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Urban ecosystem Services in Latin America: mismatch between global concepts and regional realities?

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Abstract

Latin America and the Caribbean (LAC) is one of the most urbanized and biologically diverse regions in the world but is often characterized by weak environmental governance and socioeconomic inequalities. Given large expanses of intact biomes, a long history of pre-Colombian civilizations, and recent urbanization trends, the urban ecosystem services (UES) concept has the potential to address issues of well-being for its citizens. We review relevant regional and global literature and use expert-based knowledge to identify the state of the art of the UES concept as applicable to green spaces in LAC and elucidate three overarching guidelines for management and future research needs: 1. LAC cities can be socio-ecologically unique; 2. Drivers of UES in LAC can be different than in other regions; and 3. Context and demand need to be accounted for when valuing UES. Overall, we show that research on UES is mostly from the global north and rarely accounts for the diverse and complex socio-political and ecological drivers of LAC's urbanization processes. We find that, as in other regions, the biophysical context and land use policies play a major role on UES provision. However, socioeconomic inequalities and weak governance are key drivers in UES supply and demand in LAC. Context-specific information on how to promote, educate, and apply UES is particularly important, not only in LAC, but in other regions where inequities, rapid urbanization, and climate change effects are stressing socio-political and ecological systems and their adaptive capacities. Standardized approaches from developed countries should be used to complement - not substitute – LAC context specific approaches for studying and applying UES. We suggest that improved research funding and local governance can also provide critical strategies, information and the means for more effective management, planning, and equitable provision of UES.

Keywords Green infrastructure · Socio-ecological systems · Urban ecology · Governance · Social inequities

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Introduction

With an average of 80% of its inhabitants living in urban areas, Latin America and the Caribbean (LAC) is one of the world's most urbanized regions. Fifty cities have more than one million inhabitants and four have over ten million inhabitants (United Nations 2014). Rapid urbanization and sprawling cities are affecting not only ecosystem structure and land use change, but the provision of multiple ecosystem functions and subsequent services and goods such as water quality and availability, fiber and food production, and socio-cultural experiences (Altieri et al. 1999; Myers et al. 2000; MacGregor-Fors et al. 2016). At a similar rate to other tropical and subtropical regions, urban ecosystems in LAC are also experiencing biodiversity loss within and beyond their physical limits, with consequences to the well-being of their citizens (Tratalos et al. 2007; Grimm et al. 2008).

Understanding this process and its effects is important as LAC is recognized as a region with great biological diversity, intact biomes, and many prioritized conservation hotspots (Myers et al. 2000). The region contains nearly half of the world's tropical forests and nearly 40% of its renewable water resources (United Nations 2010). Latitudinal and elevation gradients have resulted in a diverse array of biomes such as tropical, temperate, desert, high mountain, Mediterranean, and mangrove, among others (Eva et al. 2004). Growing populations and economic development are driving land use change (Inostroza et al. 2013) to the extent that urban and agricultural systems are rapidly altering the structure and function of ecosystems with high biodiversity and ecological integrity (Tratalos et al. 2007).

The concept of ecosystem services has its origin and is well established in a few high-income countries in Europe and North America (Costanza et al. 1997; De Groot et al. 2012). In 2005, the United Nation's Millennium Ecosystem Assessment (MEA 2005) provided researchers and decision-makers across the world with an ecosystem service framework and approach for quantifying and assessing changes in ecosystems and their processes and influences on human well-being. Based on this framework, an increasing body of literature on services and goods from a variety of ecosystems across the globe, including urban ecosystems, is being published. Similarly, the 2015 United Nation's Sustainable Development Goals (United Nations 2015), particularly goal 11: "sustainable cities and communities", calls for enhancing sustainable urbanization, reducing the environmental impact, such as air pollution, in cities, and providing more accessible and inclusive green spaces. These initiatives have been accompanied by The Economics of Ecosystem Services and Biodiversity (TEEB 2011), which linked the economics of ecosystem services with biodiversity, and by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, which related scientific information to policy making (Perrings et al. 2011). Despite the advances made, further information about UES and how to apply the concept outside of the high-income countries from which it was developed is needed to address pressing social, environmental, and economic problems that are relevant to LAC.

Such information should be particularly useful to urbanizing middle- and low-income countries. For example, the urbanization process in LAC is highly dynamic due to complex geo-political and historical drivers, weak governance and planning institutions, rapid population growth, dynamic socio-political transitions, emigration to cities, poverty, real estate markets, and marked socioeconomic inequities (Roberts 2005; United Nations 2014). Such is often not the reality of many high-income regions from where these UES concepts originated. Indeed, most seminal studies are based on cities of the developed world, particularly those from northern and western Europe, North America and eastern Asia (Tratalos et al. 2007; Haase et al. 2014). Thus, the role of urban ecosystem services (UES) has been little studied and global literature on the topic rarely accounts for the social, economic, and environmental context of the LAC region (Roy et al. 2012; Haase et al. 2014). Given LAC's long historical legacy dating from the Aztec, Mayan, and Incan cultures to more modern urbanistic trends and its many diverse, often intact biomes; this region can contribute to the current discourse on UES with unique lessons and experiences (Isendahl and Smith 2013).

To address this lack of information, below we review, analyze, and discuss the relevant literature related to UES and its relevance in LAC, and in doing so we aim to better understand and assess the application of the concept given the realities of the region. Specifically, as our first objective, we reviewed the international literature to identify the state of the art regarding UES across the globe. Second, we identify and assess selected regional literature from LAC on UES using expert-based knowledge to discuss and analyze the relevance of UES given the realities of LAC's context. Finally, we draw upon this knowledge to discuss three overarching guidelines and propose future research needs related to management, planning, and the equitable provision of UESs in LAC.

Methods

We reviewed the international and LAC literature by searching the Web of Science and Science Electronic Library Online (SciELO) for English, Spanish, and Portuguese language articles, reviews, and book chapters. To better compare our LAC identified literature to other regions, we used search terms reported in recent literature reviews on urban ecosystem services (Roy et al. 2012; Haase et al. 2014; Luederitz et al. 2015). Specifically, in a first search we looked for records that contained "urban" and "ecosystem services", in combination with their country's name (e.g. "urban" and "ecosystem service" and "Mexico") in the title, abstract and/or keywords. We also searched for "urban parks" AND/OR "urban forests" AND/OR "green infrastructure", in combination with their country's name. In a second step we searched for the same terms and refined the search by country's name, using the tool provided by the Web of Science.

Once the initial review was finalized, a multi-disciplinary regional working group representing experts from several of LAC's most urbanized countries assessed and filtered out non-relevant publications and selected the most UES relevant international literature from their respective LAC countries. This group of experts coincides with the authors of this manuscript. This relevant literature was identified using the publication's title and/or abstract content, resulting in a set of publications that we will use as the basis for analysis and discussion. The filtering ensured that the research was from a Latin American city and that it actually referred to an ecosystem service (i.e. was not just a tree inventory). The search was carried out during June 2017.

This approach identified the major concepts that were gleaned from a set of relevant global and regional UES literature. Key criteria in their assessment of relevance and application in LAC was that the publication accounted for the region's unique ecological, social, and environmental context. For example, terms such as "urban forest benefits" and "urban park and property values" from specific countries not matching the exact search string, were included by individual country experts in our final list as their content did meet our objectives. Finally, in our discussion, we focus our analysis of the literature relevant to the three guidelines. We then elucidate areas of future research needs and directions in the broad areas of urban and political ecology, policy, socioeconomic valuation, and land management and planning that are directly related to UES in LAC.

Results

UES in the literature

Like other reviews focused on UES (Haase et al. 2014; Luederitz et al. 2015), ours revealed an increasing number of relevant publications related to the search string "Urban" and "Ecosystem Services", which increased from 4 in 2000 to 462 publications in 2016. We note that at the time of writing, halfway through 2017, there were already 220 relevant publications, included in the Web of Science and SciELO. This search revealed a total of 1963 publication, of which 37% are from the United States, 13% from China, 10% from the United Kingdom and 9% from Germany; proportion similar to those reported by Luederitz et al. (2015). As for LAC region, after filtering out, we identified only 107 (originally 142 from LAC countries), or 5% of all publications, indicating a noticeable dearth of region-specific literature on this topic. When including other terms in our reviews such as "urban forests", "urban parks" and "green infrastructure", and specific countries in LAC, the number of LAC relevant publications increased to 408, but the inclusion of these terms does little to change LAC position as far as number of relevant publications against other global regions (Fig. 1). Our results showed an increasing number of relevant publications related to UES in LAC, specifically from 2 in year 2001 to 70 in year 2016.

Overall, our review of the global literature shows that the US and Canada have a considerably greater number of publications on "urban forests" than all other regions. Indeed, the sum of all 22 LAC countries' publications place it fifth (125), well after Asia - primarily China - and after Australia and New Zealand. We found a wide range of disciplines publishing on urban ecosystem services, but the main ones were the environmental sciences, ecology, urban studies, and geography. In LAC, the environmental sciences and ecology are the main disciplines of research. However, disciplines such as biodiversity conservation and forestry are of greater importance than in other regions.

UES literature from LAC

A more LAC focused review of the relevant literature found that only five of the 22 LAC countries had more than 10 publications on "urban ecosystem services" (Fig. 2), while only 3 countries had more than 10 for "urban parks", 2 countries for "urban forests" and all the LAC countries had fewer than 10 publications for "green infrastructure". This lack of scientific publications is not trivial, as it shows a pressing need for information and knowledge on LAC's diverse and complex contexts: biomes (e.g., climatic zone, local vegetation and soils, urban morphology), governance and values (e.g. institutional capacity, culturally held and assigned values), and scale of supplied service (e.g., tree shade for individual landowners or water regulation at the watershed scale); these factors are rarely addressed in the literature (Andersson et al. 2007; Escobedo et al. 2011). Most importantly, by relying on information and knowledge gathered from available studies in disparate temperate developed regions like the United States or Europe, there is a risk of making socially, environmentally, and economically mismatched decisions that are not contextually or scale relevant to LAC's realities.

We also found that publications frequently deal with issues related to ecosystem services in relation to biodiversity conservation (34%) and the quantification of regulating services (22%), and a large proportion addressed ecosystem services related to forests or water (43%). However, less than 5% of studies addressed cultural or provisioning services and only 6 papers included LAC in global studies. See our supplementary material for a list of the relevant literature we identified.

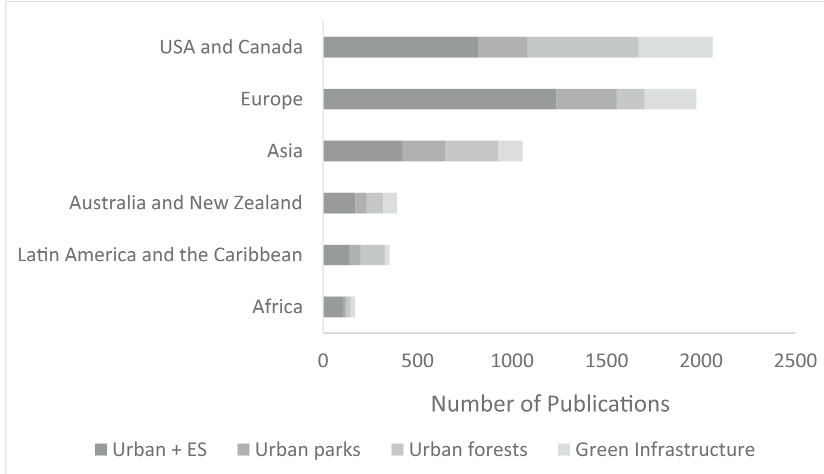

Fig. 1 Number of publications in the Web of Science (WoS) and SciELO related to Urban Ecosystem Services (UES) (June 2017)

Discussion

In comparison to literature from the Global North, fewer relevant publications from LAC could be used to quantitatively analyze and identify regional trends and metrics than those typically reported in other English Language international reviews on UES (Haase et al. 2014; Luederitz et al. 2015; Roy et al. 2012; Von Döhren and Haase 2015). Therefore, given

Fig. 2 Number of publications in the Web of Science (WoS) and SciELO relating to "Urban Ecosystem Services (UES), Urban parks, Urban Forests and Green Infrastructure" in Latin America and the Caribbean (LAC)

this limitation, we used this finite number of available literature (in English, Spanish and Portuguese) and our expert knowledge to both assess the international state of the art of the UES concept and its regional application given LAC's socio-ecological and economic context. To do so, we centered our discussion on three overarching guidelines: 1. LAC cities can be socio-ecologically unique; 2. Drivers of UES in LAC can be different than in other regions; and 3. Context and demand need to be accounted for when valuing UES. Then, for our Conclusion we synthesized our review and assessment to elucidate areas of future research needs related to UES management and planning in LAC.

Ecosystem services in the global urban context

We found a wealth of publications documenting the potential of urban green spaces to contribute to human quality of life through infrastructure, access to education, and health and labor opportunities, and this has been well established in both international and LAC regional literature (see supplementary section). But, a significant body of the UES literature focuses on their supply, which is often referred to as *benefits* derived from intermediate *ecological functions and processes* that directly or indirectly contribute to human well-being (Dobbs et al. 2011). By contrast *ecosystem disservices,* as presented in the international literature, are those ecosystem functions that detrimentally affect human well-being (e.g., allergies, nuisance wildlife, vector habitat; Escobedo et al. 2011; Von Döhren and Haase 2015). Based on these previous studies, we integrated these slightly varying definitions. For our purposes we defined UES as the ecological processes, functions, and products from both natural and semi-natural and/or managed ecosystems in urban and peri-urban areas that contribute to human wellbeing. By semi-natural ecosystems, we refer to those that are human maintained and those in, or near, human settlements that have moderate to highly disturbed ecosystem structure and functional attributes.

Accordingly, we referred to natural and semi-natural *urban green spaces* (i.e., *green infrastructure, urban parks and urban forests*) as the nature-based attributes existing in cities that are, or have been, subjected to anthropogenic management and disturbance. These attributes include trees and other vegetation in streetscapes, forests, parks, gardens, conservation areas, wetlands, streams, rivers and riparian zones, or estuaries within or adjacent to urban agglomerations. Their structural attributes also include pervious soils and planted, remnant, or ruderal vegetation and the associated fauna whose ecosystem functions provide for socially, economically, and environmentally beneficial services (Dobbs et al. 2014; Escobedo et al. 2011; MacGregor-Fors et al. 2016; Roy et al. 2012).

The international literature we reviewed refers to *regulating* UES as those that sustain processes that are key for the mediation of waste, flow of material and energy, and the maintenance of physical, chemical and biological conditions, including flood regulation, pollution removal and temperature amelioration (González-Oreja et al. 2010; Dobbs et al. 2011; Cui and De Foy 2012; Roy et al. 2012). *Provisioning* UES meanwhile influence the supply of food, fiber, and drinking water, and are key for building materials and for human nutrition (Altieri et al. 1999; Russo et al. 2017a). *Cultural* UES are the result of physical and intellectual, spiritual and symbolic interactions with ecosystem functions that provide for human recreation, education, religious, and aesthetic amenities, including increased property premiums that benefit human cognition and sense of place (De Groot et al. 2012; Henrique 2006). Finally, *Supporting* and *Habitat* UES are the ones that allow for other ecosystem services to exist although they are generally applied to non-urban ecosystems with a high degree of ecological integrity (Escobedo et al. 2011; Millennium Ecosystem Assessment 2005). We noted that other metaphors are increasingly being used that are very similar to UES and green infrastructure and include nature-based solutions, natural capital, and blue infrastructure (Hasse 2015; FAO 2016; Kabisch et al. 2016; Sarukhán and Jiménez 2016; Faggi and Caula 2017; Russo et al. 2017b; Willis and Petrokofsky 2017).

After having defined key concepts based on the global literature related to UES, in the following section we discuss three overarching guidelines that we gleaned from our review that the expert group felt should be considered when applying the UES concept in LAC. First, we discuss if indeed LAC cites are socio-ecologically unique relative to the high-income countries of Europe and North America. We discuss if the diverse and complex socio-ecological conditions in LAC cities affect the structure and function of urban green spaces differently than in Europe or North America. Second, we identify drivers of provision and dynamics of commonly studied UES in LAC and discussed if they are different from other developed regions. Finally, we discuss and argue for the need to account for both context and demand when valuing UES in LAC.

LAC cities can be socio-ecologically unique

Like other world regions with low and middle-income countries (e.g. Africa and south Asia), several urban socio-ecological factors such as rapid population growth, rural to urban migration, socioeconomic inequity, and ecological legacy characterize human settlements of Meso and South America (Isendahl and Smith 2013). But, the increased number of biodiversity hotspots makes LAC different from Europe and US-Canada. Generally, modern cities in LAC are characterized by higher population density than European and North American cities, and have a high proportion of their urban area occupied by public housing and informal settlements, impervious surfaces, and high building density, often resulting in low urban vegetation cover and fragmented patches of green spaces (United Nations 2010). However, cities across the LAC region also exhibit marked socioeconomic inequalities that influence access to public services such as sanitation and transportation (Borsdorf and Hidalgo 2010; Pauchard and Barbosa 2013). This latter reality is key in our discussion and will be discussed in the following sections.

Several international studies documented that the distribution, quantity and quality of urban green spaces are often proxies for the residents' socioeconomic status (Pedlowski et al. 2002; De la Barrera et al. 2016; Wright et al. 2012; Scopellit et al. 2016). Generally, higher income neighborhoods have a greater quantity and better quality of public green spaces, private parks, and residential gardens in larger lots. Conversely, the poorest neighborhoods have varying building densities, poor infrastructure, low quantity and quality of green spaces, small residential gardens, and sparse vegetation cover in smaller lots (Fig. 3; Pedlowski et al. 2002, Reyes-Paecke and Figueroa 2010, Reyes-Paecke and Meza 2011, Wright et al. 2012, Scopellit et al. 2016). The middle-class residential areas are generally diverse in terms of vegetation, which is mostly limited to green spaces and residential gardens (De la Barrera et al. 2016). Further, since the late 1980s, the relative proportion of urban growth in LAC has occurred mostly in medium-sized cities which in recent decades have increased rapidly throughout the region, replicating the segregated urbanization pattern of large metropolitan areas (Borsdorf and Hidalgo 2010). Such factors have been reported to lead to a significant loss in green spaces, especially remnant natural ecosystems, as well as adjacent rural areas (Aguayo et al. 2007; Pauchard and Barbosa 2013).

The relevant literature we assessed showed that socio-political and economic contexts affect the structure and function of urban green spaces and their UES (Escobedo and Chacalo 2008; Benitez et al. 2012; Biggs et al. 2015; Escobedo et al. 2015; De la Barrera et al. 2016; Favaro et al. 2016; Dobbs et al. 2017). Specifically: (1) supply, level, and interactions among UES; (2) demand for UES by different social groups; and (3) actions of different social groups and their power relations and asymmetries determine the decision-making processes that drive social inequities relating to the latter points. For example, access to urban green spaces and their UES are often stratified based on income (Romero et al. 2012; Scopellit et al. 2016). Research on the relationship between urban green spaces structure and UES provision, regarding their socioeconomic status, has often focused on the analysis of green space distribution and on certain associated biophysical characteristics (Pedlowski et al. 2002; Reyes-

Fig. 3 Low income (upper 2 photos) and high income (lower 2 photos) neighborhoods and streets in Bogotá Colombia using Google Earth and Streetview®. Note irregular land use patterns, poor condition infrastructure, and low, fragmented green space cover in upper two photos. Aerial images taken at an altitude of 3.2 km and street views are from September 2012

Paecke and Figueroa 2010; Celemin et al. 2013). Thus, like in developed countries- socioeconomic status- regardless of climate, is the predominant driver of urban green space distribution, access and connectivity in LAC (Romero et al. 2012; Escobedo et al. 2015).

However, the socioeconomic inequity that characterizes most LAC countries tends to weigh more heavily in the supply and demand for UES than in many other global regions (Lustig et al. 2015). This reality is starkly different from other regions (E.g. Northern Europe, Australia) where effective public institutions and governance can maximize the provision of UES via well-established land use and conservation policies (Balvanera et al. 2012) which differ greatly from LAC's ineffective public policies and issues of poor transparency that can limit the influence of UES on well-being (De Freitas et al. 2007, Romero-Lankao 2007; Hardoy and Pandiella 2009; Perez-Campuzano et al. 2016; Da Silva et al. 2017; Gonzalez and Ojeda-Revah 2017).

Several other regional studies indicated that historical and current regional and local-level planning and governance are key factors determining the amount and distribution of urban green spaces (Colding et al. 2006, Henrique 2006, Andersson et al. 2007, Perez-Campuzano et al. 2016, Gonzalez and Ojeda-Revah 2017). Neoliberal policies implemented in the 1980s across LAC have limited progressive governmental urban planning decisions (Roberts 2005). This has led to the development of ineffective regulatory planning instruments and increased influence of the private sector through real estate-oriented interests (Henrique 2006). Planning and governance are generally characterized by ineffective governmental institutions, lack of transparency, poorly defined tenure regimes, absence or ineffectiveness of planning tools, and prioritization of investments in built infrastructure and hard technologies at the cost of urban green spaces (Santos et al. 2010, Escobedo et al. 2015, Calderón-Contreras and Quiroz-Rosas 2017).

We also found that, because management of urban green spaces such as parks and plazas usually depends on municipal revenues and homeowner access to resources, urban municipalities and neighborhoods with lower income generally have few, sparsely vegetated urban green spaces (Pedlowski et al. 2002; Escobedo et al. 2015; Favaro et al. 2016), and subsequently lower UES provision. In addition, the occupation of ecologically sensitive peri-urban areas by informal, poorly planned settlements and slums detrimentally affects urban green space structure and function (Benitez et al. 2012; Inostroza et al. 2013; Biggs et al. 2015; Escobedo et al. 2015). For example, unplanned settlements in Bogota, Colombia, for example, are a result of people being forced to relocate due to military conflicts in rural areas or criminal activity (De Geoffroy 2009).

These unplanned urbanization patterns common in many LAC cities affect local and regional biodiversity by promoting local extinctions and introducing alien species. Regional and global studies show how changes in species pool (e.g. invasive species) can potentially alter ecosystem processes that determine the provision of UES (Lima et al. 2013; MacGregor-Fors et al. 2016). In LAC, urbanization has been documented to have greater impacts than in other regions, due to its high biodiversity and degree of endemism (Ditt et al. 2010; Myers et al., 2000; Mendoza-González et al. 2012, Flores-Meza et al. 2013, Merlín-Uribe et al. 2013, Mitsch and Hernandez 2013, Pougy et al. 2014, Salazar et al. 2015, Scarano and Ceotto 2015). Urban ecosystems in LAC, as elsewhere, are now frequently characterized for having many introduced and often-invasive flora, which are preferred over native species despite their influence in UES provision (Lima et al. 2013; Caballero-Serrano et al. 2016). For example, some fauna adapted to urban conditions can play important roles as pollinators, seed dispersers and pest regulators (Aleixo et al. 2014; MacGregor-Fors et al. 2016). Large numbers of introduced species are common in cities of Colombia, Brazil, Chile, the Caribbean, Venezuela, and Argentina (Isernhagen et al. 2009; Santos et al. 2010; Gutiérrez et al. 2013; Lima et al. 2013; Angonese and Grau 2014; Escobedo et al. 2015).

Drivers of UES can be different than in other regions

Global and some regional studies on the supply of UES have emphasized a few regulating UES, namely carbon sequestration and water quality (Fernández et al., 2010; Balvanera et al. 2012, Mazari-Hiriart et al. 2014, Vargas-González et al., 2014; Luederitz et al. 2015; Clerici et al. 2016; Cunha et al. 2016, Jujnovsky et al. 2017), and to a lesser degree, health, recreation, and aesthetic benefits related to cultural services (Escobedo and Chacalo 2008; Reyes-Paecke and Figueroa 2010; Ribeiro and Ribeiro 2016). Given the dynamic character of LAC cities, climate change mitigation, as opposed to adaptation, has become a more common approach for addressing regulating ecosystem services mainly related to climate change and air quality (Magrin et al. 2007; Escobedo et al. 2008; Escobedo and Chacalo 2008; Baumgardner et al. 2012; Dos Santos et al. 2014; Pimienta-Barrios et al. 2014; Sacchi et al. 2017).

As in other regions, the literature also shows a second set of biophysical and morphological factors driving urban green spaces (Benitez et al. 2012; Dobbs et al. 2014; Biggs et al. 2015; Favaro et al. 2016). Many cities in LAC are distributed in the extremes of temperature, rainfall, and evapotranspiration rates (i.e., Amazonian tropical lowlands to Mexican high elevation deserts) which influence primary productivity and ecosystem structure differently than most developed cities located in cool, temperate climates. This in turn determines the supply and demand of UES, such as climate mitigation and recreation (Dobbs et al. 2014). Steep topography in the mountainous Andean region, for example, influences specific regulating UES related to the mitigation of natural hazards like flooding and landslides which often affect the peri-urban poor (Aide and Grau 2004; Pisanty et al. 2009). Also, most urban expansion in LAC occurs towards floodplains and lower mountain slopes, which are frequently occupied by low-income groups following unplanned growth (Hardoy and Pandiella 2009; Benitez et al. 2012; Biggs et al. 2015). The establishment of informal settlements can often cause vegetation clearing in slopes and riverbeds, thus increasing vulnerability to natural disasters, a particularly frequent problem in LAC cities (Cilento 2002; Benitez et al. 2012). Climate change will also affect LAC cities and its substantial vulnerable populations (Cilento 2002; Aide and Grau 2004; Magrin et al. 2007; Hardoy and Pandiella 2009; Coronel et al. 2015; Favaro et al. 2016) and the structure of urban green spaces in LAC (e.g. tropical and arid cities will regularly experience severe drought and even wildfire, while coastal cities will experience sea level rise; Magrin et al. 2007).

Accordingly, we posit that mismatches between frequently studied UES provision and actual consumer demand in LAC can be due to the lack of planning, connectivity, and other factors such as spatial and educational segregation, high levels of inequity, and low community participation in urban decision-making and public affairs (Romero et al. 2012). For example, the emphasis on mitigating atmospheric pollutants research (Escobedo and Chacalo 2008), has overlooked many other pressing UES occurring in LAC such as regulating urban flooding, temperatures, food security, and access to sustainable supplies of clean water (Aide and Grau 2004; Romero-Lankao 2007; Cram et al. 2008; González-Oreja et al. 2010; Cui and De Foy 2012; Barbedo et al. 2014; Mazari-Hiriart et al. 2014; Pina and Martínez 2014). Although an increasing body of literature on soil-related UES has been developed in regard to fertility and disaster prevention (Cram et al. 2008; Fernández et al. 2010), other functions and services such as pest regulation, pollination, bioenergy, and food provision continue to receive little attention (Altieri et al. 1999; Chaves et al. 2011; De Medeiros et al. 2013; Aleixo et al. 2014; Dickie et al. 2014; Russo et al. 2017a).

Research in LAC has however started to incorporate UES such as provision of medicinal resources as part of the value of conserving biodiversity (De Medeiros et al. 2013; Aleixo et al. 2014). Cultural UES in LAC such as recreation and aesthetics are also increasingly being studied (Reyes-Paecke and Figueroa 2010; De Souza Filho et al. 2014; Ribeiro and Ribeiro 2016; Scopellit et al. 2016; De la Barrera et al. 2016b; González and Holtmann-Ahumada 2017). These studies show that local governments rarely invest in urban ecosystem restoration that is required for such UES (Pisanty et al. 2009), with few exceptions in Mexico (Mendoza-Hernandez et al. 2013; Mazari-Hiriart et al. 2014; Williams-Linera et al. 2015). This is likely because governmental resources often prioritize basic and necessary social and economic programs, such as access to housing, health and sanitation, while investing in green spaces and UES provision is considered less important (Nickson 2001).

Some of the regional literature we identified shows that efforts are being made in a few LAC cities to recover urban green spaces through large-scale restoration and tree planting programs that include the increased use of native flora and fauna to maximize ecosystem services and restoration goals (Pimienta-Barrios et al. 2014). Urban wetland restoration programs and strategies in LAC have been implemented to recover spaces for biodiversity and/or UES such as flood regulation, water filtering, air pollution removal, habitat conservation, and education (Table 1). Medium and large cities (i.e., Curitiba and Rio de Janeiro, Brazil) have established parks of remnant native patches of the Atlantic forest that not only provide biodiversity but other regulating, supporting, and cultural UES (Santos et al. 2010). More examples and quantifiable benefits from such projects are needed to inform and promote UES benefits.

Context and demand need to be accounted for when valuing UES

We were able to glean from the global UES literature that in addition to the socio-ecological and political drivers discussed above, land and real estate values and short term financial profits to a limited number of agents, will generally outweigh the use and non-use values to society of UES. The demand for such UES is usually quantified using neoclassical economic methods (e.g. hedonic valuation, contingent valuation, travel cost, and avoided and replacement costs), sociology, and other qualitative methods that measure people's perception of UES. Gómez-Baggethun and Barton (2013) and Kronenberg (2014) provide a comprehensive list of these valuation methods, along with their practices and limitations. This limited number of studies seems to show that a combination or integration of social as well as economic valuation methods are necessary, given the complex and heterogeneous nature of UES.

Regionally, we found that most current LAC literature on UES valuation is related to payment for ecosystem service instruments like water quality and biodiversity conservation (e.g. Brazil and Mexico; Larqué-Saavedra et al. 2004, Machado et al. 2014, Jardim and Bursztyn 2015, Cunha et al. 2016, Figueroa et al. 2016). Cultural UES and urban ecosystem benefits such as heritage, pollution removal, carbon sequestration, aesthetics, and others, can also be found from the Andean region, Brazil, and Mexico (Tognella-de-Rosa et al. 2006; Del Angel-Perez et al. 2011; Báez-Montenegro et al. 2012; Ponce-Donoso et al. 2012; Ordóñez and Duinker 2014; Caro-Borrero et al. 2015). Many other studies estimate Willingness to Pay (WTP) for services using contingent valuation and benefit transfer methods based on

Table 1 Urban tree planting and wetland restoration project examples from Latin America and the Caribbean

Tree plantings	Web source
Belo Horizonte (Brazil)	http://www.cemig.com.br/sites/imprensa/pt-br/Documents/Manual_Arborizacao_Cemig_Biodiversitas.pdf
Santiago (Chile)	www.arborizacion.cl;
Quito (Ecuador)	http://comafors.org/programas-y-proyectos/forestal-y-agroforestal/proyecto-planta-un-arbol-por-tu-futuro
Wetland restoration	
Bogota (Colombia)	http://humedalesbogota.com/humedales-bogota/
Belo Horizonte (Brazil)	http://www.solucoesparacidades.com.br/wp-content/uploads/2013/09/AF_DRENNURBS_WEB.pdf
Santiago (Chile)	http://www.forecos.cl/index.php/proyectos

previous studies and shadow prices from North America and Europe (Balvanera et al. 2012; Casey et al. 2006). But, as is well known, possible mismatches are created when applying these metrics for valuing demand in LAC, considering the region's diverse flora, fauna, cultures, wide range of climates and geography, weak institutions and transparency, and other socioeconomic inequities discussed in previous sections. Thus, valuing UES per se comes with several challenges: weak substitution, perception of corruption in WTP contingencies, socio-ecological heterogeneity, connectivity/infrastructure value, and scale issues (Gómez-Baggethun and Barton 2013), in addition to the risk of applying utilitarian monetary values to UES (Kronenberg 2014). In LAC, these same issues affect valuation, but the lack of region-specific information and methods may result in different and sometimes erroneous outcomes.

For example, Ordóñez and Duinker (2014) discuss Columbians' perceptions of cultural UES and associated values, and found that increased property values from urban forests were not necessarily highly valued. This might be a result of the frequent occurrence of informal economic activities near treed spaces (e.g. street vendors, intermixed commercial/residential/recreation activities), complex property rights, and high population densities; and hence, a greater number of potential beneficiaries from these services. A similar study in Mexico (Camacho-Cervantes et al. 2014) revealed that people value trees for the oxygen provision and shade that might be related to the air quality of the city and summer temperatures, despite biogenic emission from certain trees that can contribute to increased ozone concentrations (Baumgardner et al. 2012).

Thus, urban ecosystems can pose both positive (UES) and negative (disservices) externalities to different beneficiaries within the same locale. Socio-political (e.g. education, access to resources, crime) and geographic context also affect the value that different societies – and individuals- place on a specific UES, even within the same region. For instance, in arid Chile, Peru and Mexico, urban trees are valued for their shading and air quality improvement benefits, but their evapotranspiration and pollination functions of certain species can be considered disservices in these water-scarce environments and for allergy prone populations. Thus, this differentiation between service and disservices is both value-laden and context-specific (Escobedo et al. 2011; von Döhren and Haase 2015). These few relevant LAC studies account for local scale, context-specific socio-political perceptions and values towards UES, and indicate that increased environmental education, awareness, and promotion are key when managing and planning for the provision of services and minimization of disservices, in LAC and elsewhere.

Similarly, limited regional literature indicates that in most LAC megacities (e.g., Mexico City, São Paulo, Lima, Bogota, Buenos Aires), urban development infrastructure projects such as housing development, water treatment plants, and engineered storm-water structures, are regularly deemed to yield higher economic benefits than does preserving green spaces and their UES due to the opportunity costs of land (Aguayo et al. 2007; Cram et al. 2008). Interestingly, as in other regions, much of the engineered infrastructure related to urban development is often to minimize the environmental hazards and socio-ecological impacts brought about by the alteration of green space function via built infrastructures (e.g. increased floods, temperatures, quality of life; Von Döhren and Haase 2015). Hence, region-specific socio-political valuation information and methods that also prioritize sustainability and equity are direly needed. We are awared that in the time during the review-acceptance process of the manuscript, new studies from LAC are beginning to address issues such as urban ecosystem disservices, spatio-temporal intercity comparisons of UES, and the social value of provisioning UES among others (Almeida et al. 2018; Banzhaf et al. 2018; De Mola et al. 2018; Dobbs et al. 2018; Escobedo et al. 2018; Moser et al. 2018; Nadal et al. 2018).

Conclusion

Overall the UES concept's origin, development, and sheer number of publications are from the US-Canada, Europe and more recently, China and Australia. As such the development, policy uptake, and institutionalization of the UES as a research framework and governance instrument in the European Union, Canada, and the US has been well defined and accepted. Although ecosystem service related concepts and practices such as payments for ecosystem services and benefits from urban green spaces are commonly mentioned in LAC urban planning instruments, noticeably lacking are scientific UES publications from LAC and other middle and low income countries in Asia and Africa that can provide the science-based information needed for more effective policy uptake. Although we did identify similarities and dissimilarities in relation to how UES are defined, used, applied, and institutionalized between LAC and other developed regions, we conclude that standardized approaches from developed countries should continue to be used to complement, but not substitute for, LAC-specific models and frameworks for applying the UES approach in the region.

Up to this point we have used the global and regional literature as the evidence and basis for our review and analyses. But given the noticeable lack of relevant literature from LAC, here forth we use our expert-based knowledge to elaborate beyond our review and the three guidelines we laid out. We noticed a clear omission on studies regarding the role of governance and government funding for UES research in LAC. Thus, we argue that more improved governance systems are also a necessity in LAC to provide for more effective and equitable provision of UES. However, increased funding in UES research, education, and institutional capacity in LAC are urgently needed to better quantify the supply, and value the demand for UES in both an equitable and relevant manner. As in Europe and China, research using and developing geospatial tools is one approach that can be used to better understand the socioeconomic inequalities and mismatches in UES supply distribution across space and time. But, spatially explicit – context relevant – analyses need to also account for consumer demand for UES and disservices in LAC. Such efforts can be facilitated by incorporating researcher-practitioner-citizen participatory processes and by developing and making available freely available UES datasets to support research, education, and policies as is common in the US and Australia. Designing clearinghouses and guidelines in Spanish and Portuguese language and other local dialects is also necessary for disseminating science-based information to government and other administrative units such as smaller sized cities and communities that are distant from capitals.

Again, as opposed to most high-income English-speaking developed countries, there is a lack of relevant literature from LAC; thus researchers and practitioners have to rely, in many instances, on the applied research and extension education findings and experiences from countries in the Global North. Accordingly, we identified the need to account for region-specific urban ecosystem dynamics and disservices in both spatial and temporal scales as this is key for effectively applying the UES concept in the region. For example, research on UES should build upon traditional biophysical modeling and valuation based on neoclassical benefit transfer approaches developed in the US. But, site-specific valuation of UES that are context-relevant to LAC will also raise awareness on their supply and demand to beneficiaries and influential decision makers. Hence, incorporating deliberative valuation, traditional knowledge, and novel environmental psychology and behavioral economic approaches, as opposed to conventional neoclassical or reductionist ones, is warranted. Other emerging research concepts such as socio-ecological resilience of cities in LAC, insurance values of mitigating disturbances, or Nature-Based Solutions, in both monetary and socio-political metrics could be used to promote UES and conservation of peri-urban natural areas. Given LAC's biodiversity and socioeconomic disparities, such knowledge is highly relevant given the prospect of climate change effects. Similarly, the role of biodiversity and tropical climates in negatively affecting well-being (e.g., disease vectors, crime occurrence, wildlife and insect nuisances, allergens, thermal comfort) has been little studied. Improved information for the quantification and minimization of urban green spaces' costs or disservices is necessary for valuing the net benefits. Based on our experience and discussions among the group, such knowledge could facilitate the incorporation of the UES framework into local-scale policy and decision-making.

At the national level, LAC has led the development of innovative instruments and policies that protect biodiversity and promote ecosystem services. Costa Rica is recognized for their Payment for Ecosystem Service instruments, Colombia has the National Policy for Integrated Management of Biodiversity and its Ecosystem services, and recently Chile is exploring the use of urban tree plantings as part of national-level compensation policies for mitigating particulate matter pollution. But, as LAC's cities grow, a more region-specific understanding of the supply and demand for UES is crucial for maintaining human well-being and biodiversity in places where most of the region's population lives. Such context-specific information on how to more effectively promote, deliver, and apply UES is particularly important not only in LAC, but also in regions such as Africa and Asia, where inequities, rapid urbanization, and climate change effects are drastically stressing local and regional ecosystems and their adaptive capacities. We note that metaphors such as UES, green infrastructure, and biodiversity, and more recently nature-based solutions, are constantly evolving as a result of European Union and US-funded research networks.

In conclusion, our international and LAC focused review shows that the use of the UES framework in LAC can be opportune, especially in benefitting vulnerable communities and those that are at-risk of landslides, flooding, increased temperatures, and food security. We propose that UES should be incorporated institutionally by local-regional governments as part of land planning and policy uptake, biodiversity conservation, and identification of restoration targets. Incorporating the UES framework can be used to improve resilience and achieve more sustainable and equitable development in urban LAC. However, we believe the biggest challenge to LAC scientists, planners, and managers is providing context-specific UES information, instruments, and guidelines that can easily be integrated into decision making and context relevant policies.

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