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Constructing, Mapping, and Analyzing Global Urban Forest Databases Using Hyperlinks: A World of Vast Unevenness and Research Challenges

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Abstract

A distinctive feature of scholarly communities today is exploring topics and concepts in interdisciplinary and international contexts. This observation is increasingly apparent and visible in advancing our thinking and policies related to human/environmental worlds at local, regional, and global scales. Maps are an important part of these innovative and ongoing research approaches. In this context, we consider urban forests a topic meriting more attention of scholars studying the geographic and environmental intersections of the natural sciences with the social sciences and humanities. We construct two innovative knowledge bases, one a conceptual framework based on major themes and concepts related to mapping urban forests using key words of the first 100 results of a Google Scholar query and a second using the number of Google Scholar hyperlinks about mapping urban forests in 244 capital cities. We discovered that the constructed world maps reveal vast global unevenness in our knowledge about urban forests in hyperlink numbers and ratios, results that merit further attention by disciplinary, international and interdisciplinary scholarly communities.

Keywords

Urban Forests, Database, Mapping, Google Scholar, Hyperlinks, Disparities, Unevenness

1. Introduction

In the contemporary era, one distinguishing feature clearly resonating across the scholarly, political, and media worlds is the need to explore major issues in intersecting world or global contexts rather than as separate or "silo" scholarly works. This observation becomes increasingly evident when issues about boundary conflicts, security, climate change, women's rights, and human welfare are considered at global scales. These human/environmental worlds are seen as places, regions, cities, and communities where pollution, security, environmental risk, spiritual living, work, and leisure places are intertwined in relationships that are studied little or basically ignored. Such is the case when exploring new features and perspectives about human/environmental worlds related to urban forestry at regional and global scales.

In advancing our knowledge about these intersecting worlds, it is important to consider a variety of measures we can adopt to construct new conceptual frameworks and to gain new insights into topics and issues of greater global importance. These efforts might include introducing innovative new databases and approaches that consider the importance of integrating art, music, and poetry into scientific inquiries, as well as analyzing new results and constructing new maps. Scholars in both the humanities and the social and natural sciences have long contributed to our understanding of individual or collective features about human/environmental conditions. Those intersections focus on music, art, drama, photography, poetry, and storytelling as well as anthropology, biology, sociology, geography, economics, political science, and law. Each subject matter area or discipline offers a unique perspective in our reading and writing about landscapes and cultures and also presenting and representing those features with photographs or maps. These visual representation efforts also seek to relate place, landscape and environmental features to specific groups such as children, immigrants, an elderly cohort, or specific places like inner cities, new suburbs and even regions.

Intersecting perspectives are important and need to be recognized and valued as we explore new ways and conceptual frameworks to better understand an issue or some feature facing contemporary and future physical environments, cultures, landscapes, livelihoods and even those experiencing natural disasters. It is in these interdisciplinary contexts that we explore the concept of urban forests which exist at the intersections of disciplines that study nature, cities, landscapes, biodiversity, conservation, heritage, religion, and politics. It is not a concept or term that only botanists, forestry scholars, or technology scientists using Landsat or remote sensing specialists can, should, and will make quantitative contributions. It is also for those who look at forests in multiple contexts, including those studying urban expansion, human health and welfare, recreation and tourism economies, social media, green futures, sustainable development and human progress. As stated by Zhao *et al.* [1], "Urban forests are more about people than trees" (p. 64). For example, according to Timilsina *et al.* [2], "urban trees provide social, economic, environmental and ecosystem service benefits that improve the livability of cities

and contribute to individual and community well-being" (p. 3017).

In our discussion, we examine urban forests at global scales in a different light than solely conservation or green development initiatives. We construct two major knowledge databases: 1) current world urban populations of capital cities, and 2) urban forests in those capital cities. Both databases are needed to place urban forest knowledge in disciplinary and interdisciplinary contexts to help scholars and governments understand specific ecosystems, environmental projects, satellite imagery, sustainable policies and community well-being. The results from the Google Scholar searches were used to construct a database of urban forests in capital cities across the world, a database that we can also map and analyze at regional and global scales. Before proceeding with construction of the databases we discuss recent interdisciplinary research on mapping urban forests and urban forestry at both global and national levels.

2. Recent Research on Urban Forest Issues

The international and interdisciplinary dimensions of urban forest research, including innovative databases, have been a focus of recent studies. Urban nature is becoming a dominant theme in studying human civilization [3], with 68 percent of the global population predicted to live in urban areas by 2050 [4]). A number of contemporary scholars acknowledge that urban forests can have a powerful impact in resolving environmental problems [5]-[7]. This urban focus is very important because, due to increased human consumption and increased development of built-up areas, the mass of human-made objects exceeds the entire living biomass of nature [8]. Trees in urban space are considered part of a green infrastructure system that provides multiple environmental and economic functions as well as social and health services. They especially have positive influences on urban health [9] and the mentality of citizens [10]. In this context, Ordóñez-Barona [11] analyzed 31 studies around the world to explore how the changing ethnic mixture of urban populations is affecting a city's planning, management and development of its forests. At a local level, Ordóñez-Barona *et al.* [12] discuss how different cultures relate to urban forest policies in Melbourne, Australia. How city size relates to urban–nature relationships is specifically addressed by Kendal *et al.* [13] who also mention, as do others, that urban forests remain a neglected research topic. Understanding the human–nature ecosystem within the context of communities and governments has been a research focus of several scholars [14]-[16]. Svendsen *et al.* [17] were among the first to focus on urban ecological stewardship. Their research examined 135 organizations in five northeastern U.S. cities as examples of both environmental stewardship and civic environmentalism. The concepts of urban green equity and justice have been investigated by others [18]-[22]. These pioneering studies provide a valuable context for our research as they introduce and suggest some new approaches to studying urban forest topics, policy, and management. They also stimulate additional research frontiers especially at regional and global scales using maps. In this regard, constructing maps

about our urban forest knowledge at global scales is a dimension worthy of more attention. Lacking especially is detailed research that maps urban forests at global levels or more specifically capital cities.

To gain a broad perspective on recent urban forestry research and mapping urban forests, we accessed Google Scholar for relevant English language articles. This source is recognized as a leading source for current research by international and interdisciplinary scholars in disciplinary and interdisciplinary contexts. According to Google Scholar's About page, "Google Scholar aims to rank documents the way researchers do, weighing the full text of each document, where it was published, who it was written by, as well as how often and how recently it has been cited in other scholarly literature." Further, the site states: "We normally add new papers several times a week. However, updates to existing records take 6 - 9 months to a year or longer, because in order to update our records, we need to first recrawl them from the source website." At the outset of our research, we did not know what we would discover, but expected there would be articles about urban forests and urban forest policy from physical, social, and policy scientists around the world.

3. Constructing a Database Using the First 100 Google Scholar Articles on Mapping Urban Forests

We constructed a database on 23-24 January 2024 based on key words that appeared in the first 100 articles (in English) using the phrase "mapping urban forests". From this database we sought to identify major research themes, the journals publishing this research, and cities and countries mentioned in the title or in the brief description. The search included articles published in 42 different professional journals. Some articles were descriptive while others were conceptual; others were very technical; some were generic; and some broad and others narrow in focus. The journals most cited were *Urban Forestry and Urban Greening* (16), *Remote Sensing* (12), *Remote Sensing of the Environment* (6), and *Sustainability* (4). In addition, six journals were cited three times each and eight cited twice (Table 1). Of the articles, 68 percent were published between 2015 and 2022, 16 percent from 2000 to 2014, and 6 percent in 2023-2024. It requires time, sometimes several months, for recently published articles to have high rankings in Google Scholar. This background information helped us place our research in different disciplinary and conceptual frameworks.

A reading of the titles, abstracts, and key words yielded more than 125 key words and phrases. They show that current research on urban forests is very broad in scope. There were authors from many countries, but especially the U.S., Canada, China, India, United Kingdom, and Italy. Tabulating the individual cities mentioned in titles and abstracts revealed that most articles were about cities in the United States, China, and Europe. Fewer had a community/citizen base in Latin American, African, and Pacific cities. Most articles could be included in three major categories: a technical focus, an environmental focus, and human/environmental themes. These categories and their overlap are illustrated in a set

Table 1. Journals with articles in the listing of top 100 hits from a Google Scholar search of "mapping urban forests", by number of occurrences.

Journal	No. of Articles
Urban Forestry and Urban Greening	16
Remote Sensing	12
Remote Sensing of the Environment	6
Sustainability	4
Applied Geography	3
Forests	3
International Journal of Remote Sensing	3
Landscapes and Urban Planning	3
Photogrammetric Engineering and Remote Sensing	3
Urban Ecosystems	3
Catena	2
Earth's Future	2
Ecosystems and People	2
Environmental Modelling and Software	2
Geomatics	2
Journal of Environmental Management	2
Journal of Forestry	2
Sustainable Cities and Society	2
28 other journals	1

theory perspective (**Figure 1**). While some articles were very specific in their focus, others integrated two sets and some all three categories. The figure itself reflects the interdisciplinary context mentioned above which is important in obtaining new perspectives on a topic that stretches beyond the special interests of scholars in a specific field.

The technical category included articles about remote sensing, satellite imagery, carbon emissions, and machine language. Specific images included Landsat, Sentinel 1 and 2, IKONOS, AVIRIS, LIDAR, DMSP/OLS, Random Forest, and Google Street View. Some authors compared images and indexes at different scales [23]-[42].

The second category, environmental focus, includes a wide variety of topics about urban forest environments and nature. Some dealt with carbon emissions, others with ecosystem services, and still others about specific species, street-scale variations, human/climate intersections, heat islands, tree canopy mapping, digital forests, green space, and pollution (see [35] [43]-[69]).

The third category, Human/Environmental Themes, included research that reflected some new directions in our thinking. It includes articles about urban inhabitants and public participation, housing areas and green infrastructure,

environmental equity, smart forestry, sustainability, social classes, social well-being, and contemporary social media. Some studies integrated themes discussed in the second category while others focused on images and imagery mentioned in the first category. Researchers in this third category were [1] [70]-[80].

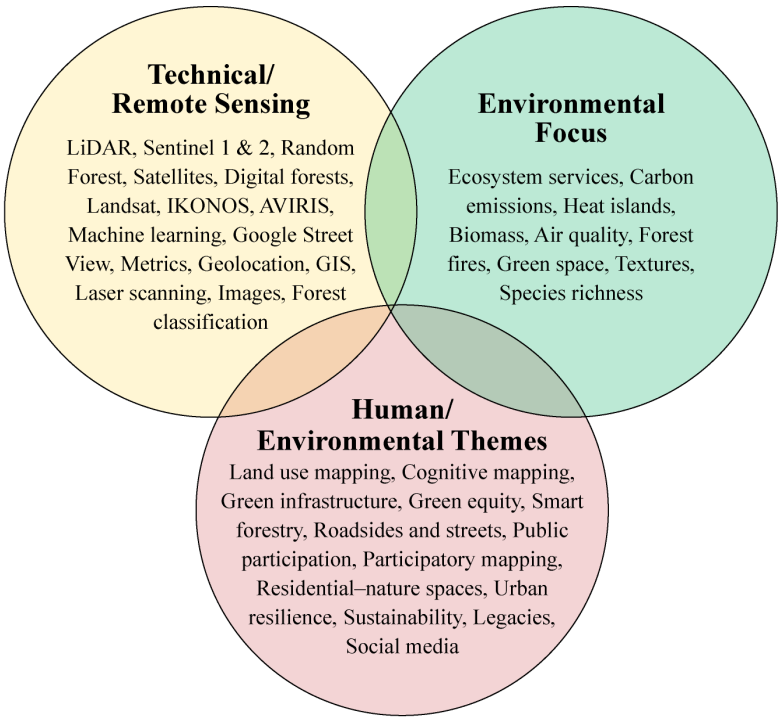

Figure 1. Set theory categories of major themes and topics of recent research (2015-2024) on mapping urban forests. Data source: Title, abstract, key words from the first 100 articles returned by Google Scholar query "mapping urban forests" conducted 23-24 January 2024.

4. Constructing Databases on Urban Forests and Hyperlinks of Capital Cities

A first task in seeking to understand the global features and dimensions of urban forest knowledge was to gather data on the urban populations of countries and capital cities. We used websites that provided these data: OurWorldinData [81] and Wikipedia [82]. OurWorldinData reported that in early 2024, 44 percent of the world's population resided in cities, 43 percent in towns and suburbs, and the remaining 13 percent in rural areas [81]. This website included global maps about distinct urbanization features. Wikipedia provided data on populations of countries and capital cities, and the percentage of a country's urban population that lives in a capital city [82]. We again searched Google Scholar to provide data on the number of academic journal article hyperlinks for various word phrases related to urban forestry and capital cities in the English language. Each entry included the title of the article, a brief (2 - 3 sentences) summary, the journal name, the number of citations, and the total number of hyperlinks in the database. Approximately ten hyperlinks were described on each screen page.

To obtain specific data on capital cities, we entered key words. For example, we searched the phrase "Madrid, Spain + urban forests". Immediately a number would appear at the top of the page; these were the number of hyperlinks with that word combination. In the same way, we obtained information for "Kuala Lumpur, Malaysia + urban forests", and other capital cities and countries. The search (capital city, country + urban forests) was carried out for 244 capital cities. We focused on capital cities since, in most countries, they usually have the largest populations and are the sites of the national government, the headquarters for non-governmental organizations, and major universities and technical colleges. Capital cities are also usually the headquarters of most economic activities (industry, transportation, banking/investment) and the center of major social services (for example, health, tourism, culture, media). The capital cities are also likely to have the largest built-up areas which impact surrounding natural environments. Examples of countries where the capital cities are not the largest in population include Brazil, Australia, the U.S., Canada, India, South Africa, Pakistan, Turkey, Switzerland, and Nigeria.

Wikipedia was used 16-19 March 2024 to collect urban population data on countries (en.wikipedia.org/wiki/list_of_national_capitals_by_population) and Google Scholar on 10 December 2023 to construct Excel files for the population of each of the 244 capital cities and the number of urban forest hyperlinks for each capital. These city data can also be compared with other cities in a region, such as Latin America or Europe, or on a global scale. The databases constructed include urban population sizes, percent urban populations of countries, populations of capital cities, and percentages of the urban population living in the capitals. We also ranked the capital cities based on the percentages of residents living in them (from most to least), the absolute number of urban forest hyperlinks for each country, and the percentage of all urban forest hyperlinks for the capital cities. In addition to our individual country and city data, we calculated the number of urban forest hyperlinks for each region, such as Europe or Africa. We also calculated ratios, viz., the number of urban forest hyperlinks per 10,000 persons. The ratios were important in discussing urban forests in capital cities as the initial data gathering and ranking of capitals revealed that some had many and others very few hyperlinks. High ratios meant there were many urban forest hyperlinks for each 10,000 residents in a capital; low ratios meant there were very few studies listed in the database for each 10,000 residents.

Some of the discussions in the following sections are based on absolute numbers of urban forest hyperlinks. Other discussions are about percentages, and still others are about ratios (number per 10,000 population). Some data are presented based on percentages (*i.e.*, 80 - 100 percent, 60 - 79, 40 - 59, 20 - 39, and less than 20 percent). In ranking cities (number of hyperlinks per 10,000 population) on some variable, we identified six categories (1 - 40, 41 - 80, 81 - 120, 121 - 160, 161 - 200, and 201 - 244).

It merits mention that we constructed the databases without knowing specifically

what we would discover. For example, would there be much evenness in the percentages of urban forests in all countries at a global scale or for the capital cities at a regional level? Where are the "information-rich urban forest capitals," that is, those with most research to date, and where are the capitals with very few references and low percentages? In countries with multiple large cities, what would the numbers and percentages reveal about the capital cities? We suspected from our personal experiences and prior knowledge about urban forests that there would be many references for Europe and North America capitals, but beyond those presumptions, we expected to learn much. When the percentages, volumes, and ratio data were gathered and mapped, we expected the maps would raise many questions.

Mapping and Analyzing Urban Forests: Global and Regional Perspectives

Before discussing urban forests in capital cities, it is useful to consider the topic from a broad and global perspective. According to OurWorldinData (accessed March 2024), 6.8 billion people (87 percent of the world population) live in cities, towns, and suburbs [81]. Of the list of states and territories listed on Wikipedia on 21 March 2024 [82], 135 had 50 percent or more of their population living in cities. Figure 2 shows the percentages of urban dwellers in states and territories. The countries with the highest percentages, above 90 percent, were mostly ministates such as Kuwait, Singapore, Monaco, Iceland, Malta, Uruguay, the Netherlands, Israel, and Luxembourg. Countries with about 75% urban included Cuba, Turkey, Iran, Russia, Czech Republic, Algeria, and El Salvador. Those with about half their populations living in cities included Guatemala, Uzbekistan, Kosovo, Senegal, and the Philippines. Afghanistan, Cambodia, Chad, Ethiopia, and Nepal were about 25 percent urban. Those with less than 20 percent urban include Malawi, Rwanda, Liechtenstein, and Papua New Guinea. In short, there is much unevenness.

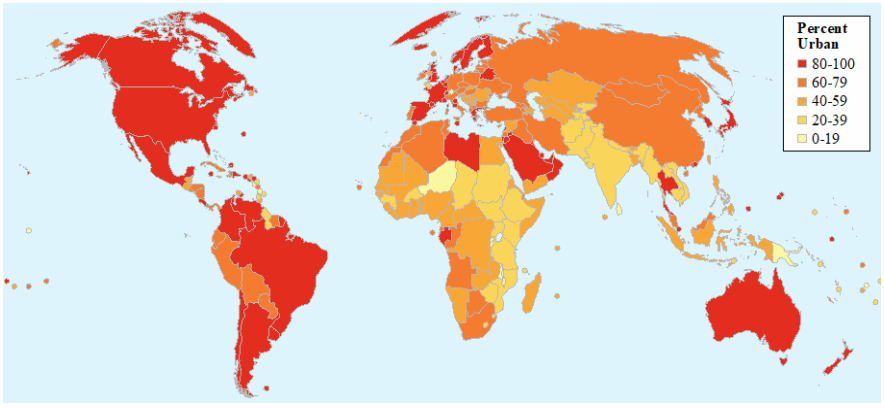

Figure 2. Percent urban population by country, 2024.

An analysis of the urban forest data collected from Google Scholar and the maps prepared based on these data reveal several distinctive features about urban forestry knowledge at both global and regional scales. First, there was wide discrepancy in the number of urban forest hyperlinks for the capital cities in major world

regions (Table 2). The three North American countries: the United States, Canada, and St. Pierre and Miquelon (a territory northeast of Nova Scotia) had nearly 2.4 million urban forest Google Scholar hyperlinks or 21 percent of the global total compared to the 29 Caribbean islands which together had 179,084 hyperlinks or 1.6 percent of the total. The Caribbean total was nearly the same as that for Vienna (160,000 hyperlinks), the capital city that ranked 11th.

Table 2. Number and percentage of urban forest hyperlinks of capital cities, by region.

Region	No. of Countries	No. of Urban Forest Hyperlinks	Percentage of Total Urban Forest Hyperlinks
Europe	55	3,878,649	34.5%
North America	3	2,376,230	21.1%
Asia	49	2,298,125	20.4%
Latin America	23	1,450,780	12.9%
Africa	56	838,700	7.5%
Pacific	29	264,075	2.3%
Caribbean	29	179,084	1.6%
TOTAL	**244**	**11,251,803**	**100**

Second, there were wide variations in the number of capital cities in the six ranks (Table 3). Most European cities, not unexpectedly, were in the top two ranks (16 cities in 1 - 40 and 12 cities in 41 - 80); likewise for most Latin American capitals. Asian and African capitals represented a mix of ranks. In the North America region, Washington, DC (US) and Ottawa, Canada were in the first rank, while Saint Pierre, capital of St. Pierre and Miquelon, was in the fifth rank with only 2200 hyperlinks.

Table 3. Number of capital cities in each urban forest rank, by region.

Capital City's Urban Forest Rank*	Number of Capital Cities, by Region							
	Africa	Asia	Europe	Caribbean	Latin Am.	Pacific	N. Am.	Total
1 (1 - 40)	4	8	16	0	8	2	2	40
2 (41 - 80)	11	10	12	2	4	1	0	40
3 (81 - 120)	2	8	8	7	2	3	0	40
4 (121 - 160)	14	7	7	4	4	4	0	40
5 (161 - 200)	10	12	4	3	4	6	1	40
6 (201 - 244)	5	4	8	13	1	13	0	44
Totals	**56**	**49**	**55**	**29**	**23**	**29**	**3**	**244**

*Rank 1 is the 40 capital cities with most urban forests; Rank 6 is the capital cities with the least urban forest hyperlinks.

There were also very wide differences in the number of urban forest hyperlinks for the individual capital cities. The total number of urban forest hyperlinks for

all 244 capitals was 11.2 million. Washington, DC was clearly the leading capital with over 2 million or 20 percent of the total. The next 8 capitals together had 5.8 million urban forest hyperlinks. Altogether the top 19 capitals had just over 8 million urban forest hyperlinks or about 70 percent of the total (Table 4). Eight of these were in Europe and four in Asia. Nineteen capitals had 50,000 - 99,000 urban forest hyperlinks. They were Athens, Guatemala City, Bangkok, Helsinki, Panama City, Copenhagen, Brussels, King Edward Point (South Georgia Island), Buenos Aires, Pretoria, Warsaw, Dublin, Lima, Cairo, Santiago, Seoul, Jakarta, San Salvador, and Luxembourg City. Altogether, the 39 leading capitals had 82 percent of all urban forest hyperlinks. Again, there was much diversity.

Table 4. The capital cities with most urban forest hyperlinks (Google Scholar).

Capital	Country	Volume
Washington, DC	United States	2,230,000
Mexico City	Mexico	856,000
London	UK	708,000
Paris	France	644,000
Berlin	Germany	571,000
Singapore	Singapore	475,000
Rome	Italy	344,000
Beijing	China	286,000
New Delhi	India	232,000
Vienna	Austria	160,000
Tokyo	Japan	156,000
Ottawa	Canada	144,000
Amsterdam	Netherlands	131,000
Moscow	Russia	128,000
Madrid	Spain	126,000
Port Louis	Mauritius	121,000
Nairobi	Kenya	110,000
Canberra	Australia	102,000
Stockholm	Sweden	101,000
TOTAL		**8,091,000**

Many capital cities with the largest populations did not have the large numbers of urban forest hyperlinks. Table 5 ranks capitals with populations over 10 million and their numbers of urban forest hyperlinks. Also, listed is a capital city with a comparable number of urban forest hyperlinks. While some capitals with large populations have many urban forest hyperlinks such as Mexico City, Paris, Beijing, and New Delhi, other cities with large populations have very few hyperlinks.

The latter include Kinshasa, Dhaka, Jakarta, and Bangkok.

Table 5. The most populous capital cities (over 10 million people) and a comparable city in terms of number of urban forest hyperlinks.

Pop. Rank*	Capital City	No. of Urban Forest Hyperlinks	Capital City with Comparable No. of Urban Forest Hyperlinks	Pop. Rank* of Comparable City
1	Tokyo	156,000	Vienna	80
2	New Delhi	232,000	Beijing	7
3	Dhaka	2,900	Yerevan	118
4	Brasilia	26,900	Hanoi	36
5	Mexico City	856,000	London	18
6	Cairo	53,400	Lima	15
7	Beijing	286,000	New Delhi	2
8	Kinshasa	12,100	Sarajevo	150
9	Buenos Aires	61,700	Pretoria	61
10	Manila	39,200	Addis Ababa	33
11	Moscow	128,000	Madrid	27
12	Bogota	23,300	Bucharest	86
13	Jakarta	50,600	San Salvador	115
14	Paris	644,000	London	18
15	Lima	53,900	Cairo	6
16	Bangkok	76,000	Helsinki	102

*Population rank among the 244 capital cities studied; ranking #1, Tokyo is the most populous.

Once the Excel files were constructed, we were able to analyze the data and map the results for each capital city in a global context. There was wide discrepancy in absolute numbers between Washington, DC (US), the capital city with the most urban forest hyperlinks (2.2 million) and five capitals at the other end of the continuum. These capitals had less than 50 hyperlinks each: Yapen, Nauru; Palikir, Micronesia; Adamstown, Pitcairn Island; Alofi, Niue; and Ngerulmud, Palau. In the middle were these capitals ranked 121 - 127: Bamako, Mali; Reykjavik, Iceland; Windhoek, Namibia; Port Moresby, Papua New Guinea; Stanley, Falkland Islands; Suva, Fiji; and Male, Maldives. Each had only 6700 - 7900 urban forest hyperlinks.

When ratios of urban forest hyperlinks to population (number per 10,000 population) were ranked, there were also very wide differences. The highest ratio was for King Edward Point, the capital of South Georgia (population of only 22) with a ratio of 29,409,091. The second was Vatican City with 274,000; third was Kingston, Norfolk Island with 134,018). These highly ranked countries had small populations but many references related to urban forests. Nine capitals had ratios less than 10: Hagatna, Guam; Ashgabat, Turkmenistan; Dar Es Salaam, Tanzania;

Kinsasha, Democratic Republic of the Congo; Sanaa, Yemen; Luanda, Angola; Teheran, Iran; Dhaka, Bangladesh; and Naypyidaw, Myanmar.

From a global perspective, there is vast unevenness in the number of urban forest hyperlinks. The three capital cities in North America (Washington, DC, Ottawa, and Saint Pierre) have 21 percent of the global total. The 55 capitals in Europe have 34 percent of the global total. The global percentage for the 49 capitals in Asia is another 20 percent. Asia has five capitals with more than100,000 urban forest hyperlinks and also 16 capitals with less than 5000 hyperlinks each. That unevenness is also very apparent even when we examine the largest capitals in population (Table 4). Some have many urban forest hyperlinks and others have very few.

The absolute number of urban forest hyperlinks also varied widely in a global perspective (Figure 3). The capital cities with the most in absolute numbers were Washington, DC (2.2 million), Mexico City (856,000), London (708,000), Paris (644,000), Berlin (571,000) and Singapore (475,000). They were followed by Rome, Beijing and New Delhi, each with over 200,000 hyperlinks. Capital cities in mid-ranks (118 - 123) were Flying Fish Cove (Christmas Island), Papeete (French Polynesia), Kigali (Rwanda), Bamako (Mali) and Reykjavik (Iceland). These had only 7700 - 8700 hyperlinks each. Most urban forest references were in the top ten capital cities. Altogether there were 134 capitals (of the 244 in the database) with less than 10,000 urban forest hyperlinks each. Their combined total of urban forest hyperlinks was 455,000, a total similar to Singapore which was ranked sixth on a global scale.

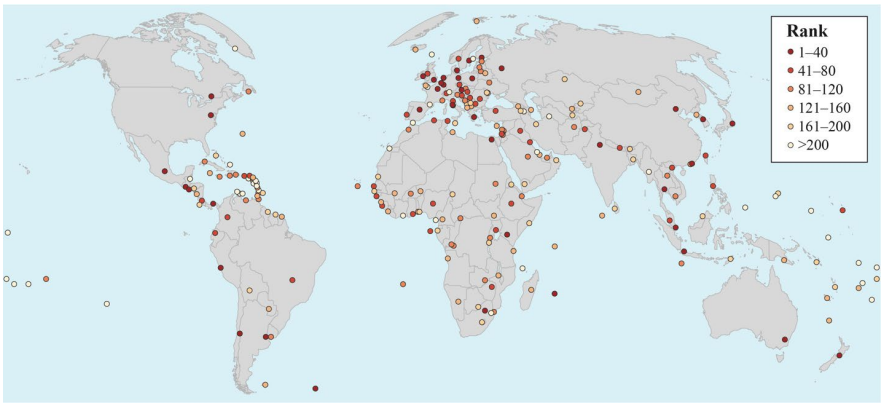

Figure 3. Ranking of urban forest hyperlinks for capital cities in absolute numbers.

There was also wide variation in the percentage of a country's urban forests in its capital city (Figure 4). If there was one dominant city in population, it would likely have a very high percentage. Examples (excluding ministates with a single urban area such as Kuwait, Monaco, Singapore, and San Marino) are Banjul, Gambia (71 percent), San Salvador (66 percent), Luxembourg (62 percent), and Panama City (58 percent), and also some larger states with a dominant central city such as Mexico City (54 percent), Vienna (54 percent), Belgrade (47 percent), Baku (44 percent), and Kyiv (40 percent). In countries where there were two,

three, or four dominant urban centers, of which one might be the capital city, the urban forest percentages in the capital city were much lower, often less than 30–40 percent. Or, if the country does not have an established urban forestry program, the percentages will be much lower than countries with long-standing urban forestry programs. Examples of capital cities with 20 percent or less of all urban forest hyperlinks include Stockholm, Buenos Aires, San Jose, Taipei, Teheran, Dublin, Tegucigalpa, Bangkok, Cairo, Harare, and Addis Ababa.

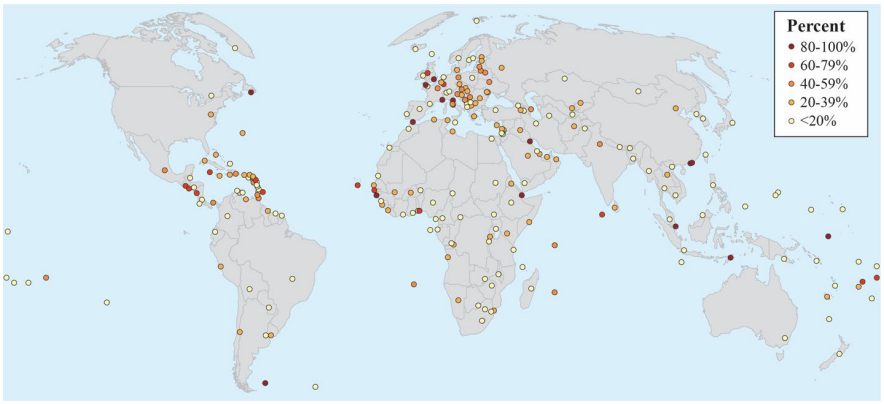

Figure 4. Percentage of a country's urban forests in the capital city.

Another perspective is gained by considering the ratios, that is the number of urban forest hyperlinks per 10,000 population. Here again, European countries especially stand out as having capital cities with many hyperlinks compared to countries in Africa, Asia, Latin America, and Pacific regions with large populations but relatively small numbers of capital city urban forest hyperlinks. There were 21 capitals with less than 10,000 population; their combined population was about 54,000, which is similar to the hyperlink totals for Charlotte Amalie (U.S. Virgin Islands) and Port Vila (Vanuatu). These 21 were in all major world regions. Most were in the Pacific (such as Tuvalu, Niue, and Pitcairn), but also about half a dozen were in the Caribbean (including Anguilla, Bonaire, and Montserrat), in North America (St. Pierre and Miquelon), Europe (Liechtenstein), and Latin America (Falkland Islands).

The very highest ratios, as noted above, were for islands with very small populations. These included King Edward Point in South Georgia (ratio: 29,409,091 and population only 22), Vatican City (ratio: 604,857, population: 453), Jamestown, St. Helena (ratio: 153,736, population: 629), Kingston, Norfolk Island (ratio: 134,000, population 341), West Island, Cocos Island (ratio: 115,672, population: 341). At the other extreme were five countries where capital cities had an urban forest ratio of less than ten: Sanaa, Yemen (ratio: 9, population: 2.6 million); Ashgabat, Turkmenistan (ratio: 9, population: 791,000); Naypyidaw, Myanmar (ratio: 6, population: 1.1 million); Teheran (ratio: 3, population: 8.7 million), and Dhaka, Bangladesh (ratio: 3, population: 9 million). Examples of capital cities with ratios in the middle ranking (122 - 126) were: Port Moresby, Papua New Guinea (ratio: 206, population: 364,000); Pretoria, South Africa (ratio: 201, population:

2.9 million); Sofia, Bulgaria (ratio: 190, population: 1.3 million); Nicosia, Cyprus (ratio: 189 and population 327,000); and Kingston, Jamaica (ratio: 186, population: 662,000). Examples of cities ranking 190 - 210 were Seoul, South Korea (ratio: 54, population: 9.5 million); Cairo, Egypt (ratio: 53, population: 10.1 million); Jakarta, Indonesia (ratio: 48, population: 10.5 million); Ulaan Baatar, Mongolia (ratio: 40, population: 1.5 million); and Kyiv, Ukraine (ratio: 37, population: 2.9 million). These figures reveal the vast differences within regions and on a global scale. Capitals in some regions, including Europe, the Caribbean, the Pacific, and Latin America to a limited extent, have cities with a mix of ratios, especially in Africa and Asia of less than 200.

5. Reflections and Challenges

The statistical and cartographic results of this new perspective on international urban forest research yielded four notable findings. First is evaluating the merits of introducing a new database to look at urban forests in a global perspective. While there is value in comparative local and regional field-based research and satellite imagery, there are additional perspective gained from examining closely the knowledge database about urban forests from social and environmental scientists. Google Scholar hyperlinks need to be added to the databases and methodologies used by urban scholars with varying backgrounds.

Second is recognizing the vast unevenness in Google Scholar data about urban forests at global levels. Only a few capitals had very many large numbers of urban forest hyperlinks. Almost 80 percent of all hyperlinks were in only 20 countries: nine European, four Asian, and two North American (U.S. and Canada). This finding reveals that more than 200 states and territories together had only about 20 percent of all urban forest hyperlinks. It also reflects a longer history of urban forestry research in North America and some European counties than in other world regions. Similar patterns of unevenness are also observed in Latin America. The dominance of Brazil was also clearly prominent compared to other Latin American and the Caribbean countries [83]. The selection of only an English language database in this study might be responsible for some of the unevenness in data entries. However, this finding agrees with Kendal *et al.*'s observation [84]: "Most studies were from large developed cities with relatively few studies from African and South America in particular. These biases mean the evidence base for the effects of urban nature on people and on biodiversity does not adequately represent the lived experience of the 41% of the world's urban population who live in small cities, nor the residents of the many rapidly urbanising areas of the developing world" (p. 124035).

Third is related to the previous statement. Why are there so many countries with so few or very few scholarly references about urban forestry in their capital cities? This may be a difficult question to answer, but it needs to be addressed if scientists wish to examine urban forests at global scales. Perhaps urban forestry is considered a "luxury science" by some governments and environmental professionals who

support more funding to train professionals about immediate daily human needs (housing, safety, diet, health care) than investing in training scientists on green ecology and sustainability projects. Perhaps priorities are higher on projects that observed and felt immediately by a population. Or maybe some low-income countries, for example, in parts of rural and urban Eastern Europe, Central Africa, Southeast Asia and elsewhere suffered, and still suffer, from wars and military conflicts that environmental and conservation policies are less pressing than recovery, health, housing, or human welfare programs.

Fourth is that, based on current scholarly research, topics related to urban forestry do not appear to be a subject that has or generates broad scholarly appeal in many capitals, especially in the Global South. It is not just a topic about counting and preserving trees, but one that relates to human empowerment, healthy living, environmental justice, and ecology measured in broad contexts, including at the intersections of the social and natural sciences and humanities. Even in Global North countries the concept of urban forest was embraced by the United States in the 1960s when it gradually evolved into a national movement over the ensuing decades [85]. It was not until the early 1990s that the concept itself generated broader interest [86]. A significant portion of the early research on urban forestry in Washington, D.C. was initiated by communities of local government and visionary architects who recognized the intersections between urban forests and healthy living. This history contrasts with cities like Dhaka, Bangladesh or Kyiv, Ukraine where there is no designated authority responsible for managing urban forests. Perhaps in many countries urban forest management and ecology are not considered a high priority for teaching children or youth in universities or for community empowerment or even worth even modest investments by governments, NGOs, and volunteer groups preparing for urban futures.

Having acknowledged that urban forestry is a global phenomenon that exists to some degree in all countries, there remain challenges that merit future study by scientists in separate or integrated scholarly communities. One is to explore in greater detail urban forestry research in an individual country or city or a set of countries and cities in a region to investigate what kind of research is being carried out and by whom. As the global maps illustrate, some sharp differences often exist even within a region. For example, there are some major differences in the ranks of capital cities across Europe (between northern and southern capitals and between eastern and western capitals), in Central and South America, in Sub Saharan Africa, across Asia, and in the Pacific. What are the underlying reasons for the variations? Also, it would be worth examining urban forest knowledge bases, policies and government/community programs in the second, third, and fourth largest cities as well as regional capitals within a country? Are they receiving financial support? Are local community efforts integrated into urban forest programs. Also, who is conducting research on urban forestry in a country or in the capital city or other large cities? Are most authors scientists from within the country, from Europe or North America, and if so, what specific countries? What

countries are authors from who study urban forests in Southwest and Southeast Asia, Central and Southern Africa, or the Caribbean and Pacific Islands? This locational question about country and university origins of published research can be extended to "who is studying what topic?" Are scholars from the "outside" studying different topics than those from the "inside?" Are they conducting on-site field work or using satellite images purchased from a European or North American company or using Zoom and social media? Related to these field-based questions are additional questions about funding. Is research funding easier to obtain to study capital city forestry questions in Western Europe or Florida and California than studying forestry questions for the three or four leading cities in India, Nigeria, Indonesia, Sri Lanka, Nigeria, China, and Brazil? Are national or international research funds even available in some African, Latin America, and Asia countries to study urban forests? All these questions about present and future research relate to a final set of questions about publications. How many urban forestry manuscripts have been submitted to major journals in the past five years? What are the percentages of authors from Africa, Central and South America, South and Southeast Asia, and the Pacific? Do major disciplinary and interdisciplinary journals focusing on sustainability, urban forestry, and environmental policies have editors and editorial board members from Global South countries and different disciplines? Do these editors regularly include Global South scholars as manuscript reviewers? Do they work with young and senior authors who have good ideas but need help in preparing quality manuscripts? Do major journals include the variety of topics mentioned in **Figure 1** and those coming from a mix of scholars from both the science and humanities or are they restricting submissions and publications to only a handful of major topics and only a singular approach to addressing a topic?

In summary, this focus on urban forests in a global context introduces a new "state-of-the-art" knowledge database and perspective related to urban forests and examines these forests in technical, cartographic, field, social media, and library contexts. Also, it addresses a series of important future research topics for scholars working in disciplinary and interdisciplinary contexts and at all scales: personal, local, regional, and global. This challenge is well summarized by Jing *et al.* [34]: "Mapping urban spaces at global and regional scales is an urgent and crucial task for detecting urbanization and human activities throughout the world and is useful for discerning the influence of urban expansion upon the ecosystem and the surrounding environment" (p. 12419).

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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