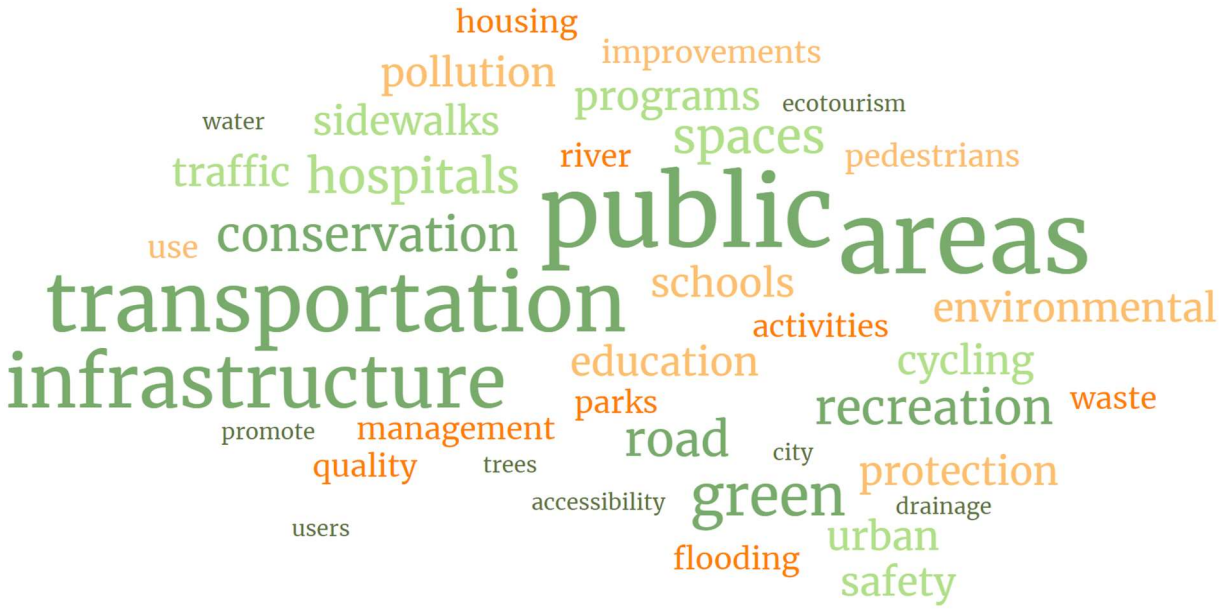


Figure 15. Word cloud on participation forums. Made by the author based on information from IMPLAN, 2020; SEDESOL, 2012b.

Chapter 4. Results

4.1 In-depth interview

The results of the interview indicate that the most frequent codes were those related to the river, native and exotic species, and deforestation (see Figure 16). The most common links were between the river and cultural identity, native species and cultural identity, and ecological identity and regulation and maintenance (see Figure 17).

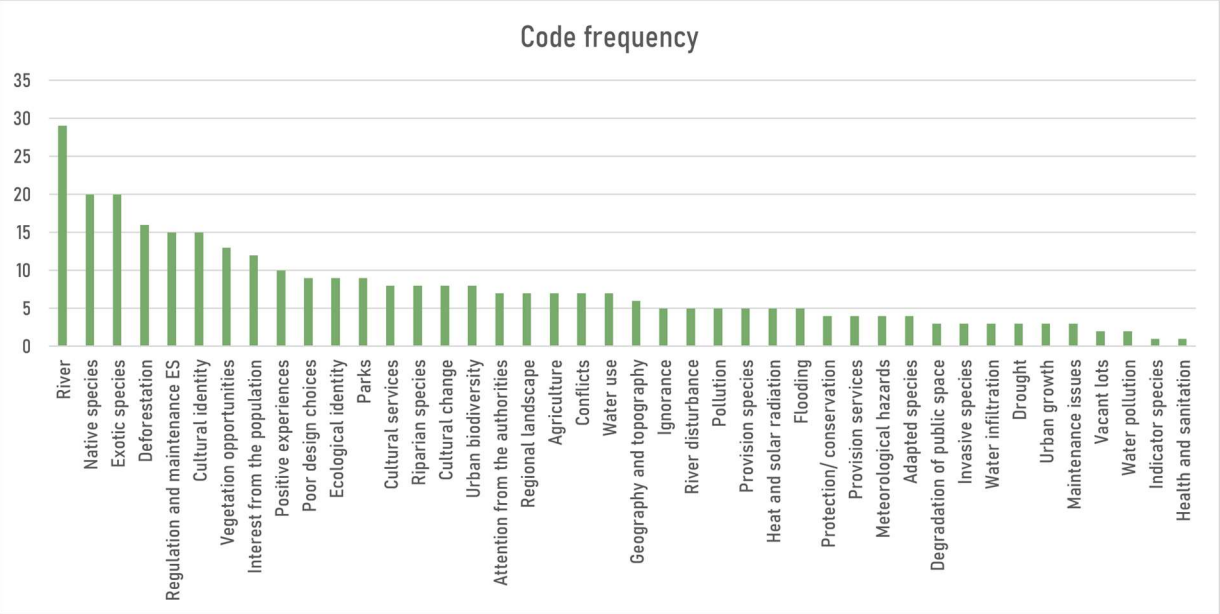


Figure 16. Code frequency from the in-depth interview.

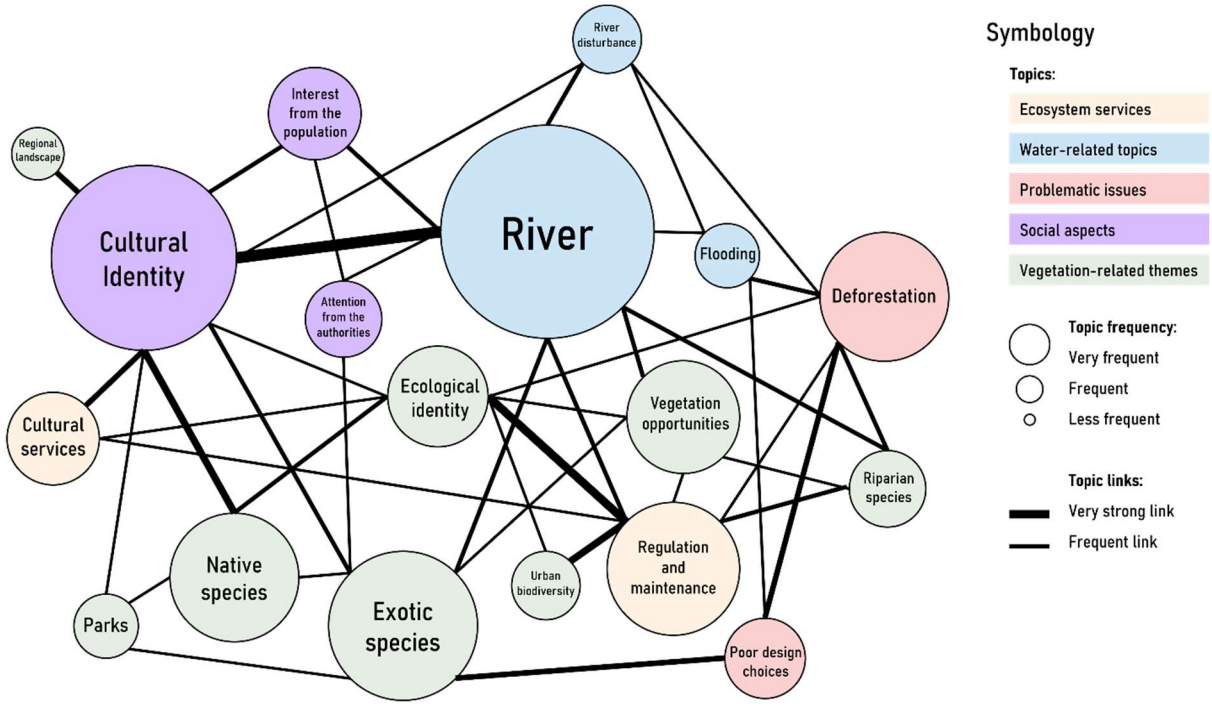


Figure 17. Key words and links describing the ecology of Culiacán, summary of the in-depth interview.

The most significant finding from the interview is **the importance of the river for the cultural identity of Culiacán** (see Figure 17). People in the city go to the park to sit with their families, to relax, to play, to walk, and to exercise. This is a city internationally known for its problems with criminal activities, and it is in the river that people can find themselves away from this identity of danger and fear. Upsettingly, the provision of these cultural services is threatened by the great amount of pollutants from urban residues and agricultural runoff. In Dr. Diaz's words, ***"we must conserve, protect, especially our water bodies, our rivers, which give us identity. And also protect those spaces in which we Sinaloans, so given to violence, unfortunately, can find areas of tranquility, of recreation, etc., that many of us need".*** Moreover, the biologist also mentions how native species attract people to the river. ***"If there is a place in the world with such a dense population of iguanas, that is precisely the part of Las Riberas park in the city of Culiacán. And just for that fact people go to see them. Now, that species that is very charismatic because of the old looks, because it looks exotic, although it belongs to us, it is our own, but people are struck by seeing that great 'dinosaur' walking there among them".***
These iguanas (see) depend on the trees by the river for their survival, their food provision, and their defense against predators. There is another species of great cultural importance that has been almost completely removed from the river, the Sabino or Ahuehuete (*Taxodium mucronatum*). Its name means "old tree that grows in the river". People recognizes this tree from a Mexican legend known as "The Night of Sorrows", in which the Spanish conquistador Hernán Cortés was driven out of the Aztec capital of Tenochtitlan, and he famously wept in sorrow under an Ahuehuete tree. The remains of this tree are still standing today, after 500 years (Comisión Nacional Forestal, 2016). It can be established that the river gives the city a cultural identity for its potential for recreation, its peaceful environment, and for the relationship between people and the river's biodiversity.

Historically, the river and the rest of the streams have provided the city with regulation and maintenance ecosystem services, but now their effectiveness have been reduced by the pressure of the city's development. In the past, the vegetation along the river and its main tributaries was so dense that the trees formed a "gallery" by joining their canopies from both sides. This canopy cover serves the function of preventing the extreme solar radiation from reaching the water and

Photo 30. Iguana iguana. Photo: Michelle Granados Johansen, 2021.

thus avoiding evaporation and heat. Their roots also provide suitable habitat for species like the river shrimp, fish, and turtles, and the trees also provide habitat and food for the iguana. But now the river has lost a great portion of its original vegetation, and so have most of the streams and canals in the city, losing the benefits that they provided. The areas along the river used to be very effective at controlling flooding, but these floodplains have been modified and reduced, increasing the city's flood risk. New developments and buildings, like the football stadium and the artificial island Musala, have been prioritized over natural green areas, modifying the original course and width of the river and its floodplains. Referring to the river's capacity to cope with flooding, Dr. Jose Saturnino Diaz mentions that: ***"two problems are fundamental, the narrowing of the riverbed, and the absence of natural vegetation that performs the functions of buffering the water currents. In other words, we have in that sense serious problems of urban design".*** So we can see that **the functions of the river and other streams as hubs for biodiversity and flood-mitigation capacity have been greatly degraded**.

Photo 31. Nannotrigona perilampoides bees inhabiting the cavities of a Pingüica tree (Ehretia tinifolia L) in the city center. Photo: Dr. José Saturnino Diaz, 2019.

A recurring theme along the entire interview was **the importance of using native species in the urban green**. Native species are part of the city's cultural identity, and people from rural communities recognize their absence when they come to the city. Species like Guamuchil (*Pithecellobium dulce*), Mora (*Maclura tinctoria*) and Palo de Brasil (*Haematoxylum brasiletto*) are examples of species associated with the rural landscape of Sinaloa, and Dr. Diaz argues that they should be seen more often in the urban landscape too. Not only are native species important for cultural identity, but they also are fundamental for keeping ecological identity. He defines ecological identity in this way: ***"Those (species) that adapt to the conditions of the environment, but also participate in the different functions of the organisms. They provide organic matter, nectar for pollinators, they provide fruits or seeds to mammals, birds, etc. I mean, this is then ecological identity".*** An example of this is the native bee species *Nannotrigona perilampoides*. They are highly efficient pollinators, they produce honey for human consumption, they do not sting humans, and they serve as food for many bird species. These species depend on big old trees like Pingüica (*Ehretia tinifolia L*) and

Guasima (*Guazuma ulmifolia*) for habitat provision and pollination flowers (see Photo 31). Instances of these trees are found scattered in the city center and the river, but are threatened by human activities and should be protected.

It is not only native species that have **ecological identity**, but also a few exotic species. For example, Lluvia de oro (*Cassia fistula L*) (see Photo 32) is an exotic species from the Mediterranean adapted to the ecological functions of Culiacán. This tree participates in the process of pollination, food provision to insects and mammals, and seed dispersion. In other words, it has formed its own ecological niche. It is because of this that the biologist recommends that ***"reforestation is good for the purpose of beautifying our cities, but let's do it with species that have ecological identity".***

Photo 32. Lluvia de oro (Cassia fistula L), an adapted species with ecological identity in Culiacán. Photo: Michelle G. Johansen, 2021.

On the opposite spectrum, it is common to find **exotic species** in green areas all around the city. Most of these species **lack cultural and ecological identity**. The biologist refers to residents that have raised questions about where these species come from, because those who come from rural areas have a closer relationship to the species characteristics of the region. They ask for Guamuchil (*Pithecellobium dulce*), Mora (*Maclura tinctoria*) or Palo de Brasil (*Haematoxylum brasiletto*) because they do not see them very much in the city. Popular exotic species like the Fan Palm (*Washingtonia robusta*) and Kentucky Bluegrass (*Poa pratensis*) require more maintenance and use more water than native species, which makes them more expensive and more vulnerable to drought. Moreover, the replacement of native vegetation with exotic and invasive species has negative consequences for the environment. For example, eucalyptus trees are weak against the strong winds of the hurricane season, and many of those trees end up falling on houses and cars, causing economic losses and possibly injuries. Exotic trees do not provide the same ecosystem services of the native ones. Trees that do not belong to the riparian forest lack the same

capabilities for flood mitigation and habitat provision. The problem is that exotic species have been introduced both by the authorities and residents, mostly because of ignorance, lack of commercial availability of native species, fixed contracts with private actors, and trends pushed by previous governments.

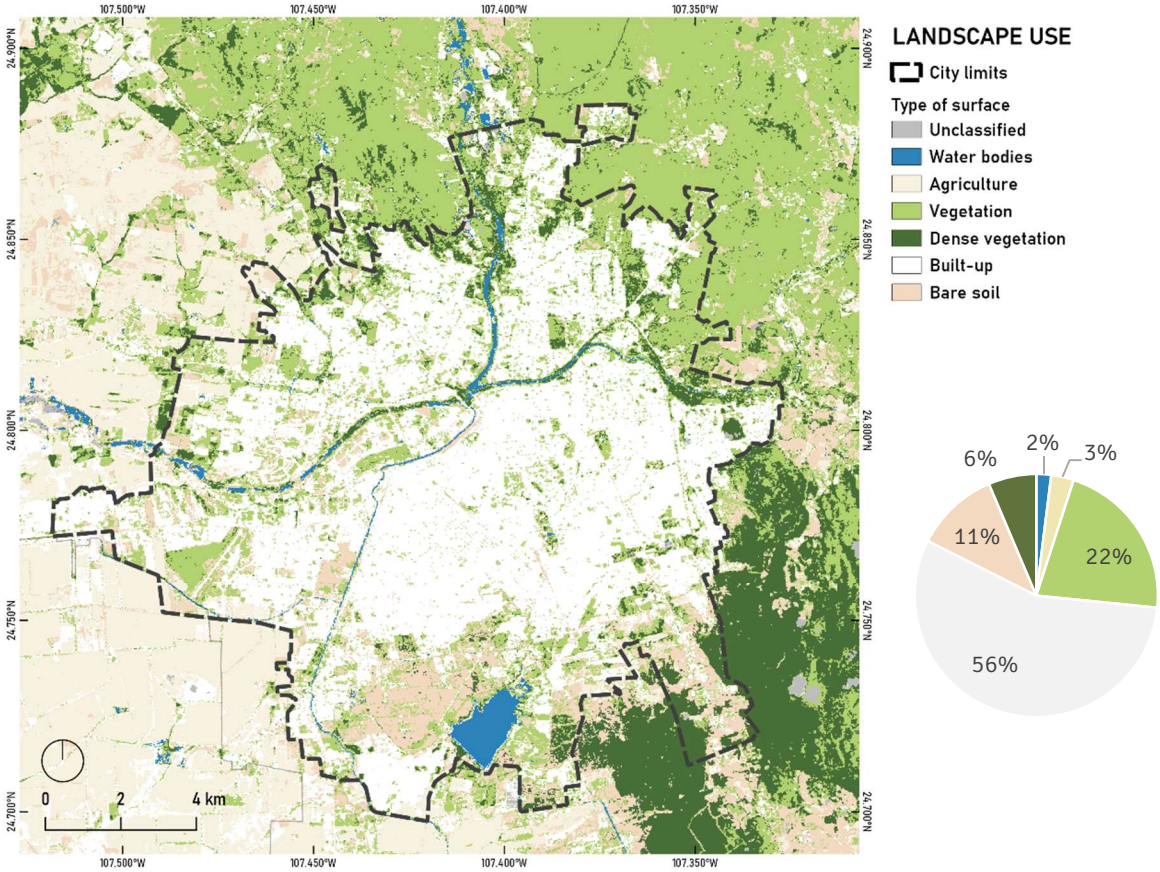
Along with all the challenges, Dr. Diaz also suggest some opportunities for improvement in urban vegetation. He commented about a recent trend towards ecotourism in the surrounding hills and explains that supporting these activities would bring people closer to nature. He mentioned earlier that it is rural people that recognizes native species, while urban residents rarely distinguish them from exotic ones. In his words, ***"people will not protect and will not be proud of what they don't know"***. He thus suggest to promote educational activities with the population and to plant native species so that people can know about them.

When it comes to environmental concerns, his main recommendation is to prioritize native species in all urban green spaces, and new developments present a great opportunity to do it from the start of development. The conservation of the river is of utmost importance, and vegetation corresponding to the riparian forest should be used more in there. Species like Alamo (*Populus mexicana*), Sauce (*Salix nigra*), Higuera (*Ficus insipida*), and Sabino (*Taxodium macronatum*) are examples of such species. Existing streams should also be protected to avoid greater flooding problems, and concrete canals can be revegetated to bring back the lost ecosystem services like habitat provision, temperature regulation and to avoid water evaporation (see Error! Reference source not found.). Species like Huizache (*Caesalpinia cacalaco*), Guamuchil (*Pithecellobium dulce*) and Guasima (*Guazuma ulmifolia*) are adequate for the limited space concrete canals provide, without compromising the stability of the structure. There are few remaining old trees in the city center, and these are of great important for pollinators so they should also be protected. The biologist suggest that sports fields could be planned for water infiltration and retention. He also suggests the use of the grass species *Cynodon Dactylon* because it needs very little water and it is easy to establish it, while also keeping the aesthetic qualities of exotic grasses. At the end he emphasizes that people in the city have great ideas, but there are few who dare to demand the authorities to apply them. He mentions for example how the pollution of the river affects the health of everyone who visits it, but there are little demands from the population to fix it. He therefore exhorts for more participation and communication between the population, the experts, politicians, farmers, and other stakeholders to implement better solutions together.

4.2 Remote sensing

The remote sensing maps describe the physical characteristics as observed from satellite data. These results, in conjunction with the literature review, field observations from the author, and geographical information files from diverse sources, form the basis for further spatial analysis.

Landscape use

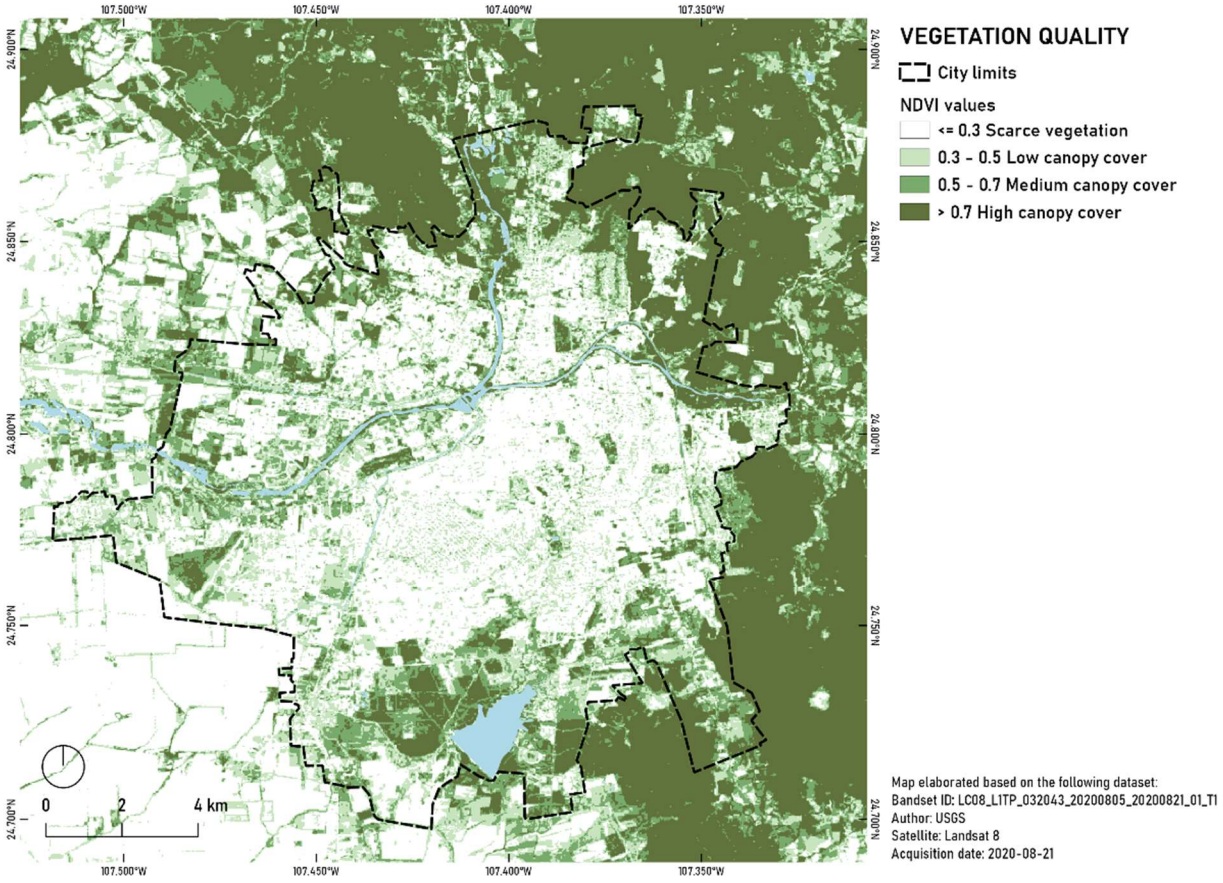


Map 10. Remote sensing results: Landscape use.

Following the land cover classification, it can be concluded that more than half of the city's territory is composed of built-up land. This includes buildings, streets, parking lots, and other structures. Water bodies make up only 2% of the territory, consisting of the Humaya, Tamazula and Culiacan rivers, the Recursos Canal, the Bacurimi Canal, the dike of La Primavera in the south, and a few small streams and artificial ponds spread around the city. Vegetation covers 22% of the land, and if we include dense vegetation the number sums up to 28%. Vegetated areas include urban parks, street vegetation, private gardens, vacant lots, forests, and overgrown areas. It is possible to see that lines of vegetation correspond to streams and other water bodies. Excluding natural and overgrown areas, the most extensive continuous green space is the field at the airport.

Vegetation quality

To determine the vegetation quality NDVI values were calculated and then divided into different levels. The information given in this map refers to the relative canopy cover of the existing vegetation. Low values indicate that there is a low vegetation cover, or that the present vegetation is either on an early or late stage of development. This could be the case of the agricultural areas that surround the city and that had been recently sowed or harvested. High values suggest a dense vegetation cover, or a very vigorous growth of the vegetation, such as areas of the tropical dry forest during the wet season.



Map 11. Remote sensing results: Vegetation quality (NDVI).

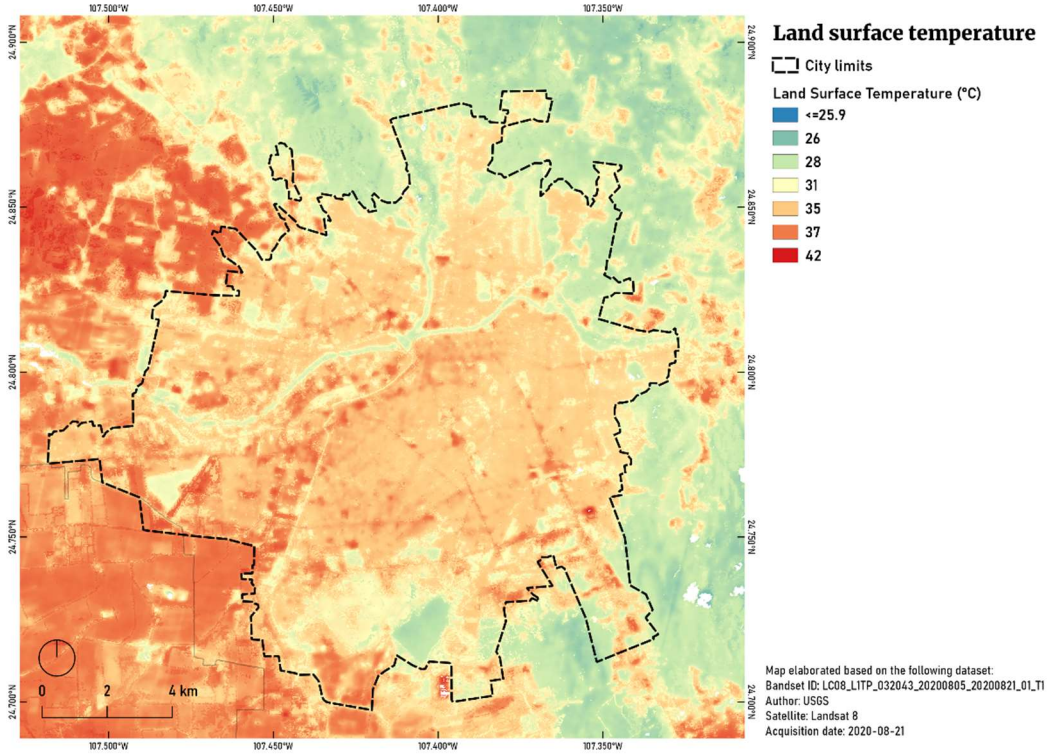
The results in this map (see Map 11) suggest that the highest quality of vegetation is located in the areas with remaining tropical dry deciduous forest, at the peripheries of the city. Inside the city, green areas like the botanical garden, the country club, the military zone, the airport, vacant lots, and some sections of the riverbanks provide the greatest patches of good quality vegetation. Areas in the city with scattering medium NDVI values could suggest the presence of many small patches of green, for example private gardens, street vegetation, and vacant lots, or simply areas with a low asphalt cover and overgrown vegetation. Areas with the lowest values of vegetation cover correspond to the densest built areas. These are streets with asphalt cover, few gardens and street vegetation, extensive parking lots, and few remaining vacant lots. In addition, clean vacant lots and recently harvested crop fields appear to be devoid of vegetation.

Photo 33. Examples of vegetation in unusual areas. From left to right: Airport field, clean vacant lot, parking lot with little vegetation in Plaza Sendero. Photos: Michelle Granados Johansen, 2021.

It is interesting to note the areas with a sharp contrast of vegetation quality. For example, in the northeast forest patch it is possible to see the deforestation caused by the most recent development of the sector called Los Angeles. Moreover, we can notice the deforestation patches in the hill areas, especially if we compare them with the satellite images. For example, the eastern slopes of the hill by the Hipico area seem to be highly degraded. The observed degradation of the soil profile and vegetation on Photo 34 support the results on the map.

Photo 34. Views on the degraded hillsides at El Hipico. Photos: Michelle Granaods Johansen, 2021.

Land surface temperature



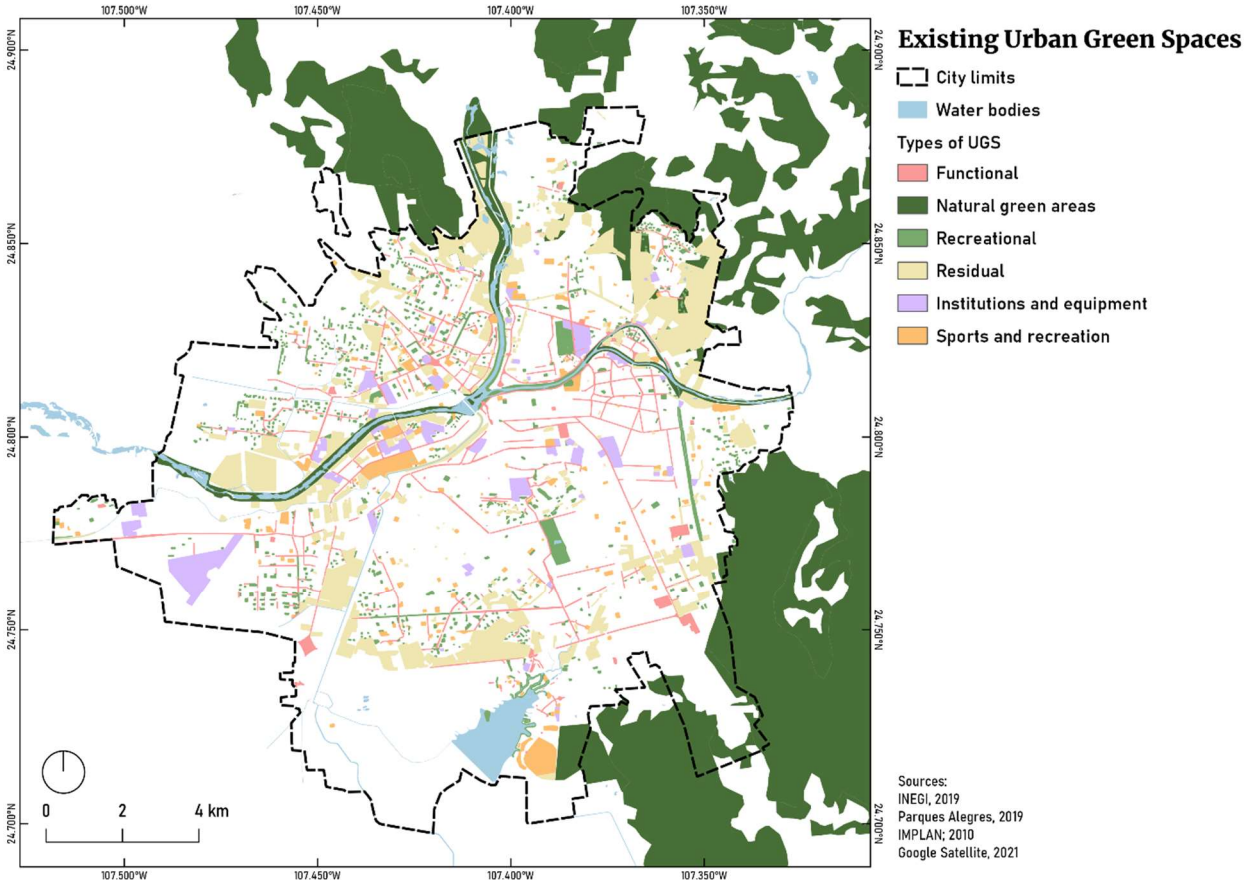
Map 12. Remote sensing results: Land surface temperature.

The results shown in Map 12 suggest that the warmest extended surfaces correspond to agricultural fields to the west of the city. Inside the city, hotspots can be found scattered around the densest urban areas, the airport, and along high traffic roads. The coldest areas match the location of the hills surrounding the city, the remaining parts of the forest, and the existing water bodies. The urban areas with lowest surface temperatures are those along the river, and within parks, vacant lots, and the airport green areas.

4.3 Spatial analysis

As a first step in analyzing the characteristics of the existing urban green areas, spaces were classified according to their size, vegetation quality, access, and landscape qualities. These categories, found in Appendix A. Classifications of urban green spaces, were further integrated in the spatial analyses below.

Distribution of Urban Green Spaces



The results of classifying the existing Urban Green Spaces gives a total 3387 green areas, including parks, vacant lots, sports fields, institutions with significant green spaces, cemeteries, and others. It we include only recreational green spaces, such as parks and sports fields, we have a total of 1206 UGS. Most recreational green spaces fall in the category of *Small Parks,* and the average size is of 4166 m^2 (see Table 22).

Table 19. Types of existing Urban Green Spaces in Culiacán.

		AVERAGE VALUES			
GREEN AREAS	TOTAL AREA (m^2)	AREA (m^2)	NDVI	LST (°C)	COUNT
SPORTS AND RECREATION	3 448 428.69	14 863.92	0.39	34.04	232
RECREATIONAL	4 058 068.13	4 166.39	0.33	34.16	974
INSTITUTIONS AND EQUIPMENT	4 729 379.69	65 685.83	0.39	33.78	72
FUNCTIONAL	1 891 462.67	1 102.89	0.28	34.73	1715
RESIDUAL	20 290 086.75	55 895.56	0.50	32.98	363
NATURAL	3 666 458.32	118 272.85	0.67	29.78	31
TOTAL					3387

Table 20. Types of existing sports related green spaces.

		AVERAGE VALUES		
SPORTS TYPES	TOTAL AREA (m^2)	AREA (m^2)	NDVI	LST (°C)
BASEBALL PITCH	272 129.16	19 437.80	0.49	33.56
BASKETBALL COURT	13 595.53	1 942.22	0.31	34.50
PRIVATE CLUB	79 631.70	19 907.93	0.46	33.13
FOOTBALL FIELD	255 594.86	8 519.83	0.41	34.16
DIVERSE SPORTS UNITS	1 288 306.84	7 760.88	0.37	34.13
GOLF COURSE	1 421 479.30	236 913.22	0.63	32.22
SPORTS ARENA	107 883.85	26 970.96	0.42	33.61

Table 21. Division of UGS by access.

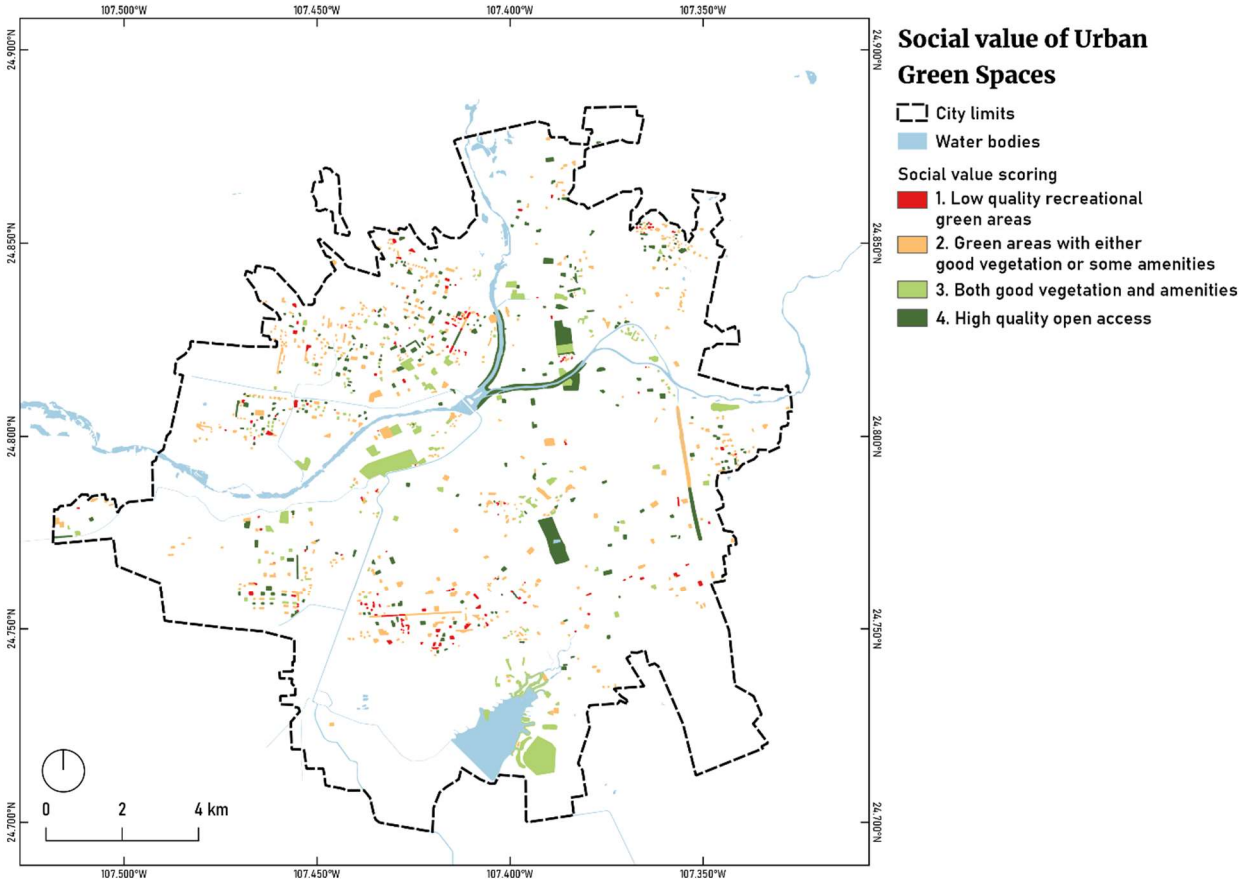
		AVERAGE VALUES		
ACCESS	TOTAL AREA (m^2)	AREA (m^2)	NDVI	LST (°C)
EXCLUSIVE ACCESS	5 935 316.64	17 405.62	0.33	33.93
OPEN ACCESS	4 200 319.68	5 097.48	0.35	34.19

Table 22. Distribution of UGS by size.

SIZE RANGES (m^2)		NUMBER OF UGS
< 400	Pocket park	115
400 - 5 000	Small park	848
5 000 - 44 000	Urban park	221
44 000 - 270 000	Urban biodiversity	19
270 000 - 533 000	Urban species richness	1
< 533 000	Habitat for urban-avoider species	2
	TOTAL	1206

Most valuable green spaces

Social value



Map 13. Spatial analysis results: Social value of urban green spaces

The result of this scoring suggests that the areas of highest social value are Las Riberas Park, the park next to the Botanical Garden (La Milla), the Constitución Civic Center, the Revolución Park, the Park 87, the Plazuela Rosales, a section of the Agricultores Linear Park, and some smaller parks scattered around the city. If we include green areas of limited and exclusive access we can conclude that the ones with the best qualities are the Botanical Garden, the Country Club, the green areas of La Primavera gated community, and many smaller recreational units. However, these are not considered of highest social value because there are limitation on who can use the spaces and are therefore less accessible. The following photos are examples of the results from the four levels.

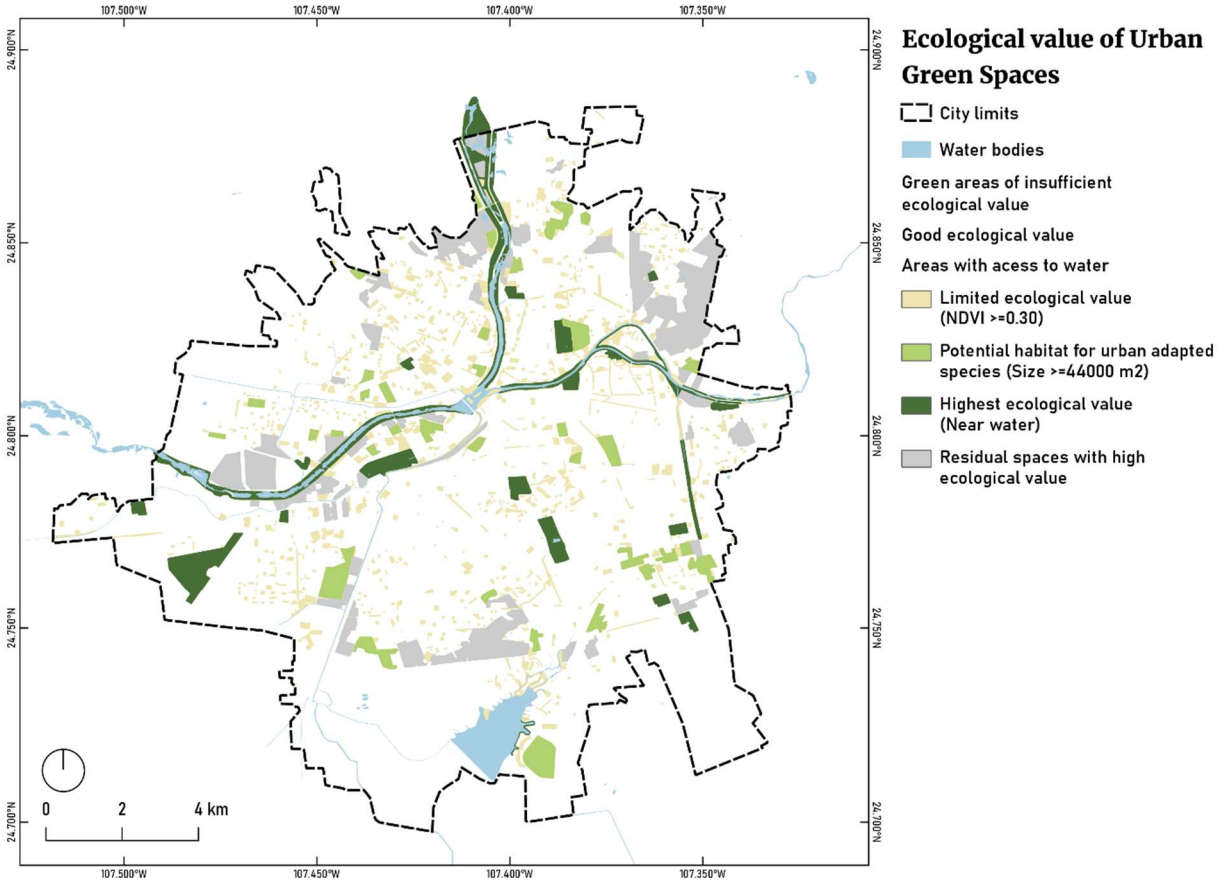
Photo 35. Level 1: Urban green areas with low or absent vegetation and recreational equipment (Left: Parque Capistrano IV. Right: park in Paseos del Rey). Photos: Google Street View, 2009.

Photo 36. Level 2: Urban green areas with some vegetation and limited amenities and equipment (Left: Parque Cañadas. Right: Dorados football stadium). Photos: Google Street View, 2009.

Photo 37. Level 3: Green areas with high vegetation quality, landscaping and recreational equipment, but of restricted access. (Left: Albercas del Seguro. Right: Community park in Tres Rios) Photos: Michelle Granados Johansen, 2021.

Photo 38. Level 4: Urban green spaces with high vegetation quality and recreational equipment, and of public access. (Left: Park 87. Right: Las Quintas Park). Photos: Google Street View, 2009.

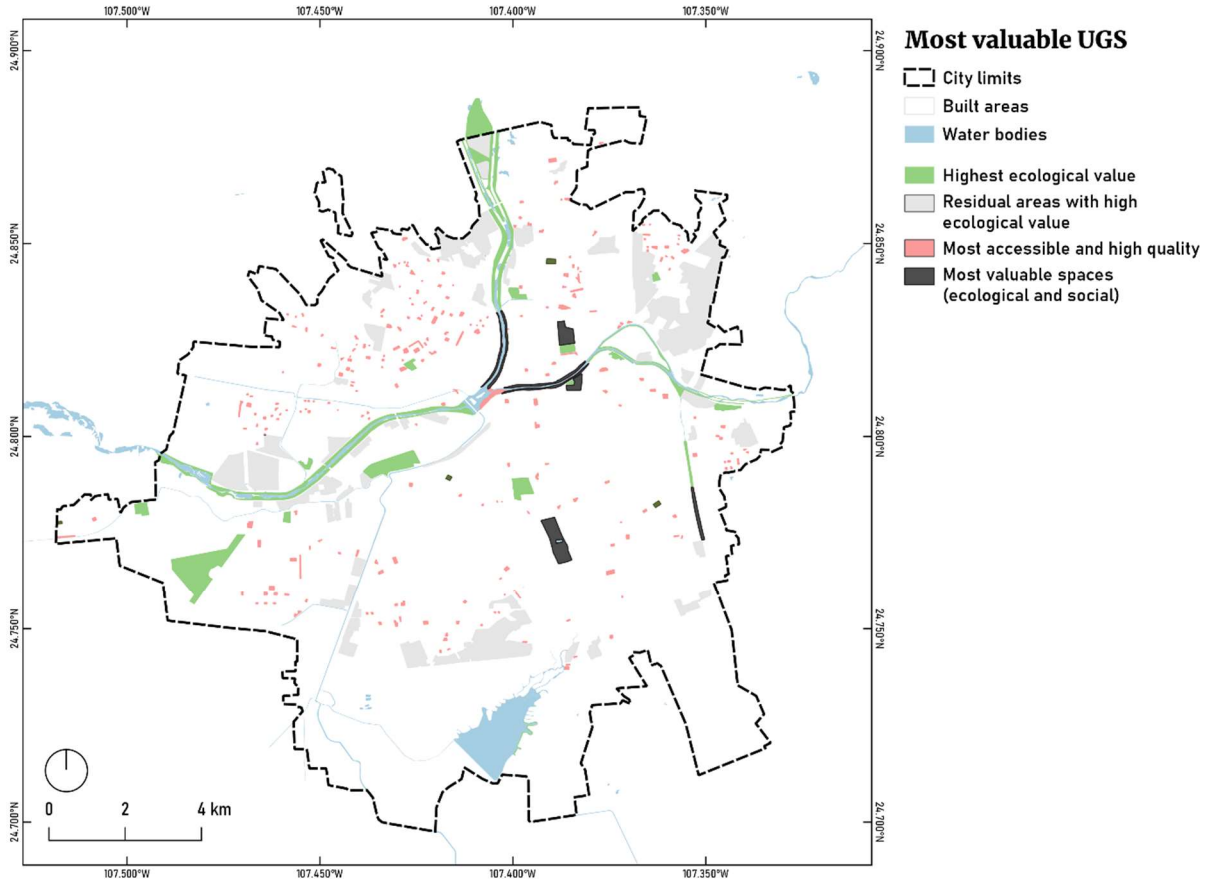
Ecological value



Map 14. Spatial analysis results: Ecological value of Urban Green Spaces.

The results indicate that the areas of highest ecological value are the margins of the river, the Country Club, the airport field, the Botanical Garden and its subsequent ecological park La Milla, the Zoo together with the Constitución Civic Center, the Park 87, the green areas of the Technological Institute of Culiacan, the linear park Agricultores, and a few smaller green areas. Large residual spaces have also shown to have ecological value due to their size, their vegetation cover, and access to water.

Combined score

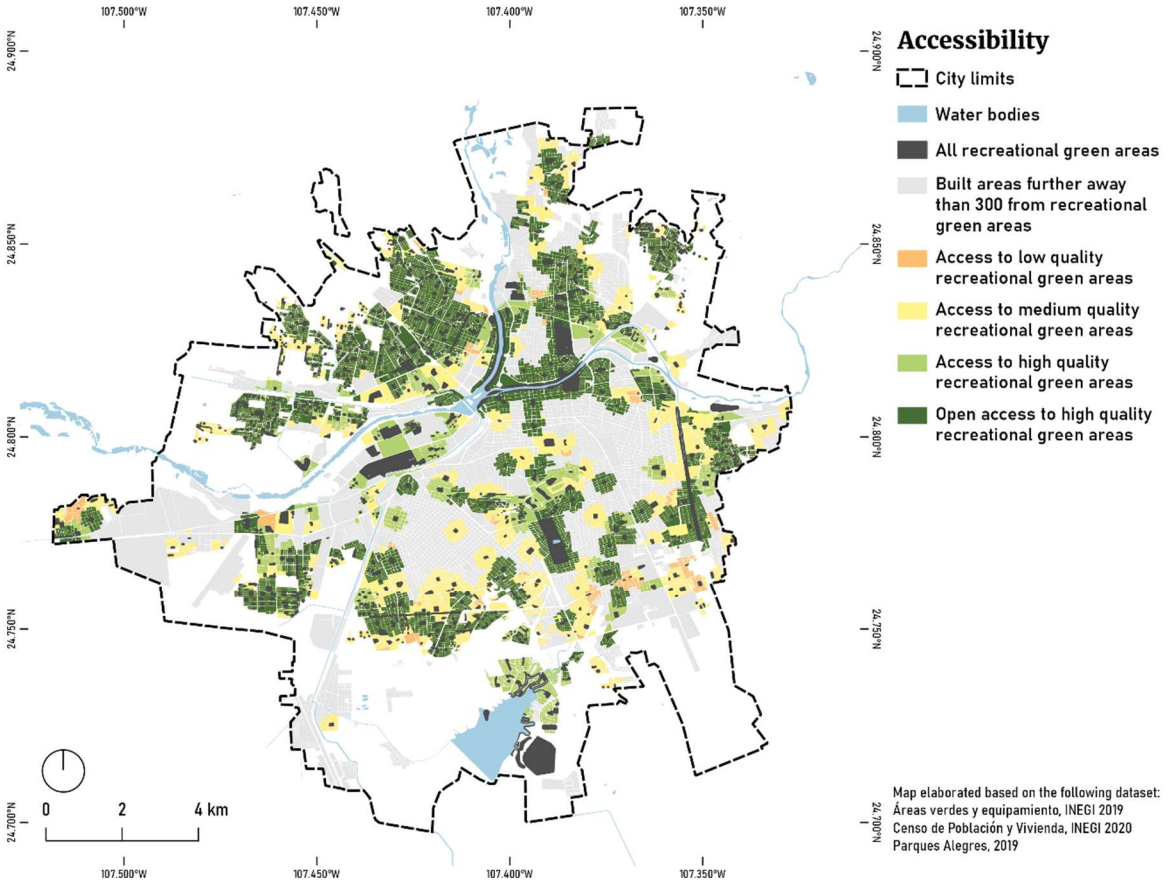


Map 15. Spatial analysis results: Most valuable green areas.

After overlaying the social and ecological values of the existing urban green spaces, five areas were found to be the most important ones (see Map 15). It was determined that the most valuable spaces for both factors are the areas of Las Riberas Park, the open area of the Botanical Garden known as La Milla, the Constitución Civic Center, the Park 87, and the southern section of the linear park Agricultores.

Accessibility

If we take in count the accessibility to all existing green areas of the city, it can be concluded that 78% of the population live within 300 m of those areas. However, if we refine these areas by their social qualities this number gets reduced to 52% of the city's inhabitants. Furthermore, by making a distinction between green areas of public access and those with limitations such as gated communities, fees or exclusive admission, the end result is less than half of the population have accessibility of high quality public green spaces. The summary of this analysis can be seen in Map 16 and Table 23.



Map 16. Spatial analysis results: Accessibility of Urban Green Spaces in Culiacán.

Table 23. Urban Green Space Indicator (UGSI) in Culiacán.

	Concept	No. of inhabitants	Urban Green Space Indicator
	Total population	819809	100%
1	Access to all recreational green areas, regardless of quality.	635789	78%
2	Access to more than average vegetation quality (NDVI values higher than 0.30), or some equipment.	613492	75%
3	Access to good quality green areas with amenities, equipment, and landscape design.	424875	52%
4	Open access to high quality recreational green areas, without any fees or limited admission.	361708	44%

Urban Heat Island Effect

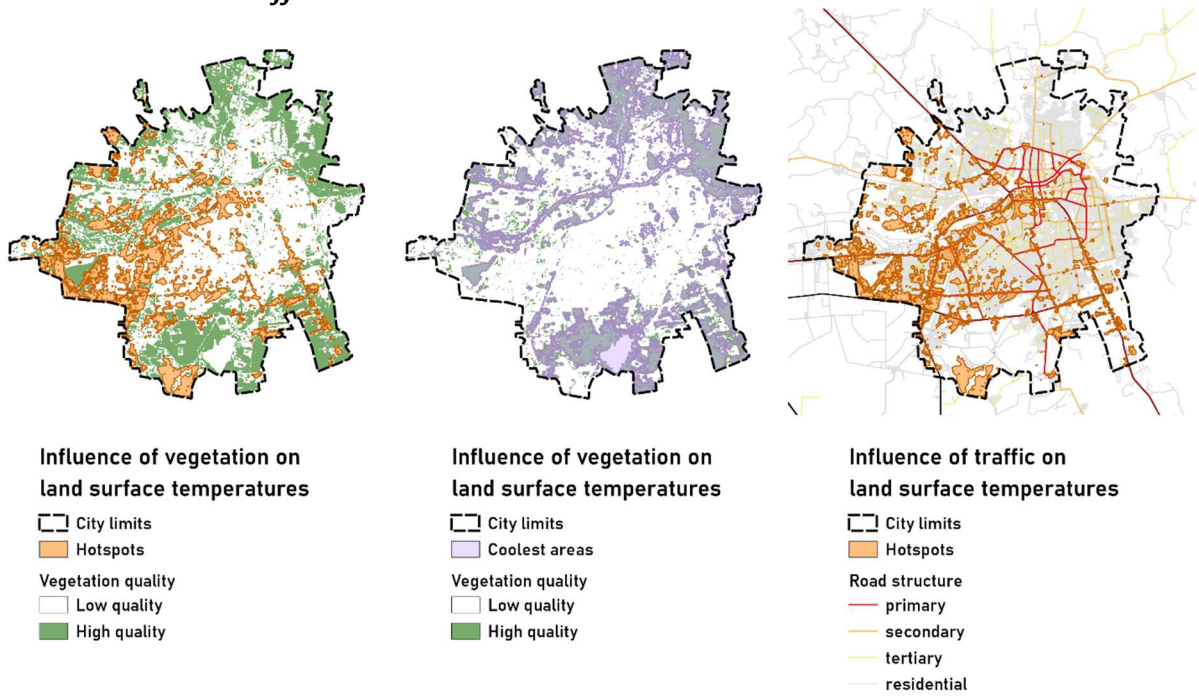
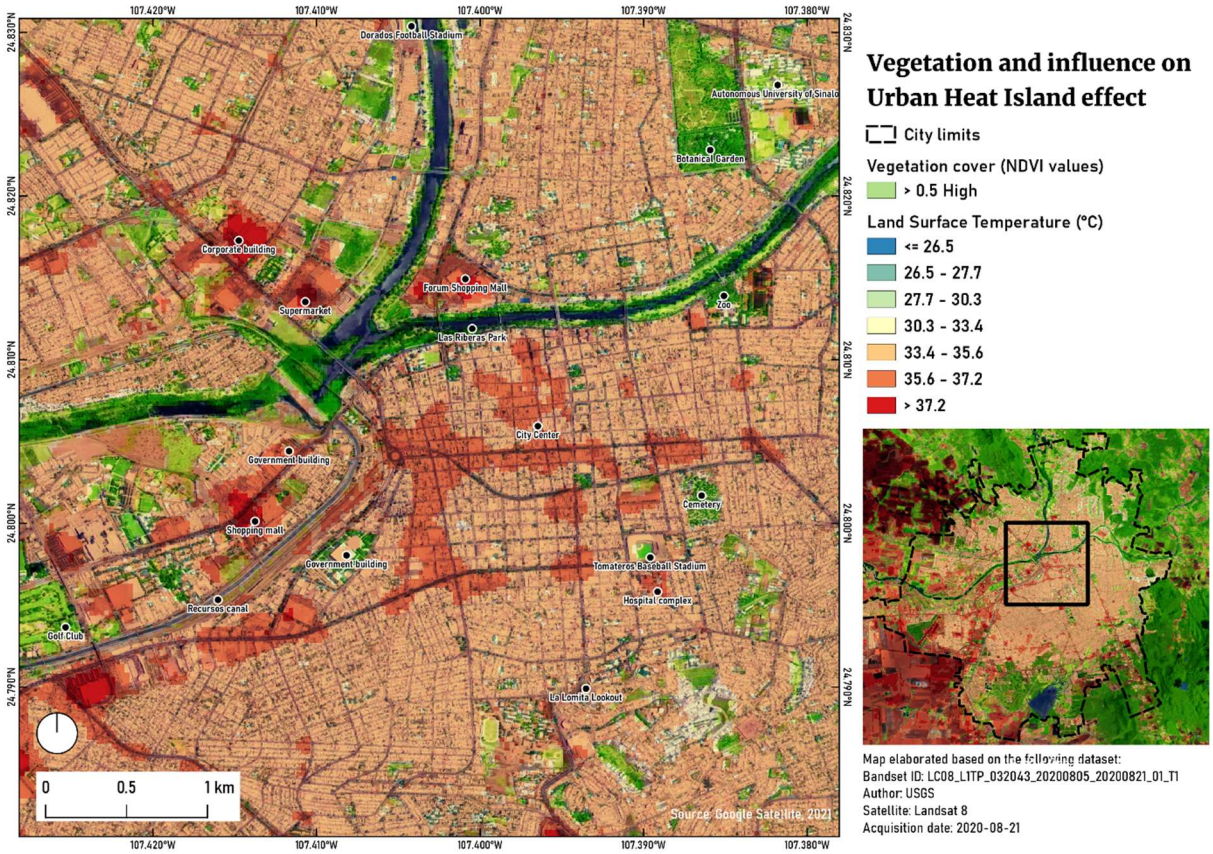


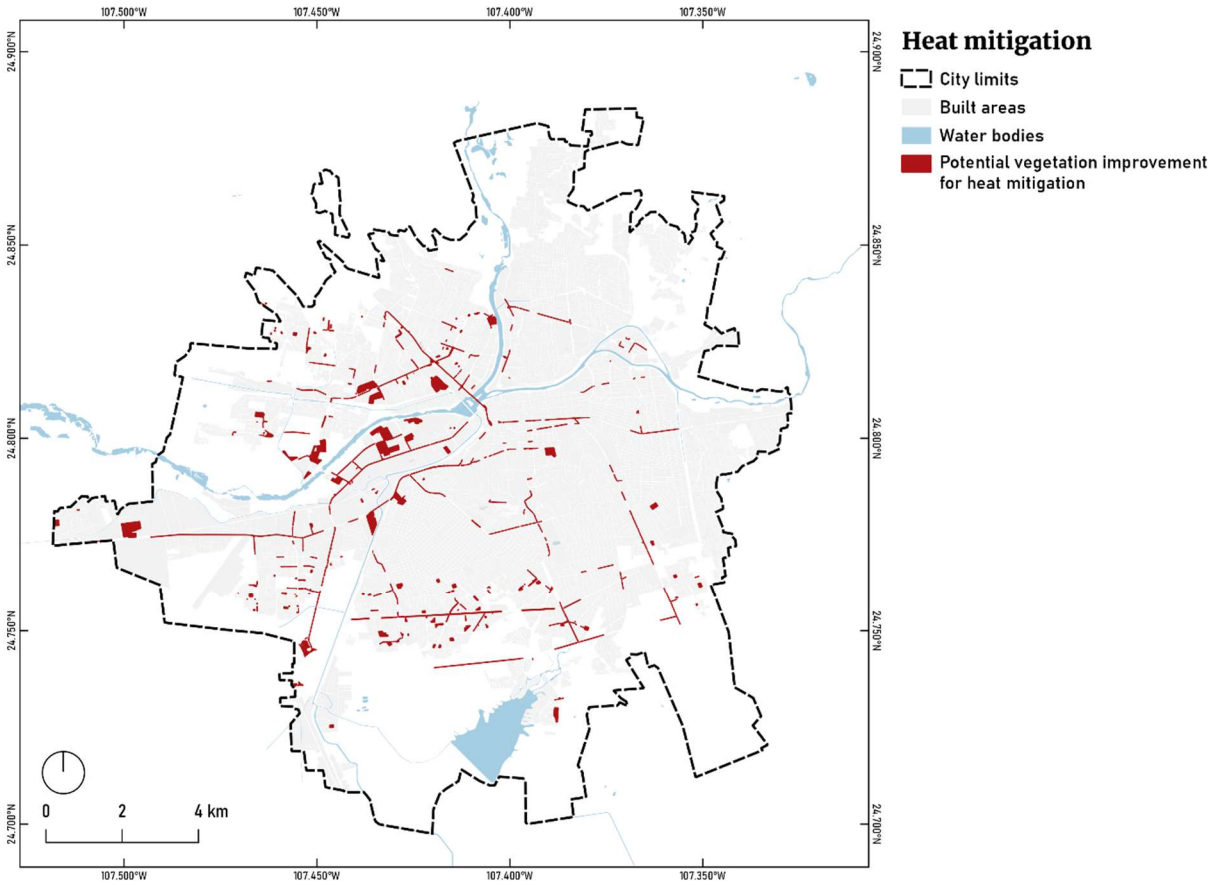
Figure 18. Spatial analysis results: Urban Heat Island effect and overlay with correlated factors.



Map 17. Spatial analysis results: Urban Heat Island effect in the city center.

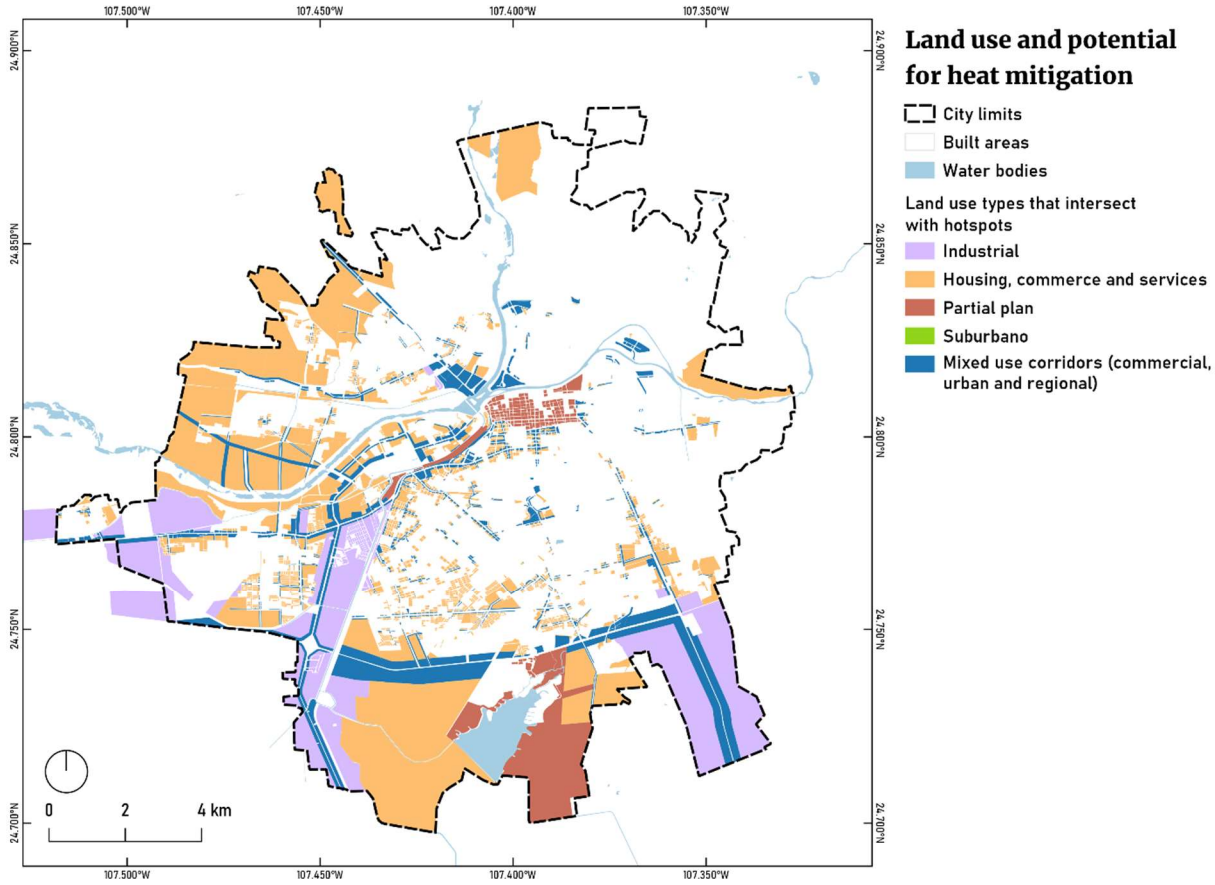
By overlaying the remote sensing maps of Land Surface Temperature and NDVI we can observe that the hotspots appear on areas with low vegetation cover (see Map 17). On the contrary, the areas of lowest surface temperature align almost perfectly with those covered with higher values of vegetation quality (see Figure 18). In addition, if we include information on road structure, we can see that many hotspots correspond to areas of high traffic. Other hotspots include impervious areas such as parking lots, large buildings, and sports fields covered with synthetic grass (these appear as black fields in Map 17). It can be easily appreciated that the hottest areas of the city center correspond to areas of low vegetation cover, wide streets, parking lots, and large buildings such as shopping malls and office.

Potential for heat mitigation by increasing vegetation quality



Map 18. Potential heat mitigation in green areas of low vegetation quality.

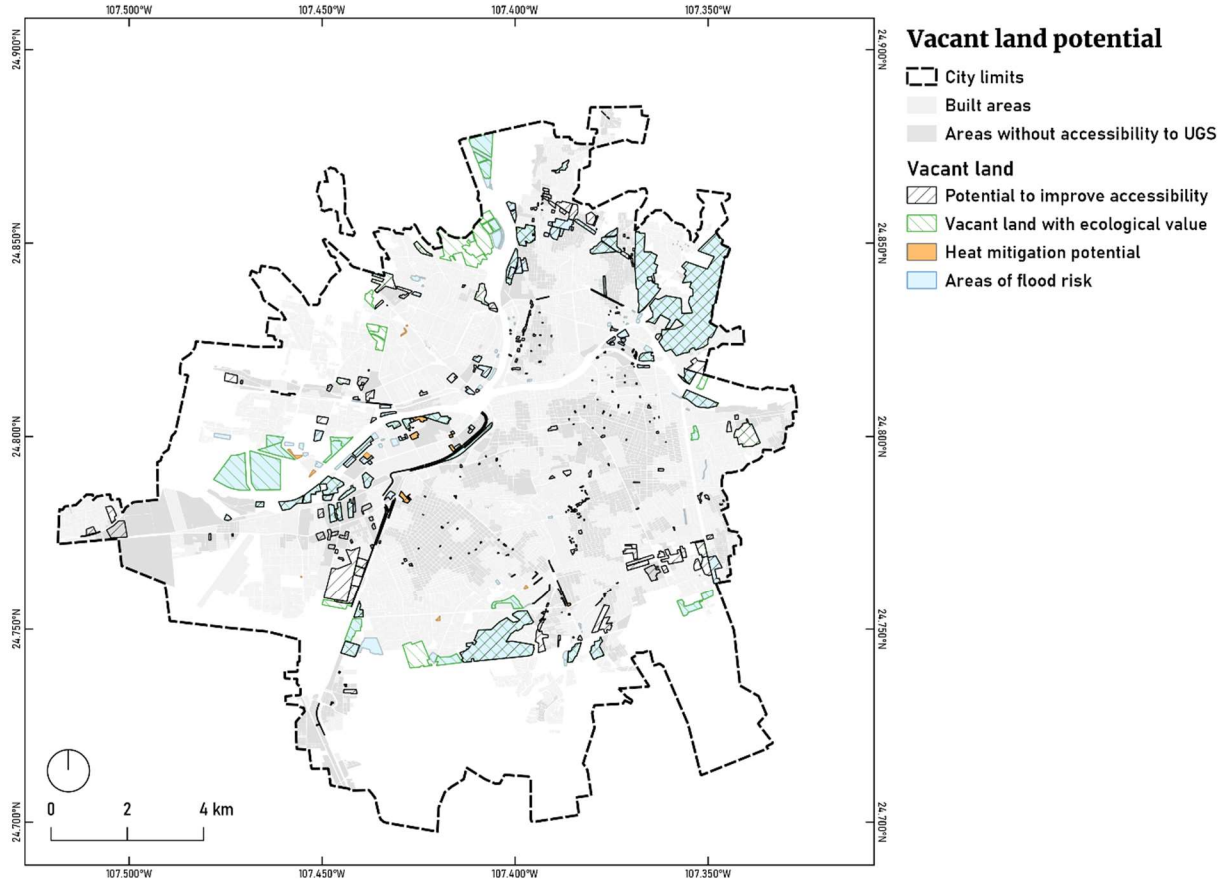
The intersection between the hottest surface temperatures and the existing green areas reveals that many of the existing green areas are not enough to mitigate the high temperatures of the city. By specifying those with a low vegetation cover (NDVI values less than 0.3), we can see that there is potential for increasing vegetation in existing urban green spaces (see Map 18). These include parks, sports fields, private areas, and street vegetation.



Map 19. Land use in areas of high surface temperatures.

By overlapping the lots of the land use plans (see Map 19) with the hottest areas of the city, it can be concluded that virtually all areas designated for industrial use contribute to the Heat Island Phenomenon. The same applies for most areas of the city center, many of the mixed-use corridors, and the land classified for housing that is located in the peripheries of the city. The last ones also correspond to area that is currently cultivated, and therefore it can be noted the influence of agricultural land in the surface temperatures.

Potential in residual areas



Map 20. Spatial analysis results: Potential in residual areas.

It was determined that there are 396 vacant lots located within or near areas that do not have access to urban green spaces. Additionally, vacant lots with some ecological value are marked with green lines in Map 20. Most of them are located in the peripheries of the city, but 39 of these correspond to lots with potential to improve accessibility. Areas that could benefit from additional vegetation for heat mitigation are highlighted in orange, while those located in areas at risk for flooding are colored in blue.

Urban green areas by sector

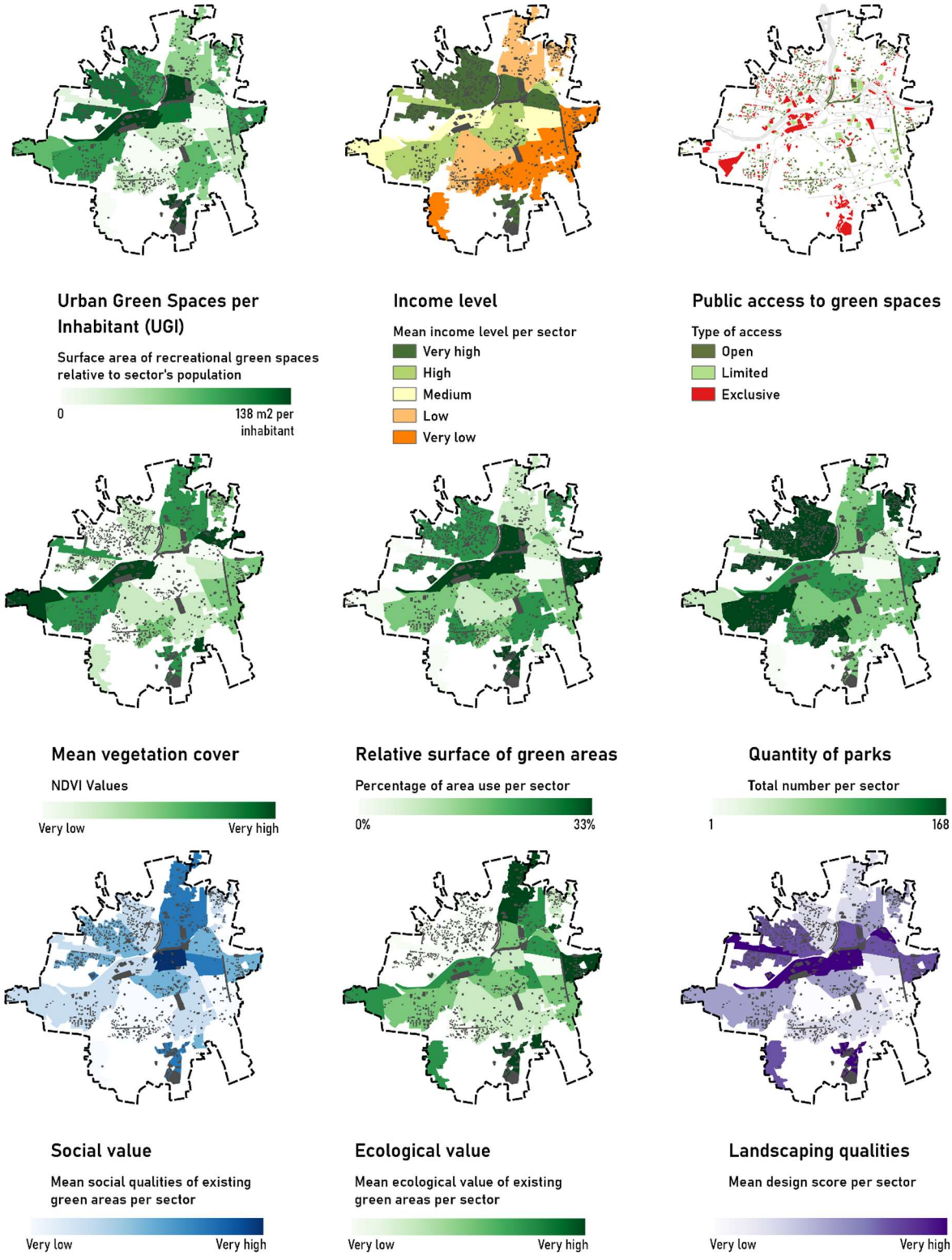


Figure 19. Spatial analysis results per sector.

Table 24. Spatial analysis numbers by sector.

SECTOR NAME	MEAN NDVI VALUES	TOTAL GREEN AREAS (M2)	MEAN GREEN AREAS (M2)	RELATIVE SURFACE OF GREEN (%)	NUMBER OF UGS	MEAN DESIGN QUALITIES	MEAN SOCIAL VALUE	MEAN ECOLOGICAL VALUE	ACCESSIBILITY (UGSI)	MEAN INCOME LEVEL	UGS PER CAPITA (M2)
La Primavera	0.32	1098819.17	30522.75	33.32%	36	0.93	0.72	0.26	0.19	1.00	137.10
Tierra Blanca	0.24	631740.54	20378.73	15.95%	31	0.66	0.70	0.19	0.33	0.50	32.25
Country	0.37	867534.99	17350.70	13.02%	50	0.79	0.63	0.21	0.05	0.33	47.83
Centro	0.14	363563.68	33051.24	9.21%	11	0.97	0.84	0.15	0.08	0.36	11.09
El Barrio	0.28	393752.61	8035.77	8.40%	49	0.63	0.64	0.26	0.33	0.26	7.88
Villas del Rio	0.27	301368.13	34490.45	7.76%	122	0.81	0.69	0.14	0.68	0.37	9.50
Solidaridad	0.17	560513.55	3336.39	6.67%	168	0.73	0.63	0.12	0.64	0.41	8.31
Lazaro Cardenas	0.22	614585.81	18623.81	6.24%	33	0.48	0.60	0.14	0.17	0.26	4.86
Humaya	0.21	527397.19	3235.57	5.97%	163	0.53	0.60	0.13	0.65	0.41	7.05
Angeles	0.28	139231.61	1808.20	5.45%	77	0.56	0.58	0.14	0.80	0.27	6.48
Barrancos	0.15	203257.87	2746.73	5.19%	74	0.50	0.48	0.14	0.44	0.31	3.31
San Isidro	0.22	216998.78	2552.93	5.09%	85	0.49	0.54	0.16	0.39	0.25	2.97
Isla Musala	0.41	41122.96	3163.30	3.69%	13	1.00	0.69	0.18	0.07	0.40	6.71
21 de Marzo	0.27	258657.89	8919.24	3.42%	29	0.40	0.53	0.19	0.22	0.27	3.36
Colinas	0.17	227729.98	3503.54	3.17%	65	0.59	0.63	0.17	0.19	0.37	3.17
Aeropuerto	0.30	424921.76	3760.37	3.11%	113	0.56	0.61	0.17	0.45	0.37	6.98
Universidad	0.30	156471.64	4012.09	3.08%	39	0.59	0.75	0.22	0.38	0.32	3.74
6 de Enero	0.35	238599.31	6627.76	2.95%	36	0.48	0.70	0.32	0.37	0.29	3.69
Las Quintas	0.18	60415.93	3776.00	1.89%	16	0.77	0.69	0.22	0.44	0.50	2.68
El Ranchito	0.37	14388.57	4796.19	1.78%	3	0.33	0.67	0.38	0.03	0.25	3.93
Diaz Ordaz	0.21	130778.77	6883.09	1.33%	19	0.47	0.55	0.16	0.09	0.29	1.23
Aguaruto	0.36	76039.65	6912.70	1.28%	11	0.58	0.61	0.23	0.27	0.36	5.12
La Limita de Itaje	0.47	14037.78	5335.35	1.25%	5	0.38	0.53	0.47	0.00	0.33	11.42
Bacurimi	0.35	18142.61	2267.83	0.67%	8	0.92	0.59	0.11	0.04	0.37	1.63
Hidalgo	0.18	18904.50	6301.50	0.50%	3	0.56	0.75	0.10	0.02	0.34	0.31
5 de Mayo	0.18	8583.70	2861.23	0.40%	3	0.33	0.58	0.20	0.07	0.33	0.26
El Diez	0.19	7602.48	7602.48	0.20%	1	0.67	0.50	0.22	0.00	0.24	0.90
	0.26	**7615161.47**	**9365.03**	**5%**	**1263**	**0.62**	**0.63**	**0.20**	**0.27**	**0.36**	**6.51**

The results shown both in Figure 19 and Table 24 indicate that the sector of the city with the best quality and quantity of recreational green areas is, by far, La Primavera, followed by Tierra Blanca and Country.

Chapter 5. Proposal

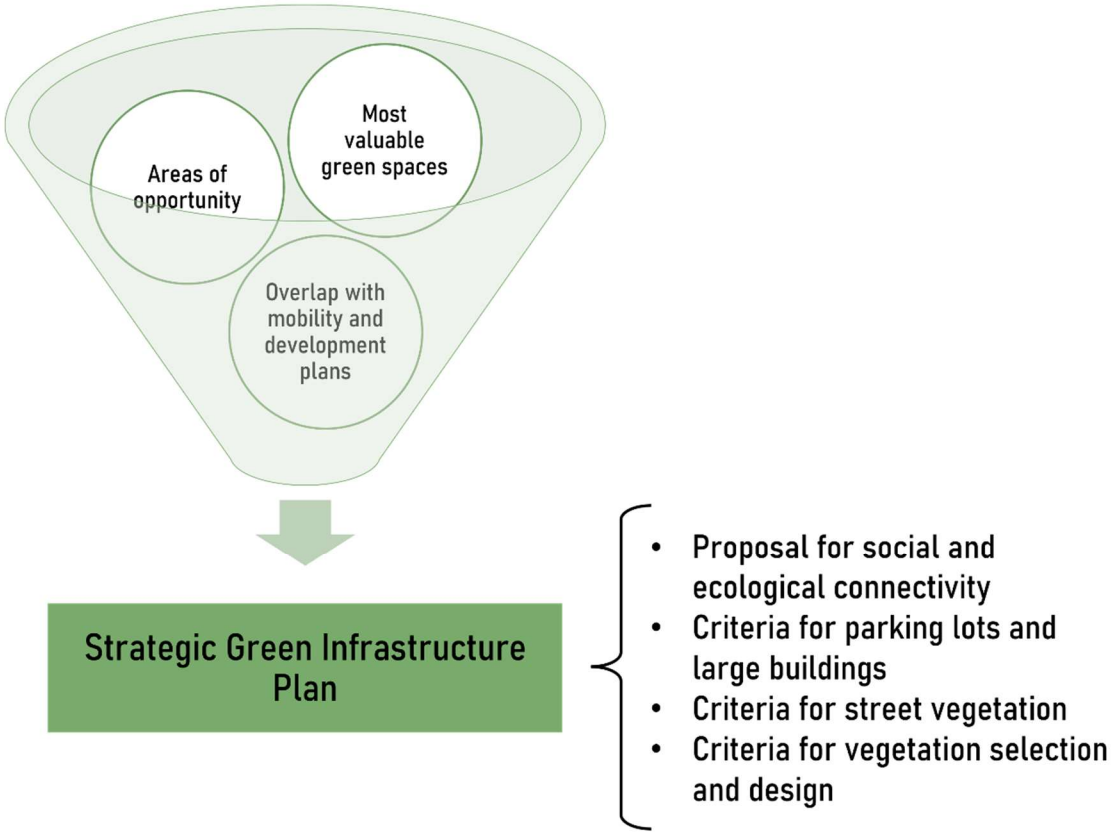


Figure 20. Diagram of the process that led to the proposal.

5.1 Principles

After an extensive review of the needs of Culiacán through documentation, GIS information and the interview, and comparing it with the knowledge acquired in the literature review, it was concluded that a Green Infrastructure plan should follow five design principles: social and ecological connectivity, social integration, protection of biodiversity, urban resilience to climate change, and cultural and ecological identity (see Figure 21). All the strategies proposed afterwards in this paper were based on these five principles.

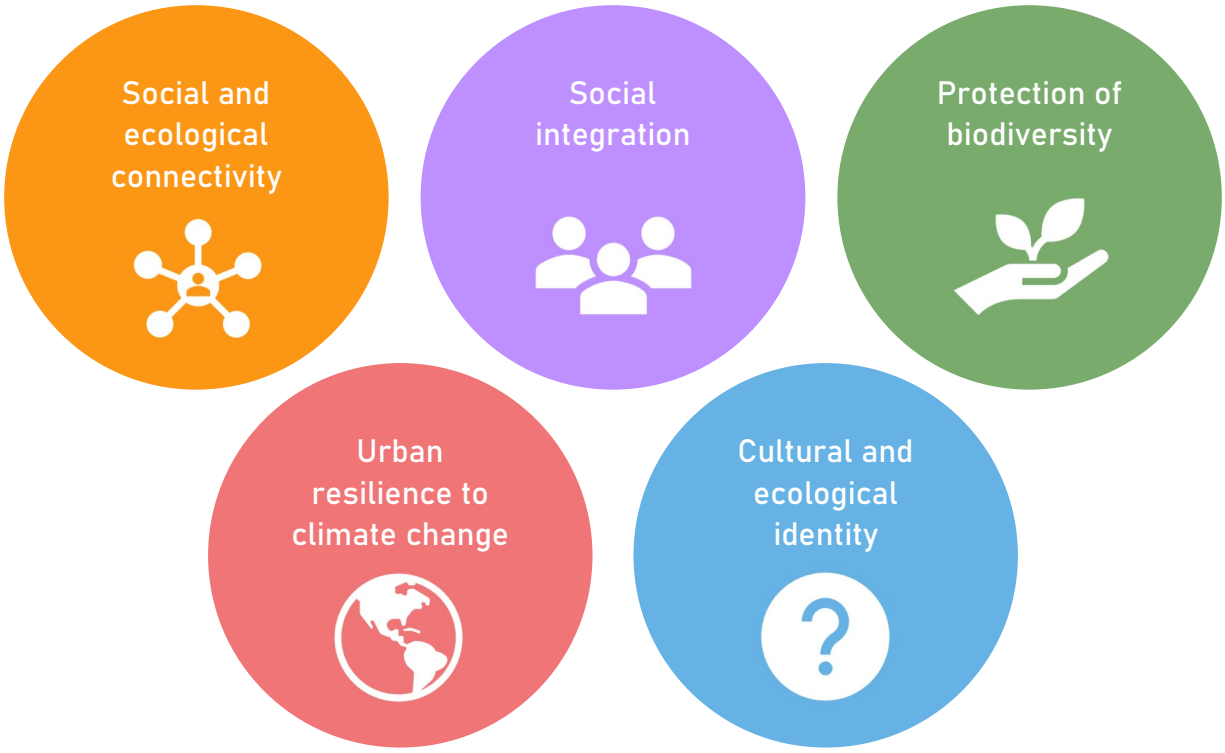


Figure 21. Principles for the Green Infrastructure Plan.

Social and ecological connectivity

This aspect relates to the importance of seeing green spaces as an integrated network and not just as islands. This is essential both for landscape ecology and for social cohesion. A green network brings people closer to nature and its associated benefits, it gives a safer access to public spaces, and it contributes to a diversification in modes of urban transportation. It also makes it easier for wildlife to find food, habitat and mating opportunities, and therefore contribute to their survival.

Why?

- Greenways/green belts, etc. and historic examples of success
- Bring closer people and nature
- Sustainable mobility objectives: diversify modes of transportation to ensure people from all backgrounds can move freely in the city

How?

- Green corridors for wildlife
- Street vegetation, linear parks
- Connect important cultural sites
- Some corridors are only for species, and some prioritize people
- Integrate street vegetation with sustainable mobility plans to make them more effective

Social integration

The spatial analysis confirmed that the areas in Culiacán with lowest socioeconomical status tend to have lower quality of Urban Green Spaces (UGS).

Why?

- Social justice: equal access to the environment and its associated health benefits

- Refer to the findings in the spatial analysis
- Evidence that UGS improve social cohesion
- There is disparity in who has access to UGS today, confirming the literature

How?

- Create new UGS in areas of low accessibility
- Improve existing UGS of low quality
- Promote community gardens, urban farming and participation in general
- Improve maintenance and attractiveness in public spaces to increase perceived safety
- Improve the quality of outdoor conditions in housing areas.
- Creation of standards for new developments.
- Opportunities for new UGS in residual areas

Protection of biodiversity

Why?

- Ecosystem services species provide
- Deforestation and urban expansion have resulted in loss of biodiversity in Culiacan
- There is a lot of ignorance and misinformation in the population

How?

- Protection of natural areas (hills and river)
- Protect remaining buffer zones along the river
- Promote the use of native species in public and private spaces
- Include protection criteria in zoning policies
- Support private efforts like Paseos Verdes and Parques Alegres
- Increase the proportion of green areas relative to built areas to ensure ES provision
- Create and protect natural parks so people can appreciate its importance
- Landscape ecology: corridors and patches, steppingstones

Urban resilience and climate change

Why?

- Natural disasters in the past have proven to be costly
- Climate change will increase the frequency of natural disasters and overall heat
- Climate change and disturbance to the environment will increase pandemics
- Little vegetation cover in the city has made us more vulnerable to flooding and heat

How?

- Flood mitigation: Sustainable Urban Drainage Systems (SUDS)
- Increase vegetation to mitigate UHI effect, to improve air quality, and to store CO2.
- Integration of strategies for future development through zoning policies (example design criteria for areas near water bodies, for local water management, BGF, for areas at risk of landslides)
- Promote sustainable mobility using vegetation to reduce CO2 emissions and air pollutants from vehicles

Cultural and ecological identity

Why?

- There is little connection between the regional landscape and the urban conditions (examples of rural people noticing lack of regional species)
- Importance of pollinators for food production and conservation of vegetation

- A clear identity improves the attractiveness of the city and its potential for ecotourism

How?

- Target species of cultural identity and improve their habitat conditions (iguana, bees, hummingbirds)
- Promote the use of native plant species for landscaping
- Create natural parks that bring people closer to the local landscape

5.2 Strategies

General strategies	Connectivity	Integration	Biodiversity	Resilience	Identity
Increase street vegetation			X	X	X
Create green corridors in housing areas	X	X	X		
Use native species in public spaces			X	X	X
Prioritize species of cultural identity		X	X		X
Promote urban farming		X		X	X
Improve quality of existing UGS		X	X		X
Integrate green network with sustainable mobility plans	X	X		X	
Create new UGS in residual areas like vacant lots and streams	X	X	X	X	X
Restore previously degraded land with the use of vegetation		X	X	X	X
Add green infrastructure to hillsides to prevent landslides		X		X	
Implement SUDS through street vegetation				X	
Promote the use of SUDS and native vegetation in land use policies			X	X	
Develop a tool similar to Blue-Green Factor adapted to the context of Sinaloa as a way to measure SUDS on a site level				X	
Connect sites of cultural importance and historical heritage	X				X
Create and protect natural parks			X	X	X
Connect natural parks to the city	X		X		X
Support independent community involvement		X	X		X

programs with finances, diffusion and coordination					
Protect remaining buffer zones along the river	X		X	X	
Protect and restore stream systems and canals	X		X	X	
Prioritize pollinator species in plant selection			X	X	
Make an integral management and restoration plan for the river			X	X	X
Increase vegetation cover in areas that generate more heat				X	
Introduce green infrastructure policies for areas with special environmental considerations			X	X	
Create landscape design standards for new housing areas promoting the use of blue and green infrastructure		X		X	X
Encourage participation forums to increase the understanding between the population and stakeholders		X			X
Add signs and interactive information about ecology on UGS and natural areas			X		X
Implement physical infrastructure that allows for safe and responsible ecotourism	X	X			X

5.3 Green Infrastructure Strategic Plan

PROPOSAL:
Green Infrastructure Plan

City limits

HUBS
- UGS of high ecological value
- Most valuable spaces
- Proposed Natural Protected Areas (IMPLAN, 2020)
- Urban centers (IMPLAN, 2021)

SITES
- Urban equipment: education, health, social assistance, public services, and similar
- UGS of high social value
- Cultural and historical sites

GREEN NETWORK
- Blue-Green Corridors
- Green Streets
- Pedestrian Pathways
- Linear Parks
- Primary network

Map 21. Green Infrastructure Plan.

The Green Network includes streets, linear parks, streams, canals, and some projections for undeveloped areas. Not all the links are of equal importance and characteristics. The thicker lines represent the most important connections. These main connections form an inner and an outer ring, and also covers the most important axes within the city and towards suburban communities.

The *Blue-Green Corridors* are those of utmost ecological importance. They are the widest links, and they include both vegetation and water elements. The river, streams and canals are included in this definition, as well as other areas in near contact with water (see Photo 41). The proposal for these links is to preserve the existing qualities and enhance them, for example by adding recreational amenities and lighting along streams and canals to bring out social benefits. The idea is also to integrate them as infrastructure and connect them to the rest of the green areas of the city.

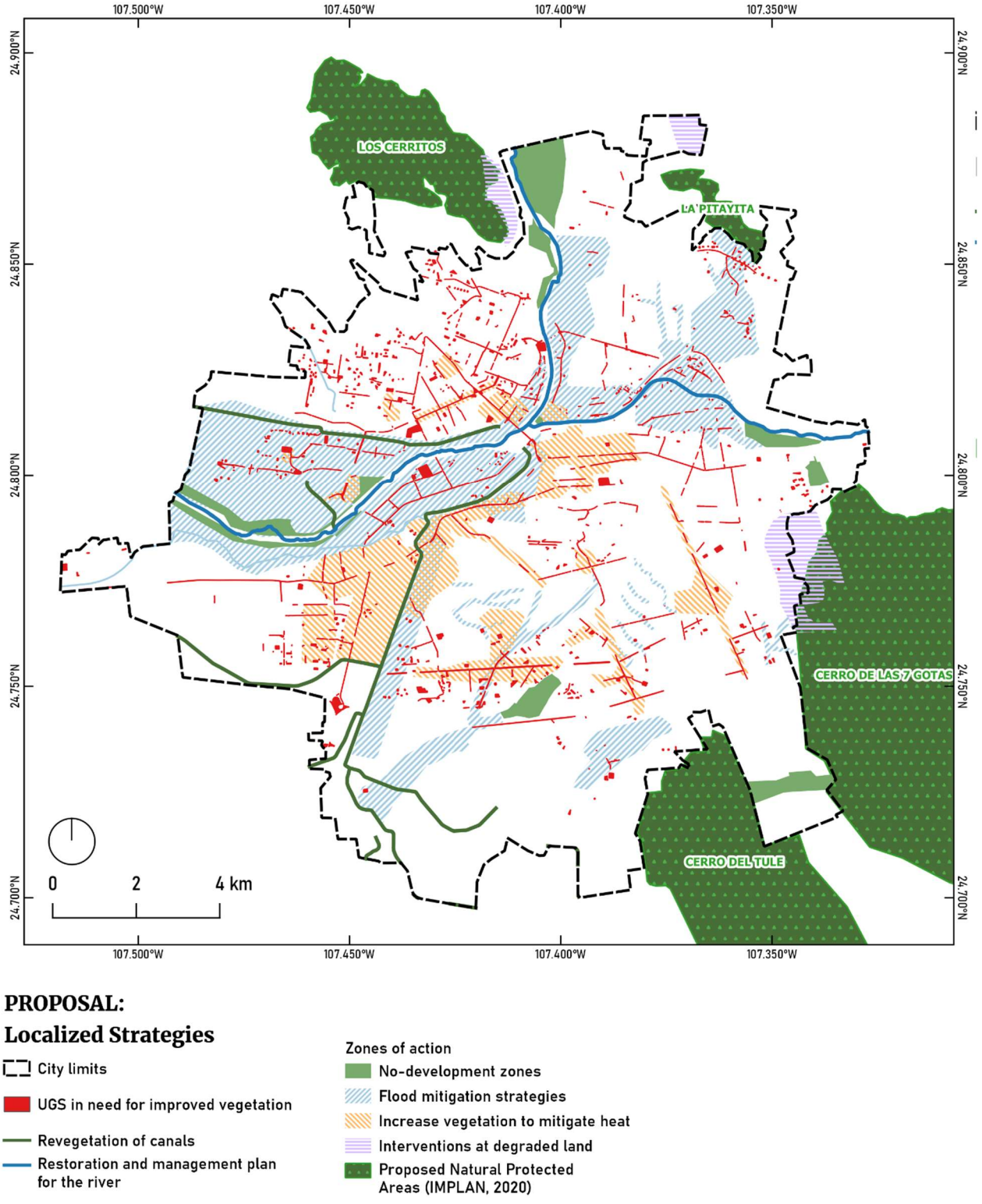
Many of the links described as *Green Streets* are already vegetated streets that are meant to be included and improved. Others do not have any significant vegetation yet, but because of their importance and their dimensions have potential to become Green Streets. Improvement on these streets would mean an increase in vegetation cover and its associated benefits, and design of street vegetation in a way that favors soft mobility. Other links include streets that are projected in planning documents for future expansion, and in this proposal are meant to be designed following principles of sustainable mobility.

Lines described as *Pedestrian Pathways* include streets with separated pedestrian trails or the potential to have it, pedestrian streets, wide medians and sidewalks, some park edges and a few residual areas. It also includes the railway tracks that are planned to be changed to another location. In areas that lack space for new parks, small streets of low demand can be turned into semi-pedestrian streets, with only local car transit, equipped with recreational amenities, street trees and ornamental vegetation.

The *Linear Parks* include those that already exist and those that have potential of being defined as such, for example along very wide streets, very wide medians, and some residual spaces in between buildings and streets. These not only provide pedestrian and cycling infrastructure, but also recreational amenities and a more versatile landscape design than pedestrian pathways.

This network connects the most important areas of the city, those defined as *Hubs*. These include the Urban Green Spaces that resulted from the spatial analyses as most valuable for both social and ecological reasons. Other hubs include the surrounding areas that the planning institute has proposed to become natural protected areas, and those of social and commercial importance defined as Urban Centers. In addition, the Green Network is designed in such a way that it is no longer than 300 m away from housing areas and other important *Sites* such as schools, hospitals, and cultural heritage locations.

5.4 Suggestions for future interventions



Map 22. Suggestions for Green Infrastructure Strategies.

Map 22 shows an overview of different suggestions that respond to the landscape needs of areas in the city. It shows the Urban Green Spaces that currently have a very low vegetation cover (NDVI values less than 0.30), and thus have potential for increasing the quality of vegetation. The plant choice for the urban greening would depend on the conditions of each site and the desired purposes. Table 25 and Table 26 shows an overview of species apt for the urban environment,

those that can be planted near water, and those that are beneficial for pollinators. Other uses and characteristics are listed in these tables to aid in the decision-making for revegetation of the city. Safety is an issue of great concern in Culiacán (CESP, 2020; Ibarra & Ceballos, 2018). Because of this, it is suggested that the vegetation used does not hinder views or look unattended (Ceccato et al., 2020; Evensen et al., 2021; Montes-Pulido & Forero, 2021). In response to this, a series of design principles based on Robinson and Wu (2017) are suggested in Figure 22.

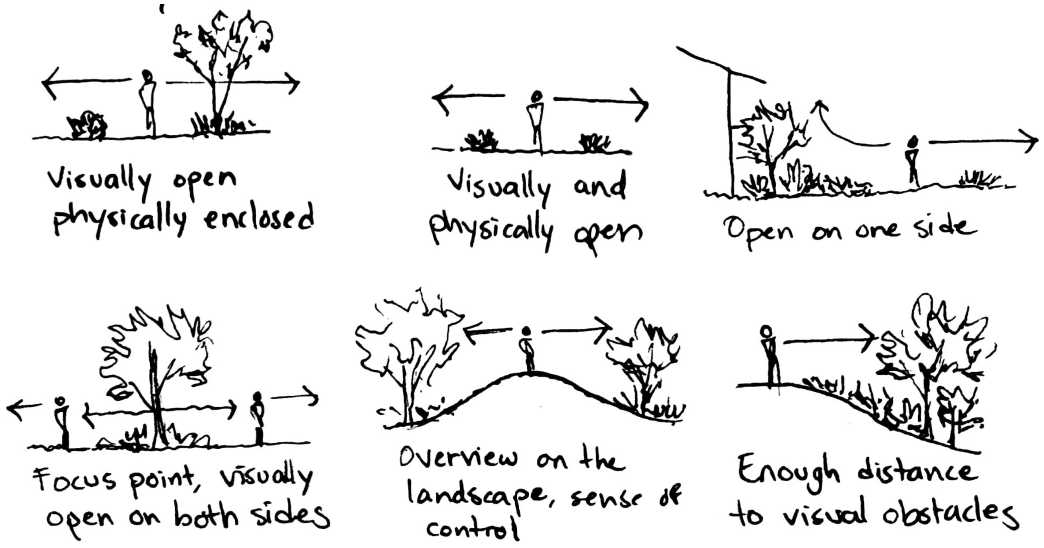


Figure 22. Design principles with vegetation for a sense of security. Made by the author based on Robinson & Wu, 2017.

No development zones are proposed to halt the construction in areas prone to flooding or with high ecological value. For example, it is proposed a green corridor in the south to preserve connectivity between the hills Cerro del Tule and Cerro de las 7 Gotas. Two residual areas at the eastern side of the city are proposed to remain undeveloped so that they can fulfill the function of steppingstones between 7 Gotas and the river, and they would be connected through the Green Network presented in Map 21. Areas near the river are also preserved. Some of these no-development zones have the potential to become ecological parks, thus fulfilling multiple benefits: protecting the population from flood risk, protecting biodiversity, and increasing the provision of Urban Green Spaces.

The areas proposed to increase vegetation to mitigate heat are meant to show where the hottest zones are. Since these correspond to high-traffic streets, intense-use buildings, parking lots, and industrial areas, it is proposed to plant street trees, to implement requirements for vegetation in extensive private areas, and to promote the use of green roofs and walls. Vegetation in these areas would focus on shading, isolation, and evapotranspiration.

Areas marked for flood mitigation are residential zones that are most vulnerable to flooding. It is then proposed to make further studies in these areas to create a plan for flood mitigation, including the implementation of Water Sensitive Urban Design (WSUD), the protection, maintenance and regeneration of streams and canals, and the application of policies that require the use of Blue-Green Infrastructure in private lots. Vegetation in these areas would prioritize water infiltration and drought resilience. Specific Green Infrastructure elements for water management include the use of swales, rain gardens, and permeable surfaces (see Figure 23). Local species appropriate for these uses are listed in Table 25 and Table 26, referring to those marked as apt for water sensitive urban design.

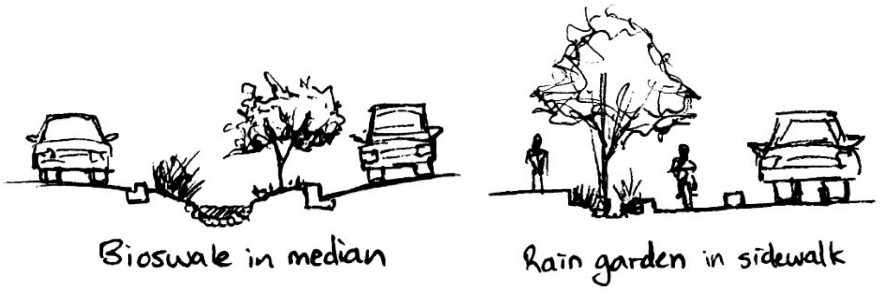


Figure 23. Examples of water sensitive urban design applied to streets. Made by the author based on Shipek et.al, 2016.

Areas designated for interventions of degraded land include the damaged hillsides of El Hipico and 7 Gotas hills, and the landfill that is meant to be out of service in the near future. Interventions in these areas include reforestation, relocation and regularization of irregular settlements, and soil consolidation by the hillsides with the use of vegetation. These areas are steep and may have unsable soil conditions. Thus, a species selection for soil consolidation would be beneficial. Some suggested species for this are listed in the tables below. Examples include *Bursera simaruba*, *Ficus petiolaris* and *Sphagneticola trilobata*. To avoid landslides, (IMPLAN Hermosillo, 2017) recommends the implementation of swales on-contour (see Figure 24) that would provide a retentive gradient for runoff.

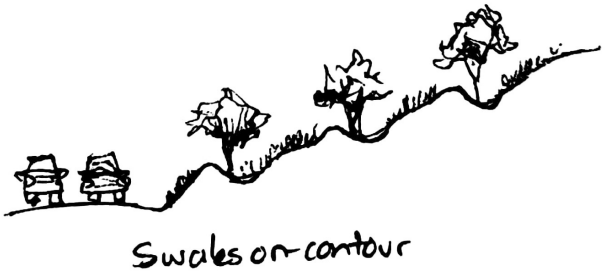


Figure 24. Conceptual drawing of swales on-contour. Made by the author based on Shipek et.al., 2016.

The revegetation of canals would include the use of trees that do not compromise the integrity of the concrete cover. Suggestions of species are listed in Table 25 and Table 26. These trees would bring back some of the ecosystem services lost when these streams were channelized. In addition, this proposal suggests not only the revegetation of canals, but a full urban regeneration that would benefit the population living in the surrounding areas. As the results of this study revealed, the river has suffered a loss of its original capacity to provide ecosystems ervices due to deforestation, pollution, and modifications on its original course (Díaz, 2021; Ibarra & Ceballos, 2018; IMPLAN, 2020). It is thus necessary to plan for the restoration and revegetation of the riparian forest in a way that it can also be compatible with recreational uses (see Figure 25).

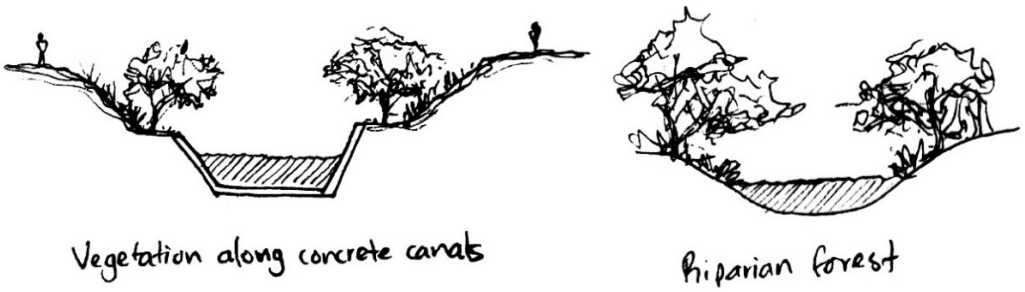
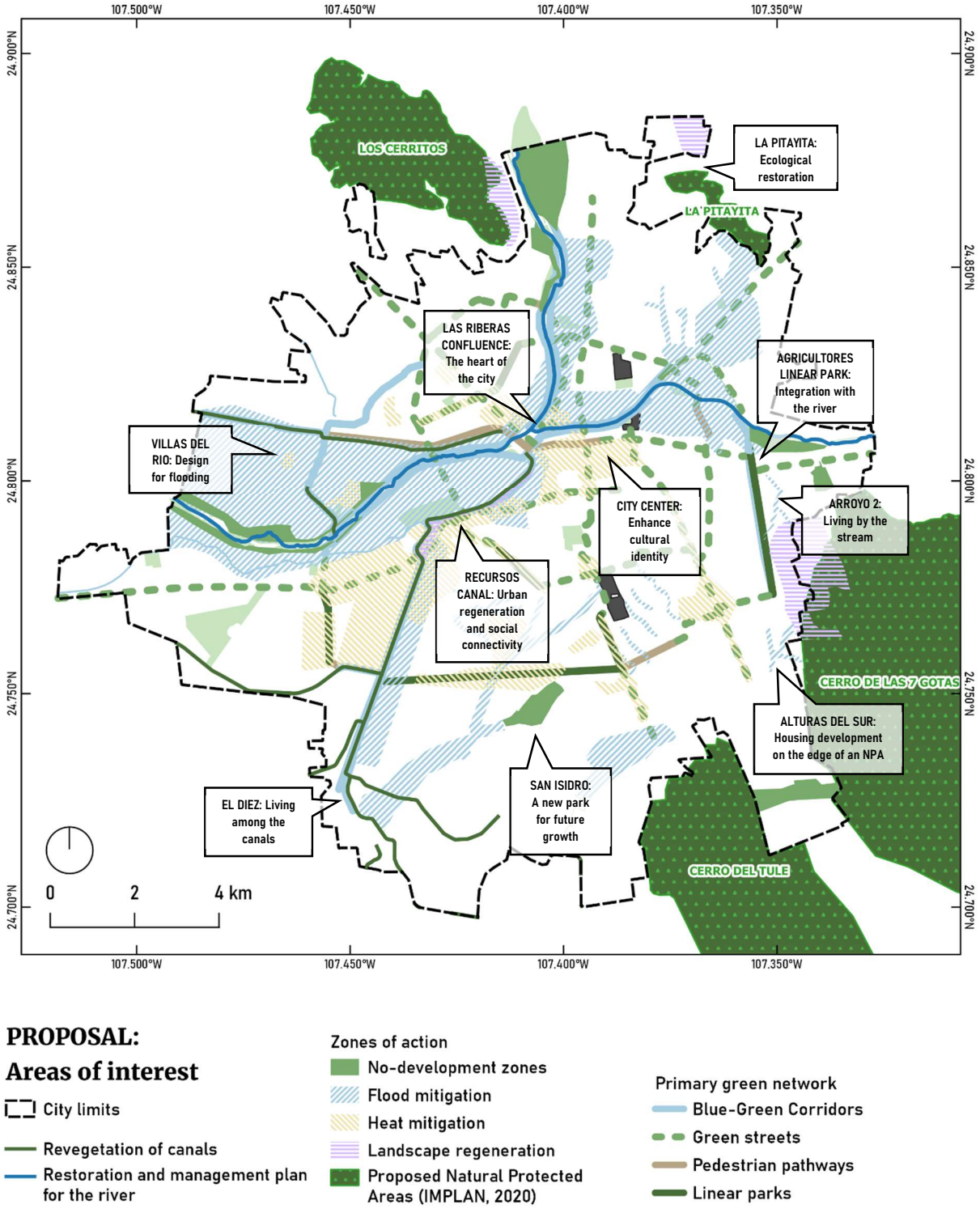


Figure 25. Diagrams for reforestation along canals and river. Made by the author based on conclusions from Diaz, 2021.

5.5 Areas of interest



Map 23. Areas of interest for future research and design projects.

Throughtout the research findings, many areas of opporunities have been found. Map 23 presents some of the areas with most potential for future research and development of landscape design interventions.

Villas del Río

This is a neighborhood that has suffered from flooding problems since its foundation. This area was selected because it has great potential for exploring strategies of resilient urban design and it would be worthy of future research. The Chinese concept of Sponge Cities is a great example of how we can deal with excess of water in urban settings (MHRUD, 2014). By preserving the floodplains near the river and restoring the wetlands previously marked by INEGI, 2014, the river's capacity to cope with flooding can be enhanced. Moreover, urban design policies that favor the use of Sustainable Urban Drainage Systems (SUDS) could contribute to mitigate flooding in streets and houses in this sector (Stankovic & Maksimovic, 2019). An integral plan for surface water runoff that integrates with the canals and river could prevent further human and economic affectations in this area (Watson & Adams, 2011). In addition, the canals and river that frame this sector could become an element of social infrastructure by creating promenades, adding recreational equipment, and planting urban trees.

Las Riberas confluence

Around this area we can find elements that give a sense of pride and identity to the city. The presence of the river is the main element, but also the park elements around it, including all the playgrounds, agoras, bridges, and monuments. The Black Bridge is a symbol for Culiacán, and the surrounding restaurants and shopping malls are among the most visited in the city. A flagpole with dancing fountains marks the apex of the confluence. But this area has room for improvement. There is a vacant lot dividing the fountain area and the rest of the attractions. The extensive parking lots and wide streets contribute to the Urban Heat Island effect while also prioritizing the presence of cars over pedestrians in the area. It is uncomfortable to walk through these extensive concrete surfaces and unsafe for pedestrians because of the traffic. Therefore, a landscape design project that integrates the gray and the green could greatly add to the cultural identity of the city, promote social integration, and contribute to a better the provision of regulation and maintenance ecosystem services of the river.

Photo 39. Las Riberas confluence. "Mexican Flag Day" by Miguel Angel Victoria is licensed under CC BY 4.0. 2017.

La Pitayita

The landfill located north of the polygon of the city is planned to be taken out of service in the upcoming years because it has exceeded its capacity to manage solid waste (IMPLAN, 2021b). Because of this, the Planning Institute has proposed to repurpose this and the surrounding areas into an ecological park. This study recognizes the importance of the last remaining patch of secondary shrub of the dry forest (see Figure 11), and the fact that the conservation boundaries have been reduced between 2010 and 2021 (see Figure 14) is alarming. The fast expansion of the sector known as Los Angeles and irregular settlements threaten the integrity of the forest. Therefore, a conservation and restoration project would be needed in this area. Moreover, if an ecological park is to be established here, there is a need for a landscape ecological assessment to make sure that the park follows landscape ecological principles.

Agricultores Linear Park

This linear park is partly developed already (see Photo 16). But the northern section lacks equipment and amenities, and some parts of the southern section are deteriorated and disregarded. Moreover, there is opportunity to make use of this park not only for recreation, but also for ecological connectivity, as its location brings potential to link to the river in the north end and the 7 Gotas Hill in the south end. These edges are already partly urbanized, so a more thorough evaluation of the possibilities is needed.

Recursos Canal

This canal used to be surrounded by riparian vegetation (Díaz, 2021). Species like iguanas, turtles, fish and even alligators used to find habitat in this stream before it was covered with concrete (ibid.). But now it is a neglected area surrounded by railway tracks, low-income settlements, and the walls of wealthy neighborhoods and the Country Club. The railway tracks are planned to change location, meaning that these will no longer have their initial purpose. There is a remaining question of what this area may become in the future. Its strategic location near the city center, government buildings, housing areas, commercial area, and the river mean that there is potential for this zone to become a hub for social integration and mobility. Moreover, the canal and the railway tracks bring out possibilities for soft mobility, connecting to the sectors in the south and north of the river. There are possibilities for a promenade, for cycle paths, for revegetation of the canal, and for recreational equipment. This canal could also be the answer to provide for more UGS to the sectors in the south that are currently lacking accessibility (see Map 16 and Figure 19). For all these reasons, there is a need for an integral urban regeneration project in this area.

Photo 40. Recursos Canal, an opportunity for urban and ecological regeneration in the middle of the city. Photo: Michelle Granados Johansen, 2021.

City Center

The city center is the historical and commercial hub of the city. Unfortunately, in the recent years there has been a reduction in the people living in the city center (IMPLAN, 2021b). Residents complain the excess of traffic, noise, and pollution. There is little vegetation cover, and the old trees important for pollinators are threatened by residents and commerciants (Dehesa, 2021). Private initiatives are working on increasing vegetation (ibid.), redesigning public space for pedestrians (Piña, 2021a), and planning for more efficient public transportation (Vizcarra, 2021). The perception of the author is that these efforts need a fellow vision, an integral plan for the city center. The historical and cultural sites present in the area provide positive qualities to make this an attractive area to visit. Increasing the urban image could also benefit the economy of the sector by attracting pedestrians to the commercial areas, and because vegetation can increase the property values. It is then suggested an urban design project that reinforces soft mobility, urban image, and cultural identity.

Arroyo 2

This stream is located in the sector of El Barrio, which has one of the lowest average income levels. It is one of the widest remaining streams in the city and it is located in the middle of housing areas. As Dr. Diaz mentioned, protecting the streams is an important tool for flood mitigation. But protection can not come at the expense of the people living near the streams. This is an area of opportunity to improve the outdoor conditions of a low-income neighborhood while also ensuring provision of ecosystem services such as water management and habitat provision. Its aesthetic qualities could provide the near inhabitants with cultural services such as spiritual, recreational, and inspirational needs. But this area lacks of enough equipment such as lighting, sitting areas and trash cans, and the lack of maintenance is evident in Photo 41. A landscaping project supported by proper follow-up, maintenance, and involvement with the community could bring benefits to the people in the vicinity. This is an opportunity to improve social cohesion, integration, connectivity, safety, and resilience.

Photo 41. Arroyo 2, a stream in a low-income neighborhood. Opportunities for social and ecological connectivity. Photo: Michelle Granados Johansen, 2021.

El Diez

El Diez is a suburban community surrounded by agricultural fields, irrigation canals, and a highway. The results presented in Figure 19 and Table 16 show that this is the sector with least area used for Urban Green Spaces. It is also one of the areas with lowest income level and UGS per capita. Its location between irrigation canals brings unique opportunities for inclusion and connectivity because these canals can become more than agricultural infrastructure, they can also become elements of social infrastructure. A project that includes vegetation and amenities could provide for recreational space that is currently lacking in the area.

San Isidro

As McHarg (1969) notes, the creation of new habitats and the restoration of degraded land are far more expensive than protecting undeveloped land. The areas around San Isidro are in recent expansion. There is still a lot of undeveloped land south from Blvd. Las Torres, and a large residual space in between some gated communities. These residual lots are marked in the land use plan as second and third priority for development (see Map 8), and following McHarg's advice, it is better to plan ahead of development. The proposed no-development polygon in Map 23 covers an area prone to flooding because of its multiple streams (see Map 7). The results in Map 14 also revealed that there is ecological potential for this area, and since there is a lack of UGS of surface area greater than 5000 m^2, this was considered as as potential area for a new ecological park of approximately 73 hectares. According to threshold Drinnan (2005), this could be enough to support habitat for urban avoider species. Currently, only the airport field and private golf courses have similar dimensions. This means that a park of these dimensions would be the first of its kind in the city.

Alturas del Sur

This is a new neighborhood in the southeast perifery of the city. Satellite images show a repetitive, reticular pattern of vertical housing with little urban vegetation. If the main purpose of vertical housing is to make a more efficient use of an urban area and leave more space for Urban Green Spaces (IMPLAN, 2021b), that brings up the question, is a traditional car-centered model the best way to design a high-rise neighborhood? Moreover, its proximity to what is proposed to become a Natural Protected Area bring concern for the integrity of the forest (Díaz, 2021). Therefore, the proposal in this master thesis suggest to reconsider the urban deisng pattern that is currently underway in this area, so that public space can favor pedestrians and a better provision of UGS, and so land use policies can consider the use of native tropical dry forest species as a priority.

5.6 Vegetation use

The Green Infrastructure proposal includes suggestions for plant selection according to their specific purposes. These species come from the literature review and information gathered during the in-depth interview, as well as complementary sources and further consultancy with Dr. Diaz.

Table 25. Suggested use of urban trees. Made by the author based on information from CONABIO, 2021; Fern, 2021b; Guaiacum, 2021; IMPLAN et al., 2018; Pima County, 2015; Rzedowski, 2006; USDA-NRCS, 2012; .

CHARACTERISTICS									QUALITIES				USE						
Type	Common name(s)	Latin name	Origin	Conservation status*	Maintenance	Evergreen	Deciduous	Max. Height (m)	Cultural identity	Ecological identity	Attractive flowers	Edible	Water sensitive urban design	Rivers and streams	Pollinator friendly	Concrete canals	Medians and sidewalks	Ecological restoration	Other uses
Tree	Palo Blanco	*Acacia willardiana*	Native		Low	X		12 to 24	X		Cream		X		X				Foraging
Tree	Papelillo	*Bursera grandifolia*	Endemic		Low		X	6 to 15	X										Grows in slopes.
Tree	Palo mulato, Turpentine tree	*Bursera simaruba*	Native		Low		X	35	X	X			X					X	Medicinal. Erosion prevention, soil restoration, sand stabilization, barrier against forest fires, shade. Fabrication of tools.
Tree	Ébano prieto	*Caesalpinia sclerocarpa*	Native		Medium	X		15 to 20			Yellow				X		X		Medicinal. Foraging.
Tree	Cedro	*Cedrela odorata*	Native	(CR), (Pr)	Low			35	X										Excelent timber.
Tree	Ceiba, Pochote	*Ceiba acuminata*	Endemic		Low			8 to 20	X	X	Cream	X			X				Generous shade in summer.
Tree	Rosa amarilla	*Cochlosphermum vitifolium*	Native		Medium		X	12	X		Yellow				X		X	X	Reforestation. Very beautiful flowers.
Tree	Siricote	*Cordia dodecandra*	Native		Low		X	30			Orange	X			X		X		Furniture products.
Tree	Inmortal	*Cordia eleagnoides*	Native		Medium		X	6 to 15	X		White						X		Furniture products. Related to Día de Muertos.
Tree	Flamboyan, Tabachín	*Delonix regia*	Exotic		Medium		X	12	X		Red		X						Foraging. Shade.
Tree	Chinito	*Ebenopsis caesalpinioides*	Native		Medium	X		15	X	X	Cream				X		X		Foraging. Edible seeds.
Tree	Pingüica	*Ehretia tinifolia L.*	Native		Low			15 to 25	X	X	White				X				Medicinal. Shade. Honey flowers.
Tree	Huanacaxtle	*Enterolobium cyclocarpum*	Exotic		Medium		X	45	X		White	X		X	X				Medicinal. Forage. Fuel. Latex.
Tree	Capule, Amate negro	*Ficus cotinifolia*	Native		Low	X		15 to 20	X	X				X	X			X	Medicinal. Woodland restoration.
Tree	Higuera blanca	*Ficus insipida*	Native		Medium	X		8 to 40		X				X	X				Medicinal. To produce paper.
Tree	Higuerón	*Ficus maxima*	Native		Low	X		5 to 30	X	X				X	X				Medicinal.
Tree	Tezcalama, Salate	*Ficus petiolaris*	Native		Medium			8 to 10		X					X				Medicinal. Grows in steep slopes.
Tree	Guásima	*Guazuma ulmifolia*	Native		Medium		X	20	X	X		X		X	X	X	X	X	Reforestation.
Tree	Amapa amarilla	*Handroanthus chrysanthus*	Native		Low		X	5	X	X	Yellow						X		Landscape
Tree	Amapa rosa	*Handroanthus impetiginosus*	Native	(A)	Low		X	30	X	X	Pink						X		Landscape
Tree	Capiro	*Hesperalbizia occidentalis*	Native		Low		X	15 to 20		X	White				X				Timber. Foraging
Tree	Cazahuate blanco	*Ipomoea arborescens*	Native		Low			10	X	X	White				X				Landscape. Honey flowers.
Tree	Tepeguaje	*Lysiloma acapulcense*	Native		Medium	X		20		X	White				X				Medicinal. Construction materials.
Tree	Mauto, Palo blanco	*Lysiloma divaricatum*	Native		Medium			3 to 15	X	X	White				X				Medicinal. Foraging. Fences.

Tree	Mora	*Macluria tinctoria*	Native		Medium			30	X	X									Production of yellow ink and furniture. Edible fruits.
Tree	Mango	*Mangifera indica*	Exotic		High			20 to 30	X			X			X				Landscape. Edible fruits.
Tree	Retama	*Parkinsonia aculeata*	Native		Low		X	10			Yellow				X		X		Foraging. Landscape.
Tree	Guamuchil	*Pithecellobium dulce*	Native		Medium	X		20	X	X	Cream	X		X	X	X			Medicinal. Foraging. To produce essential oils, fuel, and cosmetics.
Tree	Flor de Mayo, Cacalosuchil	*Plumeria rubra*	Native		Low		X	5 to 8	X		Pink, white				X		X		Landscape.
Tree	Álamo	*Populus mexicana* subsp. *dimorpha*	Native		Medium	X		12 to 35	X	X	White			X				X	Medicinal. River reforestation. Generous shade. Religious uses.
Tree	Clavelina	*Pseudobombax ellipticum*	Native		Low		X	15 to 30			Pink				X				Fabrication of soap.
Tree	Arrayán	*Psidium sartorianum*	Native		Medium	X		30	X	X	White	X			X				Medicinal. Edible fruits.
Tree	Trueno, Primavera	*Roseodendron donnell-smithii*	Exotic		Medium		X	30		X	Yellow				X				Landscape
Tree	Sauce	*Salix nigra*	Native		Low		X	10 to 30	X	X	White			X					Medicinal. River reforestation. Generous shade.
Tree	Jaboncillo, Bolichi	*Sapindus saponaria*	Native		Medium	X		16											To fabricate biodegradable soap, tools and construction materials. Insecticides.
Tree	Ciruelo, Jobo	*Spondias mombin*	Native		High			25	X		White	X			X				Edible fruits.Generous shade in summer and autumn.
Tree	Venadillo, caobilla	*Swietenia humillis*	Native	(EN)	Medium		X	15 to 20	X		White						X	X	Medicinal, generous shade. Erosion control, enhance soil fertility, agroforestry.
Tree	Sabino, Ahuehuete, Árbol del Tule	*Taxodium mexicanum*	Native		Medium	X		40	X					X					National tree. Religious uses. Medicinal. Riparian landscape.
Tree	Gloria, Tronadora	*Tecoma stans*	Native		Medium	X		20			Yellow				X		X	X	Reforestation. Medicinal. Forestry.
Tree	Perico, Periquillo	*Thouinidium decandrum*	Native		Low	X		25		X	Cream			X			X		Generous shade.
Tree	Uvalamo, Coyotomate	*Vitex mollis*	Native		High		X	15		X	Violet				X		X		Medicinal. Edible fruits.

Table 26. Suggested use of shrubs, herbs, and others. Made by the author based on information from CONABIO, 2021; Fern, 2021b; Guaiacum, 2021; IMPLAN et al., 2018; Pima County, 2015; Rzedowski, 2006; USDA-NRCS, 2012.

CHARACTERISTICS									QUALITIES				USE						
Type	Common name(s)	Latin name	Origin	Conservation status*	Maintenance	Evergreen	Deciduous	Max. Height (m)	Cultural identity	Ecological identity	Attractive flowers	Edible	Water sensitive urban design	Rivers and streams	Pollinator friendly	Concrete canals	Medians and sidewalks	Ecological restoration	Other uses
Succulent	Maguey Rabo de Leon	*Agave angustiarum*	Endemic		Low	X		0.6 (3)				X	X		X				Agroforestry, as a live fence. Production of fibers.
Succulent	Bacanora, Espadín	*Agave angustifolia*	Native		Low	X		2 (5)	X		Yellow	X	X		X				Mezcal, fibers, foraging, construction materials. Medicinal. Living fence.
Succulent	Maguey	*Agave pedunculifera*	Endemic		Low	X							X		X				
Succulent	Agave	*Agave spp*	Native		Low	X							X		X				
Succulent	Maguey espadín	*Agave vivipara*	Native	(VU)	Medium	X		1 (5)			Yellow	X	X		X				

Shrub	Batamote	*Baccharis salicifolia*	Native		Low			0.8 to 2	X		White			X					Medicinal.
Tree/shrub	Copal, torote	*Bursera fagaroides*	Native		Low		X	2 to 8	X								X		Citrus odor. Used in perfumes, incense and oils.
Tree/shrub	Huizache	*Caesalpinia cacalaco*	Native		Low	X		4	X		Yellow			X	X	X			
Tree/shrub	Tabachín de monte	*Caesalpinia pulcherrima*	Native		Low			3	X		Orange				X		X		Medicinal.
Tree/shrub	Cacachila, jalcate	*Citharexylum affine*	Native		High			10			Violet	X		X	X		X		Medicinal.
Tree/shrub	Limón	*Citrus limon*	Exotic		Medium	X		3 to 6	X		White	X			X				Medicinal.
Tree/shrub	Uva de mar, Uvero	*Coccoloba uvifera*	Native		Low	X		2 to 8				X					X	X	Stabilize sand dunes, prevent erosion
Tree/shrub	Anacahuita, Siricote de playa	*Cordia sebestena*	Native		Medium			8			Orange						X		Medicinal.
Tree/shrub	Manzana de playa	*Crateva tapia*	Native		Medium		X	2 to 25			Violet	X			X		X	X	Reforestation
Grass	Pasto limón, Lemongrass	*Cymbopogon citratus*	Exotic			X		0.8	X			X	X						Medicinal.
Grass	Zacate gangrena	*Cynodon dactylon*	Exotic		Medium			0.3	X									X	Erosion control, spreads easily. Undesired near agricultural fields.
Tree/shrub	Cacahuananche	*Gliricidia sepium*	Native		High		X	15			Pink				X		X		Medicinal. Sculpture material. Foraging. Fuel. Pesticide.
Tree/shrub	Guayacan	*Guaiacum coulteri*	Native	(A), (VU)	Low		X	1 to 12	X	X	Violet		X		X		X		Medicinal.
Tree/shrub	Palo de Brasil	*Haematoxylum brasiletto*	Native		Low			10	X	X	Yellow				X		X		Foraging. Fences. Charcoal.
Tree/shrub	Copalquin	*Hintonia latiflora*	Native		Medium			2 to 12	X		White				X		X		Medicinal.
Herb, twining vine	Trompillo	*Ipomoea pedicellaris*	Native		Medium						Pink				X				
Herb, twining vine	Campanilla morada, morning glory	*Ipomoea purpurea*	Native		Medium			2 to 3			Violet, blue or pink				X				
Herb, twining vine	Bandera española	*Ipomoea quamocitl*	Native		Low	X		1 to 3			Red, pink or white				X	X			Medicinal.
Tree/shrub	Bequillo	*Lonchocarpus guatemalensis*	Native		High	X		10			Violet				X				Timber.
Tree/shrub	Palo verde	*Parkinsonia praecox*	Native		Low	X		2 to 4			Yellow		X	X		X	X		Foraging
Tree/shrub	Mezquite dulce, Honey Mesquite	*Prosopis glandulosa*	Native		Low			5 to 15	X	X	Cream	X	X		X	X			Fuel
Tree/shrub	Mezquite	*Prosopis juliflora*	Native		Low			20	X		Cream	X				X	X		Foraging, environmental management.
Tree/shrub	Tornillo, Screwbean mesquite	*Prosopis pubescens*	Native		Low			8				X	X			X			Fuel.
Tree/shrub	Guayaba	*Psidium guajava*	Exotic		Medium	X		3 to 10	X		White	X				X			Medicinal
Herb	Wedelia	*Sphagneticola trilobata*	Native		High	X		0.4 to 0.6			Yellow		X					X	Dense carpet. Medicinal. Soil stabilization and remediate polluted soils.
Herb	Purple queen	*Tradescantia pallida*	Native		High			0.4			Violet		X						Foraging.
Tree/shrub	Cacaragua, Sitavaro	*Vallesia glabra*	Native		Medium			3	X	X	White	X				X	X		Medicinal, generous shade

*Conservation status:

IUCN 2021-2: *Critically Endangered* (CR), *Endangered* (EN) and *Vulnerable* (VU)

NOM-059-SEMARNAT 2010: *En peligro de extinción = Endangered* (P), *Amenazadas = Threatened* (A), *Sujetas a protección especial = Subject to special protection* (Pr)

The correct design and choice of Green Infrastructure elements would need further assessment depending on the intervened location. Multiple guides and manuals are published in this topic, explaining details on how to plan, design and build these elements. Among the literature that can be used for future reference includes:

- Implementación de infraestructura verde como estrategia para la mitigación y adaptación al cambio climático en ciudades mexicanas, hoja de ruta (Quiroz Benitez, 2018).
- Manual de lineamientos de diseño de infraestructura verde para municipios mexicanos (IMPLAN Hermosillo, 2017).
- Guía para el Manejo del Arbolado Urbano de Culiacán, Sinaloa (Guaiacum, 2021).
- Green infrastructure for desert communities (Shipek et al., 2016).
- Urban street stormwater guide (National Association of City Transportation Officials, 2017).
- Low Impact Development and Green Infrastructure Guidance (Pima County, 2015).
- Design for flooding: architecture, landscape, and urban design for resilience to flooding and climate change (Watson & Adams, 2011).
- Design Guidelines and Maintenance Manual for Green Roofs In the Semi-Arid and Arid West (Tolderlund, 2010).
- Rain Gardens. A how-to manual for homeowners (Bannerman & Considine, 2003).

Chapter 6.
Discussion of results

6.1 Importance of the river

Throughout all the analysis, the river seems to be the dominant landscape feature from every relevant topic. The river was there right from the foundation of the city, it was what made it an attractive location in the first place (Burian, 2015). Even the name of the city owes its origin to the river (ibid.). It connects the rivers Humaya and Tamazula into the Culiacán river, and it is the source of all the irrigation channels downstream. The river's shape influences the entire urban structure by defining the main roads and the urbanization patterns. It contains "the lungs of the city", by providing the most important vegetation corridors. It is also the most important park of the city (IMPLAN, 2020).

Comparing the available information of the river with the definition of Ecosystem Services, it can be concluded that the river provides a wide range of benefits. The most obvious one is the provision of water that is used by the nearby agricultural fields. Cultural services include all the qualities mentioned above, as the river provides a cultural identity to the city (see Figure 17) and a series of recreational and health benefits. In addition, the river park contains a series of sculptures, bridges, lights, fountains, and artistic interventions that make the city more attractive and provide with a cultural scene (see Photo 11 and Photo 12). The river is also the source of many regulation and maintenance services. Its role in the regional hydrological system is crucial, as it is the link between the rivers that flow from the mountains and into the ocean. Its vegetation and presence of water contribute to temperature regulation, as Map 12 demonstrates. The interview revealed that the riparian zone is habitat for species like the iguana, and it is also an important element for flood mitigation.

6.2 Social issues

Provision of Urban Green Spaces

It is of great concern that only 5% of the city's surface area is meant for recreational green spaces, and only 3 sectors have a relative surface higher than 10% (see Table 24). The Construction Regulations of the Municipality of Culiacán establishes a requirement of 20 to 30% of the total area for recreational purposes such as parks and gardens in residential developments (Gobierno del Estado de Sinaloa, 2007, articles 291 and 355). There is clearly a gap between the desired conditions and the existing provision of green spaces in the city. Moreover, participation forums have revealed that people in Culiacán have already pointed the need for more green spaces, for safe alternatives of non-motorized mobility, and for equal access to health and education in marginalized communities (IMPLAN, 2020; SEDESOL, 2012b). One of the targets of the SDG's Goal 11 is to "provide access to safe and inclusive green and public spaces" (see Table 3). Since there is an explicit commitment from the authorities of Culiacán to contribute to reaching this goal (IMPLAN, 2021b), it is necessary to increase the number and quality of green spaces that are socially valuable and that have enough vegetation cover to support the provision of ecosystem services.

Existing Urban Green Spaces are scattered around the city, without any cohesive plan or intention to relate them with each other. Most recreational green spaces have a surface area of less than 5000 m^2 (or 0.5 ha). According to many standards (see Table 4), this size is considered small for a park. Since there has been studies suggesting that size can be a significant factor in the choice of green spaces (Kaczynski et al., 2008), it can be inferred that having an availability of mostly small parks makes them less attractive and less encouraging for physical activity for adults. Providing an interconnected network

of walking trails between parks could make them more attractive and accessible, and creating new parks of greater dimensions could encourage adult people to exercise outdoors (ibid.).

Statistics suggest that respiratory diseases are the most common cause of death by sickness in Mexico (Soto-Estrada et al., 2016), and around 28% of the Mexican adults suffers from obesity (WHO, 2017). Studies suggest a link between physical activity and obesity rates (Owen et al., 2010), others suggest that an increased exposure to green areas can be linked to a decreased asthma incidence (Lovasi et al., 2008) and lower mortality due to respiratory diseases (Villeneuve et al., 2012). This implies that providing better conditions for physical exercise could mean a more effective and equitable provision of health services in the public space.

The size of green areas have also been linked to their capacity to provide suitable habitat conditions to urban wildlife (Beninde et al., 2015). It has been suggested that 4.4 would be a minimum threshold for minimizing the loss of urban-adapted species (Drinnan, 2005; Germaine et al., 1998), meaning that the ecological value of most of the UGS in Culiacán is very low. These findings point to the necessity to create new Urban Green Spaces of sufficient dimensions to support a wide range of ecosystem services and reinforces the need of making an integrated plan to connect green areas in Culiacán.

The results of the social value pointed that the two most important stadiums, Tomateros and Dorados, have a low overall score. This could be explained because the methodology used considered both the equipment and the vegetation cover. Since both of the stadiums have a great proportion of their area dedicated to parking lots, they both scored low in vegetation. In reality they are both of high social impact because of the activities that happen inside them and the quality of their installations, but the results bring to light the negative influence that these spaces have outside their bleachers.

Unequal distribution of Urban Green Spaces

The results of the sectors analysis suggest that there is some **correlation between income level and the relative amount of green**. Figure 19 and Table 24 show that the wealthiest neighborhood, La Primavera has by far the greatest relative surface used for green areas, with 33.32% of its total surface and 137 m^2 of urban green space (UGS) per capita. On the opposite spectrum, the sector of lowest income level, El Diez, has the least of green areas with only 0.20%, thus scoring low in the other factors related to green areas. This supports the results found in other Latin American cities (SEDESOL, 2012a; Vásquez et al., 2017). Nonetheless, we cannot say that the income-green areas correlation is perfect, as there are other factors intervening in the number of green areas a neighborhood can have. For example, the sector of El Barrio has a very low-income level, but it scores fifth in relative surface of green and it has high NDVI values, while Las Quintas, with a high-income level, has few green areas. These number do not tell the whole story. The green areas in Las Quintas may be fewer, but they are of higher quality than those of El Barrio. The city center (Centro) scores high in vegetation quantity and social value, but very low in vegetation quality (NDVI). This can be explained because the river park, the most important park in the city, is accounted as part of this sector. But as Map 17 shows, other than the river and the Zoo there is little vegetation cover in the city center.

The results from the accessibility analyses tell an interesting story. By comparing the analysis by sector with the accessibility map (see Map 16), we can see that areas with access to UGS of low and medium quality correspond to those in the southern part of

the city, which are of low income. The wealthiest neighborhood in the city, La Primavera, has a low score in the Urban Green Space Indicator (see Table 24), despite having the most UGS per capita. This is because the entire neighborhood is a peri urban gated community, meaning that only those living inside its walls have access to its Urban Green Spaces. The same phenomenon can be found in smaller gated communities all around the city, influencing the overall scores of their sectors. In areas of high income, most of the UGS tend to be of exclusive use, this is because many of them are located in gated communities (Ibarra & Ceballos, 2018). This says a lot about inequality because it shows that those of high enough income to live in gated communities are more likely to have access to high quality green spaces, while those who live outside their walls do not enjoy the benefits of having such spaces in their proximity.

Quality vs. Quantity

An interesting finding is to see that the **vegetation cover (NDVI values) per sector area does not necessarily correlate to the number of green areas**. This could be explained by looking at individual green spaces in Culiacán. Through satellite images it is possible to observe that many of these areas do not have a lot of trees, some do not have any at all. A common trend amongst high income neighborhoods is to build paved recreational areas with swimming pools, gazebos and lawns. Moreover, a great proportion of green areas are football fields or baseball pitches that do not necessarily provide a good vegetation cover. On the other hand, a high NDVI value can indicate a great proportion of unbuilt land within a sector. For example, La Limita, Bacurimi and Aguaruto are all underdeveloped sectors of the city with a low amount of green spaces, but they score high in NDVI values because of the existing wild vegetation and unpaved areas.

The results shown in Figure 19 describe which areas are lacking the most recreational green areas, and this also means that there is opportunity for improvement. Sectors Hidalgo, 21 de Mayo, El Diez, El Ranchito and Diaz Ordaz are in desperate **need for more parks**. It is striking to see that the airport has bigger and more vegetated areas than most neighborhoods (see Photo 33 and Figure 14). The social quality of existing green spaces should also be improved, prioritizing sectors Diaz Ordaz, San Isidro, El Diez, 21 de Marzo and La Limita de Itaje. These are all low-income areas with **green spaces of poor quality** in their vegetation and their equipment. Prioritizing these areas will have a positive effect in improving **environmental justice** (Vásquez et al., 2017). Moreover, sectors around the city center and the northeast part of the city could benefit from more vegetation to compensate for the impervious surface areas (see Map 11).

According to crime reports, many of the most dangerous neighborhoods in the city are located in the sectors 21 de Marzo, Centro and Lazaro Cárdenas. Studies suggest that improving urban image can have an influence in the perceived safety of an area (Beatly, 2016; Ceccato et al., 2020). It would then be interesting to see if improving the urban image with the use of vegetation and urban design could have a positive influence in these sectors.

The results on the potential for vacant lots suggest that there is potential to increase the provision of urban green spaces for the population of Culiacán (see Map 20). Vacant land located in areas prone to flooding could be considered as mitigation tools to avoid flooding in nearby housing areas. Those that are developed, may implement flood mitigation strategies to avoid potential losses during natural disasters. The findings on ecological value and heat potential can be an aid for determining the pros and cons of developing the land for housing or using it as

green area. Because housing is an important potential use for vacant lots in the city, further examination would be needed to determine the best use for these spaces.

The railway tracks are meant to be relocated. Plans for the future of these areas are not clear. However, this relocation presents an opportunity to implement new options of mobility, for creation of new green areas, and for urban regeneration. Further analysis would be needed to plan for a project that benefits the population and integrates with the existing canal and proposed Green Infrastructure Plan.

6.3 Environmental issues

Exotic species

The findings from the interview brought to light the problem of exotic species in existing green spaces. Exotic species like the Neem (*Azadirachta indica*) and Olivo Negro (*Bucida buceras*) have been widely used as street trees (Revista Espejo, 2019a), and the Construction Regulations require to use them as street vegetation (Gobierno del Estado de Sinaloa, 2007, art. 290). These species require more water than local species adapted to the climate, and species like eucalyptus cause damage to private property because they are not strong enough to hold against the strong winds that come during the hurricane season (Díaz, 2021). These and more exotic species displace native vegetation and do not provide as much of ecosystems services as the species they replace. The interview exposed that native species could enhance cultural and ecological identity, but to promote the use of native species, the regulations should be changed first. Moreover, it would be necessary to improve the communication between experts and the general population. Initiatives like Paseos Verdes (Dehesa, 2021) contribute to this purpose, so they should be encouraged and supported by the authorities. Planting native trees and adding information about them in public parks could also be a way to address to this issue.

River degradation

Urbanization has led to deforestation and changes in species composition in the riverbanks (Ibarra & Ceballos, 2018), water pollution (IMPLAN, 2020), and changes in the original course of the river (Díaz, 2021). Flood risk assessments reveal that the most vulnerable areas to flooding are housing areas too close to the river (see Map 7). This includes the area of Isla Musala, that Dr. Diaz mentions as an example of how the river has been modified in favor of housing development without taking in consideration the risk to the population. He mentioned that because the width of the river has been reduced, there is a need for constant river dredging due to a constant accumulation of sediments.

According to Watson and Adams (2011), there are three main factors contributing to changes in the riverine flood conditions worldwide: (1) increased rainfall due to climate change, (2) loss of absorptive landscape due to the rapid urbanization and the impervious surfaces that comes with it, (3) siltation of waterways due to the accumulation of sand, sediments and debris that results in constrictions to runoff. Moreover, the replacement of native vegetation with exotic species results in a reduction of ecosystem services such as water absorption, nutrient recycling, erosion control and habitat provision for local fauna. These are all factors that are present in the Culiacán River, confirming the literature review.

Biodiversity

One of the most iconic green spaces in the city is the Botanical Garden. It has an extensive collection of plants from all around the world and interventions from globally renowned architects and artists (Burian, 2015). During the interview, the biologist

mentioned that the garden is also home to many bird species that are not found elsewhere in the city. This brings up the issue of connectivity. This hub of biodiversity behaves like an island from a landscape ecology perspective, and according to the principles of island biogeography theory, remote islands have a higher risk for extinction (MacArthur & Wilson, 1967). Therefore, increasing ecological connectivity to other biodiversity hubs could increase the livelihood conditions and probability of success for the bird species that find refuge in the Botanical Garden.

Urban Heat Island Effect

The results of the analysis confirms what the literature says about the relation between low vegetation cover and the built environment and their influence in the Urban Heat Island phenomenon (Gill et al., 2007). Areas covering water bodies and the forests appeared to be the coolest ones (see Map 12). Vegetation from both public and private areas contribute to reducing temperatures (see Map 17)., meaning that private gardens, cemeteries and institutional spaces can also have a positive role for mitigating heat.

Identifying the problematic areas revealed the areas of opportunities. It is no surprise that all industrial areas contribute to increasing temperatures (see Map 19), as well as areas of high activity such as commercial zones and the city center (see Map 17). This points to the need to increase the requirements for green areas within land use types that emit excessive amounts of heat, such as industry, commerce, and high-density buildings.

It is also clear that the presence of green areas is not enough to mitigate the heat. As Map 18 points out, there is a great number of green spaces that match the hottest areas of the city and that have a low vegetation cover. This shows us that there is opportunity to increase the amount of vegetation in existing green spaces for the purpose of heat mitigation. As the literature suggests, adding more trees to parks and streets has a cooling effect on their immediate surroundings (Potchter et al., 2006; Shishegar, 2014; Taha, 1997; Tsiros, 2010).

Natural disasters and climate change

The combined effects of drought, food shortages, heatwaves, the more severe natural disasters to come, and the lack of control over pollution and deforestation mean that it is urgent to start taking actions on mitigation and adaptation to climate change. We need to take seriously the to the existing natural threats and the ones to come, and so make Culiacán a more resilient place to live. Current plans for climate action focus mainly on the reduction of carbon emissions from the transportation sector and the use of renewable energy (IMPLAN, 2021b). They acknowledge the role of green walls for sustainable construction, but do not mention the full potential that GI can have for both adaptation and mitigation efforts. We need to be prepared and integrate mitigation and adaptation measures for the threats to come. This justifies the introduction of GI strategies for climate action.

Water problems appear to be the most significant natural disasters, either because of excess or scarcity of water. As the biologist mentioned in the interview, drought has not been taken seriously enough in the past, but records show that drought events have accounted for great economical losses in the region (CNPC, 2015), and climate change predictions suggest that the frequency of droughts will increase (INECC, 2019). Implementing Green Infrastructure could enhance the land's capacity to absorb water and recharge the aquifers so that rainwater stays within the territory. Increasing infiltration would also have the effect of mitigating flood damage and improving the effectiveness of pluvial and drainage systems during heavy rainfall events. In addition, providing shade in irrigation canals by

planting trees along them may improve their effectiveness at providing water for agricultural purposes.

6.4 Strategic proposal

The idea of the Green Infrastructure plan is to provide opportunities for soft mobility, to allow for easier movement of wildlife, and to increase the accessibility to Urban Green Spaces in all sectors of the city.

The status of *Green Street* means that areas that streets that are vegetated would get protection, and they would be prioritized for interventions, maintenance, and surveillance. Those that are not built yet, provide the opportunity for future development to adapt to the green network to a better degree than existing constructions, for example by creating parks around it and by turning their facades to the corridors. It also gives the streets a priority for increasing accessibility and pedestrian infrastructure. Streets that are unpaved present a valuable opportunity to design them better from scratch, to re-think how an ideal street can and should be, including vegetation with clear purposes and favoring soft mobility. For streams and canals, becoming a Blue-Green Corridor means that they will be protected, revitalized, and maintained. Vegetation along streams and canals will provide ecosystem services such as flood mitigation, recreation, habitat provision, and water regulation.

The Green Infrastructure Plan provides an overview of *where* we can find potential links, hubs and sites in Culiacán, while the further suggestions, areas of interest, and vegetation tables give an idea of *how* Green Infrastructure can be implemented. The information about vegetation use in Table 25 and

Table 26 is meant to be a tool for decision-making in landscape architecture projects. These tables could be expanded with more species and further information of their qualities so that they can become a database for landscape architects in Culiacán.

6.5 Implementation challenges

For reasons unknown to the author, the boundaries for no-development zones have changed between the zoning plans of 2010 and 2021 (see Figure 14). According to the official plans, there is the intention to halt development in areas of high risk and high ecological value. However, in ten years the boundaries for urban growth have expanded, reducing the areas previously regarded for conservation, and risk zones are still classified for future development. In order to have success in any plans concerning environmental protection, boundaries should be respected and consistent. This poses a challenge for the implementation of future conservation areas, as it has been shown in the past that these boundaries have not been respected.

The Construction Regulations of the Municipality of Culiacán establishes that for lots of less than 500 m^2, 20% should be left unbuilt, while those greater than 5500 m^2 should leave 10% (Gobierno del Estado de Sinaloa, 2007, article 102). The limitation of this rule is that parking lots can fully account for this unbuilt portion (Gobierno del Estado de Sinaloa, 2007, article 101), meaning that there is no real requirement for vegetation cover or permeable surfaces in private buildings. The spatial analysis results on the Urban Heat Island effect reveal that built areas have a great impact for land surface temperatures, and that extensive parking lots are among the hottest surfaces in the city (see Map 17). Therefore, adding vegetation in public areas is not enough to mitigate heat. Policies for including vegetation in private areas could contribute to reduce the Urban Heat Island phenomenon. One way to do this is to follow the European example and promote tools like the Blue-Green Factor, in

which Green Infrastructure strategies can be distributed by a series of interventions, such as gardens, trees, green roofs and walls, and permeable surfaces (Standard, 2020).

A study from (Kazmierczak, 2016) suggests that brownfields bring potential to deal with shortage of green spaces. However, they are also an attractive solution to deal with housing problems. For instance, in the UK there is a government's program to address the housing crisis by building on brownfields. Even though this is a good option for achieving densification goals, it also increases the negative impacts of urban development to the cost of green spaces and all the negative effects that comes with it, such as increasing temperatures, lower air quality and absence of recreational areas (Carter et al., 2015). The Culiacán Municipality has expressed the potential for vacant land to solve housing issues, and even proposes sanctioning underutilized lots (IMPLAN, 2021b). However, they do not acknowledge other potential uses for residual spaces. As the results presented in Map 20 suggest, repurposing residual areas as green spaces could contribute to improving accessibility to UGS, heat mitigation, ecological conservation, and flood mitigation. Therefore, further assessment on the qualities of residual spaces in Culiacán could contribute to a better decision making and a smarter urban growth, which is one of the goals of the Municipality.

6.6 Limitations and future research

A limitation for the execution of this master thesis was the constraints of being one person doing such an extensive study. Time constraints proved challenging for finalizing the theoretical part, the series of methods, and the proposal. Another great challenge was the fact that the author was located in a different country than the study area. Covid-19 restrictions meant that there was no chance of making further visits to the city during the writing process, so information could not be verified physically. Reliable online information about the city was hard to find, thus the initiative to use an in-depth interview for data collection. This also meant that some sources were hard to verify, and that many plans and projects for green areas were not available for discussion.

During the spatial analysis, the ecological value only considered size, vegetation cover, and proximity to water. These factors are generally good indicators for the capacity of an area to provide ecosystem services (Beninde, 2015). However, they are insufficient to provide a clear picture of the full ecological potential of a site. To evaluate the true ecological value of green spaces, more factors should be accounted for. For example, if there are any native, threatened, or keystone species present in the area. They can also be analyzed based on landscape ecological principles of connectivity accounting for individual prioritized species. Further research on this topic could provide a closer overview on the urban ecology of the green areas in Culiacan.

The buffer method used to analyze accessibility was not very accurate because it did not take in count physical barriers like the rivers, walls, and roads, but it gives a general idea. For more precise calculations it would be needed a more complex tool that accounts for physical obstacles and topography.

The available information to determine whether a green space is of open or exclusive access was very limited, as there was not any available source for this information, and it had to be determined by the author. The same problem was found when verifying the availability of amenities and equipment. This means that the results using these methods had some degree of subjectivity because it depended on the judgement of the author and the visibility of satellite images. For more precise data it would be needed a field

assessment on each individual green space, something out of the limits of this research. For future reference, a unified database on all the characteristics of Urban Green Spaces would provide valuable for research.

The purpose of the social value analysis was to show which green spaces are in need for improvement, which ones are completely neglected, and which ones already offer a good recreational value for their neighborhood. Similar scores does not necessarily imply that their physical characteristics are similar, but that they have the same priority for improving or keeping their social qualities. The quality of data to realize this assessment was not very precise, but it provided a general panorama of the characteristics of green spaces, so despite of the limited quality of data the results are still useful as a starting point for further analysis.

The available data on residual spaces was also very limited. Meaning that the results of these analysis only provide a starting point for future assessments. More considerations come into play to decide the best use for residual spaces like vacant lots, unused railway tracks, and abandoned spaces. Information on the social dynamics of the area, the juridical status of the lots, and their ecological composition are examples of data that could be considered for future analysis on whether to use these areas as UGS or for development.

Chapter 7. Conclusions

Throughout the process of this study, it has been shown the different functions and impact that vegetation can have for urban development. In the past, the perception about vegetation use in the city of Culiacán has been mostly recognized as ornamental, but it is time to recognize the role that vegetation can have to achieve other goals in the city, not only in intention but also in official planning and regulations.

The intended purpose of the results from master thesis is to provide a framework for landscape architects in Culiacán to design and implement Green Infrastructure projects in the city. The findings of this research can provide a knowledge platform for decision-making in future interventions. After conducting this research, it can be concluded that:

- Only half of the population of Culiacán has access to high quality green spaces by walking distance.
- To effectively provide with social and ecological benefits, Culiacán needs more public UGS larger than 5000 m^2 with amenities and equipment of high quality and native vegetation.
- Accessibility to UGS in Culiacán can be improved by making use of residual spaces and by providing safe links between housing areas and green spaces.
- The effectiveness of ecosystem services provision in existing UGS can be enhanced by improving ecological connectivity between patches.
- Extensive impervious surfaces like parking lots and buildings largely contribute to the extreme heat experienced in Culiacán.
- To improve urban resilience to natural hazards and climate change, green areas of all types offer a potential for heat and flood mitigation.
- Even though drought problems have not been taken seriously before, it is predicted that these events will happen more frequently. Increasing vegetation and permeable surfaces are potential strategies to do something about it.

The proposal for this GI strategic plan was based on five principles: social and ecological connectivity, social integration, protection of biodiversity, urban resilience to climate change, and cultural and ecological identity (see Figure 21). These principles were the result of analyzing the main issues of the city, meaning that other cities may have different results based on their own particular issues. Nevertheless, Culiacán shares many social and environmental issues with other cities in Mexico and Latin America, for example the presence of informal settlements in risk areas, the unequal distribution of UGS across neighborhoods of high and low income, and the absence of previous Green Infrastructure planning for reaching climate goals. This implies that some of the findings from this study may also apply to other Latin American cities.

The difference between this project and other interventions and studies in the city is that it looks at the potential for Green Infrastructure as a comprehensive network, while other green projects in the city have been isolated contributions. As it has been defined by Benedict and McMahon (2006), Green Infrastructure is "an interconnected green space network that is planned and managed for its natural resource values and for the associated benefits it confers to human populations". Therefore, we cannot apply GI projects in the city from a fragmented vision. The GI proposal aims to address the landscape issues with the use of vegetation, and to link the existing qualities of the city, the initiatives currently taking place in the public arena, and the vision of the authorities to contribute to the Urban Agenda 2030 and the Sustainable Development Goals. Without a general strategy for Green Infrastructure on a city level, any green project would be like an island surrounded by a sea of concrete.

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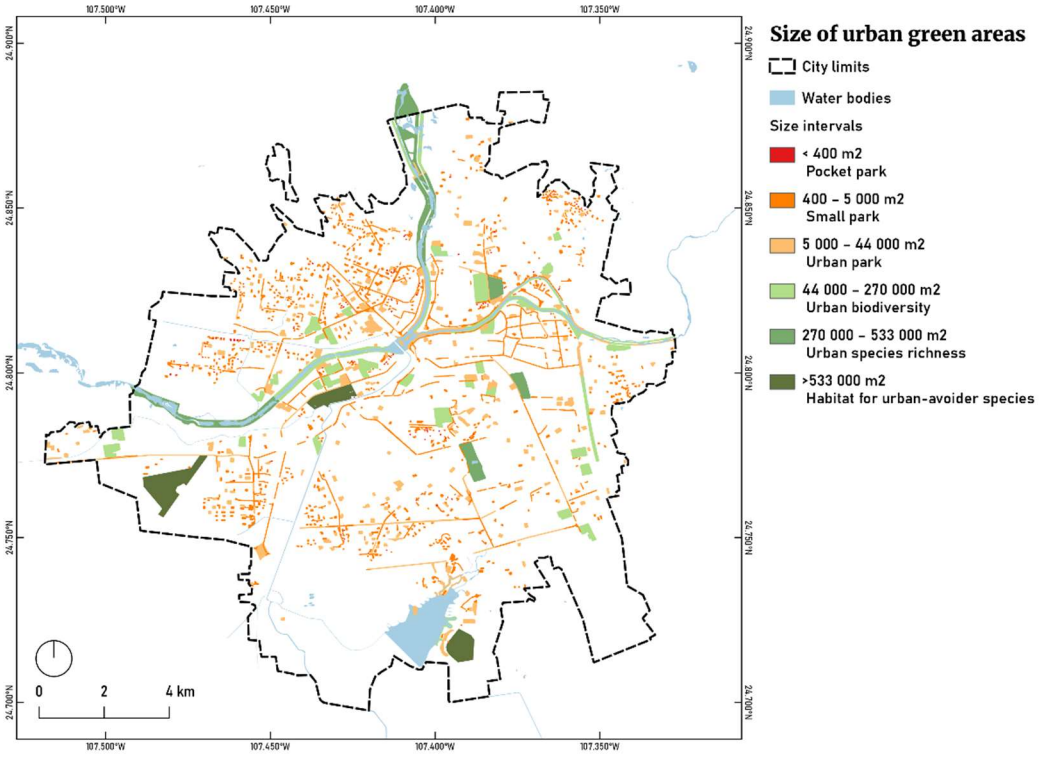
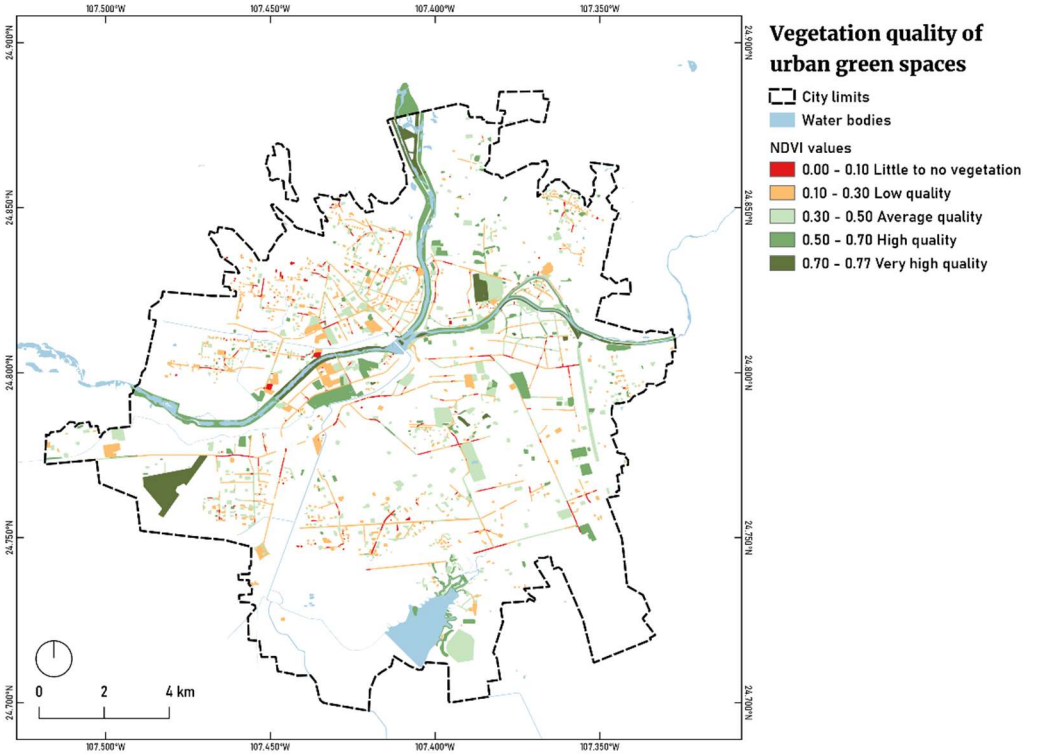
Appendix

7.1 Appendix A. Classifications of urban green spaces

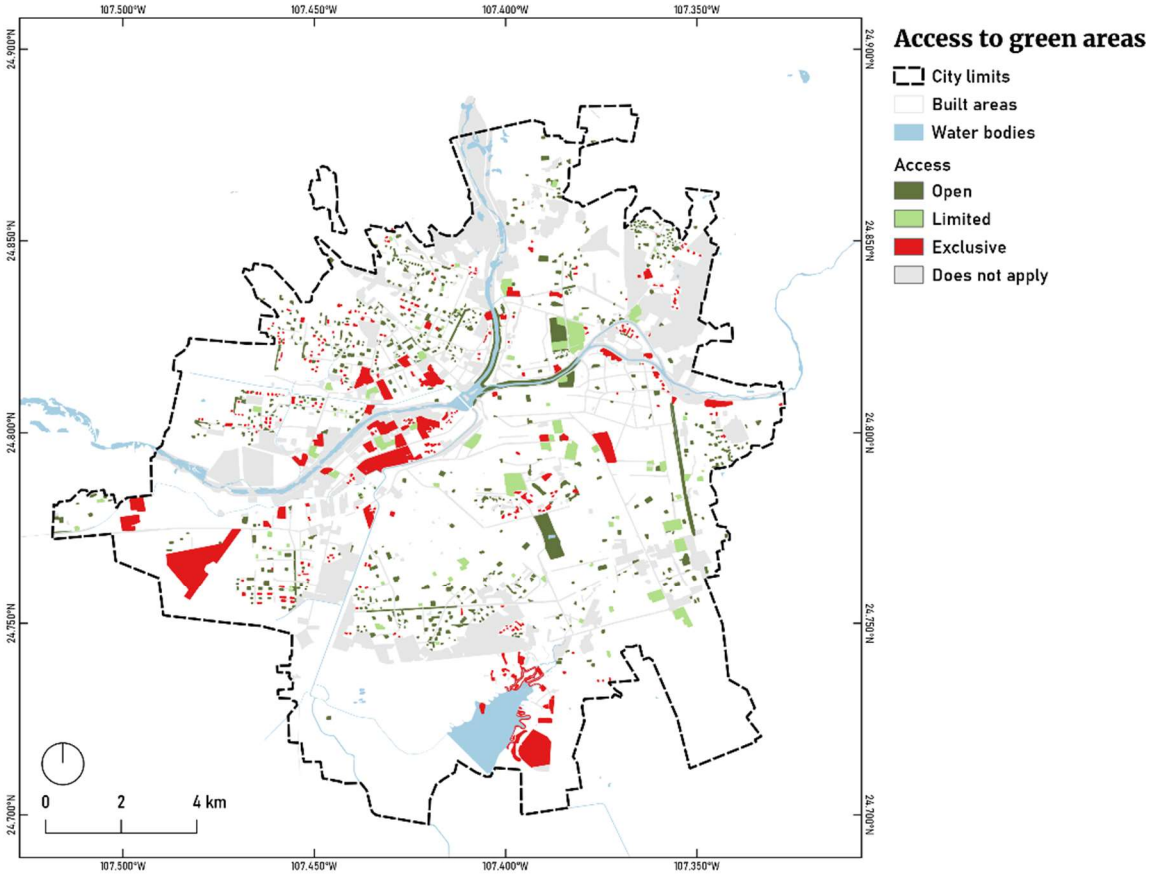
By size



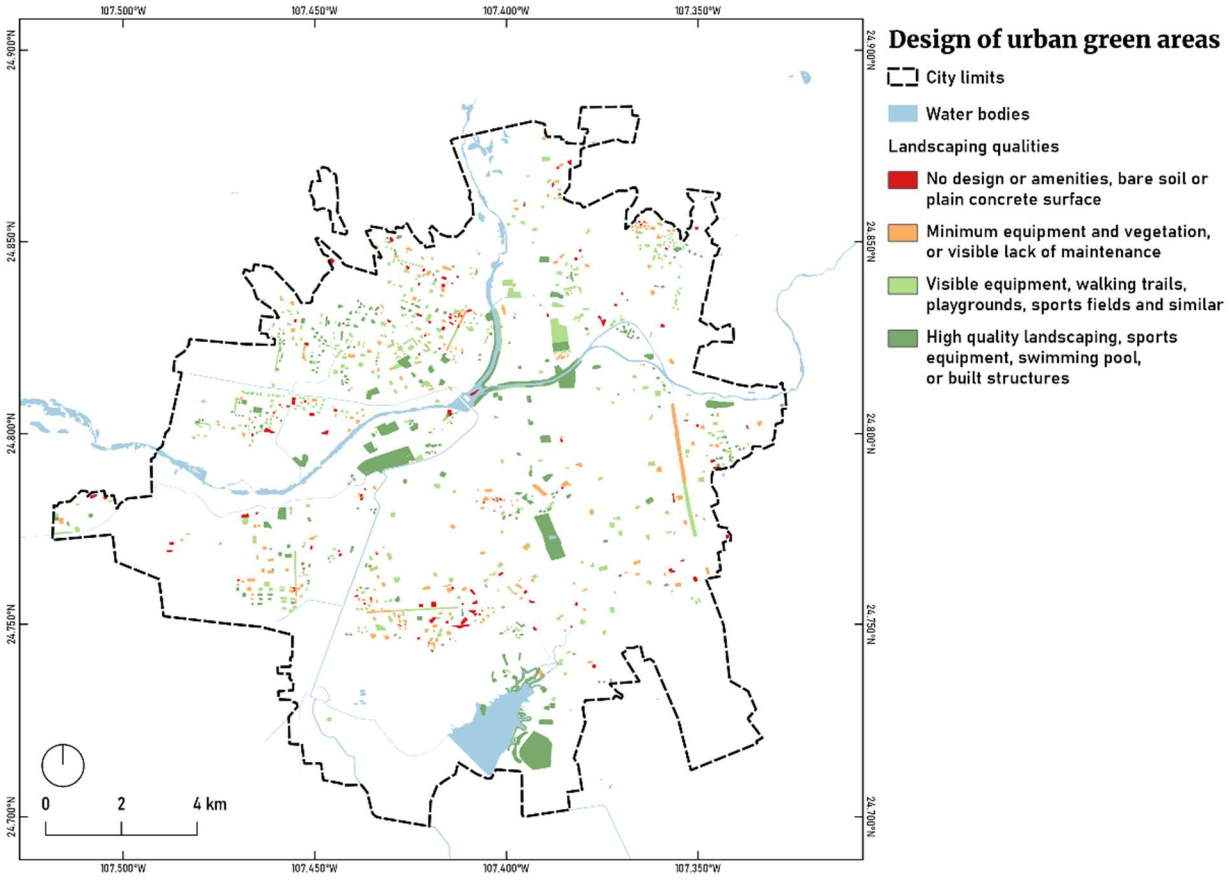
By vegetation quality (mean NDVI values)



By access



By equipment and amenities



7.2 Appendix B. Details of the interview and transcript

Interviewer: Michelle Granados Johansen

Interviewee: José Saturnino Díaz

Date: 2nd of November, 2021

Language: Spanish

Transcript of the interview

00:00:03 Speaker 1

Bueno, ahí está.

00:00:05 Speaker 1

¿Entonces, primero que nada, podría hablarme un poquito de usted: quién es usted, qué profesión tiene y que cargo o qué funciones desempeña para la biología en Culiacán?

00:00:19 Speaker 2

Bueno, este yo soy el doctor José Saturnino Díaz, doctor en Biotecnología.

00:00:26 Speaker 2

Egresé de la carrera en biología en las áreas especializadas de botánica y ecología en 1994.

00:00:37 Speaker 2

Soy egresado de la Facultad de biología de la Universidad Autónoma de Sinaloa y desde ese año soy docente en la misma Universidad donde imparto diferentes materias relacionadas precisamente con las plantas, las algas, aspectos ecológicos vinculados al estudio de las Comunidades vegetales, fundamentalmente.

00:00:59 Speaker 2

Índice de diversidad, similitud, extinción y todas esas cosas vinculadas precisamente a lo que son las plantas, como son los síntomas de polinización, dispersión.

00:01:13 Speaker 2

Etcétera, de tal manera entonces que en base a ese conocimiento, yo estudié la maestría en recursos naturales y medio ambiente en el Instituto Politécnico nacional y luego ya le quise dar un plus a ese conocimiento y estudié el doctorado en Ciencias en biotecnología, también en el Instituto Politécnico Nacional.

00:01:38 Speaker 2

En el caso de la maestría, yo estudié la flora y la vegetación o estructura de la vegetación de las islas de la Bahía de Navchiste

00:01:47 Speaker 2

en la parte de Guasave, Sinaloa y con biotecnología y yo trabajé capacidad antioxidante y micro encapsulado de metabolitos secundarios de *maclura tinctoria*, que es una planta típica del bosque tropical seco de Sinaloa y Campeche. Entonces sigo fungiendo como docente.

00:02:10 Speaker 2

En la misma Universidad y también como profesor invitado en el Instituto Politécnico Nacional.

00:02:19 Speaker 1

Muy bien.

00:02:21 Speaker 1

¿Entonces, para empezar, podría decirme, o no sé explicarme un poco sobre la ecología de Culiacán en general, primero como un panorama general?

00:02:30 Speaker 2

Bueno, en términos generales, Culiacán, si hablamos de la ciudad, pues es una ciudad que está establecida dentro de lo que es lo que se conoce como la llanura costera del noroeste.

00:02:45 Speaker 2

En una superficie plana completamente, rodeada por un lado por lo que serían algunas extensiones de la Sierra Madre occidental.

00:02:57 Speaker 2

Pequeños cerros como el cerro del Tule, el cerro de la Chichi, el Cerro de las 7 Gotas, etcétera.

00:03:05 Speaker 2

y la extensión que tenemos nosotros, hacia Imala. Y en la ciudad precisamente hay 3 ríos característicos muy importantes porque forman parte precisamente de lo que es el paisaje característico de la ciudad de Culiacán que es conocida precisamente por sus ríos Tamazula. Humaya.

00:03:26 Speaker 2

Y el río Culiacán Ahora bien, las ciudad es precisamente es una extensión abierta porque reciente los impactos en ocasiones de los ciclones que provienen del Pacífico, precisamente porque ahí no hay formaciones geológicas que permitan o que protejan precisamente a la ciudad de los impactos de los vientos que vienen

00:03:54 Speaker 2

del Pacífico. Entonces no tiene, digamos, un fenómeno de contaminación producto de las actividades.

00:04:04 Speaker 2

industriales o por la cantidad de automóviles, etcétera que, digamos nosotros, puede resultar nocivo, precisamente porque esos vientos que vienen del Pacífico le permiten estar, digamos más o menos con sus Aires limpio. El gran problema de la ciudad, explican, está vinculado

00:04:28 Speaker 2

A lo que es su ambiente agrícola. Es en el ambiente agrícola, precisamente donde el municipio tiene un gran auge económico, pero también tiene un gran impacto donde la cobertura vegetal, la flora y la fauna se ha perdido en más del 80% y se ha cambiado precisamente por diferentes cultivos como maíz, sorgo, tomate, chile, etcétera. Ahora bien, el sostenimiento de esta actividad agrícola requiere precisamente del uso.

00:05:03 Speaker 2

De grandes cantidades de fertilizantes.

00:05:06 Speaker 2

de fungicidas, herbicidas, insecticidas, etcétera que muchos de ellos precisamente,

00:05:14 Speaker 2

son descargados en gran cantidad de sus residuos en los cuerpos de agua, en algunas lagunas costeras y también en los ríos y arroyos de la región. En realidad. Culiacán ese es el gran problema que tiene la actividad agrícola exagerada y ahora

00:05:36 Speaker 2

El crecimiento de la población está exigiendo entonces

00:05:42 Speaker 2

mayor apertura de espacios que hace unos años, digamos, hace 20 años, eran prístinos. Eran, digamos, valles, márgenes de los ríos que estaban completamente vírgenes, las pequeñas montañas, que estaban también alrededor de la ciudad, pues conservaban ampliamente su vegetación. Sin embargo, la creación o el desarrollo de espacios

00:06:13 Speaker 2

de parques, de desarrollos habitacionales, comerciales, pues han llevado a que gran cantidad de la cobertura vegetal original se haya perdido y esto se revierte en un problema también.

00:06:30 Speaker 2

Porque los parques, los jardines, que los hay, ahora sí en gran cantidad.

00:06:35 Speaker 2

No tienen vegetación natural adaptada a las condiciones climáticas edáficas

00:06:44 Speaker 2

de la ciudad o del municipio. Tenemos nosotros, el problema es que se llama.

00:06:49 Speaker 2

introducción de especies exóticas e invasoras.

00:06:54 Speaker 2

Muchos de los parques de la ciudad no tienen elementos naturales característicos de lo que es el bosque tropical caducifolio, el bosque espinoso y el bosque de galería. Sí, sino que tienen elementos que provienen de diferentes lugares de África, de Oceanía, de Asia.

00:07:15 Speaker 2

Y hasta de Europa. Podemos desglosar.

00:07:19 Speaker 2

Si tú consideras que esa parte, ¿por qué razón? Porque muchos de los jardines de la ciudad en realidad incluyen especies

00:07:33 Speaker 2

Muy llamativa, sí, especies que adornan y no cumplen funciones ecológicas, como lo es la polinización, como lo es el aporte de.

00:07:45 Speaker 2

De hojarasca, el aporte de frutos, semillas, etcétera, de las cuales se puedan alimentar los animales, no hablando de lo que son los mismos insectos, las aves, los mamíferos, etcétera.

00:08:03 Speaker 2

Si gusta, les sigo este porque hay mucho.

00:08:07 Speaker 2

Que platicar en ese sentido.

00:08:08 Speaker 2

¿O no?

00:08:09 Speaker 1

Sí, claro.

00:08:09 Speaker 2

Y puedes preguntar, por ejemplo, si tú consideras.

00:08:13 Speaker 1

Sí, eso le iba a preguntar sobre ejemplos tanto de.

00:08:17 Speaker 1

Especies problemáticas como de especies que deberíamos de implementar. En lugar de eso, ya sea por polinizadores o por otras razones.

00:08:28 Speaker 2

Bueno, precisamente como la ciudad está en un entorno todavía, digamos vinculado a su pequeña serranía a sus valles, este sigue teniendo

00:08:43 Speaker 2

Una amplia diversidad faunística y también florística por fuera de la ciudad.

00:08:49 Speaker 2

Pero en el interior de la ciudad hay ejemplos. Hemos encontrado, por ejemplo, en el Jardín Botánico una diversidad bien amplia de aves, inclusive aves que fuera del Jardín Botánico no se encuentran, es decir, estando el botánico en el corazón de la ciudad.

00:09:08 Speaker 2

Pues nada más están ahí este grupo de organismos, ¿no?

00:09:12 Speaker 2

Entonces, ahí estás aves como si hay especies nativas, pero también hay especies exóticas. encuentran precisamente su alimento, su hábitat, en toda la extensión, es decir, tienen su nicho ecológico bien definido y lo desarrollan, precisamente porque ahí son protegidas.

00:09:34 Speaker 2

en cierto sentido. Sin embargo, en el resto de la ciudad, llámese por ejemplo parques que tú conoces como las riberas

00:09:44 Speaker 2

que están en los márgenes

00:09:51 Speaker 2

del río Tamazula y en el río Humaya, principalmente, y una extensión en el río Culiacán.

00:09:57 Speaker 2

En realidad son.

00:10:00 Speaker 2

Parques artificiales, hablando en términos precisamente de su composición florística y faunística, ¿por qué razón? Porque tienen muchísimas especies exóticas. Los Álamos, los sauces.

00:10:17 Speaker 2

Pero también los guamúchiles, si gustas ya después te mando un listado de los nombres científicos de esas especies, con los nombres comunes. Los guamúchiles, las guásimas y toda esa flora característica.

00:10:31 Speaker 2

Del del río en su parte no afectada, ha sido cambiada. ¿Por qué tipo de especies? Pues por especies exóticas como casuarinas, eucaliptos, plantas ornamentales también.

00:10:52 Speaker 2

E inclusive por una gran cantidad de malezas que debido a la apertura

00:10:59 Speaker 2

De esos espacios cuando no se les cuida cuando no se los protege, las malezas de verano empiezan a desarrollarse de manera muy amplia.

00:11:09 Speaker 2

Malezas como los pastos, como los quelites o bledos. ¿Probablemente tú te acuerdas de ellos o los había escuchado mencionar?

00:11:17 Speaker 2

y muchísimas otras especies. Te digo, te voy a mandar una lista porque tenemos todo ese listado de especies y ahí viene exóticas, y malezas etcétera, para que tú puedas ahí desglosar y escojo estás, etcétera, etcétera.

00:11:32 Speaker 2

Ahora te digo, entonces ese es el del río, pero nosotros precisamente también vemos que en la ciudad hay una gran cantidad de acaparamiento de lotes. Hay muchos lotes baldíos, sí, y estos lotes baldíos tienen décadas.

00:11:48 Speaker 2

Abandonados esos lotes funcionan, en ocasiones, como basureros.

00:11:54 Speaker 2

y cuando se les limpia.

00:11:58 Speaker 2

Esos lotes quedan a la intemperie y son invadidos por propágulos, por ejemplo, por semillas de malezas.

00:12:08 Speaker 2

Muchos pastos, muchos quelites, bledos etcétera, que en la época de verano, pues cubren completamente al 100%, cubren esos lotes baldíos. Y ahora nos vamos a los parques, los parques donde hay este juegos para los niños y aparatos

00:12:31 Speaker 2

Para hacer ejercicio. Muchos de esos parques en realidad

00:12:35 Speaker 2

no incluyen especies naturales propias de la de la Comunidad. Por ejemplo, no hay palo blanco, no hay amapas.

00:12:47 Speaker 2

No hay guamúchil, etcétera. Y hay una razón

00:12:51 Speaker 2

de que no los haya.

00:12:53 Speaker 2

De que esas especies el mismo nombre te dice se llama bosque tropical caducifolio, es decir, esas especies de plantas pierden el follaje en la época seca del año. Que para nosotros, pues es un periodo bien prolongado, no?

00:13:10 Speaker 2

Normalmente empieza ya en estamos en el otoño.

00:13:14 Speaker 2

Y las plantas ya empiezan a mostrar el amarillamiento típico, es decir, que para febrero las plantas ya no tienen follaje.

00:13:24 Speaker 2

Y la gente empieza a decir que el bosque se ha secado, no? En realidad sigue latente. Entonces estas especies, la gente no las quiere en sus parques, quiere que sus partes siempre estén verdes

00:13:40 Speaker 2

¿Y cómo conservan ese verdor? con pastos, digamos introducidos.

00:13:46 Speaker 2

Los pastos naturales de estos jardines como el pasto de Kentucky, etcétera, y luego también exigen plantas que tengan follaje todo el año.

00:13:56 Speaker 2

Por lo tanto, entonces introducen especies como eucaliptos, casuarinas, Grevillas, plantas que no son propias de la región. ¿Cuál es el problema?

00:14:08 Speaker 2

El problema es que esas plantas exigen mucha agua, muchos cuidados.

00:14:14 Speaker 2

Sí, porque? porque también son plantas que crecen muchísimo más allá que lo que suelen crecer las plantas nativas.

00:14:24 Speaker 2

Las plantas nativas su crecimiento oscila entre 12 y 18 M, es lo más que pueden llegar a crecer, pero plantas exóticas como los eucaliptos como las grevillas, como las casuarinas.

00:14:40 Speaker 2

Como inclusive.

00:14:43 Speaker 2

Las araucarias, probablemente hayas escuchado hablar de ella, son pinos inmensos que llegan a crecer, hasta 40 M.

00:14:52 Speaker 2

De tal manera, entonces, que ahora vincula tu esas especies de árboles leñosos

00:14:59 Speaker 2

Con los ventarrones que pegan en la ciudad que nos viene precisamente de la zona del Valle. Entonces provocan problemas bien serios ¿por que?

00:15:09 Speaker 2

Porque la madera de los eucaliptos decimos nosotros que es muy vidriosa es muy quebradiza. Los eucaliptos son inmensos. Ya hay muchísimos casos, muchísimos reportes de grandes ramas que caen encima de los autos. Sí y.

00:15:25 Speaker 2

A veces de las casas, etcétera, entonces?

Si nosotros vinculamos entonces.

00:15:35 Speaker 2

Eso a los aires o a los ventarrones que nos vienen de los ciclones, eso se convierte en un problema bien serio y en un peligro. Sí, para la sociedad.

00:15:47 Speaker 2

De tal forma, entonces que tenemos nosotros en los parques, muchísimas especies exóticas e invasoras requieren muchísimos cuidados, mucha agua y

00:15:59 Speaker 2

este año tuvimos un problema serio precisamente de sequía.

00:16:04 Speaker 2

¿Por qué razón?

00:16:05 Speaker 2

Porque gran cantidad, más del 70% del agua que captan las presas que alimentan el Valle agrícola de Culiacán, solamente, llámese la presa Sanalona, pero también la presa del Varejonal que está a las afueras de la ciudad, hacia la parte norte, alimentan

00:16:31 Speaker 2

la actividad agrícola. Mucha del agua en realidad, se escurre hacia el mar de tal manera, entonces que perdemos agua nosotros por la actividad agrícola y perdemos agua en el mantenimiento de parques

00:16:47 Speaker 2

¿Por qué razón? Porque no tenemos las plantas adecuadas, es decir, esas plantas que soportan largos periodos de sequía porque están adaptadas para ello y por eso pierden el follaje, no?

00:17:01 Speaker 2

Es una estrategia vinculada a los factores del ambiente.

00:17:09 Speaker 2

Muchos hemos nosotros impulsado la idea de que los parques de la región sí tengan especies.

00:17:16 Speaker 2

Exóticas no hay problema, pero que la gran mayoría sean especies nativas.

00:17:25 Speaker 2

Es a veces es muy llamativo ver, por ejemplo, hasta 10 especies diferentes de Palmas, Palmas cocotero, por ejemplo.

00:17:36 Speaker 2

Palma Washingtonia, Palma Areca, Palma Real, Palma datilera.

00:17:44 Speaker 2

Formando parte precisamente, de esos parques, de estos jardines.

00:17:50 Speaker 2

Y esas Palmas precisamente requieren mucha agua y son organismos muy pesados de raíces superficiales. Cuando le sopla el viento, entonces esas palmeras caen con todo su peso. Entonces le digo, el diseño de los parques de la ciudad.

00:18:11 Speaker 2

aunque muchos hemos trabajado ya de manera conjunta en la Facultad de arquitectura, en la Facultad de biología, precisamente para impulsar.

00:18:22 Speaker 2

La introducción de especies nativas, todavía hemos chocado con esas ideas que se tienen por parte de las autoridades del municipio.

00:18:37 Speaker 2

Hay un buen tumbaburro que te puede servir a ti también que es, acaban de publicar unos chicos, este la guía de árboles urbanos de Culiacán.

00:18:51 Speaker 2

Sí estaba por ahí en PDF te lo consigo y te lo envío para que al menos vaya conociendo los elementos y tengas tela de dónde cortar.

00:19:02 Speaker 2

Y hace poco también. Por cierto, si conoces tú el parquecito que está entre medio del del Jardín Botánico y el Centro de Ciencias, creo que se llama la milla.

00:19:13 Speaker 2

No sé qué.

00:19:14 Speaker 2

Entonces me tocó a mí hacer un dictamen. ¿Por qué? para justificar que ese parque a ese parque no se le construyera un paseo.

00:19:28 Speaker 2

¿Por qué? Porque ese paseo lo impulsa una de las grandes empresas comerciales de la ciudad o del país, podemos decir, porque es la empresa Coppel. Entonces

00:19:42 Speaker 2

la empresa Coppel impulsó la apertura de un paseo, así como en los parques europeos, pero en un ambiente

00:19:53 Speaker 2

sin tomar en cuenta la opinión de los usuarios.

00:19:58 Speaker 2

Sin tomar en cuenta las condiciones ecológicas del sitio.

00:20:03 Speaker 2

¿Por qué razón? Porque imagínate un espacio en el que tú le abras –

00:20:10 Speaker 2

Un espacio arbolado un poquito abierto, el que tú abras, una rúa de al menos.

00:20:19 Speaker 2

6 m - 8 m de ancho.

00:20:23 Speaker 2

Y que lo cubras de concreto.

00:20:27 Speaker 2

Ese es el gran problema que tiene la ciudad entonces, que tiene mucho concreto, mucho asfalto y poco arbolado.

00:20:36 Speaker 2

Es cierto, puede decir muchos, “pero comparado por ejemplo con hermosillo con Obregón... con Tijuana y con Mexicali”, pero Estas son ciudades que están netamente en el desierto.

00:20:53 Speaker 2

La ciudad de Culiacán, no. La ciudad de Culiacán, todavía está ubicada.

00:20:58 Speaker 2

justo en los márgenes de lo que es el trópico de cáncer ¿y qué importa eso? Está influenciado todavía por un clima tropical-subtropical,

00:21:11 Speaker 2

De tal manera que todavía tiene muchos elementos naturales de origen tropical.

00:21:20 Speaker 2

Desde los Mochis para arriba. Tú entonces, ya estás plenamente en el desierto Sonorense, entonces ya estás por fuera de los límites de lo que es el trópico de cáncer. Y la expresión te lo dice, entonces las influencias tropicales, la humedad, el follaje, etcétera.

00:21:41 Speaker 2

Pues ya disminuye bastante, ¿no?

00:21:47 Speaker 1

Entonces hablando de las especies y del problema que usted menciona, si quisiéramos hacer una propuesta para dar prioridad a ciertas especies, ya sea por su contribución excesivamente importante para para la fauna local o para el clima, para adaptarse a las condiciones.

00:22:09 Speaker 1

¿podría nombrarme unas pocas especies como para darles prioridad?

00:22:15 Speaker 2

Sí, por ejemplo, no solamente en el sentido ecológico del papel que juegan, sino también en la identidad cultural, que tenemos los sinaloenses, por ejemplo, ahí tienen que estar de cajón los guamúchiles, las amapas.

00:22:31 Speaker 2

las guásimas.

00:22:35 Speaker 2

Los Álamos, los sauces en los márgenes de los ríos, no.

00:22:40 Speaker 2

Pero también pueden estar otros elementos como los papelillos.

00:22:48 Speaker 2

Hay varias especies de papelillo. ¿Por qué razón? Porque son plantas muy llamativas, por el color de su corteza, tienen corteza lisa, con diversidad de colores.

00:23:00 Speaker 2

Dependiendo de la época del año, ellos cambian de color, su corteza, de naranja, rojizo, verdoso, azuloso. Y todo tiene que ver, precisamente, el cambio de la estación o la cantidad de luz que irradie en las diferentes épocas del año. Pero también nosotros podemos incluir árboles muy bonitos, como la Rosa amarilla. Sí que da las flores, una de las flores más grandes del bosque tropical caducifolio.

00:23:33 Speaker 2

Las ceibas, O Pochotes.

00:23:38 Speaker 2

hay también otros que los conocemos nosotros.

00:23:43 Speaker 2

Por ejemplo.

00:23:48 Speaker 2

Las cordias, que son

00:23:51 Speaker 2

Como las pingüicas, me parece, me imagino que has de conocer las pingüica.

00:23:55 Speaker 2

¿Y si no?

00:23:55 Speaker 2

Entonces las pingüica también, antes eran una de las plantas más, digamos, más utilizadas.

00:24:04 Speaker 2

en la zona urbana de Culiacán y hoy han perdido.

00:24:08 Speaker 2

densidad o abundancia. Entonces, más o menos 10 especies pueden ser muy bien utilizadas y cambiadas en lugar de tener esas que te comentaba anteriormente, esos eucaliptos, esas casuarinas, esas grevillas, etcétera. ¿No?

00:24:29 Speaker 2

Entonces, teniendo guamúchiles, teniendo guásimas, teniendo moras.

00:24:38 Speaker 2

Que como antes mencionadas tú pueden desempeñar un papel bien importante porque florecen y participan un montón de insectos con ellas en la polinización.

00:24:48 Speaker 2

Fructifican y un montón de aves y mamíferos consumen sus frutos. Lo mismo sucede con los guamúchiles, que la misma gente, porque ya sabes que tenemos nosotros mucha gente de origen rural o con ideas rurales, entonces sigue consumiendo ese tipo de frutos. Es decir,

00:25:09 Speaker 2

forman parte de nuestra identidad cultural. Y ahora nosotros nos preguntan mucho a las personas

00:25:16 Speaker 2

por la identidad de ciertos árboles que hay en la región: “¿y eso que tiene que ver con nosotros?”, dicen ellos. No pues nada. tiene que ver con los maoríes con los vietnamitas.

00:25:30 Speaker 2

Con otros grupos étnicos, pero con nosotros propiamente no. ¿Ah y entonces por qué no poner guamúchiles, moras? y nos empiezan a mencionar, palo de Brasil, etcétera, no es decir, tenemos muchísima flora autóctona, nosotros que pueda ser utilizada en lugar de esa flora exótica que tenemos en la actualidad y que me acuerde. Te mando una lista más grande.

00:26:00 Speaker 2

Para que tu entonces la consideres e inclusive algunos links para que veas ahí

00:26:06 Speaker 2

Sí está ese libro de la flora urbana te puede servir para comparar y ver las características de esos árboles que te voy a comentar, no? Una parte de exóticos. Otra parte de nativo.

00:26:22 Speaker 1

He leído también sobre, por ejemplo, en Estados Unidos, el problema que tienen similar, no de especies desplazadas.

00:26:29 Speaker 1

Pero hablando sobre pastos que mantienen el agua en el sitio no, y que a causa de que se han quitado, ahora tienen problemas de sequías. No sé si existe algo parecido ahí en Culiacán, sobre pastos o especies herbáceas, no solamente árboles.

00:26:48 Speaker 1

¿Como especies que podríamos usar, pues?

00:26:51 Speaker 2

Sí, sí las hay, De hecho.

00:26:54 Speaker 2

Está hay un zacate que le llaman gangrena.

00:27:02 Speaker 2

Que desempeña precisamente las mismas funciones que esos pastos exóticos ornamentales no.

00:27:10 Speaker 2

Por qué razón que es lo que queremos nosotros de un pasto, que el pasto cubra completamente la extensión del sitio. Pero no solamente eso, que sea suave y que conserva el precisamente, su color verdoso, llamativo, ¿no?

00:27:27 Speaker 2

El plus que tiene el zacate gangrena que es el

00:27:30 Speaker 2

Género sinodon.

00:27:32 Speaker 2

Sinodon Dactylon se llama.

00:27:34 Speaker 2

es que requiere poca agua.

00:27:43 Speaker 2

Y luego.

00:27:44 Speaker 2

Libera muchos propágulos y se extiende por unas, digamos, unas prolongaciones.

00:27:54 Speaker 2

Rizoidales.

00:27:55 Speaker 2

Es decir, crece de manera vegetativa también.

00:27:59 Speaker 2

Produce semilla, pero también crece de manera vegetativa de tal manera, entonces.

00:28:04 Speaker 2

Que es barato

00:28:06 Speaker 2

y no requiere de mucha agua. Eso es un ejemplo, pero hay otros que podrían ser utilizados.

00:28:18 Speaker 2

Ahorita no recuerdo sus nombres, pero que nosotros hemos impulsado presente para que los.

00:28:24 Speaker 2

Los consideren no.

00:28:28 Speaker 2

Precisamente ¿por que? proponiendo ese plus de que ellos ponemos nosotros, un pequeño espacio lo cubrimos con esos pastos y dejamos el otro espacio desnudo.

00:28:40 Speaker 2

Pero con la humedad sobre todo el verano. Esos pactos se tienen rapidísimo.

00:28:46 Speaker 2

No se tendría que plantar

00:28:49 Speaker 2

la otra parte. Ahora eso depende de en qué época se plante, no, porque si se planta.

00:28:57 Speaker 2

Una semana, 2 semanas antes de las lluvias, tú le ayudas un poquito esas 2 semanas regándolo. Pero ya después lo dejas suelto a la lluvia de la temporada de verano y ese pasto, entonces va a formar.

00:29:13 Speaker 2

Una sabana bien amplia.

00:29:22 Speaker 1

No sé si usted ha.

00:29:23 Speaker 1

Leído sobre los jardines de lluvia y este.

00:29:28 Speaker 1

De bioretención

00:29:31 Speaker 1

Aquí se usa mucho esto, ahorita es como el boom de hacer esos jardines de lluvia, pero desconozco qué especies se pudieran utilizar en un clima como Culiacán para ese tipo de cosas, ¿usted sabe algo?

00:29:44 Speaker 2

En la parte norte, por ejemplo, ahí, en la zona Escandinavia, son muy usuales los musgos. Sí.

00:29:51 Speaker 2

¿Por qué? Porque aguantan el frío.

00:29:54 Speaker 2

Y retienen mucho, mucha, mucho el agua, ¿no? Pero aquí en Culiacán, eso es muy difícil porque deberías de utilizar, por ejemplo, ahora sí que plantas introducidas, sobre todo helechos,

00:30:10 Speaker 2

Selaginellas, y también musgos, que si los hay aquí en la región. El asunto es de que esas plantas las tienes que proteger mucho de la insolación porque.

00:30:22 Speaker 2

El sol es muy fuerte. Entonces

00:30:25 Speaker 2

cualquier superficie, cualquier material que tú utilices, vas a requerir.

00:30:32 Speaker 2

tape la luz,

00:30:33 Speaker 2

Y luego vas a requerir estar precisamente humedeciendo estas plantas en su follaje, no. Hace 2 años precisamente participé con el arquitecto Heriberto Soberanes, es un muchacho que recién terminó su maestría en la U de G, es egresado de la de la Facultad de arquitectura de Culiacán.

00:31:00 Speaker 2

Precisamente en el diseño de espacios cerrados utilizando plantas.

00:31:06 Speaker 2

Y él me mencionaba ese aspecto de que en la ciudad de Culiacán podría implementarse precisamente los jardines captadores de agua.

00:31:19 Speaker 2

Y le comentaba precisamente eso, que el gran problema de las de la ciudad de Culiacán es que es muy caliente y tiene una alta incidencia de radiación ultravioleta.

00:31:29 Speaker 2

Entonces, Eh, ahí

00:31:33 Speaker 2

Lo más importante es implementar precisamente,

00:31:38 Speaker 2

ampliar la cantidad de plantas en los márgenes de los ríos, más que en espacios construidos, no?

00:31:49 Speaker 2

¿Por qué razón? Porque también una gran cantidad del agua que se capta por la lluvia

00:31:59 Speaker 2

Se evapora ¿Por qué? porque los cuerpos de agua están desprotegidos, sí.

00:32:05 Speaker 2

De tal manera entonces que va concatenado el tener especies autóctonas, que formen un dosel.

00:32:14 Speaker 2

Por eso, antaño al bosque de los ríos se le llama bosque de galería. ¿Por qué razón? Porque los árboles de un margen y los árboles del otro margen arriba en su copa

00:32:27 Speaker 2

Se juntaban.

00:32:29 Speaker 2

Y formaban entonces un dosel, un techo.

00:32:32 Speaker 2

El problema es que gran parte de esa vegetación entonces se ha cambiado por otros elementos. ¿Sí?, y entonces esos elementos no desempeñan esa función, ¿no?

00:32:44 Speaker 2

Eso es la cuestión entonces vinculada aquí, que aquí no se piensa en esa situación relacionada a tener espacios que capten el agua.

00:32:53 Speaker 2

Creo que en el Distrito Federal ya se está haciendo no, pero aquí en Culiacán todavía no hay, digamos esa idea, o al menos yo no conozco casos así, relevantes.

00:33:06 Speaker 2

¿Y por qué razón? Porque los que nos han comentado nosotros precisamente, les hemos dicho que primero tiene que proteger a esas plantas de la radiación ultravioleta, que es muy fuerte.

00:33:21 Speaker 2

Segundo, necesitarían espacio, es un poquito más amplio, no? Por ejemplo,

00:33:27 Speaker 2

Antaño pensamos nosotros que esas canchas de fútbol, esos grandes espacios abiertos, pudieran tener un sistema de drenaje para que el agua fuera a los depósitos.

00:33:38 Speaker 2

Son sitios de captación, precisamente de agua que no se han considerado. No sé por qué razón ¿no?

00:33:45 Speaker 2

¿Y por qué? Porque precisamente el agua que hay sobre el pasto y el pasto y el suelo funcionan como filtros y esa agua entonces puede ser captada. Sí, hay muchos espacios abiertos. El problema de nuestras ciudades es.

00:33:59 Speaker 2

El calor que hace durante

00:34:03 Speaker 2

Pues todo el año no estamos en noviembre y aquí dice 30°.

00:34:08 Speaker 2

El termómetro que tengo aquí en la computadora. Entonces imagínate en el verano fácilmente llegas a los 40° pero facilito,

00:34:17 Speaker 2

Y con más o menos más de 12 horas de luz.

00:34:25 Speaker 2

De tal manera, entonces que

00:34:29 Speaker 2

No es muy, digamos, muy recomendable eso.

00:34:32 Speaker 2

Ya si tú tienes una idea más padre y todo el rollo que nosotros desconocemos, a pues welcome Michelle ¿no? A lo mejor entonces es.

00:34:40 Speaker 2

Chicle y pega.

00:34:45

Sí, De hecho.

00:34:46 Speaker 1

Leí sobre una propuesta que hay en conjunto en la ciudad de Hermosillo y Tucson, precisamente para hacer ese tipo de intervenciones, no? De captación de agua, de infiltración por medio de jardines de lluvia y otro tipo de intervenciones, y ahí mencionan especies aptas al desierto mucha cobertura de grava y de pastos. Pensaba hacer una propuesta así, más o menos.

00:35:12 Speaker 1

Pero pues se necesita mas información.

00:35:13 Speaker 2

Pero bueno, si comparamos también este, los regímenes de precipitación de esa área en Arizona, en Sonora y sobre todo esa parte donde están ubicadas las grandes ciudades como Hermosillo y Ciudad Obregón, etcétera, pues comparadas con las de la ciudad de Culiacán, pues en realidad a veces nosotros nos ponemos a pensar cómo puede vivir tanta gente con tan poca cantidad de agua, no?

00:35:41 Speaker 2

Y ellos entonces, si piensan en esas alternativas porque pues tienen que buscar.

00:35:49 Speaker 2

soluciones a su problemática de sequía, que no es una sequía que digas tú es de ahorita es reciente, no.

00:35:57 Speaker 2

Ellos están en el desierto Sonorense y cuando las lluvias caen son lluvias muy fuertes, pero duran unos cuantos, no duran horas dura unos cuantos minutos, cae muchísima agua, pero también la capacidad de retención de sus suelos, que suelen ser arenosos gravosos. ¿Qué es lo que sucede con el agua?

00:36:20 Speaker 2

El agua se filtra y se escurre. ¿Sí?, y ahora hay otra cuestión, Sonora

00:36:29 Speaker 2

Y parte de Arizona son ambientes también agrícolas.

00:36:35 Speaker 2

Entonces, les cae poca agua.

00:36:37 Speaker 2

parte del agua se filtra, parte del agua se evapora porque el sol está a todo lo que da.

00:36:43 Speaker 2

y gran parte del agua lo utilizan para sus cosechas. Entonces a la ciudadanía, pues le viene quedando poco.

00:36:53 Speaker 2

Y por eso entonces ellos sí tienen que buscar soluciones. A parte, a ellos no les llegan los ciclones

00:37:00 Speaker 2

que nos llegan a nosotros. Ya ve que los ciclones si se meten a la axila, que forman la península de Baja California y el país, los ciclones se disipan, pero cuando nos llegan a nosotros aquí a Culiacán, sí, hasta los mochis los ciclones nos dejan a nosotros

00:37:20 Speaker 2

miles y miles de litros de agua en un solo día.

00:37:26 Speaker 2

Y esa agua queda almacenada en las presas, esa es la razón por la cual precisamente entonces, la gente acá en Sinaloa en general no piensa en una alternativa como esa que tú comentabas, porque también.

00:37:41 Speaker 2

hay una gran cantidad de presas en la entidad y captan la lluvia que a veces no cae en la zona costera. No hay problema, pero cae en la Sierra. La humedad del Pacífico

00:37:55 Speaker 2

sube a la Sierra y en las partes altas se condensa, se precipita y gran parte de ella queda almacenada en las presas.

00:38:05 Speaker 2

Esa es la razón por la cual nosotros aquí en Culiacán, bueno, en general en Sinaloa, no nos ponemos histéricos, precisamente.

00:38:16 Speaker 2

¿Por qué razón? Porque tenemos periodos de lluvias también muy fuerte. Sí y gran captación de agua en las presas

00:38:25 Speaker 2

y en los ríos. Ahora si le unimos a esas presas las protegemos un poco y a los afluentes, como los ríos, arroyos, etc. también, y cuando pasan por las ciudades, pues sería mucho mejor, tendríamos mucha más agua disponible para nuestras actividades.

00:38:45

Así es.

00:38:48 Speaker 1

Y hablando de agua, este, pues también está el problema de las inundaciones, ¿no? que tenemos que pues como bien sabemos es por la falta de espacios permeables y de vegetación.

00:39:00 Speaker 1

entonces me puse a preguntarme, ¿no? Sí existen algunas especies que de hecho nos puedan ayudar a, pues, a absorber lo más rápido posible el agua. No sé si usted sepa algo al respecto.

00:39:14 Speaker 2

Precisamente, el problema de las inundaciones aquí en la ciudad viene de que del hecho.

00:39:24 Speaker 2

de que se nos vienen las lluvias de la parte alta,

00:39:28 Speaker 2

Y la no hay vegetación, no hay cobertura de vegetación

00:39:33 Speaker 2

nativa propia en los afluentes que detengan precisamente las corrientes que vienen bastante fuertes. Es decir, no hay Álamos, no hay sauces, no hay higueras.

00:39:47 Speaker 2

Que sean lo suficientemente grandes.

00:39:49 Speaker 2

¿Y cuál es la razón? cuando nosotros vemos

00:39:53 Speaker 2

Los ríos, nos damos cuentas que cuenta de que están conectadas las raíces

00:39:59 Speaker 2

en el cuerpo de agua ¿qué es lo que sucede?

00:40:02 Speaker 2

Tú sabes que han dragado a cada rato, dragan los ríos, el río Humaya, el Río Tamazula y parte del río Culiacán,

00:40:09 Speaker 2

¿Y que es lo que hacen?

00:40:10 Speaker 2

Rompen, precisamente, la unión de las raíces. Esas raíces, cuando el agua viene bastante fuerte, ¿que es lo que hacen?

00:40:20 Speaker 2

Detienen, amortiguan el golpe que trae esa corriente de agua, ese volumen. Como no hay esa cobertura vegetal, entonces el agua se desparrama.

00:40:33 Speaker 2

y se sale de su afluente. Ahí el problema no sería, digamos, las especies de cajón que tienen que quedarse son Los Álamos, los sauces, las higueras, etcétera. ¿No? pero los hemos cambiado, no todos. Si si los hay, no.

00:40:50 Speaker 2

Pero los hemos cambiado en parte en ciertos sitios

00:40:53 Speaker 2

por vegetación que no cumple esas funciones. Ahora te das cuenta, tú, por ejemplo, en la parte digamos hacia arriba del Puente Juárez

00:41:02 Speaker 2

ya hay construcciones, desviaciones del río. ¿Si? esa isla Musala creo que sabes tu de ella, no? esta isla Musala, lo que provocó fue que el río se desviara en lugar de tener una sola corriente.

00:41:19 Speaker 2

se hicieron 2. Pero no solamente eso, la vegetación natural fue eliminada y le dejaron un margen muy estrecho, una pared, muy próxima a al afluente. Entonces,

00:41:37 Speaker 2

antes el río, tú puedes ver fotos históricas, te das cuenta de que el río tenía a los 2 lados llanuras extensas,

00:41:45 Speaker 2

de tal manera que el río se podía, como decimos nosotros, vulgarmente desparramar y no inundaba la ciudad.

00:41:54 Speaker 2

Y ahora entonces el río, ¿qué es lo que se hizo? con el crecimiento de la ciudad, se ha venido angostando su cauce.

00:42:01 Speaker 2

Pero sigue lloviendo en la misma cantidad.

00:42:04 Speaker 2

Entonces, a veces las presas no tienen el suficiente volumen como para captar toda esa toda esa agua de lluvia de las escorrentías y tienen que soltar.

00:42:16 Speaker 2

Pero se han angostado los cauces, ¿y el agua donde va a dar? brinca hacia el malecón o hacia las colonias próximas, hacia la zona, por ejemplo, de Villa satélite, el Barrio, que ahora si tú te das una vuelta y te vas a dar cuenta de que estaban súper construidas justo en la orilla de El río Tamazula, para darte un ejemplo, y si vienes al río Humaya, están

00:42:43 Speaker 2

también construcciones. El estadio de los dorados, siempre estuvo ahí pero en un campito pequeño, ahora es un monstruo, y a un lado del estadio construyeron precisamente desarrollos inmobiliarios que están metidos netamente en el cauce del río y no tienen vegetación.

00:43:03 Speaker 2

2 problemas entonces son fundamentales. El angostamiento del cauce de los ríos, y la ausencia de vegetación natural que cumpla las funciones de amortiguamiento de las corrientes de agua.

00:43:17 Speaker 2

O sea, entonces nosotros tenemos en ese sentido, pues problemas bastante serios de diseño urbano, no?

00:43:29

Así es.

00:43:35 Speaker 1

Como parte de la propuesta que voy a hacer he estado pensando en cómo podemos aprovechar, los arroyos existentes precisamente para lo que usted menciona, no? Para...

00:43:48 Speaker 1

Digo, ya se han tomado malas decisiones de desarrollo urbano, pero entonces, ¿qué podemos hacer para para mejorar esta situación

00:43:55 Speaker 1

Con lo que sí tenemos? con los arroyos, con los canales. ¿Cómo podríamos aprovechar lo que existe para combatir este problema que nosotros creamos?

00:44:06 Speaker 2

Sí, y lo seguimos aumentando, no, porque precisamente eso que dice tú, la ciudad tiene canales precisamente que drenan el agua hacia la zona agrícola. Ya veces se canal principal que le llaman,

00:44:17 Speaker 2

qué pasa ahí por Recursos y sigue hacia Aguaruto y desparrama el agua tanto para la zona de del campo El Diez, toda esa zona que vas a Costa Rica, pero también hacía Navolato.

00:44:33 Speaker 2

¿Qué es lo que se hizo? Y te digo, porque yo vivía ahí en la colonia de Recursos, ese canal tenía monte.

00:44:42 Speaker 2

Tenía las plantas naturales: guamúchiles, guásimas, batamotes.

00:44:50 Speaker 2

Y tenía entonces la vegetación propia de los cuerpos de agua de nuestro municipio.

00:44:59 Speaker 2

¿Qué es lo que se hizo?

00:45:01 Speaker 2

Esos canales se han revestido de concreto.

00:45:05 Speaker 2

¿Ahora entonces?

00:45:06 Speaker 2

¿Qué es lo que sucede? Lo mismo que te comentaba hace rato, ¿no?

00:45:09 Speaker 2

Que se quita la vegetación natural que no cumple.

00:45:14 Speaker 2

El concreto, las funciones propias, por ejemplo, las raíces de esas plantas están insertas en el agua

00:45:22 Speaker 2

y forman entonces hábitat para crustáceos, los cauques que son un ejemplo de ello, que probablemente los has escuchado mencionar...

00:45:31 Speaker 2

Esos esos camarones grandotes que le dicen Cauques.

00:45:36 Speaker 2

Camarones de Río.

00:45:38 Speaker 2

Entonces, los cauques viven en las oquedades propias.

00:45:43 Speaker 2

de las raíces de esas de esos arbustos que están insertos en el lodo,

00:45:48 Speaker 2

Pero también están peces como las mojarras, como los bagres, las tortuguitas de Casquito, que viven junto con esa vegetación. Inclusive te puede decir, en ese canal de recursos en la década de los 70, cuando yo era niño, había hasta Caimanes.

00:46:08 Speaker 2

Ahora no los hay, ¿no los hay por qué razón? Porque no hay donde se protejan, se cubran. Entonces, yo pienso de ahí que tu propuesta sería el evitar, el no cubrir

00:46:21 Speaker 2

los afluentes, esos arroyos, esos canales de concreto. Y los que ya están, pues protegerlos un poco, precisamente con vegetación natural porque tienen un terraplén. Y no solamente, te digo ese canal de recursos, tú te vas al a un canal grande que viene de la presa del Varejonal por la parte de limón de los Ramos,

00:46:45 Speaker 2

¿Qué conoces del limón de los Ramos? Me imagino ha sido mencionar a la

00:46:48 Speaker 2

Salida norte.

00:46:49 Speaker 2

Hay también un canal

00:46:51 Speaker 2

de riego que entra hacia lo que es el Tamarindo, la Palma, etcétera. Ese canal también está revestido de concreto.

00:47:02 Speaker 2

Pero no tienen vegetación que proteja precisamente la radiación solar.

00:47:08 Speaker 2

Tienen un terraplén, un pequeño espacio, un margen para que se puedan poner esas plantas.

00:47:14 Speaker 2

El problema es de que creen que estas plantas pueden reventar las planchas de concreto, pero sus raíces, las raíces de esas plantas, normalmente crecen hacia abajo y no se extienden a los lados.

00:47:27 Speaker 2

Entonces, no son revienta concretos.

00:47:31 Speaker 2

Son revienta concretos, eso si

00:47:33 Speaker 2

Los Álamos porque son bien grandes, no?

00:47:37 Speaker 2

las higueras.

00:47:41 Speaker 2

Pero hay árboles de baja talla como las guásimas como los guamúchiles, que pueden cumplir perfectamente esa función.

00:47:52 Speaker 1

A eso que menciona es muy interesante.

00:47:53 Speaker 1

O sea, las especies que sí se podrían introducir en espacios que ya tienen concreto, este que.

00:48:03 Speaker 1

¿Cuáles me dijo que eran? el guamúchil, la guásima, ¿que otro?

00:48:06 Speaker 2

Ahí pueden producir, por ejemplo, Guamúchiles, guásimas,

00:48:12 Speaker 2

huizaches.

00:48:16 Speaker 2

Que en la zona se dan muy bien, pues entonces y protegen, entonces evitan que el concreto se caliente, si le dan sombra, evitan que el concreto se caliente.

00:48:25 Speaker 2

Y entonces, al no calentarse el concreto, el agua, pues también disminuye sus, digamos, su rango de evaporación o sus cantidades de evaporación.

00:48:36 Speaker 2

Porque también, ¿qué es lo que vemos nosotros en nuestros canales? que están a cielo abierto

00:48:42 Speaker 2

Tú puedes circular

00:48:44 Speaker 2

a lo largo y ancho de donde están distribuidos esos canales, no tienen ninguna protección, ninguna.

00:48:51 Speaker 2

¿Y qué hacen

00:48:52 Speaker 2

Ante la radiación ultravioleta? pues nada, solamente entonces.

00:48:58 Speaker 2

el volumen de agua les puede ayudar, pero aún con eso, la parte superficial se evaporar y se va a perder.

00:49:07 Speaker 2

Entonces, ese tipo de alternativas

00:49:09 Speaker 2

Son muy buenas.

00:49:11 Speaker 2

el asunto está en cómo convencer a los usuarios, cómo convencer

00:49:19 Speaker 2

a las autoridades municipales,

00:49:22 Speaker 2

al mismo Gobierno estatal, a los productores agrícolas, a los ganaderos.

00:49:33 Speaker 2

Y hay otro problema que probablemente tú no has contemplado, que es el de la contaminación que está arrojando la ciudad

00:49:42 Speaker 2

a los cuerpos de agua y a esos parques que están sobre todo a la orilla de los ríos.

00:49:53 Speaker 2

Probablemente no te ha tocado y bueno, es bueno que que no te haya tocado, pero también sería bueno que te dieras una idea. En la época de lluvias, la cantidad

00:50:05 Speaker 2

De agua.

00:50:07 Speaker 2

de origen doméstico, industrial que va a parar al río. El gran problema no es ese, Michelle, el problema es de que.

00:50:16 Speaker 2

En los ríos tenemos parques, no tenemos los dichosos parques de la Ribera, juegan cantidades de gente muchísima, probablemente de haya tocado ver.

00:50:25 Speaker 2

como es que abrieron un puente hace unos días y la ciudad de Culiacán se volcó hacia ese puente, obviamente porque tenemos la cultura "poser", ¿no? entonces.

00:50:37 Speaker 2

La gente no se da cuenta de que escurre y escurre y escurre gran cantidad de agua residual.

00:50:45 Speaker 2

Directamente al río sin ningún tratamiento.

00:50:49 Speaker 2

Y parte de esa agua residual queda

00:50:53 Speaker 2

repartida entre el pasto y las plantas que forman parte del parque donde va la gente se sienta a comer sus cosas, a organizar fiestas infantiles, a jugar porque hay juegos infantiles, a ejercitarse, etcétera.

00:51:09 Speaker 2

Entonces ese es un detalle también que está deteriorando esos espacios de uso público.

00:51:15 Speaker 2

Pero no decimos nada. Y los que llegamos a decir algo, pues.

00:51:21 Speaker 2

"No, no pasa nada".

00:51:22 Speaker 2

O nos tildan de locos. Desde el año antepasado, a mí me tocó publicar en el Facebook un vídeo.

00:51:30 Speaker 2

Para que la gente viera ese detalle. Y quién sabe, por angas o mangas. No sé porque quedó bloqueado.

00:51:35 Speaker 2

¿No? quien sabe.

00:51:37 Speaker 2

A veces uno ni sabe porque no es un ente importante, no es una entre relevante. Y no cree que le suceden esas cosas estrambóticas de que las autoridades lo están vigilando, algo así por el estilo, o sea, quién sabe. No, no sé

00:51:48 Speaker 2

qué pasaría. Pero te digo, entonces,

00:51:51 Speaker 2

recién yo traigo a mis alumnos, precisamente haciendo prácticas de campo, a la orilla del río.

00:51:57 Speaker 2

En la parte de ecología básica para que vean el problema de la eutrofización, la eutrofización es un problema bastante serio porque está contaminando nuestros parques, nuestros cuerpos de agua.

00:52:09 Speaker 2

Entonces ellos ya se dan cuenta

00:52:11 Speaker 2

de ese problema. Si, aprenden y distinguen entre especies exóticas, especies nativas, aprenden a medir diversidades, similitudes. Todos esos parámetros ecológicos que nosotros tratamos de enseñarles para diferenciar comunidades, y ver qué comunidades están afectadas, qué comunidades están más o menos bien conservadas, etcétera.

00:52:33 Speaker 2

Y se dan cuenta de ese problema. Es decir,

00:52:36 Speaker 2

este tipo de ideas impacta mucho en el mundo académico, pero lo que necesitamos nosotros es de que impacte en la toma de decisiones de nuestras autoridades, de nuestros productores agrícolas, ganaderos, comerciales, etcétera.

00:52:53 Speaker 2

Porque hay un problema también en la ciudad.

00:52:57 Speaker 2

El centro de la ciudad tiene sus parques, algunos parques por ahí repartidos, bastantes.

00:53:04 Speaker 2

Pero las calles hasta ahora empiezan a tener especies autóctonas. Probablemente te haya tocado ver a ti

00:53:13 Speaker 2

la coloración amarillenta de las amapas de la lluvia de oro, sí, en un montón de calles de la ciudad.

00:53:21 Speaker 2

Eso es a raíz precisamente de que hemos buscado nosotros impulsar la introducción de estas especies locales.

00:53:31 Speaker 2

Pero no solamente eso, está el casco viejo, el casco antiguo, la parte histórica.

00:53:38 Speaker 2

En la parte histórica tú te encuentras una gran cantidad de árboles ya viejos, pero esos árboles tienen una identidad con un insecto. Sí que se le llama el insecto de las colmenas.

00:53:51 Speaker 2

La gente curiosa se da cuenta de que en esos árboles.

00:53:56 Speaker 2

Hay un montón de pequeños, digamos pequeños ductos, como mangueritas cortas, pero son de cera, de ahí salen montonales de insectos polinizadores. Sí, esa zona de la parte histórica, desde el malecón, digamos.

00:54:17 Speaker 2

Colindando con el puente de la carretera internacional.

00:54:21 Speaker 2

Hasta el Madero.

00:54:25 Speaker 2

Y de ahí hacia arriba, hasta el edificio central de la Universidad Autónoma de Sinaloa. ¿Tú tienes entonces una parte bien importante para un fenómeno natural que es

00:54:38 Speaker 2

el establecimiento de especies polinizadoras que están vinculadas a estos árboles que están ahí, que te los encuentras poco en el resto de la ciudad.

00:54:49 Speaker 2

Y eso es un aspecto cultural que lo sabemos, los viejos, dicen los de acá, y lo sabemos los biólogos.

00:54:55 Speaker 2

Porque entendemos la importancia que tienen estos insectos para la polinización de muchas especies urbanas, principalmente, porque ese insecto se ha adaptado muy bien a las condiciones urbanas y no es para nada nocivo, al contrario, poliniza

00:55:13 Speaker 2

y almacena gran cantidad de miel en las oquedades de los árboles, que por cierto está prohibido estrictamente

00:55:20 Speaker 2

Tumbarlos, golpearlos, etcétera. A propuesta precisamente de los biólogos, esos curiosos que andan queriendo ordenar el mundo.

00:55:31 Speaker 2

Y a ver si lo logran con los arquitectos del paisaje.

00:55:35 Speaker 1

¿Me podría decir cómo se llama esa especie?

00:55:39 Speaker 2

Esta especie fíjate que ahorita no tengo el nombre,

00:55:44 Speaker 2

Pero nuestro amigo Google

00:55:48 Speaker 2

No puedo ayudarte volada.

00:55:50 Speaker 2

De hecho.

00:55:52 Speaker 2

Consulta tu una página en el Facebook se llama plantas regionales de Sinaloa.

00:55:58 Speaker 1

Así, si estoy en esa página.

00:56:01 Speaker 2

Ah, OK, en esa página.

00:56:06 Speaker 2

Busca tú la pingüica.

00:56:11 Speaker 2

Están unos vídeos, ahí estaba, creo que es un vídeo, unas fotos, no sé de ese insecto con las flores, los frutos de las pingüicas y ese en ese lugar que te estoy mencionando, hacia la parte donde están las oficinas de la Comisión Federal de Electricidad.

00:56:29 Speaker 2

Dónde está todo el casco viejo de la prepa central, el estadio universitario. Entonces por esa zona, no?

00:56:37 Speaker 2

Y son abejas melipona se le llama porque no pican, o sea, son tranquilas, no?

00:56:49 Speaker 1

Entonces, si quisiéramos hacer una propuesta para otorgarle más habitat esta especie, o alimento o flores de donde polinizar, ¿tendría algunas recomendaciones?

00:57:04 Speaker 2

Sí. Ahí, por ejemplo, que es importante que sigan manteniéndose, por ejemplo, la planta llamada Pingüica para empezar, las pingüicaa y los guamúchiles.

00:57:19 Speaker 2

Las guásimas.

00:57:22 Speaker 2

Con esas 3, las amapas.

00:57:27 Speaker 2

Sí, bueno, ya son cuatro.

00:57:31 Speaker 2

El trueno que es una planta que tiene unas flores amarillas como trompetita.

00:57:38 Speaker 2

Y es trueno o primavera, le dicen. Entonces, en ellas abreva mucho esa abejita. Y en esa zona.

00:57:48 Speaker 2

Reiteró, es donde hay bastante de este tipo de plantas, por eso está el insecto ahí.

00:57:59 Speaker 1

En esas plantas, ahí viven y polinizan también.

00:58:03 Speaker 2

Polinizan esas plantas y plantas ornamentales, también muchísimas.

00:58:09 Speaker 2

Entonces desempeñan una función digamos,

00:58:14 Speaker 2

pues bastante amplia, son polinizadores extensivos, es decir, no están, no son selectos para una, no, para un montón.

00:58:22 Speaker 2

Pero luego también están en los troncos de los árboles viejos, los árboles viejos per se, ya están ya tienen esa oquedad, ellos no la hacen. Cuando no encuentran esa oquedad ellas precisamente se introducen en las oquedades de las paredes de las bases de las jardineras, etcétera, no?

00:58:42 Speaker 2

Polinizan, pero también almacenan miel, y a su vez ellos sirven de alimento para diferentes aves como las palomas,

00:58:53 Speaker 2

Las “torcacitas” que le dicen a unas palomas chiquitas.

00:58:57 Speaker 2

Los chanates que son ese tipo de, digamos,

00:59:01 Speaker 2

De aves que tu pudiste bueno, tenías que haber conocido aquí en la ciudad, aunque no las hayas tomado en cuenta en un momento determinado, pero son las típicas de aquí, no?

00:59:12 Speaker 2

Chuparrosas... aunque la chuparrosa a otro detalle también algo bueno que tiene también la ciudad, es que es una de las ciudades que tienen mayor abundancia de chuparrosas y diversidad.

00:59:26 Speaker 2

Y es una cosa bien importante porque tenemos nosotros, un especialista, precisamente doctorado en este rollo de las chuparrosas, y está estudiando ahorita el fenómeno vinculado a la adaptación de diferentes especies de chuparrosas al entorno urbano.

00:59:44 Speaker 2

Es decir, que él nos comenta

00:59:48 Speaker 2

que habiendo ese tipo de especies (las chuparrosas y abejas) se garantiza la polinización, y garantizándose la polinización, se garantiza la reproducción de las plantas, de tal manera, dice, teniendo estos insectos, esas aves, nosotros entonces tenemos indicadores del ambiente que nos dicen que no estamos tan mal, no?

01:00:17 Speaker 1

Está muy interesante que usted menciona, ¿Tiene en mente alguna otra especie que para usted considera un indicador del ambiente, o que es su presencia tenga un gran impacto en el resto del ecosistema?

01:00:31 Speaker 2

Fíjate que hay una que.

01:00:34 Speaker 2

Es abundante en la parte alta del río, pero hay muy pocos individuos, son escasísimos raros y debería haber más: Los sabinos.

01:00:45 Speaker 2

¿Cuáles son los sabinos? ¿Conoces, has oído hablar del ahuehuete?

01:00:50 Speaker 2

El ahuehuete tiene su nombre así precisamente porque en la expresión quiere decir “árbol viejo que crece en el río”. Entonces.

01:00:58 Speaker 2

Nuestros ríos deberían de tener, aparte de Álamos de sauces, de guamúchil, deberían de tener también ahuehuetes, pero aquí en la ciudad se les conoce más como Sabino.

01:01:08 Speaker 2

Cuando ella le dices a la gente es que el Sabino es lo mismo que el ahuehuete, entonces ya hay una identidad más, no porque te empiezan a hablar del árbol de la noche triste y ese rollo.

01:01:24 Speaker 2

Entonces, Álamos. Estoy hablando de la parte, digamos sensible del río. Álamos, sauces, guasimas,

01:01:33 Speaker 2

Higueras, sabinos son como de cajón. En el resto de la ciudad, sería bueno y ya empieza a ver precisamente lo que te decía amapas Rosa amarilla, trueno o primavera, lluvia de oro. Eue si bien.

01:01:52 Speaker 2

Ahora no todas las especies. Michelle, que vienen de otros lugares del mundo, son malas, no hay especies que se han adaptado precisamente al a las condiciones ambientales y desempeñan un papel en la trama trófica.

01:02:08 Speaker 2

Esa lluvia de oro, se llama casiafístula, no es oriunda de aquí de

01:02:14 Speaker 2

América. En realidad es una planta, digamos, de Medio Oriente de la parte de Egipto y brindando así Israel, Libia etcétera, para acá.

01:02:22 Speaker 2

Pero está en un ambiente digamos más o menos Mediterráneo y seco en su región de origen. Pero acá en Sinaloa y particularmente en el municipio de Culiacán, la hay en grandes cantidades.

01:02:34 Speaker 2

Muchos impugnaban para buscar que ya no se introdujera a la ciudad. El asunto es, yo comenté entonces en una reunión de este tipo de los urbanistas y ambientalistas,

01:02:46 Speaker 2

que, en realidad, la planta tenía identidad ecológica. Fue cuando me preguntan a mí ¿qué es eso, de identidad ecológica? que la planta, participa en los procesos de polinización, libera unos frutos largos de color café, unas vainas, largotas. Cuando se caen esas vainas,

01:03:04 Speaker 2

y se humedecen, son consumidas por insectos y por algunos mamíferos.

01:03:10 Speaker 2

Entonces, esos mamíferos también se encargan de dispersar las semillas, de tal forma que eso es lo que le decimos nosotros identidad ecológica. Aunque vengas de otro lugar, te adaptas a las condiciones del ambiente y participas

01:03:25 Speaker 2

En las funciones

01:03:26 Speaker 2

que realizan los organismos nativos.

01:03:31 Speaker 2

O sea, llegas y te adaptas bien padre.

01:03:34 Speaker 2

Y ayudas a fulano y ayudas a perengano, y ellos también te ayudan a ti, no?

01:03:40 Speaker 2

Es entonces cuando tú estás formando parte de un nicho ecológico.

01:03:46 Speaker 2

O tienes tu nicho ecológico bien definido.

01:03:59 Speaker 2

Entonces yo creo que sí también hicieras énfasis en la parte de que, nosotros es bueno, que reforestemos, que embellezcamos nuestras ciudades, pero hagámoslo con especies que tengan identidad ecológica. Y ya si te preguntan por la identidad ecológica, aquellas que

01:04:18 Speaker 2

se adaptan a las condiciones del entorno, pero participan, si, en las diferentes funciones de los organismos. Aportan materia argánica, aporta nectar a los polinizadores, aportan frutas o semillas a los mamíferos, a las aves, etcétera. Es decir, esto entonces es identidad ecológica, no?

01:04:44

¿Se le ocurre

01:04:45 Speaker 1

a usted lugares de la ciudad que usted considere que tiene un gran potencial, que en el momento están desaprovechados como lo decía con el canal de recursos, por ejemplo,

01:04:57 Speaker 1

y que podrían tener un gran impacto?

01:04:59 Speaker 2

Si. Bueno,

01:05:08 Speaker 2

Han abierto nuevas colonias y se ha...

01:05:12 Speaker 2

Obviamente, para abrir nuevas colonias, como en la parte del cerro de las 7 gotas, cuando tú vas hacia la parte sur por donde está el mercado de Abastos, enfrente estará un cerro grande, ahí entonces se están abriendo esas colonias, no?, pero.

01:05:27 Speaker 2

Están destruyendo la vegetación original. El asunto es de que esas colonias en lugar.

01:05:32 Speaker 2

De adornar las, de protegerlas con plantas autóctonas, les están introduciendo presente, o los mismos los mismos ciudadanos, están introduciendo especies exóticas.

01:05:45 Speaker 2

De tal forma que son las nuevas colonias a las que hay que enfocarse. Pero otra parte es también digamos.

01:05:55 Speaker 2

¿Qué otros sitios serían adecuados?

01:06:01 Speaker 2

Que yo vea bueno, la zona agrícola per sé, pues ya está afectada, no? Pero grandes centros comerciales que tienen recursos podían modificar, podían cambiar

01:06:12 Speaker 2

esas especies exóticas buscando precisamente tener especies autóctonas, no?

01:06:20 Speaker 2

Y te digo por qué razón, porque se están abriendo centros comerciales aquí en grandes cantidades.

01:06:27 Speaker 2

Ya tenemos- y ahorita por ejemplo tenemos uno gigantesco donde estaba la comercial mexicana, cerca de la Plaza Fórum, la misma plaza fórum es un ambiente que tienes tú.

01:06:39 Speaker 2

Yo creo yo pienso que es por contrato ya preestablecido.

01:06:44 Speaker 2

De que tienen sus propios vendedores y compradores de plantas ornamentales, mediante lo cual precisamente se adornan esos espacios. Ahora, otro aspecto también que es importante destacar es que no hay

01:07:01 Speaker 2

Invernaderos, no hay viveros que se dediquen

01:07:06 Speaker 2

A la reproducción de plantas

01:07:09 Speaker 2

Autóctonas.

01:07:11 Speaker 2

Solamente hay unas cuantas personas que están viendo precisamente este aspecto de reproducir plantas autóctonas, sí, y luego entonces

01:07:23 Speaker 2

están pasando, por ejemplo, a utilizarlas para la apertura de carreteras. La carretera por ejemplo Chihuahua-Parral, hace poco, nosotros vimos que estaban introduciendo especies propias de ahí.

01:07:35 Speaker 2

Brasiles, amapas, palo blanco, etcétera. Al palo blanco, que es un ejemplo también de una planta, un árbol bien llamativo porque da unas flores grandes de color blanco.

01:07:47 Speaker 2

Y ese está vinculado a nuestra cultura. ¿Por qué razón? Porque esas flores de color blanco se las comen los venados. Y debajo de esos árboles.

01:07:58 Speaker 2

se danza precisamente esta cuestión de la danza del Venado, no?

01:08:03 Speaker 2

Y que no hay, no encuentras tú en la ciudad, cuando deberían de estar en la ciudad.

01:08:07 Speaker 2

Entonces te digo.

01:08:09 Speaker 2

Falta ese aspecto, esa visión de una persona y los recursos de una persona de una compañía que se dedique a la reproducción de plantas autóctonas.

01:08:21 Speaker 2

El problema es la desventaja que tienen en la actualidad con respecto a aquellas empresas que ya tienen muchos años reproduciendo especies exóticas que ellos ya tienen una infraestructura instalada, tienen una clientela definida. De tal manera entonces

01:08:41 Speaker 2

Ya tienen su cadena de comercialización, tienen sus contactos en el mundo precisamente de la política.

01:08:48 Speaker 2

De tal forma

01:08:50 Speaker 2

Que aquellos que se arriesgan a la reproducción de plantas autóctonas, pues tienen que empezar desde cero, desde cambiar la cultura de la gente.

01:09:00 Speaker 2

Y luego.

01:09:03 Speaker 2

Establecer su infraestructura, sus, digamos.

01:09:08 Speaker 2

Sus bases de reproducción, ¿qué especies de plantas requiere la ciudad? ¿cuáles que cumplan funciones ecológicas?

01:09:21 Speaker 2

Y luego tener la clientela, no. Entonces,

01:09:25 Speaker 2

Para muchos puede ser, digamos “no, pues podemos tener nosotros semilla y luego empezar a reproducirla en el medio”. El problema es que cuando trae semilla tú de la naturaleza, mucha de esa semilla

01:09:37 Speaker 2

Ya trae sus propios, digamos depredadores, vamos a decir. Porque tienen huevecillos de insectos, los embriones ya vienen mordidos, ya vienen picados.

01:09:51 Speaker 2

Traen los insectos mismos, etcétera, y muchas de las semillas o de los pies de cría que tú consigues para las plantas exóticas. Esas vienen limpias. Es como si las compras, por ejemplo, de Israel, no? Cuando compras la semilla certificada.

01:10:09 Speaker 2

Entonces te digo, es un problema bien grande.

01:10:12 Speaker 2

Eso de tratar

01:10:13 Speaker 2

de cambiar la cultura, porque tiene décadas.

01:10:16 Speaker 2

Muchas décadas tiene.

01:10:18 Speaker 2

Antaño de la ciudad tenía sus árboles típicos: moras, brasiles, guásimas, guamúchiles. Sí, todo eso propio de la cultura de nosotros, pero eso se fue cambiando con el tiempo por las modas introducidas precisamente por nuestros Gobiernos.

01:10:37 Speaker 2

¿De dónde vienen los eucaliptos, las grillas, las casuarinas? de la década de los setentas, con el Gobierno de Echeverría ¿Por qué? Porque el señor estaba

01:10:47 Speaker 2

Archi-enamorado de Oceanía, Australia, Tasmania y Nueva Zelanda eran sus paraísos. Y entonces, por esos convenios existentes, él introdujo gran parte de ese tipo de plantas al país y te los encuentras regados por toda el área nacional. Sinaloa no es la excepción. Ahora,

01:11:12 Speaker 2

te encuentras tú también de que el Gobierno impulsa proyectos silvícolas. ¿Con qué especies? con especies exóticas. Tú ves campos de cultivo, o campos cultivados de eucalipto. Grandes extensiones. Tal parece que ahora,

01:11:31 Speaker 2

el Gobierno este le puso, digamos “el cascabel al gato” y tiene ese programa de sembrando vida.

01:11:39 Speaker 2

Y en sembrando vida. Ahora se busca precisamente

01:11:45 Speaker 2

Producir, el reforestar, sitios con plantas autóctonas y sobre todo con especies frutales también características de los lugares si no, por ejemplo, no ir a plantar manzanos a la ciudad de Culiacán. Sí, sino sabemos nosotros que ahí son los mangos, son las lichis, etcétera.

01:12:08 Speaker 2

Esas especies que inclusive se exportan. De tal manera que nosotros hemos visto que esté sembrando vida, tiene ese beneficio, pero ahora tiene una contra la cultura de nosotros es la “gandallés”.

01:12:26 Speaker 2

¿Qué es lo que se está haciendo en ciertas regiones rurales? Ya cerca de la ciudad de Culiacán

01:12:32 Speaker 2

Se están deforestando espacios con vegetación natural.

01:12:38 Speaker 2

¿Para que?

01:12:39 Speaker 2

Para, precisamente, meterlos a ese programa.

01:12:42 Speaker 2

Sembrar, plantar un montón de especies que están dentro de lo que es el stock de especies de sembrando vida, ¿Por qué? porque sembrando vida, aportar recursos

01:12:54 Speaker 2

A las personas para que lleven a cabo esa actividad.

01:12:59 Speaker 2

Ahí, por ejemplo, me parece que sale hoy en el diario El País, ese diario español que también está en México.

01:13:05 Speaker 2

Sale una nota vinculada precisamente a este problema que está provocando sembrando vida en ciertas regiones rurales de México, y Sinaloa no es la excepción, no?

01:13:15 Speaker 2

Culiacán tampoco, porque ya cerca se está llevando a cabo esa actividad nociva. Lo nocivo no es de que planteen los árboles, no.

01:13:26 Speaker 2

Lo nocivo es de que tumben vegetación natural para abrir espacio para plantar estos árboles y recibir recursos de parte del Gobierno.

01:13:37 Speaker 2

No es un secreto a voces, es una realidad que todos ya sabemos.

01:13:41 Speaker 1

¿Y no se pudiera hacer algo parecido, pero en lugar de proyectos de reforestación, más bien, cómo se aprovechen espacios ya dentro de la ciudad, camellones, banquetas, lo que sea para introducir especies que produzcan alimentos? ¿se podría hacer algo así?

01:13:58 Speaker 2

Si los ha habido. Hace, que te diré, 20-30 años en la ciudad había árboles de mango, Guayaba, naranja, limón.

01:14:11 Speaker 2

Etcétera. Tú te encontrabas por arrayanes, por ejemplo.

01:14:15 Speaker 2

Tú te encontrabas, entonces ese tipo de árboles en el principal casco de la ciudad. El problema desde que la ciudad empezó a crecer bastante y

01:14:26 Speaker 2

Empezaron a cerrar calles precisamente para arreglarlas, para acondicionarlas. En esas aglomeraciones de gente, precisamente los mismos árboles se empezaron a ver afectados porque también, igual que nosotros, sufren depresión, o sea, si tienen mucha gente encima, también ellos se estresan.

01:14:48 Speaker 2

Y aparte no se no se les dio el riego necesario, la luz no les llegaba en cantidades que digamos que ellos las requieren, etcétera. Entonces, el crecimiento urbano, el aumento en la altura de los edificios, por ejemplo.

01:15:02 Speaker 2

Precisamente, se convirtió en todo un conjunto de factores que fueron eliminando esas especies frutales.

01:15:14 Speaker 2

Entonces, ahora, si las puedes encontrar, Pero nada más, por ejemplo, en el casco antiguo, en esa zona que te mencionaba de.

01:15:23 Speaker 2

Ese espacio no, que te mencionaba desde la orilla del malecón a al Madero y de ahí hasta el edificio central, más o menos encuentras diferentes árboles frutales: mangos, guayabas, limoneros, sí? etcétera, ciruelos, esa ciruelas amarillas que nosotros comemos acá.

01:15:44 Speaker 2

Había en toda la ciudad.

01:15:46 Speaker 2

El problema es de que.

01:15:48 Speaker 2

Precisamente, el aumento de la ciudad y el aumento de la población, pues eliminó completamente este tipo de árboles y quedaron especies exóticas que ahora tú ves.

01:15:59 Speaker 2

Por ejemplo, hay 2 especies exóticas fundamentales en la ciudad de Culiacán, el Olivo Negro y el Laurel de la India son de cajón. Y después se les juntó otro amiguito.

01:16:13 Speaker 2

Qué es el neem.

01:16:16 Speaker 2

Ninguno de los 3

01:16:19 Speaker 2

Es de ahí, de la ciudad, para empezar, no es de Sinaloa.

01:16:25 Speaker 2

2 de ellos, el neem y el Laurel de la India,

01:16:30 Speaker 2

Son precisamente de Asia.

01:16:33 Speaker 2

Y el Olivo Negro es una un árbol característico de los bosques perennifolios de mesoamérica.

01:16:44 Speaker 2

Es de lo que es Campeche, Quintana Roo, Chiapas y hacia Centroamérica no.

01:16:50 Speaker 2

¿Cómo se lo sostiene ahí en la ciudad? Pues se le da agua en cantidades industriales.

01:17:00 Speaker 2

Entonces tenemos ese problema cultural que es ancestral.

01:17:06 Speaker 2

Pero que ya es necesario que ustedes, precisamente como generación, empiecen a darse cuenta y empiecen a aportar soluciones y sobre todo a exigir, no porque somos una sociedad también muy agachona.

01:17:18 Speaker 2

Y ese tipo de

01:17:20 Speaker 2

Propuestas actualmente en el mundo están este tornándose cada vez más importantes, más relevantes.

01:17:28 Speaker 2

Ante la problemática mundial del calentamiento global, sí? de la deforestación.

01:17:35 Speaker 2

De la contaminación en las grandes ciudades.

01:17:38 Speaker 2

Es increíble que, es cierto todavía la ciudad de Culiacán no sufre un problema serio de contaminación atmosférica, pero ya empiezas a ver por el flujo del transporte, empiezas a ver ciertos árboles, que en la superficie de sus hojas ya van acumulando hollín, polvo, se enferman, se estresan y se mueren.

01:18:22 Speaker 1

Entonces como conclusión y en base a su experiencia, ¿cómo ha sido esta lucha de intereses de entre lo político, lo social, lo cultural y lo que dice la ciencia, lo que estudian ustedes, los biólogos, como ha sido todo esto?

01:18:43 Speaker 2

Bueno, lo que estudiamos los biólogos y lo que estudian los arquitectos, porque también arquitectos, hay arquitecto precisamente con una mentalidad ambientalista y muchos de ellos se nutren también de aspectos científicos, es decir, no andan gritando nada más porque tienen ganas.

01:18:57 Speaker 2

Como suele suceder con muchos ambientalistas. Es gente preparada que sabe precisamente y que inclusive a nosotros los biólogos nos han enseñado muchas cosas de lo que es el ambiente urbano, no?

01:19:10 Speaker 2

De tal forma, entonces que hemos participado de manera conjunta.

01:19:16 Speaker 2

Con los gobiernos municipales, estatales, inclusive con los gobiernos federales, proponiendo cambios a la arquitectura del paisaje, en el sentido de que nosotros como ciudad de Culiacán.

01:19:31 Speaker 2

Debemos de conservar, de proteger.

01:19:34 Speaker 2

Sobre todo nuestros cuerpos de agua, nuestros ríos, que nos dan identidad.

01:19:38 Speaker 2

Y también proteger aquellos espacios en los cuales nosotros los sinaloenses, tan dados a la violencia, desgraciadamente, pues ahí encontramos solas(¿), encontramos tranquilidad, encontramos recreo, etcétera, no que muchos nos hace falta. Parte precisamente de esa de esa cultura que tenemos nosotros por la que somos conocidos alrededor del mundo, viene precisamente de que ese tipo de espacios.

01:20:10 Speaker 2

No son bien utilizados por nosotros, porque también no están bien acondicionados, no?

01:20:17 Speaker 2

Hasta ahora nos damos cuenta de que nuestros parques no tienen sí en su paisaje una identidad cultural, ¿Por qué? porque no hay esos árboles, esas plantas que.

01:20:32 Speaker 2

Que nos caracterizan, de las cuales, nosotros hablamos.

01:20:36 Speaker 2

Es decir es muy usual, reitero, la población culichi en gran cantidad es de origen rural,

01:20:46 Speaker 2

Y trae su cultura rural, su conocimiento sobre flora y fauna.

01:20:52 Speaker 2

De tal manera que nos hablan, nos preguntan por los guamúchiles por las guásimas, por las moras, por los sabinos, etcétera, ¿por que no los hay aquí? y entonces, porque precisamente los encargados de parques y jardines,

01:21:08 Speaker 2

Los mismos presidentes municipales.

01:21:11 Speaker 2

no tienen ese... yo digo que es desconocimiento.

01:21:20 Speaker 2

Ellos quieren también soluciones inmediatas. Quieren algo que se Note inmediatamente. Algo que no se le caiga el follaje, que no atraiga, aves, mamíferos, etcétera, enfadosos para que no se asuste a la gente, pero no se dan cuenta de que esa es la parte fuerte, Michelle.

01:21:39 Speaker 2

¿Por qué razón? Porque la gente hablando nada más del parque, las riberas, la gente va a una sola cosa, al parque de la Ribera: a ver las iguanas. No sé si a ti te ha tocado precisamente.

01:21:51 Speaker 2

Si hay un.

01:21:52 Speaker 2

Sitio en el mundo con una población tan densa de iguanas.

01:21:58 Speaker 2

Ese es precisamente la parte del parque Las Riberas. La ciudad de Culiacán. Y solamente por ese hecho la gente va a verlas. Ahora, esa especie que es bien carismática por lo antigua, por la exótica también, aunque es de nosotros ¿no? es propia nosotros, pero a la gente le llama la atención ver a ese gran dinosaurio caminando ahí entre ellos. Ahora tiene también un problema.

01:22:26 Speaker 2

Que a esas

01:22:26 Speaker 2

Especies que están relacionadas básicamente con 4 árboles:

01:22:32 Speaker 2

Con Álamos, con sauces.

01:22:35 Speaker 2

con guamúchiles,

01:22:38 Speaker 2

Con las higueras, pues tiene.

01:22:42 Speaker 2

Una reducción en cuanto a la cantidad de ese tipo de árboles que son su hábitat. Hay 2 especies de iguanas ahí,

01:22:51 Speaker 2

y carismáticas las 2 por ser iguanas, pero una no viven en los árboles, les vale. Entre más desnudo

01:22:58 Speaker 2

Está el suelo

01:22:58 Speaker 2

Ellas felices porque hay más oquedades porque vienen las cuevas, en las banquetas, etcétera. No se suben a los árboles, salvo que estén secos.

01:23:06 Speaker 2

Entonces, pero las Iguanas Verdes o Baquetas que les dicen, ellas si dependen de esa cobertura vegetal de esos cuatro especies que te menciono ¿Por qué? porque se comen los frutos de las higueras, se comen los frutos de los guamúchiles. Se comen un montón de insectos que van a comerse esos frutos.

01:23:26 Speaker 2

Y luego viven en las oquedades de Los Álamos y los sauces. Pero no solamente eso, ellos perchan. ¿Qué es eso de percha? ellos salen en las mañanas,

01:23:39 Speaker 2

Se suben a las ramas de esos árboles, abren la boca y están captando la luz, se activan.

01:23:46 Speaker 2

Y entonces se activan y realizan- empiezan a realizar sus actividades normales.

01:23:51 Speaker 2

Pero cuando no hay ese tipo de especies, ellos tienen un problema porque entonces se van a las banquetas, se van a las paredes.

01:24:01 Speaker 2

Sí, y ahí quedan desprotegidas, y las matan los gatos o los perros, etcétera. Son un montón de cosas bien interesantes que están vinculadas a nuestros espacios verdes en la ciudad de Culiacán.

01:24:16 Speaker 2

Pero entonces, ¿cómo cambiar ese aspecto cultural? diciéndole a la gente las bondades que tiene el hecho de que en lugar de que tengamos plantas de por allá de Oceanía, etcétera tengamos, alamos, tengamos sauces, tengamos guamúchiles, tengamos Higueras.

01:24:31 Speaker 2

¿Por qué? Porque cumplen una función, protegen el río, y están relacionadas con la fauna, con las iguanas que ustedes quieren mucho, con las ardillas, etcétera. Yo creo que por ahí nosotros le podemos hacer llegar a la gente esa situación.

01:24:46 Speaker 2

¿Por qué? Porque ya cada vez las nuevas generaciones

01:24:50 Speaker 2

Tienen más información en el aspecto ecológico, de tal forma que ya tenemos que hacerle ver.

01:24:58 Speaker 2

Sobre todo a esa...

01:25:00 Speaker 2

Digamos a ese conjunto, a esos jóvenes que ya tiene que empezar a tomar decisiones, a participar de manera más activa en la toma de decisiones. Somos muy agachones, no queremos participar nosotros en las actividades ambientales.

01:25:17 Speaker 2

Pero manifestándonos. Si tú invitas a los chicos a reforestar, los chicos van a reforestar aunque no sepan, pero ellos saben que es por su bien. Si tú invitas a los chicos a recoger plásticos, los chicos van.

01:25:31 Speaker 2

Sí? hace poco nosotros fuimos a muestrear.

01:25:35 Speaker 2

Con 38° de temperatura y una humedad del 90% a los cerros de aquí de la localidad, que yo la neta dije, “hasta aquí llegaste Saturnino”.

01:25:46 Speaker 2

Y los muchachos encantados de ir a muestrear. ¿Será precisamente por la cuestión de que tuvieron encerrados tanto tiempo? ¿O será porque realmente necesitan ese espacio abierto? Hay otro detalle que también es importante ahora para tu tema.

01:26:02 Speaker 2

Que cada vez hay más gente que sale a caminar a los cerros. Probablemente te han hablado de ti del hípico,

01:26:10 Speaker 2

O del cerro... si no, entonces te vas a dar cuenta de ese detalle que ya sale más gente a caminar.

01:26:16 Speaker 2

Precisamente estos espacios. Y nosotros aplicamos un principio de que tú no vas a proteger, no te vas a enorgullecer de lo que no conoces.

01:26:25 Speaker 2

Pero cuando lo conozcas, entonces ahí sí te vas a dar cuenta del papel que desempeña para tu vida cotidiana, no?

01:26:32 Speaker 2

Y eso es bueno. Nosotros hemos impulsado este tipo de actividades, talleres presente para identificar las especies de plantas de la zona urbana:

01:26:43 Speaker 2

Los árboles del río, los árboles de los parques, etcétera. Entonces, cada vez la gente está participando y quiere aprender más de eso. Ahora,

01:26:52 Speaker 2

Falta, eso sí.

01:26:54 Speaker 2

Que las autoridades se pongan las pilas y realmente desempeñen las funciones necesarias. Que utilicen esa información para que entonces favorezcan el entorno verde de la ciudad.

01:27:10 Speaker 2

Trayendo plantas exóticas

01:27:12 Speaker 2

que no tienen identidad cultural y que no tienen identidad ecológica, lo que están haciendo precisamente es afectar más el entorno verde del espacio urbano.

01:27:24 Speaker 2

Y se gastan millones, millones, cantidades industriales. Como mexicanos, nosotros inmediatamente, pues se nos paran las antenitas, no?

01:27:36 Speaker 2

Y empezamos a pensar cosas malas, ¿a dónde van a parar esos millones?

01:27:40 Speaker 2

En el negocio.

01:27:45 Speaker 1

Pero es oportunidad también porque.

01:27:47 Speaker 1

Si uno.

01:27:48 Speaker 1

les demuestra que el introducir especies nativas les va a costar menos por todo el mantenimiento, pues tal vez se convenzan un poquito más.

01:27:57 Speaker 2

Sí, sí o sea.

01:27:59 Speaker 2

Cambiar esa, esa, esa idea que tiene, ya hay muchos políticos jóvenes, eso es lo bueno, que también los jóvenes se inserten en el mundo de la política y que sean jóvenes preparados, conscientes de su papel.

01:28:10 Speaker 2

No? eso es lo más importante. De tal manera que tenemos que ir arrojando ya esos políticos viejos, anquilosados, con ideas retrógradas.

01:28:23 Speaker 2

Pero también creo que la ciudadanía ha dejado de participar en la manifestación.

01:28:32 Speaker 2

Participa en la actividad, pero no participa en la manifestación, pues.

01:28:39 Speaker 2

Es, como decimos nosotros acá, es muy aborregada, sí, adelante.

01:28:44 Speaker 1

No, que sí. ¿A qué se refiere?

01:28:48 Speaker 2

Es muy aborregada, te digo porque es.

01:28:50 Speaker 2

Es, como dicen.

01:28:53 Speaker 2

Si recibe ordenes, lo hace, si no recibe órdenes no lo hace.

01:29:01 Speaker 2

Te digo, nosotros recibimos pocas propuestas de la raza, este, “oigan, ¿por qué no dan un curso sobre polinizadores o sobre las especies carismáticas de la ciudad?”, etcétera, y nosotros estamos disponibles porque nosotros salimos- por la formación propia, nosotros salimos cada fin de semana al monte.

01:29:25 Speaker 2

o a un parque X

01:29:28 Speaker 2

De tal manera entonces

01:29:30 Speaker 2

Que requerimos ese contacto y siempre estamos disponibles para eso, porque sabemos que, digamos el compromiso que tenemos con la ciudadanía.

01:29:42 Speaker 2

Porque es gracias a ellos que nosotros salimos adelante con nuestros estudios de tal manera que nosotros estamos siempre listos... y digo como nosotros, como ese grupo de profesionistas muy bien formados,

01:29:57 Speaker 2

Que estamos siempre dispuestos a participar de a gratis.

01:30:01 Speaker 2

Con la ciudadanía, con el municipio, con las asociaciones civiles, etcétera, no?

01:30:13 Speaker 1

¿Pero qué se refiere con que falta participar en la manifestación?

01:30:17 Speaker 2

En la manifestación es de que la gente, digamos, no exige

01:30:23 Speaker 2

De buena manera y en masa. Sí?, cambios en.

01:30:28 Speaker 2

En, digamos.

01:30:30 Speaker 2

En la estructura de la ciudad, en el paisaje, en el transporte, etcétera, sino que a la sociedad... si el presidente municipal dice "se va a cambiar la dirección de la calle Obregón ya no va a ser de norte a sur y de sur a norte", como antes era que tenía las 2 direcciones. Se le ocurrió y entonces ahora es de

01:30:58 Speaker 2

Norte a sur, solamente. Y se convirtió en un caos precisamente, porque nos cambió las rutas de transporte, etcétera, a muchos ciudadanos, pero los ciudadanos.

01:31:08 Speaker 2

Se manifestaron poco.

01:31:10 Speaker 2

Es decir, es ahí entonces donde el ciudadano tiene que salir en masa, "¿te afecta? Te afecta mucho, te afecta poco, etcétera, etcétera.

01:31:17 Speaker 2

Reunir las opiniones y, si es necesario entonces exigir a nuestras autoridades, entonces saliendo a manifestarnos. Se te hace a ti

01:31:29 Speaker 2

Padre, por ejemplo, que salgan a manifestarse precisamente para que saquen del bote al Chapo Guzmán.

01:31:37 Speaker 2

Cualquier persona con un poquito de seso dice ¿qué le pasa a esta sociedad?, su río está recibiendo grandes cantidades de aguas residuales

01:31:49 Speaker 2

Y la raza no dice nada.

01:31:51 Speaker 2

Su río está siendo deforestado, cambiado de ruta. Su río está haciendo permanentemente casi cada 3-4 años dragado.

01:32:01 Speaker 2

No le interesa a la gente, entonces dice, ¿por qué? Porque la gente también tiene desconocimiento, no? Y entonces también faltan líderes que lleven a esa gente a esa masa.

01:32:12 Speaker 2

A ese tipo de manifestaciones

01:32:14 Speaker 2

en beneficio de todos.

01:32:21 Speaker 2

Esa es la parte de la manifestación que te comento, pues los muchachos van a salir a vestirse de otakus, o de esas figuras de anime, etcétera. ¿Iban a participar tan activamente? Yo creo que ahí donde estás tú no se celebró

01:32:36 Speaker 2

tan efusivamente el Halloween como se celebró precisamente aquí en la ciudad de Culiacán, el sábado o el domingo en la noche.

01:32:47 Speaker 2

Miles, miles de personas.

01:32:50 Speaker 2

Festejando el Halloween, ya no hay Covid, Michelle, ya no hay nada.

01:32:56 Speaker 2

Y la gente se reunió para eso. Qué bueno sería entonces que hubiera una cabeza pensante y sobre todo una cabeza aceptada con buena opinión, con confianza por parte de la ciudadanía que los llevará precisamente.

01:33:07 Speaker 2

A revisar su entorno.

01:33:10 Speaker 2

Y así esas propuestas, esas ideas que tú tienes.

01:33:14 Speaker 2

Pues entonces pegarían, porque son buenas, no?

01:33:19 Speaker 2

Y los políticos ante esta manifestación social es cuando entonces, si se ponen a temblar, y si entonces cambian decisiones tontas, y toman en cuenta a la ciudadanía.

01:33:35 Speaker 2

Mientras ésta no se manifieste.

01:33:38 Speaker 2

No pasa nada.

01:33:40 Speaker 2

Y eso aplica.

01:33:42 Speaker 2

“Ah, no, no, no, no. Nadie se quejó. Nadie dijo nada.”

01:33:47 Speaker 2

¿Qué es lo que sigue? “todo

01:33:48 Speaker 2

Está bien”. ¿sí o no?

01:33:54 Speaker 1

Sí, he notado esa diferencia de venirme para acá y darme cuenta que incluso en la escuela se me motiva que piense yo, a que proponga y a que qué importa si no estás de acuerdo con el maestro, y eso es algo que yo no veía en México no. Allá, es tú, sigue lo que te dice el jefe.

01:34:09 Speaker 2

No, exacto.

01:34:13 Speaker 2

Lo que te dice él, eso es.

01:34:15 Speaker 2

Es el mantra que tú vas a seguir, es el dogma y hasta ahí.

01:34:19 Speaker 2

Entonces no nos llega inclusive a muchos de los de los profesores, a los docentes, no solamente en la Universidad, donde precisamente ya el alumno tiene una idea, tiene conocimientos, tiene una experiencia y tiene obviamente digamos sus deseos de manifestarse, no?, sino desde la escuela primaria, desde el Kinder, lo que diga el profe eso es.

01:34:42 Speaker 2

Sí, habemos pocos, y yo estoy dentro de esa Mancha.

01:34:45 Speaker 2

Que le exige al estudiante que proponga, que manifieste sus ideas.

01:34:52 Speaker 2

Estudiantes que salen al mundo profesional y no saben cobrar sus trabajos.

01:34:58 Speaker 2

No lo saben cobrar y les da pena a veces cobrar. “Chicos, les cobra el médico, les cobra el ingeniero, les cobra el abogado, les cobra el arquitecto,

01:35:09 Speaker 2

¿Y ustedes les da pena cobrar porque hicieron un estudio de impacto ambiental? Resulta que ese estudio es necesario para que se realice una obra.

01:35:18 Speaker 2

Y si no hay el aporte de ustedes, esa obra no se realiza.

01:35:23 Speaker 2

¿O imagínese ustedes?”

01:35:25 Speaker 2

No tienen propuestas que... que todas las propuestas sean en pro de la construcción de obras que a las claras estén afectando a la naturaleza.

01:35:34 Speaker 2

A la larga, eso como sociedad nos va a afectar bastante y nos está afectando en la actualidad, no?

01:35:42 Speaker 1

Así es.

01:35:44 Speaker 2

Sí, entonces, qué bueno que allá este.

01:35:48 Speaker 2

Si no tenías tú, digamos facilidad para expresar tus ideas, etcétera, etcétera, o no te daban chance, pues órale, es hora. Y si tú te insertas en este mundo precisamente de la docencia y la investigación, etcétera.

01:36:02 Speaker 2

Piensen compas, piensen, piensen, piensen.

01:36:07 Speaker 2

De eso se trata este negocio, no de lo que nos paguen.

01:36:10 Speaker 2

La ganancia es un plus, si nosotros disfrutamos lo que hacemos y aparte nos paga por eso Welcome ¿no?.

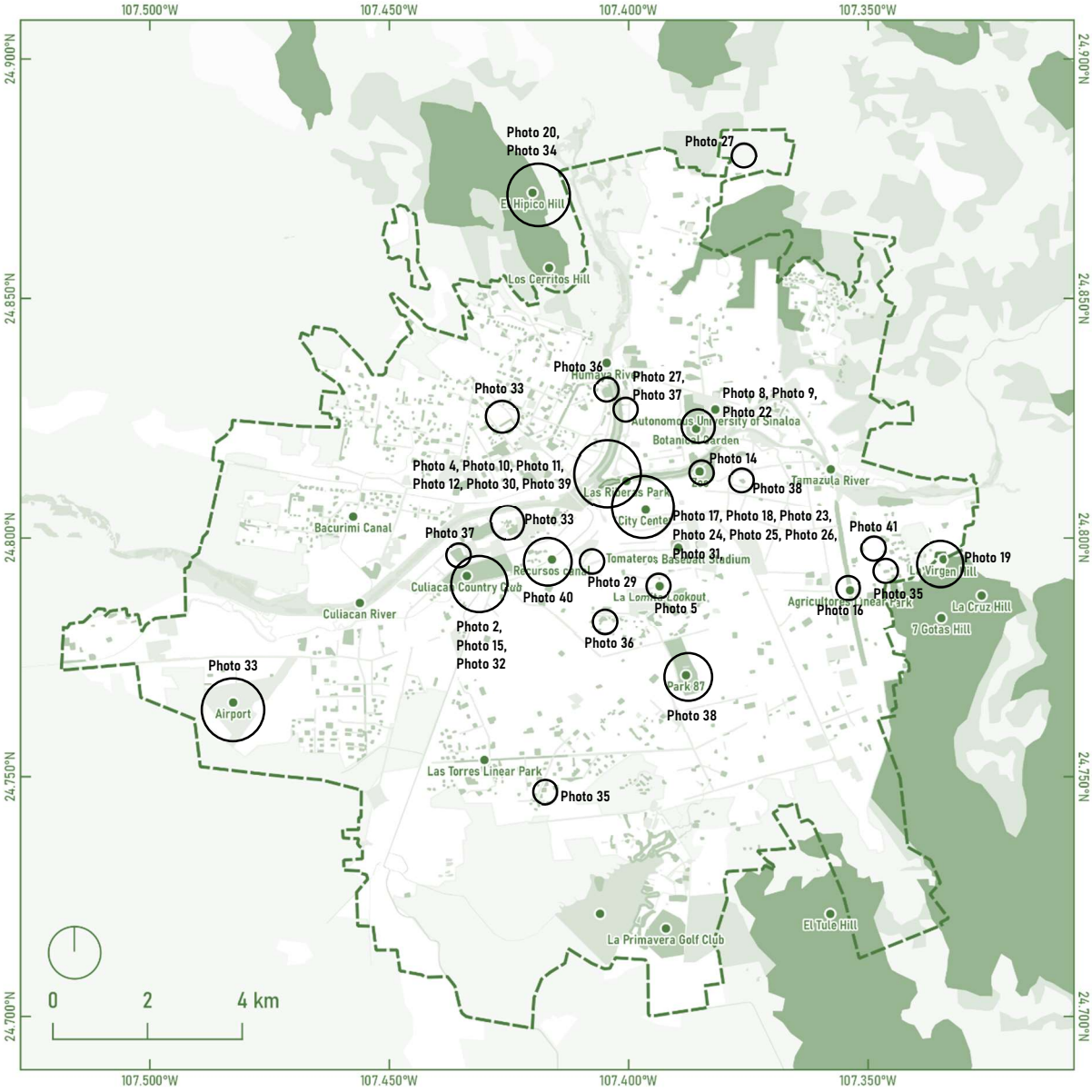
01:36:19 Speaker 2

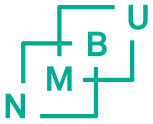
Y podemos aportar a nuestra sociedad, entonces somos entes felices, aunque vivamos debajo de un árbol, dijo el filósofo griego aquel.

01:36:29 Speaker 1

Tiene usted toda la razón

7.3 Appendix C. Map of all photos of Culiacán included in this document





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