A Survey of Trends and Developments in Green Infrastructure Research

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Abstract – One of the most crucial measures for accomplishing sustainable development is the application of Green Infrastructure (GI), which could effectively coordinate social, environmental, and economic growth. Different publications on GI were analyzed in this research using bibliometric and visualization techniques with the help of the programs CiteSpace and VOSviewer, which were accessed through the Web of Science database. The number of publications relating to GI has increased dramatically over the past few decades, with research done in the United States and Europe taking the lead. Journal of Environmental Management, Urban Planning and Landscaping, and Urban Greening & Urban Forestry are the most often referenced periodicals for green infrastructure research. Investigation of co-cited literature has shown that several aspects of GI are studied, including their effect on human health and ecosystem; their management, appraisals, and design; and the evaluation of a particular feature of GI. Results from a keyword cluster analysis for "green infrastructure" show that most previous research has focused on this topic in four main areas: stormwater regulation, natural ecosystems, biodiversity preservation, and climate change.

Keywords – Green Infrastructure**,** Storm-Water Regulation, Natural Ecosystems, Climate Change, Biodiversity Preservation.

I. INTRODUCTION

The term "Green Infrastructure" (GI) is used to describe any system of plant-based infrastructure that helps the environment in some way [1]. It outlines the interconnected green environments and systems of water, which provide a diversified social, economic, and environmental value essential to achieving sustainable urban growth. A few examples of GI integrate cemeteries, sport fields, plazas, green corridors, footpaths, transportation corridors, wetlands, rivers, gardens, backyards, reserves, parks, living walls, and green roofs. In addition, ecosystem services that contribute to or improve urban sustainability are provided and connected by green infrastructure. The term "Green Infrastructure" (GI) is also used to describe systems of semi-natural and interconnected natural areas and other environmental characteristics that are planned, developed, and maintained to provide many ecosystem services. It includes both terrestrial (particularly coastal) and marine habitats, as well as natural elements such as greenery (or blue if marine ecosystems are in question). Land GI includes green roofs, facades, constructed wetlands, parks, communal gardens, forest cover, green-space, and urban forests and may be found in both rural and urban areas. Storm-Water Management (SWM), climate adaptability, urban heat island reduction, better biodiversity, carbon capture and storage, enhanced quality of air, renewable energy generation, improved storm water quality reverting to the deep soil profile and the natural habitat, enhanced ethnocentric functionalities including enhanced biophilia and quality of life are just a few of the advantages of green infrastructure.

Food, materials, clean water and air, climate management, flood prevention, pollination, and recreational opportunities are just few of the many ways in which human civilization relies on the advantages offered by nature. Many of these advantages, sometimes referred to as ecosystem services, are, however, employed as if their supply were almost infinite and regarded as free commodities whose actual worth is not completely recognized. As a consequence, governments may

favor constructing artificial solutions, known as “grey infrastructure”, instead relying on more sustainable methods such flood walls. Australasian countries continue to deplete their natural capital, putting their long-term viability at risk and weakening their capacity to withstand the effects of environmental hazards. Smart, sustainable, and equitable development requires fixing hazards such as undervaluing ecosystem services and failing to adequately safeguard natural capital, as outlined in the Resource Efficiency Roadmap. Investment in GI is highlighted in the EU Roadmap as a means to safeguard natural capital. To formulate a GI strategy, the various levels of government in the AUS must work together to form a GI Commission. According to the Roadmap for Resource Efficiency in the European Union (EU) as described by Barbosa et al. [2], the EU Commission will be writing a Communication on GI. This report serves as the Commission's response to these pledges. It describes the ways in which a coordinated EU response might supplement existing efforts at the regional level.

When it comes to offering ecological, economic, and social advantages via natural solutions, GI has been shown to be an effective instrument. It's useful for quantifying the societal benefits provided by natural environments and rallying resources to maintain and improve them. Moreover, it aids in reducing the need for man-made infrastructure, which can be rather pricey compared to the free, long-lasting options that nature typically provides. There are many local employment possibilities generated by this. Protecting and strengthening environment and natural processes, as well as the various advantages human society receives from nature, are central to the concept of "Green Infrastructure," which is founded on the premise of integrating these goals into deliberate spatial planning and territorial development. Many advantages of GI exist as compared to the grey infrastructure that serves just one function. It doesn't put any brakes on expanding into new territories, but instead encourages using non-intrusive methods wherever possible. In certain cases, it may serve as a supplement to or replacement for the status quo of "grey" approaches. Urban farming and garden allotments were among the first ideas for environmentally friendly city planning, emerging in the 1870s. Terms like "stormwater best management practices,"[3] "source controls," [4] and "low impact development" (LID) [5] are alternatives.

According to Lampinen, García-Antúnez, Olafsson, Kavanagh, Gulsrud, and Raymond [6], concepts of "green infrastructure" date back to the mid-1980s, when ideas were made for "best management practices" that would better manage stormwater quantities as a whole by preventing erosion, lowering runoff volumes, and recharging aquifers. U.S. regulations mandated the adoption of methods that, in contrast to traditional drainage infrastructure, regulated runoff "at source" in 1987 as a result of revisions made to the Clean Water Act to address the problem of diffuse pollution from urban land uses. Large MS4s are required by the United States Environmental Protection Agency (EPA) [7] to create stormwater pollution prevention plans and apply "source control measures" since the EPA's first rules for MS4s were released in 1990. Vegetative controls, filtration activities, and infiltration methods were all included as recommended management strategies to consider in the EPA's 1993 guide-book, titled: Urban Runoff Pollution Prevention and Control Planning (trenches, porous pavement). In 1999, guidelines for less populous municipalities were released to the public. MS4s drain an area equivalent to 4% of the United States' total land mass and serve more than 80% of the country's population. By emphasizing the value of the natural world in land-use planning, "green infrastructure" is a notion gaining traction. The phrase, however, lacks a common understanding of what it means. [Blue-green infrastructure, often known as "green-blue urban grids" A wide range of architecture, conservation, and planning fields make use of these terminologies, and they often refer to topics such as multifunctional green space, climate adaptation, and SWM.

Sometimes "green infrastructure" is defined as including many functions. The term "multifunctionality" [8] is used to describe the combination and interactions of various activities and users on a similar plot of land. By using natural systems or manufactured systems that resemble natural systems, the EPA has expanded the notion of "green infrastructure" to include the control of stormwater run-off at a regional level. Although peripheral to the wider notion, referring to "green" best management practices in urban areas as "green infrastructure" helps sustain ecological systems. It is clear, however, that the phrase "blue-green infrastructure" is used in an urban environment, with a focus on stormwater control as a key component in developing a sustainable, multifunctional city [9]. Blue-green architecture [10] refers to a smaller scale use of these elements in building design. Greening buildings via the use of recycled water and other non-potable sources of water are the topic at hand.

There are well-established correlations between socioeconomic position and health outcomes. To a lesser extent than economic and social problems, environmental concerns have been acknowledged in the European Ministerial Conferences on the Environment and Health Process and the European Union's Environment and Health Strategy. Growing research supports the good link between happiness, health, and access to green space, albeit the data is still preliminary. Green spaces have been shown to increase the life expectancy of seniors in epidemiological studies that account for factors such as age, sex, marital status, and socioeconomic position. Positive associations between green space and self-reported health have also been observed while controlling for socioeconomic and demographic variables and for urbanicity. In spite of its size (N= 10197), the sample from which Andrade [11] drew is likely to have been skewed since it consisted of patients at primary care clinics. In [12], park goers had a more positive outlook on their health, were more physically active, and were able to unwind more quickly.

Despite the fact that socioeconomic status was accounted for in these research, it is still conceivable that other variables, such as the kind of lifestyle that is more common in neighborhoods with parks, might have contributed to the observed associations. It has been speculated that there is a causal mechanism linking the availability of green space to subjective measures of happiness and health. People who live in places with more greenery may be more likely to spend

time outside and engage in physical activity, as well as reduce air pollution and the urban heat island effect. A growing corpus of theoretical and empirical research highlights the significance of physical environmental impacts on walking and physical activity in neighborhoods. Studies that account for demographic variables including age, sex, and level of education give evidence that living near green spaces increases one's likelihood of engaging in physical exercise. In terms of the effects of green space on society, According to research by Britten et al. [13], the presence of greenery and open spaces in a neighborhood may have a positive effect on people's sense of belonging there and on their relationships with their neighbors. However, people's worry about crime may have a detrimental impact on their well-being if they see green areas as overgrown or poorly maintained. The geographic distribution of illnesses such as Lyme disease and West Nile Virus may also be influenced by ecological changes in urban and peri-urban areas. Consequently, the advantages of green space cannot be generally applied. It remains to be seen whether the environmental affects and resultant beneficial or negative health consequences of various kinds and configurations of urban Green Infrastructure can be quantified in future studies. More study is needed to determine how various types of environments could affect people's health in different ways.

Twenty-one hundred and ninety-four publications on green infrastructure were analyzed in this research using bibliometric and visualization techniques with the help of the programs VOSviewer and CiteSpace, which were accessed through the Web of Science database. The volume of study focusing on GI has increased drastically over the past few decades, with the United States and Europe taking the lead. Journal of Environmental Management, Urban Planning and Landscaping, and Urban Greening & Urban Forestry often referenced periodicals for green infrastructure research. Investigation of co-cited literature has shown that several aspects of green infrastructure are studied, including their effect on human health and ecosystem; their management, appraisal and design; and the evaluation of particular features of GI.

The rest of the article is structured as follows: Section II presents a background analysis of the research. Section III focuses on the methodology and data sources employed for this research. Section IV presents the GI study where the distribution of countries publishing research works in GI and distribution of most cited publications, is discussed. Section V reflects on the results and discussion of the trends in GI research, and the evaluation of GI research trends. Section VI presents concluding remarks to the research as well as future research.

II. BACKGROUND ANALYSIS

According to Sauvé, Bernard, and Sloan [14], concepts such as circular economy, smart growth and sustainable development have become central to contemporary environmental challenges in light of the inherent tension and competition between human-driven economic expansion and the planet's natural ecology. In order to achieve sustainable development, Green Infrastructure (GI) has emerged as a crucial strategy due to its proven effectiveness in coordinating environmental, social, and economic progress. Important to the study of "harmonious cohabitation between humans and environment," the notion of green infrastructure has taken years to fully materialize. The public has already acknowledged the "preserving nature" and "respecting nature" design ideals, although nature is now in a rather passive condition, whereas "green infrastructure" places heavy emphasis on coordinating the conservation of natural resources with the development of human settlements and man-made structures. Additionally, "green infrastructure" promotes the proactive upkeep, restoration, construction, and even reconstruction of green network systems.

In [15], adapting to climate change; increasing stormwater management capacity; decreasing the impact of heat islands; and decreasing environmental pollution are all significant benefits of green infrastructure. This infrastructure serves as the area environment's "natural life support system" and paves the way for environmentally sound growth in the region. The social and health benefits of green infrastructure stem from its ability to enrich the built environment, connect people with nature, boost the aesthetic value of landscapes, and advance social equality. As a result of its positive effects on the environment, local economies, and regional growth, green infrastructure is increasingly seen as a competitive economic development tool. Environmentalism, urban studies, geography, botany, architecture, and economics are only few of the disciplines represented in current green infrastructure research.

In [16], various research subfields have been developed from the extensive discourse among academics on green infrastructure's theoretical underpinnings, methodological tools, and technological advancements. First, the idea and fundamental value of GI have been the major emphasis of much research. By looking for publications on GI in four different databases, including books, documents from global agencies, Web of Science (WOS), research institutes, and federal agencies up to 2016, Wang, Zhang, Gan, Liu, and Mei [17] provided a summary of green infrastructure's growth up to that point; they also stressed the significance if multi-function for the analysis and design of GI. Second, a subfield of green infrastructure has been the subject of a comprehensive scholarly analysis. Guidelines for SWM were provided for several forms of green infrastructure after Aguilar and Dymond [18] evaluated the relevant literature and addressed flood control of green infrastructure. Wu, Zhang, Geng, Wang, Wang, and Liu [19] looked into the topic of evaluating ecological systems in green infrastructure by sifting through 76 publications published between 2000 and 2019 in WOS and Scopus to determine the most common approaches and broad categories used in this field.

Studies have also assessed green infrastructure's growth tendencies and hotspots for further study. Comprehensively summarizing the subject clusters and cutting-edge of GI study in Europe, Schreiner and Madlener [20] reviewed 313 publications done by approximately 28 EU member states ranging from 2008 up to 2022. Research in the field of green infrastructure is predicated on the maturation and refinement of concepts, with an eye on the current scholarly fashions in a

particular subfield or geographical area. This study employed bibliometrics to analyze the trajectory, frontiers, and distribution of the literature concerning GI across many dimensions. In order to aid in the strategic research of green infrastructure and its role in promoting sustainable development, this approach seeks to comprehensively explain the knowledge development and progression frontiers of GI from a detailed longitudinal viewpoint. Section III focuses on the methodology and data sources employed for this research.

III. METHODOLOGY AND DATA SOURCES

Methodology

In the domains of scientometrics and bioinformatics, the knowledge and technology map is a relatively new approach of research. This approach displays the knowledge framework and development law in domains associated with graphics, and it may show the sources of knowledge and advancement law of a certain topic. The knowledge and technology map has the traits of both a graph and a spectrum. In other words, a knowledge and technology map signifies a visual networking and a serial lineage of the history of knowledge. When viewing a graph in CiteSpace, the progression of time is represented by the color of every node, which ranges from red to blue, and the frequency of occurrence is shown by the extent of the nodes and the legibility of the labels. Additional analysis parameters, such as the degree of the network mediation center, essentially complete visual representations, and the time series analysis element, may be gleaned from the tree diagrams and the thickness of connectivity between different nodes, which signify the degree of data correlations.

Nees Jan van Eck and Ludo Waltman created a visualization program called VOSviewer. The program includes a powerful clustering function, and the visualization impact is helpful for spotting research hotspots and other areas of interest related to the topic at hand. Each node's font size in the graph shows how often that node occurs, and each node's color conveys the concept that it belongs to one of many clusters. In scientometrics, both kinds of software have been employed extensively due to their potential to reinforce one another's benefits. Knowledge map visualization was utilized in this research to create the maps of publishing organizations, co-cited journals, and publishing nations, and to undertake a basic analysis of the state of international green infrastructure research. Additionally, the combined use of CiteSpace's cited work, keyword co-occurrence knowledge, and subject propagation visualizations visualizations and VOSviewer's keyword clustering graphs allowed us to investigate the fundamental understanding, research trends and hotspots of global GI research.

Sources of Data

The research's basic data was extracted from the main repository of WOS dataset using the search term "green infrastructure" as the search object. The WOS database contains the first "green infrastructure" research from 1995. Therefore, "1995-2020" was chosen as the retrieval range, while the four article, conference paper, reviews, and books categories were chosen as the retrieval types. In an effort to guarantee the quality of data extraction, we collected a total of 2194 articles with the hope that this would be sufficient to cover all research findings.

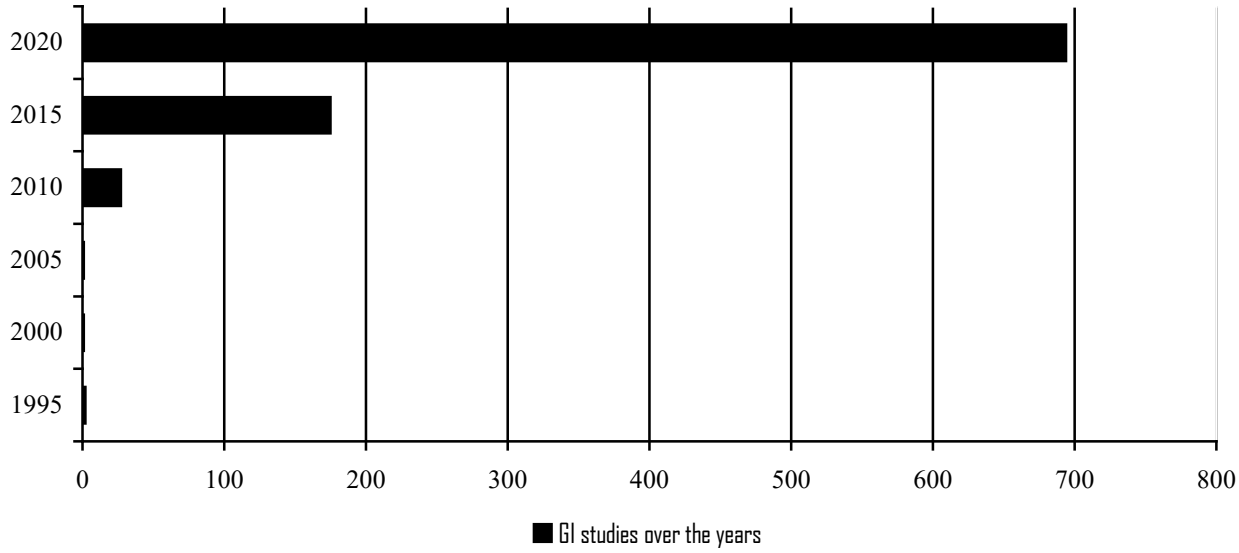

Fig 1. GI Studies Gathered in the WOS

Approximately a dozen papers on green infrastructure appeared in print between 1995 and 2008, as determined by a statistical examination of the retrieved literature. However, between 2009 and 2014, there was an explosion of growth that

caused the number to quickly surpass 100. Since 2015, there has been a discernible uptick in the number of studies, with the yearly number of new publications rising by the hundreds (see **Fig 1**). It's clear that "green infrastructure" is an issue that needs much research and debate. Section IV presents an overview of the GI study in different years over the past few decades.

IV. GREEN INFRASTRUCTURE STUDY

Distribution of Countries Publishing Research Works in GI

Using CiteSpace's time zone function, a temporal evolution map of nations and areas interested in green technologies was created, with nodes representing individual countries. By adjusting the cutoff, we were able to compile a list of all years with more than two research published, and from that we were able to extract 62 significant nodes (see **Fig 2**). U.S. publications account for 34.05% of the worldwide total, with 747 articles appearing there thus far. This is followed by China (10.53%), the United Kingdom (10.26%), Italy (7.29%), Australia (6.09%), and Germany (6.43%). The sum of the percentages from all the other nations is less than 5% (see **Fig 3**). In addition, several nations in Europe and the United States have done research on green infrastructures, and the findings from these studies are quite relevant. In the CiteSpace visualization, we classified the nodes of knowledge as universities as well as a criterion to Top N 14 50. Every university or research center is represented by a node, and the size of a base station indicates the total number of scholarly works produced by that entity.

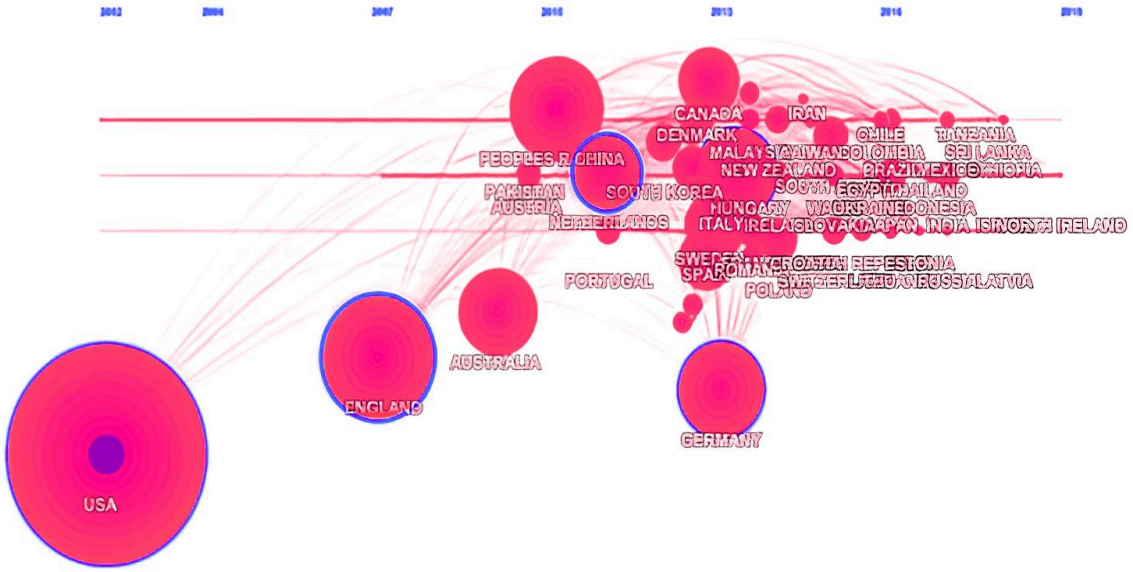

Fig 2. Time Zone Evolution Mapping of Regions and Countries Researching GI

Indicating that the university has produced many research, the greater the nodes, the more distinct the label fonts (fonts are heavier and the opacity is higher). According to the data, the USEPA (United States Environmental Protection Agency) is the most influential organization in domain on GI, publishing 49 publications with a 0.02 centrality score; the second one is Swedish University of Science and Technology Agriculture with 0.12; the UFZ Helmholtz Centre for Environmental Research is sixth with a centrality of zero; the University of Hong Kong is fourth with 0.04; the Chinese Academy of Sciences is fifth with 0.01; and Drexel University is sixth with 0.01. Drexel University ranks highest (7.02), followed by the Wageningen University (4.50) and the Swedish University of Agricultural Sciences (5.98) in terms of suddenness (see **Fig 4**).

By examining the visualisation map, we may learn the following. (1) Institutional diversity supports the claim that Drexel University and the US Environmental Protection Agency are among the foremost centers for research on green infrastructure in the United States and Europe. Macháč, Brabec, and Arnberger [21] on green infrastructure have already been done in several nations throughout Europe, the United States, and even certain parts of Asia, indicating a promising growth pattern. (2) Groupings are formed on the basis of the collaborative connection between various institutions, as shown by the map's structural analysis. The most prolific publishing institutions are dispersed among the dense clusters. In most cases, there are many research establishments inside each cluster. Accordingly, influential institutions may play a pivotal role in the birth of each cluster. (3) Based on the examination of several variables, we know that 15 institutions have centralities of 0.12 or higher and 38 institutions have centralities of 0.04 or higher. Centralities range from 0.12 for the six most productive academic institutions to below 0.04 for the rest.

Because of this finding, it seems that highly productive academic institutions are not very central. According to the centrality definition, this behavior may indicate that large institutions are not very well connected to one another, while

publishing a large number of publications. This is due in part to the fact that these establishments are equipped with thorough research models, and robust scientific study skills. Nonetheless, intellectual interchange and advancement are aided by collaborations between universities that focus on the same topic but use distinct research approaches.

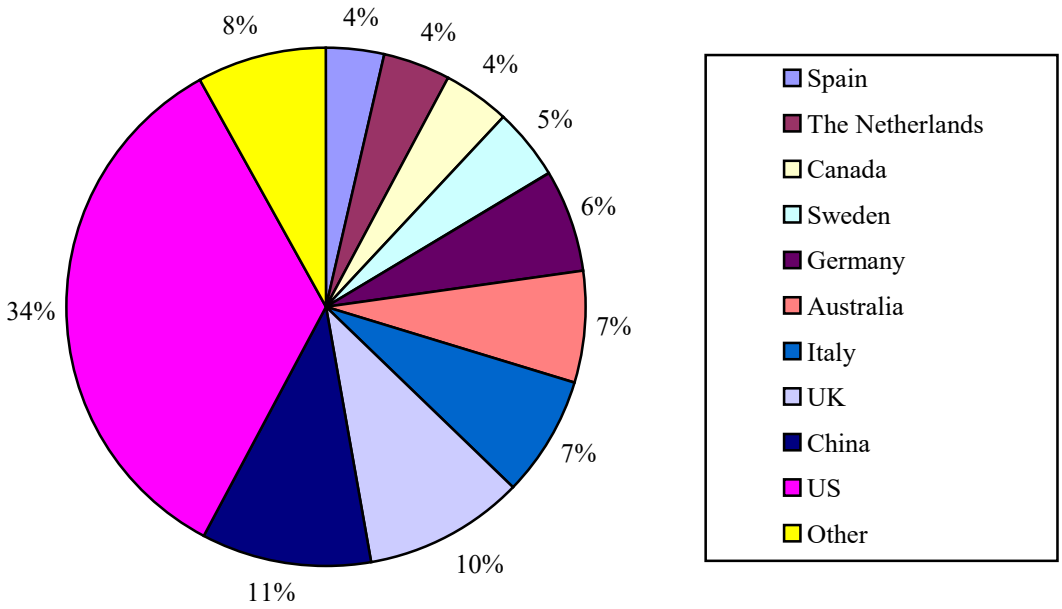

Fig 3. Ration of GI Literatures to the Overall Published works in Different Countries up to 2022

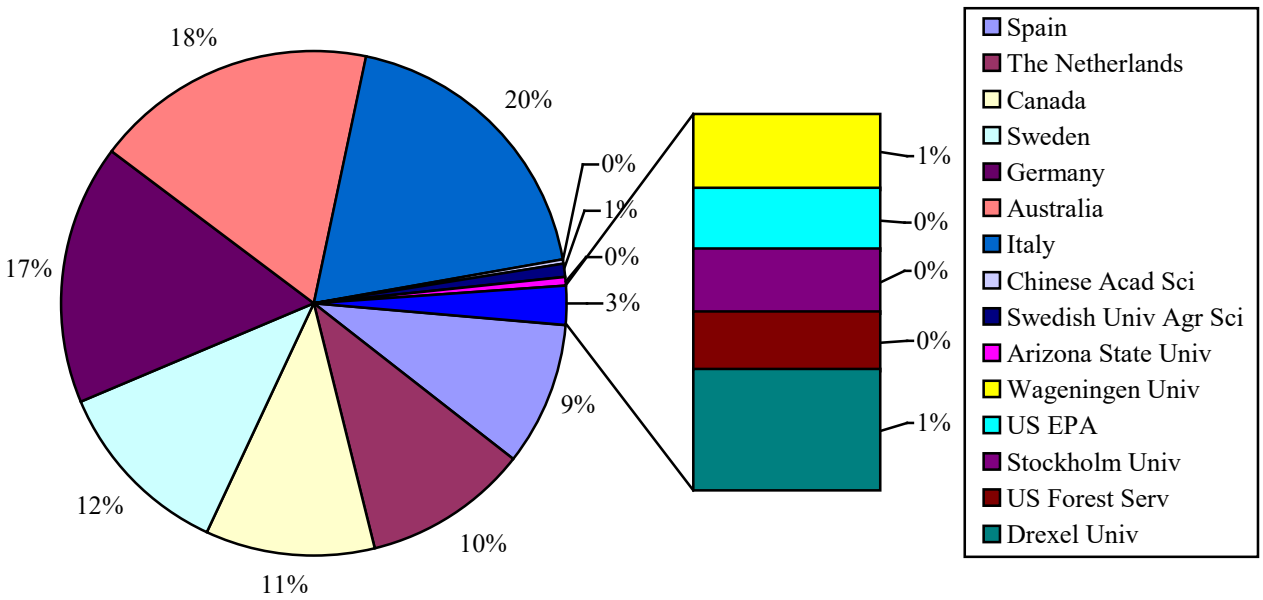

Fig 4. Top 8 Educational Institution with A Higher Citation Degree

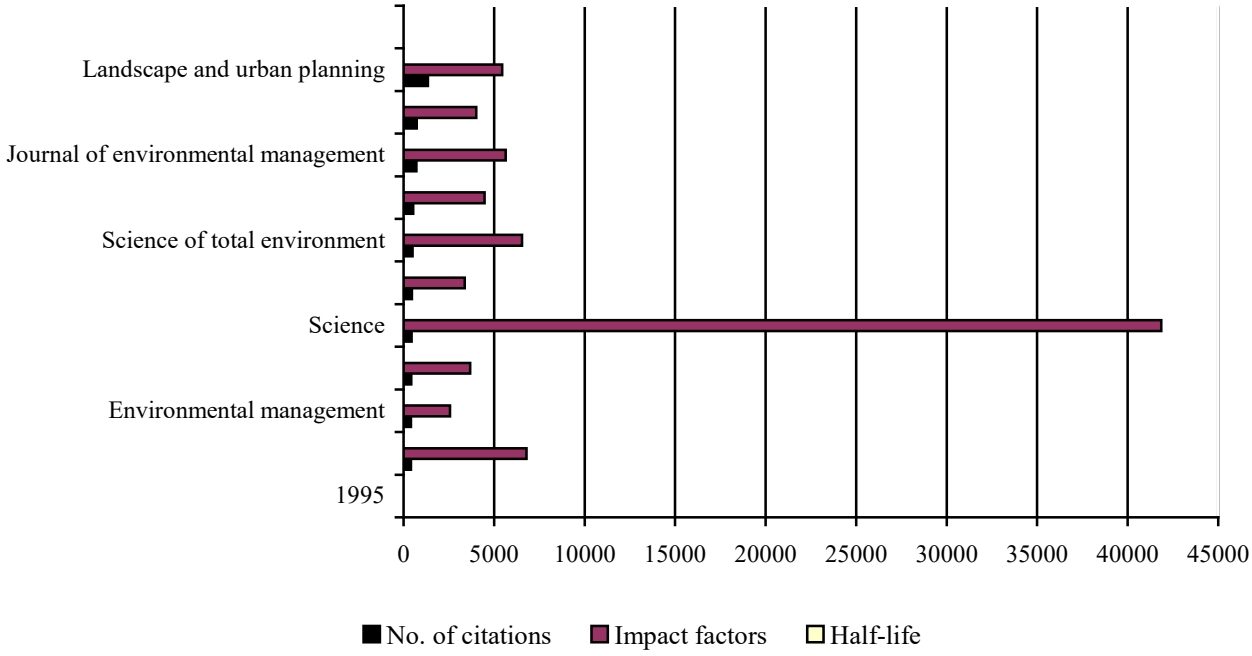

Fig 5. Publications on GI Research that are Frequently Published.

Distribution of Most Cited Publications

The knowledge map of the mutually cited journals was generated in CiteSpace with the set of nodes as cited publications. **Fig. 5** highlights the impact factors and half-lives of the 10 most-cited journals in the domain of GI research. There is no mention of the book "Green Infrastructure Finance: Leading Initiatives and Research". There is a lot of weight behind the 250-times-cited figure. After carefully examining the material presented by approximately ten publications and more publications with a higher prominence, the following conclusions may be formed. (1) Current green infrastructure journals tend to be city-centric and include topics linked to the environment, ecology, and specialized forms of green infrastructure (such as forestry and water resources). (2) High-impact journals have high impact factors, which means the publications they publish have a lasting effect in the academic community (It means that the research released are relevant for a long time; many articles that were published decades ago are still being referenced). Based on these three metrics, the following journals have established themselves as the foremost authorities in the domain of GI research in academia.

V. RESULTS AND DISCUSSION

Trends of Green Infrastructure Research

Main Knowledge Base

Some of the most important parts of Europe's present environmental agenda include the ideas of resource-efficiency, cyclical and bio-economy economy, green and blue growth, and environmental sustainability. Consensual standards and policies, which focus on reconciling conflicting agendas by integrating environmental issues in decision-making processes, are a key to the dominant narratives, which claim a long-term tension between environmental conservation and economic development conservation can be overcome. The promise of Green Infrastructure (GI) to incorporate multiple sectoral standards and policies across several scales is illustrative of a concept and strategy that follows the aforementioned narrative.

Although the GI method did not become popular in the United States until the mid-1990s, its roots may be traced back to the 1850s, when the first allusion to the greenbelt in the UK and the development of open spaces and the public parks in industrialized regions for ecological and recreational reasons appeared. Within the past decade, the word has skyrocketed in popularity. Through its promotion of a view of nature as 'infrastructure,' this movement has been intimately connected to the broader trend toward the economic assessment of nature and the many efforts seeking to quantify the worth of ecological systems and natural capital. The 2013 Green Infrastructure Strategy for the European Union (EU) reflects this trend. The European Union's policy describes GI as "a strategically planned infrastructure of natural or semi-natural regions with other environmental characteristics developed and maintained to supply a broad variety of ecosystem services." GI encompasses terrestrial, maritime, and marine regions and may be used to describe rural, peri-urban, or urban locations.

The EU GI approach is predicated on the basis of adaptability. In reference to the approach, one of the major objectives of GI is to serve different objectives for a broader extent of ecosystems over urban-rural divides, policy domains, and food security. Climate change mitigation and adaptation energy conservation, food security, human health and happiness,

biodiversity protection, risk management, recreational opportunities, increased property values, increased economic output, competitiveness, and strengthened territorial cohesion are all examples. The diversity of the European Union is mirrored in the aspect that GI is integrated into such a wide variety of policies as infrastructure investment, climate change, agribusiness, and forestry. The European Union's (EU) current Biodiversity Policy to 2020 includes GI, and so does the EU's ecological policy on land-use change and spatial planning [22]. Recent EU-funded initiatives have highlighted the versatility of GI by investigating its conceptual basis for its urban parts and developing nature-based solutions, demonstrating its variety.

In light of the above, it should come as no surprise that policymakers, academics, and the general public often use the term "GI" to refer to diverse things. This has resulted in a wide variety of research methods, foci, and products, as well as a swathe of divergent scholarly writing. Despite the growing use of the term "geographic information" (GI) and the establishment of a specialized EU strategy in 2013, there has been very little study of how GI is understood or how it has informed or driven research agendas in Europe. Given the interconnected nature of GI and the trend toward "nature-based remedies," this pause seems all the more noteworthy.

Distribution of Disciplines

A knowledge map of disciplinary distribution structure of 2194 texts was drawn using CiteSpace, yielding 73 nodes. Here are the findings from our investigation. Review of Traditional Academic Fields (1) The environmental sciences are the most popular academic field and account for more than half of all published research. Strong centrality is shown by the fact that water resources, ecology, engineering, and urban studies are all cited more than 200 times. This finding suggests that many investigations into GI have been done in the earlier-mentioned fields. Discipline-specific time distribution and cluster analysis (2) Timeline The burst function was applied to the results of using CiteSpace's View with the keywords as the clustering components. "Green infrastructure" research has grown in scope as time has passed, including a wider range of academic fields. The examination of the visual representation summed up the general pattern of the distribution of academic fields.

"Environmental studies" and "urban research" were the primary areas of study in 2006 and 2007. Research in engineering and agriculture was conducted between 2007 and 2010. After then, there was a clear tendency toward a more dispersed distribution of disciplines, with geological geographies, botany, engineering, and business economics all receiving a significant amount of attention. It's important to keep in mind that "green infrastructure" encompasses a wide range of topics, and that further in-depth research in a variety of fields is needed. (3) Evaluation of promising research avenues for future growth. CiteSpace's analytical outcomes were obtained and examined in three ways. To begin, we used the timing, frequency, and prominence of research directions as signs of complete analysis. We chose to focus our attention on research topics that had either 15 or more mentions or a centrality score of 0.10 or higher in the most recent five years (i.e., 2014-2019).

Summarized below (in **Table 1**) are the fields of study of Environmental ecology, Human Environment, and Municipal Engineering. Second, we selected people who were quite infrequent (appearing just 50 times before 2014) but relatively central (appearing 0.3 times). Additionally, the following points in the right way were uncovered: economics and business, materials engineering, and public administration. These areas were far from mature, yet they held great promise for future study. Third, we eliminated fields that had high bursts (3) but a lower frequency (50), and we were left with limnology and marine and freshwater biology as our two main paths of study. In conclusion, there has been an uptick in research showing that green infrastructure may preserve a wide range of values and advantages.

However, individuals lack the requisite knowledge-acquisition and comprehension skills to fully appreciate the benefits of green infrastructure in a variety of contexts. However, there have been significant ecological ramifications from prior GI research. The impact of GI is being investigated in a growing number of fields, including biodiversity (biophysics) and the commercialized economy (SWM and roof greening), but only a chosen limited quantitative analytic technique can give convincing proof of this. Further, there is a lack of research into the "blind zone" that is the social, insurance, and cultural benefits of GI. The examination of disciplinary distribution reveals that green infrastructure receives a unique amount of attention and is interpreted differently by various academic fields. As a result, several distinct ideas about green infrastructure have emerged, each informed by a unique academic field of study. These ideas may be grouped into three broad categories. The first group consists of fields concerned with protecting ecosystems, such as Geosciences, Green Ecology, Biodiversity Conservation, etc., and its application to the notion of green infrastructure. Second, the study of GI from the perspective point of accomplishing the demands of human settlements falls within the purview of disciplines such as Urban Studies, and Rural and Urban Planning, which focus on the built environment. The third category describes GI from the perspective of greening urban development facilities, including fields like engineering, water management, and design (see **Table 1**).

Evaluation of Literature Co-Citation

In-depth analysis of the most-cited literature may provide light on the "green infrastructure" research's inception and direction by revealing the knowledge basis on which the topic development was based. CiteSpace's data input was used to generate the co-citation network diagram through the "cited reference" option. The authors and publication years of papers that were referenced more than fifty times were labeled as nodes once the threshold value was set to fifty. Labels for the

clusters (#0-#6) were derived from the keywords via the use of the clustering algorithm. Most of the most-cited papers can be found in reference group 0, suggesting that this is where the bulk of current green infrastructure study is centered.

Table 1. GI Related Fields and Major Definitions

Disciplines	Objects	Definitions
Environmental ecology (environmental sciences, environmental ecology, and biodiversity conservation)	A system's potential to generate and distribute ecosystem services	Ecological services, such as support, supply, regulation, and cultural services, are provided by a set of interconnections between diversification, biophysical structures and ecological functions.
Human Environment (rural and urban planning, and urban research)	Protecting and enhancing people's health	The term "urban and regional planning" refers to a wide range of community efforts to foresee, depict, and control the growth of an urban or regional area. Infrastructure planning, land use regulations, and social and financial forecasts are all brought into harmony with this approach.
Municipal Engineering (engineering, water resource engineering, architecture)	Environmental maintenance of public buildings	An array of environmentally friendly practices in man-made settings that help cities deal with issues like floods, improve water quality, reduce pollution, and adjust to climatic changes.

We studied and summed up the map's visualization findings. Early work on green infrastructure produced highly dense clusters, as seen from a historical viewpoint. Studies eventually radiated outward from the original research hubs, and other research hubs were born. Studies having a large number of citations tend to be concentrated in key areas, providing additional evidence that the studies mentioned therein formed a solid groundwork for further study. Research on green infrastructure progressed quickly according to the degree of linkage between clusters. Co-citation networks depicted a very typical first-stage research environment prior to 2009. The study's network was highly concentrated and overlapping, with a limited number of directional branches. The urban economic approach was applied to a number of the issues with the standard development model, including biodiversity and resource use. Improvements in green infrastructure and stormwater management have resulted from expanded study in this sector (The latter era saw the development and enrichment of this grouping).

The clustering results from 2009-2013 were used to complement and broaden the mentioned literature by taking into account the overlapping networks that had emerged during the earlier phases of the clustering. More growth direction, however, did occur, which paved the way for the later theoretical investigation. Since 2013, a number of distinct multi-directional study fields have formed, and novel clusters have been created on the perspectives of the current literature in order to examine the intersection of green infrastructure and other disciplines in depth and with sufficient context. The focus of the green infrastructure research, from a theoretical point of view, was on two elements of human health. Green infrastructure has been shown to have positive effects on people's physiological and psychological well-being. Green infrastructure also affects people's health in a roundabout way because of how it shapes people's everyday environments. The term "city" has been the subject of a great deal of research.

Evaluation of GI Research Trends

All parts of the articles, including titles, abstract, and body copy, were scoured for relevant keywords. Keywords that are used often might be indicative of the most sought after areas of study. It is crucial to the study of research hubs to look at the evolution and centrality of terms in the co-occurrence evaluation of keywords of CiteSpace. VOSviewer has the capability of grouping related search terms into a single category and coloring them all the same. It's possible to communicate a variety of ideas via a variety of perspectives. The analytical findings in this research are considerable in scope and credibility thanks to the usage of CiteSpace and VOSviewer.

Evaluation of Research Evolution

The following outcomes are possible with the burst function in CiteSpace, whereby the visual map was developed using keywords as nodes: The findings were paired with a study of the relevant literature and assessed according to the keywords. In order to better understand green infrastructure, it is helpful to break it down into the following phases.

(1) 2009–2012. The research focused mostly on sustainable development, which emerged as a buzzword in 2009. It was in 2010 when the buzzwords "urban area," "stormwater management," and "ecological network" all made their debut. Both "energy" and "urban ecosystem" went through a rapid expansion period in 2011. Exploratory study is now underway. The "sustainable development idea" found in green infrastructure has gained widespread recognition and is seen as a solution to a variety of difficulties that increasing urbanization has introduced. "Green Infrastructure" was the focus of the 2009 IFLA (International Federation of Landscape Architects) Congress. Similarly, in 2012, Molla [23] presented an argument praising the value of "green infrastructure" in helping communities respond to environmental concerns and highlighting the need for landscape architects. In this context, "green infrastructure" has been given substantial societal weight.

(2) 2013–2014. Green infrastructure studies expanded and matured steadily throughout this era of change. Green infrastructure, for instance, has been the subject of sustained discussion in "landscape architecture" and may be seen mirrored in "park" planning. In the realm of stormwater management, studies on green infrastructure progressed to the level of technical interventions, and "permeable pavement" was investigated in depth. Meanwhile, a lot of attention was paid to the concept of "water quality."

(3) 2015–2019. Green roofs, urban green infrastructure, and restoration were all buzzwords at this point. Taking place in Manchester, the 6th Global Forum on Restoration Ecology focused on "Enhancing the Rapid Restoration Capability of Environment: Restoring Cities, Villages, and Countryside." Green roofs and sustainable construction quickly gained attention. Research has progressed to reveal that green infrastructure is being used on site, municipal, and regional levels.

Our review of the abstracts revealed a total of 865 papers covering a wide range of research methodologies. Green infrastructure, which includes systems for managing stormwater and collecting and reusing rainfall, is studied at the smaller, more manageable size of individual sites. As the meso-scale of GI, the urban scale is fundamentally the natural framework, which can be counted on to guarantee sustainable development of the urban ecosystem. It provides ecological benefits to the city and its inhabitants. Maintaining spatial stability, providing general environmental benefits, and safeguarding species variety are all functions of green infrastructure on a macro-scale regional level. Significantly greater spikes for "urban area," "park," and "restoration" than for other keywords suggest that urban environmental restoration is a primary focus of city-scale green infrastructure studies. The design of parks is a crucial component in urban environmental restoration.

VI. CONCLUSION AND FUTURE RESEARCH

A review of co-cited literature has shown that several aspects of Green Infrastructure (GI) are studied, including their effect on the human health and the ecosystem; their management, design, and appraisal; and the evaluation of a particular feature of GI. Results from a keyword cluster analysis for "green infrastructure" show that most previous research has focused on this topic in four main areas: storm-water management, ecosystem services, biodiversity preservation, and climate change. Concepts such as circular economy, smart growth and sustainable development have become central to contemporary environmental challenges in light of the inherent tension and competition between human-driven economic expansion and the planet's natural ecology. To investigate the growth of green infrastructure in the vertical direction and to establish a benchmark for future studies, this study performed a comprehensive review of green infrastructure research from a variety of angles. The research has some gaps in it as well. Some study findings may have been left out since just the most essential WOS data set was chosen. As GI is a normal complex framework incorporating multiple fields, this study did not adequately investigate the contents of interdisciplinary, while having a rich discussion of the topic background, knowledge progression, and research hotspots. Future research will focus on promoting and improving this particular component.

Data Availability

No data were used to support this study.

Conflicts of Interests

The author(s) declare(s) that they have no conflicts of interest.

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Ethics Approval and Consent to Participate

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