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Review

Trends in Urban Forestry Research in Latin America & The Caribbean: A Systematic Literature Review and Synthesis

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ABSTRACT

Research on urban forests has expanded in the last 30 years in the US, Canada, Europe, and Australia. Nonetheless, urban forestry has been explored to much less extent in the Latin America and the Caribbean region, despite being one of the most urbanized and biodiverse regions in the world. We address this gap by providing a baseline understanding of urban forest research in the region based on a systematic review of the academic literature. Of the 55,000 studies found, 195 were selected for review, and 182 were analysed and synthesized. These studies came from 13 countries and were published from 1970 to mid-2018 (inclusive) in English, Spanish, and Portuguese. Almost half of the studies were based in Brazil, followed by Mexico and Chile. To comparatively assess article output by country, we accounted for country population and Brazil, Chile, Nicaragua, and Puerto Rico had higher than average per capita article output. Most articles were ecological studies (64%) that used field surveys (58%) to research urban vegetation diversity. Most ecological studies did not include any social or management considerations. Only a few studies focused on spatiotemporal dynamics (12%) or the direct opinions of stakeholders (9%). We observed a notable increase in article output from the region during the last decade. The units of analysis targeted by these studies mostly focused on single trees in public areas (streets and parks). Understanding urban forests regionally could be strengthened by scaling up research across multiple units of analysis and across regional cities, which could provide a better understanding of regional spatiotemporal dynamics. To respond to current global trends and nurture regional strengths, research could also focus on a wider range of ecosystem services provided by urban forests, and the relationship of urban forests with poverty, crime, climate vulnerability, biodiversity loss, and social equity. These findings can inform key stakeholders in the region managing urban forests and trees about research trends and gaps to be filled. This article shows that the region indeed has an important body of research in urban forestry that should be recognized in global assessments.

1. Introduction

Urban forests in the United States (US), Canada, Europe, and Australia have been recognized, and studied for a long time, due to their highly-urbanized contexts (Roy et al. 2012; Boulton et al. 2018). More recently, China, South Asia, and Africa are becoming the foci of research as their populations and forests urbanize (Krajter-Ostoić and Konijnendijk van den Bosch, 2015; FAO, 2016). However, despite high

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levels of urbanization and biodiversity (UN-HABITAT 2016, MacGregor-Fors et al. 2016), urban forests in Latin America & the Caribbean (LAC) have received less global attention relative to other highly urbanized regions. In this article, we systematically review urban forest research in LAC to synthesize the state of the art on this topic within the region. We first provide an overview of the urban forest research discipline, and then present the geographical and socio-ecological context of LAC, before detailing our approach and findings from the review.

Research on urban forests has been a long-studied topic (Rowntree, 1984; McPherson et al., 1994; Brack, 2002; Konijnendijk, 2003; Tzoulas et al., 2007). While urban forests can be broadly defined as all the trees in a city (Rowntree, 1984; Konijnendijk et al., 2006), a more comprehensive definition should imply that urban forests are networks or systems comprising all woodlands, groups of trees, and individual trees located in urban and peri-urban areas (Nowak, 1993; FAO, 2016) as well as their associated infrastructure, and ecological and social connections (Dobbs et al., 2011; Threlfall & Kendal, 2018; Steenberg et al., 2019). Even before the advent of the ecosystem services concept (MEA, 2005) and the more recent green infrastructure and nature-based solution frameworks (Nesshöver et al., 2017), urban forest research was already addressing the links between urban forest structure and composition and ecosystem services, including human well-being (McPherson et al., 1994; Nowak et al., 2001; Tzoulas et al., 2007; Dobbs et al., 2011; Roy et al., 2012; Camacho-Cervantes et al., 2014; Willis & Petrokofsky, 2017; Escobedo et al., 2019). For example, urban forest studies in the US (Nowak et al., 2001; Nowak and Greenfield, 2012; Roman et al., 2018) and Europe (Krater-Ostoić et al., 2018) have shown the connection between urban forests and environmental services, such as the mitigation of climate change impacts and environmental pollution (e.g. air quality, urban climate, stormwater). Studies in Australia (e.g., Brack, 2002; Daniels & Kirkpatrick, 2006; Dobbs et al., 2014) have looked at the potential of urban forests to mitigate climate change impacts, capture carbon, and conserve biodiversity. In China, studies have addressed several questions related to the benefits of urban forests related to environmental and socio-economic issues (Jim & Chen, 2009; Yang et al., 2005), as well as the spatial and temporal distribution of urban trees and the services they provide (Yang et al., 2014). Meanwhile in Japan, studies have explored the role of forests in an around the city for psychological well-being (Park et al., 2010).

Part of the urban forest literature has focused on the role of biodiversity and urban tree-cover in supporting the resilience of cities, yet this has been documented in literature primarily from North America and Europe (Alvey 2006, Fuller and Gaston 2009; Tzoulas et al. 2007; Nowak and Greenfield, 2012). Such studies have found that the functionality of urban forests, in terms of ecosystem service provision, not only depends on traditional measures of urban forest structure (Beninde et al. 2015), but on the diverse palette of tree species to protect the urban forest from pest and diseases (Tubby & Webber 2010; De Santis et al., 2013), climate change, and to address other important ecological and social considerations (Threlfall & Kendal, 2018). Topics that are increasingly being studied in this area of research include the role of urban forests and trees in the improvement of people's social interactions (de Vries et al., 2013), psychological well-being (Sugiyama et al. 2008), health, such as respiratory illnesses (Donovan et al. 2013) and morbidity (Maas et al. 2009), and physical activity (Giles-Corti et al. 2005), thus linking urban forests and trees to human well-being issues (Tzoulas et al. 2007). The role of urban forests in environmental justice is becoming a prominent topic in the urban forest literature (Kuruneri-Chitepo and Shackleton 2011; Shackleton, 2012; Watkins et al. 2016; Nesbitt et al. 2018). Throughout this long-standing research, the benefits of urban forests to urban human communities has been well documented, leading to both the inclusion of forests in municipal planning and sustainability objectives (Calaza et al. 2018), and a recognition of their uniqueness, which implies the need to account for context when assessing the social, economic and environmental factors or drivers affecting urban forests (FAO, 2016).

Understanding urban forest research in LAC is necessary for a more diverse and global appreciation of urban forestry. The region provides an interesting context, being home to several megacities of the world, as well as a diversity of biomes, climates, nations, and cultures, yet unified by shared environmental, socio-cultural, and economic characteristics (UNEP 2010). Many LAC cities are experiencing rapid urbanization which is causing an unprecedented rate of loss of agricultural land and conservation areas (UNEP 2010; Inostroza et al. 2013; Rincón-Ruiz et al. 2019). Social inequalities in LAC cities are some of the highest in the world (UN-HABITAT 2016). These inequalities, along with their diverse geographical and climatic contexts, makes LAC cities some of the most vulnerable to future climatic changes (Hardoy & Pandiella 2009). Many LAC countries are also experiencing high rural-urban migration due to conflict (e.g., Colombia; Rincón-Ruiz et al. 2019; see also Rolnik 2014) and increased economic pressures from globalized markets (Topik et al. 2006). Despite these challenges, LAC cities such as Curitiba (Brazil), Medellín (Colombia), San José (Costa Rica), Buenos Aires (Argentina) and Santiago (Chile), are well-known global case studies in environmental sustainability (C40, 2019; ICLEI 2019). Many of these cities are also paying attention to the urban greening agenda, particularly, urban forests (Escobedo et al. 2008).

However, there is little knowledge on the current state of the art and trajectories of urban forest research in the region, despite there being an increase in studies on urban forest ecosystem services, urban forest structure, and the socio-economic aspects of urban forests (Dobbs et al., 2019; Escobedo et al., 2018). Regional urban forestry reviews have been done for the US (Nowak et al., 2001; Nowak and Greenfield, 2012; Wolf & Kruger 2010), Europe (Fuller and Gaston, 2009; Konijnendijk 2003), and China (Yang et al., 2014), but there are none, to our knowledge, that have focused in LAC (Dobbs et al., 2019). Studying urban forestry in LAC will shed light on how the region is contributing to global discourses on urban ecosystem services, nature-based solutions, and green infrastructure (Haase et al., 2014; Luederitz et al., 2015; Kabisch et al., 2016; Nesshöver et al., 2017; FAO, 2016). It also offers opportunities for understanding the relationship of urban forests with climate change, payment for ecosystem services, management and planning, public opinions and values, and social equity, in a Global South context (Locatelli et al., 2008; Meléndez-Ackerman et al., 2014; Ordóñez & Duinker, 2014; Pérez-Campuzano et al., 2016; Reynolds et al., 2017; Escobedo et al., 2018, 2019; Dobbs et al., 2019; Robson et al., 2019). Being a region composed of low to mid income countries (i.e., the Global South), LAC research necessitates a lens grounded in the local realities of its cities (Dobbs et al., 2019), a lens that is different to those used in higher income countries (i.e., the Global North), and accounts for the environmental, social, and economic characteristics of the Global South (see Shackleton, 2012; FAO, 2016).

Accordingly, a regional LAC review of the urban forest research literature can provide information to both practitioners and researchers on the contribution of LAC to the science and practice of urban forestry. For this purpose, the present review was guided by the following questions: 1) what are the trends of research in the region in terms of research themes, methods, and case studies?; 2) what do these findings mean for understanding urban forest research and practice in the region?; and 3) how can this information be synthesized to guide future research endeavours, fund new initiatives, and translate science into practice? To answer these questions, we: i) identify relevant empirical studies using a systematic review process; ii) categorize these studies in terms of their dimensions, topics, units of analysis, scales, methods, and geographical foci to facilitate comparison across studies; iii) extract main findings by focusing on similarities among the studies; iv) critically discuss these findings in the context of current research on urban forests; and v) comment on future research opportunities. This effort builds on studies that try to understand research trends holistically through reviews (e.g., Haase et al. 2014; Luederitz et al. 2015; Boulton et al. 2018), particularly urban forest research through a regional lens

(e.g., Konijnendijk 2003; Nowak et al. 2001; Nowak and Greenfield, 2012; Yang et al. 2014; Nesbitt et al. 2017; Krater-Ostoić et al. 2018). The analysis will help researchers and practitioners understand what makes urban forest science specific to LAC, a perspective that can also be useful in a global context to advance urban greening research worldwide.

2. Methods

2.1. Design

Following the systematic review guidelines established by Pullin & Stewart (2006), Moher et al. (2009) (i.e., PRISMA procedures), and CEE (2013), we developed a protocol for searching, finding, and selecting articles. The scope of the search was regional, focused on the LAC, defined by the United Nations including predominantly Spanish & Portuguese speaking countries (UNEP 2010). We limited our search to English-, Spanish-, and Portuguese-language articles. All the authors of this article speak at least two of these languages, and hence participated in the review of articles. Studies were selected for assessment based on their relevance to the definition of urban forests as all the trees in a city and their infrastructure, ecological, and social connections (see Rowntree 1984; Nowak 1993; Konijnendijk et al. 2006; Dobbs et al. 2011; Threlfall & Kendal 2018; Steenberg et al. 2019).

2.2. Searching, Finding, and Selecting Articles

Systematizing literature review procedures is an important process to avoid the subjective and purposeful selection of articles (Pullin & Stewart 2006). We developed a protocol for searching and finding articles that was as objective and replicable as possible. The search was limited to peer-reviewed articles in academic journals including empirical research studies as well as conceptual, and review studies, if they focused on LAC; however, we excluded book chapters, conference proceedings, or other publications. To facilitate the search, we grouped keywords in three main clusters that reflected our inclusion and exclusion criteria: 1) the space (i.e., urban areas, cities); 2) the geography (i.e., LAC); and 3) the themes of the articles (i.e., urban forests, urban trees) (Table 1). General terms, such as "green areas" or "ecology" were used to cast a wider search and identified more articles. However, given our above definition of urban forests, most of our keywords included terms that were focused on trees and tree-dominated ecosystems (Table 1). We avoided terms that could yield results focused solely on wildlife (e.g., "biodiversity") to narrow the search. We also did not use individual country or city names in our search, as this list could have been very long and difficult to manage in one line of code. This is also done in systematic literature reviews to avoid biasing searches towards case-specific studies and to ensure consistency in the final search code (see below and Appendix 1). We discuss some of the implications of these limitations in the searches in the discussion section.

Four academic databases were searched using the keywords and an analysis period of 1970 to mid-2018 in an iterative manner (Table 1). The search was carried out in three stages: 1) the keywords were used interchangeably in an open initial search (i.e., two or more search terms at once), so as not to restrict the search procedure (see Pickering and Byrne, 2014), and the hits in these searches were saved and aggregated; 2) the keywords were re-applied to the aggregated and saved hits from the initial search to filter out more relevant results (re-applying searches on hits retrieved from an initial search is necessary to filter hits further); and 3) the keywords were hen applied to the titles and abstracts within these hits using a refined search code (i.e., all final search terms at once) consisting of all search keywords for further filtering (see Pickering and Byrne, 2014). The search finalized in May 31, 2018. Articles were then selected for subsequent analyses according to the above criteria. Only articles with full-text access were used for analysis (see Appendix 1). Articles considered relevant found purposefully through other means (e.g., colleague or reviewer suggestions), but not found in the search, were not included in the review and are listed in Appendix 3.

Table 1
Details of review stages, including search procedures and selection criteria.

Review stage	Procedure	Details		
Data collection	Database search by title and abstract using keywords. Databases used: *Scopus*[a] *Web of Science*[a] *Redalyc*[b] *SciELO*[b]	*Keywords used:* [c,d]		
		Group 1: Urban City	*Group 2:* Latin America Latino America Latin-America Latino-America Latino North America Central America South America Caribbean Hispanic America Antilles	*Group 3* dasonomy [e] ecosystem ecology forest forestation greening green area green infrastructure green space natural area park silviculture[e] street trees tree vegetation woodland
	Individual *Redalyc* journals[b]	*Keywords as above* [c,d]		
Data screening	Screen abstracts of initial database using selection criteria	*Selection Criteria* 1 Focuses on cities or urban areas 2 Study in LAC 3 Includes information about tree-dominated systems (including urban wooded area, treed or forested urban park, or street trees)		
Data eligibility	Obtain full-text articles and analyse the full content of text using selection criteria	*Selection Criteria* 1 Focuses on cities or urban areas 2 Study in LAC 3 Includes information about tree-dominated systems (including urban wooded area, treed or forested urban park, or street trees)		
Data analysis	Apply classifications to the data	Build database of all studies, synthesize content, develop categories for classification items, use data to create synthesis tables and diagrams		
	Network analysis of themes	Construct visualizations that help identify patterns from the data based on a network structure analysis using centrality metrics.		

[a] Searches done in English, Spanish, and Portuguese.
[b] Searches done in Spanish and Portuguese. For a list of Redalyc journals, see Appendix 2.
[c] Matching Spanish and Portuguese terms also used.
[d] Bolean operators such as AND OR were used in between groups to include or exclude words in the search.
[e] "Dasonomy", or forest sciences, and "urban silviculture: are terms used in many LAC educational institutes (e.g., http://areasverdesyarboladourbano.com.mx/).

Searching and finding articles in Spanish- and Portuguese-only databases such as Red de Revistas Científicas de América Latina y el Caribe, España y Portugal (Redalyc; www.redalyc.org); and Scientific Electronic Library Online, (SciELO; www.scielo.org; Table 1) was nuanced and thus deserves further explanation. As of mid-2018, the SciELO online search function only allowed for title and not abstract searches, so only relevant titles were identified in the search. The Redalyc main search function was determined to be not adequate in finding individual articles (Appendix 1; note the search function in Redalyc was changed in 2019). For this reason, out of a total of 1278 (as of May 31, 2018) existing individual academic journals in the Redalyc database, 72 journals were selected based on thematic fit, including

Table 2
Categories and themes that emerged from the content analysis of selected literature organized by classification items.

Classification items	Definition	Emerging categories and themes		Categories assigned as
Geographical focus	Country(s) or geographic extent where study was conducted	Argentina Bolivia Brasil Chile Colombia Costa Rica Honduras Mexico	Nicaragua Perú Puerto Rico Uruguay Venezuela National study (country-wide) Regional study (a state, department, or province within the same country) Country-country comparative study	Mutually exclusive (except for country-country comparisons)
Dimension	Broad character of the study	Ecology Social	Management	Overlapping
Unit of analysis	The object(s) of analysis targeted by the study	All trees (incl. private and public trees) Public street trees Urban and peri-urban parks (i.e., parks) Woodlots	Other (includes: University campuses (private and public); Private property (incl. gardens, patios); Wetlands; Agricultural land; Mangroves)	Mutually exclusive
Scale	The spatial scope / coverage of the study	Urban forest only Peri-urban forest only	Urban-rural forest	Mutually exclusive
Method type	Broad method classifier	Biophysical methods	Social methods (also classified as empirical/non-empirical)	Mutually exclusive
Method	Procedures of data collection and analysis	Field surveys Field experiment Remote sensing & aerial photography Geospatial data & analysis Literature review (i.e., review) Social intercept questionnaires	Social interviews (qualitative) Social surveys (phone, postal, or electronic) Other (includes: genetic analysis, use of secondary data, economic valuation, historical analysis, conceptual or opinion piece, and undefined methods)	Mutually exclusive at two levels: methods of collection and methods of analysis[a]
Topic	Matter or aspect of urban forests being investigated; these are associated with the dimension of the study (see above)	<u>Ecological:</u> Vegetation diversity Species traits & functions Pests & diseases Pollination dynamics Soil & nutrients Ecosystem functions & services Green cover Landscape dynamics Urban forests & water bodies Fauna (wildlife interactions)	<u>Social:</u> Local values & preferences Effects of human activity Economic valuation Accessibility & green equity <u>Management & strategy:</u> Governance Design & planning Management criteria Tree maintenance Tree monitoring Challenges & barriers Opportunities	Overlapping

[a] Only the first level used for visualizations; see Fig. 3.

journals in the fields of Biology, Forests, Architecture, Planning, Environmental Sciences, Social Sciences, and Geography. These fields reflect grouping labels already assigned in Redalyc (as of mid-2018). The search protocol was then applied to the search function in the individual webpages of each of the 72 selected journals. As with the SciELO system, many of these searches were title-only searches due to the limitations in the online search function. Since we limited our search to journals that were registered in either Redalyc or SciELO databases, any other journal not registered in these databases was not included in our searches (see Appendix 2).

2.3. Classification and Analysis

Once the final set of articles was obtained (Appendix 3), we conducted a content analysis. This entailed reading the articles in full, extracting information from them, and classifying them according to categories to facilitate comparison and pattern identification across studies, regardless of their differences in methods (an example of this is the review by Boulton et al. 2018). The classification items that we used were not pre-determined, but rather emerged from our reading of the articles, as our study was exploratory in nature, and applying a predetermined list of categories would have been insensitive to the article content (see Pickering and Byrne, 2014). Rather, our categorization was based on a procedure grounded in the data and based on reductive and integrative techniques, specifically an inductive qualitative content analysis (see Krippendorff 2018). The final list of categories was ob tained iteratively by densifying and clustering ideas that were closely related to avoid redundancy. This classification facilitated subsequent analysis and data visualization. Articles were left uncategorized if a category that described at least one other article could not be assigned. Some categories were assigned in an overlapping manner, while others were mutually exclusive (Table 2).

Analysis of emerging categories was conducted using different visualization techniques, including network graphs. Two-mode networks allowed to visualize connections among categories, and to identify patterns in the data. We analysed network structure using metrics such as degree centrality based on graph theory (Diestel 2005, Newman 2010). In addition, we used other, more conventional, graphical representations such as bar charts, pie charts and maps to visualize the data. Since the search ended in the middle of 2018, we excluded 2018

Fig. 1. Location of reviewed studies by country (all studies) and city (names of cities with > 10 studies shown; cities with 1 or less studies not shown), using data from articles included in literature review of urban forest research in Latin America & the Caribbean (n = 182).

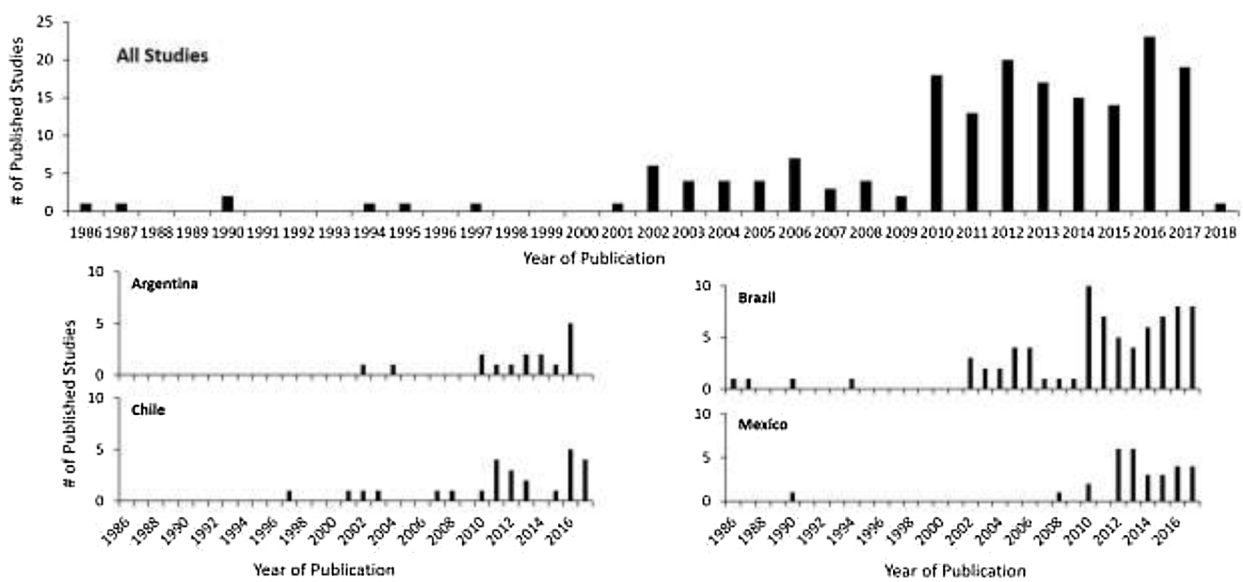

Fig. 2. Timeline of reviewed studies based on year of publication, and individual timelines for countries with more than 10 studies, using data from articles included in literature review of urban forest research in Latin America & the Caribbean (n = 182) (articles published in 2018 removed; see methods).

in the annualized graphs of articles to ensure a more reliable comparison. All network graphs and analyses were implemented using the igraph and tcltk2 packages in R (v. 3.4.3). Other graphs were produced using Excel (v. 15.33) and Tableau (v. 2019.1.2).

To better understand the distribution of articles by country, we normalized the number of studies by a country's population. This allowed us to better compare a country's article output. We used the standard deviation distance from the average of all countries to determine whether a country had a higher article output compared to the average (Appendix 4).

3. Results

3.1. Spatiotemporal distribution

We found that most LAC urban forest research has been conducted in Brazil (42%), followed by Mexico (17%), Chile (15%) and Argentina (9%) (Fig. 1). Some country-country comparisons (4%), national or country-wide studies (3%), and within country regional studies (4%) were also identified in the review. The countries common in such comparative studies were Brazil, Colombia, Chile and Mexico. Two studies also provided comparisons with cities in Spain and Portugal.

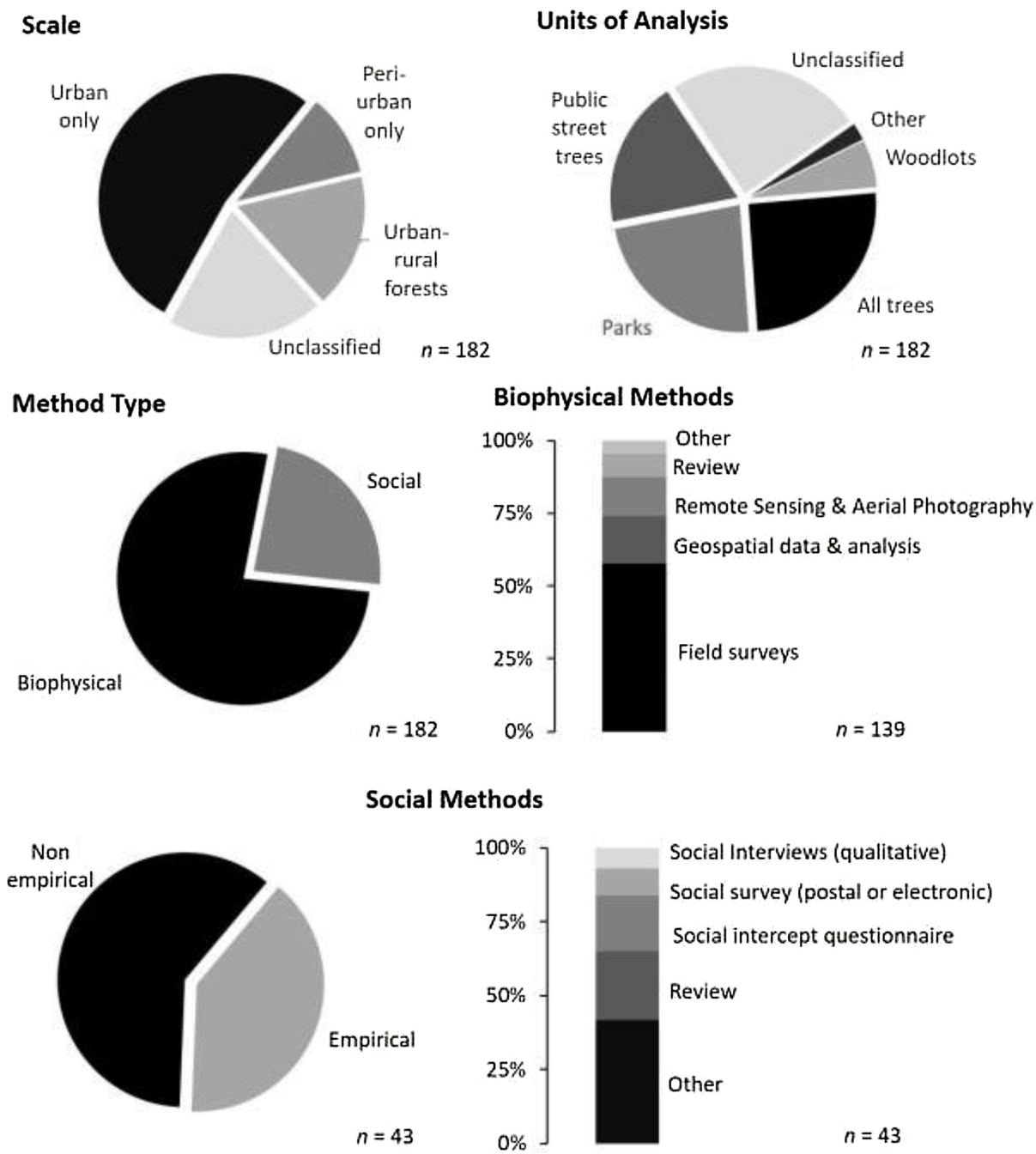

Fig. 3. Scale, units of analysis, and methods used by the studies in the review, indicating biophysical and social science methods of data collection, indicating sample sizes for social studies, using data from articles included in literature review of urban forest research in Latin America & the Caribbean (n = 182; for other categories, see Table 2).

Authors' affiliations were spread throughout the region, as well as Europe and North America. The cities of Curitiba, Mexico City, and Santiago had the most studies, with more than 10 studies each, followed by the cities of Bogotá, Concepción, Juiz de Fora, León, Medellín, Mendoza, Rio de Janeiro, Santiago del Estero, and São Paulo, with 3 studies each (Fig. 1). When normalizing a country's article output by that country's population (average of all fractions = 0.36 articles/capita ± 0.027), Brazil, Chile, Nicaragua, and Puerto Rico had an above average article output (i.e., > 1 standard deviations from average; see Appendix 4). The number of articles has increased over time, with a sharp surge after 2010 (Fig. 2). This pattern was similar for each country with more than 10 studies (Fig. 2). Brazil has been the first country to publish on urban forestry, since the 1980s, followed by Mexico and Chile, both of which started publishing in the early 1990s. All other countries started publishing studies since the 2000s (Fig. 2).

3.2. Content & Relationships

Most studies considered or were focused on an ecological dimension (64%). In terms of scale, only a few studies focused on peri-urban forests (10%) or combined rural-urban forests (17%). The units of analysis were equally split among all urban trees (25%), public parks (23%), and public street trees (19%). Only a very small part of the literature (~8%) involved other units of analysis (see Table 2 for a list). A few studies could not be classified according to the categories that described at least one other study in terms of unit of analysis and scale

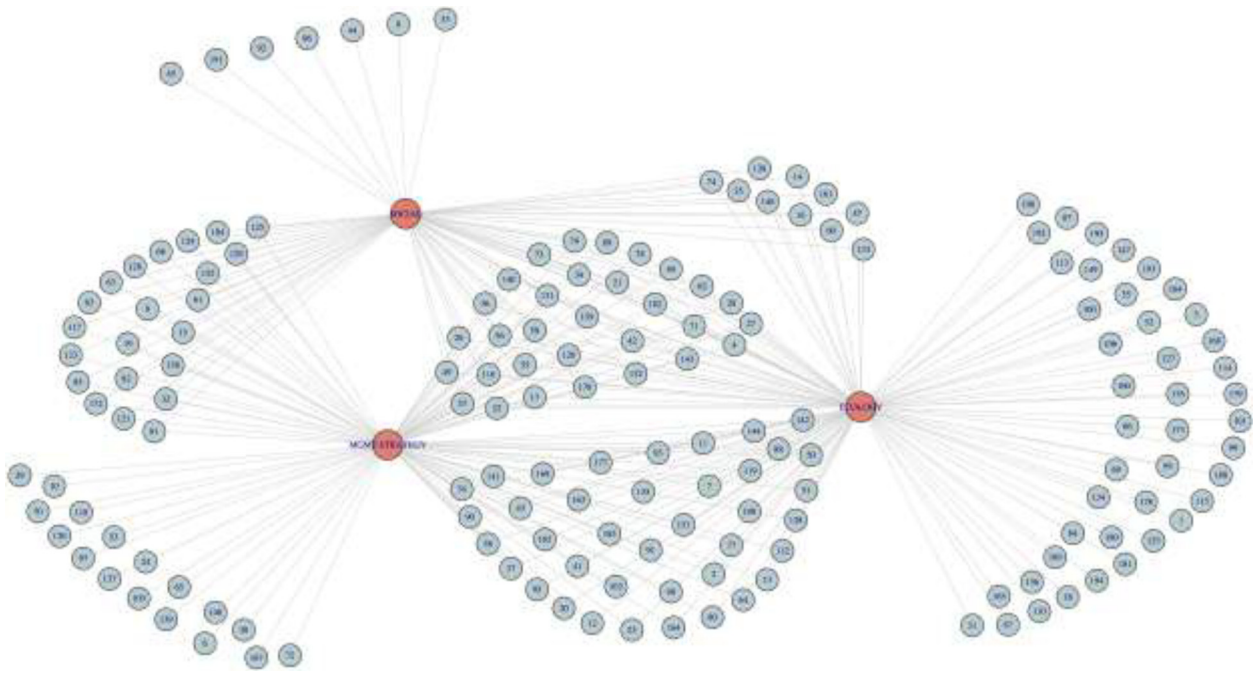

Fig. 4. Network map showing article identification number (ID; small nodes; see Appendix 3 for cross-referencing ID), article dimension (i.e., ecological, social, and management (MGMT); large nodes), and overlaps in the classification. Overlaps are visualized by links between an article ID to two or more dimensions in the network. Graph produced using data from articles included in literature review of urban forest research in Latin America & the Caribbean (n = 169; 13 articles were excluded as they were left unclassified by dimension; see Methods section and Appendix 5).

(see Table 2; Fig. 3), and some could not even be classified according to a dimension (for a list see Appendix 5).

Most studies focused on biophysical methods (76%) using field surveys as their data collection method (58%), followed by geospatial data and analysis (16%), and remote sensing and aerial photography (13%) (Fig. 3). The remaining studies focused on social aspects, but only a fraction of these (n = 17) were empirical studies that collected data directly from people, using a variety of methods (Fig. 3).

The network graph analysis confirmed that many of the ecological studies (n = 44) focused purely on biophysical issues without any mention of social or management factors. It also confirmed an overlap between many of the social and management studies (n = 39; Fig. 4). About a 20% of the reviewed articles (n = 31) integrated all three dimensions. Some ecological studies (n = 39) discussed management implications or integrated some social considerations, mostly in terms of impacts of human activity on biodiversity (n = 10).

The overlapping topics made it difficult to explore the patterns in the categories assigned in this classification item. Nonetheless, the principal topic of the ecological studies was the diversity of tree species, and that ecosystem services and green cover became more predominant topics after 2010. Many of the studies categorized in both the social and management dimensions aimed at identifying or assessing management criteria and providing recommendations for urban forest strategy, design, and planning (Fig. 5, see also Appendices 6 and 7 for more detail).

4. Discussion & Conclusion

The increase of scientific literature on urban forests in LAC in the past 10 years confirms what has become a general trend in other regions of the world: an increased interest in understanding urban forests and their potential for addressing urban environmental, ecological, and social problems (Tzoulas et al. 2007; Escobedo et al. 2008; Nesshöver et al. 2017; Willis & Petrokofsky 2017; Boulton et al. 2018). While most of the LAC urban forest literature in the past 30 years has focused on vegetation diversity (Figs. 3–5), topics such as the provision of ecosystem services, particularly air pollution regulation and heat mitigation, are beginning to be explored (Fig. 5), as in other world regions (Roy et al. 2012; Krajter-Ostoić and Konijnendijk van den Bosch, 2015). However, the LAC literature is still not tuned in to the topics being covered more recently in urban forest research, such as the spatiotemporal variation of urban forests, socio-cultural issues, and human health, as demonstrated by recent urban forestry reviews (Dobbs et al. 2014; Yang et al. 2014; Escobedo et al. 2015; Nesbitt et al. 2017; Krater-Ostoić et al. 2018; Steenberg et al. 2019). Current research on spatio-temporal variation in LAC is more focused on greenery, derived from remote sensing techniques (e.g., Martinuzzi et al., 2018), rather than being explicitly and specifically about trees and tree-dominated systems. This difference might be because of regional realities, such as that LAC is a highly biodiverse region where many research institutions focus on conservation priorities, including the impacts of urbanization on nature (UN-HABITAT 2016, MacGregor-Fors et al. 2016) and the current rate of loss of conservation areas (UNEP 2010; Inostroza et al. 2013; Rincón-Ruiz et al. 2019).

There is also a wide diversity in the LAC literature in terms of geographical focus, methods, and disciplinary approaches to study urban forests. While the regional dominance of Brazil was clear, this dominance was not explained by population size. Examples of this are countries like Mexico, with a sizeable population but a below-average article output relative to its population size; and countries like Chile, Nicaragua, and Puerto Rico, with smaller populations but an above-average article output. The dominance of Brazil may be explained by the fact that research on urban forestry there started earlier than in any other country in the region (Fig. 2). While some of the research is carried out in many of nation's capitals (e.g., Mexico City; Santiago), there is a significant amount of research published from non-capital cities, such as Curitiba, Medellín, and Concepción, but a lack of research from more populous, capital cities like Buenos Aires, Lima, and La Paz. These facts serve to dispel any assumption that populous countries and capital cities lead urban forest research in LAC. Nonetheless, urban forest research in LAC lacks regional cohesiveness. Only a few studies in this review looked at more than one city or more than one country (Fig. 1). The lack of comparative studies limits the ability

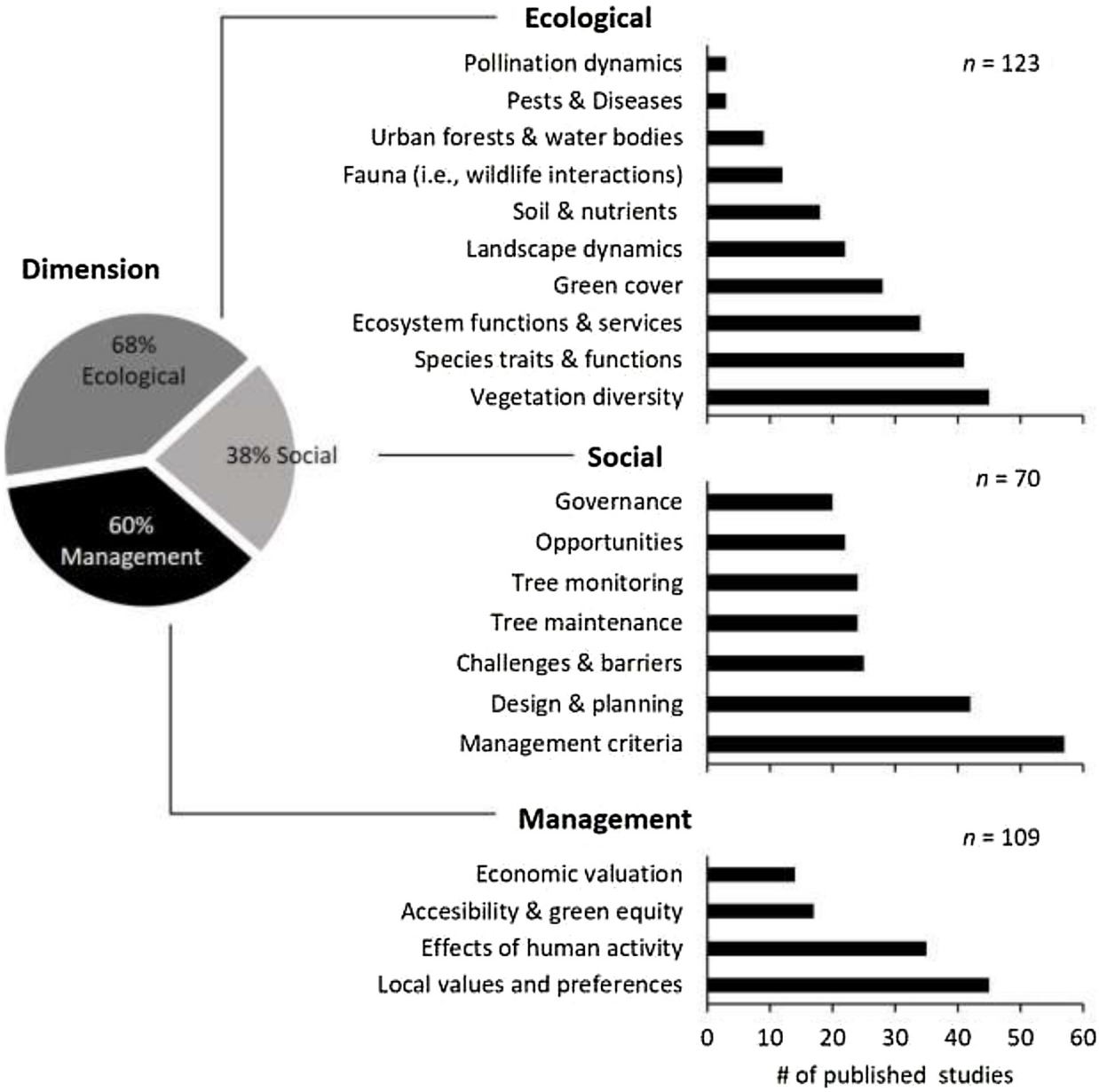

Fig. 5. Most common topics of the articles in this review classified by their ecological social, or management dimension, using data from articles included in literature review of urban forest research in Latin America & the Caribbean (n = 182; many overlaps exist among studies; see Methods section and Appendix 7).

to scale up research efforts regionally, where the research could have the most impact and where it is the most relevant.

The view that single trees in public areas (parks and streets) are the main unit of analysis in urban forest research is as much evident in LAC (Fig. 3) as it is in other regions, reflecting a historical and past trend in urban forest research (Krajter-Ostoić and Konijnendijk van den Bosch, 2015). The dominance of this view reveals a gap in our current understanding of the role played by other units of analysis, such as private urban greenspaces with trees in LAC (see González-García et al. 2009) and forest patches in public and private areas, among other significant spaces with trees. Rarely is a system-level interpretation of urban forests used, one that sees the urban forest as a continuous resource that combines both public and private spaces, and its biotic and abiotic components (Dobbs et al. 2019). Diverse and overlapping interpretations of urban forests, greenspace, and green infrastructure are common in the global literature (Nesbitt et al. 2017; Taylor & Hochuli 2017; Boulton et al., 2018; Escobedo et al. 2019), but few studies in this review integrate these views within a system-level interpretation that captures a more nuanced, inclusive view of urban forest ecosystems.

An integrative, system-level interpretation of urban forests is vital to help answer some of the interdisciplinary research questions that are inherent in urban forest research. For instance, a central aspect of the global discourses on urban ecosystem services, Nature-Based Solutions, green infrastructure, and Nature's Contributions to People (Dobbs et al. 2011; Haase et al. 2014; Luederitz et al. 2015; Kabisch et al. 2016; Nesshöver et al. 2017), as well as on urban forests (Threlfall & Kendal 2018; Roman et al. 2018; Steenberg et al. 2019), is the connection between socio-economic, socio-cultural, environmental, and ecological dynamics, as an intrinsic feature of these so-called socio-ecological systems. However, most of the ecological research in LAC on urban forests has been carried out without a consideration of the social aspects that may influence the ecological dynamics of urban forests (Escobedo et al. 2015). Complementarily, most empirical social studies in the region also do not integrate ecological data or discuss the relevance of ecological dynamics (Figs. 3–6; see also Dobbs et al. 2019).

This research gap has a significant impact on urban forest practice.

Many LAC cities are creating strategies and policies based on an agenda aimed at increasing tree planting and tree-canopy cover (Calaza et al. 2018). This agenda is being boosted by the ecological research in the research, such as species representativeness and wildlife connections (MacGregor-Fors et al. 2016), which provides the evidence to establish ecological considerations and priorities in management. However, this agenda might fail if it does not adequately connect social and ecological issues and reflect the context, desires and needs of stakeholders (Camacho-Cervantes et al. 2014; Ordóñez & Duinker 2014). Understanding how social and ecological variables interact in urban forests can give meaning to these greening initiatives by enhancing the palette of considerations and priorities that drive them (FAO, 2016). Some of these considerations may include the connection between the progressive loss of natural areas and biodiversity, rural-urban migration, poverty, crime, and social equity (Escobedo et al. 2015, 2018; Dobbs et al. 2019; Rincón-Ruiz et al. 2019), issues that also affect rapidly urbanizing areas of the Global South in Asia (Yang et al. 2005, 2014) and Africa (Kuruneri-Chitepo and Shackleton 2011; Shackleton, 2012). To answer these socio-ecological question, researchers must adopt a more integrative view of urban forests that builds on the strengths of multiple disciplines.

Our systematic review had its limitations, but also some key strengths. We recognize that some relevant articles may have not been found in our searches and subsequently covered in this review (see Appendix 3). The defining factor in finding articles through the systematic search procedure presented here was the inclusion of terms specific to forests and trees in the titles and/or abstracts of these articles. In this context, rather than exhaustive, this systematic review is, at the very least, representative of what is available and what the state of science is on urban forest research in Latin America (see Appendix 3). In addition, the searches in the Redalyc and SciELO databases were limited to the title and not exactly replicable from other searches carried out in English-based databases, which also include the abstract. Also, these databases could not be used for retrieving article meta-data (e.g, author affiliation in BibTex files), which could have provided us with the opportunity to do more robust analyses. Nonetheless, the use of non-English language databases did provide us with the opportunity to go beyond a traditional English-only literature review based on English databases, such as Scopus, which also provides access to multilingual articles (Rupprecht & Byrne 2014). Our large number of articles (n = 182) is indicative of the strength of using multiple databases in reviews, and these results are similar to other regional reviews (see Rupprecht & Byrne 2014; Nesbitt et al. 2017; Krater-Ostoić et al. 2018).

In conclusion, this systematic literature review has shed light on the significant body of existing research on urban forestry in LAC, as well as helped identify gaps in the knowledge about this topic and region. Most ecological research on urban forestry in LAC has raised concerns about loss of tree species diversity in cities, especially native diversity, but further research is needed to understand this concern in a broader, more dynamic, socio-ecological context. Moreover, further research is needed to understand the context-relevant benefits provided by urban forests in regional cities, and to associate urban forests with social issues, including rural-urban migration, crime, poverty, and social equity, and with ecological and environmental issues, such as biodiversity loss and climate vulnerability, issues that are at the top of the current urban socio-ecological research agenda. Although this review has illuminated some of the trends in disciplinary research in LAC urban forestry, a further look at the trans-disciplinary aspects of this research is required to understand the practice of urban forestry in the region, including the work of practitioner stakeholders, such as municipal managers, entrepreneurs, politicians, technical agents, and other local stakeholders. For a more nuanced understanding of these issues, it is necessary to use methods that capture their perceptions more directly. This will provide for a more empirical basis for connecting ecological and social issues, and for understanding the importance of urban forests in the social context of the region, instead of relying on the empirical evidence from other regions and assuming, prematurely, that urban forests in LAC function or should be managed in the same way as other regions. Future research requires more regional inter- and trans-disciplinary partnerships, and more funding to encourage collaboration in this field at the regional level.

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Appendix A. Supplementary data

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