The Scientometric approach of mapping sustainable green infrastructure research development

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Abstract. While sustainable green infrastructure research has progressed substantially in the last decade, there has been a lack of study mapping on the developments of existing research publications in this area. This research aims to systematically review and map the development of existing publications during the period of 2009 – 2019 using the Scientometric review approach of Scopus metadata and VOSviewer software. The results show there were 1784 publications and 4894 authors from 109 countries, with the top 3 countries, i.e. the United States (472 publications), the UK (162 publications) and China (151 publications). The top 3 rankings of the main research area trends were green infrastructure (260), sustainability (211), and sustainability development (134). The publications were dominated by articles (50.2%), conference papers (32.2%), book chapters (7%), reviews (7%), and books (6.4%), which consist of 338 open-access documents, and 1396 closed-access documents. The top 3 authors with the most citations were Wang J. (261 citations), Jensen M.B. (82 citations) and Haase D. (76 citations). The outcomes of this study are expected to fill the existing research gap as well as to provide an overview of the development of sustainable green infrastructure research publications and to see future research development opportunities.
Keywords: green infrastructure, VOSviewer software, sustainability development

1. Introduction

The rapid development of the economy and society, energy deficiency, and environmental damage have become a significant problem faced by people nowadays [1]. The existence of infrastructure projects has a significant impact on influencing environmental sustainability [2] and the economic growth of the community. Future conditions for sustainable infrastructure development will grow significantly [3]. Due to the emergence of global awareness about the importance of sustainability concept and there is a projection of high population growth which contributes to generating 75% greenhouse gases (GHG). According to the United Nations, it is predicted that in 2050, 65% of the population will live in urban areas with the largest concentration of growth in Asia and Africa [4]. Based on UNCTAD publications, around 10% - 15% of the required infrastructure investments can be assigned to generate sustainable investments to ensure lower emissions, higher efficiency, and resistance to change Climate [5].

Sustainable infrastructure is a planned infrastructure project, designed, built, operated, and closed in a way to ensure economic and financial, social, environmental (including climate resilience), and sustainability throughout the project's life cycle [6]. The benefits of sustainable green infrastructure are not only realized well by developed countries. Many developing countries are also aware of the benefits of sustainable green infrastructure, in which its existence is the primary aspect that can

accelerate the presence of the balance between the social, economic, and environmental aspects that make up the triple bottom line [3].

In recent decades, the study of sustainable green infrastructure has increased significantly with the development of environmental and sustainability issues. It can be seen by the growth of scientific publications which is the indicator of productivity at microlevels and simultaneously, it can give an impact to assist policymakers in evaluating the macro level, such as research centers, universities, and countries [8].

So far, the quality research evaluation using scientometric or bibliometric measurements has not been so popular. Many researchers generally do not feel comfortable to be placed on a performance scale [9]. Of the many studies, there were several studies conducted using a particular Bibliometric review in the last 10 years that correlated with sustainable green infrastructure. Among them is green infrastructure planning research to tackle climate change in Latin America, using the keywords “green infrastructure” and “climate change” [10] and the analysis of urban infrastructure research developments From the years 1991 to 2017 using WoS data using the keywords “critical infrastructure”, ”urban planning and design”, “development need”, “technology innovation”, and ”cyber-physical system" [11]. Based on the existing publications so far, there has been no study about mapping the development of sustainable green infrastructure, especially in the last 10 years, thus this study seeks to fill the gap.

The study aims to view and map the development of research relating to the sustainable green infrastructure period from 2009 to 2019. By using the Scientometric approach, several reviews are conducted against: (1) The number of publications per year, (2) The number of publications by source, (3) The mapping of publications by country of origin, (4) The mapping of publications by document type, (5) Mapping publications based on the author's contribution, and (6) Mapping key research areas. In addition to providing an overview of existing research developments, the results of the study are also expected to contribute to the development of research correlated with sustainable green infrastructures in the future.

2. Research Method

This paper uses the quantitative-based science mapping technique. This technique can be used to construct a bibliometric map that generates an overview of how certain disciplinesscientific domains, or fields of research are conceptualized intellectually and socially structured [12]. This technique is also a way widely used by researchers to get an overview and analyze a large number of bibliometric data analyses that will be used for a particular purpose [12] [11]. Through the Bibliometric data obtained using the help of Vosviewers software, scientometric analysis is performed to get an overview of the relationship patterns, and developmental conditions of the research reviewed [12]. The Scientometric analysis is believed to be able to analyze and accommodate the large amount of the published data. It can overcome the limitations that exist compared to other methods [13]. The research flowchart used in this research is shown in Figure 1.

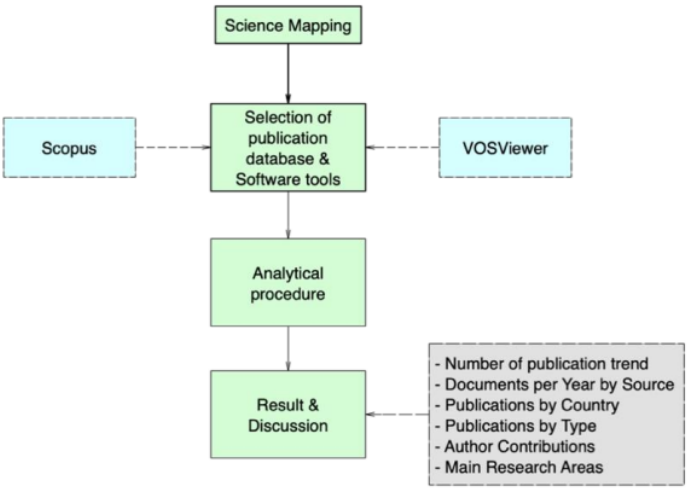

Figure 1. Flowchart of research methodology

In this study, the bibliometric data is obtained from the metadata Scopus in the last 10 years (2009 – September 2019). The Bibliometric data collected includes the year of publication, source, type, country, subject, and author using the keywords "sustainable green infrastructure", "sustainable infrastructure" and "green infrastructure" and also make limitations on the subject of publication including engineering, environment, energy, social science, computer science, business, material science, economics, and decision science. The selection of Scopus metadata is based on a broader area of literature than the Web of Science in terms of impact, quality, and document type [14].

3. Results and Discussion

3.1 Publication Types and Total Number per Year

The total number of publications within the last 10 years is 1784 publications, with 388 open-access documents and 1396 other publications of closed-access documents. The details can be seeb in Figure 2 and Figure 3.

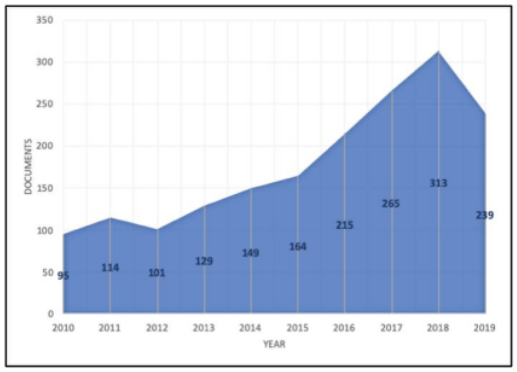

Figure 2. Document counts per year

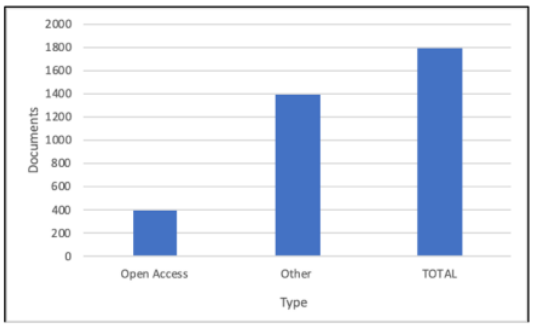

Figure 3. Document Access type

From Figure 2, it can be seen that the number of publications experienced a sufficiently sharp increase in Medio 2015 – 2018. In contrast, for the year 2019, the final number of publications was seen declining.

3.2 Number of documents per year by source

Based on Scopus data search results throughout the yearof 2009 – 2019, there are 94 sources that actively publishing related to the reviewed research. The top 5 sources are the Sustainability Switzerland (62 publications), Urban Forestry and Urban Greening (25 publications), Landscape and Urban Planning (20 publications), Science of The Total Environment (18 publications), and Ecological Indicators (17 publications). The top 10 sources of publication over the past 10 years can be seen in Table 1.

Table 1. Number of documents per source

Source	Documents
Sustainability Switzerland	62
Urban Forestry and Urban Greening	25
Landscape and Urban Planning	20
Science of The Total Environment	18
Ecological Indicators	17
E3s Web of Conferences	16
Journal of Environmental Management	16
IOP Conferences Serie Materials Science and Engineering	15
Land Use Policy	14
Renewable and Sustainable Energy Reviews	13

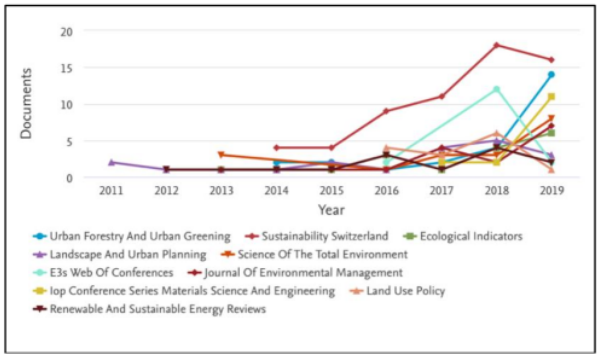

Figure 4. Documents per year based on source

Figure 4 shows the growth in the number of yearly publications for the 10 most-contributed sources in this field in the last 10 years. Landscape and Urban Planning was the first source to publish this topic in 2011 with 2 articles about conserving biodiversity [15] and economic valuation to create public support on green infrastructure [16]. Among the 10 sources, Sustainability Switzerland is the source of the most popular publications compared to other sources.

3.3 Number of publications by country

After mapping the number of publications by country using the co-authorship type analysis, the full counting method, and the limitation on the minimum number of 5 documents per country, it shows that there are 55 countries out of 109 countries that meet the threshold. The size of the node in Figure 5 shows the size of the contribution, and the node color indicates a clustered grouping of the displayed country.

Figure 5 shows the division of clusters based on countries that contribute to publications related to sustainable green infrastructure in the period of 2009-2019. Based on the network visualization, the cluster 1 and cluster 2 each consist of 12 countries, cluster 3 consists of 11 countries, cluster 4 consists of 10 countries, cluster 5 consists of 5 countries, clusters 6 and 7 each consisting of 2 countries, and cluster 8 consists of 1 country.

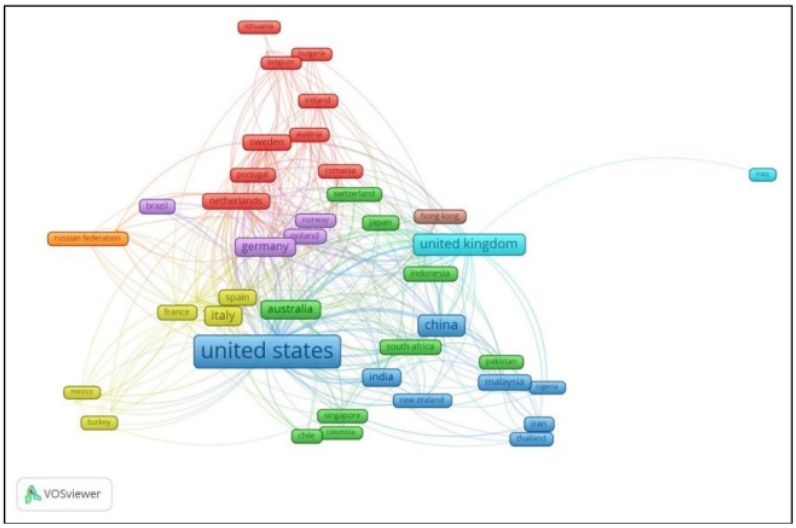

Figure 5. Contribution of publication per country

Table 2. The most productive country in publications.

Country	Documents	Citations	Total Link Strength
United States	472	4520	160
United Kingdom	162	2464	137
China	151	1215	93
Italy	128	1423	84
Australia	108	1550	70
Germany	93	1238	111
India	82	381	38
Canada	79	1047	75
Spain	63	518	52
Netherlands	57	1115	77

Table 2 shows the top 10 countries ranked by the number of publications equipped with the number of citations and the total link strength. Here is the analysis based on the Big 3. The United States (472 publications), the UK (162 publications), the Chinese (151 publications), Italy (128 publications) and Australia (108 publications) are countries with contributions over the 100 paper and publications of these countries are widely referenced for other publications around the world. Based on the total number of citations, the top three are the United States (4520 citations), UK (2464 citations), and Australia (1550 citations), and based on the review of the total links strength is the United States (160), the United Kingdom (137) and Germany (111).

3.4 Publication number by document type

This study uses all types of documents found within the last 10 years (Figure 6). Document types are grouped into 11 categories, consisting of the article, conference paper, book chapter, review, book, conference review, editorial, note, business article, Erratum, and undefined.

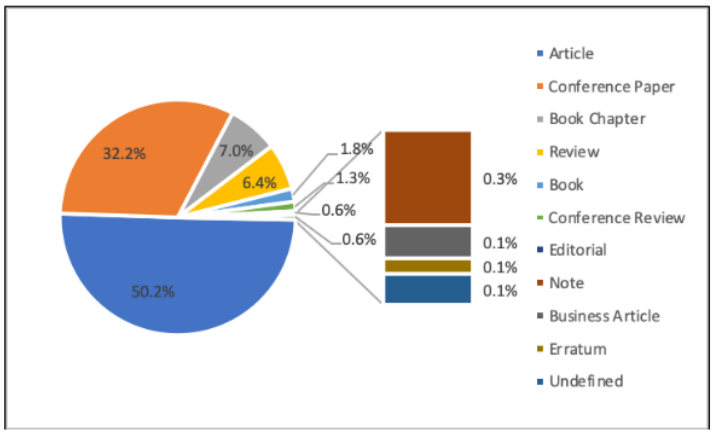

Figure 6. Publications by documenttype.

By using the existing 1784 publications, the contributions in the form of document are derived from the Journal of Articles with 896 publications (50.2%), Conference paper with 574 publications (32.2%), Book Chapter with 124 publications (7%), Review with 124 publications (7%), and Books with 114 publications (6.4%).

3.5 Author contributions

Author contributions use the co-authorship analysis type and full counting calculation. The threshold is used consists of the minimum number of documents per author as many as 5 documents and a minimum number of citations as many as 5 citations.

The analysis results shows that out of 4894 authors, there are 28 authors that could qualify the threshold, and only 19 authors belong in the greatest total link strength and interconnected with each other. Based on network visualization (Figure 7) There are 5 clusters of author contributions's to the publication. Cluster 1 consists of 5 items (Li F., Li X., Liu X., Zhang X.), cluster 2 consists of 5 items (DiGiovanni K., Montalto F., Wang S., the X., Zhou J.), cluster 3 consists of 3 items (Badiu D.L., Lafortezza R., Onose D.A.), cluster 4 consists of 3 items (Haase D., Pauleit S., Wang J.), cluster 5 consists of 3 items (Kumar A., Wang Y., Zhang Y.).

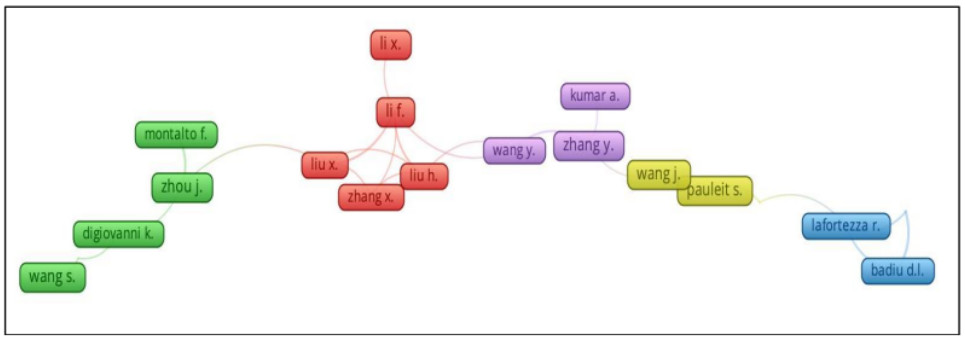

Figure 7. Documents based on author contributions.

Table 3 shows 10 authors with top contributions. The pattern of the displayed relationship is a pattern of relationship between authors to the number of documents, citations, and total link strength. The top 3 contributors based on the number of publications in particular order are Zhou J. With 9 Publications, Li X., Wang J., and Zhang Y together in second place with 8 publications, and Li F., Pauleit S, and Wang S together in 3rd place with the 7 publications.

Table 3 Results Analysis of publication and author relations

Author	Documents	Citations	Total Link Strength
Zhou J.	9	19	5
Li X.	8	8	1
Wang J.	8	62	2
Zhang Y.	8	42	4
Li F.	7	73	7
Pauleit S.	7	25	3
Wang S.	7	261	1
Badiu D. L.	6	43	6
Haase D.	6	76	3
Jensen M. B.	6	82	1

Essentially, the number of documents is not necessarily correlated with the number of citations and the strength of total link generated. The top 3 authors with the highest number of citations are Wang J. (261 citations), Jensen M.B. (82 citation), and Hasse D. (76 citation), while based on total link strength Top 3 authors consisting of Li F. (5), Badiu D. L (6), and Zhou J. (5).

3.6 Major research areas

The content of this research article is largely reflected in the keywords used in the title and abstract [13]. Major research areas of research can generally be seen through the keywords used. This analysis uses keywords threshold with a minimum amount of 15. Based on 4483 existing keywords obtained results of 31 keywords that belong to the requirements and interconnected as Figure 8.

Figure 8. Clusters of key research areas

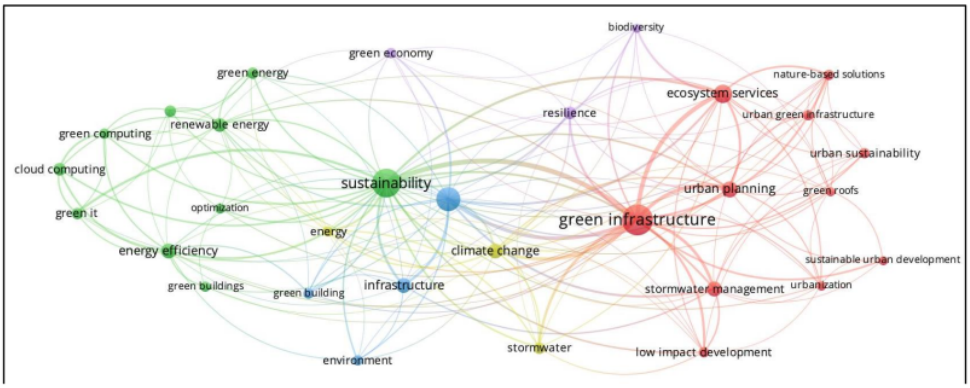

Figure 8 can be seen as a cluster of major research area deployments in the last 10 years. Based on the results of the mapping, there are 5 clusters for 31 items of research areas that become a trend over the previous 10 years. The cluster consists of cluster 1 with 11 keywords, cluster 2 with 10 keywords, cluster 3 with 4 keywords, cluster 4 with 3 keywords, and cluster 5 with 3 keywords.

Table 4 presents a major research area consisting of 31 keywords compiled based on the number of occurrences and supported by total link strength data per each keyword. There are 3 keywords with the number of occurrences above 100, namely green infrastructure (260 occurrences), sustainability (211 occurrences) and sustainable development (134 occurrences), and there are 4 keywords with a total link strength above 100, which Consists of green infrastructure (319 total link strength), sustainability (236 total link strength), ecosystem services (135 total link strength) and sustainable development (126 total link strength).

Table 4. Major research areas

No.	Keyword	Occurrences	Total Link Strength
1	Green Infrastructure	260	319
2	Sustainability	211	236
3	Sustainable Development	134	126
4	Ecosystem Services	75	135
5	Urban Planning	51	83
6	Climate Change	47	74
7	Infrastructure	47	51
8	Energy Efficiency	45	44
9	Stormwater Management	44	61
10	Renewable Energy	36	34
11	Cloud Computing	29	32
12	Resilience	29	51
13	Green It	24	31
14	Stormwater	23	43
15	Green Energy	21	20
16	Smart Grid	21	16
17	Energy	20	36
18	Green Computing	20	30
19	Green Economy	20	24
20	Low Impact Development	20	36
21	Urban Sustainability	20	23
22	Environment	19	21
23	Urban Green Infrastructure	18	15

No.	Keyword	Occurrences	Total Link Strength
24	Green Building	17	20
25	Green Buildings	16	12
26	Nature-Based Solutions	16	34
27	Optimization	16	12
28	Biodiversity	15	31
29	Green Roofs	15	22
30	Sustainable Urban Development	15	14
31	Urbanization	15	20

Based on the data obtained from Figure 8, Table, the Scopus datasetusing the minimum threshold for the number of occurrences, the total number of the link is 100. The top 3 keywords are "green infrastructure" at first position, with the current scope of research discussing Stormwater management [17][18][19] and blue-green infrastructures [20][21][22]. Secondly, the research trend culminated in the keyword "sustainability" with the scope of the current study focus related to urban areas and facilities matters[23][24][25][26][27][28], and the third position is the "sustainable development" study area where studies related to Development or Modelling of blue-green infrastructure based on case studies [19][28][30].

4. Conclusion

This paper performs a mapping of developments related to sustainable green infrastructure based on literary studies with a Scientometric approach. The conclusions that can be taken from these studies are as follows:

a) In the last 10 years, there has been an increase in publications related to sustainable green infrastructures. The total publications is 1784 documents consisting of 388 open-access documents and 1396 closed-access documents.
b) There are 94 sources contribute to this field research, and the top 3 ranks are the Sustainability of Switzerland (62 documents), Urban Forestry and Urban Greening (25 documents), Landscape and Urban Planning (20 documents).
c) Based on state contributions to publications correlated with sustainable green infrastructure, there are 8 clusters with 55 interconnected countries. The United States is the country with the most significant number of publications with 472 documents, followed by the UK with 162 documents and China with 151 documents.
d) In the period of 2009-2019, a research study in the form of journal article contributes 50.2% and became the main container for researchers in publishing their research, followed by conference paper (32.2%) and book chapters (7%).
e) Based on a network visualization map, there are 4894 authors that has contributed to research related to sustainable green infrastructure and 19 major authors having interconnected publications grouped into 5 clusters. The top 3 authors were Zhou J. (9 documents), Li X. (8 documents), and Wang J. (8 documents).
f) The trend of major research areas by keyword-based generates 5 major research area with a total of 31 keywords. Taking into consideration the results of network visualization and network overlay based on Scopus database.The top 5 major research trend are green infrastructure, sustainability, sustainability development, ecosystem services, and urban planning.

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