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Abstract

Green infrastructure (GI) has been an object of different theoretical-practical approaches concerning its application as a tool to build a sustainable and resilient land use plan. The key would be to guarantee the cities' functions and services to work with nature. The challenge requests a clear association between conceptual terms and the design practices that have been developed in recent years, attending urban functions and protecting ecosystem services. The present work contributes to the debate, establishing the relationship between principles, urban scales, urban functions and configurable components of green infrastructure with the potential to guarantee the ecosystem service and to respond to the demands of the city's functioning. The research approach is related to the ecosystem service associated with the water cycle in cities. The method is based on the organization of conceptual review bases and some research results on green infrastructure, landscape architecture and urbanism, to build a framework of analysis that can be validated in an empirical study that will subsidize plans of urban spatial planning. As a result, we present the primitive analytical and methodological steps for the identification of aspects raised for the intervention of a plan of urban land occupation based on nature.

Keywords: Ecosystem service, green infrastructure, Landscape Planning

Introduction

The theme of green infrastructure (GI) applied to cities has been the subject of several academic and political studies with emphasis on the theoretical discourse on the benefits of promoting environmentally sustainable urban land planning (Ahern, 2007), with resilience and adapted to climate change.

There is no doubt that the term green infrastructure is increasingly used in plans and projects associated with urban design and planning actions, with emphasis on green area interventions, riparian corridors and drainage solutions. These approaches came out with punctual responses and dissonance with what is seen in the scope of discourses. (Mell, 2009).

Most of the concept's applicability attempts are inconsistent with its principles, protection of ecosystem services, and more importantly in responding to urban problems at the functional level that cities need. When analyzing the application-oriented frameworks and the potential that came out in the planning and implementation of Landscape urban and territorial planning as seen in Hansen; Pauleit, 2014; Lafortezza et al, 2013 shows that there is still a long way to go until green infrastructure becomes part of the mainstream of urban management practice. The risk is that green infrastructure ends up being reduced to a simple urban branding strategy, to advertise a particular city-green brand or a major urban operation, or a real estate enterprise project.

The challenge to be faced by the concept is its applicability in different scales, since it can be used in national and regional approaches to the ecological network, in the design of an open space system, neighborhood/district plans, urban design and in residential buildings and houses, commercial and mixed-use projects. It is important to emphasize that the term *green infrastructure* organizes knowledge and practices of different disciplinary approaches linked mainly to the promotion of a physical and ecological connectivity of green urban structures with the aim of promoting ecosystem balance. There are many examples associated with the case of the water cycle where sustainable drainage systems (SuDS), or environmental comfort as responses to climate change (Mell, 2010).

The concept of Ecosystem Services (ES) is often associated with GI as can be seen in Austin (2014), summarized in Figure 1. Green Infrastructure Planning differs from other Landscape Planning practices because it considers ecological and social perspectives in articulation with land use in development – land use development (Aegisdóttir et al, 2009 in Lafortezza et al, 2013). Thus, what should be kept in mind for the operative translation of a concept in territorial planning is that the practice must break with the preconceived proposals (of technical truths applicable everywhere) and disregard the characteristics of a particular place.

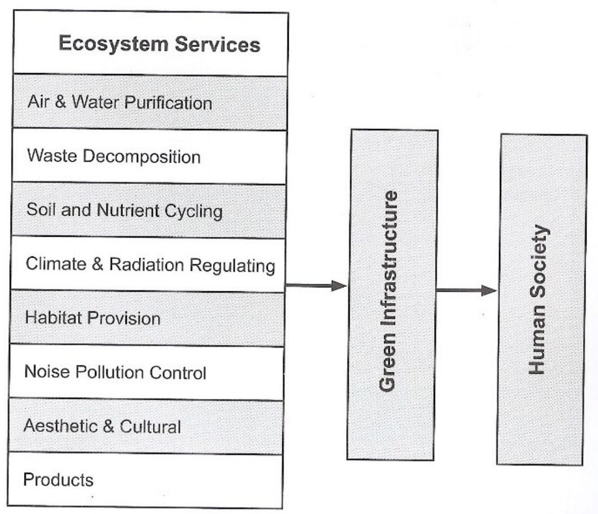

Fig. 1- Ecosystem Service and Green Infrastructure benefits to human society. Source: Austin, 2014, p.8.

The relevance of the present study is to identify the relationships between principles of green infrastructure, urban scales, functions and configurational elements of green infrastructure with the potential to guarantee ecosystem services and respond to the demands of the city's functioning. Subsequently, identify the main green infrastructure planning solutions associated with ensuring ecosystem services for water supply and regulation.

Background and Literature Review

Of Anglo-Saxon origin, the term green infrastructure was coined by the Florida Green Corridor Commission in 1994 and "Green infrastructure has its origin in two important concepts: (1) linking parks and other green spaces for the benefit of people, and (2) preserving and linking natural areas to benefit biodiversity and counter habitat fragmentation" (Benedict and McMahon, 2006, p.8). Still according to Benedict and McMahon (2006), green infrastructure is "a strategically planned and managed network of wilderness, parks, greenways, conservation easements, and working lands with conservation value that supports native species, maintains natural ecological processes, sustains air and water resources, and contributes to the health and quality of life for America's communities and people".

According to some authors, the term innovates in proposing holistic and multidisciplinary approaches that are more effective, more capable of dealing with complexity than those of traditional planning or open spaces (Kambites and Owen, 2006 in Hansen and Pauleit, 2014). It innovates by proposing that the process of urban and landscape planning should integrate ecological and socioeconomic understandings of development into a holistic approach to urban planning and management (Mell 2016; Rouse et al., 2013; Firehock, 2012; Ahern, 2007). However, it is also applied on smaller scales as a design instrument, structured by the balance of the water cycle and green areas in articulation with the infrastructure built to provide ecological functions (Rouse et al., 2013; Ahern, 2007).

Methods

The approach of this paper considers the contribution of GI in these two perspectives: it identifies important contributions to city landscape planning, but also to solutions of green structures sensitive to water at the local scale, regulating the hydrological cycle of a certain hydrographic basin that integrates the territory. In this sense, identification of the principles that guide it is necessary as a first approximation towards a methodological ordering for intervention.

Principles that guides GI Interventions

Based on a conceptual review, it was attempted to understand the principles that guide the elaboration of Green Infrastructure, as well as the services and the functions provided and their configurational elements. Benedict and McMahon (2006), in their book *Green Infrastructure: Linking Landscapes and Communities*, were the first to try to define the principles that guide the concept. According to them, there are ten:

> *(i)connectivity is key; (ii)context maters; (iii) green infrastructure should be grounded in sound science and land-use plannig theory and practice; (iv)green infrastrcuture should function as the framework for conservation and development;(v)green infrastrcuture shuld be planned and protectd before development; (vi)green infrastructure is a critical public investment that should be funded up front; (vii)green infrastructure affords benefits to nature and people; (viii)green infrastructure respects the needs and desires of landowners and other stakeholders; (ix)green infrastructure requires making connections to activities within and beyond the comunity; (x) green infrastructure requires long-term commitment (Benedic and McMahon, 2006, p.37, Box 2.3).*

Subsequently, several other researchers detail and seek to define and organize the different areas of the green infrastructure approach and give it characteristics that in this research was sought organise to later associate the scales of action and ecosystem services that can contribute to protect. After an accurate conceptual review, the following authors stand out:

Table 01. Guiding principles of green infrastructure, bold and gray the most recurrent. Sources: adapted from Ahern (2010), Mell (2010), Rouse et al. (2013).

CONCEPT	DEFINITION	AUTHORS											
		Rouse et al (2013)	Benedict and McMahon (2006)	Mell(2010)	Davies et al (2006)	Ahern (2014, 2013, 2010, 2007)	Brears (2018)	Firehock (2012)	Austin (2014)	Ginger (2016)	Pauleit et al (2011)	Kambites and Owen (2006)	Hassen and Pauleit (2014)
BIODIVERSITY OR HETEROGENITY (Ahern, 2010, p.148)	In terms of biodiversity green infrastructure provides the resources and the networks (i.e. the corridors or matrix) that promote the process of connectivity and mobility. (Mell, 2010, p.55);			X		X		X	X				
CONECTIVITY	It is the physical and functional connection between the elements of the infrastructure that favors biodiversity, comfort, mobility, among other factors;		X			X		X	x	X	X	X	X
MULTIFUNCTIONALITY	Refers to the potential of green infrastructure to have different performance (environmental, social, aesthetic, recreational, ecological, among others)	X	X	X	X		X	X	x	X	X	X	X
MOBILITY	Spatial arrangement of patches, their different quality, the juxtaposition and the proportion of different habitat types are elements that influence and modify the behaviour of species, populations and communities' (Farina, 1998 in Mell, 2010, p. 54).			X									

CROSS-DISCIPLINARY APPROACH	The ability to bring together different disciplines;		X	X		X	X	X	x	X	X		X
REDUNDANCY	Redundancy is defined as multiples elements or components providing the same, similar or backup functions (AHERN et al, 2010, p. 148)					X							
MODULARITY	Modularity refers to design and operation of discrete, subsystems rather than centralized integrated systems (AHERN et al, 2010, p. 148).					X							
ADAPTATIVE PLANNING	Provide an alternative strategy \. Under an adaptative approach, plans, and policies can be developed in the face of uncertainty and incomplete knowledge (AHERN et al, 2010, p. 155).	X		X		X				X			
HABITABILITY	”Include improving air and water quality (resulting in improved health of humans and ecosystems” (Rouse et al 2013, p.21).	X											
IDENTITY	Addresse the potential of green infrastructure to contibute to a visual definition of the place (Rouse et al 2013, p.21).	X											
INVESTMENT RETURN	“this principle calls on planners and designers to demonstrate how green infrastructure can reduce costs and yield positive and financial outcomes for governments, institutional, businesses and citizen (Rouse et al, 2013, p.22).	X					X			X			
ACESSIBILITY	Whether the project is accessible to all types of public;			X									
STRATEGIC APPROACH	It lays down clear guidelines for a given proposal;			X									X
LOCAL CONTEXT	If he considers the context in which he is being projected;		X	X					x				
ADAPTABILITY	Ease of adapting to hostile changes or conditions;	X				X				X			

MULTISCALE	Acts on different scales;		X		X	X	X	X		X	X	X	X
INTEGRITY	Considers the green infrastructure as an infrastructure and seeks to integrate it with other existing infrastructures;		X							X	X	X	X
SOCIAL INCLUSION	It includes all social classes;		X	X				X				X	X

A recurrence analysis of the studied material indicates that the most important principles are **connectivity, multifunctionality, interdisciplinarity, social inclusion and multiscalarity.**

Multiscalarity and interdisciplinarity in green infrastructure

The contribution to Landscape planning would be in the objectification of the multiple scales. The multiscale of green infrastructure clarifies its relation with the levels of performance in the politics of the territorial planning, in the urban and regional planning and the architecture. According to Steinitz in Ginger (2016), in practical terms of planning and projects, there are three scales of action in the territory: (i) global; (2) intermediate; (3) location. Thus, we can relate the scales and their performances as follows:

- **The global scale** refers to national and international scale focusing on the interrelationships between ecosystems and the support capacity of the territory – regional policy scale;
- **The intermediate scale** encompasses the scope of the city and the region, metropolis and river basins also in the interrelationships between ecosystems and the support capacity of the territory - scale of environmental, urban and regional planning;
- **The local scale** is centered in the specificities of the place and in the planning of the territory to attend the needs of the populations - scale of the urban and architectonic design;

However, planning and projecting the territory from these three scales of approach presents a complicator that is the performance of the national public power, which in the planning and management of the territory briefly group the definition of land use and occupation in five broad scale categories:

- **Scale of the site: where the punctual interventions occur;**
- **Local, neighborhood scale**: but related to the scale of the neighborhood;
- **City and district scale**: geared toward city scale;
- **Scale of the city-region, landscape, metropolitan, regional and national scale**: but focused on the dialogue between the hydrographic basins of the territory;
- **Global Scale**: international agreements on urban and environmental policy.

In this context, a systemic planning of the territory presupposes ecological processes at all scales and their interdependencies and complementarities. All of these scales provide a way to address the diverse interests of a given place, identifying common values and goals that can be used to guide decision-making on land use and occupation. For Firehock (2012), in a more founded view on environmental conservation, the analysis of the different scales is fundamental to guarantee the connectivity of the landscape that "is a key factor in protecting biodiversity and ensuring species resilience"(Firehock, 2012, p.14).

The green infrastructure thus constituted an ecological approach to different scales always structured by a system of landscape elements composed of sites, links and hubs and to interconnect the ecosystem and the landscape. Figure 2

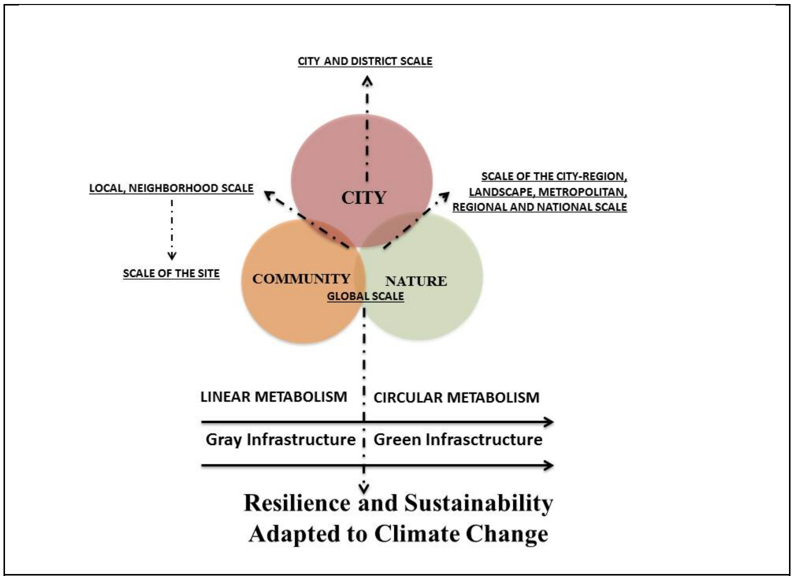

Fig.02. Relation between scales. Source: authors.

<u>Multifunctionality and ecosystem services</u>

The implementation of green infrastructure requires an integrated vision of ecosystem services (EC, 2013), focused on promoting its multifunctionality, helping to establish actions and guidelines in line with the ecological and social values of the territory and the expected economic benefits and returns.

Benedict and McMahon (2006) seek to define these elements in two groups of typologies according to their ecological contribution: one is more focused on the natural ecosystem values and their functions (biodiversity, ecological process and ecological services) and another is associated with the benefits for human populations (ecological services, social and economic values). However, its relationship with scales of approach and with the ecological network, composed of link, core and site, is not clear, and there is an understanding that these elements function as urban infrastructures.

However, there is no consensus among researchers on what elements make up this green infrastructure at their different scales of action, and how they interact with each other, although this may vary by location. In order to develop a green infrastructure model composed of sites, links and core, it is necessary to understand how the linked elements and the individual elements that make up the green infrastructure in the different scales of approach local scale to global) and what would be their multifunctionality, or the range of ecosystem services and functions provided by them.

GREEN INFRASTRUCTURE			SERVICES																					
			PROVISIONING						REGULATING									HABITAT		CULTURAL				
			FOOD	WATER	RAW MATERIALS	GENETIC RESOURCES	MEDICINAL RESOURCES	ORNAMENTAL RESOURCES	AIR QUALITY	CLIMATE REGULATION	MODERATION OF EXTREME EVENTS	REGULATIONS OF WATER FLOWS	WASTE REATMENT, ESPECIALY WATER PURIFICATION	EROSION PREVENTION	MAINTENANCE OF SOIL FERTILITY	POLINATION	BIOLOGICAL CONTROL	MAINTENANCE OF LIFE CYCLES OF MIGRATORY SPECIES	MAINTENANCE OF GENETIC DIVERSITY	AESTHETIC INFORMATION	OPPORTUNITIES FOR RECREATION AND	INSPIRATION FOR CULTURE, ART, DESIGN	SPIRITUAL EXPERIENCE	INFORMATION FOR COGNITIVE DEVELOPMENT
Benefits	Biodiversity/species protection	Habitats for species;																						
		Permeability for migrating species;																						
		Connecting habitats.																						
	Climate Regulation	Mitigation urban hest Island effect- evaporatranspiration, shading & air flow;																						
		Strengthening ecosystems'resilience to climate change;																						
		Storing floodwater &reducing run-off to reduce risk of flooding.																						
	Climate Change Mitigation	Carbon sequestration;																						
		Encouraging sustainable travel;																						
		Reducing energy use for heating and cooling building;																						
		Providing space for renewable energy;																						
	Water management	Sustainable drainage systems – attenuating surfasse water run-off;																						
		Fostering groundwater infiltration;																						
		Removal of poluants from water(e.g.reed beds).																						
	Foods production and security	Direct food &fibre production on agricultural land, gardens, etc;																						
		Keeping potential for agricultural &food security (safeguarding soil);																						
		Soil development and nutriente cycling																						
		Preventing soil erosion																						
	Recre ation, weel-	Recreation																						
		Sense of space and nature																						
		Clean air																						
	Lan d valu	Positive impact on land and property																						
	Culture &communities	Local distinctiveness;																						
		Opportunities for education, training and social interaction;																						
		Tourism opportunities.																						

Table 2. Potential topics and benefits of green infrastructure grouped according to the main types of ecosystem services. Source: Fonte: European Environment Agency, 2011, p.8.

Land occupation planning should consider the environmental resources and services that come from the biotic, abiotic and cultural environments in order to generate the benefits to the environment and the population. This approach can be summarized by Table 2 supported by European Environment Agency, 2011, p.8.

With regard to urban water management, the ecosystem services that are consecrated are associated with provision (food, water, raw material, genetic resources, medicinal resources and ornamental resources) and regulation (air quality, climate regulation, moderation extreme events, regulation of water flow, treatment of waste, mainly water purification, prevention of erosion, maintenance of soil fertility, pollination and biological control). The actions here are implied in the use of water resources associated with sustainable drainage systems and urban land occupation patterns that promote urban circular metabolism (Figure 3).

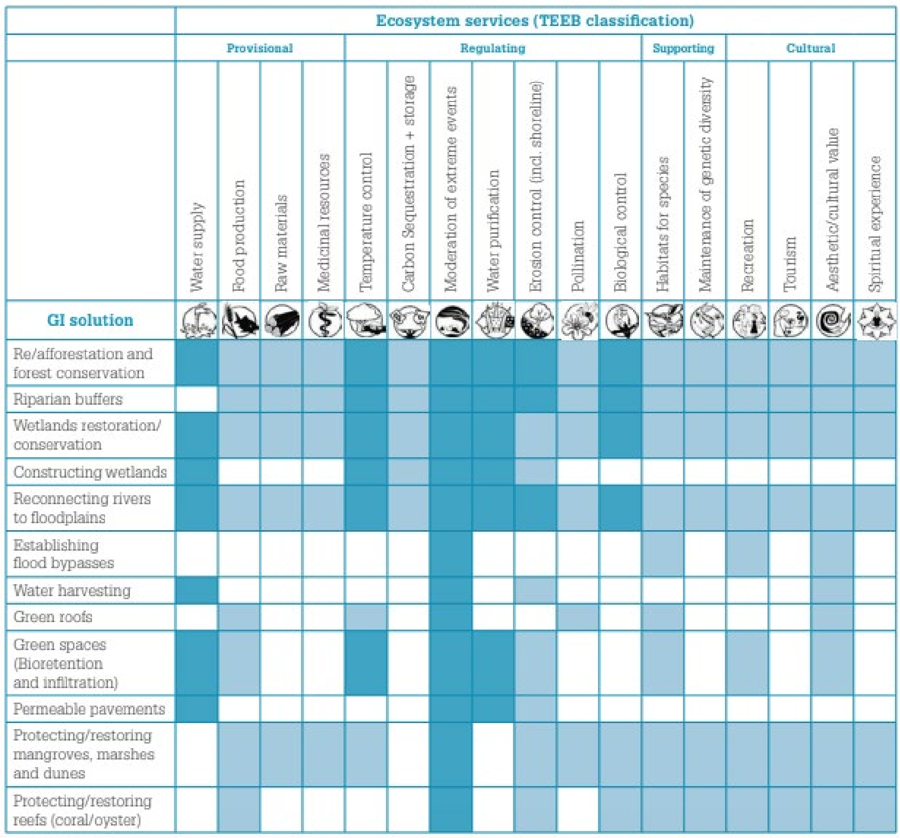

Fig.3. Green infrastructure solutions linked to water and ecosystem services Source: Jan Sasse in UNEP; IUCN. Green Infrastructure Guide for Water Management: Ecosystem-based management approaches for water-related infrastructure projects. Kenya: UNEP, 2014, p.76.

To plan the green infrastructure from a urban hydrology model (Ahern 2010, p. 137), emerges as a way of [...] "redesigning the city so that the water circuit is closed, by means of the reuse and recycling of natural resources, with the aim of imitating nature in the reproduction of the hydrological cycle, mitigating and transforming the contributions within the city" (Ginger, 2016, p.154).

Within this perspective, the infrastructure becomes a strategic landscape for urban water, not only using the elements of landscapes such as rain gardens, rainforest, biovaleta, permeable paving, rain pond, green roof, green grid, among others, but changes the paradigm related to water in the urban area overcoming hygienic visions, promoting an expansion of the concept of drainage to the study of the river basin.

Results

<u>Connectivity and its forms of green infrastructure intervention</u>

The connection between these different sites and hubs gives rise to greenways or to green corridors that act as links, as can be observed in Figure 4. These links promote the dialogue between the typologies of the system composed of the elements of the landscape of public and private use as valleys, water bodies, flood plains, retention ponds, streets, bikelanes, greenways, green corridors and greenbelts.

Sites are relatively homogenous and non-linear spaces, minor or not for public use in areas of preservation or recreational value (integral or partial conservation units, parks, gardens, parks, clubs, among others (Benedict and McMahon, 2006, p.13). These sites often function as step stones, as they would not be the habitat of the species alone, but are vital because they allow species mobility in the landscape (Firehock, 2012).

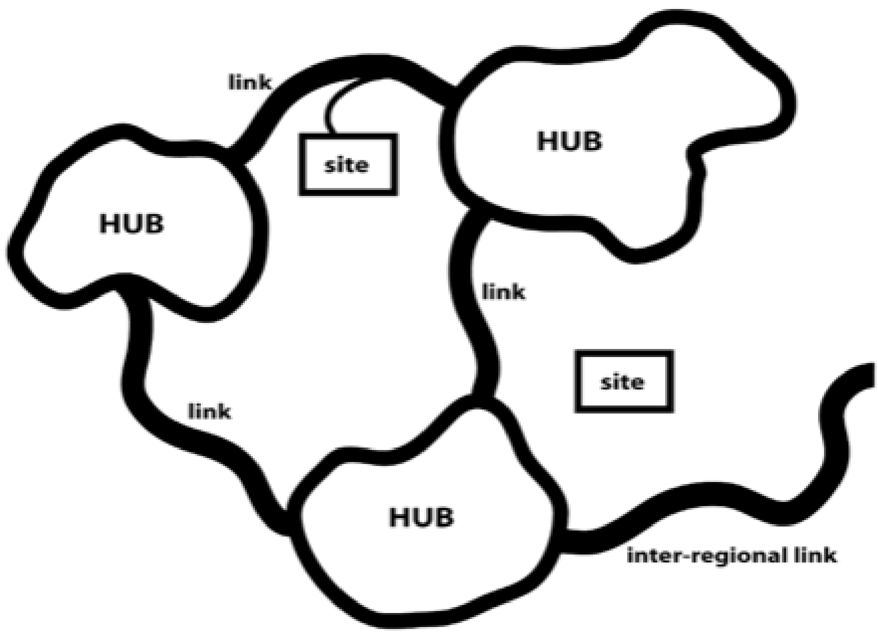

Fig. 04. The Green Infrastructure network that connects ecosystems and landscapes to a hub, link, and site system. Source: Benedict and McMahon (2006, p.13)

With different shapes and sizes, hubs, or core would translate into landscape elements of environmental conservation interest, areas of full or partial public or private protection, ranging from national wildlife refuges or state parks to recreational, agricultural, or extractive areas. At the edge of the core we find the edges that functions as a transition zone or buffer between the core and the urbanized zone, Figure 5 (Firehock, 2012).

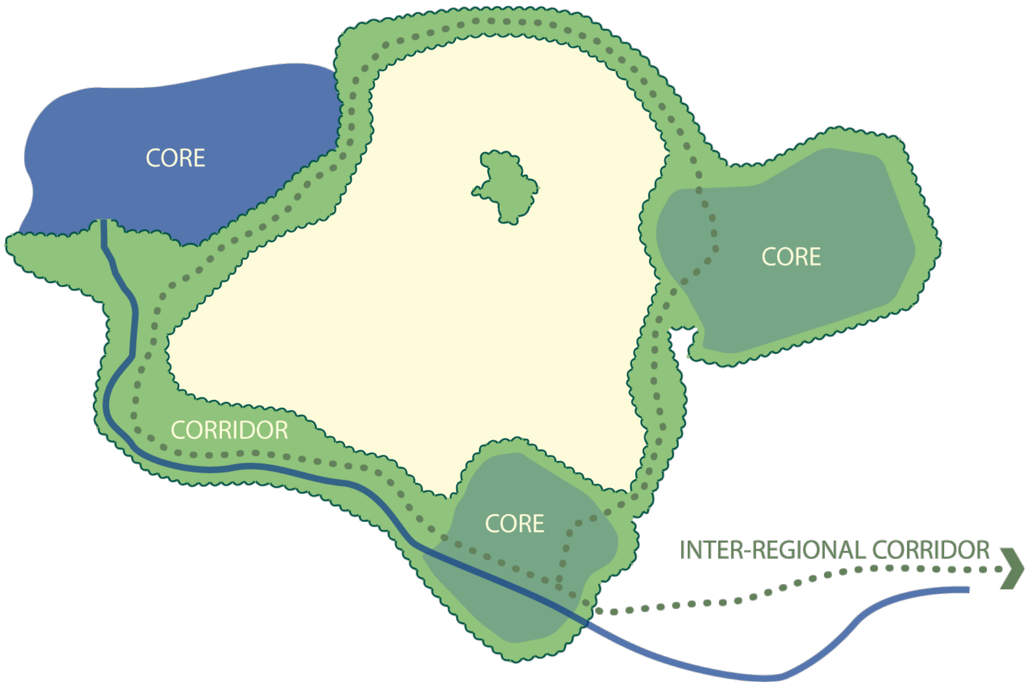

Fig.05. Core and its connections. Source: Firehock, 2012.

The authors (Ginger 2016; Vasconcelhos 2015; Austin; 2014, Rouse et al 2013; Mell, 2010 and Firehock 2012) collaborate to deepen the debate about the elements that compose the green infrastructure in trying to define more accurately the typologies of architecture that anchor the spatialization of the concept in each scale, but without even considering Green Infrastructure ecological elements (core, hub and sites) and without considering these elements as urban infrastructure. Table 02 defines the elements and their relationship with the ecosystem service, in blue those related to the hydrological cycle.

The organization of the principles of Green Infrastructure and its possibility of adoption at the intervention scales through landscape structuring elements can constitute a methodological arrangement to support urban planning and project actions that aim to promote and guarantee ecosystem services.

Most of the experiences in this process of reframing the Urban Planning and Project practice, such as Ahern et al. (2014) focus on structuring this process from the analysis of case studies (Hasen; Pauleit, 2014). Still, according to Hasen; Pauleit (2014) "a combination of elements from theoretical frameworks and planning process guidance to contribute to scientific discourse on GI as well as inform practitioners on planning design" (Hasen; Pauleit, 2014, p.520). Rouse et al., 2013, demonstrates how this incorporation occurred with regard to plans, strategies and projects in each scale of territorial approach. Based on these authors, Figure 06 proposes a model reflecting how the Green infrastructure could be incorporated in the planning process from the water resources.

GREEN INFRASTRUCTURE				SERVICE															
				Provisioning						Regulating									
				FOOD	WATER	RAW MATERIALS	GENETIC RESOURCES	MEDICINAL RESOURCES	ORNAMENTAL RESOURCES	AIR QUALITY	CLIMATE REGULATION	MODERATION OF EXTREME EVENTS	REGULATION OF WATER FLOWS	WASTE TREATMENT	EROSION PREVENTION	MAINTENANCE OF SOIL FERTILITY	POLINIZATION	BIOLOGICAL CONTROL
SCALES	MICROSCALE	SITE	parks, pockets park, gardens, squares, allotments, courtyard;																
			green walls ;																
			University campus;																
			Cemitery;																
			Sustainable drainage system (SUDs);																
			Perveous pavement;																
			Wetlands;																
		CORE	Local nature reserves;																
			Lakes;																
			Urban Parks.																
		LINK	Greenways, cycle routes, boulevards, , trails and shared streets;																
			parks;																
			swales, raingardens;																
			costal area;																
			rivers , creek and urban canals;																
	MESOSCALE	SITE	city park, squares, historical Gardens, forest parks;																
			Country parks;																
			Forest parks;																
			Mining area;																
			Landfil;																
			Natural belvederes;																
		CORE	Agricultural land;																
			Forest parks																
			Community woodlands																
		LINK	Continous waterfront;																
			Urban canals;																
			Cycle routes;																
	MACROSCALE-	SITE	Urban park;																
			Forest area;																
		CORE	Agricultural land;																
			Common lands;																
		LINK	Urban canals;																
			Green corridors;																
			Road and railnetworks;																
			Greenbelt.																

Table 2. Elements of green infrastructure and ecosystem services. Source: Adapted from Ginger, 2016; Vasconcelhos, 2015; Austin, 2013; Rouse et al, 2013; Mell, 2010; Firehock, 2012)

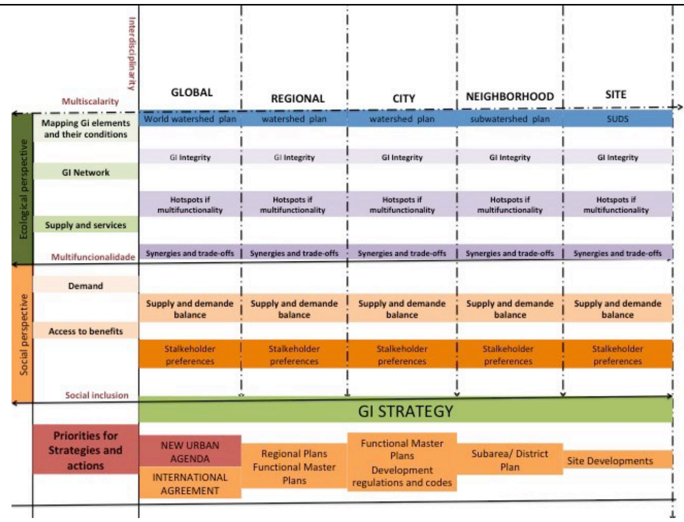

Fig. 06. Incorporating green infrastructure. Source: adapted by the author from Hansen and Pauleit, 2014, p. 521; Ahern et al, 2014, p. 256; Rouse et al, 2013, p.24-25.

Discussion and Conclusion

The work organizes the conceptual frameworks of GI associated to scales and elements of intervention of the urban planning and design surrounding the relationships between principles of green infrastructure, urban scales, functions and configurational elements with potential to guarantee urban ecosystem services. The methodological framework presented aims to support the practical actions of elaboration of Territorial Planning Plans that aim to respond to the demands of the city's operation and protection of the ecosystem services associated with the water cycle.

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