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Systematic Review

A Megacities Review: Comparing Indicator-Based Evaluations of Sustainable Development and Urban Resilience

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Abstract: Urbanization is defining global change, and megacities are fast becoming a hallmark of the Anthropocene. Humanity's pursuit toward sustainability is reliant on the successful management of these massive urban centers and their progression into sustainable and resilient settlements. Indicators and indices are applied assessment and surveillance tools used to measure, monitor, and gauge the sustainable development and urban resilience of megacities. Unknown is how indicator-based evaluations of sustainable development and urban resilience of the world's largest 43 cities compare. In response, this review paper used the PRISMA reporting protocol, governed by 33 established and 10 emerging megacities, to compare and contrast evaluations of sustainable development and urban resilience. Results reveal that applied assessments of sustainable development of megacities appeared earlier in time and were more abundant than those of urban resilience. Geographically, China dominated other nations in affiliations to scientific research for both sustainable development and urban resilience of megacities. Among the 100 most recurrent terms, three distinct key term clusters formed for sustainable development; seven budding key term clusters formed for urban resilience suggesting breadth in contrast to sustainable development depth. The most cited assessments of sustainable development emphasize topics of energy, methodological approaches, and statistical modeling. The most cited assessments of urban resilience emphasize topics of flooding, transit networks, and disaster risk resilience. Megacities research is dominated by few countries, suggesting a need for inclusion and international partnerships. Lastly, as the world's people become increasingly urbanized, sustainable development and urban resilience of megacities will serve as a key barometer for humanity's progress toward sustainability.

Keywords: cities; index; megacities; population growth; rural to urban migration; sustainable development; sustainability indicators; systematic literature review; urban assessment; urban resilience

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1. Introduction

Megacities (>10 million people) are fast becoming a hallmark feature of the Anthropocene. As global population growth and urbanization intensify, these hyper-urban, human-based ecosystems will become controlling hubs for environmental and socioeconomic landscapes. Population growth is anticipated to continue rising into the 22nd century, adding one billion people (totaling 8.5 billion) by 2030 alone; reaching 11 billion globally by 2100 [1]. Simultaneously, the world is becoming intensely urbanized as more people desire urban rather than rural settlements. Urban populations globally exceed 4 billion people [2], including over 600 million inhabitants of megacities [3]. Trends suggest that urban population will reach 60% by 2030, almost 70% by 2050 [4], and reach 100% urban by the turn of the century as predicted by Michael Batty [5]. Megacities will play a dominant role in this growth since their decades-long trend of the highest rates of population growth among all urban classes is expected to continue [6]. This has fueled the global explosion

from two megacities dotting the earth in the 1950s (New York City, USA, and Tokyo, Japan) to today's 33, with an additional 10 expected to break the megacity barrier by 2030 [4]. By mid-century, the establishment of 67 megacities is predicted, with regions in Africa seeing the highest rates of growth; the Asia Pacific region continues to host the largest megacities in the world, with Delhi approaching a population of 47 million [7]. Humanity's progress toward sustainability is reliant on the successful management of these controlling cities and their transition into sustainable and resilient human settlements.

Environmentally, megacities are having a lasting impact on planetary limits. Due to their size, they consume enormous amounts of energy and resources. Globally, megacities use nearly 7% of total energy (~9% of total electricity and ~10% of gasoline) while producing approximately 13% of total waste worldwide [8]. These wastes include the release of significant amounts of greenhouse gases and particulate matter (PM) into the atmosphere [9], impacting air quality and climate change across local, regional, and global scales [10]. All megacities exceed the World Health Organization (WHO) guidelines for air pollution based on average annual concentrations of air particulates for PM_{10} [11], while tolerance levels were exceeded for $PM_{2.5}$ in five Indian megacities for more than 50% of days across several years of study [12]. Of the total anthropogenic emissions of megacities, carbon dioxide (CO_2) is foremost due to its critical link to climate change as a highly abundant, radiative forcing greenhouse gas (GHG) [13]. Human-induced climate change is associated with increased temperature and weather extremes as observed through elevations in sea-level rise, precipitation and storm events, heatwaves, and drought [14]. As the majority of megacities are coastal, and situated in the developing world, they are increasingly exposed to sea-level rise and enhanced storm activity [15]. Examples of adversely impacted megacities from climate change events were: New York City in 2012 [16]; Lagos in 2011 [17]; and Mumbai in 2005, Jakarta in 2007, Manila in 2009, and Bangkok in 2011 [18]. Urban heat islands (UHIs), the term used to depict hotter surface and atmospheric temperatures found in urban areas compared to their cooler suburban, exurban, and rural counterparts [19,20], will intensify in megacities, especially those situated in the southern hemisphere [21]. As megacities grow, their contributions to climate change through energy and resource consumption will increase; megacities will suffer adverse consequences due to their climate change vulnerabilities without strict commitments to sustainable development and urban resilience.

Socioeconomically, megacities are the heartbeat of their host nations. Cities account for over 80% of gross domestic product (GDP) worldwide, but tendencies for growth favor the largest cities, allowing them to grow quicker than smaller ones economically due to infrastructure investments and employment opportunities [22]. More specifically, megacities are responsible for a major portion of their host nation's GDP. For example, São Paulo contributes 19% [23], Seoul 48.6%, Paris 27.9%, Mexico City 26.6%, and New York City 8.5% [24] to their host nation's GDP. High rates of population growth and urbanization can lead to declining economic conditions and the emergence of poor megacities [25]. Investments and growth in real estate and industrial sectors have led to the expansion of urban boundaries and farmland metabolization increasing food insecurity in Jakarta [26]. Traffic congestion is also rampant and tends to radiate outward from the core to peripheral areas, which may impact the quality of life and personal health of citizens [27]. With high population densities, megacities are more susceptible to the negative health impacts of UHI (i.e., morbidity, mortality) due to concentration of human activities, heat from high energy consumption, reduced greenspace, thermal inversions, and higher concentrations of GHGs [19,28].

Essential to humanity's pursuit of sustainability is the successful management of megacities' progression into sustainable and resilient human settlements that account for global changes. For this study, "sustainability" is viewed as humanity's objective of human–ecosystem equilibrium, while "sustainable development" comprises the holistic methods and temporal processes that guide humanity toward sustainability [29]. "Urban resilience" is defined as the ability of an urban system, its components, and its net-

works, to maintain or rapidly return to a desirable state upon disturbance, adapting to changes and quickly transforming any systems that limit current or future urban adaptive capacity [30]. To achieve these objectives, 17 international Sustainable Development Goals (SDGs) have created pathways towards sustainability by balancing environmental integrity, social equity, and economic prosperity [31]. Simultaneously, steps are being taken to integrate resilience into urban development objectives [32]. However, progress on SDG 11—make cities and human settlements inclusive, safe, resilient, and sustainable—has remained relatively stagnant, adding little improvement. The *2030 Agenda* [31] provided a framework for organizing the breadth of sustainability into 17 SDGs using 169 targets monitored by 231 unique indicators [33]. Indicators and composite indices are being used by government and non-government agencies to measure elements of sustainability, monitor development progress, and enhance decision making at all levels [34–39]. The metric options available to practitioners for their uses have become nearly endless [40–42]. Applied assessments employ these tools as surveillance systems that measure, monitor, and assess the sustainable development and urban resilience of cities. To date, no reviews of indicator-based evaluations of sustainable development and urban resilience have been compared and contrasted across megacities. Filling this gap, thirty-three established and ten emerging megacities were investigated using four research questions (RQ):

RQ.1. How have scientific assessments of megacities emerged over time?

RQ.2. Does the scientific literature on sustainable development and urban resilience of megacities correspond with their geographical locations?

RQ.3. What are the most common research topics connected to the sustainable development and urban resilience of megacities, and what are the most cited articles corresponding to the sustainable development and urban resilience of megacities?

RQ.4. What can we learn from the most prominent articles on sustainable development and urban resilience in how to best evaluate megacities' progress to ensure a sustainable future?

Those questions were investigated across 43 of the world's largest cities through a systematic review following PRISMA reporting protocols to compare indicator-based evaluations of sustainable development and urban resilience. Temporal (time) distributions were first determined followed by the spatial (geographical) distributions of published articles using the national affiliations of their authors. Keyword networking using the 100 most frequent words revealed common themes for both sustainable development and urban resilience. The most popular publications based on citations generated were analyzed to determine and compare prominent topics. This systematic literature review aims to further establish understanding of these two interrelated themes as they have been applied in indicator-based evaluations of megacities. Insights will be useful to researchers, practitioners, and policymakers to advance development strategies and enhance monitoring systems as megacities become global foci of environmental, social, and economic concerns.

2. Materials and Methods

2.1. Current and Emerging Megacities

A megacity can be broadly defined as an urban area exceeding 10 million inhabitants that includes administrative boundaries such as city proper, urban agglomeration, and metropolitan area [43] (see Appendix A). As of 2018, thirty-three megacities were established worldwide, while an additional ten cities will break the 10 million inhabitant barrier by the end of this decade [43]. Geographically, the 33 established megacities are unevenly dispersed throughout five continents: Africa (3), Asia (20), Europe (2), South America (5), and North America (3); the 10 emerging megacities are concentrated in the three continents of Africa (2), Asia (7), and Europe (1). The established megacities span roughly 90 degrees of latitude from Moscow, Russia, in the north to Buenos Aires, Argentina, in the south; the emerging megacities cover approximately 60 degrees of latitude from London, England, in the north to Luanda, Angola, in the south. As of 2020, megacities account for over 20% of all urban inhabitants, or 600 million people [3]. The 10 emerging megacities are expected to add

over 220 million urban inhabitants by 2030 [43]. Populations for the 33 established megacities range from Tokyo, Japan (37.5 million), to Krung Thep (also known as Bangkok), Thailand (10.1 million); the 10 emerging megacities range from Seoul, South Korea (9.9 million), to Dar es Salaam, United Republic of Tanzania (6 million).

2.2. Literature Search and Eligibility Criteria

Developing and documenting a sound, structured, and repeatable methodology for a systematic review is essential but until recently has been absent from nearly all reviews [44]. This systematic literature review follows the PRISMA—Preferred Reporting Items of Systematic reviews and Meta-Analyses—framework [45]. PRISMA is a detailed, orderly way to document procedures and protocols to standardize methodologies for easy reproduction (Figure 1). Five academic databases—Engineering Village (GEOBASE and Ei Compendex), GreenFILE, ProQuest, Scopus, and Web of Science—were scoured for scientific articles relating to the subject matter. These databases were confined to a search end date of 31 December 2023. Four unique database explorations captured a comprehensive list of journal articles related to the applied use of indicators/indices covering "sustainability/sustainable development" and "resilience/urban resilience" of megacities. Searches were constrained to English-language articles from journal publications only. The four-step systematic literature review is detailed herein:

(1) The first set of academic database searches were focused on capturing articles evaluating sustainability and sustainable development. Each search commenced with an article title search of "sustainability" OR "sustainable development" followed by title, abstract or keywords containing "megacity" OR "megacities" AND "indicator*" OR "index" OR "indices" OR "quantitative assessment" AND "appl*" OR "assess*" OR "monitor*" OR "measur*".

(2) The second set of academic database searches was identical to the first set, with a change being made to the "megacity" OR "megacities" title, abstract, or keyword search criteria. To enhance the scope, these two search terms were replaced by 58 formal and/or common place names for the established and emerging megacities included in this study (Appendix A). The list of city names was established from the United Nations 2018 World Urbanization Report [4], in which proper names are listed along with common names indicated in brackets. For example, "Los Angeles" and "New York City" were used as common reference names in addition to the full names of "Los Angeles-Long Beach-Santa Ana" and "New York-Newark." Additionally, regional and/or national studies were included if a megacity was identified in the document abstract.

(3) The third set of academic database searches targeted English-language articles focused on urban resilience or the resilience of cities. Urban resilience often intersects with sustainable development [46], and due to this study's focus on megacities, this parameter was critical to capturing a full scope of articles focused on sustainable development in megacities. The search duplicated the procedures set forth in the first and second academic database searches above but targeted resilience and urban resilience. The search commenced with an article title search containing either "resilien*" OR "urban resilien*" followed by title, abstract, or keywords containing "megacity" OR "megacities" AND "indicator*" OR "index" OR "indices" OR "quantitative assessment" AND "appl*" OR "assess*" OR "monitor*" OR "measur*".

(4) Similarly, the fourth database search mimicked the second, with an alteration to the "megacity" OR "megacities" portion of the title, abstract, and keywords searched by substituting the 58 formal and/or common place names given to the established and upcoming megacities. Separating the article searches compartmentalized the applied evaluations of megacities, which allowed for a unique comparison of the two closely aligned paradigms.

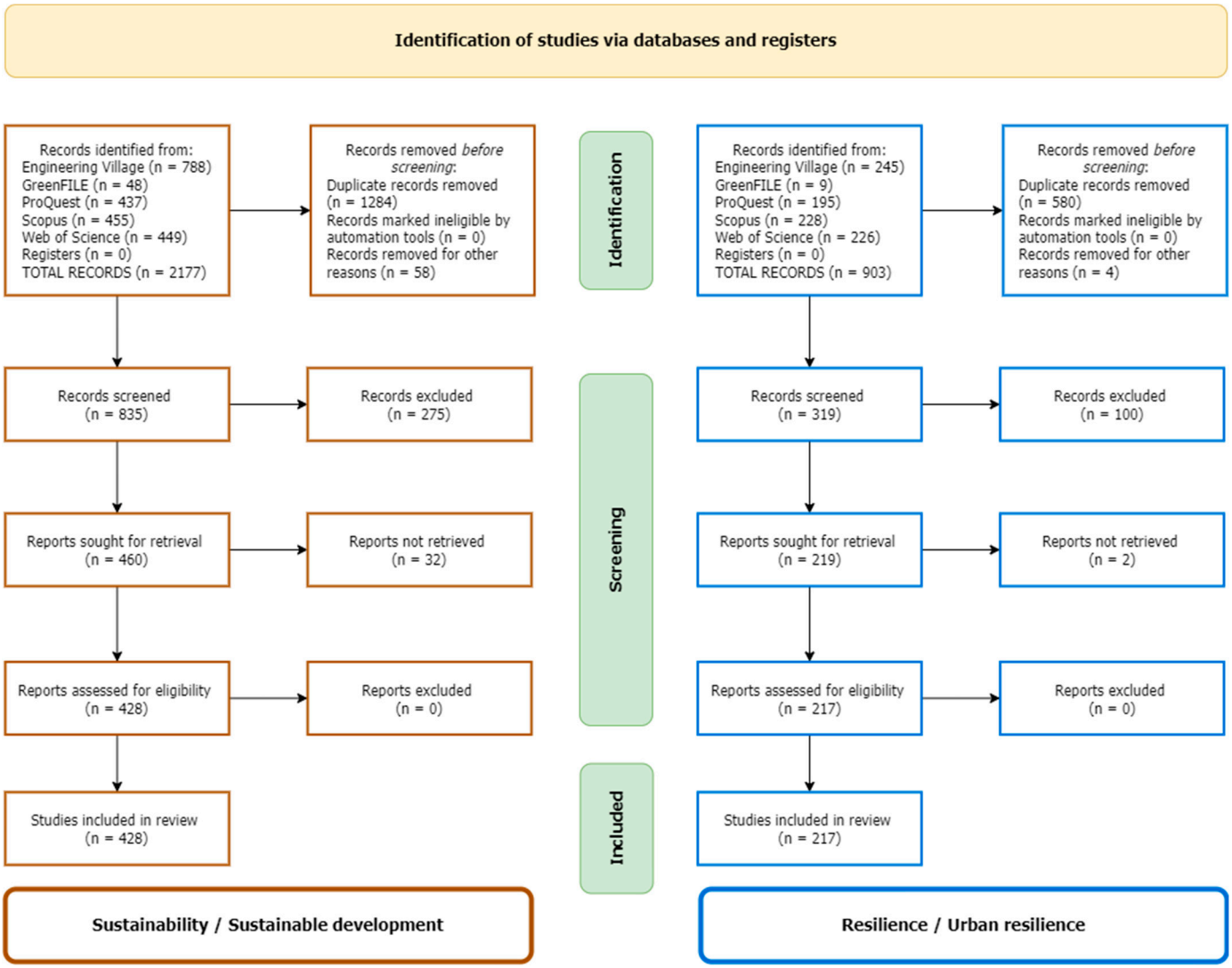

Figure 1. PRISMA flow charts of the two separate database literature searches used for comparing and contrasting sustainable development and urban resilience of megacities.

Searches one and two focusing on sustainability and sustainable development combined to identify 2177 total records (Figure 1). Of these, 1284 records were removed as duplicates and 58 were removed for other reasons (e.g., book chapters, conference proceedings, foreign language, newer than the year 2023, etc.) based on the search criteria. A total of 835 records were screened for eligibility and were further reduced by 275 after title and abstract review. Four hundred sixty (460) total reports met the intentions of this study and were sought for retrieval. Thirty-two (32) of these reports were unable to be properly retrieved via their DOI links, thereby disqualifying them. The final total of studies included in the review based on the above criteria for sustainability and sustainable development was 428. Searches three and four focusing on urban resilience and resilience identified a total of 903 records (Figure 1). Five hundred eighty (580) duplicates were removed, plus four (4) additional records for other reasons (e.g., book chapters, conference proceedings, foreign language, published beyond the year 2023, etc.). A total of 319 records were screened for eligibility and after title and abstract review, 100 more records were disqualified. There were 219 reports that met the intentions of this study and were sought for retrieval. Of these reports, only two (2) failed retrieval via their DOI links, thereby disqualifying them. The final total of studies included in this review based on the above criteria for applied evaluations of resilience and urban resilience was 217. Zotero (ver. 6.0.36) [47] and Mi-

crosoft Excel (ver. 2406) [48] software were used to remove duplicate records and screen article titles and abstracts. Title and abstract screening ensured the included articles met all previously defined search criteria for indicator-based evaluations involving 1 or more of the 43 selected cities. Many articles were excluded for contextual reasons that did not align with this study's objectives (i.e., an abstract mentioning the "Paris Agreement" but studying location(s) beyond the 43 selected cities). Data processing during the retrieval steps involved the use of VOSviewer (ver. 1.6.20) [49] to ensure all articles in the database had appropriate DOI links compatible for analysis.

2.3. Spatiotemporal Analyses

The open start date of the database searches was intentional to temporally track, compare, and establish the emergence of applied evaluations related to the two disciplines. Microsoft Excel [48] was utilized to provide a graphic overview of the distribution of publications across time. Spatial analysis of the two individualized databases involved the use of VOSviewer (ver. 1.6.20) [49] software. To understand the country affiliations of the document authors within the databases, maps based on bibliographic data were created in VOSviewer [49] using DOI input files and the integrated application programing interface (API) OpenAlex [50]. The OpenAlex API [50] is advantageous to this study as it has greater coverage of works from the Global South [50] and provides VOSviewer [49] with the country affiliations of the authors involved in the publications through a full count of documents. Using this process, a total of 428 documents were retrieved for the sustainable development theme, while 217 documents were retrieved for the urban resilience theme. The country affiliations by author were extracted from VOSviewer [49] by creating a citation analysis of countries using full counting (i.e., count each article's author/co-author(s)'s national affiliation once) and setting the parameters of minimum number of documents per country to 1 and minimum number of citations per country to 0, which ensured all associated countries were recognized. For consistency in showcasing internationally recognized, sovereign nations, the document counts for China include the aggregate of Hong Kong SAR China, Macao SAR China, and Taiwan. The extracted data of document frequency counts per country were inputted into ArcGIS Pro (ver. 3.3.0) [51] for visual presentation of results.

Utilizing identical protocols, VOSviewer [49] was employed for keyword mapping of the two databases. The protocol for this segment involved creating a map based on text data taken from publications retrieved through the DOI input files and OpenAlex API [50]. Terms were extracted from title and abstract fields utilizing the full counting method. For the sustainable development theme, 428 documents were retrieved with 40 documents missing abstracts, while 217 documents were retrieved for the urban resilience theme with 19 documents missing an abstract. Term occurrence parameters were set at 20 for the sustainable development theme, which rendered 138 terms of 11,429 meeting the threshold. In contrast, term occurrence parameters were set at 10 for the urban resilience theme, which isolated 151 of 6229 terms meeting the threshold. In both cases, the top 100 terms were selected for network mapping in VOSviewer [49]. For network visualization, key terms are depicted by variously sized circles and labels indicating the weight of the item in the network [52], and the visualization was calibrated to the frequency of word occurrences found in the titles/abstracts. Clusters of terms were also generated by the software to reveal bundles of similarity as indicated by unique color coding, while the closeness of terms indicates the relation strength [52]. The key term linkages were set to the default of 1000 total links, which indicates the connection strength between different items [52]. Key term networks were analyzed individually before being contrasted against one another. The identification of the most prominent articles in the two databases was drawn out by ranking the articles by the number of citations each generated. This process was conducted in VOSviewer [49] using the DOI input files and OpenAlex API [50] to create a map based on bibliometric data. All documents from the previous analyses were retrieved for sustainable development and urban resilience themes, totaling 428 and 217, respectively.

Publications were analyzed by citation using documents as selected units, generating a table of documents, citations, and links that were exported and rank-ordered for analysis. The top ten most cited articles of each theme were selected for in-depth analysis to reveal common themes among and between the two databases and to generate an understanding of the state of indicator-based evaluations of the two related academic fields.

3. Results

3.1. Temporal Distribution of Publications

Of the 428 sustainable development themed publications, the first megacities-related article came in 1996 (Figure 2). It was titled "Local authorities and sustainable development: Turning policies into practical action through performance review—A case study of the London Borough of Hackney" [53], published in the journal *Local Environment*. Over a decade later in 2010, "Rapid assessment methods of resilience for natural and agricultural systems" [54] debuted among the 217 urban resilience-themed articles and was featured in the *Annals of the Brazilian Academy of Sciences*. Over the next decade, sustainable megacity evaluations were sparse and did not reemerge with traction until 2004, when a total of six publications appeared. Yearly publications were relatively stagnant and plateaued for another decade until 2013, when 19 articles were published relating to sustainable development evaluations of megacities. In the following decade through 2023, the trend showed a moderate increase in the number of yearly papers published under the sustainable development paradigm. The number of yearly publications doubled to 40 by 2018, which gradually increased to its peak in 2022 with 63, before a small decline in 2023 with 61 publications. When observing the temporal trends of urban resilience-themed articles, publications remained dormant alongside sustainable development until 2010, when a resilience-based assessment of megacities emerged. Urban resilience established itself relatively quickly after a short five-year period of stagnation. From 2015–2017, articles per year fluctuated between six and eight, nearly tripling from years prior. A surge in publications evaluating the resilience of megacities occurred in 2018, nearly tripling to 19 per year. This number more than doubled again to 46 in 2022 before reaching its peak and outpacing sustainable development with 65 publications in 2023.

Notable results emerged when comparing the temporal distribution of yearly publications of indicator-based evaluations of megacities. The debut year among the published articles for each theme similarly tallied one document but were separated by a 14-year span. The evaluation of sustainable development first established itself in 1996 before urban resilience emerged in 2010. During this 14-year timeframe, 31 total articles were published under the sustainable development umbrella, accounting for approximately 7% of the 428 articles in this database. Looking at the establishment and significant surges in publications, there was a 17-year timespan from the first megacities-related sustainability article until reaching 19 works in 2013. In contrast, there was an eight-year delay in the emergence of megacities-related resilience evaluations, which surged to 19 publications in 2018 after starting in 2010. Although the number of yearly publications has been more under the sustainable development theme, urban resilience publications have followed the same gradual but upward trend in yearly publications since 2015. Over the last four years of the analysis, there was a tripling of yearly articles published, totaling 65 within the urban resilience umbrella. During the same timeframe, sustainability-themed yearly publications increased overall, but yearly gains were not always detected. In the last six years, over 85% of the 217 megacities-related resilience evaluation articles were published compared to 70% of the 428 sustainability evaluation articles. Not until the last two years (2022, 2023) did publication totals reach their highest levels. Sustainable development peaked in 2022 with 63 publications, surpassed by urban resilience in 2023 with a total of 65 publications. In 2023, the two themes were comparable, surpassing 60 publications per year. Overall, indicator-based evaluations of megacities appears to be new, as most publications under the two umbrella themes have surfaced within the last five years (SD > 60%, UR > 78%).

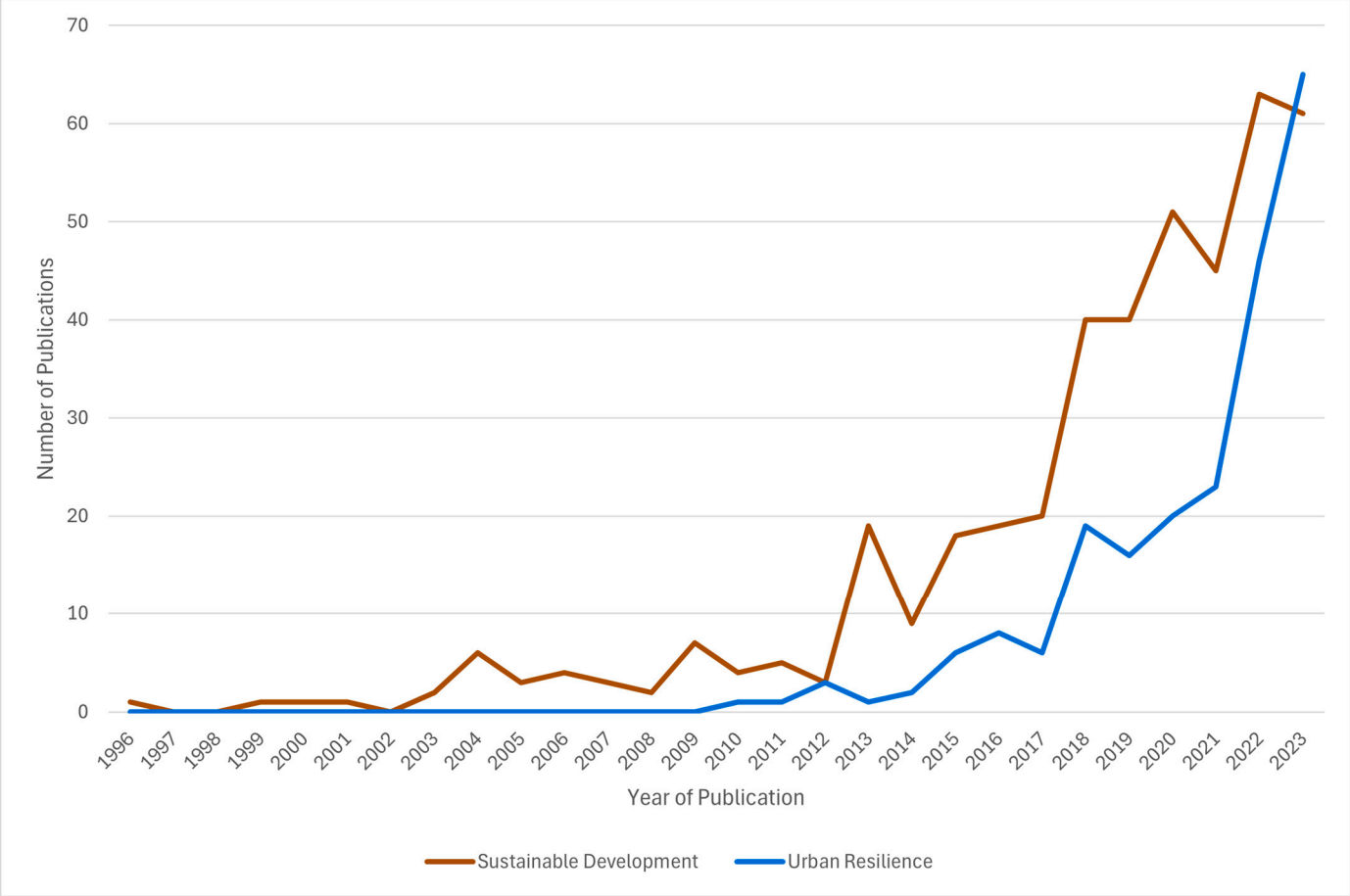

Figure 2. Temporal distribution of annual counts of indicator-based evaluations of "sustainability/sustainable development" and "resilience/urban resilience" of megacities from 1996 to 2023. Global events to consider include the following: United Nations Millennium Summit/Millennium Development Goals (2000); 100 Resilient Cities (2013); United Nations Sustainable Development Goals (2015); Paris Agreement—COP21/United Nations Climate Change Conference (2015); COVID-19 Pandemic (2019); Resilient Cities Network (2020).

3.2. Spatial Distribution of Publications—Sustainable Development

When observing the country affiliations of publication authors, there are notable trends for each of the two analyzed topics regarding indicator-based evaluations of megacities. Overall, a total of 57 unique countries were affiliated with studies regarding the sustainability of megacities (Figure 3). An overwhelming majority of publications were linked to China, totaling 216 documents and over half of the 428 articles in the database. The United States of America (USA) had the second highest number of publications, totaling 43. Rounding out the top six were the United Kingdom, Iran, India, and Brazil with 36, 28, 26, and 21, respectively, documented through author affiliations. Five nations (South Korea, Netherlands, Canada, Japan, and Australia) were tied to 10–14 publications each. Following this classification were 17 nations (Egypt, Italy, Mexico, Germany, Spain, Indonesia, Turkey, France, Malaysia, Pakistan, Sweden, Switzerland, Colombia, Nigeria, Thailand, Russia, and South Africa) falling within four to nine publications. Of the remaining 57 nations, over half (29/57) of them included Bangladesh, Portugal, Saudi Arabia, Austria, Finland, Ireland, Philippines, Poland, Qatar, Singapore, Vietnam, United Arab Emirates, Belgium, Brunei, Chile, Cyprus, Czech Republic, Denmark, Greece, Lebanon, Luxembourg, Morocco, Norway, Nepal, New Zealand, Oman, Romania, Serbia, and Zambia, tied to publications totaling between one and three articles. None of the remaining recognized countries by the

United Nations were linked to sustainable development-themed publications within the database.

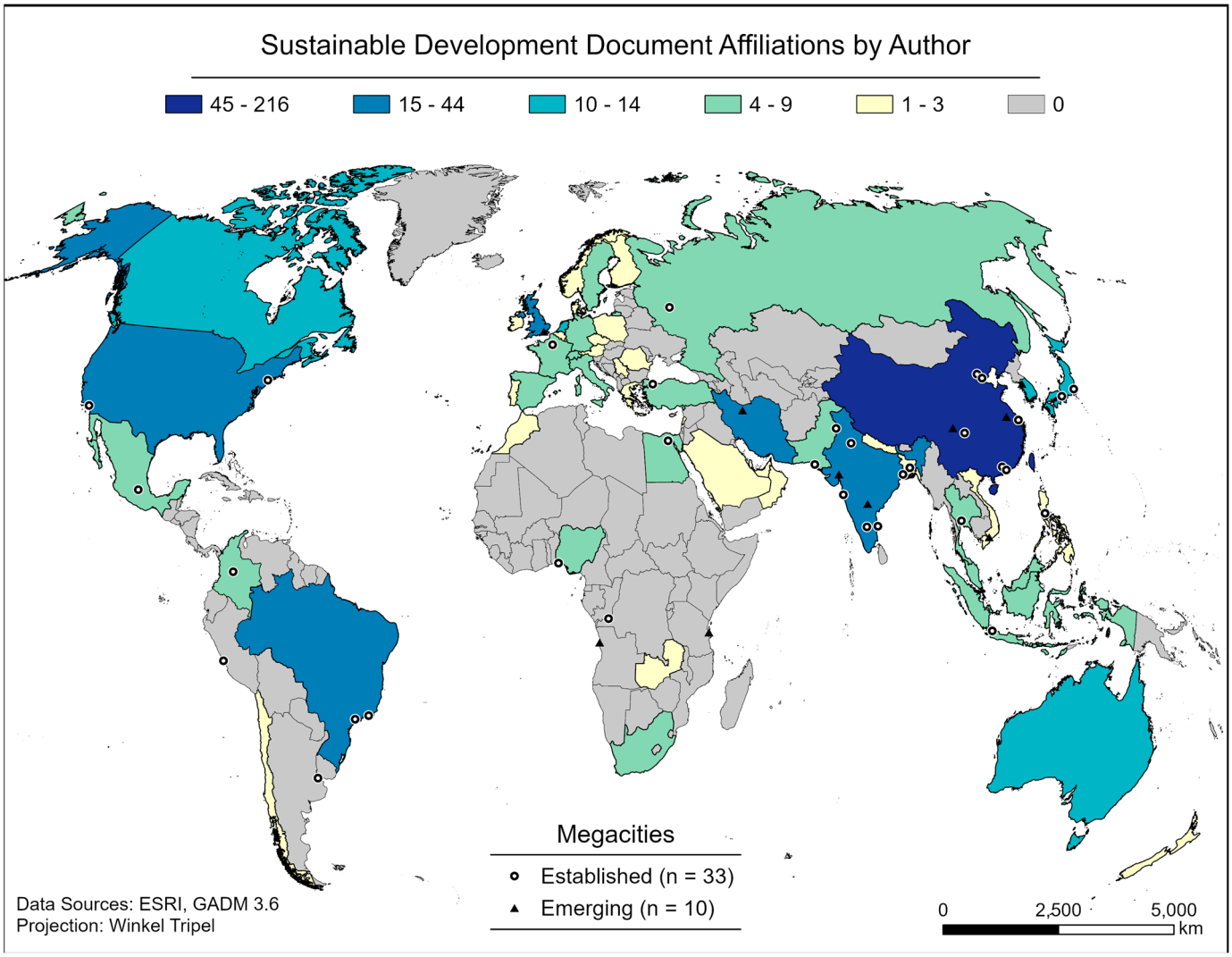

Figure 3. Global distribution of scholarly results from the systematic literature review of sustainable development of megacities. Data sources: ESRI [51], GADM [55].

Geographically, most nations tied to publications within the megacities-related sustainable development database were within the northern hemisphere. Of these, China is champion with six established and two emerging megacities while being the best in research with links to a majority (216/428) of publications. India was ranked second with five established and two emerging megacities, but their ties to publications within this database ranked fifth overall. Ahead of India was the USA with 43 total publications and host to two established megacities. Ranking third and fourth ahead of India are the United Kingdom and Iran, having publication link totals of 36 and 28, respectively, while anticipating their first megacity each by 2030. Other countries within the northern hemisphere contributing to this literature theme are spread across the Westernized regions of Europe, Scandinavia, Russia, and North America while spotted throughout Middle Eastern countries. Three nations with established megacities within the Global South (Argentina, Peru, and the Democratic Republic of Congo) have no author affiliated ties. Two African nations (Angola and United Republic of Tanzania) are set to establish one megacity each by the end of the decade but had no affiliations within the research. However, Brazil hosts two established megacities and ranked sixth overall in document affiliated authorship with a total of 21. Colombia, Egypt, and Nigeria all have one established megacity each and fell within the

four to nine range of document affiliations. Overall, many nations or forthcoming nations corresponded to indicator-based evaluations of sustainable development of their own megacities, apart from Peru, Argentina, Democratic Republic of Congo, and the two future countries of Angola and the United Republic of Tanzania.

3.3. Spatial Distribution of Publications—Urban Resilience

There were a total of 33 unique nations identified when assessing the megacities-related urban resilience-themed database ties to authorship (Figure 4). China was linked to an overwhelming number of publications, totaling over half in this database (109/217). The next four nations, Iran, USA, United Kingdom, and Japan, had significantly fewer publications, totaling 40, 35, 20, and 16, respectively. The next range of five to nine publications included the four nations Australia, Brazil, Canada, and South Korea. Nine countries (Chile, Germany, France, Italy, Sweden, Mexico, Nigeria, Netherlands, Singapore) had three to four publications each through author affiliations. Nearly half of all affiliated nations (Austria, Spain, Indonesia, India, Qatar, Turkey, United Arab Emirates, Czech Republic, Malaysia, Norway, Pakistan, Peru, Philippines, Serbia, Thailand) were linked to only one or two publications. None of the remaining United Nations recognized countries were linked to urban resilience-themed publications within the database.

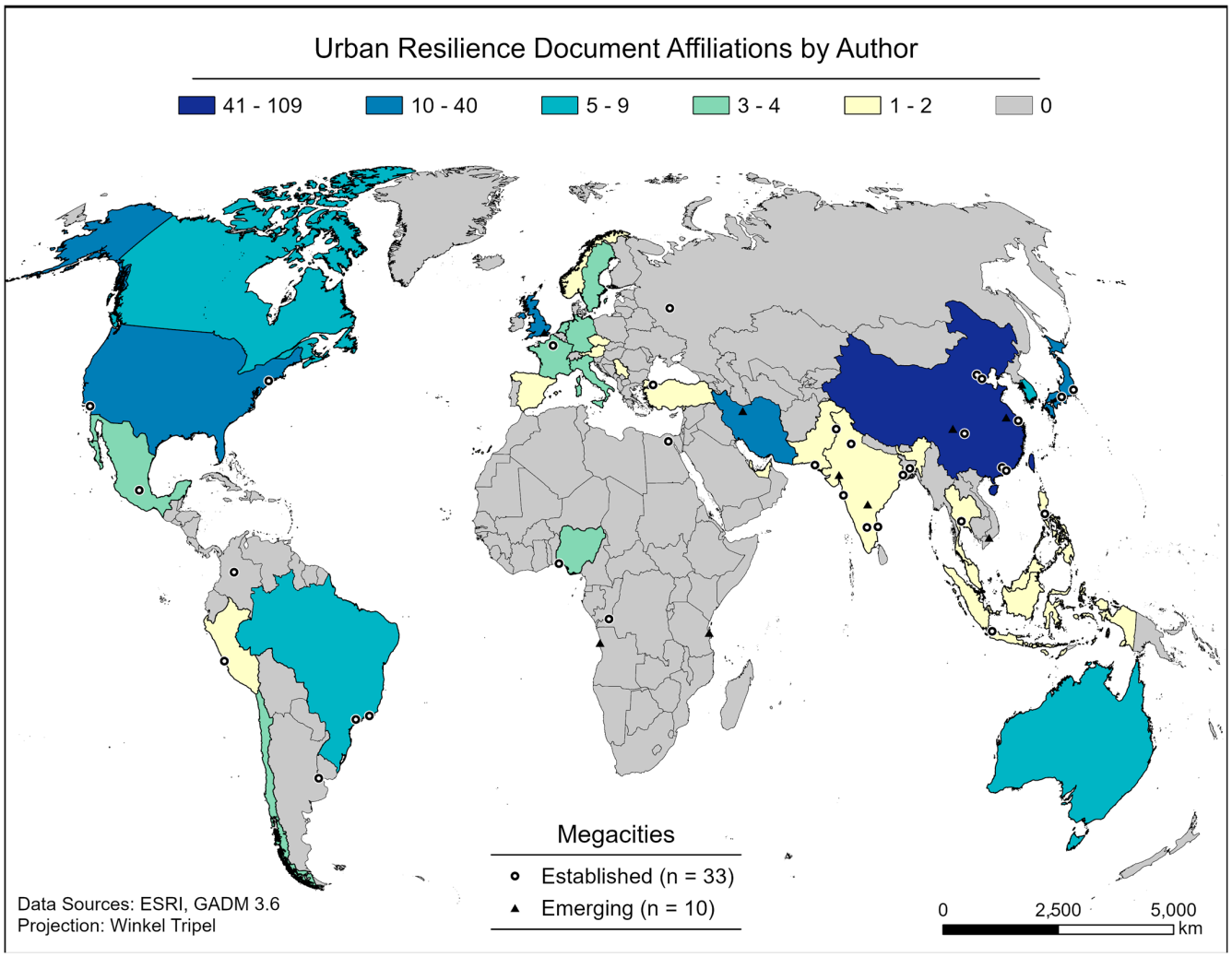

Figure 4. Global distribution of scholarly results from the systematic literature review of urban resilience of megacities. Data Sources: ESRI [51], GADM [55].

Geographically, most indicator-based evaluations of urban resilience were tied to nations distributed across the northern hemisphere favoring North America, East and South

Asia, and Western Europe. China again was the forerunner in research with 109 publication links to indicator-based evaluations of urban resilience in megacities. China's dominant connections to research in this database match the six established and two emerging megacities within its borders. Next was the future megacity host Iran with 40 publications. Closely behind and hosting two megacities was the USA with 35 publications. Ranking fourth and hosting an emerging megacity was the United Kingdom with 20 document ties. Fifth was Japan, hosting two established megacities and linked to 16 indicator-based publications of urban resilience. The next four leading countries had between five and nine publications each and include three developed nations, Canada, Australia, and South Korea; South Korea expects its first megacity by 2030. Brazil is the fourth nation in this group, hosts two established megacities, and is the highest-ranking nation within the Global South based on total publications. The nations with three to four publications were concentrated in Western Europe and included France, with its megacity Paris. Other notable countries within this category included Mexico and Nigeria, which host one megacity each. Of the nations ranging between one and two documents each, India is of particular importance with five established and two emerging megacities. Established and emerging megacities were found within seven additional nations in this publication grouping including Indonesia, Turkey, Malaysia, Pakistan, Peru, Philippines, and Thailand. The remaining United Nations recognized countries rendered no authorship affiliations. Five nations have established megacities without researchers from within: Argentina, Bangladesh, Colombia, and Democratic Republic of Congo. Three nations, Angola, United Republic of Tanzania, and Vietnam, have emerging megacities without author affiliations.

3.4. Key Term Networks—Sustainable Development

The top 100 key terms related to the sustainable development of megacities rendered a network composed of three distinct clusters when searching the titles and abstracts of the documents (Figure 5). Cluster 1 (approach; red) is a grouping of 39 terms. The highest-frequency word within this cluster is "approach" (198 occurrences), found near the center of the term network. Other high-frequency words found nearby include "impact" and "management", which are very closely linked to one another, in addition to "project" and "process". Mid-frequency words such as "energy" and "strategy" are closely linked with one another and sandwiched between high-frequency words "scenario", "impact", and "management". Other mid-frequency words like "aspect", "case", and "issue" are most closely linked to the higher-frequency word "process". Mid- to low-frequency terms found within the center of the cluster include "stakeholder", "need", "application", "building", "methodology", and "sustainability assessment". Towards the edge of the term network within Cluster 1 is a mix of low- and mid-frequency terms, with distant links to the higher-frequency words found toward the center of the term network. These terms include "comparison", "london", "resilience", "decision maker", "rio de janeiro", "criterium", "uncertainty", "tehran", "cost", "alternative", "environmental impact", "climate change", "water", and "implementation". A notable low-frequency term found within Cluster 1 towards the middle of the term network is "urban area", which is also closely linked to the term "project".

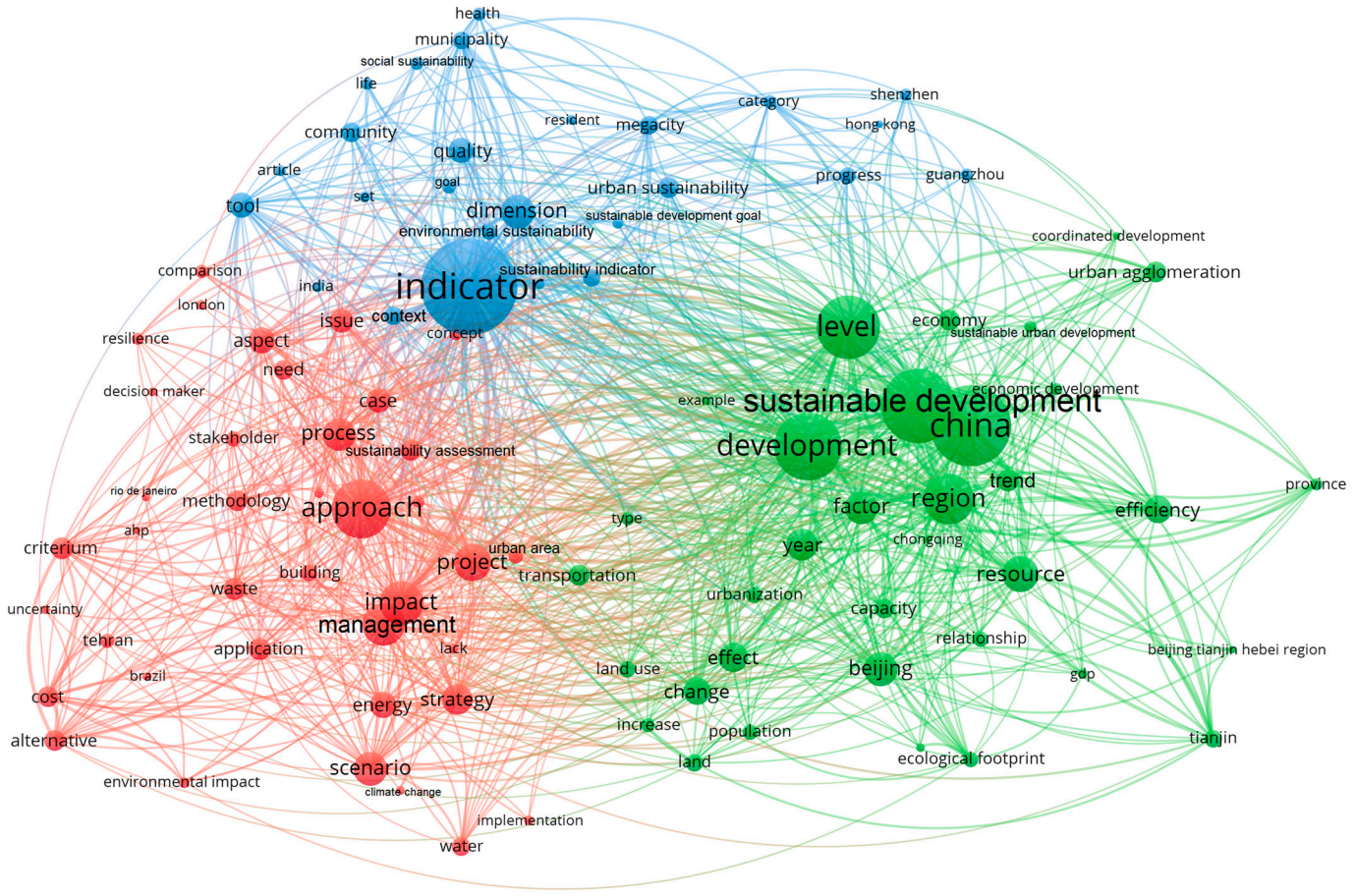

Figure 5. The top 100 key terms from articles related to the sustainable development of megacities. Cluster 1: 39 terms centered around "approach" (red); Cluster 2: 35 terms centered around "sustainable development" (green); Cluster 3: 26 terms centered around "indicator" (blue). Very-high-frequency terms (>200 occurrences); high-frequency terms (100–200 occurrences); mid-frequency terms (50–99 occurrences); low-frequency terms (20–49 occurrences).

Cluster 2 (sustainable development; green) is a grouping of 35 terms. The highest-frequency word within this cluster is "china" (284 occurrences), closely followed by the very-high-frequency terms "sustainable development", "development", and "level" in very close proximity. High-frequency words "factor" and "region" and mid-frequency words "year", "trend", and "economy" are nearby. Moving outward, the linkages to the core four terms are not as strong, but the occurrences of words are still in the mid-frequency range, including "change" and "effect", which are closely linked to one another, along with "beijing", "resource", and "efficiency". Low-frequency words are dispersed throughout Cluster 2, with some having closer links to mid-frequency words within the cluster. The terms "land use", "increase", "land", and "population" are found near "change". Other low-frequency terms are found on the periphery of Cluster 2 and include "ecological footprint", "gdp", "beijing tianjin hebei region", "province", "coordinated development", and "sustainable urban development". The mid-frequency term "transportation" is found very near terms "urban area" and "project".

Cluster 3 (indicator; blue) is a grouping of 26 terms total. The highest-frequency word within the entire network is "indicator" (348 occurrences) and belongs to Cluster 3. Following is the high-frequency word "dimension", being closely linked to "indicator" and distally linked to the mid-frequency terms of "urban sustainability", "quality", "megacity", "municipality", "community", and "tool". Mid-frequency terms with close links to "indicator" are "context" and "sustainability indicator", while distal links include low-frequency

terms like "article", "life", "social sustainability", "health", and "resident". Interestingly, there is a smaller grouping of moderately linked terms within Cluster 3 that are very distant from "indicator" but near key terms belonging to Cluster 2. These low-frequency terms include "shenzhen", "hong kong", "progress", and "gaungzhou", which are nearest Cluster 2 terms "level", "economy", and "coordinated urban development".

3.5. Key Term Networks—Urban Resilience

The key term networking for the top 100 keywords from the urban resilience-themed database rendered a total of seven clusters (Figure 6). These seven clusters are more intertwined with one another than the cluster results obtained from the sustainable development database. Cluster 1 (disaster; red) is a grouping of 20 different key terms centered on "disaster" (80 occurrences). This is the highest-frequency word belonging to Cluster 1, which is found in the center of the entire seven-cluster network. Other high-frequency words in Cluster 1 include "building" and "time", which are near one another; "tehran" is situated at a roughly equal distance from "disaster", "time", and "building". The term "district" is another high-frequency word within Cluster 1 that is located far from "disaster" and situated in the center of Cluster 2. Near "district" are two mid-frequency terms, "disaster resilience" and "social resilience", with others including "attention", "covid", "criterium", "need", "neighborhood", "state", and "iran". The low-frequency terms within this cluster are dispersed throughout, including "decision maker", "earthquake", "pandemic", and "policy maker". Cluster 2 (urban resilience; green) includes two of the top three most occurring keywords of "urban resilience" (125 occurrences) and "area" (121 occurrences). Other high-frequency terms closely linked to these two include "china" and "climate change". Further away from this grouping of terms are high-frequency words "region" and "shanghai", which are near the mid-frequency word "urbanization". Other mid-frequency terms belonging to Cluster 2 include "urban agglomeration", "role", "resilience level", "megacity", "economy", "sustainable development", and "urban development". Some of the low-frequency terms belonging to this cluster are "disaster risk", "influencing factor", and "contribution". Cluster 3 (performance; blue) is composed of 19 terms and centered around its highest-frequency word "performance" (93 occurrences), which is closely linked to high-frequency word "vulnerability". Surrounding these two terms are mid-frequency terms including "flood", "methodology", "resilience assessment", "sustainability", and "uncertainty". Low-frequency terms include "coastline building", "natural hazard", "new york city", "reliability", "robustness", and "smart city", which are more dispersed throughout the network and further from the high-frequency words of the cluster.

There are 14 terms making up Cluster 4 (network; yellow) of the term network. The highest-frequency word belonging to Cluster 4 is "network" (140 occurrences), which is also the most frequently found term amongst all seven clusters. One high-frequency term "station" is near "network". Further away are two other high-frequency terms "evaluation", and "loss" that are closely linked to one another. Mid-frequency terms dispersed throughout Cluster 4 and the broader network include "application", "beijing", "disruption", "flood disaster", "recovery", and "shock". Low-frequency terms include "example", "resistance", and "waterlogging disaster". Cluster 4 is irregularly shaped, and many of the mid- and lower-frequency words are found dispersed and more closely linked to words in other clusters of the network. Twelve terms compose Cluster 5 (community; purple) of the networked terms. The highest-frequency word in this cluster is "community" (74 occurrences). Following are mid-frequency terms like "context", "flooding", "province", "community resilience", "influence", and "part". Low-frequency words belonging to Cluster 5 include "comparison", "effort", and "society". The terms belonging to Cluster 5 also spread across the entirety of the term network, and few words are compactly grouped. Key terms defining Cluster 6 (strategy; aqua) include "strategy" (50 occurrences), which is the highest-frequency term belonging to this cluster of nine keywords. "Effect" is the next most frequent and closest term to "strategy" within Cluster 6. Mid-frequency words include "variable" and "person", while low-frequency terms include "basis", "chongqing",

"livelihood resilience", and "poverty". Cluster 7 (risk; orange) is a grouping of seven keywords. The highest-frequency term within this cluster is "risk" (63 occurrences), which is also found near the epicenter of all 100 networked terms. Next is the mid-frequency term "flood resilience", which is far from "risk", located in the periphery of the network. Other mid-frequency terms in the vicinity of "flood resilience" include "relationship", "urban area", and "urban flood resilience", in addition to the low-frequency term "flood risk".

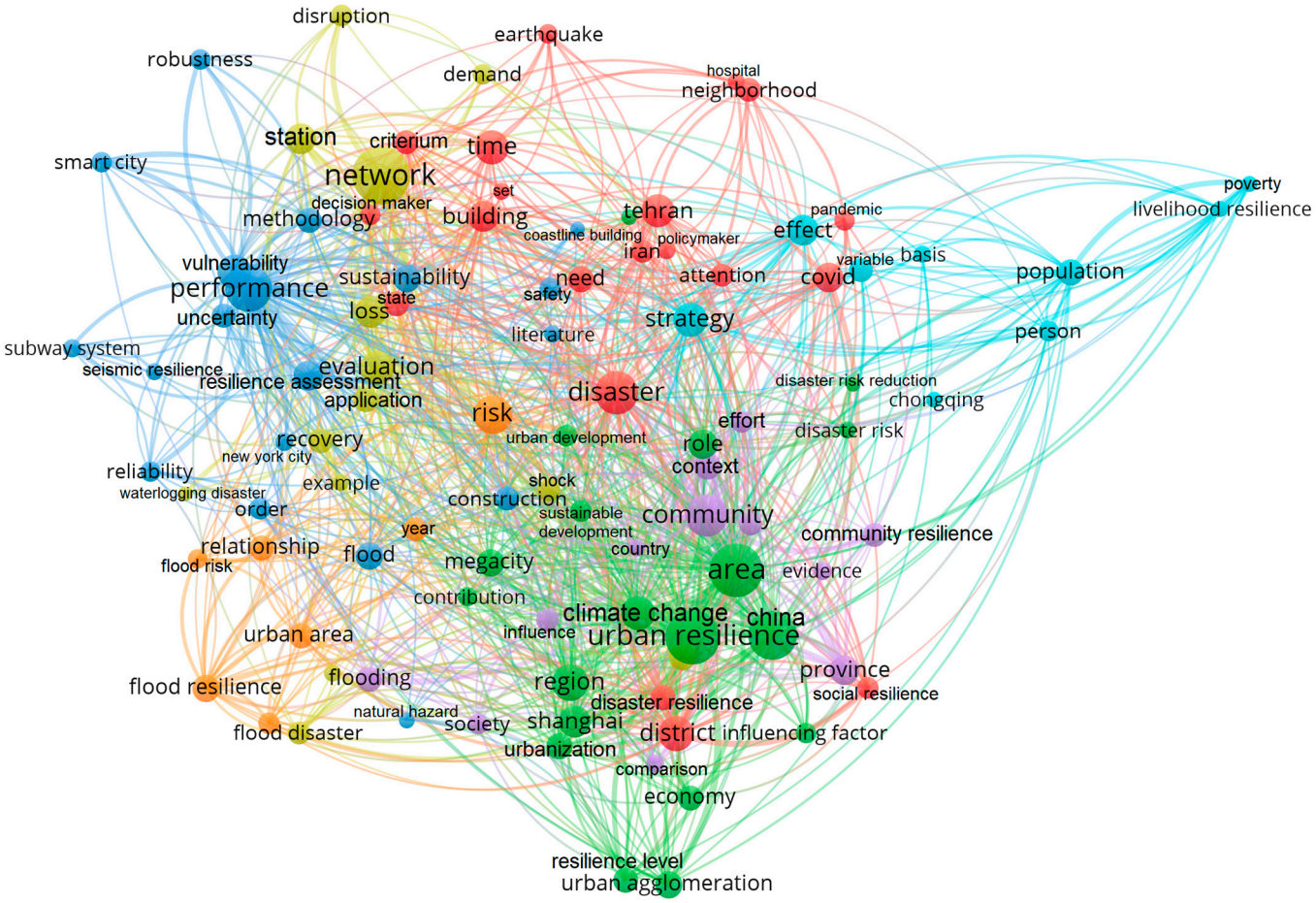

Figure 6. Top 100 key terms from urban resilience-related articles. Cluster 1: 20 terms centered around "disaster" (red); Cluster 2: 19 terms centered around "urban resilience" (green); Cluster 3: 19 terms centered around "performance" (blue); Cluster 4: 14 terms centered around "network" (yellow); Cluster 5: 12 terms centered around "community" (purple); Cluster 6: 9 terms centered around "strategy" (aqua); Cluster 7: 7 terms centered around "risk" (orange). Very-high-frequency terms (>100 occurrences); high-frequency terms (40–100 occurrences); mid-frequency terms (20–39 occurrences); low-frequency terms (10–19 occurrences).

3.6. Comparison of Key Term Assessments

When comparing the top 100 terms from the sustainable development and the urban resilience databases, there were notable observations. Sustainable development terms are neatly clustered into three groupings of unique similarity. Each of these three clusters have a few distinct key terms of very high frequency that define the cluster, suggesting research depth has occurred over the years. In contrast, terms from the urban resilience database, although clustered into seven definitive clusters, is more jumbled and intertwined throughout the overall network, suggesting research breadth has occurred over the years. Additionally, the terms associated with each of the seven budding clusters are less prominent and more subdued in comparison to the key terms defining the three clusters from the sustainable development-themed term network.

3.7. Overview of the Most Prominent Articles—Sustainable Development

The topmost cited article within the sustainable development-themed database (Table 1) was published in 2015 and is titled "Optimal site selection of electric vehicle charging station by using fuzzy TOPSIS based on sustainability perspective" and authored by Guo and Zhao [56]. This *Applied Energy* paper has generated 318 total citations, nearly 100 more citations than the second-most popular article authored by Tan et al. [57]. Authors Guo and Zhao [56] have national affiliations with China and the USA. The second-most cited article authored by Tan et al. [57] is also found in the journal *Applied Energy*, entitled "A holistic low carbon city indicator framework for sustainable development", and has rendered a total of 239 citations. The authors of this publication have affiliations with the countries of Malaysia, Sweden, and China. The third-most cited and oldest article of this group, being published in 2009, has accumulated a total of 193 citations. This publication in the journal *Habitat International* is titled "Planning for sustainable urbanization in fast growing cities: Mitigation and adaptation issues addressed in Dhaka, Bangladesh" and author Roy [58] has national affiliations with the United Kingdom. The fourth-most cited article recorded 191 citations, while the remaining top ten articles range to a low of 115 citations. The remaining top cited articles were published between the years 2011 and 2020 in various journals including *Ecological Indicators*, *Construction and Building Materials*, *Journal of Cleaner Production*, *Energy Economics*, *Science of the Total Environment*, *Landscape and Urban Planning*, *Resources*, and *Conservation and Recycling*. Of the remaining most impactful articles, authors had national affiliations with China (×3), Canada, USA (×2), Republic of Korea, Greece, Portugal, United Kingdom, Ireland, Italy, Netherlands, Switzerland, and Brazil.

The following is a summary of prominent themes based on review of titles and abstracts of the top cited articles within the sustainable development database. The top two most cited articles are found within the same academic journal, *Applied Energy*. Fittingly, these two articles are focused on energy-related topics impacting megacities, with the first being the sustainable site selection and optimization of electric vehicle charging stations [56] and the second focused on a framework for the advancement of a sustainable-development, low-carbon-city indicator [57]. Through a sustainability perspective, these two papers applied novel methodological approaches involving different megacities with goals to be used as guidelines and examples of urban management techniques that can be adopted by other cities. The remaining top cited articles similarly emphasize methodological approaches and modeling using various indicators and indices to promote sustainable development concepts. Topics include planning for sustainable urbanization in rapidly growing cities by addressing climate change mitigation and adaptation concerns using a locally informed model and scenario-based approach [58]; how to quantitatively measure sustainable development in urban areas using an eco-efficiency indicator [66]; employing sustainability's triple bottom line to determine the most sustainable type of flooring system through life cycle assessment modeling [60]; assessing the coordinated development of subsystems related to economic, social, and environmental realms within an urban context to provide policy recommendations [61]; diversifying resource allocations while discussing policy directions and implications to ensure more sustainable urban futures [62]; assessment of groundwater sustainability using indices to address depletion and deterioration concerns and inform policy and decision making [63]; developing a decision support system model and tool through end-user consultation to define objectives related to the interactions between environmental and socioeconomic components of urban sustainability [64]; and a study of sustainable waste management solutions using a life cycle assessment approach to determine the most effective strategy for an environmentally conscious and sustainable waste management system in Rio de Janeiro [65].

Table 1. The ten most cited articles covering indicator-based evaluations of sustainable development of megacities.

Rank	Author (Year)	Title	Journal	Number of Citations	Country Affiliation (Unique Only)
1	Guo & Zhao (2015) [56]	Optimal site selection of electric vehicle charging station by using fuzzy TOPSIS based on sustainability perspective	Applied Energy	318	China, United States of America
2	Tan et al. (2017) [57]	A holistic low carbon city indicator framework for sustainable development	Applied Energy	239	Malaysia, Sweden, China
3	Roy (2009) [58]	Planning for sustainable urbanisation in fast growing cities: Mitigation and adaptation issues addressed in Dhaka, Bangladesh	Habitat International	193	United Kingdom
4	Yin et al. (2014) [59]	Using eco-efficiency as an indicator for sustainable urban development: A case study of Chinese provincial capital cities	Ecological Indicators	191	China
5	Reza et al. (2011) [60]	Sustainability assessment of flooring systems in the city of Tehran: An AHP-based life cycle analysis	Construction and Building Materials	172	Canada
6	Li & Yi (2020) [61]	Assessment of city sustainability-Coupling coordinated development among economy, society and environment	Journal of Cleaner Production	171	China
7	Sueyoshi & Yuan (2015) [62]	China's regional sustainability and diversified resource allocation: DEA environmental assessment on economic development and air pollution	Energy Economics	164	United States of America
8	Jia et al. (2019) [63]	Groundwater depletion and contamination: Spatial distribution of groundwater resources sustainability in China	Science of the Total Environment	145	China, Republic of Korea, United States of America
9	Chrysoulakisa et al. (2013) [64]	Sustainable urban metabolism as a link between bio-physical sciences and urban planning: The BRIDGE project	Landscape and Urban Planning	137	Greece, Portugal, Spain, United Kingdom, Ireland, Italy, Netherlands, Switzerland, Finland, France, Poland
10	Goulart Coelho & Lange (2018) [65]	Applying life cycle assessment to support environmentally sustainable waste management strategies in Brazil	Resources, Conservation and Recycling	115	Brazil

3.8. Overview of the Most Prominent Articles—Urban Resilience

The topmost cited article within the urban resilience-themed database (Table 2) was published in 2019, titled "Urban flood resilience—A multi-criteria index to integrate flood resilience into urban planning", and authored by Bertilsson et al. [66]. This *Journal of Hydrology* paper has generated 221 total citations. The authors of this publication have national affiliations with Sweden and Brazil. In the same year, the second-most cited article, authored by Moghadas et al. [67], is found in the *International Journal of Disaster Risk Reduction* and titled "A multi-criteria approach for assessing urban flood resilience in Tehran, Iran", which has rendered a total of 193 citations. The authors of this publication are nationally affiliated with Germany. The third-most cited article was published in 2018 and has accumulated a total of 150 citations. This publication in the journal *Safety Science* is entitled "Resiliency assessment of urban rail transit networks: Shanghai metro as an example." Its authors Zhang et al. [68], have national affiliations with China, USA, Germany, and the United Kingdom. The remaining top-seven cited articles were published between the years 2014 and 2018 in various journals including *Reliability Engineering and System Safety*, *Sustainable Cities and Society*, *Transportation Research Part C*, *Transportation Research Part A*, *Tunneling and Underground Space Technology*, and *Disasters*. The remaining most impactful articles have total citation counts ranging from 139 to 96 and author affiliations to the following nations: France, USA (×2), United Kingdom, China (×2), Switzerland, Japan, and India.

Table 2. The ten most cited articles covering indicator-based evaluations of resilience of megacities.

Rank	Author (Year)	Title	Journal	Number of Citations	Country Affiliation (Unique Only)
1	Bertilsson et al. (2019) [66]	Urban flood resilience—A multi-criteria index to integrate flood resilience into urban planning	Journal of Hydrology	221	Sweden, Brazil
2	Moghadas et al. (2019) [67]	A multi-criteria approach for assessing urban flood resilience in Tehran, Iran	International Journal of Disaster Risk Reduction	193	Germany
3	Zhang et al. (2018) [68]	Resiliency assessment of urban rail transit networks: Shanghai metro as an example	Safety Science	150	China, United States of America, Germany, United Kingdom
4	Adjetey-Bahun et al. (2016) [69]	A model to quantify the resilience of mass railway transportation systems	Reliability Engineering and System Safety	139	France
5	Kontokosta & Makik (2018) [70]	The Resilience to Emergencies and Disasters Index: Applying big data to benchmark and validate neighborhood resilience capacity	Sustainable Cities and Society	137	United States
6	Donovan & Work (2017) [71]	Empirically quantifying city-scale transportation system resilience to extreme events	Transportation Research Part C	122	United States of America
7	D'lima & Medda (2015) [72]	A new measure of resilience: An application to the London Underground	Transportation Research Part A	107	United Kingdom
8	Huang & Zhang (2016) [73]	Resilience analysis of shield tunnel lining under extreme surcharge: Characterization and field application	Tunnelling and Underground Space Technology	106	China
9	Lu (2018) [74]	Modeling network resilience of rail transit under operational incidents	Transportation Research Part A	100	China
10	Joerin et al. (2014) [75]	The adoption of a climate disaster resilience index in Chennai, India	Disasters	96	Switzerland, Japan, India

An overview of key topics follows, derived from an analysis of titles and abstracts of the most cited publications in the urban resilience repository. The top two most cited articles showcase multi-criteria approaches to address the issues surrounding urban flood resilience and megacities. The topmost cited article found in the *Journal of Hydrology* produced an urban flood resilience index capable of accommodating future development scenarios including population growth, uninhibited urbanization, and climate change and can be utilized in urban planning initiatives [66]. The second-most cited article again composed a composite index involving six resilience dimensions (social, economic, institutional, infrastructural, community capital, and environmental dimensions of community resilience) to measure and track progress temporally to provide decision makers with a tool that can be used to integrate resilience-based intelligence into urban development and planning initiatives [67]. Of the remaining top ten most cited articles, six directly relate to the resiliency of transit-based networks. These topics include the creation of a framework to assess the resilience of large and complex rail transit networks through models addressing their vulnerability and recovery after a disruption event [68]; developing a simulation-based model of resilience quantifying passenger delay and passenger load as performance indicators with the integration of all relevant subsystems making up the mass transit rail network [69]; measuring the resilience of a transportation system using GPS data collected from taxi trips in New York City to analyze the transportation infrastructure resilience to Hurricane Sandy [71]; measuring the resilience of the London Underground subway system to disruption events and how quickly its conditions normalize using the return of passenger counts as an indicator [72]; analyzing the resilience of shield tunnel lining in the Shanghai metro system through performance under a disruption event and ensuing recovery [73]; and modeling the resilience of the Shanghai Metro Network under daily operational incidents and the practical implications useful for decision making and the management of rail transit systems [74]. The two remaining studies in the top ten most cited documents relate to disaster events. One article evaluates neighborhood resilience in New York City through a composite index of resilience to emergencies and disasters by using pre- and post-event service request data linked to the Hurricane Sandy catastrophe [70].

The second article employs a climate disaster resilience index to assess ten administration zones in Chennai, leading to its potential capacity to serve as a support mechanism to scheduled and future city planning initiatives [75].

4. Discussion

4.1. Assessments of Sustainable Development and Urban Resilience

Indicator-based evaluations of megacities' progress under the sustainability or resilience lens rendered several intriguing observations in answering RQ.1: *How have scientific assessments of megacities emerged over time?* Less surprising was the early emergence of sustainable development-themed evaluations of megacities, as the concept has been a global focal point for several decades since being famously defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [76]. Following, proceedings in Chapter 40.4 of Agenda 21 proclaimed that "indicators of sustainable development need to be developed to provide solid bases for decision making at all levels and to contribute to a self-regulatory sustainability of integrated environment and development systems" [77]. However, the delayed emergence of the first indicator-based evaluation of resilience nearly two decades later is perplexing, as the historical origin of resilience in environmental science traces back to Holling's (1973) work on the resilience and stability of ecological systems [78]. Further, urban resilience has been described as a multi-disciplinary field including geography, engineering, natural disasters, hazards, and energy systems [30,79], which are all topics of concern for a megacity. Perhaps the late emergence of urban resilience publications relates to the ambiguity and vastness of definitions, as noted and succinctly defined by Meerow et al. in 2016 [30].

Applied assessments of megacities for both sustainable development and urban resilience took off after 2015. Notable in this year is the introduction of the SDGs [31] and specific targets and measures used to monitor and assess human progress at various geographical scales. Through international collaboration and adoption of these goals, practitioners have had clear pathways toward sustainability, and indicator-based evaluations have become more targeted to better align with these agreed-upon targets. Simultaneously, urban resilience research has been following suit, as research is now becoming more attuned to the desirable and sustainable states of urban ecosystems and the various components that must be resilient to global changes. Last, in the final year of findings, urban resilience-themed evaluations outpaced those of sustainable development, which may signal a shift in dominant research streams or that the research topics of resilience are becoming more diversified and interdisciplinary, adding to its breadth. At national and regional scales, governments are implementing their own plans and programs to guide cities, communities, and authorities to attaining urban resilience [79], and it is fast becoming a prominent discipline in urban development contexts [46]. This trend in indicator-based evaluations for both sustainable development and urban resilience themes is promising. As these topics gain traction, greater efforts will be devoted to improving humanity's relationship with life-supporting biogeochemical systems in megacities.

4.2. Global Effort toward Sustainable and Resilient Megacities

In addressing RQ.2, *Does the scientific literature on sustainable development and urban resilience of megacities correspond with their geographical locations?*, we found that indicator-based evaluations were unevenly distributed across the host nations of established and emerging megacities for both sustainable development and urban resilience. China is champion on both research fronts and has the largest share of the global population and is the prime host of established and emerging megacities. This corresponds with its research affiliations to over half of the indicator-based evaluations of megacities in each of the sustainable development and urban resilience databases. Lagging are many developed nations that host established and/or emerging megacities. Nations like the USA, Brazil, and India are host to multiple megacities, yet their ties to scientific research were moderate, indicating that monitoring development outside of economic growth is not a priority in

their most influential cities. However, the United Kingdom and Iran appear to be concerned about their emerging megacities London and Tehran, as national ties to assessments of sustainable development, although moderate, highlight their concern and interest in the progression of these significant urban areas. This shows that some nations are taking responsibility to ensure a sustainable future, as their research contributions exceeded those of other nations currently hosting or anticipating a megacity. More concerning are the five nations in the Global South (Angola, Argentina, Democratic Republic of Congo, Peru, United Republic of Tanzania) that do not have any national ties to indicator-based evaluations of the sustainable development of megacities despite having or expecting to host one. Improving scientific ties with these nations will be paramount to keep these megacities from progressing into degraded environmental and socioeconomic urban ecosystems. The USA was linked to a moderate number of publications, signaling their urgency, awareness, and interest in evaluating the resilience of megacities and addressing their vulnerabilities. Iran had moderate ties to contributions of urban resilience, reinforcing their desire to establish a megacity that is not only sustainable but resilient. Trailing far behind is India, with a minimal number of indicator-based evaluations of urban resilience, suggesting a lack of preparedness. India's moderate ties to indicator-based evaluations of sustainable development is perhaps a steppingstone towards greater involvement in resilience-based assessments of megacities. This delay mimics the precursory timeline highlighting the lagging nature of urban resilience evaluations observed in our analysis. Last are nations with ties to sustainable development and urban resilience publications that host neither an established nor an emerging megacity. Their involvement in research is promising and signals international interest and concern for the sustainable development and resilience of megacities beyond host nations. Greater international collaboration will foster sustainable and resilient megacities in host nations with limited resources available to surveil and address their environmental and socioeconomic challenges.

4.3. The Future of Megacity Evaluations

Results from the key term networks led to effectively answering RQ.3: *What are the most common research topics connected to sustainable development and urban resilience of megacities and what are the most cited articles corresponding to sustainable development and urban resilience of megacities?* The key term network of the top 100 most frequent words from the sustainable development assessments of megacities revealed three neatly organized clusters. One cluster centered around the term "approach", a second surrounded "sustainable development", and a third surrounded "indicator". These three clusters of terms indicate that the literature compiled for indicator-based evaluations of sustainable development of megacities is well established, with great depth. Contributing practitioners appear to be conducting research within coherent niches. For example, the cluster of terms surrounding "approach" suggests a niche focused on the sustainable development approaches, processes, management, and impacts of indicator-based applied assessments. The cluster focused on "sustainable development" is concerned with levels and spatial areas such as regions and locations, as well as trends, efficiencies, and the economy. The cluster centered on "indicator" eludes a theme of dimensions, quality, tools, context, and progress. Last, this clustering of terms into well-defined themes suggests that sustainable development is well defined, and practitioners have clear goals and objectives when conducting applied assessments in accordance with international agreements and targets.

The key term network of the top 100 most frequent words for urban resilience is more ambiguous and intertwined, suggesting it has great breadth. Seven clusters were revealed, resembling a tangled and jumbled accumulation of grouped terms, which were harder to decipher thematically. For example, Cluster 1 is centered on "disaster" and includes other terms such as "tehran", "building", "neighborhood", and "time", alluding to a theme of disasters and the resilience of structures and various geographic regions through time. However, Cluster 2 is centered on "urban resilience" and includes other terms such as "china", "area", "climate change", "region", "urbanization", and "economy", which is very

broad, including larger regions and areas and ideas of the general resilience of urban areas to global changes. Interestingly, two terms belonging to Cluster 1, "district" and "disaster resilience", are intertwined with the center of Cluster 2, introducing some ambiguity to the compartmentalization of themes within applied assessments of the urban resilience literature. Such ambiguities and disorganization of the key term network suggests that indicator-based evaluations of urban resilience of megacities are in their infancy and that the discipline has not had enough time to establish well-defined niches due to its breadth. The large number of clusters revealed may also indicate that practitioners disagree on how urban resilience is defined and/or how, or which, megacity components should be assessed. The jumbling of terms and themes may also result from the global objectives, goals, or targets set for urban resilience, which have not been internationally defined, established, or agreed upon as the SDGs have been. Rather, urban resilience appears to be supplemental, working alongside the agreed-upon SDG targets with assessments being reactionary to advances of progress.

The key themes among the top cited articles covering indicator-related sustainable development evaluations of megacities were variable. The top two articles are concerned with energy, which is fitting from a megacity perspective as they are major consumers of energy. Efficiencies of use through location optimization or frameworks for developing monitoring systems using indicator frameworks are key to their management and successful development into sustainable urban settlements. Another important topic of consideration, ranking as the fifth top cited article among sustainable development, is the assessment of flooring systems based on life cycle. This study by Reza et al. [60] was conducted in the city of Tehran, which is an emerging megacity in a less-developed region. This provides an excellent example for all cities looking for sustainable, long-term, and cost-effective solutions for building materials, especially useful where economic barriers may limit successful growth. China was found separately in the title of three documents, while Dhaka (Bangladesh), Tehran (Iran), and Brazil were separately found in three others. Despite China's thematic dominance, the popularity of articles featuring Bangladeshi, Iranian, and Brazilian megacities is promising, as the host nations are in less-developed world regions in need of attention. Their popularity highlights that researchers are noticing these developing regions and their megacities and are conducting exemplary indicator-based evaluations of sustainable development in places needing it most.

Several observations can be made when addressing the top cited articles for indicator-based evaluations of urban resilience. The two most popular articles focused on flood resilience in megacities. The second-most popular article focused on the emerging megacity Tehran, which is also listed within the topmost cited articles of sustainable development. This is significant because great consideration is being given to sustainable and resilient development of a rapidly emerging megacity in a less-developed region of the world. The focus and popularity of assessments associated with Tehran's development showcases the unique environmental and socioeconomic challenges it faces. This will serve as a roadmap to the successful management and progression of current and future megacities worldwide. Six of the ten most cited articles are indicator-based resilience assessments of transit networks and systems. The resilience of transit networks within a megacity are critical for the efficient operation of infrastructure. As an example, transit disruptions during business rush hours can impact local and global economies. The popularity of transit-themed articles also imply that transit systems in megacities are poorly managed, are inefficient, and negatively impact economic systems. Two top cited articles focus on assessing the resilience of megacities to emergencies and disasters through the use of indicators. Natural hazards and disasters remain important urban issues worldwide, while indicators and indices remain efficient tools for assessing and monitoring their impacts.

Last, we answer RQ.4: *What can we learn from the most prominent articles of sustainable development and urban resilience in how to best evaluate megacities' progress to ensure a sustainable future?* Practitioners should be wary of the multitude of environmental and socioeconomic issues facing megacities. Themes focusing on sustainable energy use are

warranted due to megacities' continued mass consumption of resources. The sustainable use of energy should be pursued to increase efficiencies and quality of life of citizens through reductions in waste and air pollution. However, energy is not among the popular themes associated with indicator-based evaluations of urban resilience, which deserves increased attention from practitioners. Perhaps energy is less studied among scholars due to the urgency required by megacities to mitigate and adapt to disasters and emergencies related to climate change, such as flooding. The variety of themes across the top cited indicator-based evaluations of sustainable development reflects the interdisciplinary nature of sustainability and the clearly defined objectives set forth by international sustainability agreements and objectives. Sustainability assessments should continue in this diverse fashion. Indicator-based assessments of the environmental, social, and/or economic dimensions of sustainability are vital to the advancement of the science and the overall successful management of megacities. The popularity of only a few themes among the indicator-based assessments of urban resilience of megacities suggests the discipline is in its infancy and focused on environmental aspects, as publications associated with the social and economic pillars of sustainability are less prominent. As this discipline matures and becomes more established, the breadth of themes among the most popular publications is likely to diversify and more closely align with the popular publications associated with sustainable development. Practitioners, governments, and non-government agencies must conduct holistic, indicator-based evaluations, considering the environmental, social, and economic aspects of megacities to ensure their development is sustainable and resilient as they rapidly expand.

5. Conclusions

Megacities are growing throughout the world faster than ever. Effective management of their development is vital, as these controlling hubs influence environmental, social, and economic well-being. The use of indicators and indices as surveillance tools to measure, monitor, and assess megacities' progress have been applied throughout the world for over a decade. However, involvement in such studies is not evenly distributed across space, and the intellectual capital pertaining to indicator-based evaluations of sustainable development and resilience of megacities is concentrated in too few nations. The sustainable development and resilience of megacities in the face of global changes should be a top priority for host nations, as mismanagement threatens humanity's progress to sustainability. International involvement by all countries in indicator-based evaluations of sustainable development and urban resilience will help safeguard megacities' progress through scientific discoveries and partnerships promoting environmental integrity, social equity, and economic prosperity. These discoveries will assist those regions ill-equipped to deal with looming threats of rapid population growth and urbanization by providing resources and pathways towards beneficial partnerships.

No known reviews of indicator-based assessments of sustainable development and urban resilience have been compared across megacities. In response, this study was designed around four research questions to better understand the state of scientific research and the progression made to better manage the 33 established and 10 emerging megacities of the world. Through a systematic literature review comparing indicator-based evaluations of sustainable development and urban resilience of megacities, 428 and 217 publications, respectively, were reviewed. Temporal distributions of publications in this capacity revealed the earlier emergence of sustainable development in 1996 compared to urban resilience publications debuting in 2010. Country affiliations of publications through author ties revealed that China is leading indicator-based research in both the sustainable development and urban resilience of megacities. Contributions are being made elsewhere, albeit with a lack of involvement by some megacity host nations. Due to China's dominance in applied evaluations, future research could investigate the nuances within this eastern region obscured by data aggregation. Key term networks for sustainable development-themed publications unveiled three distinct and neatly organized clusters centered on the

terms "approach", "sustainable development", and "indicator". Key term networks for urban resilience-themed publications uncovered seven ambiguous and more intertwined clusters centered on the terms "disaster", "urban resilience", "performance", "network", "community", "strategy", and "risk". Last, a comparison of the ten most cited articles found that those related to sustainable development were more diverse thematically, with the top two articles focusing on energy-related topics, while the ten most cited articles for urban resilience were less diverse thematically, having a majority focused on flooding resilience.

This systematic review comparing indicator-based evaluations of sustainable development and urban resilience across 43 of the world's largest cities resulted in several new findings. However, it would be premature to conclude that this Anglocentric systematic review is extensive enough to equally cover all global regions and languages. Instead, this systematic review provides a reproducible, systematic method for use in similar studies, and the results provide a broad overview of the state of research specific to megacities' progress. The insights gained herein demonstrate that very few megacity host nations are heavily involved in applied evaluations, and some are completely absent, while other nations appear curious about megacities' progress despite being vacant hosts. That said, another fertile area for future research would be to investigate how the studies from this literature review could inform future policies at the international, national, or local levels. Applied evaluations of sustainable development appear to be well established. With clear, internationally agreeable goals, research is tailored to finding diverse pathways towards established sustainable megacities balancing environmental integrity, social equity, and economic prosperity. In contrast, indicator-based evaluations of urban resilience are in their infancy, playing catch-up with sustainable development objectives. Given time, it is hoped that these two paradigms will better align and greater integration of the concepts will be adopted in future research and practice. Moving forward, these hyper-urban human settlements warrant special attention as they are growing faster than ever. Greater involvement from all world nations will enhance the management practices and surveillance tools available to megacities. Enhanced participation in future indicator-based evaluations of sustainable development and urban resilience must be generated, followed by the commonplace integration of the concepts to more holistically assess megacities' progress. Lastly, as the world's people become increasingly urbanized, sustainable development and urban resilience of megacities will serve as a key barometer for humanity's progress toward sustainability.

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Appendix A

Table 1. Summary of populations and rates of change for established and emerging megacities for years 2000 to 2030.

				City Population (Thousands)			Average Annual Rate of Change (Percentage)		City Population as a Proportion of the Country or Area's Total or Urban Population in 2018 (Percentage)	
Region	**Country**	**City**	**Statistical Concept**	**2000**	**2018**	**2030**	**2000–2018**	**2018–2030**	**Total Population**	**Urban Population**
Africa	Egypt	Al-Qahirah (Cairo)	Metropolitan area	13,626	20,076	25,517	2.2	2	20.2	47.3
	Nigeria	Lagos	Urban Agglomeration	7281	13,463	20,600	3.4	3.5	6.9	13.7
	Democratic Republic of the Congo	Kinshasa	Urban Agglomeration	6140	13,171	21,914	4.2	4.2	15.7	35.3
	Angola	Luanda *	Urban Agglomeration	2829	7774	12,129	5.6	3.7	25.3	38.6
	United Republic of Tanzania	Dar es Salaam *	Urban Agglomeration	2272	6048	10,789	5.4	4.8	10.2	30.3
Asia	Japan	Tokyo	Metropolitan area	34,450	37,468	36,574	0.5	−0.2	29.5	32.2
	India	Delhi	Metropolitan area	15,692	28,514	38,939	3.3	2.6	2.1	6.2
	China	Shanghai	City Proper	14,247	25,582	32,869	3.3	2.1	1.8	3.1
	India	Mumbai (Bombay)	Metropolitan area	16,147	19,980	24,572	1.2	1.7	1.5	4.3
	China	Beijing	Urban Agglomeration	10,285	19,618	24,282	3.6	1.8	1.4	2.3
	Bangladesh	Dhaka	Metropolitan area	10,285	19,578	28,076	3.6	3	11.8	32.1
	Japan	Kinki M.M.A. (Osaka)	Metropolitan area	18,660	19,281	18,658	0.2	−0.3	15.2	16.5
	Pakistan	Karachi	Urban Agglomeration	9825	15,400	20,432	2.5	2.4	7.7	20.9
	China	Chongqing	Urban Agglomeration	7863	14,838	19,649	3.5	2.3	1	1.8
	Turkey	Istanbul	Urban Agglomeration	8744	14,751	17,124	2.9	1.2	18	24
	India	Kolkata (Calcutta)	Metropolitan area	13,097	14,681	17,584	0.6	1.5	1.1	3.2
	Philippines	Manila	Metropolitan area	9958	13,482	16,841	1.7	1.9	12.7	27
	China	Tianjin	Urban Agglomeration	6989	13,215	15,745	3.5	1.5	0.9	1.6
	China	Guangzhou, Guangdong	Urban Agglomeration	7812	12,638	16,024	2.7	2	0.9	1.5
	China	Shenzhen	Urban Agglomeration	6550	11,908	14,537	3.3	1.7	0.8	1.4
	Pakistan	Lahore	Urban Agglomeration	5576	11,738	16,883	4.1	3	5.8	15.9
	India	Bangalore	Urban Agglomeration	5581	11,440	16,227	4	2.9	0.8	2.5
	Indonesia	Jakarta	Metropolitan area	8390	10,517	12,687	1.3	1.6	3.9	7.1
	India	Chennai (Madras)	Urban Agglomeration	6593	10,456	13,814	2.6	2.3	0.8	2.3
	Thailan	Krung Thep (Bangkok)	Urban Agglomeration	6395	10,156	12,101	2.6	1.5	14.7	29.4
	Republic of Korea	Seoul *	Urban Agglomeration	9879	9963	10,163	0	0.2	19.5	23.9
	India	Hyderabad *	Urban Agglomeration	5650	9482	12,714	2.9	2.4	0.7	2.1
	Iran (Islamic Republic of)	Tehran *	City Proper	7128	8896	10,240	1.2	1.2	10.8	14.5
	China	Chengdu *	Urban Agglomeration	4607	8813	10,728	3.6	1.6	0.6	1.1
	China	Nanjing, Jiangsu *	Urban Agglomeration	4279	8245	11,011	3.6	2.4	0.6	1
	Viet Nam	Thành Pho Ho Chí Minh (Ho Chi Minh City) *	Urban Agglomeration	4389	8145	11,054	3.4	2.5	8.4	23.5
	India	Ahmadabad *	Urban Agglomeration	4815	7681	10,148	2.6	2.3	0.6	1.7

Table 1. *Cont.*

				City Population (Thousands)			Average Annual Rate of Change (Percentage)		City Population as a Proportion of the Country or Area's Total or Urban Population in 2018 (Percentage)	
Region	**Country**	**City**	**Statistical Concept**	**2000**	**2018**	**2030**	**2000–2018**	**2018–2030**	**Total Population**	**Urban Population**
Europe	Russian Federation	Moskva (Moscow)	City Proper	10,005	12,410	12,796	1.2	0.3	8.6	11.6
	France	Paris	Urban Agglomeration	9737	10,901	11,710	0.6	0.6	16.7	20.8
	United Kingdom	London *	Urban Agglomeration	7273	9046	10,228	1.2	1	13.6	16.3
South America	Brazil	São Paulo	Metropolitan area	17,014	21,650	23,824	1.3	0.8	10.3	11.9
	Argentina	Buenos Aires	Urban Agglomeration	12,504	14,967	16,456	1	0.8	33.5	36.5
	Brazil	Rio de Janeiro	Metropolitan area	11,307	13,293	14,408	0.9	0.7	6.3	7.3
	Colombia	Bogotá	Urban Agglomeration	6329	10,574	12,343	2.9	1.3	21.4	26.5
	Peru	Lima	Metropolitan area	7294	10,391	12,266	2	1.4	31.9	41
North America	Mexico	Ciudad de México (Mexico City)	Metropolitan area	18,457	21,581	24,111	0.9	0.9	16.5	20.6
	United States of America	New York-Newark	Urban Agglomeration	17,813	18,819	19,958	0.3	0.5	5.8	7
	United States of America	Los Angeles-Long Beach-Santa Ana	Urban Agglomeration	11,798	12,458	13,209	0.3	0.5	3.8	4.6

NOTE: Cities listed by descending 2018 population per region. * indicates emerging megacity. Adapted from United Nations World Urbanization Prospects: 2018 Revision [4].

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