

Scientific and Technical Productivity of African Countries: What Scopus and WIPO Patentscope Data Tell Us?

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ABSTRACT

This study maps the scientific publication and patenting activity of the member countries of the African Union (AU) using different Scientometrics indicators. This study uses the *Scopus* data of Elsevier science. Scopus extensively covers global as well as African scholarly literature. This study traces the literature growth, subject wise productivity and citation pattern of AU member countries. Besides the literature data, this study also maps the patenting activity using data from the World Intellectual Property Organization (WIPO) PATENTSCOPE database. The study observed a visible growth in publication since the last decade. The major activity is in Medicine related subject areas followed by Agriculture and Biological Science. The publications from African countries are well-cited (9.08 per paper) and above the average of Asian and Latin American countries but below the world average. The patenting activity as reflected from WIPO data, is limited and South Africa is the only country with quite a visible number of patents. The outcome and the recommendations of this study will undoubtedly be useful for scholars, policy, and decision-makers in the governments of the member states of AU.

Keywords: Science in Africa, Bibliometrics, Scientometrics, Citation Analysis, Patent, Science and Technology, Research and Development, Science Technology Indicator.

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INTRODUCTION

In recent years, the African continent has taken several initiatives to boost Science and Technology (S&T). Among the many initiatives, the Monrovia Strategy (1979), the Lagos Plan of Action (1980), the Abuja Treaty (1991), the establishment of the African Economic Community, and the most recently in 2007, the adoption of Africa's Science and Technology Consolidated Plan of Action (CPA) by the African Union (AU). Africa's S&T Consolidated Plan of Action has taken many initiatives to map the S&T output of the African Union,^[1] for example, the publication of African Innovation Outlook in 2014. In 2014, AU adopted the *Science, Technology, and Innovation Strategy for Africa – 2024 (STISA-2024)* (Science Technology and Innovation Strategy for Africa 2024, 2014).^[2] This policy document aimed to shape Africa's S&T and innovation activities for the future. This document has significant potential for the S&T growth and overall socio-economic development of Africa. The policy document is widely acclaimed across the African continent as well as globally for sustainable and better Africa.^[2]

To map African Science, the *New Partnership for Africa's Development* (NEPAD) has released the *African Science, Technology, and Innovation Indicators Initiative* (ASTII). So far, this initiative has published two detailed innovation and R&D surveys in various African countries. During the implementation of these surveys, it was realized that the true state of Science, Technology, and Innovation (STI) in any country requires more data than is ordinarily collected in innovation and R&D surveys. Thus, the reports of African Innovation Outlook (AIO) include bibliometric analyses of scientific productivity in African countries besides innovation surveys that participated in the ASTII.^[1]

Developed countries in the world have systematic and well-organized data sets on S&T activities.^[3] For example, publication and patenting activities are well documented as well as properly maintained. This is not the case of developing and emerging economies where these kinds of databases are not available or not properly organized.^[3] Hence, to map the scientific activities in developing countries, one must depend on the globally available citation databases (for example, Web of Science, Scopus, Google Scholar). These databases certainly have an English language bias, and publications from developed countries generally get more coverage than the developing countries in any form of publications (journals, books, conference proceedings, etc.).

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As the developing and less developed countries' scholarly articles are covered less in globally indexing and abstracting databases. For developing countries, the indicators like WIPO Patentscope data, Clarivate Analytics' Web of Science (WoS), Scopus database of Elsevier are quite underused. Naturally, these indicators have pros and cons. The shortcomings of global literature databases to map African S&T outputs have been broadly discussed in many scholarly literatures.^[4-7] The limitations of patent data as an indicator of technological activities are discussed by Griliches^[8,9] and so on. Keeping these inherent limitations in consideration, this study will map the African scientific literature and patenting activities using the broader scientometrics / bibliometric analytical framework.

The section follows will briefly discuss the earlier bibliometric studies in the African context. Also, in this section, a brief literature review will be carried out on the bibliometric analytic tools for mapping S&T activities and the patent as an indicator of technological activities. The section follows will discuss the research objectives. The next section will discuss the research methods and data sources, followed by the limitations of the study. The next section will deal with the results. The last section is the discussion, followed by conclusions and policy recommendations.

Literature review

The exhaustive Scientometrics study of African scientific output is minimal. So, the overall S&T performance in the African continent is somewhat less researched. This is because of the peripheral nature of science on the continent. Many of the poorest countries in the world are in this continent have their weak S&T infrastructure.^[5] However, it is observed that among the African countries, South Africa and Egypt are the two most productive countries that have quite a significant number of scientific publications and patents. Moreover, South Africa is a country among the African countries that have made remarkable progress in terms of scientific publications.^[10-14] Several studies have mapped the first-hand reality of the various aspects of scientific publications in South Africa.^[14] For example, the subject wise bibliometric study includes engineering research in South Africa,^[10,11] medical research in South Africa,^[13] and the collaboration patterns among the scientists in South Africa.^[10] Using various citation databases, these studies have observed that South African research publications mainly come from the universities.^[15] Although the two countries (South Africa and Egypt) are more productive than any other African countries, the overall publication profile in terms of global standards, even for these two countries, was not growing till the end of the last century.^[16,17]

This proposition has been further asserted with the study conducted by Tijssen^[6] using data from Web of Science (WoS).

It was observed that the share of international co-publications from African researchers had increased in the early 2000s. The co-authorship patterns African research output showed that 80 percent of middle Africa's research papers are produced in collaboration with a partner outside the African continent. The study further observed that middle African countries still have contacts with their formal colonizers in terms of research collaborations. Joint papers showed that 46 percent of papers are produced in collaboration with European countries, and 35 percent of papers are in collaboration with past colonial rulers. Above all, the scientific collaboration patterns show that Europeans are still the dominant partners and co-authored about 77 percent of papers.^[7] Also, another important observation was made that African science had little impact on the global scientific landscape, as reflected in the citation pattern. In comparison to the global trend, African publication was comparatively less cited than the publications from other continents. This indicated less relevant research, or perhaps the African researches are unnoticed by the global scientific community. Contrary to this, a study also observed that research output published in many South African journals showed a distinctive citation impact. Many of the scholarly publications are cited globally. However, many of the journals published from the continent are not indexed in the globally recognized indexing and abstracting databases like Web of Science and Scopus.^[6] Hence there is a clear bias and many of the African research outputs have not been indexed in their database.

Almost all of the previous Scientometrics studies have asserted that the African continent as a whole is lagging in terms of scientific innovation. This trend was relevant till 1996 because Africa's share of the world's scientific output remained under 1.5 percent. Many of the developed, as well as emerging economies in the world publish more than the cumulative publication of the African continent. Opposing to this view in recent years, it is observed that the number of scientific papers published by researchers from Africa has been proportionally rising faster than the total world scientific output, particularly after the year 2004. This perhaps indicates a possible rise in African science.^[18] According to Elsevier's estimate, the number of scientific papers published by the Africans has tripled in the past decade. The number of papers published by African scientists reached an all-time high in 2013. In that year, more than 55,400 articles have been reported published by the African Scientists. Although the number is quite low and contributes only about 2.4 percent share of the global total, but the phenomenon is perhaps a possible indication of a rise in African science.^[19]

Hence, it is very relevant to study the state of African Science with reference to the global landscape. The rationale is to undertake a bibliometric analysis of S&T production and

knowledge flow as a critical aspect of the state of science, technology, and innovation in the participating countries. This study undertakes the bibliometric analysis of publication and patenting of the AU member countries. For this study, data is obtained from the Scopus database and the SCImago Journal and Country Rank^[20] website. The website extracts data from the Scopus database for the ranking purpose. To map the patenting activity of the African countries, the patent data are extracted from the WIPO Patentscope database.

Bibliometric indicators as analytical tools

Allan Pritchard, in the year 1969, first coined the term 'Bibliometrics'. He defined Bibliometrics "application of mathematical and statistical methods to books and other media of communication".^[21] In the same year, Nalimov and Mulchenko (1969) coined the term Scientometrics as "the application of quantitative methods dealing with the analysis of science viewed as an information process".^[22] So, the term Scientometrics was generally used for measurement of science communication, and Bibliometrics was used to deal with more general information processes.^[23] However, nowadays, Bibliometrics and Scientometrics are used interchangeably.^[24]

Bibliometrics has become a standard tool of science policy and research administration in the last couple of decades.^[24] The assessment of the nature of scientific productivity is the topic of study in Scientometrics. By considering all the documents published in any field it is possible to construct an indicator considering different variables.^[23] By using Scientometrics indicators, scientific productivity can be analyzed in any field of knowledge (natural science, social sciences, or humanities). Although a bibliometric analysis can be applied to define general productivity in a given research field, it can also be used to assess the individual scholar's productivity, the core journals that publish most of the articles in a given field, and the productive institutions, countries and so on.

In any Scientometrics analysis, the most important issue is the database coverage on which the study is based on.^[23] As there is no database that extensively covers the African publication output, so to map the African scientific outputs, one has to depend on the global databases. Presently there are three citation databases (Web of Science, Scopus, and Google Scholar) available globally, which provides citation analysis. However, Scopus of Elsevier has better coverage among these three databases than any other indexing and abstracting database globally. It covers scholarly journals, books, and other materials from different publishers encompassing the universe of knowledge (Science, Social Science, and Arts and Humanities subjects). Scholarly publication records for 54 African countries who are a member of the African Union (Appendix 1) are extracted from the Scopus database, and SCImago^[20] SJR – SCImago Journal and Country Rank

website is used to extract citation information. This database extracts data from the Scopus® database of Elsevier B.V.

Patent as an indicator of technological capability

Patents as innovation indicators are widely used in scholarly as well as popular literature. Patent information is the rich source of growth and development of a particular technology. It is also considered as an indicator of national technological capability building in neo-Schumpeterian literature.^[25]

However, there are limitations in using the patent data to map innovation output.^[9] Firstly, the value of patents is highly twisted, as there are relatively small numbers of patents that are highly valuable, and a large number of patents are of little value. Secondly, many inventions are not patented. Besides these issues, it isn't easy to get a patent by African inventors because of its cost. Many African countries' patent offices are not well equipped to keep their records online or available in computer-readable formats. So, keeping these options in mind, this study is based on the analysis of WIPO patent data to access the African countries' technological capability.

Objectives

The broad objectives of this study are as follows:

- (i) To find the overall and region-wise scientific productivity of AU member countries in terms of their scientific publications in the Scopus database.
- (ii) To map the subject wise scholarly publication patterns of different regions and countries.
- (III) Citation analysis of the African continent as a whole and region-wise citation matrix of the African continent.

Map the technological capability of African countries in terms of patenting activity, as reflected in the WIPO patent data.

METHODOLOGY

Scholarly articles published in the peer-reviewed and professional journals are the internationally comparative sources of information on scientific outputs. Presently there are three globally available databases, the Scopus, provided by Elsevier, Web of Science (WoS) by Thomson Reuters, and Google Scholar provided by Google.

Scopus® database of Elsevier B.V. is the largest database of peer-reviewed scholarly literature. It covers about 46 million abstracts from more than 25,100 peer-reviewed journals (as of January 2020). Scopus is also one of the globally available databases which provide citation analysis facilities. It has very wide coverage in almost all fields of knowledge covering science, arts and humanities, and social sciences. Although it has the extensive coverage of scholarly journals globally, there are only about 136 journals indexed in Scopus are from Africa.

As mentioned in the literature review section, no database extensively covers the African publication output. However, Scopus of Elsevier is better coverage than any other indexing and abstracting database available globally. Scholarly publication records for 55 AU member countries are extracted by searching affiliation country. For example, the search string to retrieve records from South Africa was the following: (AFFILCOUNTRY (South Africa) AND PUBYEAR > 1989 AND PUBYEAR < 2020). Further, citation information was searched from The *SCImago Journal and Country Rank*.

RESULTS

The following section will deal with the publication pattern of different African countries. The data available from the *SCImago Journal and Country Rank* website^[20] was further used to analyse the citation patterns of the member countries of AU. The indicators are developed from the records of the Scopus database of Elsevier B.V. These indicators are freely available on the Internet and can be used to assess and analyze scientific domains. The indicators are available at <http://www.scimagojr.com>^[20,26]

Scientific publications of AU member countries

Publication data of the total 54 African countries shows that during 1990–2019, the whole African continent publishes 1,158,398 articles. The African publications are further categorized into five categories based on the different regions of Africa. These categories are; Eastern Africa, Western Africa, Southern Africa, Northern Africa, and Middle Africa, based on the United Nations Classification of countries by major areas and regions of the world (appendix 1).

Figure 1 shows the growth of African publications over the years. In the year 1990, there were about 20,605 publications indexed in Scopus cumulatively from Africa. In the year 2019, about 2,25,720 articles are available in Scopus. The number is more than ten times increase from the year 1990. The growth of African publications increased, particularly after the year 2000. However, this cumulative number is significantly less in comparison to many developing and emerging economies.

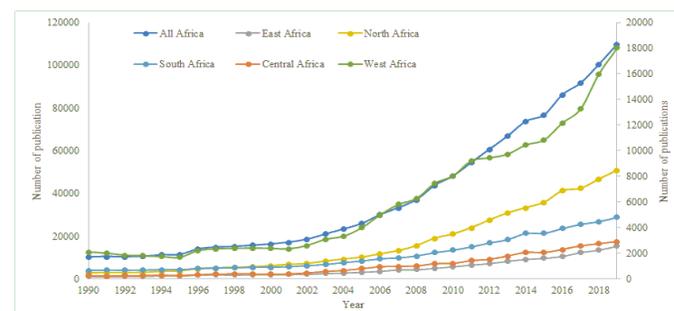
Among all African countries, South Africa ranks at the top with 385,368 records Egypt 274420. Among the top 100 highly productive countries globally, South Africa Ranks 35th position and Egypt 39th position. Among the top 100 productive countries globally, the ranks of these countries are as follows: Nigeria (53rd), Tunisia (54th) Algeria (56th) Morocco (57th), Kenya (67th), Ethiopia (77th) Ghana (79th), Tanzania (86th), Uganda (87th) Cameroon (90th), Zimbabwe (97th), Senegal (98th) and Sudan (100th).

Appendix I: Countries in African Continent.

Eastern Africa	Middle Africa	Northern Africa	Southern Africa	Western Africa
Burundi	Angola	Algeria	Botswana	Benin
Comoros	Cameroon	Egypt	Lesotho	Burkina Faso
Djibouti	Central African Republic	Libya	Namibia	Cabo Verde
Eritrea	Chad	Morocco*	South Africa	Cote d'Ivoire
Ethiopia	Congo	Sudan	Swaziland	Gambia
Kenya	Democratic Republic of the Congo	Tunisia		Ghana
Madagascar	Republic of the Congo	Republic Arab Saharawi Democratic		Guinea
Malawi	Equatorial Guinea			Guinea-Bissau
Mauritius	Gabon			Liberia
Mayotte*	Sao Tome and Principe			Mali
Mozambique				Mauritania
Réunion*				Niger
Rwanda				Nigeria
Seychelles				Saint Helena*
Somalia				Senegal
The Republic of South Sudan				Sierra Leone
Uganda				Togo
United Republic of Tanzania				
Zambia				
Zimbabwe				

Source: United Nations Classification of Countries by Major Area and Region of the World.

<https://unstats.un.org/unsd/methodology/m49/>



Source: Own drawing based on Scopus data

Figure 1: Growth of African Publications during 1990-2019.

Region wise distribution of publications

It is mentioned already that the whole African continent produces about 1158,398 articles during the 1990–2019 period. In Eastern Africa, there are altogether 18 countries produce 148,818 scholarly publications, which constitutes about 12.8 percent of total African publications. Middle Africa (a total of 9 countries) altogether produced 31,142 publications (only about 2.6 percent) of total publications. In Northern Africa, seven countries have produced 499,944 (43.1 percent) articles.

Five Southern African countries produced 340,081 (29.3 percent), and Sixteen countries in West Africa produced 180,021 (15.5 percent) articles. So, it can be concluded that in terms of the number of publications, Northern Africa produced more articles than the other regions of Africa, and the performance of Middle Africa is at the lowest.

It is important to note here that there are only a few countries that perform better in terms of publications in every region. From a total of 18 countries of Eastern Africa, only the following four countries have more than 10,000 publications. These countries are Kenya (41,840), Ethiopia (28,440), Tanzania (20,675), Uganda (19,966), and Zimbabwe (13,230). Among the nine countries of Middle Africa, only Cameroon at the top with 19,123 publications. In the northern zone, the number of articles published by the countries is as follows Egypt 242523, Tunisia 97,044, Algeria 75,961, Morocco 73,540. In Southern Africa, South Africa is the most productive country, not only in that zone but all over Africa with 328,353

articles. In western Africa, Nigeria is the most productive with 109,207, followed by Ghana with 24,431 articles.

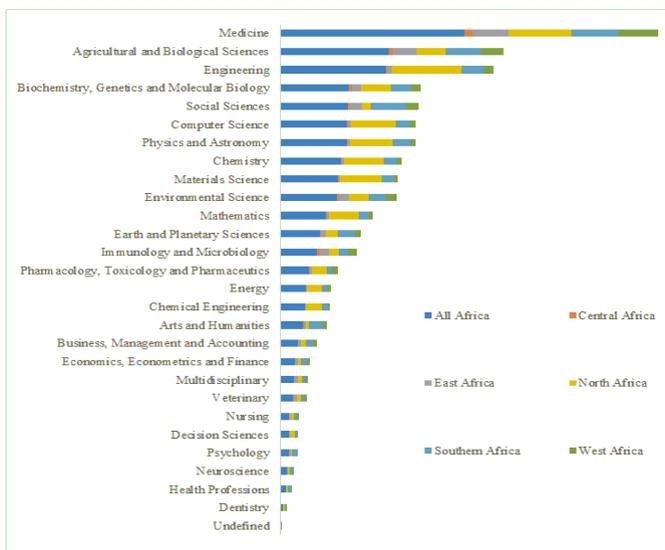
In sum, in every zone, only a few countries perform better and in terms of the number of publications. The whole continent's productivity is based on only a few 'star performer' countries.

Subject wise distribution of publications

Scopus has categorized the universe of knowledge into 27 major thematic categories. These categories are further classified into 313 specific subject categories. Table 1 and Figure 2 show the subject-wise distribution of articles from AU member countries' cumulative publications based on these thematic classification schemes. Africa all together published the maximum number of articles in medicine (304,331 articles and 29.26 percent). The next productive areas are Agriculture and Biological Science (179,598 articles 15 percent), Engineering (174,791 articles 15 percent), Biochemistry Genetics, and Molecular Biology (113,900, 9.8

Table 1: Subject wise distribution of publications.

Subject Areas	All Africa	Middle Africa	East Africa	North Africa	Southern Africa	West Africa
Medicine	304331	12877	60262	103150	78812	65264
Agricultural and Biological Sciences	179598	7129	39230	46903	57921	37633
Engineering	174791	1843	7112	115507	37271	16182
Biochemistry, Genetics and Molecular Biology	113900	3856	15989	49406	31937	17690
Social Sciences	112607	2424	20689	14382	57034	22360
Computer Science	110830	894	4893	74668	22808	9080
Physics and Astronomy	110024	1954	2732	72129	29684	6803
Chemistry	99581	1785	3821	66608	21585	7859
Materials Science	95884	1101	2237	68295	19458	6798
Environmental Science	94454	2506	17107	33082	28049	17792
Mathematics	76023	1681	2434	50571	16499	6104
Earth and Planetary Sciences	65938	1859	7137	20821	27936	10260
Immunology and Microbiology	61228	3861	15954	16247	14902	14471
Pharmacology, Toxicology and Pharmaceutics	46889	1612	3763	24691	8664	9584
Energy	41775	581	2567	24289	8473	6685
Chemical Engineering	41063	534	1597	25908	9366	4383
Arts and Humanities	37937	605	4017	4451	23868	5838
Business, Management and Accounting	29652	310	3789	8385	12480	5641
Economics, Econometrics and Finance	24390	529	3948	5010	10429	5388
Multidisciplinary	22377	955	5799	6948	5513	4748
Veterinary	21619	744	5592	6901	5225	4389
Nursing	14857	407	3109	3577	4816	3783
Decision Sciences	14680	129	979	7894	4596	1420
Psychology	14503	254	2616	1416	9054	1815
Neuroscience	10888	331	1347	4372	3624	1589
Health Professions	9073	163	889	3001	3986	1373
Dentistry	4865	26	431	2620	992	849
Undefined	325	0	9	243	43	32



Source: Own drawing based on Scopus data

Figure 2: Subject wise distribution of publications from different regions of Africa.

percent articles). From their scholarly publication profile, it is observed that North Africa more engineering articles (115,507 articles 23.10 percent).

Citation Analysis

Citations are a powerful analytical tool and widely used measure of the impact of scientific publications. Citation analyses are increasingly used as an effective tool to compare research productivity and impact between authors, institutions, or countries. Generally, scholarly literature includes references to the earlier related research works of other scholars. The literature that refers to earlier works is somehow related to that work. In that way, citations link between authors, groups of researchers, topics of study, or countries. So, the effect and significance that earlier researcher(s), studies, or journals have on a scientific community can be measured by means of citation analysis.^[22] However, there are many pros and cons of the citation analysis and its interpretations. Hence, Citation analysis cannot be taken as a sole indicator for evaluation of research preformation, but it can give some indications of its impact on a given field of research.^[23]

SJR — SCImago Journal and Country Rank^[20] data shows that during the 1996–2018 African continent altogether publishes 767,845 documents, and 710166 (92.49%) documents are cited (Table 2). This is much higher than the global average (89.71 percent), Western Europe (91.18 percent), and even North America (90.44 percent).

Citations per documents in African countries are about 8.94 per document (Table 2). This is higher than North America (11827611 documents 88.74%), Pacific Region (1384248

documents 88.36%), Western Europe (12680641 documents 89.88%), and even the world average (43246239 documents 89.24%). The citable documents and the number of average citations show that the African continent’s scientific publications are not lagging behind. Although the publication from Africa is lower in terms of other continents, this can be a possible indicator that shows the relevance of African research in a global context.

So, the earlier observations that African science had little impact on the global scientific landscape is perhaps not true. Research outputs published in many African authors or scholars have a good impact and perhaps not less than any other international research communities. However, many journals from Africa are not indexed in the globally recognized indexing and abstracting databases (Tijssen 2007).^[6] The inclusion of more African journals or possibly an African Citation Database created solely from the continent’s literary resources will perhaps give a better picture of African science as a whole.

The self-citations of papers are also comparatively lower (about 30 percent). This indicated that African scholars do not self-cite much of their articles.

Eastern Africa

During the 1996–2018 period, Kenya is the most productive country among 18 East African countries, with 35,120 publications (Table 3). Kenya ranked 67th globally and 7th in Africa in terms of the number of publications. However, Seychelles (26.57 per paper) is at the top with citations per paper followed by Mozambique (20.27 per paper).

Kenya has *h*-index of 179 and is at the top, followed by Uganda with 128 and Tanzania with 122, Malawi 104, Ethiopia 101. These five countries are only *h*-index of more than 100. This shows that highly cited articles in these countries.

Middle Africa

Middle African countries are the least productive group of countries among the African continent. Among the nine countries in this group, Cameroon is the most productive with 11th position among African countries and 90th position globally in terms of the number of publications (Table 4). Cameroon has produced 16,395 publications during the 1996–2018 period. In terms of citations per paper, Gabon has the highest citation rate per paper (20.33 per paper).

Northern Africa

From North Africa, Egypt is the most productive country with 203952 publications. It ranks 2nd in Africa and 39th position globally (Table 5). Among the six Northern African countries Egypt, Tunisia, Algeria, and Morocco have quite a good number of publications. However, in terms of citation per paper, Sudan is at the top with 11.01 citations per paper.

Table 2: African publication and their citations in global landscape 1996-2018.

Region	<i>h</i> -index ^I	Documents ^{II}	Citable documents ^{III}	Citations ^{IV}	Self-citations ^V	Citations per document ^{VI}
Africa	499	767845	710166 (92.49%)	8281712	2477580 (29.92%)	10.79
Asia	1231	12896091	12416246 (96.28%)	137516946	81215259 (59.06%)	10.66
Eastern Europe	784	3132263	3018537 (96.37%)	26528297	8739776 (32.95%)	8.47
Latin America	698	1816658	1710337 (94.15%)	20817056	6696807 (32.17%)	11.46
Middle East	743	2020299	1897677 (93.93%)	23787230	6391839 (26.87%)	11.77
North America	2247	13328752	11827611 (88.74%)	323695302	156336989 (48.3%)	24.29
Pacific Region	952	1566561	1384248 (88.36%)	30997242	6698212 (21.61%)	19.79
Western Europe	1859	14108645	12680641 (89.88%)	269821968	135843914 (50.35%)	19.12
World		48458625	43246239 (89.24%)	700113418		14.45

I. The Hirsch index, more commonly known as the *h*-index, was proposed by Hirsch (2007) to quantify an individual’s scientific output. The index is defined as... “a scientist has index *h* if *h* of his or her *N* papers have at least *h* citations each and the other (*N* – *h*) papers have ≤ *h* citations each” (Hirsch, 2007).^[27]

II. Documents- Cumulative scholarly documents from that continent

III. Citable documents- includes articles, reviews, and conference papers and percentage (in bracket) of citable documents with respect to total documents

IV. During the period 1996–2018, the total number of citations received by the total published documents

V. Self-citations to the published documents during 1996–2018 and Percentage of self-citations

VI. Average citation per documents of the whole continent during that period

Source: SCImago. (2007). SJR — SCImago Journal and Country Rank. Retrieved March 12, 2020, from <http://www.scimagojr.com>

Table 3: Citation matrix of East African Countries.

Africa Rank	Global Rank	Country	Documents	Citable documents	Citations	Self-citations	Citations per document	<i>h</i> -index
7	67	Kenya	35120	31548	652942	91803	18.59	233
8	77	Ethiopia	22934	21479	251468	54208	10.96	136
10	86	Tanzania	17484	16072	298625	42246	17.08	161
11	87	Uganda	17406	15748	312337	45222	17.94	169
13	97	Zimbabwe	10529	9411	154617	16210	14.68	128
17	104	Malawi	7452	6716	137339	16561	18.43	135
20	113	Zambia	6150	5453	108366	10696	17.62	118
24	120	Madagascar	4445	4199	62733	9364	14.11	91
25	125	Mozambique	3854	3488	78115	6250	20.27	97
28	129	Mauritius	3358	3012	34756	3194	10.35	74
29	131	Rwanda	3167	2787	45260	3598	14.29	78
42	174	Seychelles	653	606	17347	1046	26.57	59
43	175	Burundi	646	595	7732	383	11.97	42
45	177	Eritrea	624	585	8338	539	13.36	44
49	195	Djibouti	266	251	2130	169	8.01	23
50	200	Somalia	222	179	2105	77	9.48	22
52	207	Comoros	157	139	1600	97	10.19	16
55	-	South Sudan	67	67	448	0	6.69	12

Source: SCImago. (2007). SJR — SCImago Journal and Country Rank. Retrieved March 12, 2020, from <http://www.scimagojr.com>

Table 4: Citation matrix of Middle African Countries.

Africa Rank	Global Rank	Country	Documents	Citable documents	Citations	Self-citations	Citations per document	<i>h</i> -index
12	90	Cameroon	16395	15300	196206	35163	11.97	124
23	116	Congo	4842	4464	69027	5953	14.26	97
30	135	Gabon	2691	2544	54716	5217	20.33	100
35	158	Angola	1159	1088	12315	944	10.63	45
37	161	Democratic Republic Congo	1023	940	17399	460	17.01	61
39	168	Central African Republic	776	719	11601	639	14.95	51
47	180	Chad	562	534	8414	641	14.97	40
51	202	Equatorial Guinea	216	206	3183	273	14.74	25
53	219	Sao Tome and Principe	68	65	1088	68	16	21

Source: SCImago. (2007). SJR — SCImago Journal and Country Rank. Retrieved March 12, 2020, from <http://www.scimagojr.com>

Table 5: Citation matrix of Northern African Countries.

Rank	Global rank	Country	Documents	Citable documents	Citations	Self-citations	Citations per document	<i>h</i> -index
2	39	Egypt	203952	195777	1933453	378635	9.48	260
4	54	Tunisia	86600	81933	678610	141681	7.84	174
5	56	Algeria	65714	63705	444666	94937	6.77	157
6	57	Morocco	62636	58839	507921	95955	8.11	179
15	100	Sudan	9133	8590	100524	9060	11.01	92
21	114	Libya	5689	5457	43656	2162	7.67	67
54	232	Arab Saharawi Democratic	11	9	43	0	3.91	4

Source: SCImago. (2007). SJR — SCImago Journal and Country Rank. Retrieved March 12, 2020, from <http://www.scimagojr.com>

Southern Africa

Among the five Southern African countries, South Africa is the most productive with 272886 articles. South Africa is at the top among African countries and ranked 35th globally (Table 6). Rest other countries ranked low globally because of minimal scientific publications. In this group of countries, Namibia has the highest citation paper (13.53). Although South Africa has a very high number of publications, its self-citation rate is also relatively high. The *h*-index of South Africa is 423 and the highest among the whole continent. It indicates productive researchers from this country.

Western Africa

Among the 16 countries in Western Africa, Nigeria is the most productive country. Nigeria is also placed in the 53rd position globally, with 90031 publications (Table 7). Gambia has the highest citation per paper (37.38 citations per paper), followed by Guinea-Bissau (21.29 citations per paper). The top productive country Nigeria got 7.17 citations per paper and is the lowest. Nigeria has the highest *h*-index (181), followed by Ghana (142).

Patenting Activity

To analyze African countries’ patenting activities, patent statistics was downloaded from the Patentscope database of the WIPO website. By searching all African countries in the applicant and inventors address field, till 2019, the 54 African countries altogether produce about 18,827 patents.

Figure 3 shows the growth patterns of African patents in WIPO. The cumulative growth curve of African patents as a whole shows an increasing trend. The growth of African patents in USPTO is quite visible from 1995 onwards (Figure 3). However, the recent drop in the number of patents may be due to the incomplete coverage of patents from the African continent.

Among all five regions of Africa, the southern zone is the most productive. This productivity is solely due to South African patents. No other country on the continent is the match of South African patenting activity. Details of the number of patents in different countries are listed in Table 8.

Table 6: Citation matrix of South African Countries.

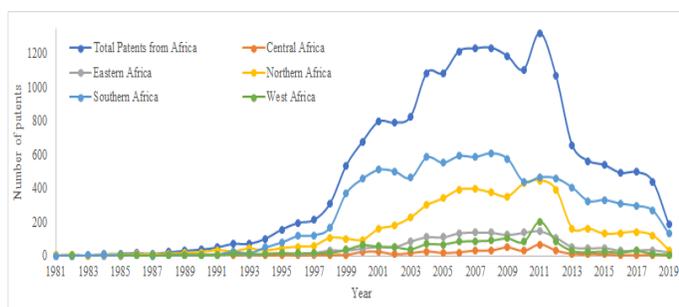
Rank	Global Rank	Country	Documents	Citable documents	Citations	Self-citations	Citations per document	h index
1	35	South Africa	272886	247039	3677627	771119	13.48	423
16	103	Botswana	7457	6602	92640	8537	12.42	98
26	127	Namibia	3720	3268	50346	4670	13.53	91
34	152	Swaziland	1589	1433	17959	745	11.3	60
41	172	Lesotho	678	615	6619	294	9.76	36

Source: SCImago. (2007). SJR — SCImago Journal and Country Rank. Retrieved March 12, 2020, from <http://www.scimagojr.com>

Table 7: Citation matrix of West African Countries.

Africa rank	Global rank	Country	Documents	Citable documents	Citations	Self-citations	Citations per document	h index
3	53	Nigeria	90031	84718	645110	134927	7.17	181
9	79	Ghana	20052	18232	236627	31015	11.8	142
14	98	Senegal	10381	9676	122439	14051	11.79	120
18	108	Burkina Faso	6763	6429	96199	13291	14.22	102
19	112	Côte d’Ivoire	6461	6115	89974	7696	13.93	111
22	115	Benin	5497	5212	74742	9724	13.6	89
27	128	Mali	3572	3339	62516	5445	17.5	94
31	137	Gambia	2601	2411	97228	6527	37.38	119
32	140	Niger	2218	2085	34128	2717	15.39	74
33	143	Togo	2082	1925	17546	1261	8.43	50
36	160	Sierra Leone	1128	987	17171	1529	15.22	52
38	162	Guinea	998	919	17273	968	17.31	60
40	171	Mauritania	682	638	7526	523	11.04	40
44	176	Guinea-Bissau	644	589	13711	2672	21.29	58
46	179	Liberia	588	486	6413	581	10.91	37
48	190	Cape Verde	325	316	3130	240	9.63	26

Source: SCImago. (2007). SJR — SCImago Journal and Country Rank. Retrieved March 12, 2020, from <http://www.scimagojr.com>



Source: Own drawing based on WIPO patent data

Figure 3: Growth of Patents in different African Regions.

DISCUSSION

This study attempts to map the scientific publication and patenting activity of the 55 member countries of AU. Standard bibliometric indicators are used to map the literature growth

patterns, citation, and patenting activities of the African continent as a whole. The study mapped zone wise literature growth and citation analysis and patenting activities of the member countries of AU. This study uses Scopus data because Scopus extensively covers global as well as African scholarly literature.

The study observed that during 1990–2019 publication data of the total 55 African countries altogether published 1,158,398 articles. It can be seen from the Scopus data that the scientific publications from Africa have increased almost ten times from the year 1990 to 2019. The advance of African publications is visible, particularly after the year 2000. This has been observed in many scholarly publications as well as popular articles.^[28]

Like other previous studies, South Africa ranks at the top among all African countries, followed by Egypt. Among the top 50 highly productive countries globally, only these

Table 8: Patent portfolio of different African countries in WIPO.

Middle Africa	Number of Patents	Eastern Africa	Number of Patents	Northern Africa	Number of Patents	Southern Africa	Number of Patents	Western Africa	Number of Patents
Angola	10	Burundi	18	Algeria	821	Botswana	10	Benin	29
Cameroon	296	Comoros	6	Egypt	2101	Swaziland	34	Burkina Faso	16
Central African Republic	10	Djibouti	2	Libya	60	Lesotho	3	Cabo Verde	3
Chad	8	Eritrea	49	Morocco	1442	Namibia	41	Cote d'Ivoire	71
Congo	51	Ethiopia	308	Western Sahara	0	South Africa	9784	Gambia	0
DR Congo	34	Kenya	366	Sudan	172			Ghana	292
Equatorial Guinea	7	Madagascar	62	Tunisia	1023			Guinea	14
Gabon	32	Malawi	17					Guinea-Bissau	4
Sao Tome and Principe	2	Mauritius	308					Liberia	35
		Mozambique	5					Mali	23
		Rwanda	27					Mauritania	121
		Seychelles	155					Niger	51
		Somalia	11					Federal Nigeria	564
		South Sudan	0					Senegal	113
		Tanzania	135					Sierra Leone	39
		Uganda	103					Togolese Republic	33
		Zambia	47						
Zimbabwe	169								

two countries ranked in the global publication landscape. In terms of global publication, South Africa Ranks 35th position and Egypt 39th position. Region-wise analysis of publication patterns shows that in terms of the number of publications, Northern Africa cumulatively produced more articles than the other regions of Africa. The performance of the countries in the middle regions is at the lowest. In sum, in every zone, only a few countries perform better in terms of the number of publications. The whole continent's productivity is based on only a few 'star performer' countries.

In terms of the number of publications, Africa is at the lowest in comparison to other continents. Citations per documents in African countries are about 10.79 per document. This is higher than Asia (10.66) and East Europe (8.47) but lower than the global average (14.45). The citable documents and the number of average citations show that the African continent's scientific publications are not lagging behind. This also shows the relevance of African research in a global context.

The subject wise productivity based on 27 major thematic categories shows that the maximum number of articles are published in medicine (304,331 articles 26.27 percent), followed by Agriculture and Biological Science (179,598 articles 15.50 percent), Engineering (62,436 articles, 11.89 percent).

WIPO patent data shows that 55 African countries altogether produce 18,827 patents. The cumulative growth curve of African patents as a whole shows an increasing trend. However, there is a drop in patenting in recent years. This may be due to the incomplete coverage of African patents. However, the findings are inconclusive and require further investigation. Among all five regions of Africa, the southern zone is the most productive solely due to South African patents. The South African patents are the reflection of the whole continent's patenting. No other country on the continent is the match of South African patenting activity.

CONCLUSION

This study is based on Elsevier's Scopus database, where the coverage of African scientific literature is limited. A large volume of African scientific literature is out of the database's coverage. So, an African Citation Index covering African scientific literature is the need of the hour. A recent initiative by the Council for the Development of Social Science Research in Africa (CODESRIA) headquartered in Dakar, Senegal, has taken the initiative to develop the African Citation Index. However, the process is still under the development and testing phase and will take time to implement the database for public use. Similarly, the patent database from the WIPO has many limitations. However, this study recommends a possible

indicator of the African continent's science and technological capability.

ABBREVIATIONS

AIO: African Innovation Outlook; **ARIPO:** African Regional Intellectual Property Organization; **ASTII:** African Technology and Innovation Indicators Initiative; **AU:** African Union; **CODESRIA:** The Council for the Development of Social Science Research in Africa; **EPO:** European Patent Office; **GIS:** Geographic Information System; **JPO:** Japanese Patent Office; **NEPAD:** New Partnership for Africa's Development; **R&D:** Research and Development; **S&T:** Science and Technology; **STI:** Science, Technology and Innovation; **STISA-2024:** Science, Technology and Innovation Strategy for Africa – 2024; **UK:** United Kingdom; **USA:** United States of America; **USPTO:** United States Patent and Trademark Office; **WoS:** Web of Science.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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