Green Infrastructure for Metropolitan Areas in Mexico

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Abstract
Mexicans have decided to live in large metropolitan areas, this is a fact since the year 2000, when most of the country's population lives in one of them. However, this change in population distribution was not paired with key components for sustainable development, such as large green areas which could define metropolitan level green infrastructure (GI). Metropolitan areas should include a network of strategically planned and managed natural areas to preserve living ecosystems, build resilience for climate change and at the same time provide the population with the benefits associated to living near GI.
This study aims at defining the main features of Metropolitan GI, how it should look like and what criteria should be considered in order to face climate change. Although neighborhood and urban green areas are well specified in planning literature, there are no references for the metropolitan scale; therefore, to address this gap the article elaborates an inventory of the GI in place in one actual Metropolitan Area. The selected case study is the second largest city in Mexico with 4.8 million inhabitants, but with little information about its GI: the Guadalajara Metropolitan Area (GMA). In order to understand how the existing GI helps climate change mitigation and adaptation, the urban ecosystem services actually provided are highlighted. This services include provisioning (urban agriculture and water sources), regulating (climate regulation, water infiltration, erosion control), cultural (tourism and recreation), and supporting and habitat (habitat for species and diversity).
The study uses existing plans, images and local sources as inputs for spatial analyses, which are complemented with field visits to monitor and calibrate the information. By assessing the services provided by existing GI, as well as conducting a suitability analysis of the metropolitan territory, this article also shows the potential areas which could help enhancing/ building a comprehensive GI system for the GMA.
The article concludes with recommendations that could help consolidate and enhance the Green Infrastructure of the GMA. These recommendations could be considered for future cool Metropolitan planning and resilience.

Key words: Green Infrastructure ï Metropolitan Planning ï Guadalajara.

1. Mexican Metropolization

Mexico has gone through an urbanization process of several stages (Unikel, Ruiz Chiapetto, & Garza Villarreal, 1976) which has led the population of the country to live predominantly in cities since 1980. Within this process, it is required to point out the phenomenon of metropolization: a tendency to the physical articulation of localities that formerly operated independently, but that now are integrated forming a single unit, in such a manner that they add up to a population of 50,000 inhabitants, whether they are localities of a single municipality or, alternatively, localities that are based in two or more municipalities that show a degree of physical and functional integration (SEDESOL - CONAPO - INEGI, 2012).
Large metropolitan areas became the predominant form of population concentration in Mexico from the year 2000 on, when more than 50% of the population was already settled in 55 metropolises (idem, 2012). This phenomenon continues to be a trend and will probably last for a few more years (see Table 1).
In 1980, there were already 26 Metropolitan Areas (MAs) in the country, of which Mexico City, Guadalajara and Monterrey stood out; by the year 2010 there were 56.8 million inhabitants in 59 MAs.
The substantial concentration of people in MAs -mainly due to migration from other cities, has caused the territory to be occupied without regard for the most sensitive natural areas that represent the potentiality of bringing nature to the metropolis, leaving the environment out of the urban structure and therefore, failing to reach the global target of a sustainable urban

development (UN-Habitat, 2009, United Nations, 2015). It is even possible to affirm that the system of open green spaces has yet to be recognized in the metropolises as a fundamental element of the networks/infrastructure systems of a city.

Indicator	1980	1990	2000	2010
Metropolitan areas	26	37	55	59
Districts and metropolitan municipalities	131	155	309	367
States	20	25	29	29
Total population (millions)	26.1	31.5	51.5	63.8
National Population Percentage (%)	39.1	38.8	52.8	56.8

Table 1. Indicators of the metropolization process 1980-2010. Adapted from SEDESOL - CONAPO - INEGI, 2012.

The environment thus, is a fundamental system that has been affected by the urbanization process, and which is necessary to attend given that all the changes made by the human being in metropolitan territories have ecological and socioeconomic effects. Among the first, we count the loss of natural areas that are replaced by the development of housing, roads and other city needs; this development has also caused the fragmentation of natural spaces, which in terms of biodiversity limits the possibility to preserve existing resources; as well as the degradation of water resources when rivers are erased with earthworks and when aquifers are overexploited; overall, nature's ability to respond to changes is diminished. Among the latter, it stands out the loss of "free" natural services such as flood control and at the same time, the risk of floods increases, which leads to great economic losses as well as the loss of human lives; additionally, the uncontrolled urban growth in the distant peripheries of the cities causes disproportionate expenses for the introduction of infrastructure for mobility, water and electricity (Benedict & McMahon, 2001).

Despite this situation, when reviewing the metropolitan public agenda it is evident the great concern that exists to know and to plan the infrastructure for mobility, for the supply of electricity, for the provision and treatment of water, or even for rainwater (gray infrastructure); but it is also evident the lack of a commitment to understanding and planning for a system of metropolitan green spaces to support the natural environment, particularly to increase environmental sustainability (Benedict & McMahon, 2001, Vásquez, 2016, IMEPLAN, 2016).

Just as in other urban/ metropolitan infrastructures systems, a multi-scaled approach is necessary in which a specific recognition of the relationship between patterns and processes carried out in the territory can be accomplished. This approach implies the establishment of main and secondary systems in order to achieve an efficiency at a regional / metropolitan level but also at a local, intra-urban level. The observance of an order of hierarchy as established in the planning of the most recognized urban systems (roads, water, sewers, electricity, among others) must also exist in the way we plan green spaces; namely, green infrastructure.

Like any system, existing and potential nodes and links should be identified where there are important connections in order to interrelate the different hierarchical levels, which in urban contexts are multiple scales such as the regional / metropolitan, the districts / neighborhoods and the plots or individual sites (Ahern, 2007).

These elements are present in the territory through a spatial language that according to Ahern (2007), is distinguished as a "Mosaic Model". This model uses the following three elements of the landscape to define its structure: patches, corridors and the matrix. Patches are homogeneous polygons of the territory that differ from their surroundings (they provide multiple functions, including wildlife habitat, aquifer recharge areas, or sources and sinks of species and nutrients). Corridors are areas with an elongated shape such as pathways for the flow of animals, nutrients, and wind. The matrix refers to the dominant land cover in terms of area, degree of connectivity and continuity (see Table 2).

Urban Patches	Urban Corridors	Urban Matrix
Parks	Rivers	Residential Neighborhoods
Sportsfields	Canals	Industrial Districts
Wetlands	Drainageways	Waste Disposal Areas
Community Gardens	Riverways	Commercial Areas
Cemeteries	Roads	Mixed Use Districts
Campuses	Powerlines	
Vacant Lots	Poliducts	

Table 2. Elements of the urban landscape as classified in the model Patch - Corridor ï Matrix. Adapted from Ahern, 2007.

2. Biophilic Cities: Between Sustainability and Resilience

Sustainability has already been extensively addressed by the existing urban planning literature. It is appointed as a holistic frame of reference to guide the development of cities, and to simultaneously improve their performance among the three dimensions of sustainable development: economic development, social equity and the protection of the environment (Campbell, 1996, Farr, 2007, UN-Habitat, 2009).

In addition to sustainability, another concept that has been incorporated into theoretical discussions about cities is that of resilience. The impacts of global climate change (i.e., an increasingly volatile climate and the large number of disasters and the consequent damages that have occurred around the world) have turned resilience into an urban and metropolitan aspiration (Metropolis Observatory, 2017). What started as adaptation to disasters and damages, has currently expanded to discussions about resilient cities, which take into account in a wide range the potential impacts and stress that cities will most likely face in the future: water scarcity, rise in food prices, and increasingly high temperatures during the summer, among others (Newman, Beatley, & Boyer, 2008). Resilience can be defined in several ways; in this study it is understood as the ability to successfully adapt and to respond to those impacts. The word resilience is derived from Latin *resiliere*, which means to spring back or to rebound. Godschalk (2003) describes resilient cities as ones "capable of withstanding severe shock without either immediate chaos or permanent harm... While they might bend from hazard forces, they would be able to adapt and would not break. Composed of networked social communities and lifeline systems, resilient cities would become stronger by adapting and learning from disastersò

Resilience does not imply a return to dysfunctional or unsustainable conditions, but adaptation to dynamic social and ecological conditions in ways that protect and enhance quality of life, long-term ecological productivity, as well as public and personal health of the inhabitants of the MAs. Resilience is not only a matter for cities and metropolises, but has important implications for both individuals and families, which is precisely at the level where the stresses, pressures and shocks of modern life will come to bear (Beatley & Newman, 2013).

In order to improve sustainability, but above all to increase resilience, cities may become biophilic, and there are several paths through which biophilic urbanism can make it happen. Some of them have already been thoroughly studied, but others are still experimental and require extensive analyses (see Table 3).

One of the clearest paths is biophysical, the resilience benefits provided through the protection and enhancement of the natural systems and features in and around a city (Beatley & Newman, 2013). The natural systems in a city and region provide essential services that help cities and urban regions respond to and spring back from climatic and natural events. Cities with large natural wetland systems will be better able to absorb flood waters from hurricanes and storms, for instance. Protecting and restoring these great ecological systems is a key strategy that allows cities to be more resilient in the face of disasters.

Biophilic Conditions and Infrastructure
-Percentage of population within a few hundred feet or meters of a park or greenspace; -Percentage of city land area covered by trees or other vegetation; -Number of green design features (e.g., green rooftops, green walls, rain gardens); -Extent of natural images, shapes, forms employed in architecture and seen in the city; -Extent of flora and fauna (e.g., species) found within the city.
Biophilic Behaviors, Patterns, Practices, Lifestyles
-Average portion of the day spent outside; -Visiting rates for city parks; -Percent of trips made by walking; -Extent of membership and participation in local nature clubs and organizations.
Biophilic Attitudes and Knowledge
-Percent of residents who express care and concern for nature; -Percent of residents who can identify common species of flora and fauna.
Biophilic Institutions and Governance
-Priority given to nature conservation by local government; percent of municipal budget dedicated to biophilic programs; -Existence of design and planning regulations that promote biophilic conditions (e.g., mandatory green rooftop requirement, bird-friendly building design guidelines); -Presence and importance of institutions, from aquaria to natural history museums, that promote education and awareness of nature; -Number/extent of educational programs in local schools aimed at teaching about nature; -Number of nature organizations and clubs of various sorts in the city, from advocacy to social groups.

Table 3. Important elements (indicators) of a biophilic city. Adapted from Beatley, 2011.

Large wooded areas provide ecological benefits that will make cities more resilient -including effects such as moderation of air pollutants, cooling through evapo-transpiration and shading as well as flooding reduction.
Protection and restoration of rivers and urban streams reduce the vulnerability to floods, provides important cooling benefits and helps to moderate the weather and temperature changes predicted as a result of climate change. That is why cities with extensive networks of parks and green spaces are also likely to fare better in the face of long term climate change (idem, 2013).
Biophilic urbanism can help to protect or strengthen favorable climatic and micro-climate conditions in cities, which also helps them become more resilient in the face of a host of emerging resource scarcities likely in the decades ahead (idem, 2013).
ñGreeningò cities can significantly reduce energy consumption for heating and cooling by the function of trees as climate regulators. In promoting modes of urban mobility other than automobiles (walking, bicycling) there is the possibility of greater resilience in the diminished oil supplies. Additionally, the principles of biophilic urbanism can achieve significant water conservation, but also, through the protection of peri-urban farms and agriculture and by promoting urban agriculture, might help to ensure the food security of a city (idem, 2013).
A biophilic city is one with abundant biodiversity, full of nature, a place where residents see, feel and experience the richness of plants, trees and animals in the course of their lives, and do so in their homes, in their jobs, in the spaces where they perform recreational activities, as well as they commute. The components of nature, large and small, from the tops of trees to the invertebrates and even microorganisms that are part of larger natural elements and ecosystems, define a city and provide it with character and meaning (Beatley, 2011).Biophilic

cities are not simply green cities; the abundant presence of nature is a necessity but it is not a sufficient condition. In biophilic cities, the residents are directly and actively engaged in learning, enjoying, and protecting the nature that surrounds them and with which they have developed an important emotional connection (idem, 2011).
The possible indicators that should be integrated in a city in order to be considered biophilic are composed by the conditions and infrastructure, behaviors, patterns, practices and lifestyles, attitudes and knowledge, as well as institutions and governance (see Table 3).

3. Green Infrastructure (GI)

Green Infrastructure (GI) is a strategically planned network of high quality natural and semi-natural areas with other environmental features which must be designed and managed to provide a wide range of ecosystem services and to protect the biodiversity in both rural and urban settings (EEA - European Environment Agency, 2011).
The GI is a tool to deal with environmental problems through different solutions based on natural processes. Biodiversity acts as its central axis, since the functioning, resistance and quality of ecosystem services depend directly on the richness and abundance of the species that house the elements that make up the system. It also promotes the creation of ecological networks at different scales, requires spatial and temporal planning as well as an adequate design and is based on collaboration between citizens, managers and politicians (idem, 2011).

Habitat Services	Biodiversity and species protection.	-Wildlife habitat. -Migratory species permeability. -Habitat networking.
Regulating Services	Adaption and mitigation against climate change.	-Mitigation of the urban heat island effect. -Reinforcement of the resilience of ecosystems to climate change. -Retention of water and decrease of runoff to reduce flood risks. - Carbon seize and storage. -Encouragement of sustainable traveling. -Reduction of energy consumption to heat and cool buildings. -Encouragement of renewable energies. -Promotion of sustainable mobility.
Provisioning Services	Water regulation	-Sustainable drainage systems ï reduction of runoff. -Increased water infiltration. -Water treatment.
	Food production and security	-Food supply and production of raw materials in agricultural areas, orchards, among others. -Maintenance of the fertility of agricultural land. -Development of the soil and the cycle of nutrients. -Prevention of soil erosion.
Cultural Services	Recreation, wellness and health.	-Recreational activities. -Aesthetic appreciation of nature. -Clean air. -Tourism / Ecotourism.
	Land value.	-Positive impact on the land and its property.
	Culture and sense of community.	-Local identity. -Opportunities for education, training and social interaction. -Opportunities for tourism.

Table 4. Ecosystem services provided by green infrastructure. Self-elaborated with information from Millenium Ecosystem Assessment, 2005 and European Environment Agency, 2011.

According to the classification of ecosystem goods and services, the benefits of the GI are classified into four groups: habitat services, regulating services, provisioning services and cultural services (idem, 2011). The first ones refer specifically to the habitat of species of flora and fauna; the second are those that generate benefits from the regulation of ecosystem processes; the third to products that are generated directly in the ecosystem; and the cultural ones are intangible benefits that people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences (see Table 4). The incorporation of these services into a public policy instrument at the metropolitan level is fundamental. For this reason, ñThe Economics of Ecosystems and Biodiversity ï TEEBò(2011) a global initiative focused on making natureôs values visible, establishes a six-step methodology for ecosystem services to be included in the processes of developing public policies for the creation of a GI network. The first step is to develop the problem; what it means and what the lack of green infrastructure can mean, what should be discussed together with the stakeholders, then the most relevant ecosystem services of the metropolis should be identified, as well as determining valuation methods for them, and then the valuation must be made. Once the management alternatives have been identified, the impact of the options that are available to the stakeholders will be assessed, so that they are included in a public policy instrument that can be a Metropolitan GI Plan (see Figure 1).

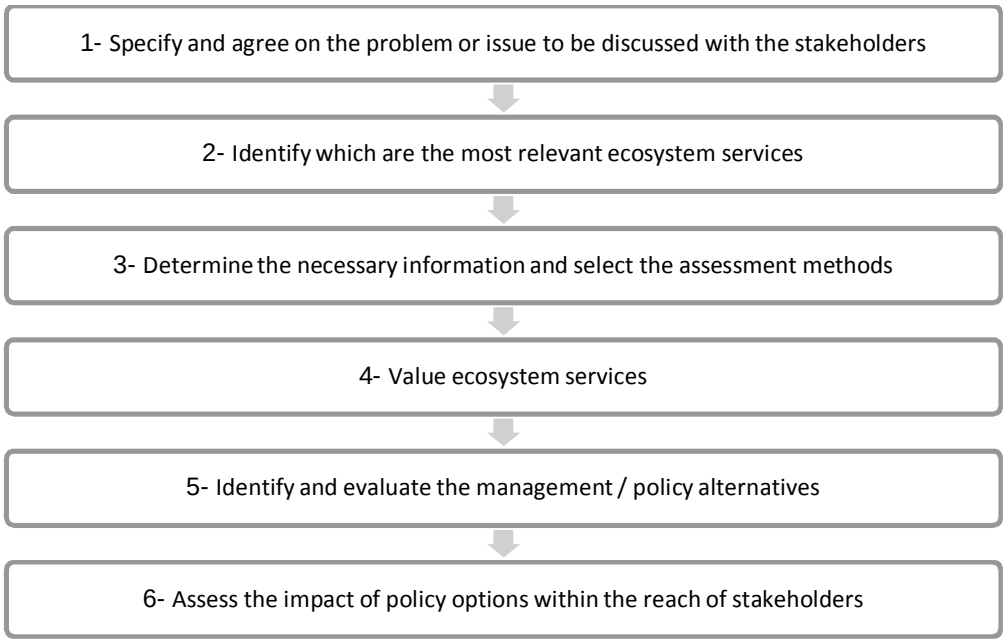

Figure 1. Methodology to include ecosystem services in public policy decision making. Adapted from The Economics of Ecosystems and Biodiversity, 2011).

The ecosystem services must be valued in order to be able to assign to each green space that integrates a GI network the importance and the hierarchy that corresponds to it according to its scope, so a set of indicators must be determined for each type of service. As part of the indicators of habitat services, there is the abundance of birds, butterflies and other species valued for their aesthetic characteristics. Among the supply services is the production of food, expressed in tons per year (T/year), as well as water supply, expressed by spending in cubic meters per year (m^3/year). While on those of regulation, there are the infiltration capacity, measured by the percentage of impermeable surface in relation to the permeable surface in hectares (Ha); the regulation of the urban temperature can be measured by the *leaf area index*; the reduction of noise by the leaf surface (m^2) and the distance to the roads (m) and the reduction of noise (dB (A)) / unit of vegetation; the purification of the air by means of the measurement of polluting particles O_3, SO_2, NO_2, CO and PM_{10} (g/cm^2/s) multiplied by the

arboreal coverage (m^2). With regard to water treatment, the suggested indicator is the amount of Phosphorus, Potassium and Magnesium in mg/kg compared to the averages of soil and water; for climate regulation the amount of CO_2 absorption by trees (carbon multiplied by 3.67 to convert to CO_2). Among the cultural ones, the key indicator is the surface of public green spaces (Ha/inhabitants) and its proximity to the districts or neighborhoods of the Metropolitan Areas.

Some of the services provided by urban green spaces are the regulation of air quality, the regulation of water in floods, the regulation of local climate, as well as direct services such as recreation and environmental education, particularly when these spaces have witnessed historical events to become cultural heritage (see Table 4). The elements that make up the urban landscape and constitute the Green Infrastructure (GI) of urban areas are classified according to their scale of service. This scale is related to the frequency of use of the facilities and the distance to which these should be located. The service scales considered in Handbooks for Urban Design Criteria such as SEDESOL standards (1999) are: neighborhoods, districts and cities, but there are other sources that also address scale issues (see Table 5) and which refer to the neighborhood, city and regional scales (Vásquez, 2016).

Planners, and governmental authorities should be aware of the services provided by GI in Metropolitan Areas; but even more important is that ordinary citizens recognize their value and how they can generate opportunities for sustainable development, but they can also serve as evidence for environmental policies in any governance setting. Some ecosystem services such as air cleaning and noise reduction are regulatory services which are often not recognized even by the planners or by the citizens themselves (Kabisch, 2014).

Neighborhood Scale	City Scale	Regional Scale
Wooded streets	Rivers and flood plains	Wild protected areas
Green roofs and walls	Inter-communal parks	National parks
Neighborhood squares	Urban channels	Coastline and beaches
Private garden	Lagoons	Strategical and long distance pathways
Open institutional spaces	Suburban forests	Forests
Ponds and streams.	Natural parks	Protective belts in high voltage lines
Walkways rights	Continuous water fronts	Network of roads and railways
Pedestrian and bike paths	Municipal squares	Designated green belt
Cemeteries	Hills	Agricultural lands
Sport tracks	Large recreational spaces	Rivers and flood plains
Ditches	Estuaries	Canals
Small forests	Deserted lands	Open-fields
Playground areas	Community forests	Mountain range
Streambeds	Deserted mining sites	Common territory
School yards	Agricultural lands	Aqueducts and gas pipelines
Orchards	Wastelands	Geological faults
Deserts		Lakes

Table 5. Green Infrastructure Scales. Elaborated by Vasquez, 2016, based on EEA - European Environment Agency, 2011 and Landscape Institute, 2009.

This approach based on ecosystem services -which includes green spaces for the sustainable development of metropolises, could benefit metropolitan planning instruments such as urban development plans.

The literature determines a series of approaches for Green Infrastructure planning: the need for a holistic design as it occurs with other infrastructures such as the one for mobility; the comprehensive planning, as it happens with the electric power network attending to social, economic and environmental issues; strategic territorialization including various jurisdictions and government levels; public planning and implementation, which refers to the generation of

the GI with public participation; multidisciplinarity, because it must be based on science and should be strengthened with knowledge of professional disciplines, including landscape ecology, ecological economics, urban and regional planning, and landscape architecture (Benedict & McMahon, 2001). In addition to these, it is essential that the GI is financed through specific funds as happens with the other sectoral programs, and not only be a recipient of residual monies.

4. GI in Mexico and the Guadalajara Metropolitan Area (GMA)

Because it has not been adopted as a public policy concept yet, Mexico lacks regulations for GI implementation. However, there is a legal framework that allows to include GI.

Article 4 of the Political Constitution of the United Mexican States (Spanish: *Constitución Política de los Estados Unidos Mexicanos*) establishes that every person has the right to an adequate environment for their development and well-being. The National Development Plans (NDP) have included principles to protect natural resources and to guarantee their permanence in the future. For example, in the NDP of 2007-2012, a strategy was specified so that the preservation of ecosystems and biodiversity could be achieved under schemes of conservation, management and sustainable use. Despite the fact that the need to protect natural resources is recognized as a goal in the NDP for the current administration (2013-2018), the strategies to achieve it are not in place.

Within the territorial environmental policies that have been implemented in Mexico, we can include the designations of protected natural areas, the ecological planning of the territory, the environmental impact assessment, and the payment for environmental services (Quadri de la Torre, 2006). Among these, the Protected Natural Areas (PNAs) are defined as "zones of the national territory and those on which the nation exercises its sovereignty and jurisdiction, where the original environments have not been significantly altered by human activity, or those which require preservation and restoration" by the General Law of Ecological Equilibrium and Environmental Protection (Spanish: *Ley General del Equilibrio Ecológico y la Protecció al Ambiente* - LGEEPA). The PNAs are usually established by presidential decrees whose main purpose is the conservation of biodiversity. The PNAs can also be constituted by states and municipalities through decrees that must be approved in state congresses.

The determination of PNA of state or municipal nature, has among its objectives the preservation of representative natural environments to ensure the balance and continuity of the environmental processes, and the assurance of the sustainable use of ecosystems and their elements.

There is also more specific legislation: Law for the Protection, Conservation and Promotion of Trees and Urban Green Areas of the State of Jalisco and its Municipalities (Spanish: *Ley para la Protección Conservación y Promoción del Arbolado y Áreas Verdes del estado de Jalisco y sus municipios)*, which aims to establish the provisions for expanding, protecting, managing, preserving and restoring urban green areas, palms and trees that are located over non-forest areas of the state. For its effects, the following are considered as public green areas: parks and gardens, wooded or gardened squares, planters, median strips, groves, outdoors sport courts with natural vegetation of public property, and areas or structures with any vegetal cover on public spaces.

In the V Volume of the National System of Urban Facilities (Spanish: *Sistema Nacional de Equipamiento Urbano*), the Ministry of Social Development (SEDESOL, for its initials in Spanish) makes recommendations for recreational and sport spaces, which are considered as areas that "promote communication, interrelation and social integration, as well as coexistence with nature and its conservation inside the urban areas, contributing to their ecological improvement". This regulation dates back to the 1970s, and it has been used as a standard for the design of urban facilities; however, it is not mandatory, since its implementation is optional for the stakeholders interested in urban development.

The Guadalajara Metropolitan Area (GMA) includes 9 municipalities: Guadalajara, Zapopan, Tlaquepaque, Tonalá, Tlajomulco de Zúñiga, El Salto, Juanacatlán, Ixtlahuacán de los Membrillos and Zapotlanejo, where a population of 4,865,122 inhabitants is settled.

Year	Guadalajara	Zapopan	Tlaque-paque	Tonalá	Tlajomulco de Zúñiga	El Salto	Juanacatlán	Ixtlahuacán de los Membrillos	Zapotlanejo	Metro Guadalajara (GMA)
1970	1,199,391	155,488	100,945	24648 NA	35145 NA	12367 NA	5501 NA	10652 NA	31819 NA	1,455,824
1980	1,626,152	389,081	177,324	52158 NA	50697 NA	19887 NA	8081 NA	12310 NA	35588 NA	2,192,557
1990	1,650,205	712,008	339,649	168,555	68428 NA	38281 NA	10068 NA	16674 NA	39902 NA	2,870,417
2000	1,646,319	1,001,021	474,178	337,149	123,619	83,453	11792 NA	21605 NA	53461 NA	3,665,739
2010	1,495,189	1,243,756	608,114	478,689	416,626	138,226	13,218	41,060	63636 NA	4,434,878
2015	1,460,148	1,332,272	664,193	536,111	549,442	183,437	17,955	53,045	68,519	4,865,122
*2020	1,549,200	1,414,972	689,659	568,367	601,122	169,212	15,009	59,435	73,931	5,140,907
*2025	1,594,291	1,479,949	725,621	601,034	644,641	179,921	15,711	63,459	77,814	5,382,441
*2030	1,632,307	1,535,393	758,905	630,810	683,952	189,981	16,355	67,015	81,459	5,596,177

*Table 6. Population 1970 - 1980 AMG. Source: INEGI and * CONAPO, 2017*

With regard to the footprint of the city, this has experienced a stronger and disproportionate increase in relation to the population, which is evident in the period of 15 years comprised between 1990 and 2015. While the population of the GMA went from 2'870,417 in 1990, to 4'865,122 in 2015 -that is, an increase of almost two million inhabitants (1.59 times); the footprint of the city increased 1.9 times its size (IMEPLAN, 2016). This data allows us to determine that the occupation of the territory is more accelerated than the population increase up to 21% (see Table 6).

Consolidated	Potential Consolidation
Parque Agua Azul	Bosque urbano Miravalle
Parque Metropolitano	Cerro El Gato
Parque González Gallo	Parque Lomas del Cuatro
Parque Solidaridad	Parque Cerro del Tesoro
Parque Natural Huentitan	Parque Las Liebres
Parque Morelos	Cerro Santa María
Bosque Los Colomos	Cerro del Cuatro
Bosque Pedagógico del Agua	Parque Lomas de Aztlán
Parque Revolución	Cerro San Martín de las Flores
Parque El Dean	La Piedrera
Parque Alcalde	Parque San Rafael
Parque Eca Do Queiros	Parque Roberto Montenegro
Parque Agroecológico Ixtépete	Bosque urbano El Palomar
Parque Tucson	Cerro de la Reina

Table 7. Urban Forests in the Guadalajara Metropolitan Area (IMEPLAN, 2016).

At the metropolitan level, there is a recently created planning instrument: the Metropolitan Territorial Plan (Spanish: *Plan de Ordenamiento Territorial Metropolitano* - POTMet). This plan must define a metropolitan structure to be developed along with the municipalities within the GMA. This is why the inventory of GI that currently exists is fundamental. The POTMet (IMEPLAN, 2016) tries to determine this infrastructure of metropolitan scale and character under the concept of urban forests. These are considered as ecosystems composed of trees and other vegetation with a dense tree mass, which provide different ecosystem services to cities for the well-being of their inhabitants (idem, 2016). As a result of a mandatory national policy to favor the development of compact cities (H. Congreso de la Unión, 2016), the POTMet itself establishes the need to inhibit urban development in areas far from the boundaries of

already existing urbanized areas, however it doesn't include a strategy to increase green spaces that at least correspond proportionally with the number of new inhabitants that are expected to return to the central city as a result of this policy.
POTMet considers two sets of green open spaces: consolidated and with potential for consolidation (see Table 7). Although they are already presented as strategic urban forests should also be valued according to the particular ecosystem services they provide. For this purpose, assessments of those green spaces should be based on the existence of evidence of the provision of ecosystem services.
The assessment proposed refers to a rating of 1-10, and considering the services that are ideal for the improvement of the quality of life conditions of the inhabitants of the GMA; or simply considering the existence of any evidence that proves that the green space is actually providing the service (see Table 8).

	Mobility	Provisioning services		Regulating services								Cultural services				Habitat services	
Space	Mobility Corridor	Food	Water	Urban weather regulation	Noise regulation	Air purification	Extreme weather moderation	Runoff decrease	Water treatment	Polinization, pest control	Global climate regulation	Recreation	Landscape/ Aesthetics	Education	Social cohesion and values of the place	Biodiversity	TOTAL
Bosque Urbano Miravalle	0	0	0	1	0	1	0	1	1	1	0	1	1	1	1	1	10
Cerro El Gato	0	0	0	1	0	1	0	1	0	0	0	0	1	0	0	1	5
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Table 8. Assessment of Urban Forests. Evidence of provision of Ecosystem Services. Self-elaborated with criteria from (EEA - European Environment Agency, 2011).

In order to calibrate the criteria, it is necessary to establish ideal objectives considering the opinion of the citizens, because as it has already been said they are the ones who may or may not legitimize the priority character of the elements of the GI network.
According to the legal and regulatory framework in the state of Jalisco, where the Metropolitan Area of Guadalajara is located, the State Law of Ecological Equilibrium and Protection of the Environment consigns as protected natural areas within the competence of the state government: state parks, natural formations of the state interest and state areas of hydrological protection. And as a competence of the municipal governments: the municipal ecological parks, the ecological preservation zones of the population centers, and municipal areas of hydrological protection.
POTMet states that within the GMA there are five decreed natural protected areas: one is federal (Bosque de la Primavera), two state (Cerro Viejo - Chupinaya - Los Sabinos and Colomos) and two municipal (Bosque el Nixticuil y Barranca del Río Santiago), which altogether occupy an approximate area of 73,330 hectares. The adequate conservation of these areas is relevant for territorial planning, since it helps to maintain the quality of ecosystems and their biodiversity, as well as their provision of environmental services which are achieved through their conservation and sustainable management (IMEPLAN, 2016).

5. Recommendations

As previously explained, not only the presence of nature in abundance is needed for a city to qualify as biophilic, since it must also be one that holds green infrastructure and adequate governance and institutions. The latter would favor the development and strengthening of the

other dimensions that make up a city of this kind: behavior, patterns, practices and lifestyles of its inhabitants, as well as attitudes, and the generation of knowledge about nature.

Metropolitan Scale
-Rivers and flood plains. -Lagoons. -Urban forests. -Natural parks. -Continuous water fronts. -Large recreational spaces. -Deserts. -Wild protected areas. -National parks. -Coastline and beaches. -Strategical and long distance pathways. -Forests. -Protective belts in high voltage lines. -Network of roads and railways. -Designated green belts. -Agricultural lands. -Canals. -Open-fields. -Mountain range. -Common territory. -Aqueducts. -Gas pipelines. -Geological faults. -Lakes.

Table 9. Metropolitan Green Infrastructure. Based on EEA - European Environment Agency, 2011; Landscape Institute, 2009; Vasquez, 2016.

In addition to urban forests, some elements of a metropolitan scale could be considered to be integrated into the GMA's Green Infrastructure (see Table 9). These elements must be assessed to confirm their relevance based on criteria such as the one described in the previous section. That is the reason why it is recommended that before establishing a proposal for the GI system, this evaluation should be carried out.

It is foreseeable that some elements are left out of this classification, but they should be integrated into the urban or neighborhood scales, and will continue to be part of the large GI multi-scale system.

Among the recommendations we could consider the proposal of Valdes and Folukes (2016) that refers specifically to mobility, safety, recreation and sports as well as to the economic, environmental and management issues, such as the sectors in which it is opportune to influence in order to define a strategy for generating a GI network.

In terms of mobility, it emphasizes green corridors or linear parks for cyclists and pedestrians that interconnect public places such as squares, parks, schools, libraries, workplaces, even shopping centers, including universal accessibility for these corridors to guarantee its utilization to every user. In Mexican metropolises, security is also fundamental, so the system should take into account both lighting and space monitoring. The use of the GI as recreational spaces, which allows outdoor exercises (depending on air quality), to lead a healthy lifestyle. The GI should also be used to educate and raise awareness about the importance of green areas, particularly by making the value of spaces known; it is advisable to use maps with information such as physical characteristics, and services that are provided inside of them. In the economic aspect, the GI must be considered to attract tourists to urban areas; it must recognize the increase of surplus value of the properties located in the vicinity and that the citizens through the authorities are able to capitalize it; there must be an annual operating budget that ensures continuity in the maintenance of green spaces. It is also recommended the application of tax

incentives to encourage both individuals and companies to donate land destined to increase the GI network, as well as considering as a generator of transfer rights, in order to obtain compensations for the maintenance of properties with the potential to increase floor area ratios (FAR). On environmental matters, spaces in the GI network should be considered as part of the flood reduction strategy in the metropolises, and simultaneously as aquifer recharge areas. About management, it is necessary to prepare, as part of the metropolitan planning instruments, a GI network that includes its implementation through an organizational structure for the planning of the metropolitan territory; an organization must also be created in order to launch a public awareness campaign, integrating volunteer programs, and encouraging fundraising to manage green infrastructure in the Metropolitan Areas.
Although this study concludes that GI is necessary for metropolitan resilience, ultimately, the participation of citizens and their recognition is the only essential element for the GMA to have a GI system/network suitable for their needs.

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