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Assembling the pieces: a framework for the integration of multi-functional ecological main structure in the emerging urban region of Bogotá, Colombia

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Abstract Bogotá, the capital of the Republic of Colombia, is a tropical highland city located 2,650 m above sea level. It is the 25th largest city in the world and, among large cities, is also one of the highest. In common with other cities in Latin America, a large part of its urban growth during recent centuries has been unplanned and informal. The introduction of green spaces into urban planning in Bogotá began in the mid-20th century, but was first included in official legislation during the 1990s through the concept of Ecological Main Structure (EMS). Initially developed by Dutch scholars, EMS was brought to Colombia via biological conservation practitioners as a means of enhancing biological connectivity in rural and natural landscapes, extended in this case to urban landscapes as a top-level planning instrument. EMS originally included a variety of components, from protected areas and biological conservation tools to environmental urban elements - the emphasis being on biodiversity conservation, without sufficient recognition of specific urban structures and functions. This process led to conceptual disciplinary-based divergence and conflicting political interpretations. The current emergence of EMS as a planning tool for urban regions represents an opportunity for integration, although the risk of divergent interpretations remains, as no integrative conceptual framework has yet been developed. In this paper we review the concepts underlying EMS that have been incorporated within urban and regional planning, especially those of ecological networks and green infrastructure, and also diagnose conceptual and institutional barriers to its current integration, challenges and opportunities which are set in the context of an emerging urban region. We propose a trans-disciplinary framework for multi-level integration of EMS, along a gradient from wild environments to built structures that incorporates emerging concepts such as urban biodiversity, ecosystem services and design in the urban landscape, with the aim of contributing to the creation of an urban landscape that is resilient to environmental change and suitable for human well-being and adaptation.

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Introduction

Cities are complex integrated ecological systems (Grimm et al. 2000). From a biological conservation perspective, urban systems have been conceived as human impacts on natural ecosystems, contributing to biodiversity and species loss, as well as affecting natural biological connectivity between habitat fragments (Bennett 2003). At the end of the 20th century, urban planners and conservation biologists worldwide began to collaborate in order to improve urban structures as habitats for wild nature (Clergeau 2007), with some authors recognizing that specific urban structures could also play a role in species and genetic fluxes across urban-dominated landscapes. A synthesis of these approaches was presented under the concept of 'green infrastructure' by Benedict and McMahon (2006) and 'green networks' by Clergeau (2007). Some of these approaches were then incorporated into planning through the integration of urban biodiversity with design, as exemplified by the URBIO (Urban Biodiversity and Design) initiative (Muller and Werner 2010).

Only in the year 2000 did conservation biologists in Colombia start to recognize the conservation value of urban green spaces (Andrade 2005). It was in this year that Bogotá's first Land Use Plan, POT (*Plan de Ordenamiento Territorial*), incorporated the concept of Ecological Main Structure (EMS) (*Estructura Ecológica Principal*) in the sense proposed by Bischoff and Jongman (1993), who emphasized biological connectivity over other environmental and social functions. In Bogotá, EMS, infrastructure and risk management comprise three top-level hierarchical planning structures. Although born in Colombia with a biology conservation outlook, from the outset EMS comprised heterogeneous instrumental components from natural to building structures, including urban parks and tree planting schemes along roads and drainage systems. In 2007, EMS was incorporated within national environmental legislation as one of the environmental determinants of land use planning (Decree 3600 2007). Bogotá's 2011 EMS proposal included, in addition to that defined previously in the urban planning instrument (POT), the integration of natural and semi-natural ecosystems (forests, scrubland, high Andean moorlands and wetlands) into the Ecological Main Structure at the regional level. As the scope of EMS application increased, so did barriers to its real-world implementation. A major conceptual gap currently underlies the difficulty of this implementation, with urban planners, government officials and the public often using the same words (i.e. biodiversity, parks and corridors) and giving different interpretations of emphasis, leading in some cases to conflicts of interest among stakeholders. In this paper we examine the creation and management of EMS in the city of Bogotá, analyzing conceptual, institutional and political barriers, as well as opportunities for actual integration, especially in view of the new challenges arising in this emerging urban region in the face of global environmental change.

Study area

Founded in 1538, Bogotá, the capital of the Republic of Colombia, is a humid tropical city located in a highland plateau valley of the Eastern Andean Mountains at 2,650 m above sea level (Fig. 1). The city is surrounded by hills on its eastern and southern sides; its physical

boundary to the west and north is the Bogotá River. From a base of only 100 inhabitants, it grew slowly over the next four centuries and at the turn of the 19th century Bogotá was a town with a population of 100,000, camouflaged within rough mountains, wetlands and rustic rural landscapes (Mejía 2000). During the 20th century, economic deprivation and social unrest in the country's rural areas made Bogotá very attractive for immigration, triggering considerable unplanned urban growth. In 1938 the population was 330,312, with the city's boundaries being the Eastern Hills and the Sabana de Bogotá plateau, composed of farms and 50,000 hectares of wetlands (DAMA 2000). In the mid-20th century, the city expanded over farmland and wetlands mainly located on the Bogotá plateau. In 1954, Bogotá became a Special District and six towns were added to the city's central administration. Between 1951 and 2000 the population grew from 715,250 to 6,484,968; in 2005, the human population of Bogotá was 6,763,325 and only 800 hectares of wetlands remained (DAMA 2000), located either inside the urban area or along its boundaries. Today the city belongs to Bogotá's Capital District; the administrative units extend over 177,598 ha, of which 30,736 ha have been legally ascribed for urban use, 17,045 for suburban use and 129,815 for rural use (POT 2011). Urban sprawl resulted in conurbation with Soacha a town located to the southwest of Bogotá – and suburban development affecting nearby towns such as Chía, La Calera, Sopó, Tabio and Briceño. The population of Bogotá is projected to be 10,000,000 by 2025; urban growth is currently occurring beyond the administrative boundaries of the city in nineteen adjacent towns and other nearby municipalities of the Sabana de Bogotá region (Dureau et al. 2007), conforming to a typical emerging urban region (*sensu* Forman 2008) although still unrecognized as such in urban planning and management instances.

Methods

We carried out inhouse research based on historical planning documents and maps related to urban development, focusing on the extent and identity of non-built up and open green areas as they appeared during the history of the city, from the colonial town that remained until the end of the 19th century, through to the entire 20th century. The most important recent planning documents studied were those relating to the concept of EMS, as the latter was adopted by city planners for green space and nature conservation. These elements were analyzed in terms of the concepts of Green Infrastructure (GI) and Ecological Networks

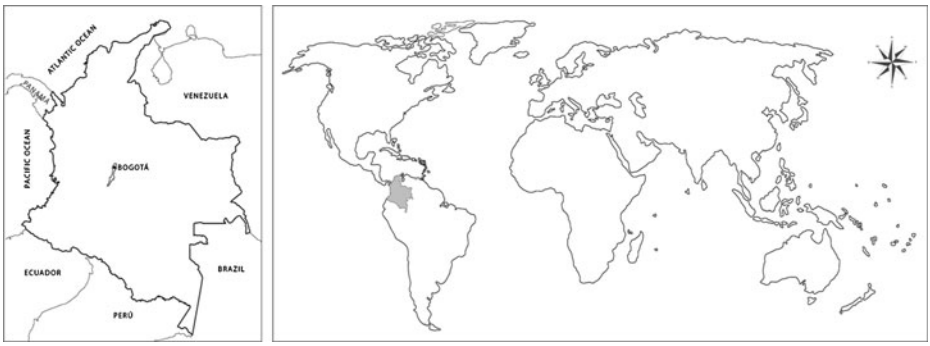

Fig. 1 Study site: Bogotá, Colombia

(EN), with special attention paid to published cases pertaining to specific urban or suburban environments. Green infrastructure is here considered in the sense proposed by Benedict and McMahon (2006), which includes the network of open spaces within the urban tissue. Ecological Networks are considered in the sense of Clergeau (2007), as the ensemble of linear and interconnected natural structures within or nearby the city.

Our own involvement in the city's environmental planning from the 1990s allowed us to diagnose the state and evolution of EMS, especially the barriers to integration of its numerous elements, between 2001 and the present. Taking into consideration emerging concepts in urban planning such as urban biodiversity (Ignatieva 2010), ecosystem services in the interface of science and policy (Samper 2003), design in urban landscapes (Musacchio 2011) and urban biodiversity and design (Muller and Werner 2010), here we propose a framework for a conceptual multi-level integration of EMS at the regional level.

Results

Green spaces from colonial town to megalopolis

Colonial Bogotá, following the Spanish urban grid type, was composed of a dense urban tissue with a few public spaces in the form of squares and plazas; the only green spaces were small patios and larger orchards located to the rear of private houses, with natural areas absent within the small city (Mejía 2000). At that time, natural ecosystems were extensive in the surrounding landscape of the eastern Bogotá Mountain Range - the 'Cordillera de Bogotá' as it was named by the German geographer Alfred Hettner (1892). These ecosystems included cloud forests and *páramos,* the latter being a unique Andean moorland above the tree line. Wetland complexes associated with the Bogotá River basin and floodplain were extensive to the east of the city, and were perceived by colonial inhabitants as outlandish spaces to be drained. From an outsider's view, the city was visually integrated into its surrounding natural landscape (Mejia 2000).

Urban green spaces modestly appeared at the end of the 19th century with the first urban parks, which were transformed squares in which gardening and tree planting activities began (Mejía 2000). The first attempt to create an urban park took place in 1872 on the northern border of the city, incorporating tree planting, the creation of an artificial lake, as well as several promenades and walkways lined with rows of planted trees called 'alamedas'. The effort to create public parks failed due to both a shortage of resources and a lack of specific bodies to take responsibility within the public administration (Zambrano 2003). The idea was revisited in 1910 with the Centenario Park, the first designed public green space in the city (Mejía 2000), and was followed during the century by other parks such as the Parque Nacional Olaya Herrera (1931), El Tunal (1968) and Parque Metropolitano Simon Bolivar (1968) (Zambrano 2003). The designs (layout and vegetation) of the Centenario and Nacional parks were inspired by landscape architecture prototypes in Europe and the United States, a common tendency in colonial cities (see Faggi and Ignatieva 2009), with a mixture of lawns, flowerbeds, tree rows and monuments. The El Tunal and Simon Bolivar parks were designed by landscape architects for leisure and sports, with special attention paid to the larger-scale design of promenades, lakes, trees and sports facilities.

Linear green spaces appeared in the city's urban planning in 1930 when Bogotá had 270,000 inhabitants, with Brunner (1939) developing an urban plan aimed at correcting 'bad development' by focusing on standardizing urban typologies and mobility axes, as well as the definition of a modest 'circuit of green spaces'. A visionary master plan was later

proposed by the famous Swiss architect Le Corbusier (1950), who introduced a variety of 'green elements' in a multi-level approach ranging from individual trees, through parks and avenues, to the city's regional context. Along with the legacy of leading American urban park designer F.L. Olmsted (Twombly 2010), the aim of this plan was "to cultivate the body and the spirit" with an integrative approach comprising "reforestation architecture to organize the country … to compose, for example, the rivers that come from the mountain with selected trees". However, neither Brunner's nor Le Corbusier's plan was fulfilled to any great extent in terms of the city's green components while Bogotá continued to grow. In the context of the unstable political climate which prevailed in the city during the 1930s, the two proposals can be seen as expressions of a societal demand for a more democratic and less socially fragmented city, as a perceived need for spaces for social integration. Between 1930 and 2000, Bogotá experienced dramatic demographic growth and as a result, public policies were directed towards coping with the huge demand for public services such as water, sanitation and transportation.

Green spaces reappeared in legislation late in the century, impregnated with the environmental spirit of the 1992 United Nations Rio Convention on Biological Diversity. In 2000 the city's first Land Use Plan, or POT (*Plan de Ordenamiento Territorial*), integrated the concept of Ecological Main Structure (EMS) (*Estructura Ecológica Principal*) - brought to the country by conservation advocates and practitioners (van der Hammen 1998) - in the sense proposed by Bischoff and Jongman (1993), who emphasized biological connectivity over other environmental functions. Despite the fact that its aim was to "improve biological connectivity", the components of EMS were heterogeneous, including protected areas, urban parks and several types of links, as well as a Bogotá River hydraulic zone aimed at managing flood risks. EMS was then incorporated, in 2007, in national environmental legislation (Decree 3600, 2007) as one of the environmental determinants of land use planning (MAVDT 2007). The 2011 Land Use Plan proposal also included the integration of semi-natural spaces (such as extensive tree plantations within natural regenerating scrub, and emerging prairies along the banks of the Bogota River) and natural ecosystems (forests, scrubland, high Andean moorlands and wetlands) into the Ecological Main Structure at the regional level.

In Bogotá, the 'green' integration of the city with its surroundings was first recognized by Le Corbusier in 1947, who proposed a network of spaces for recreation and leisure. After awaiting full implementation for a number of years, the concept was finally introduced into planning schemes in the 1990s thanks to the advocacy of conservation biologists. Van der Hammen (1998) proposed an EMS along the upper Bogotá River watershed, encompassing the rural areas under the direct influence of the city. Valbuena et al. (2008) developed an EMS model for Cundinamarca Province, including critical areas for the maintenance and recovery of biological connectivity between fragmented natural ecosystems. Notoriously, as the city continued to grow and EMS structures evolved and diversified (Table 1), the spatial scope of its application increased considerably, from urban elements to semi-natural and natural vegetation around the city (2001 2004), to the proposed integration of a major realm of natural and semi-natural areas at the regional level (Figs. 2 and 3 and Table 2). However, despite the high level ranking of EMS in planning, its implementation has encountered many obstacles that are conceptual – perceptual and social or institutional.

Conceptual and institutional barriers to the integration of EMS

The range of concepts and instruments considered in EMS, from the natural environment to building structures, has led to variations of emphasis in policy and interpretation, as well as

Table 1 Evolving definitions of ecological main structure in Colombian legislation

EMS definitions used in Colombia	
POT (2000)	"Network of spaces and corridors that sustain and link biodiversity and ecological processes along the territory in its different forms and intensities of human occupation, and provide environmental services for sustainable development."
van der Hammen and Andrade (2003)	"Natural and semi-natural ecosystems that have a location, extension, connectivity and state, so as to assure the maintenance of the integrity of biodiversity and the provision of environmental services or the satisfaction of human needs and the perpetuation of life in the territory."
Decree 3600 (2007)	"The ensemble of biophysical elements that support essential ecological processes in the territory, with the purpose of preservation, conservation restoration and sustainable use of natural renewable resources, that sustain social and economic development of human populations."
Proposal for POT (2011)	"A part of the territory that, having the main natural and built elements that sustain environmental services, is assigned for protection and sustainable use, as the main structuring element for urban and rural systems."

conflicts of interest among stakeholders such as local communities, environmental NGOs, urban developers and planners, and public servants, especially regarding the definition of management models for urban green spaces. The discussion attained maximum intensity between 1998 and 2000 when Enrique Peñalosa, a leading city mayor, launched a campaign to rehabilitate invaded public spaces. Despite wanting to increase the number of parks and public spaces, the focus of the policy was weak in terms of biodiversity conservation and landscape ecology. With emphasis placed on visual and transiting connectivity and no recognition given to the natural components of EMS such as the natural and semi-natural ecosystems listed above in the adopted planning instrument (Andrade 2005), the policy collided with environmentalists' visions for urban protected areas and biodiversity conservation. Conservation stakeholders emphasized the isolation of natural areas in order to protect fragile species from external threats, rejecting public uses such as bicycle trails and active recreation. The conflict was especially bitter over urban wetlands, with a network of grassroots non-governmental environmental organizations bringing the administration to court, resulting in 36 civil actions in the form of tribunals (Galindo 2003). Supported by the national promulgation of a wetlands law following Ramsar Convention principles (Law 357, 1997), the conservationists' view prevailed and expanded into the components of the EMS, widening the gap between disciplinary views regarding its biological as opposed to its social functions. For the public servants in charge of infrastructure and housing, EMS became an inconvenient concept.

This failed opportunity for early integration was also the result of Bogotá's complex institutional framework. Offices within the city's administration include an environmental secretary in charge of urban protected areas (wetlands and forest reserves), a planning secretary in charge of infrastructure and housing, an authority in charge of Bogotá's rural lands and protected areas, and a risk management unit. All of these offices have mandates related to EMS, but none focus specifically on it. As a result, EMS has been implemented with weak coordination, high institutional transaction costs and conflicts. An illustrative example is the fact that EMS was not taken into consideration during the planning of a major freeway, the Avenida Longitudinal de Occidente, delineated since 1961 as crossing the Juan Amarillo, Conejera and Capellanía urban wetlands . In 2012, despite the fact that EMS was

already adopted within the POT, the freeway's outlined route still crossed the mentioned wetlands. In addition to planning organizational misfit, a significant implementation gap has

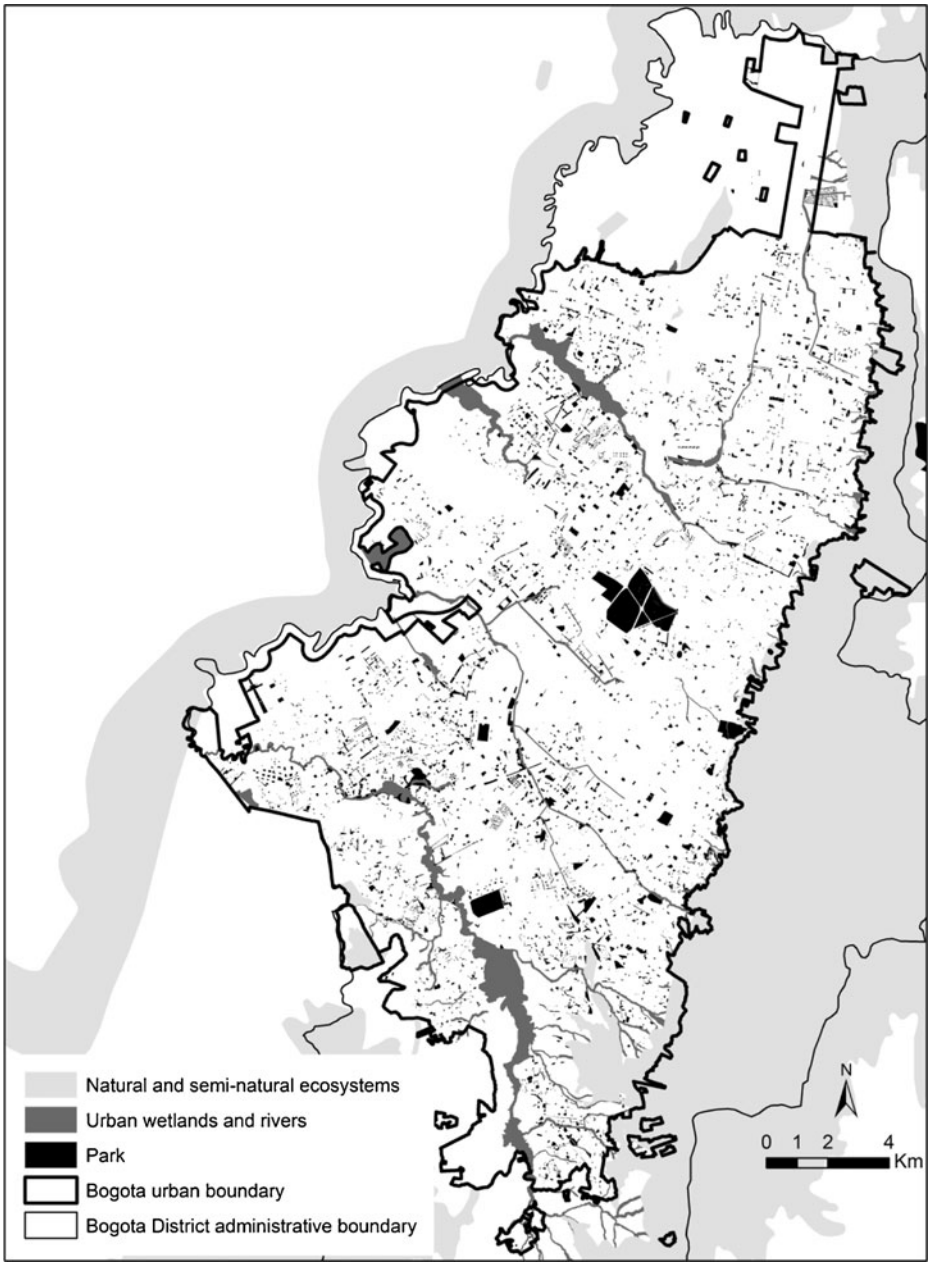

Fig. 2 A close-up of the EMS (2001–2004), including urban parks (*black*) and wetlands (*dark grey*), and natural and semi-natural ecosystems around the city (*light grey*); natural and semi-natural forest vegetation and tree plantations dominate the eastern side, and river, wetlands and novel kikuyu (*Pennisetum clandestinum*)-dominated prairies the west. (Original by second author F. Remolina)

existed, since EMS in Bogotá lacks a corresponding top-level authority and master plan, resulting in a diffuse mandate which in practice conflicts with other agencies. The city's institutional interfaces with regional and national conservation agencies are also complex.

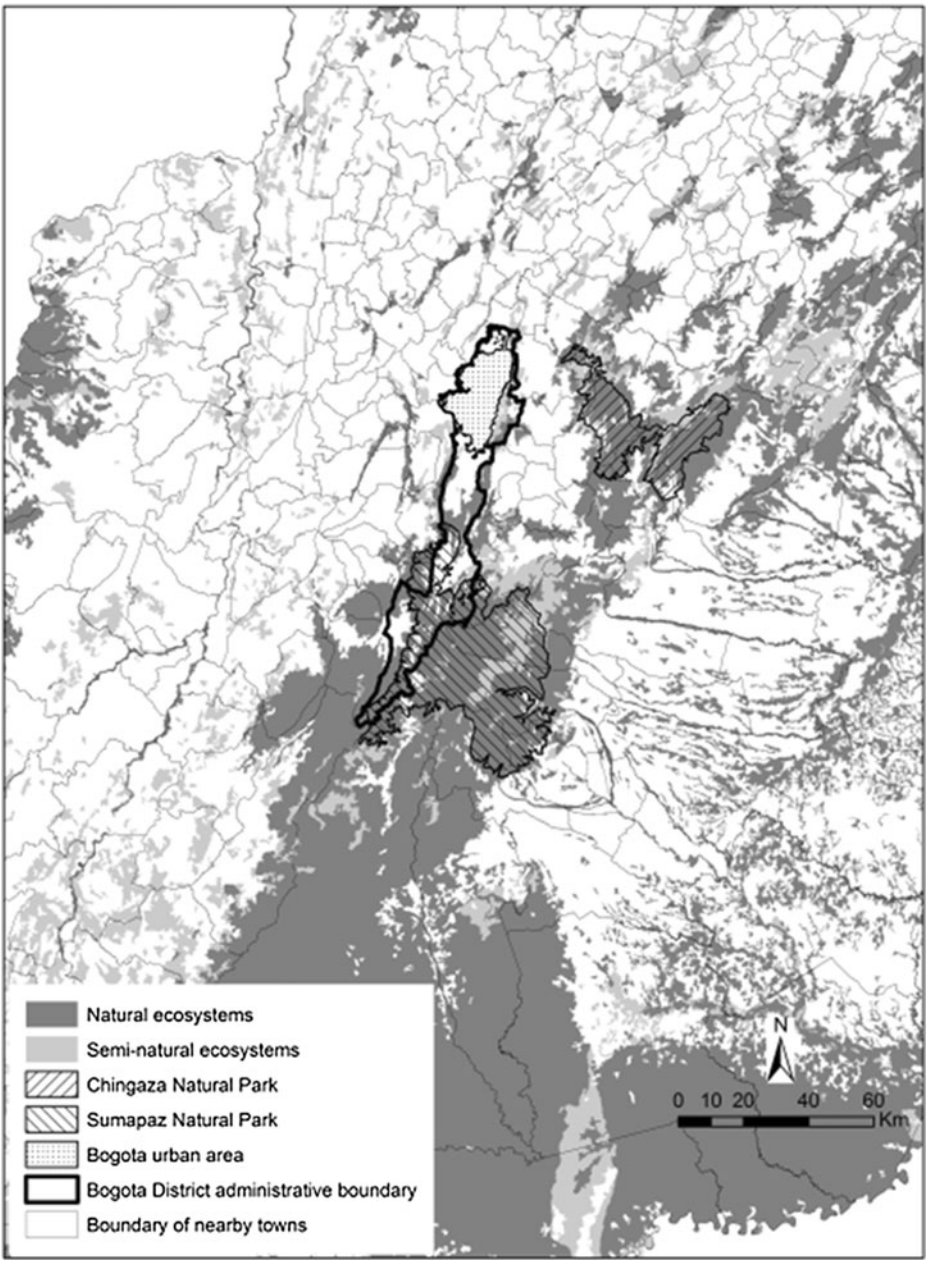

Fig. 3 Areas designated for the integration of EMS at the regional level. Dark grey: natural montane cloud forests and *páramos* (tropical highland moorlands); light gray: seminatural ecosystems (wetland complexes, native scrub land, tree plantations and emergent mixed vegetation). (Original by second author F. Remolina)

Table 2 Components of EMS in Bogotá (2001) and proposal (2011)

Components	Explanation
Ecological Main Structure (POT 2001)	
Protected areas	Standard protected area types in natural and semi-natural ecosystems, both within the city (remnant wetlands) and in surrounding regions (forest reserves).
Riverine edges	Fringes of green and inbuilt areas along rivers designated by law, in which a variety of landscape and ecological restoration treatments are undertaken.
Regional corridors	Mosaics of protected areas under different management categories, as well as other types of green space following a large-scale linear pattern, allowing for ecological connectivity.
Urban metropolitan parks	Large artificial open spaces with extensive tree planting schemes and landscaping features allowing wildlife habitation.
Zonal parks	Small parks constructed within dense urban settlements, including tree planting schemes.
Ecological Main Structure (POT 2011)	
Protected areas	Standard protected area types of natural and semi-natural ecosystems, both within the city (remnant wetlands) and in surrounding regions.
Ecological regional links	Formerly called 'regional corridors': mosaics of protected areas under different management categories, as well as other types of green space following a large-scale linear pattern, allowing for ecological connectivity.
Areas of special ecological importance	Any remnant natural or semi-natural ecosystem not set aside for conservation.
District parks with ecological values	A selected set of metropolitan parks and regional recreational parks not included in EMS (2001) that have ecological value (remnant natural vegetation or river systems).
Greenways: Areas of special environmental importance	Regional bicycle, car (and future train) routes along which the aim is to incorporate large-scale tree planting schemes.
Protected area buffer zones	Fringes of areas with a varied type of current land use, in which special management schemes are to be defined in order to enhance protected area conservation and connectivity between protected areas.
Living fences	Agroforestry practices specifically designed to improve biodiversity in rural landscapes; akin to the French term 'bocage'.
Complementary ecological structure (POT 2011)	
Household gardens	Open spaces within and between houses and buildings, including both ornamental and productive plantations.
Routes (pedestrian, bicycle and car) with tree row planting schemes	Any kind of linear urban transportation structure in which tree planting schemes are suitable.
Urban trees	Almost one million trees within the city have recently been inventoried and incorporated into the city's ecological complementary structure for their spatial relevance.
Green facades and roofs	An incipient practice in *avant-garde* architecture, with great potential for expansion as current common practice.

Disconnect between the centralized scheme of national protected areas and the decentralized regional environmental authorities have led to limited integration of local protected areas

within the National Protected Area system. Efficient integration of EMS is also hampered by the lack of a landscape approach to protected area planning, with 70 currently independently-protected area units in fact belonging to 28 continuous wildlands (Remolina 2011).

The harmonization of management instruments, such as the protected area categories proposed by the International Union of Conservation of Nature (Dudley and Stolton 2008), has been proposed for Bogotá's protected areas (Andrade 2011), as has the functional integration of management bodies, especially with respect to trans-jurisdictional protected areas that are still managed independently on both sides of the political divide. Current discussions focus on the creation and funding of a specific management unit - a kind of natural park service - for the numerous spaces designated as urban protected areas, and its organizational coordination with the National Park authority. This is the intended plan for the national parks of Sumapaz and Chingaza and the surrounding regional protected areas that provide water for the city and the urban region (Fig. 4).

At the regional level, barriers to the integration of natural ecological networks with constructed green infrastructure components have been less conceptual and/or perceptual, but instead rather more institutional. In his review of EMS components defined in the POTs of the 33 municipalities surrounding the city, Remolina (2011) found numerous denominations, although all could be clearly assigned to protected areas, corridors or green infrastructure. A striking case is the eastern mountain range and the river system, the region's most important ecological links, being divided between the jurisdictions of 36 municipalities. In addition, the impossibility of a clear-cut division between the rural and the urban (as the Capital District has rural areas and the city continues to grow) creates administrative grey zones, such as suburban areas and urbanization poles in small rural towns beyond the city limits. In the revised version of the POT (2011), the scope of EMS was broadened to

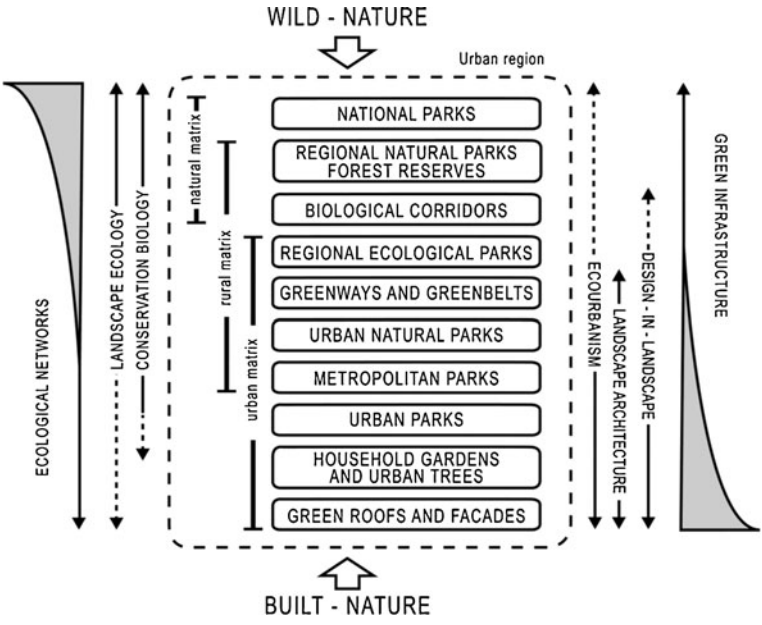

Fig. 4 Components for the multi-scale and trans-disciplinary integration of ecological networks and green infrastructure in the urban region of Bogotá

encompass the territorial planning and management of ecosystem services (Samper 2003); here its components were technically differentiated, clarifying both the scope of application (called EMS *sensu stricto,* akin to EN) and green infrastructure (known as 'complementary ecological structure', akin to GI). The latter definition introduced man-made structures as components of spatial environmental planning structures - including gardens, planting schemes along pedestrian and bicycle routes and roads - and, as a new legal statement, provided space for interdisciplinary dialogue and local integration (Andrade 2011).

Table 3 Cross-scale misfits for the integration of EMS in the territory

Issue	Problem	Solution for integration
Within the urban realm of the Capital District		
Conceptual	The fragmented and discipline-oriented view of nature and biodiversity as opposed to culture.	Promotion of a trans-disciplinary and emergent inclusive concept of urban biodiversity.
Institutional	Too many institutions in charge of urban components of EMS, such as urban streams and canals.	A single empowered authority for green spaces with the city.
	EMS, despite being one of the three top-level structures, lacks a specific management body and master plan.	Creation of a concomitant body of three top-level planning institutions.
Between the urban and rural realms of the Capital District		
Conceptual	No stable status for rural productive areas. Agricultural and forestry areas only considered in planning when threatened by urbanization.	Incorporation of "protected cultural landscapes" as components of land use planning.
Institutional	The environmental authority in charge of Bogotá´s rural areas, the regional environmental authority (CAR), does not belong to the city´s administration.	Redefine environmental authorities at the emergent urban region level.
	Too many protected areas designated, resulting from artificial partitioning of the territory, as well as heterogeneous and often *ad hoc* management regimes.	Integrate current protected areas at the landscape scale and standardize protected area management categories.
Between the city´s urban realm and the region		
Conceptual	Individual disciplinary approaches to each of the major components of EMS prevail (protected areas, urban parks, links, etc.).	Trans-disciplinary working groups, focusing on emergent issues such as urban biodiversity, ecosystem services and landscape design.
	Fragmented views of the territory bringing rural and urban into opposition, with transitional zones not recognized.	Educate for the recognition and appreciation of the emergent urban region, as an opportunity for planning human well-being.
Institutional	A plethora of administrative and mandate-oriented institutions with overlapping and conflicting jurisdictions, creating complex high-transaction cost scenarios for coordination.	Recognition of the emergent urban region as such for planning and management endeavours.
	Autonomy of municipalities in defining land use plans.	Formulation of a vision for the urban region, followed by master plans, all of which become mandatory for planning and management at the municipal level.

Overall, Bogotá's planning instruments and management institutions have proven unable to cope with the complex urban–rural interfaces of the emerging urban region. The recently approved National Land Use Planning Law (*Ley Orgánica de Ordenamiento Territorial* 1454 of 2011) defines inter-jurisdictional planning and management bodies for regional development projects between the capital city and its surrounding municipalities. However, the joint formulation of environmental regional projects has yet to be envisioned; such projects represent an opportunity for the integrative implementation of EMS through the technical differentiation of its components, as well as its further trans-disciplinary integration. A synthesis of emerging cross-scale misfits with respect to the integration of EMS is presented in Table 3.

Discussion

Towards integration

Whereas EMS was first defined as an instrument for biodiversity conservation, closely related to the concept of the ecological network (Jongman 2004, Clergeauy 2007), green infrastructure (GI), in addition to its biological conservation objectives, was developed to improve environmental quality, as well as visual and social connectivity in urban and regional spaces (Benedict and McMahon 2006). The latter was a hybrid concept, as proposed later by Ignatieva et al. (2011) when referring to urban biodiversity. In early 21st century Bogotá, technical discussions surrounding EMS remained captured by disciplinary approaches, creating divergences due to biological conservation being perceived to pertain only to rural natural areas and landscape architectural functions concentrated primarily in urban areas (Andrade 2005). For many citizens, analysts and even judges, when conflicts were brought to court, EMS was interpreted as comprising only no-go protected areas (Andrade 2005), hampering what could have been an innovative model. However, this opposition is today losing ground in the face of the recognized importance of urban biodiversity (Ignatieva 2010), as well as the emergence of urban phenomena at the regional level (Forman 2008). Today cities are considered not only sinks of ecosystem services, but also a special kind of landscape in which ecological processes take place (Pickett et al. 2001).

With technical clarification of its components, EMS can now be seen as an opportunity for trans-disciplinary and cross-level integration, one that could assist in the proposal of planning goals at the regional level which so far, according to Ignatieva et al. (2011), are "…an unplanned emergent property of the territory". In order to face up to the emergence of the urban region and to the imminence of the impact of global environmental change, a renewed vision of the territory is needed. The development of such a vision may be facilitated by emerging concepts in urban planning, including urban biodiversity (Ignatieva 2010), ecosystem services at the science-policy interface (Samper 2003) and design in the urban landscape (Nassauer and Opdam 2008).

Urban biodiversity and ecosystem services

In a country such as Colombia, generously endowed as it is with extensive natural ecosystems, recognition of the values of biodiversity in cities took a long time. Indeed, the Andean region has a history of human pressure on its natural ecosystems that dates back 400 years (Etter et al. 2008) - although 90,000 ha (60 % of the territory) of extensive natural and semi-natural ecosystems currently remain within the first ring of municipalities surrounding Bogotá (Remolina 2010) (Fig. 2). Currently, urban biodiversity conservation in the city is an extension of standard biodiversity management agenda for wild and rural areas, with no

specific urban biodiversity values recognized as such. The construction of a working definition of biodiversity which can be used in (and is not opposed to) urban planning is therefore needed, for which the renewed concept of urban biodiversity (Ignatieva 2010) could be of great help. In fact, an opportunity to do just this has arisen, as the Colombian government has formulated a new conservation policy in which biodiversity is to be conceived as the basis of ecosystem services and human well-being. Biodiversity management in urban areas requires a broader scope, targeting not only charismatic or endangered species present within the city, such as marsh dwelling and migratory birds, but also 'ordinary biodiversity' (Kellert 2005) including common species, urban trees and garden flora, close to where people live.

An explicitly urban biodiversity outlook implies bringing to urban management some of Colombia's rich native biodiversity, since tree planting and urban gardening in Bogotá have until now focused on alien species, with no understanding of the value of using those native to the region; the attachment to 'cosmopolitan' elements is directly connected to globalization, including the adoption of certain landscape architecture styles and the same 'global' plant material in different plant nurseries (Ignatieva 2010). The 'Green Guide' study carried out by the University of the Andes (Wiesner 1998) gives emphasis to tree diversity, mixing native and alien species selected according to not only their site-specific suitability for an urban environment (soil, rainfall, air pollution), but also to additional criteria reflecting aesthetic value (colour and shape), biodiversity (attraction to birds), hazard prevention (tree or branch fall) and landscape design. The promotion of native biodiversity also has implications for protected areas, since larger parks and surrounding semi-natural ecosystems belonging to the EMS show evidence of the acute spread of alien species, which from a biodiversity conservation standpoint have little, indeed if any, conservation value. Among the latter species, the highly invasive African kikuyu grass (*Pennisetum clandestum*) stands out for its encroachment and pervasive resilience against conservation and landscape management, while also notable is the virtually irreversible takeover of abandoned lands by the common gorse (*Ulex europeus*) (Rios 2005).

Adequate integration of EMS at the regional level requires a shift away from the restricted structural approach that has prevailed in Colombia in land use planning since the 1980s, with the latter involving the mapping of ecosystem types and subsequent derivation of prescribed uses. The transition from a structural to a functional outlook has already been incorporated into the redesign of the city's protected area system (Andrade 2011), based on the explicit reconnaissance of ecosystem services and integrating the many protected area's denominations and institutional jurisdictions. Such a functional approach also has to take into consideration the larger rural agricultural landscapes currently perceived as having no environmental value, but which are in fact indispensable in the regional landscape framework. Indeed, Le Corbusier included the concept of 'protected agricultural zones' in his 1947 plan. However, no spatial assessment of the full range of ecosystem services provided at the city's regional level is currently available, nor is a scientific description of the ecosystems' functional attributes relevant to land use planning at this level, especially with respect to adaptation in the face of environmental change. In this regard, global climate change brings to the city major planning challenges, not only in terms of the need to assure the water supply that comes from the vulnerable highlands (Poveda et al. 2010), but also to reduce the vulnerability of ca. 1,000,000 inhabitants currently living in disaster-prone areas, such as those affected during the 2010–2011 La Niña year.

The new vision of a regional territory endowed with biodiversity values and managed for environmental functions necessarily implies a change in Bogotá's institutional framework. Planning a regional ecological network integrated with the city´s green infrastructure will be the major challenge facing regional institutions, one which will require implementation by

each of the surrounding municipalities, respecting their own autonomy to select and balance instruments accordingly.

A framework for integration

The challenges posed by the emergent region of Bogotá exemplify the general need for a shift in urban landscape planning, from a structural and functional approach to a paradigm of designing within the landscape (Nassauer and Opdam 2008), with the ultimate aim of an assisted and goal-oriented adaptive transformation of the larger urban ecosystem. In this regard, the concept of eco-urbanism (Ruano 2005), centred in the harmonic development of sustainable human communities in urban environments, represents an opportunity to diversify and expand green spaces as supporting structures for the amelioration of human well-being. Intensive political discussions are currently being held concerning the model of the compact city versus urban sprawl (Rueda 1998), discussions which would surely benefit from the inclusion of the green spaces concept proposed here. Figure 4 presents a conceptual framework for the integration of EMS components within a system of multi-functional green spaces, covering a gradient from wild to 'heavily urban' in nature and based on an interdisciplinary approach (Fig. 4).

This proposal, at least in part, is not completely new for Bogotá, with some new initiatives currently ongoing. From an architectural standpoint, the broader concept of 'biophilic design' (Kellert 2005) aspires to introduce biodiversity values within the city; such a plan could also involve a wider ecological vision of the territory, in which perhaps the very concept of Bogotá as a 'biophilic city' (Beatley 2010) could emerge. Many local initiatives are already up and running in this regard. For example, the construction of urban green roofs and facades is incipient in Bogotá, although no data as to its present extent is currently available. These features have already been incorporated into the norms of city planning for public buildings and are also being developed by private consultants. Biophilic design in the city is dominated by the above-mentioned gardening approach, with the latter representing a starting point from which to introduce a multi-functional scope (see Köhler 2008) which should also include biodiversity conservation and water efficiency. A new generation of landscape architects has also emerged, who are introducing native species and layouts that mimic natural forms. The one proposal in Table 2 relating to this area is the 'Ecological and Recreational Corridor' put forward by Wiesner (2011), to be located along the hilly terrain lying beside the eastern mountain ridge and urban border, which features the conceptual and spatial integration of natural and built components through community and citizen involvement, ecological restoration, public use and interpretation of cultural and natural values. This proposal was endorsed by the City's current administration and has been included in its future land use plans. The proposed integration of green infrastructure and ecological networks does not spatially overlap with the advanced transit system (TransMilenio) in which tree planting along some avenues, pedestrian-friendly roads and bicycle paths complement each other with green infrastructure elements such as those seen in greenways and greenbelts.

Closing perspectives

In the emerging cosmopolitan urban region of Bogotá, citizens are currently undergoing deep cultural changes with regard to their perception of environmental issues. The colonial

frontier concept of nature opposed to civilization that prevailed in the city from its foundation (1538) to the mid-1950s began to be replaced by the concept of protected wild nature, as opposed to human transformed lands. Having been characterized by divergent institutional and disciplinary paths and trajectories from 1959 to 2000, urban planning and nature conservation are now beginning to encounter one another at the scale of the urban region. A new 'restorative environments' outlook is emerging (*sensu* Hartig and Staats 2006), linking people with nature conservation, urban planning and design. For conservation planners focusing on urban protected areas and regional ecological links, the challenge is to balance conservation with public use, as the emerging urban region demands green spaces. Although this much-needed integration, here referred to in the title as "assembling the pieces", brings major challenges to politicians, planners and managers, it also represents an opportunity for interdisciplinary dialogue and multidisciplinary creation. Landscape architecture could become here the umbrella discipline as proposed by Ignatieva et al. (2011), with the potential for application of the design-in-nature paradigm (Nassauer and Opdam 2008) to become integrated within land-use planning and management (Musacchio 2011). The renewed planning framework would include promotion of a societal valuation of emerging landscapes, a process that could be initiated on the basis of landscape icons defined as "particular spaces, features and practices that have cultural saliency as images of nature and metaphors" (Musacchio 2011); such icons are numerous within the urban region of Bogotá and include glacial highland lagoons held sacred by indigenous peoples, waterfalls, mountains, rivers and Roman Catholic religious sanctuaries.

The recognition of a multifunctional landscape as the ultimate planning goal is supported by innovation in governance systems and an emphasis on community participation (Guzman et al. 2011), redirecting planning exercises from responding to land use planning conflicts to anticipating adaptation. The integration of natural and built components is key to the construction of an urban regional landscape that is resilient to environmental change. Such a process will help provide society with the time to prepare for and withstand climatic changes, which have been predicted as being potentially severe in the highland Northern Andes (Poveda et al. 2010). The alternative - the business-as-usual scenario of a coalescent, fractured megalopolis in which the societal valuation of nature and management of ecosystem services become restricted to isolated protected areas - must be avoided at all costs.

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