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## Review Article

# Cloud Computing Research in Nigeria: A Bibliometric and Content Analysis

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## Abstract

In recent times, there is a growing global interest in cloud computing which has necessitated a huge financial and intellectual investment in cloud research and development and developing countries are not left out, especially Nigeria. The aim of this paper is to measure Nigeria's contribution to the global cloud computing research endeavours in terms of quantity and impact. Bibliometric and content analysis was performed on research documents that were retrieved from the Scopus database based on defined search terms relating to cloud computing. The year of publication and the author's country was limited to "2016" and "Nigeria" respectively. A total of 51 documents met the search criteria and the oldest article on cloud computing was published in 2011, while the publication output has increased consistently with the highest number of the document published in 2016. Covenant University emerged as the most productive institution. Malaysia emerged as the country with the highest number of collaborations with Nigeria. The trend of cloud computing research in Nigeria revealed a majority of original researches and research interests are focused on Education and the Software-as-a-Service model of cloud computing. Although, cloud computing research in Nigeria is still very nascent, the publication trends portend more growth in the research area in the nearest future.

**Key words:** Scientometrics, bibliometrics, cloud computing, research productivity, citation analysis, developing countries, emerging markets

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**Data Availability:** All relevant data are within the paper and its supporting information files.

## **INTRODUCTION**

Cloud computing is an internet-based service provision and consumption model virtualized resources, including infrastructure, platform and software, are delivered and accessed as services<sup>1</sup>. It is a ubiquitous and on-demand access to a configurable and elastic pool of computing resources that are provided and consumed with minimal users' and/or providers' involvement. The computing resources are provisioned as services grouped into three categories including, software, platform and infrastructure. The nomenclature describing these cloud services are Software-as-a-Service (SaaS), Infrastructure-as-a-Service (IaaS) and Platform-as-a-Service (PaaS). More sophisticated services are currently being provided via the cloud computing model, as an extension of the traditional three delivery models. The term XaaS was coined to describe a collection of anything (or everything) as-a-Service; where 'X' stands for Anything/Everything that can be provided as services. Some examples of XaaS include Database as a service (DBaaS), Desktop-as-a-Service, Functions-as-a-Service, Business process as a service (BPaaS), Desktop as a service (DaaS), Data Analytics as a Service (DAaaS) etc. The overall benefits of the cloud computing can be summarized as follows: Easier manageability, lower cost of maintenance, quicker time-to-market for application development and reduction in the development cost<sup>2,3</sup>.

A number of developed countries are already reaping the benefit of cloud computing, particularly since its formal introduction in 2006 and numerous advancements have since being recorded including web-of-things (WOT)<sup>4</sup>. Cloud computing has the potential to positively impact on the socio-economic landscape of developing countries, particularly in the domains of government, education, health-care and commerce, while eliminating the need upfront investments in computing infrastructure<sup>5-7</sup>. Although, studies report that an increasing number of Small and Medium Scale Enterprises (SMEs) in some emerging economies are already adopting cloud computing to enhance business activities, there is need to multiply this effect by giving more local small-scale enterprises a platform to participate in the on-going IT revolution<sup>8-11</sup>. Currently, these resource-constraint SMEs in emerging economies contribute both directly and indirectly to the national Gross Domestic Products (GDP), through employment generation and wealth creation<sup>12</sup>. The contributions can be sustained and possibly increased by the addition of technology input factors, provided via the cloud computing model, to enhance productivity and returns, with premium service delivery and customer satisfaction. For

example, small information and technology firms can benefit from affordable access to advanced software development tools and environments, underlying hardware requirements and a global market for service provisioning to increase their revenue streams<sup>13</sup>.

The rising interest in cloud computing in recent times has necessitated huge financial and intellectual investments in research and development efforts in cloud computing and many emerging economies, including Nigeria, are not left out<sup>14</sup>. There seem to exist a positive correlation between the volume of research and development endeavours into cloud computing and the success of cloud computing in the developed countries like the United States and China. For example, the United States and China rank among the top countries with the largest research outputs in cloud computing<sup>7,15</sup> and at the same time the biggest players in the cloud computing domain are US-based and China-based companies like Amazon, Microsoft, Google and Alibaba. An observation is that a number of emerging economies, especially in Africa, still lags behind in cloud computing research and development endeavours<sup>7</sup>. Therefore, it becomes necessary to measure the contributions of emerging economies countries to cloud computing research. Hence the aim of this paper is to study Nigeria's contribution to the global cloud computing research. This aim is pursued by employing a bibliometric approach to measure the cloud computing research output from Nigeria. The world economic forum in 2017 released the 2016 global information technology report. This report ranked Nigeria at the 119th position on the list of countries based on the network readiness index. The report revealed that there was no significant change from Nigeria's position in the previous year, i.e., 2015, although the Readiness sub-component of the index placed Nigeria six-steps upward to the 117th position out of 139 countries. The upward movement was accounted for by Nigeria attaining its full mobile coverage in 2016 with the broadband prices slightly more affordable. Following the slight increase in broadband coverage, the growth of cloud computing in Nigeria is expected to increase; this is without prejudice to the various technical and regulatory barriers that may inhibit full-scale adoption of cloud computing<sup>9,16</sup>.

Bai and Dong<sup>15</sup> performed a bibliometric analysis of 89 papers covering cloud computing published in Chinese core periodicals in the Chinese Journal Full-text Database (CNKI) within the period 1993 to 2010. The study analyzed author and subjects spread, as well as the extent of financial support, research attainments and collaborations. Interested in the widespread and inter-disciplinary nature of cloud computing research, Heilig and Vob<sup>17</sup> employed scientometric means to

empirically understand the evolution and current state of cloud computing research. Based on data obtained from the Scopus database between 2008 and 2013, the study revealed the publication patterns, research productivity and research impact of cloud computing research. Cai *et al.*<sup>7</sup> quantitatively reviewed the global cloud computing research progress by analyzing data comprising 10,579 documents obtained from the IEEE Xplore, Science Citation Index Expanded and Conference Proceedings Citation Index-Science databases between 2007 and 2013. The study showed that China and the US are the most productive countries in terms of cloud computing research outputs. Another study by Gupta *et al.*<sup>18</sup> analyzed 21397 cloud computing publications as indexed in the Scopus databases from during 2004-2013. The results obtained agrees with those of Cai *et al.*<sup>7</sup> that the China and the United States are the most productive cloud computing research countries, while also reporting that the cloud computing research grows at a rate of 96% per annum as corroborated by Jan *et al.*<sup>19</sup>. Jan *et al.*<sup>19</sup> investigated the growth of cloud computing research literature during the years of 2009 through to 2013 as obtained from the 1879 publications indexed in the web of science (WoS) database. The scope of the study was limited to India and also the top ten cloud computing research active countries that include the United States, China, Australia, England, Taiwan, South Korea, Spain, Germany, Canada and Japan. The result of the analysis puts India as the least productive country as far as cloud computing is concerned.

With a more specific focus, Haag and Eckhardt<sup>20</sup> performed a Scientometric analysis of 52 journals and proceedings to 36 articles which were categorized systematically to provide insights into the adoption of cloud services by organizations. The study proposed five new areas of research based on the result of the analysis that describes the determinants and consequences of the organization-wide adoption of cloud services.

The scope of the studies reviewed mainly covers the global cloud computing research outputs, which trumps the revealing of the research performance of emerging economies. This study explores the research performance of an emerging economy like Nigeria by adopting some of the descriptive statistical measures employed in previous studies and used data from the Scopus database.

## **BIBLIOMETRIC AND CONTENT ANALYSIS**

The data that was analyzed in order to answer the research questions posed in this study was downloaded from the Scopus database. The Scopus database was selected to

retrieve documents related to cloud computing research because it is the largest abstract and citation database of peer-reviewed literature covering more than 22000 titles from over 5000 publishers; comprising journals, conference and workshop proceedings. The Scopus database currently indexes about 70 million records in various fields including medicine, science, technology, art and social sciences, besides over 12 million author profiles<sup>21</sup>.

Specific keywords containing "cloud" and "computing" were formulated to retrieve relevant documents that included the Boolean operators OR. The search query was framed as follows: TITLE-ABS-KEY ("cloud\* computing\*") AND (EXCLUDE (PUBYEAR, 2018) OR EXCLUDE (PUBYEAR, 2017)) and (LIMIT-TO (AFFILCOUNTRY, "Nigeria")). The country was limited to Nigeria to capture the scope of this study. Meanwhile, the years "2017" and "2018" were excluded because as at the time of performing the search (November 26, 2017, 12:38 PM) there would be some documents that are yet to be included in the database for both years. Also, there was no specific time restriction imposed prior to 2016, as the researchers were also interested in knowing when the first research documents originating from Nigeria was published.

The use of the asterisk (\*) was employed (as in cloud\* computing\*) as a wildcard to capture all relevant variants of the search term. Also, quotation marks (" ") were included to ensure that only concurrent occurrence of the words "cloud\* and computing\*" were included in the retrieved documents. This was to eliminate the chances of returning documents referring to the cloud (as in sky) and computing relating to the calculation of the movement of the clouds or other celestial bodies. The search returned documents where the search strings are contained in the Title, Keyword and Abstract, these three fields succinctly reflects the content of a research document. Initially, the search result returned 52 documents. However, to ensure that the corpus contained relevant documents in line with the purpose of the study, the abstract, keyword and title of all the documents returned were reviewed. Through this process, one paper was excluded because it focused more on online services in the banking sector, leaving the 51 documents that formed the corpus of document used for this study. The data points for the 51 documents that were considered in the study included Authors, Title, Year of publication, Source title, Number of Citations, Affiliations, Abstract, Author Keywords, Index Keywords, Publisher, Language of Original Document and Document Type. The 51 documents were all written in the English Language, particularly since English is Nigeria's official Language. The extracted data were exported as a Comma Separated Version (CSV) file format for convenience and was

accessed through the MS Excel application for further analysis. The data used for this study is available at <http://bit.ly/Nig-cloud-research-data>.

Data pre-processing operations were performed on the data to ascertain its veracity before analysis was carried out. During the data pre-processing operation, it was observed that some institutions appeared as separate institutions due to how the bibliometric information was captured *ab initio*. For example, "Federal University of Technology, Minna" appeared also as "Federal University of Technology Minna". The same was also observed for authors' name where the Azeta, A.A also appeared as Ambrose, A.A, both refereeing to the same individual. The authors had to ensure that such research documents from such institutions or authors were grouped to count for the institutions and authors as the case may be.

In order to answer the research questions posed in this study, content analysis and bibliometric methods were employed. This study used relevant statistical metrics that comprise the annual research outputs, publishers, source titles and the number of citations, as well as top productive institutions, authors and countries with most the collaborations with Nigeria. Still, content analyses of each document in the corpus were also performed to determine the specific trends of cloud computing research activities originating from Nigeria.

**National distribution of total research outputs:** The first research question aims to determine the national distribution of cloud computing research outputs. Based on the corpus of data used for this study, it is observed that the earliest research article originating from Nigeria was published in the proceedings of the IEEE international symposium on parallel and distributed processing workshops and PhD forum that held in May, 2011. The document, authored by Okorafor<sup>22</sup> is titled- A fault-tolerant high-performance cloud strategy for scientific computing. Figure 1 shows the number of articles from 2011-2016 and reveals the complete trends of publications across these years.

Although, the growth trend of research output from Nigeria has been positive over the years, it is noteworthy the country still lags behind in global cloud computing research contributions. For example, cloud computing research first appeared in the Scopus database much earlier than 2011, meanwhile, the first research document on cloud computing published from Nigeria was in 2011. In 2011, Nigeria had only 2 publications out of approximately 4510 documents on the subject matter from the global community of research outputs

in the same year. However, the growth trends in the last three years give a ray of hope that cloud computing research productivity in Nigeria will be on the increase in the future.

**Active international collaborations:** The aim of the second research question is to identify the international collaborations of cloud computing researchers in Nigeria. The dataset used revealed that Nigeria has collaborated with 14 countries on cloud computing research (Fig. 2). However, Nigerian researchers collaborate mostly with researchers from Malaysia, with 13 out of the 51 publications (25.5%). The institution in Malaysia that has the most collaboration with Nigeria is the Universiti Teknologi Malaysia of Malaysia (collaborating on 10 publications). In other words, Universiti Teknologi Malaysia alone accounts for 19.6% of all of the Malaysian collaborations with Nigeria. On the other hand, the Federal University of Technology, Minna emerged as the Nigerian institution with the most collaboration with Malaysia is (5 publications) followed by Ahmadu Bello University (3 publications) and Abubakar Tafawa Balewa University (3 publications). Other countries that have collaborated with Nigeria on cloud computing research include-Japan, United Kingdom, United States, Viet Nam and South Africa with 2 publications each

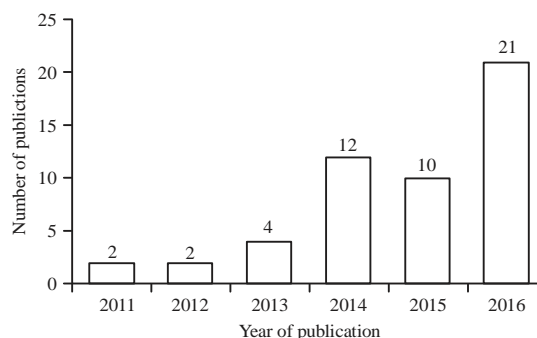


Fig. 1: Publication spread per year since 2011

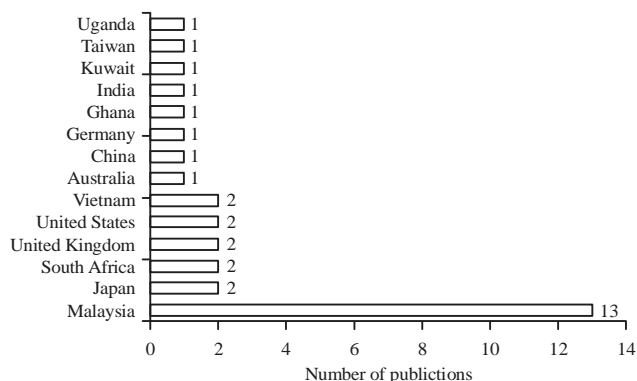


Fig. 2: Collaborating country

(3.92%). Meanwhile, other countries like Uganda, Taiwan, Kuwait, India, Ghana, Germany, China and Australia have collaborated on one publication each with Nigeria.

**Productive research institutions in Nigeria:** The second research question was posed to determine the most research-productive institutions in the cloud computing research in Nigeria. To answer research question-3, the authors investigated the number of publications attributed to Nigerian institutions. Thirty institutions have contributed to cloud computing research in Nigeria. Meanwhile, the analysis depicted in Fig. 3 shows the top ten institutions with Covenant University, Ota, emerging as the highest number of research publications on cloud computing with 14 publications out of all 51 (27.45%) followed by the Federal University of Technology, Minna (6 publications- 11.76%). Other institutions include the University of Ibadan (4 publications-7.84%); Abubakar Tafawa Balewa University (4 publications-7.84%). Three publications each (5.88%) originated from the following institutions-Ahmadu Bello University, Federal University of Technology, Akure, Federal College of Education Technical, Gombe and Lagos State Polytechnic, while Bayero University and Obafemi Awolowo University contributed 2 publications each (3.92%). The

remaining institutions contributed only one publication each to cloud computing research in Nigeria.

**Leading publication outlets:** One of the objectives of this study is to determine the form and the publication outlet of cloud computing research originating from Nigeria. This quest was captured in research question 4 and it includes ranking the publishing outlets in terms of the number of published documents. Table 1 shows the top 7 publishers that have published output of cloud computing research from Nigeria. Springer Verlag has published the highest (12 of 51 publication-23.53%). The list is followed by Institute of Electrical and Electronics Engineers Inc. with 6 publications (11.77%). The following publishers have published 3 publications on cloud computing from Nigeria- Asian Research Publishing Network, CEUR-WS (publish mainly workshop proceedings), Elsevier, IGI global and Newswood Limited.

Table 2 shows the major sources where cloud computing research outputs from Nigeria have been published together with the citation count from the articles published by those sources. The Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) published the highest number of documents and also has the highest citation counts.

Table 1: Top 7 Publishers of cloud computing research by year

Publisher	2011	2012	2013	2014	2015	2016	Total
Springer Verlag	-	-	-	2	5	5	12
Institute of Electrical and Electronics Engineers	-	-	-	4	1	1	6
Asian Research Publishing Network	-	-	-	3	-	-	3
CEUR-WS	-	-	-	-	-	3	3
Elsevier	-	-	-	1	-	2	3
IGI Global	-	1	-	-	1	1	3
Newswood Limited	-	-	-	1	1	1	3

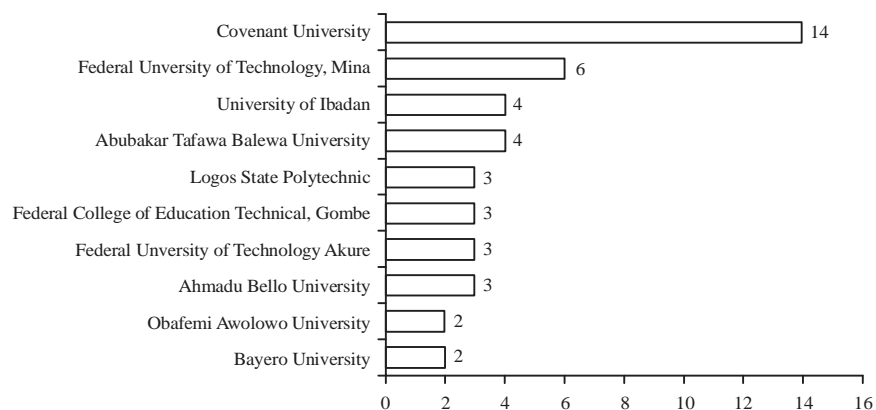


Fig. 3: Top institutions contributing to cloud computing in Nigeria



Table 2: Major sources

Rank	Source title	Pub count	Percentage (51)	Citation count
1	Lecture Notes in Comp. Sci.*	4	7.84	16
2	Lecture Notes in Eng. & Comp. Sci.	3	5.88	1
3	CEUR Workshop Proc.	3	5.88	0
4	Comm. in Comp. & Infor. Science	2	3.92	1
5	Frontiers in Artificial Intelligence & App.	2	3.92	1
6	Indian J. of Sci. & Tech.	2	3.92	1
7	J. of Theoretical & Applied Infor. Tech.	2	3.92	8
8	Neural Comp. & App.	2	3.92	6
9	PLoS One	2	3.92	12

\*Including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics, Pub: Publication

Table 3: Top authors and their affiliations

Author	No. of article	Citations	Avg. citation/article	Affiliation and country
Sanjay Misra	10	20	2.0	Covenant University, Ota
Haruna Chiroma	3	28	9.33	Federal College of Education (Technical), Gombe
Adewole Adewumi	3	1	0.33	Covenant University, Ota
Abdulsalam Ya'u Gital	3	1	0.33	Abubakar Tafawa Balewa University, Bauchi
Nicholas Omoregbe	3	1	0.33	Covenant University, Ota

Table 4: Top cited publications per year

Title	Source	Citations
Symbiotic organism search optimization based task scheduling in cloud computing environment	Abdullahi <i>et al.</i> <sup>25</sup>	33
The role of big data in smart city	Hashem <i>et al.</i> <sup>26</sup>	27
Acceptance and use of E-learning based on cloud computing: The role of consumer innovativeness	Nguyen <i>et al.</i> <sup>27</sup>	12
A fault-tolerant high performance cloud strategy for scientific computing	Okorafor <sup>22</sup>	11
Tasks scheduling technique Using league championship algorithm for makespan minimization in IaaS cloud	Abdulhamid <i>et al.</i> <sup>28</sup>	10

Interestingly, PLoS One, an open source multi-disciplinary journal, has published only two documents it has the second highest citation counts. The articles include the works of Abdulhamid *et al.*<sup>23</sup> and Abdullahi *et al.*<sup>24</sup> were both published in PLoS One in 2016 and have both been cited 6 times each.

**Most productive authors:** The fifth research question seeks to identify the top contributing authors to cloud computing research in Nigeria. Out of the 51 publications analyzed in this study, the authors found that there are 39 first authors whose originating country/territory is Nigeria (Table 3). The mean number of author per document is 3.08, while the median is 3. The spread of the number of authors per publication is as follows single authors (6, 11.76%), two authors (14, 27.45%), three authors (16, 31.37%), four authors (9, 17.65%), five authors (2, 3.92%), six authors (1, 1.96%), seven authors (1, 1.96%), eight authors (2, 3.92%). There are a total of 120 authors for all 51 publications. The authors observed that some authors had more than one affiliation and those authors were added to the countries and institutions that they are affiliated with. Table 4 shows the top 5 most productive authors (with three publication or more), their number of publications, citation count as well as their affiliation based on the dataset used in this study. Sanjay Misra of Covenant University, Ota Nigeria, emerged as the most productive

author with 10 publications and a citation count of 20 from all 10 publications (mean citation per document is 2.0).

**Citation impact:** The aim of the sixth research question is to reveal the impact of research output of cloud computing research in Nigeria measured quantitatively by the citation counts per article and per year. The result of the analysis shows that the papers with very high citations are those with foreign collaborators, particularly from Malaysia and Vietnam; they include Abdullahi *et al.*<sup>25</sup> and Hashem *et al.*<sup>26</sup> with 33 and 27 citations respectively; both articles were published in 2016. Table 4 shows top-cited publications since 2012, while Fig. 4 shows the citation spread per year since 2012.

**Research trends:** The last research question explores the trend of cloud computing research from Nigeria by performing content analysis on the corpus used for this study. The content analysis was based on the following four criteria: (1) The type of research publication; the goal of this was to ascertain whether the published document reported an original research or a review paper, etc., (2) The cloud domain each study focused on, (3) The evaluation approaches employed in the publications and (4) The application domain that the approaches and findings were applicable.

- Type of research document:** The survey the type of research that has been published in the area of cloud computing from Nigeria was carried out. Each document was reviewed and classified according to the following categories: original research, review and others (Fig. 5). It was found that 41 of the 51 publications (80.39%) on cloud computing from Nigeria are original research publications; whereas, review articles are 8 in number (15.69%). Other article types accounts for 3.92% of documents and includes a periodical (1 article by Oyelude<sup>29</sup>, in which the authors are highlighted the latest trends in cloud computing from the internet cybersphere and one document, i.e., Nekesa and Oyelude<sup>30</sup> was classified as a report of a 2016 standing conference of Eastern, Central and Southern African Library Associations, where the discussion centred around the possibilities of cloud computing as an important technology for modern libraries in Africa.
- Applicable cloud domain:** The documents used in this study were classified according to the popular cloud service models, including IaaS, PaaS and SaaS. Where a document is applicable to all three models, such documents were classified as general. Based on the analysis, 8 documents are classified as general (15.69%); 17 documents focused on IaaS (33.33%) and 6 documents (11.76%) focused on PaaS. SaaS was the focus of 19 documents (37.25%) and is the cloud model with the largest of the categories. Figure 6 depicts the document distribution by model. The following documents are categorised as belonging to general cloud computing: Mustapha *et al.*<sup>31</sup>, Amadi-Echendu *et al.*<sup>32</sup>, Hashem *et al.*<sup>26</sup>, Oyelude<sup>29</sup>, Ibukun and Daramola<sup>33</sup>, Ibrahim *et al.*<sup>34</sup>, Nekesa and Oyelude<sup>30</sup> and Amadi-echendu and Boglo<sup>35</sup>.

Publications belonging to the IaaS categorisation includes works of Abdullahi and Ngadi<sup>24</sup>, Gabi *et al.*<sup>36</sup>, Abdulhamid *et al.*<sup>37</sup>, Usman *et al.*<sup>38</sup>, Sule<sup>39</sup>, Okorafor<sup>22</sup>, Udanor *et al.*<sup>40</sup>, Sodiya and Adegbuyi<sup>41</sup>, Mojisola<sup>42</sup>, Abdullahi *et al.*<sup>43</sup>, Abdulhamid *et al.*<sup>44</sup>, Abdulhamid *et al.*<sup>23</sup>, Dayo *et al.*<sup>45</sup>, Waziri *et al.*<sup>46</sup>, AlShahwan *et al.*<sup>47</sup>, Abdullahi *et al.*<sup>25</sup> and Abdulhamid *et al.*<sup>28</sup>. PaaS are the focus of the following research publications: Akinwunmi *et al.*<sup>48</sup>, Ajayi *et al.*<sup>49</sup>, Nguyen *et al.*<sup>27</sup>, Jambhekar *et al.*<sup>50</sup>, Mohammed and Hamada<sup>51</sup> and Tabot and Hamada<sup>52</sup>.

Meanwhile, publications representing the SaaS category are as follows: Aliyu *et al.*<sup>53</sup>, Achumba *et al.*<sup>54</sup>, Azeta<sup>55</sup>, Ayeni and Misra<sup>56</sup>, Gital *et al.*<sup>57,58</sup>, Boyinbode and Akintade<sup>59</sup>, Ifijeh<sup>60</sup>, Adewumi *et al.*<sup>61</sup>, Balogun *et al.*<sup>62</sup>, Oludele and Oluwabukola<sup>63</sup>, Daramola *et al.*<sup>64</sup>, Bello and Reich<sup>65</sup>, Nguyen *et al.*<sup>66</sup>, Adeyemo *et al.*<sup>67</sup>, Olokunde and Misra<sup>68</sup>, Ayeni *et al.*<sup>69</sup>, Osofisan *et al.*<sup>70</sup> and Azeta *et al.*<sup>71</sup>.

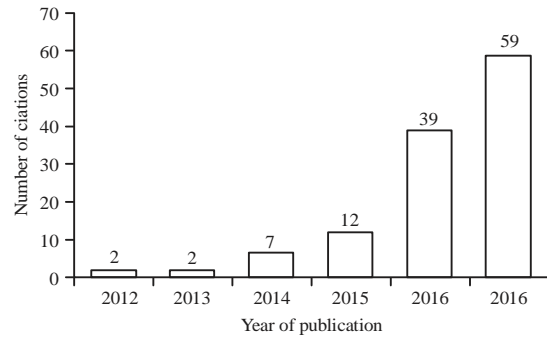


Fig. 4: Citation spread by year

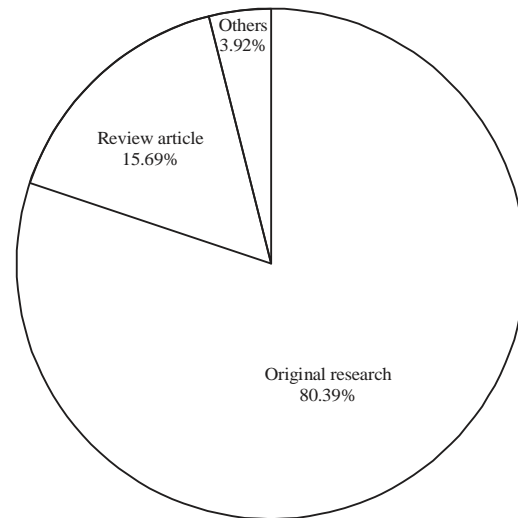


Fig. 5: Documents distribution based on research type

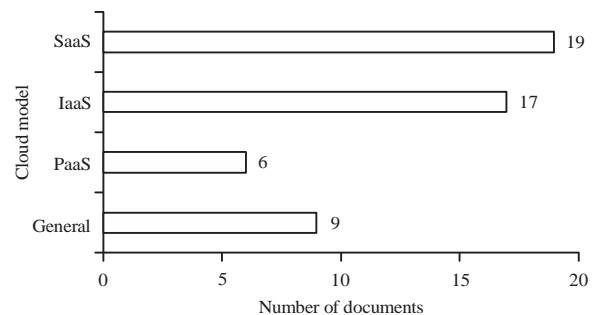


Fig. 6: Documents distribution based on cloud model

- Evaluation approaches:** The authors also reviewed the evaluation approaches used in the documents of this study. The evaluation types were classified into Experiments, Questionnaires and Statistical Analysis, Illustrative examples, Functional Testing and comparative analysis. The breakdown is as follows: 23 documents (45.09%) employed simulation experiments and they include: Okorafor<sup>22</sup>, Gital *et al.*<sup>58</sup>, Daramola *et al.*<sup>64</sup>,



Akinwunmi *et al.*<sup>48</sup>, Bello and Reich<sup>65</sup>, Udanor *et al.*<sup>40</sup>, Abdulhamid *et al.*<sup>28</sup>, Abdulhamid *et al.*<sup>23</sup>, Azeta *et al.*<sup>71</sup>, Nguyen *et al.*<sup>66</sup>, Sodiya and Adegbuyi<sup>41</sup>, Ajayi *et al.*<sup>49</sup>, Adeyemo *et al.*<sup>67</sup>, Abdulhamid *et al.*<sup>44</sup>, Sule<sup>39</sup>, Achumba *et al.*<sup>54</sup>, Abdullahi *et al.*<sup>25</sup>, Dayo *et al.*<sup>45</sup>, AlShahwan *et al.*<sup>47</sup>, Abdullahi and Ngadi<sup>24</sup>, Gabi *et al.*<sup>36</sup>, Gital *et al.*<sup>57</sup> and Aliyu *et al.*<sup>53</sup>.

Illustrative examples were used in 5 documents (9.80%), as in Amadi-Echendu *et al.*<sup>32</sup>, Adewumi *et al.*<sup>61</sup>, Boyinbode and Akintade<sup>59</sup>, Jambhekar *et al.*<sup>50</sup> and Ifijeh<sup>60</sup>. Questionnaire and statistical analysis were employed in 3 documents (5.88%), including Nguyen, Nguyen, Pham, *et al.*<sup>27</sup>, Oludele and Oluwabukola<sup>63</sup> and Ayeni and Misra<sup>56</sup>. Whereas, two documents reported testing as the evaluation approach (Mohammed and Hamada<sup>51</sup>, Balogun *et al.*<sup>62</sup>), while only one document (i.e., Waziri *et al.*<sup>46</sup>) used comparative analysis. Seventeen documents (33.33%) did not report any form of evaluation. Figure 7 shows the frequency distribution of documents based on evaluation approaches used.

- **Application contexts:** This study also presents the specific application context that has been the focus of cloud computing research from Nigeria. The authors classified the documents into the most suitable application domain based on the information provided in each paper. The analysis shows that cloud computing research outputs from Nigeria has contributed to the following areas; Education, Learning and Research Development with these 15 documents: Sule<sup>39</sup>, Tabot and Hamada<sup>52</sup>, Mohammed and Hamada<sup>51</sup>, Nguyen *et al.*<sup>27</sup>, Ya' *et al.*<sup>58</sup>, Azeta *et al.*<sup>71</sup>, Ifijeh<sup>60</sup>, Nguyen, Nguyen and Misra<sup>66</sup>, Ibrahim *et al.*<sup>34</sup>, Udanor *et al.*<sup>40</sup>, Azeta<sup>55</sup>, Boyinbode and Akintade<sup>59</sup>, Olokunde and Misra<sup>68</sup>, Mustapha *et al.*<sup>31</sup>, Gital *et al.*<sup>57</sup>, amounting to 29.41%-this included applications for virtual collaborative platforms.

Others include: Task Scheduling and Optimization, with 7 publications (13.72%) as in Abdullahi and Ngadi<sup>24</sup>, Gabi *et al.*<sup>36</sup>, Abdulhamid *et al.*<sup>44</sup>, Abdullahi *et al.*<sup>25</sup>,

Abdulhamid *et al.*<sup>28</sup>, Abdulhamid *et al.*<sup>37</sup> and Abdulhamid *et al.*<sup>23</sup>. Eight documents (15.67%) could be classified as belonging to Cloud Infrastructure, Service Provisioning, including concepts such as service discovery, composition and pricing. They include: Okorafor<sup>22</sup>, Abdullahi *et al.*<sup>43</sup>, Bello and Reich<sup>65</sup>, Akinwunmi *et al.*<sup>48</sup>, Amadi-echendu and Boglo<sup>32</sup>, Aliyu *et al.*<sup>53</sup>, Hashem *et al.*<sup>26</sup>, Usman *et al.*<sup>38</sup>.

Security had 6 documents (11.75%) including Waziri *et al.*<sup>46</sup>, AlShahwan *et al.*<sup>47</sup>, Dayo *et al.*<sup>45</sup>, Jambhekar *et al.*<sup>50</sup>, Achumba *et al.*<sup>54</sup> and Onwudebelu and Chukuka<sup>72</sup>, Health management had 5 documents (9.80%) as with Sodiya and Adegbuyi<sup>41</sup>, Ayeni and Misra<sup>56</sup>, Adeyemo *et al.*<sup>67</sup>, Ayeni *et al.*<sup>69</sup>, Ajayi *et al.*<sup>49</sup>. Others include mobile banking and e-commerce applications (2 documents, 3.92%); as well as Library Science with one document (1.96%) and Energy (1 article, 1.96%). The remaining six articles could not be classified accordingly as they do not contain any specific information in this regard. Figure 8 shows the documents distribution based on application areas of cloud computing research efforts from Nigeria.

**Key findings:** Figure 1 shows that there is an increase in cloud computing research publications from Nigeria since 2011, with a nearly double increase in the number of publications from 2015 to 2016. The increase in interest in cloud computing can be explained by the perceived benefits cloud computing portends for developing countries like Nigeria<sup>27</sup>. For Nigeria, the increase in broadband access and the explosive growth of the mobile broadband industry, which is the highest in Africa, as well as the wide range of commercial cloud applications can also pave the way for cloud computing adoption in Nigeria.

Second, it was also observed from Fig. 2 that there are low international collaborations, particularly with researchers and institutions based in Europe and America. However, the citation impact of the top five articles on cloud computing as

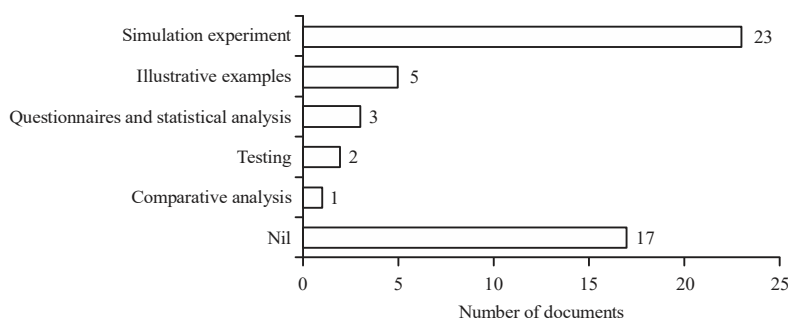


Fig. 7: Document distribution based on evaluation approaches used

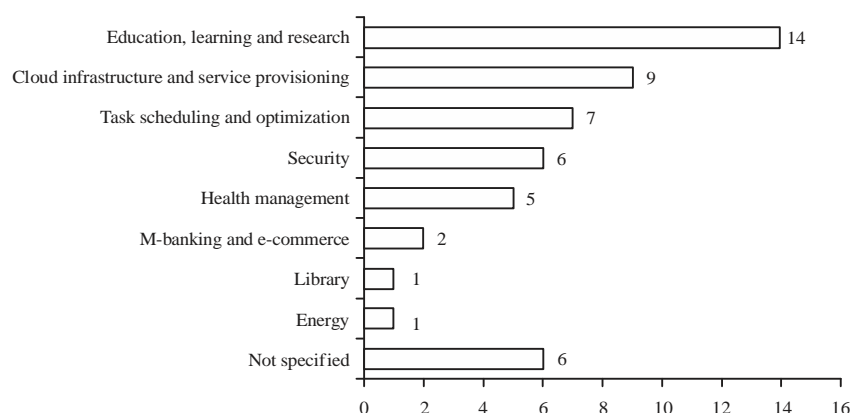


Fig. 8: Documents distribution based on application context

presented in Fig. 4 reveals the citation counts grew exponentially through the years, with a total of 160 citations from all 51 documents since 2012. Therefore, publishing in high-quality open source journal such as PLoS One has the potential to increase citation rates for Nigerian researchers as shown in Table 2.

The use content analysis to establish the research emphasis of Nigerian researchers in the cloud computing domain revealed that a major emphasis was on original research as confirmed by the over 80% of research documents that have proposed and evaluated new models, algorithms, and/or approaches in the cloud computing domain. Furthermore, the majority of the publications reported the used experiments as the primary evaluation approach. In this wise, these researchers have used CloudSim, as well as, Sun wireless toolkits 3.0 or NS2 simulators for the experimental evaluation of the approaches they proposed.

Finally, cloud computing research efforts from Nigeria have focused largely on SaaS compared to other models, meanwhile, the application domains where proposals have been made covers a range of areas including health, cloud infrastructure and service provisioning, security and privacy concerns of cloud computing. However, there seems to be a widespread interest in the potential of cloud computing to the impact of the quality of education delivery. This interest is justified in noting that a number of developing countries, like Nigeria, are plagued by inadequate IT infrastructure to support the development of education<sup>2</sup>. In this case, cloud computing portends a technology acquisition model with the potential to support IT demands of education development in developing countries. As Nigeria intensifies research efforts in cloud computing in the nearest future, the impact of these research endeavours ought to impact on the quality of education,

enrolment and Science, Technology, Engineering and Mathematics (STEM) education, as well as other vital aspects of the society.

### THREATS TO VALIDITY

There existed a number of threats to the validity of this study. First, similar to previous studies, for example Thelwall and Fairclough<sup>73</sup> and Guan and Ma<sup>74</sup>, the scope of the study was limited to one country (Nigeria) and a particular database (Scopus). It is not impossible that the results obtained from the analysis could have been different if data was retrieved from more than one database, e.g., ISI Web of Science (WoS), INSPEC or EBSCO host. Also, the choice of one country Nigeria is based on the researcher's interest to understand and report the state of cloud computing research in Nigeria, which has also been done in similar studies related to computer science, e.g., Gupta and Dhawan<sup>75</sup>.

Secondly, it is possible that more documents could have been retrieved if a different search term that relates to cloud computing was used, rather the researchers' depended on the search term "cloud\* computing\*". More documents could have been retrieved if the search field was not limited to title, abstract and keyword alone but also included the body of the article itself. However, even keywords alone are sufficient bibliometric field to decipher the contents of a research article<sup>76</sup>.

Lastly, although a carefully executed content analysis was carried on the data retrieved, more complex bibliometric analysis methods, e.g., author co-citation analysis, the h-index and the g-index could have provided more insights into the cloud computing research landscape in Nigeria. However, this study employed simplistic bibliometric indicators such as

document counts and citation counts to answer the research questions posed in this study. The quantity and impact of cloud computing research in Nigeria were assessed viz a viz research institutions, authors and sources where these research articles were published.

### **CONCLUSION**

Cloud computing holds innumerable benefits for developing countries to the extent that it has the potential to fast-track national development and reduce the digital divide experienced by many emerging economies. A national commitment to research and development is vital to reap the benefits of emerging innovations in science, technology and engineering, like cloud computing. This study measured the quantity, impact and research emphasis of cloud computing research in Nigeria using bibliometric and content analysis methods for the duration between 2011 (when the first research was published) and 2016. This study exposed the contributions of institutions, authors and collaborators of cloud computing research activities in Nigeria, as well as the sources, citation counts and research trends of the research articles. Following the bibliometric analysis carried out, this study concludes that cloud computing research in Nigeria is extremely nascent, comparing the 51 identified documents in Scopus, compared to the global research output of over 30000 documents during the same period (2011-2016). However, given the current growth trends, the volume of research outputs from Nigeria is expected to increase in the coming years.

### **SIGNIFICANCE STATEMENT**

This study analyses the contribution of Nigerian's researchers to cloud computing research literature. This study reveals the efforts towards and trends of cloud computing research in Nigeria and will stimulate the interest of younger researchers from Nigeria in the cloud computing research domain. Although, cloud computing research in Nigeria is still very nascent, the publication trends portend more growth in the research area in the nearest future.

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