A SCIENTOMETRIC ANALYSIS AND VISUALIZATION OF GREEN BUILDING RESEARCH IN AFRICA

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ABSTRACT

Owing to the adverse impact of the architecture, engineering and construction industry on the human and natural environment, the adoption of green building (GB) has been on the rise globally. The significant rise in the number of global research output on GB is a pointer to its proliferation. In this paper, a novel scientometric analysis of GB research in Africa is presented. This study aims to analyze and visualize GB research output in Africa from the millennium development goals (MDGs) era up to the present sustainable development goals (SDGs) era. A quantitative method (science mapping) was employed to analyze the 156 bibliometric records gathered from the Scopus database. An analysis of the dataset reveals that significant contributions to GB research in Africa originate from Egypt, South Africa, Nigeria, Algeria, Ghana, Morocco, Kenya, Mauritius, Ethiopia and Cameroon. This research provides stakeholders in the built environment with the requisite knowledge and understanding of the trend and state of GB research in Africa, which will help in guiding policymaking, research directions and intervention areas in every sector of the economy.

KEYWORDS

Africa, built environment, green building, sustainability, sustainable development

1. INTRODUCTION

As one of the major concepts of sustainability, Green Building (GB) is a notable term which has gained global acceptability over the years. As a concept for achieving sustainable development (SD) in the architecture, engineering and construction (AEC) industry, GB is often used interchangeably with other terms such as sustainable design, green construction, integrated design, sustainable building, sustainable construction (SC), environmentally friendly, green, design of high-performance, and sustainable architecture (Hastings & Wall, 2007; Presley & Meade, 2010; Robichaud & Anantatmula, 2011; Azis et al., 2012; Kubba, 2012; Zabihi et al., 2012; Kibert, 2013; AlSanad, 2015). Some researchers regarded GB as a paradigm in reaction to the environmental degradation and crisis facing mankind and the resulting efforts to ensure the efficiency of the built environment through materials, energy, and utilisation (Kubba, 2012). GB,

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also known as *sustainable building* (SB), as a concept, strives to meet both environmental and economic goals by leveraging *resource-efficient* processes throughout the lifecycle of a building. The aim is to address and solve the measurable challenges associated with the construction and use of traditional buildings (Windapo, 2014). The development of GBs is mainly based on the principles and concepts of SC. However, GBs are believed to be a subset of SC, encompassing the social, economic and environmental aspects of buildings in the spirit of SD (Kibert, 2004; Hwang et al., 2017).

There are numerous records of GB definitions and differing perspectives of what the term entails. However, there is no single definition of GB that is globally accepted, but a critical review of the existing ones reveals a common thread (Robichaud & Anantatmula, 2011), which is the alignment to sustainability principles. Despite the enormous number of definitions, GBs are regarded as resource-efficient, consume less energy and pose minimal environmental impacts (Hwang & Tan, 2012). According to the definition of Kibert (2016), GB refers to the attributes and qualities of a building structure developed using the methodologies and principles of SC. Based on the study of Anoop et al. (2018), GBs are described as the construction that minimises the use of non-renewable construction materials and other resources while maximising the use of recycled content and modern efficient engineered materials through efficient engineering design, planning, construction and effective recycling of construction waste. It is also described as the "responsible creation and management of a healthy building environment, considering the ecological principles and efficient use of resources" (Kibert, 2013; Carvalho et al., 2019). In summary, GBs are developments that enhances human productivity and do not negatively impact the human and natural environment throughout the lifecycle of the building (planning, design, construction, operation, maintenance, demolition and decommissioning stages).

According to Henderson (2012), the GB of today is not a new concept, but a movement initiated by the United States (U.S) energy crisis of the 1970s which led to the establishment of the US Environmental Protection Agency (USEPA). Since its early formative years, GB has experienced significant transformation and has since become a mainstream appeal and a "revolution" sweeping the whole world (Kubba, 2012; Nykamp, 2017). Owing to the global clamour to reduce greenhouse gas (GHG) emissions and climate change issues generally, GB is perceived as a potential panacea to this menace. To achieve sustainability in the built environment, several countries have embarked on programmes, agendas, missions, and masterplans to ensure construction activities and processes are done in an environmental-friendly manner. Many governments are adopting a regulatory approach in their efforts towards addressing the direct and indirect environmental impacts of the construction industry (Lam et al., 2010). For instance, Singapore aims to achieve the greening of 80% of all buildings in the country by the year 2030 and has rolled out a series of masterplans and programmes to this effect (Hwang et al., 2016).

The literature has established several goals or reasons that encourage the planning, design, construction and use of GBs. The main goal of GB identified by Singh and Sharma (2014) is to minimise the overall negative impact of the CI on both the natural and human environment by using water, energy, and other resources efficiently; reducing pollution, waste, and environmental degradation; and protecting occupant health and improving employee productivity. The study of Shukla et al. (2015) indicated that GBs must embed and achieve the following: conservation of resources and water, improved indoor air quality, building space and green material use, renewable energy generation, energy efficiency, site regeneration, and operational, maintenance and waste recycling. Mehta and Chakraborty (2017) listed the following important

factors to achieving GB: the use of non-toxic and recyclable/recycled materials, minimal disturbance to landscapes and site conditions, reduction of building footprints, measurement and verification plans to ensure water and energy savings, use of onsite renewable energy, and use of energy-efficient equipment for lighting and air conditioning systems. It is therefore important for the GB stakeholders to ensure the aim of building green is attained by incorporating and implementing the afore-mentioned fundamental principles.

As the latest of the many global efforts geared towards achieving SD, the Sustainable Development Goals (SDGs) are a simplified and comprehensive 2030 Agenda of the United Nations (UN) for achieving SD. All countries and stakeholders under the auspices of the UN are expected to adopt and implement this plan in a collaborative partnership. Contained in the report titled Transforming Our World, the SDGs were adopted by the General Assembly of the UN member states in 2015 to stimulate actions for SD over the next 15 years in important areas for the planet and humanity (United Nations, 2015; Holden et al., 2017). The 2030 Agenda and goals resulted from decades of work by countries, the UN, and the success and deficiencies of the recently elapsed Millennium Development Goals (MDGs) in driving the world towards a resilient and sustainable path. Since the core target of SD is human welfare (people dimension), it is argued that the SDGs must be comprehensible for the people being the major stakeholders required to drive the sustainability agenda. Also, each country and region should be allowed to develop a blueprint for meeting the SDGs and targets in tandem with the global objectives. It is imperative for different national or regional policies, peculiarities, levels, priorities and capacities of development to be considered in meeting the SDGs and targets. The study of Olawumi and Chan (2018) also supported the development of SD policies and the view that programmes should be country-specific but with a global perspective.

There have been waves of GB research output generated globally. Recognizing that GB is the AEC industry's way of embracing the SD paradigm, it is noteworthy that stakeholders within the AEC industry have responded significantly to the global SD drive by creating awareness and encouraging the adoption and implementation of GB. Based on the studies of Darko et al. (2019) and Wuni et al. (2019) on GB research globally, it is evident that the volume of research publications on GB is on the increase globally especially in the MDG period (2000–2015) and the present SDG era (2015–2030). While there have been records of studies done on global GB research and other sustainability-related subjects, there is a paucity of studies on Africa's contribution to the subject of GB as far as literature survey could ascertain. Hence, the need for a study that presents an understanding of the status quo and trend of GB research contribution from the continent of Africa. The present study attempts to ascertain the developments and trends of research studies about GB in Africa between the years of 2000 and 2020 covering the MDG and SDG years. To better characterize the current status of Africa's research contribution on GB, a scientometric analysis was conducted. Owing to its potential in identifying the hot-areas of focus for future research, providing a comprehensive understanding of the current state of GB research in Africa and serving as a valuable reference for supporting stakeholders' and policymakers' funding and planning efforts, the findings of the research will contribute to the continental and global body of GB knowledge.

2. RESEARCH APPROACH

This scientometric review focused study employs a science mapping method to analyze journal articles, conference proceedings and book series published between 2000 and 2020 in the GB

domain. The review year is intended to capture the MDG era (2000–2015), and the SDG era (2015–2030). However, the second part of the review year only captures publications available on the Scopus database as at September 2020 when this study was conducted. Figure 1 shows the pictorial representation of the research framework employed in this study. The research approach employed will help in achieving the following objective for the study, namely to identify the countries and authors with the highest focus on GB research in Africa, to identify the most cited published works on green building in Africa, to map out research focus on GB in Africa and to identify the trends in GB research in Africa.

2.1 Science mapping method

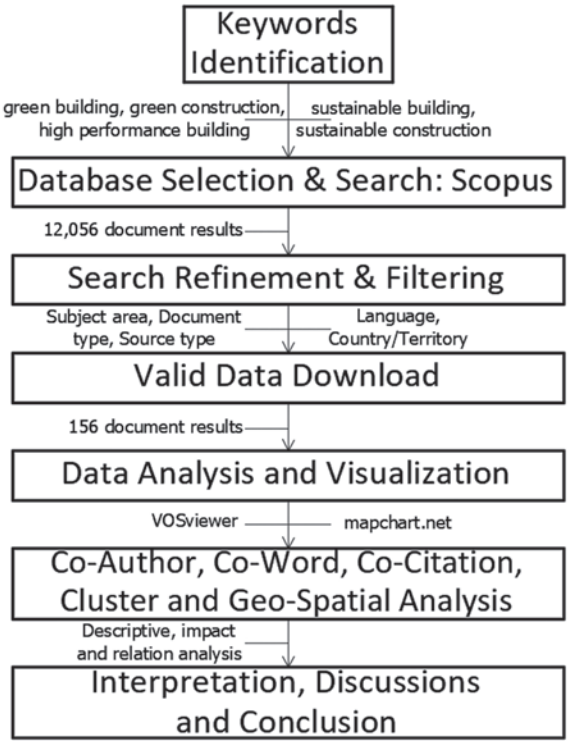
A quantitative method (science mapping) was employed in the present study. Science mapping is described as a bibliometric tool for analyzing and mining scientific output and measuring scholarly productivity and quality (Moral-Muñoz et al., 2019). Science mapping presents an overview of scholarly works in a way that it can be utilized to support the examination, interpretation or description of the development and state of scientific practices and knowledge (Chen et al., 2014). According to Chen (2017), a science mapping or bibliometric study is typically composed of scientific literature, set of scientometric and visual analytic tools, and indicators that can identify important trends and patterns that can pilot the exploration, description, or explanation of dynamic patterns and visualized intellectual structures. Software tools such as VOSviewer, SciMAT, CitNetExplorer, BibExcel, Sci^2 Tool and CiteSpace II are commonly used in analyzing data for scientometric studies as they are detailed, user-friendly, free and easily accessible. The present study employed the use of VOSviewer to visualize the bibliometric networks supported by tables and graphs for presenting the deduced data.

2.2 Bibliographic data collection

The bibliographic data were collected from the Scopus database by Elsevier Science. As a departure from Web of Science considered as a major database for research publications, Scopus database since its inception in 2004 has swiftly become a top choice for literature search (Aghimien et al., 2019). Scopus is regarded as the largest citation and abstract database of peer-reviewed publications. Therefore, Scopus is used in this study because it has been adopted for use in previous similar studies (Darko et al., 2109; Wuni et al., 2019; Darko et al., 2020;), possess a broad range of scientific research publications (Zhao et al., 2018) and is characterized by more updated publications retrieval owing to its relatively fast indexing process (Meho et al., 2008). The terms green building, green construction, high-performance building, sustainable building and sustainable construction were used to retrieve the bibliographic data owing to the earlier review studies (Kubba, 2012; Zabihi et al., 2012; Kibert, 201; AlSanad, 2015) which affirm that these terms mean the same and can be used interchangeably.

The search was focused on published conference proceedings, journal articles and book series within the subject areas of earth and planetary sciences, energy, engineering, environmental science and materials science. The language selection was set as 'English' because it is common knowledge that publications in Africa are mainly disseminated in English language. Search countries or territories were limited to the continent of Africa. Based on these refinements, a total of 156 publications were found as of 16 September 2020, for which all bibliographic information was exported thereby forming the dataset for this study.

FIGURE 1. Pictorial representation of research framework



2.3 Data analysis method

A scientometric review, analysis and visualization were performed to achieve the objectives of this study. The scientometric analysis technique provides a quality evaluation of the scientific rationality of research publications (Masic, 2016). The scientometric technique involves co-author analysis, co-word analysis, co-citation analysis, cluster analysis and geospatial analysis (Olawumi & Chan, 2018). The above five scientometric analysis and visualization was performed using the VOSviewer package while the animated maps for the geospatial analysis were presented using mapchart.net.

3. SCIENTOMETRIC ANALYSIS, RESULTS AND DISCUSSION

3.1 Trend in research publications on GB from 2000 to 2020

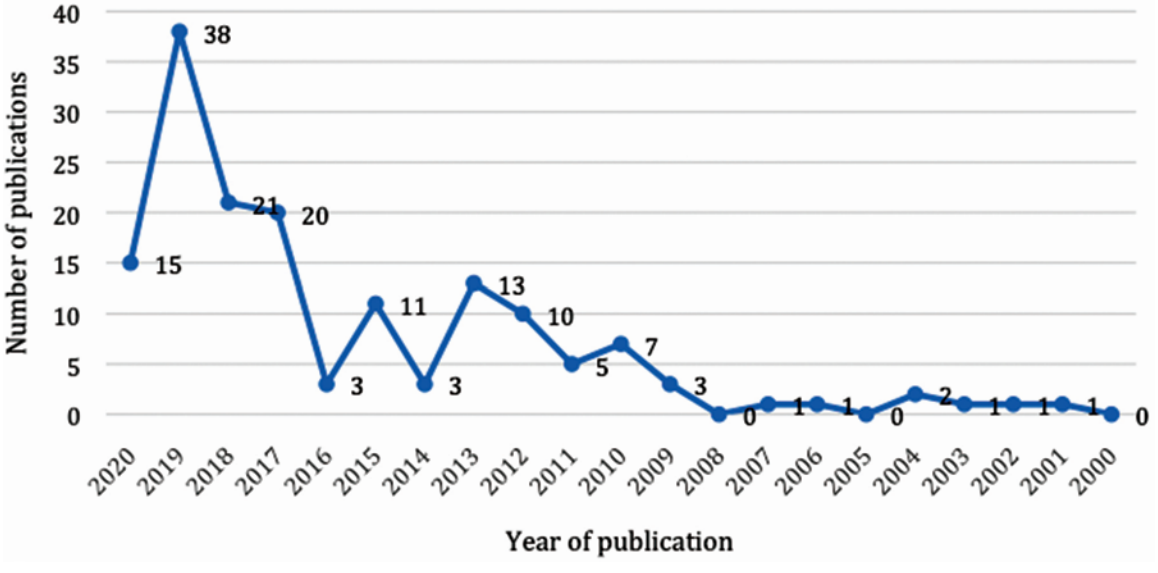
A total of 156 articles were extracted after refining and filtering the search criteria. Out of the 156 publications extracted, conference articles accounts for 79, while the remaining 77 were journal articles. Figure 2 presents the number of research publications on GB from 2000 to 2020 (as of 16 September). In the year 2000 which marks the start of the MDG era, no publication output on GB was recorded from Africa. It can be said that there is a steady increase in the number of GB research outputs emanating from Africa to date, with the last three years (2017, 2018 and 2019) recording 20, 21 and 38 GB research publications respectively. However, Africa records no GB publication in the year 2005 and 2008 while the year 2014 and 2016 records only three (3) research publications. The low research output on GB in Africa

compared to the significantly high number from developed countries (Darko et al., 2019) is an indication that Africa is still lagging in the adoption of GB. Despite that the GB concept started in the 1970s and in the US, which is a developed nation, the United States Green Building Council (USGBC) was only established in 1993. The first GB Council in Africa, that is, the Green Building Council South Africa (GBCSA) was founded in 2007, which is 14 years after the creation of the USGBC, thereby signifying the slow-paced adoption of GB on the African continent. As indicated by the study of Wilson and Rezgui (2013), a major barrier hindering the adoption and implementation of GB is the lack of awareness and education among stakeholders. Also, the studies of Saleh and Alalouch (2015) and Wimala et al. (2016) indicates resistance to change, inadequate knowledge and information about the GB concept, lack of awareness and lack of demand as major barriers to the adoption of GB. Therefore, the barriers can be agreed to be responsible for the scanty and low GB research output emanating from Africa. Despite the Covid-19 pandemic that characterizes the year 2020 thereby crippling most academic and research activities, the 15 research publications recorded so far is believed will increase and surpass the 38 for 2019 by the end of the year when the indexing of 2020 research publications is completed on the Scopus database.

3.2 Trend in research publications and citations on GB per country

A total of 10 countries are found to have contributed to GB research in Africa. The result is inclusive of some articles with more than one country of affiliation. However, those with more than one country of affiliation are found to be within Africa and within the 10 countries revealed in the result. All the countries in Africa with at least one research publication on GB were considered owing to the low number of countries revealed in the result. As shown in Figure 3, Egypt tops the chart with a total of 59 publications with 159 citations. This is followed by South Africa (43 publications with 173 citations), Nigeria (28 publications with 33 citations), Algeria (17 publications with 48 citations), Ghana (8 publications with 20 citations), Morocco (6 publications with 15 citations), Kenya (4 publications with 1 citation) and Mauritius (1

FIGURE 2. Trend in research publications on GB from 2000 to 2020.



publication with 1 citation). Other countries include Ethiopia (1 publication with 0 citation) and Cameroon (1 publication with 0 citation). The result shows that Egypt, South Africa and Nigeria tops the list of the highest contributor to GB research output in Africa. The result is not surprising as the three countries all have universities in the top 500 of the global ranking Times Higher Education (THE) world university rankings for 2020.

3.3 Trend in research publications on GB per document source

This section presents the trend in research publications on GB per document source as shown in Table 1. The dataset consists of 156 articles published in 74 different conference proceedings and journal sources. Table 1 presents the result on the document sources with at least three

FIGURE 3. Number of publications and citations per country.

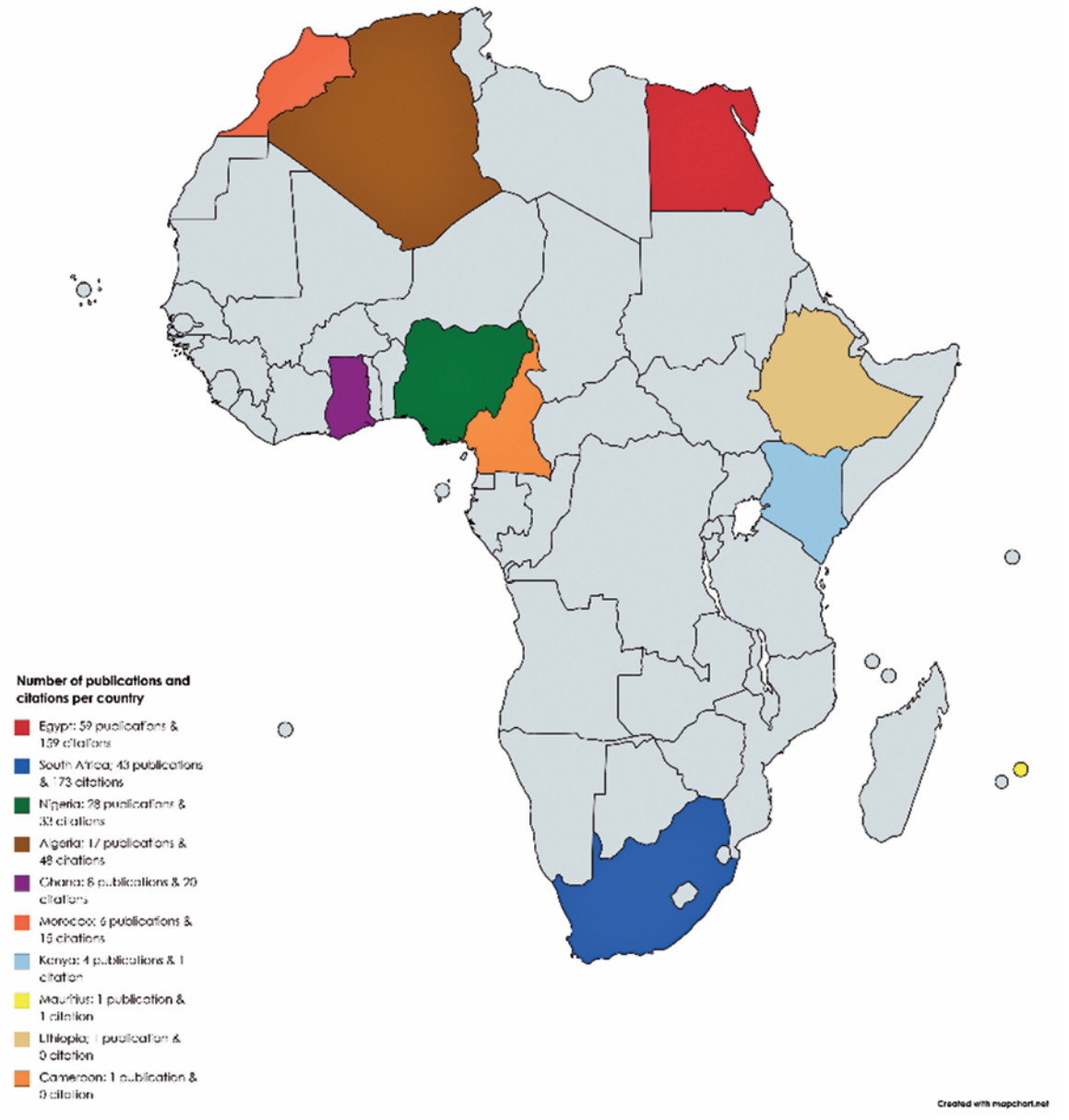


TABLE 1. Trend in research publications on GB per document source.

Source title	Documents	Citations
Energy Procedia	12	120
IOP Conference Series: Earth and Environmental Science	10	2
IOP Conference Series: Materials Science and Engineering	9	0
Journal of Engineering, Design and Technology	8	11
International Journal of Sustainable Building Technology and Urban Development	7	5
Alexandria Engineering Journal	6	20
Sustainable Construction Materials and Technologies	6	4
Journal of Engineering and Applied Science	5	1
Key Engineering Materials	4	6
Advanced Materials Research	4	5
WIT Transactions on Ecology and the Environment	3	9
Case Studies in Construction Materials	3	8
ISEC 2019—10th International Structural Engineering and Construction Conference	3	1
AEJ—Alexandria Engineering Journal	3	1
E3S Web of Conferences	3	0

research publications on GB. Based on this criterion, 15 documents sources were revealed. Energy Procedia was ranked first having 12 publications with 120 citations. As an open-access collection of peer-reviewed articles spanning the field of engineering, technology and science, the number of documents and the resultant high citations is understandable and largely justified. Despite the discontinuation of the Energy Procedia title as of 2020, the document source still boasts of a significant number of open access and easily accessible publications. This is followed by IOP Conference Series: Earth and Environmental Science (10 publications with 2 citations), IOP Conference Series: Materials Science and Engineering (9 publications with 0 citation), Journal of Engineering, Design and Technology (8 publications with 11 citations) and International Journal of Sustainable Building Technology and Urban Development (7 publications with 5 citations).

3.4 Most cited research publication on GB

Since the number of citations is widely used to judge the impact of publications (Zhao et al., 2020), it is important to analyze the dataset to identify the most cited documents. Table 2 presents the result on the titles and authors of GB research publications with at least 10 citations. Based on this criterion, 10 documents were revealed. The article titled *Towards a regenerative paradigm for the built environment* and published by Du Plessis (2012) is the most cited GB

research publication in Africa (96 citations). The study argued that the dominant sustainability paradigms which support urbanization project have failed to effectively engage the dynamic ecological system (Du Plessis, 2012). Hence, the study strongly supports the concept of regeneration, where the natural world is engaged and partnered in achieving resilience and sustainability in the built environment. With research interests spread across sustainable construction, urban resilience, sustainable human settlement and regenerative design and development, Du Plessis is regarded as one of the foremost researchers on GB in the world and in South Africa, a position which is further indicated in this study. The Article titled *the living walls as an approach for a healthy urban environment* by Sheweka and Magdy (2011) is the second most cited publication on GB research in Africa (40 citations). The study showcased the potential of the natural ecosystem (with a focus on the living wall) in achieving a sustainable urban environment. Out of the 10 publications retrieved, Energy Procedia accounts for five.

3.5 Trend in research publications on GB per co-occurring keywords

Co-occurrence of keywords looks at a situation where two or more keywords occur at the time. According to Darko et al. (2020), networks of co-occurring keywords is made up of nodes (keywords) and edges (relations among sets of keywords). Keywords are important for indexing research publications in databases as they reflect the theme of the articles (Wuni et al., 2019).

TABLE 2. Most cited research publication on GB.

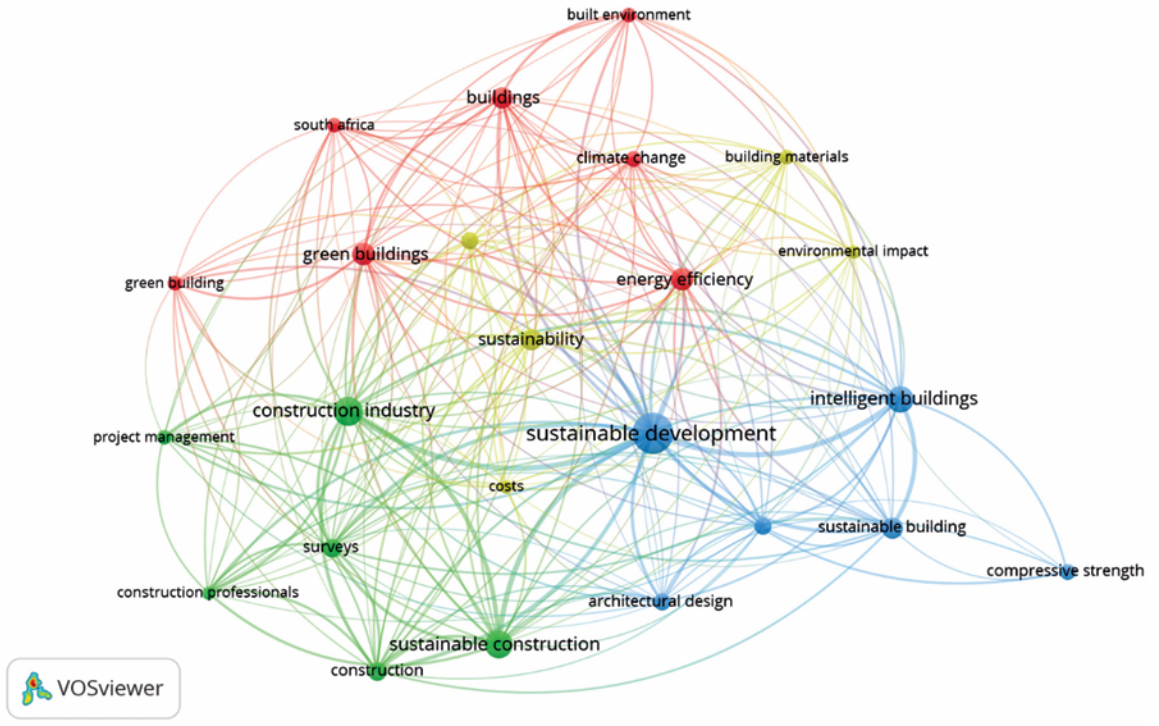
Title	Author(s)	Citations
Towards a regenerative paradigm for the built environment	Du Plessis (2012)	96
The living walls as an approach for a healthy urban environment	Sheweka and Magdy (2011)	40
Energy efficiency and thermal properties of the composite material clay-straw	El Azhary et al. (2017)	15
An optimal model for a building retrofit with LEED standard as reference protocol	Michael et al. (2017)	15
Examining the interaction between lean and sustainability principles in the management process of AEC industry	Khodeir and Othman (2018)	15
Experimental study of thermal performance and the contribution of plant-covered walls to the thermal behavior of building	Nadia et al. (2013)	14
Design of sustainable buildings through Value Engineering	El-Alfy (2010)	13
Selecting sustainable building materials using system dynamics and ant colony optimization	Marzouk et al. (2013)	11
Compact cities as a response to the challenging local environmental constraints in hot arid lands of Algeria	Bourchair et al. (2013)	10
Sustainable Construction Practices: "a Lazy View" of Construction Professionals in the South Africa Construction Industry	Aigbavboa et al. (2017)	10

Using VOSviewer software, a keywords co-occurrence network was produced. The type of analysis (set to co-occurrence), counting method (set to fractional counting), unit of analysis (set to all keywords) and the minimum number of occurrences of a keyword (set to a value of 10) were set. A total of 24 keywords out of 1493 keywords met the threshold of 10 co-occurrences and were further grouped into four (4) clusters. Figure 4 presents the co-occurrence network visualization map of keywords as generated from VOSviewer. At the centre of the network visualization map is "sustainable development" keyword to which all other keywords are linked. Cluster 1 (the red network of the map) contains 7 keywords, namely buildings, built environment, climate change,

TABLE 3. Most cited research publication on GB.

Keywords	Occurrences	Total link strength
Sustainable development	82	293
Construction industry	41	171
Sustainable construction	38	137
Intelligent buildings	37	132
Green buildings	26	87
Energy efficiency	25	71
Sustainability	23	94
Buildings	23	82
Sustainable building	22	82
Construction	19	101
Surveys	18	91
Architectural design	16	58
Energy utilization	16	52
Developing countries	15	63
Climate change	14	55
Compressive strength	13	18
Building materials	12	43
Green building	12	38
Project management	11	49
Built environment	11	47
South Africa	11	43
Construction professionals	10	61
Costs	10	37
Environmental impact	10	37

FIGURE 4. Co-occurrence network visualization map of keywords.



energy efficiency, green building, green buildings and South Africa. Cluster 2 (the green network of the map) contains 6 keywords, namely construction, construction industry, construction professionals, project management, surveys and sustainable construction. Cluster 3 (the blue network of the map) contains 6 keywords, namely architectural design, compressive strength, energy utilization, intelligent buildings, sustainable building and sustainable development. Cluster 4 (the yellow network of the map) contains 5 keywords, namely building materials, costs, developing countries, environmental impact and sustainability. Based on the number of occurrences and total link strength, the top 24 most frequently used keywords are presented in Table 3. By computing the Pearson product-moment correlation coefficient (r) between the total link strength and the number of occurrences, the study of Wuni et al. (2019) indicates a significant and strong correlation between the two indices. Hence, the higher the number of times a keyword occur, the higher the chances of co-occurring with other frequently used keywords in GB researches. This approach has been utilized by the studies of Olawumi and Chan (2018), Wang et al. (2020), Zhang et al. (2020), Zhao et al. (2020) and Zheng et al. (2020).

4. CONCLUSION

This study is aimed at identifying research focus on GB within the AEC industry in Africa through a bibliometric approach. The study has been able to identify the key area of concentration in GB research based on the dataset (published GB research publications from 2000 to 2020 and indexed in the Scopus database). From the findings of the study, it can be concluded that GB research publications are low in Africa with 2019 recording the highest number of

publications of 38. Despite the global clamor for the adoption and implementation of GB, the low record of GB research publications emanating from Africa is an indication that the concept is still at its infancy. Only 10 countries in Africa contribute to GB research publications, namely Egypt, South Africa, Nigeria, Algeria, Ghana, Morocco, Kenya, Mauritius, Ethiopia and Cameroon with at least one publication. There is no evidence of GB research publication from other 44 countries on the continent of Africa thereby revealing a knowledge gap that can be addressed to advance and improve the adoption and implementations of GB by research institutions, governmental and non-governmental agencies, governments and other stakeholders.

The study contributes to the body of knowledge as it identifies the present focus areas on GB and other aspects that require urgent attention if Africa will keep up with the global sustainability pace and greening agenda. While the study was able to identify and present the trend in GB research publications in Africa from 2000 to 2020, it is recommended that generalizing the results in other continents should be done cautiously bearing in mind that the study is limited to the Scopus database, the continent of Africa and captures GB research publications from 2000 to 2020. It is therefore recommended that further studies can be conducted using other reputable databases or a combination of several ones to have a broader understanding of the trend in GB research publications. Also, collaboration between African researchers and their counterparts from other parts of the globe is recommended to significantly aid the adoption and implementation of the GB concept in every nation of Africa.

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