**IAES International Journal of Artificial Intelligence (IJ-AI)**
Vol. 13, No. 1, March 2024, pp. 597~609
ISSN: 2252-8938, DOI: 10.11591/ijai.v13.i1.pp597-609 

# Artificial intelligence research in Nigeria: Topic modelling and scientometric analysis

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**Article Info**

***Article history:***

Received Sep 20, 2022
Revised May 24, 2023
Accepted Jun 3, 2023

***Keywords:***

Artificial intelligence
Natural language processing
data mining
Scientometric analysis
Topic modelling

**ABSTRACT**

In developing countries such as Nigeria, artificial intelligence (AI) research has the potential to drive rapid advancement in various aspects of development, including the economy and technology. However, it is crucial to understand the focus of Nigerian AI researchers and identify unexplored areas of research that could lead to unprecedented development. To address this need, we used natural language processing, machine learning, and statistical algorithms to investigate the main areas of interest of Nigerian AI researchers. We identified ten topics and used scientometric analyses to reveal key concepts, keyword co-occurrences, and authorship networks. Our study found that Covenant University was the most prolific institution, with 375 publications, followed by the Federal University of Technology with 135 publications and the University of Ibadan with 121 publications. Overall, our research provides valuable insights into the structure and progression of AI research in Nigeria and highlights areas for improvement.



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## 1. INTRODUCTION

According to various studies, technology innovation has largely benefited people worldwide, particularly with the emergence of computer systems and machines that are designed to imitate human thought processes [1], [2]. One of the remarkable advancements in this area is artificial intelligence (AI), which involves the development of computer systems capable of performing tasks that typically require human intelligence. The primary objective of AI is to enhance computer functions associated with human cognition, such as problem-solving, learning, and reasoning. As defined by experts in the field, AI is a field of computer science that aims to create intelligent machines that can function and interact with their environment in the same way as humans [3].

During the recent global health crisis, AI aided the healthcare system by easily monitoring the transmission of the virus and identifying high-risk patients, and it was also suitable for real infection prevention and control [4]. Moreover, the banking and finance sector is undergoing a massive transformation as a result of the obvious arrival of AI applications. Humans are being replaced at an increasing rate by intelligent systems in loan processing and even fraud detection. MasterCard, for example, by analysing a wide range of data points, uses AI-based decision intelligence technology to track fraudulent transactions. The rise of AI has assisted various companies in generating value in a variety of business aspects such as automation, getting useful information by mining data which can be used for decision-making, also creating and implementing new products and services [5]. AI has also made significant contributions to education by providing customized learning support systems to students based on their learning status, interests, or personality attributes [6].

Utilizing AI in education has opened up new avenues for creating a more effective learning process and improved digital learning systems or environments [7].

Many countries in the world have adopted the use of AI research to solve many problems in their country. Mexico used AI in its tax collection procedures. The government agency called tax administration service (SAT) developed a rapid system that uses AI algorithms to integrate information from diverse sources. The platform's goal was to diagnose organizations that simulate operations or evade their obligations with a level of certainty, and to enhance the mechanism to ensure taxpayer compliance with tax obligations [8]. The National Institutes of Health in the United States created AiCure, an intelligent program that monitors patients' medications and conditions [9]. TymeBank, a "digitalized bank" in South Africa, can connect with customers online through AI. No human beings work in call hubs or branches and the bank has been able to provide services to customers at a low cost [10]. However, the global market for AI systems is in a transitional phase, with innovative opportunities to enhance products and economic growth across the globe. As a result, in times of slowing economic growth, AI plays a big role in the development of the global economy [11].

The integration of AI research into various sectors in Nigeria is expected to bring significant changes to the country. Specifically, the application of AI in auditing processes is likely to impact materiality and risk analysis, internal control assessment, audit planning, evidence evaluation, contracting, account analysis, opinion selection, report issuance, and other related activities [12]. AI research can change the state of security in Nigeria by automating security. To achieve this, machine learning, big data, and anti-dark skin bias facial recognition software would have to be implemented [13]. AI research can be used to mitigate the issue of fraudulent activities in the banking sector of Nigeria. Merchants, for example, may participate in these activities. Some may not follow through on the agreement to deliver the products after customers have paid for the products. AI can use techniques such as computer vision and pattern-matching algorithms to process the validity of knowing your customer (KYC) documents. Internet activity of the merchant can also be examined, to detect potentially fraudulent behaviour [10]. AI research has the potential to make Nigeria's system of education intelligent. Self-teaching classrooms can be introduced. Machines can interact with students to teach them and answer questions. Admittedly, cutting-edge technology innovations can be incorporated into modern classrooms to provide students with the adequate educational environment possible. Virtual networks can be used to create an ideal learning environment for students and teachers [14]. AI research can be used to create virtual assistants to assist with daily responsibilities, reducing the burden on administrative workers in Nigeria. AI can be used to build intelligent machine learning algorithms from data input and improve their capacity to forecast the needs of the end-user. AI-powered bots are capable of comprehending and carrying out numerous requests. AI research can help to enhance the Nigerian automobile industry through innovative development such as self-driving vehicles, and automatic vehicle speed maintenance through cruise control. These would greatly benefit the nation by preventing accidents [15]–[17]. Finally, current AI trends include, but are not limited to, quantum AI, reinforcement learning, natural language processing, conversational AI, and robotic process automation. The subsequent sections are: section 2 discusses the conceptual underpinning which gives an overview of AI in Nigeria and discusses several kinds of literature that relate to the topic. Section 3 discusses the methodology which introduces the various techniques and methods that are used in this research. Section 4 discusses Topic Modelling and its application in conducting the analysis discussed in this study. Section 5 discusses the scientometric analysis which was used to get the keyword co-occurrence, co-authorship, and co-citation results. Section 6 discusses the recommendation for AI future research in Nigeria, which suggests areas that can be researched more by researchers to boost AI in Nigeria. Section 7 gives the conclusion of the research. It briefly summarizes the research.

## 2. CONCEPTUAL UNDERPINNINGS

The use and application of AI have been documented in various countries. For instance, in China, AI based on deep learning was utilized to improve breast cancer screening and imaging diagnosis by [18]. The study aimed to develop a more accurate and efficient model for breast cancer image screening and diagnosis by using convolution and deconvolution neural networks (CDNN). In addition to the use of fuzzy c-means clustering algorithm (FCM) for enhancing breast cancer images and experimental evaluation, a study by [19] reported the application of AI through deep learning to detect Pulmonary Nodules in chest computed tomography (CT). The research utilized a self-built nodule database from Tianjin Medical University General Hospital in China, and the obtained results were compared to those of radiologists. The study showed that both AI and radiologists had a 100% detection rate for the nodules. However, the sensitivity of AI on nodule detection was significantly higher than that of radiologists. These findings are in line with the benefits of AI-assisted medical diagnosis and the potential for improved accuracy in medical imaging analysis. In their study, researchers cited in [20] developed a malaria outbreak prediction model using machine learning for health centres in Limpopo, South Africa. They utilized two datasets for the study. The first dataset consisted of

monthly malaria incidence that occurred over 21 years, while the second dataset was monthly weather data containing the effective drought index (EDI), available water resources index (AWRI), and monthly rainfall/precipitation. The researchers chose the best algorithm based on computation time ranking factor and decided to use the decision tree algorithm to build the malaria prediction system. Another study by researchers cited in [21] used multispectral images from the Landsat 8 satellite to detect pest diseases in coffee production in Colombia. The researchers created various band combinations and calculated the normalized difference vegetation index (NDVI) to identify the best combination for crop detection and disease identification. Lastly, researchers cited in [22] developed a decision support system to predict Tuberculosis prevalence in South Africa. They used a Bayesian network to aggregate, analyse, and mine data from the health department of Mpumalanga Province. A web application was developed, and the model was able to estimate the likelihood of contracting tuberculosis based on location, age group, and gender. Meanwhile, [23] used various classification techniques to predict the probability of a person being infected by the Ebola Virus. Hybrid models with classifiers such as stochastic gradient descent, random forest (RF), and K-nearest neighbour (KNN) classifier were recommended. All of these studies demonstrate the potential for AI to improve healthcare and disease detection in different countries.

Several studies have explored the potential of AI to improve operations in Sub-Saharan Africa, including academic libraries. For instance, a review by [24] examined the benefits and drawbacks of AI in academic libraries in the region. The study discussed various features of AI, such as machine learning, automation, natural language processing, pattern recognition, and expert systems, and highlighted several opportunities for AI applications in libraries, including cataloguing, indexing, automation, and collaboration. The study also identified several drawbacks, including reduced employment opportunities, potential malfunctioning, human error, and negative impacts on younger generations. Another study by [25] used machine learning techniques to examine the prevalence of anaemia in children and adolescents in Brazil, Russia, India, and South Africa (BRICS) countries. The study found that machine learning methods, such as discriminant analysis (DA), K-nearest neighbours (KNN), classification and regression trees (CART), support vector machines (SVM), and random forest (RF), could help policymakers identify high-priority areas for intervention. While previous studies have used predictive models for various disorders, including acute appendicitis, diabetes, and multiple sclerosis, the use of machine learning for anaemia prevalence is still limited. In this paper, we focus on the state of AI research in Nigeria and make recommendations for future research using scientometric analysis and semantic text clustering techniques.

## 3. METHODOLOGY

To gain a thorough grasp of the types of study that Nigerian researchers conduct, particularly concerning some selected AI fields such as computer vision, image processing, natural language processing, deep learning, big data analytics, optimization methods, convolutional neural networks, AI, recurrent neural networks, generative models, recommender systems, data mining, data science, text mining, text analytics, data analytics and so on, we explored the connections between Nigeria researchers and the content of their research. To explore the researchers, the outputs, the quality of research and so on we used the scientometric analysis [26], and to complement this, the Topic modelling [27] techniques in Natural language processing were used to analyse the textual contents of their research publication. The methodology workflow of the research is shown in Figure 1. The first step is to retrieve data from the Scopus database. After this, three different techniques were applied to the data namely descriptive analytics, scientometric analysis, and content analysis. Descriptive analytics was used to reveal the main information of articles used for the research and give a statistical background to the research. The scientometric analysis helped to reveal the authors and the important themes in the research. Finally, the content analysis involved using a topic modelling algorithm which is the latent dirichlet allocation (LDA) to shine the light on the future research direction on AI in Nigeria.

– Data collection

To cover a wide range of publications for Nigeria A.I.-related publications, the Scopus database was used. It is the single largest database for abstract and indexing that is produced by Elsevier Co [28]. At the initial search in the Scopus database, the search criteria used include, TITLE-ABS-KEY ("Computer Vision" OR "Image Processing" OR "Natural Language Processing" OR "Deep Learning" OR "Big Data Analytics" OR "Optimization Methods" OR "Convolutional Neural Networks" OR "Artificial Intelligence" OR "Recurrent Neural Networks" OR "Generative Models" OR "Recommender systems" OR "AI" OR "Data Mining" OR "Data Science" OR "Text Mining" OR "Text Analytics" OR "Data Analytics") we retrieved 1,577,004 documents. This indicates all research in the world in the Scopus database is related to these criteria. This result was then refined by filtering based on country (Selecting only Nigeria as the affiliation country) on the Scopus database interface. After this refinement, we had 1448 documents and this search was carried out on the 14$^{th}$ of September 2021. To obtain a comprehensive view of all AI-related research conducted in Nigeria, we

deliberately avoided using any search refinement criteria apart from those provided on the Scopus platform. Thus, we downloaded the data in various file formats including open access, document type, and source type. The metadata downloaded comprised 1448 articles, and included information such as authors' names, publication numbers, citation counts with total citations, journal sources, keywords, and country/region of origin. Additionally, author-level metrics such as h-, m-, and g-indices were also included in the downloaded data, in accordance with Scopus platform standards [29].

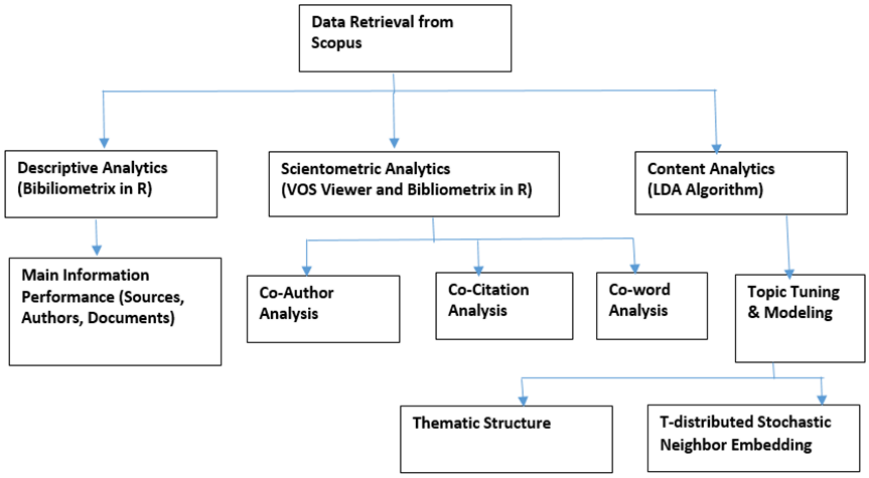


Figure 1. Methodology workflow diagram

## 4. RESULTS AND DISCUSSION

To conduct the analysis for this study, topic modelling was performed using the LDA algorithm, while descriptive analytics and scientometric analysis were carried out using VOSviewer and the Bibliometrix package in R. The LDA algorithm is a probabilistic machine learning model used for topic modelling. It views text as a combination of various topics, and each word in the document can be linked to one of the topics. LDA is a Bayesian model with three levels that model each item in a document as a definite mixture of a set of topics. These topics are modeled as a combination of topic probabilities. This is quite useful in the context of topic modelling, as these topic probabilities provide an explicit representation of the document [27]. The genism library in Python was utilized for the topic modelling in this study.

VOSviewer is a program that uses network data to develop maps and also to visualize and explore the maps. It is also used in scientometric analysis. It is built to use files from bibliographic databases files such as Scopus, PubMed and also files for reference managers such as EndNote, RIS. Bibliometrix is a flexible tool that may be improved and connected with other statistical R tools. It is written in R. It's utilized to do a thorough science mapping analysis. To perform bibliometric analysis, bibliometrix offers a recommended workflow [30]. The main information about the data used is given in Table 1. These contain the information on the timespan representing the years in which the publications are covered. The first article was published in 1977. The data contained a total of 760 articles and 548 conferences with a total of 4359 authors. Table 1 gives a breakdown of the data description retrieved using bibliometrix.

The yearly publication trend of Nigerian AI researchers is given in Figure 2, revealing very minimal AI-related research before 1999. The research in the invested field started peaking close to 2007 but experienced a sharp increase between 2015 and 2019 and has continued at this peak till recent times. This shows that there was a significant increase in the interest of Nigerian researchers in A.I.-related research from the year 2015.

Table 1. Main information about the data

| Description | Results |
|---|---|
| Total Documents | 1448 |
| Average Citation per document | 7.243 |
| Article | 760 |
| Book chapter | 36 |
| Conference paper | 548 |
| Others | 104 |
| Total Authors | 4359 |

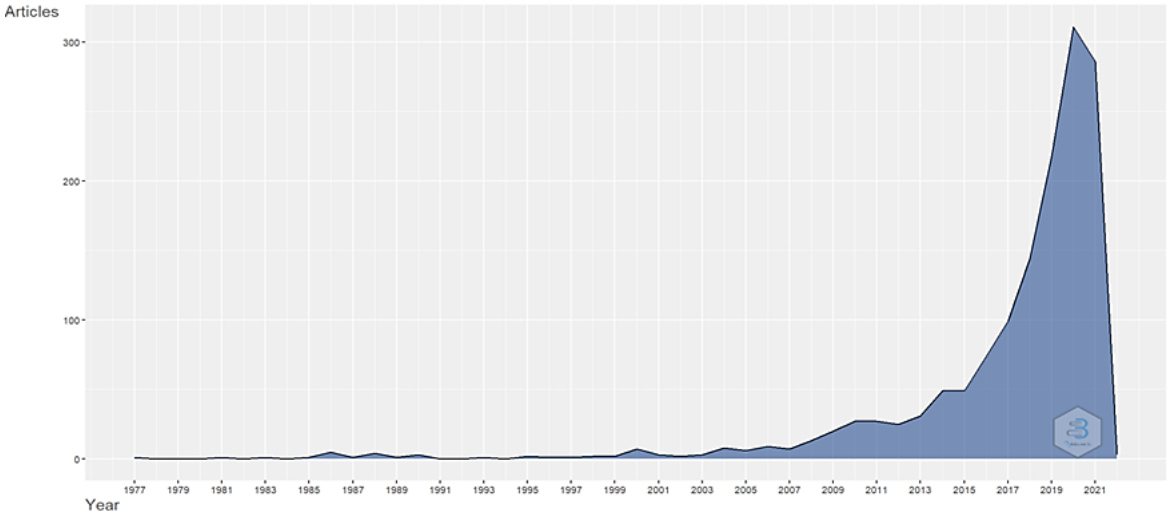


Figure 2. Annual scientific production

The Bradford law was applied to determine the sources in which the journals were published, as presented in Figure 3. This law, first described by [31], estimates the diminishing returns of searching for references in science journals in an exponential manner. As depicted in Figure 3, lecture notes in computer science have the highest number of articles followed by advances in intelligent systems. However, upon further investigation, it was observed that the Scopus percentile of journals that Nigerian researchers publish AI-related research is equal to or less than 50%. This finding is concerning, as high-impact or percentile journals are typically associated with research that can bring about significant advancements, as highlighted by scival.com.

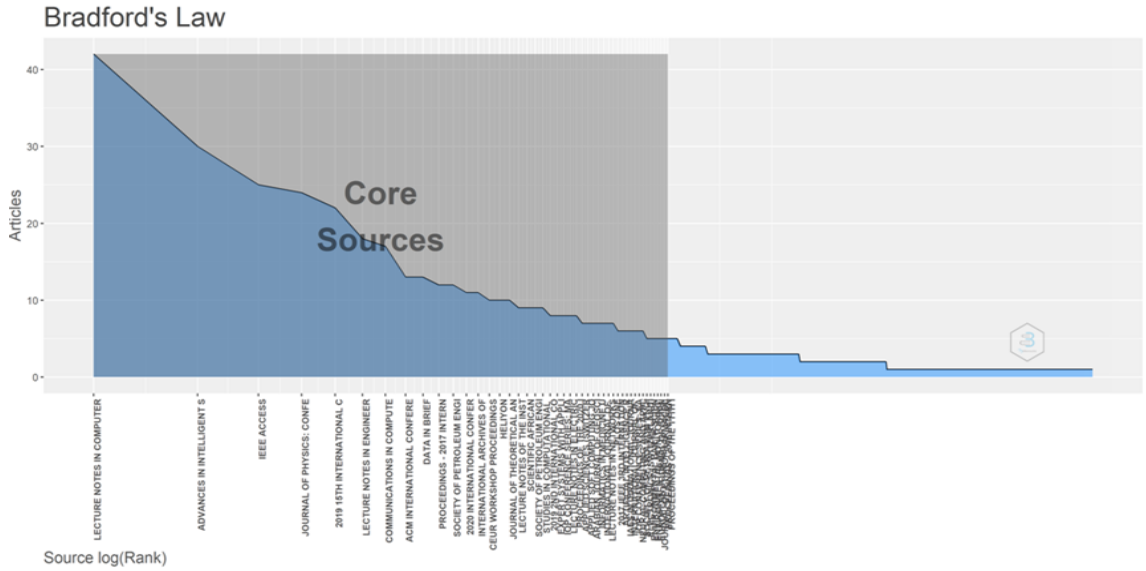


Figure 3. Core publication sources

The most relevant university affiliations are presented in the treemap in Figure 4. Covenant University tops the chart with 375 publications followed by the Federal University of Technology with 135 publications and in the third position is the University of Ibadan with 121 publications as revealed by the Scopus database. Also of note is that relevance is not just estimated by many publications so it was also discovered on further investigation that even though Covenant University had the highest number 375, the impact measure by overall university citation per paper from scival.com is 4.2 compared to the University of Ibadan for example with 121 publications and 11.7 overall citations per paper.

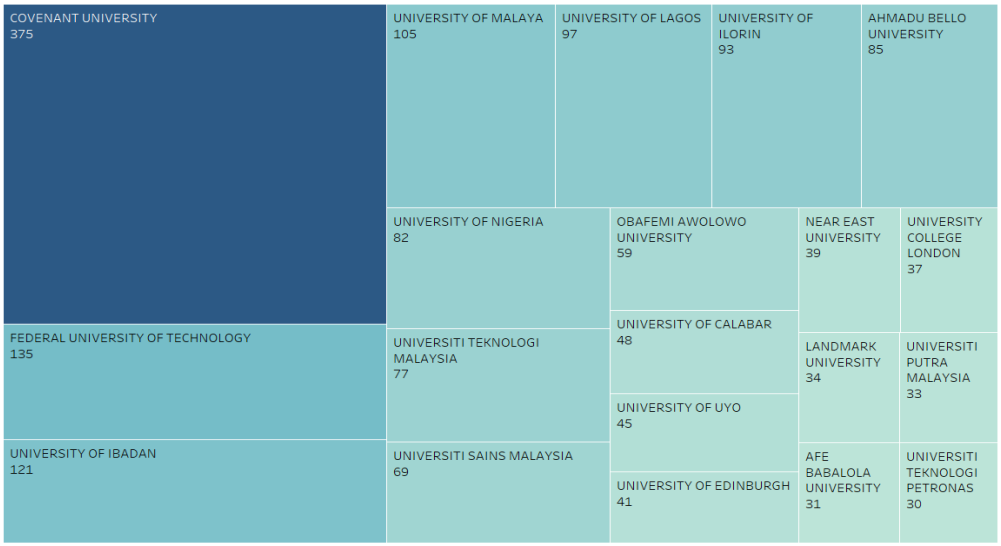


Figure 4. Most relevant affiliations

Finally, the author's impact is revealed in Figure 5, which is an expression of the top 20 authors as revealed by the Scopus database and their production number over time together with their Total citations. It can also be seen here that the number of publications does not directly translate to the number of impacts in form of citations. The recommendation here is that authors should focus more on writing more impactful papers that can be referenced or cited.

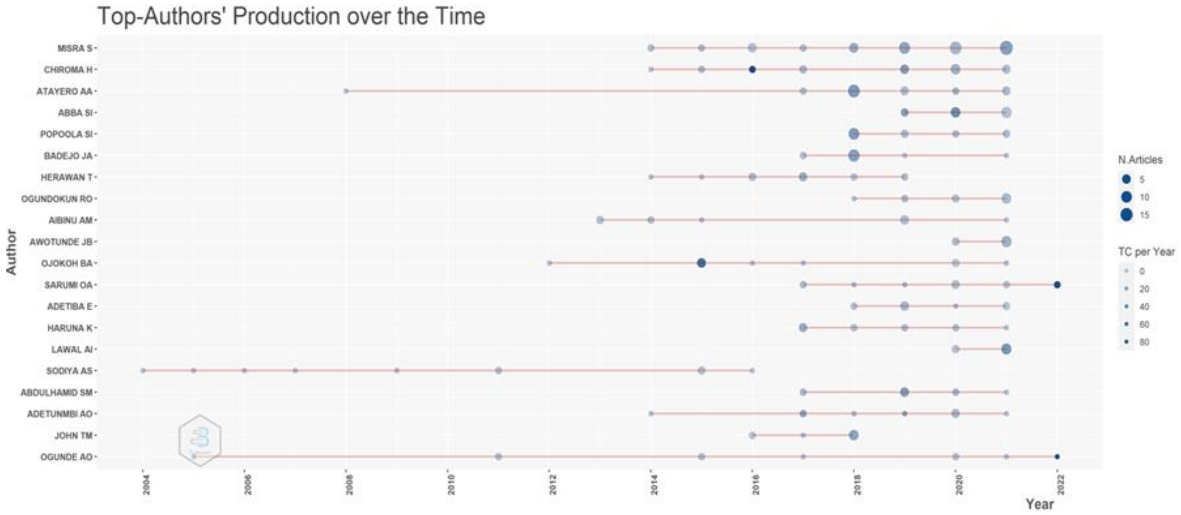


Figure 5. Authors' impact

### 4.1. Topic modelling

In situations where information is so much and humans cannot process it efficiently, topic models help to solve this problem [32]. Topic models can be used to identify latent semantic structures and topics in a huge amount of literature, social media text, and a variety of other sources. In this research, the LDA algorithm was used to uncover untapped research areas in AI in Nigeria. We also revealed areas that we would want to focus on further even though they have enjoyed some attention in the past.

#### 4.1.1. Discovered topics

The Table displays the 10 topics that were discovered in the LDA Topic Modelling. Each topic addresses a unique research area though some topics overlap it's safe to say that what the topics address can be

easily described from the words that make up the topic. In Table 2, the topics have been labelled to provide this description by domain experts and can see that these range from applying machine learning to text to medical analytics.

Table 2. Discovered topics

| Topic Number | Label of the Topic | Words |
|---|---|---|
| 1 | Applying machine learning to text | classification, feature, detection, machine_learning, deep_learning, based, method, dataset, approach, accuracy, technique, algorithm, recognition, proposed, datasets, performance, language, text, class, deep |
| 2 | Data mining on database | data, analysis, data_mining, technique, wa, study, set, result, database, number, pattern, mining, area, clustering, point, source, information, ha, found, selection |
| 3 | Experiments | wa, ai, control, study, group, effect, level, compared, activity, index, extract, significantly, treatment, day, age, significant, total, risk, higher, test |
| 4 | Prediction and classification | model, prediction, performance, wa, neural_network, based, result, accuracy, ann, developed, training, artificial_neural, artificial_intelligence, error, technique, predict, input, predictive, regression, support_vector |
| 5 | Education | system, design, management, knowledge, research, student, learning, process, study, university, engineering, development, tool, science, software, work, framework, computer, limited, finding |
| 6 | Natural resources | method, parameter, optimization, field, technique, function, property, process, water, production, application, time, reservoir, gas, result, oil, surface, map, ha, factor |
| 7 | Network traffic analysis | algorithm, system, network, problem, proposed, energy, architecture, power, based, solution, intelligent, computing, ieee, application, efficient, performance, work, cost, high, traffic |
| 8 | Image analysis | image, based, quality, area, low, image_processing, device, structure, sensor, monitoring, measurement, developed, filter, imaging, signal, assessment, spatial, time, region, high |
| 9 | Internet, mobile | user, paper, technology, review, big_data, approach, challenge, research, information, application, ha, service, analytics, researcher, recent, mobile, recommendation, based, cloud, security |
| 10 | Medical analytics | nigeria, disease, diagnosis, patient, ha, case, human, system, state, medical, global, world, study, covid, artificial_intelligence, health, country, malaria, year, clinical |

### 4.1.2. Connectedness and cohesion of the topics

To justify the connectedness of the topic discovered by the LDA algorithms, we used the mallet library in python to get the optimal topic number. Since the way the LDA algorithms work, you have to supply the topic number, the mallet library was used to discover the optimal topic number that gave rise to the best cohesion value of the topics discovered. Figure 6 reveals the graph gotten from the result of using the mallet package to evaluate each topic number and then selecting the number of topics with the highest cohesion score and also not too many given the quantity of data used, which in this case is 10. The t-SNE scatter plot of the 10 LDA topics is displayed in Figure 7, the t-SNE function is used to reduce a high dimensional graph that keeps a lot of original information. It reduces the dimensional view of a graph to 2 dimensions. The pyLDAvis function was used to generate Figure 8. It shows a cluster of the best topics and the distances between them. The bars on the right show the contents that make up each topic.

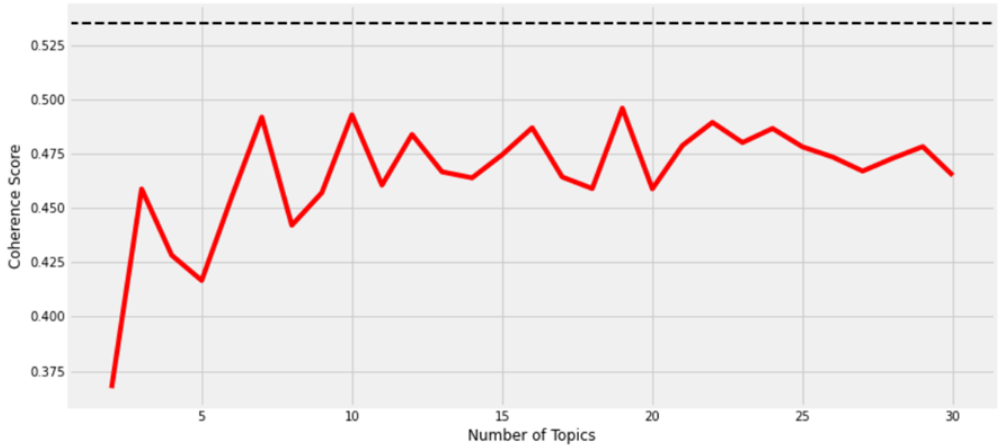


Figure 6. Graph of the result of topic tuning

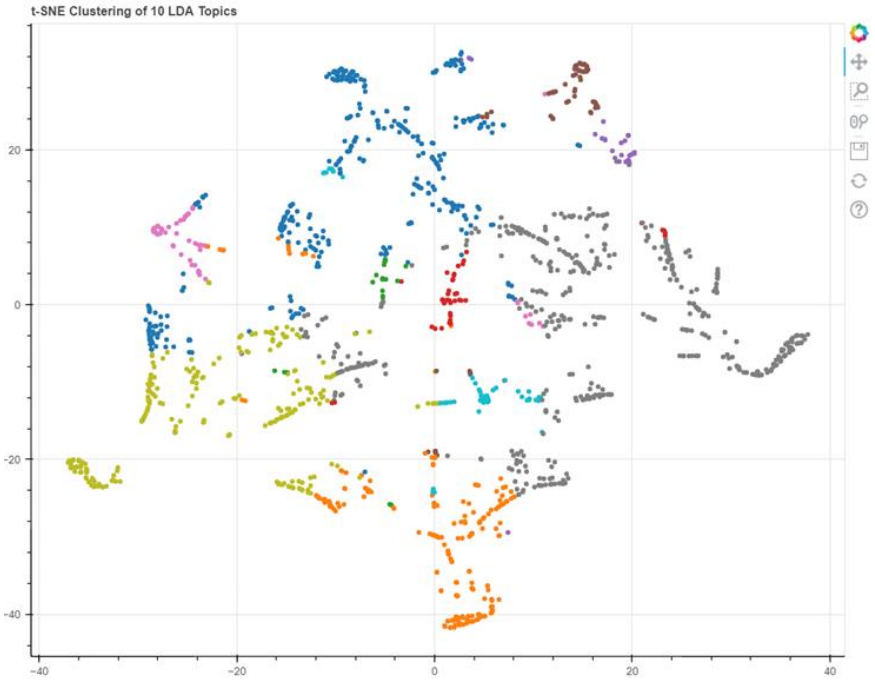


Figure 7. T-distributed Stochastic Neighbour Embedding (t-SNE) of the modelled topics

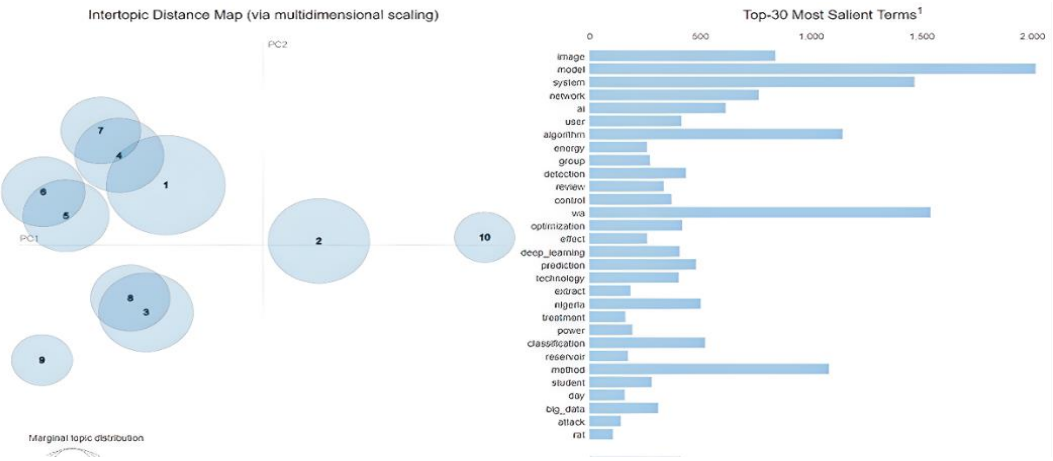


Figure 8. Inter-topic distance map of the modelled topics

In this study, the LDA algorithm was used for topic modelling to cluster natural language. Due to the high dimensionality of the data, t-distributed stochastic neighbour embedding (t-SNE) was employed to validate and visualize the topics discovered [33], [34]. The t-SNE algorithm was able to reduce the large points in high-dimensional space to the 2D plane, where the relative distances between low-dimensional points were used for validation. The modelled topics were validated by the coloured clusters shown in Figure 7. An inter-topic distance map was also created using Python latent Dirichlet allocation visualization (pyLDAvis), which is depicted in Figure 8. The size of each circle in the map shows the importance of each topic within the literature base, while the distances between the centres of the circles demonstrate the connectivity and relationship across themes. The inter-topic distance map in Figure 8 clearly shows the different levels of consideration given to the major study topics. Topic 1 (Applying Machine Learning to Text) was among the most significant AI research in Nigeria and was closely related to Topic 4 (Prediction and Classification) and Topic 7 (Network Traffic Analysis). Topic 10 (Medical Analytics) was relatively farther from other topics and closer to Topic 2 (Data Mining on Database) and Topic 9 (Internet, Mobile.), but also close to Topic 8 (Image Analysis) and Topic 3 (Experiments) [35], [36].

### 4.2. Scientometric analysis

The results gotten from the scientometric analysis are presented in Figures 9, 10, 11 and 12. The co-authorship network created in Figure 9 was done using the threshold of a minimum of 5 documents per author and at least 0 citations. Bigger lines mean that 2 authors are together many times. Different co-authorship clusters are depicted in different colours. The co-Author countries are revealed in Figure 10. The co-authorship countries help us to know which countries the Nigeria A.I. researchers are collaborating with. The coauthor country network was created using a threshold of at least 5 documents in a country and at least 0 citations for the document. A total of 125 countries existed but only 50 meet the threshold. From Figure 10 we can see that the biggest country collaboration is with Malaysia, followed by the United Kingdom and the United States, and South Africa.

Figure 11 depicts the keyword co-occurrence in the analysed contents of the extracted literature. The threshold for coming up with the keyword co-occurrence network is at least 5 occurrences of the keyword. There exist 12718 keywords while only 694 were able to meet the criteria. While a co-citation network focuses on links between citations in the literature to study scientific communication structure, a keyword co-occurrence network (KCN) focuses on links between keywords in the literature to comprehend the knowledge components and knowledge structure of a scientific/technical field [37]. For any given list of terms concerning any collection of texts, co-occurrence networks can be formed. "Neighbors" are co-occurring pairs of phrases that are often grouped into "neighbourhoods" based on their interconnections. There could be numerous neighbours for a single word. Neighbourhoods may connect through at least one individual term or may remain unconnected. Co-occurrence networks can be shown using a graphical representation, and inferences can be derived about relationships between entities in the domain represented by the dictionary of terms applied to the text corpus. Figure 11 reveals several strong keyword co-occurrences such as AI and forecasting, Female and major clinical study, and so on. Of importance is also the emergence of 4 major keyword clusters which can be labelled as Artificial Intelligence, Deep Learning, Humans and Articles, and Control Study, indicated by the colours green, red, blue, and purple respectively. The co-cited sources (sources cited together) are given in Figure 12 (see an appendix) with a threshold of at least 20 citations for sources.

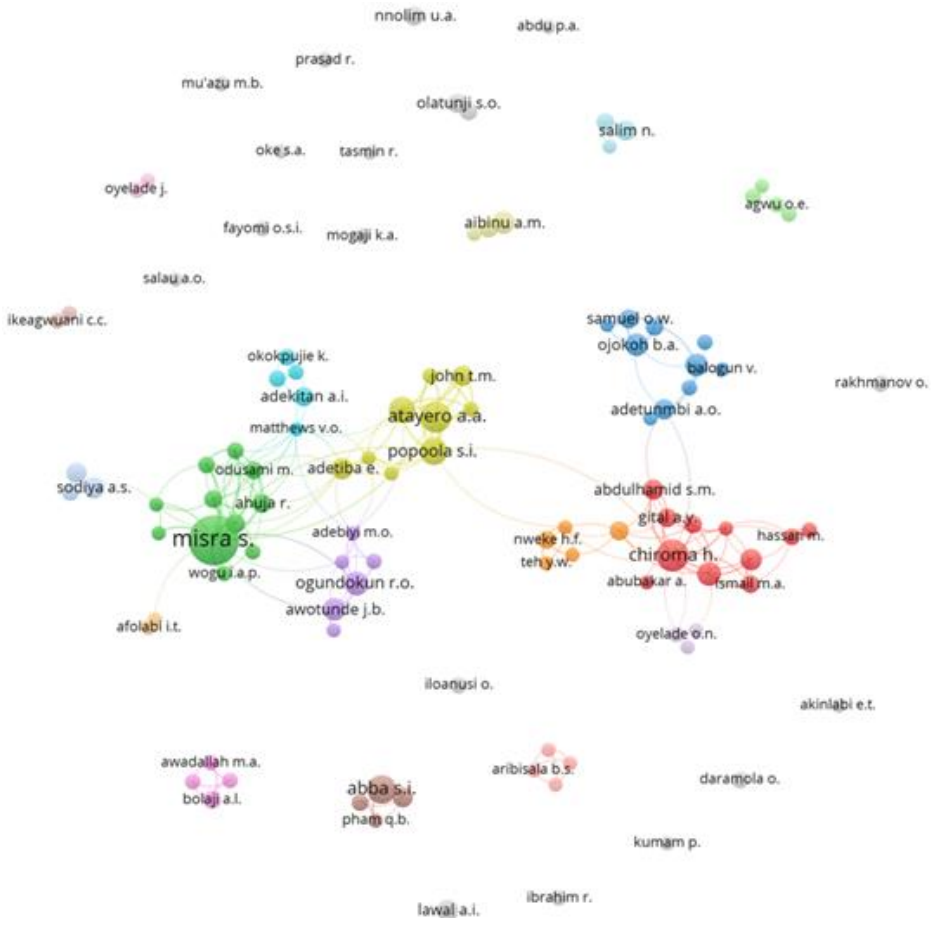


Figure 9. Co-authorship cluster

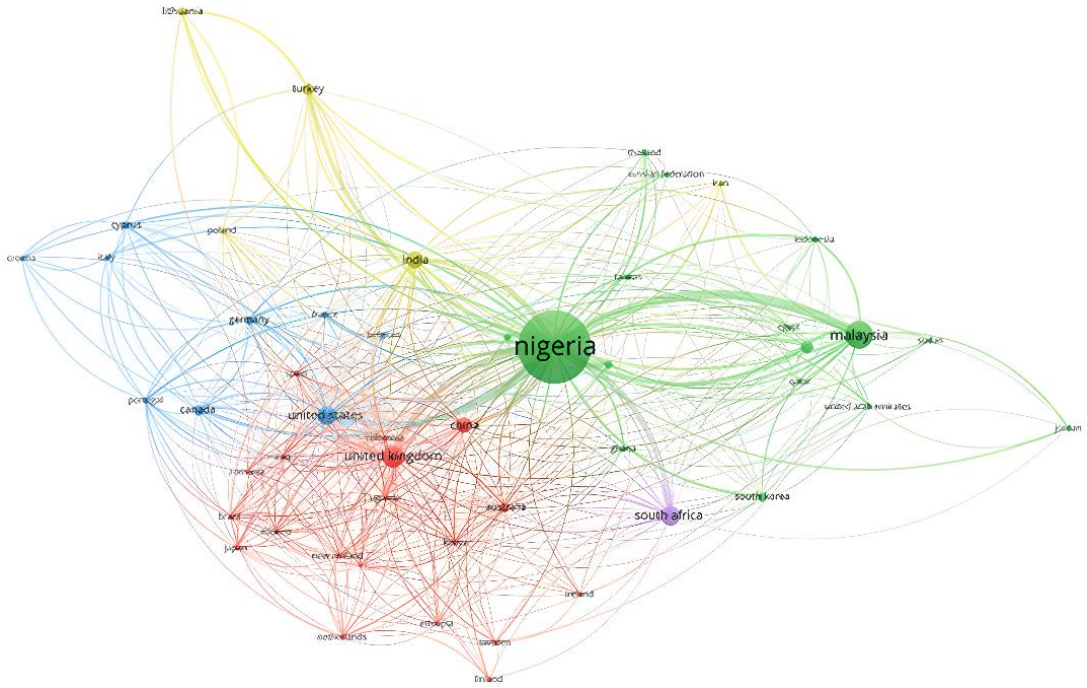


Figure 10. Co-author countries

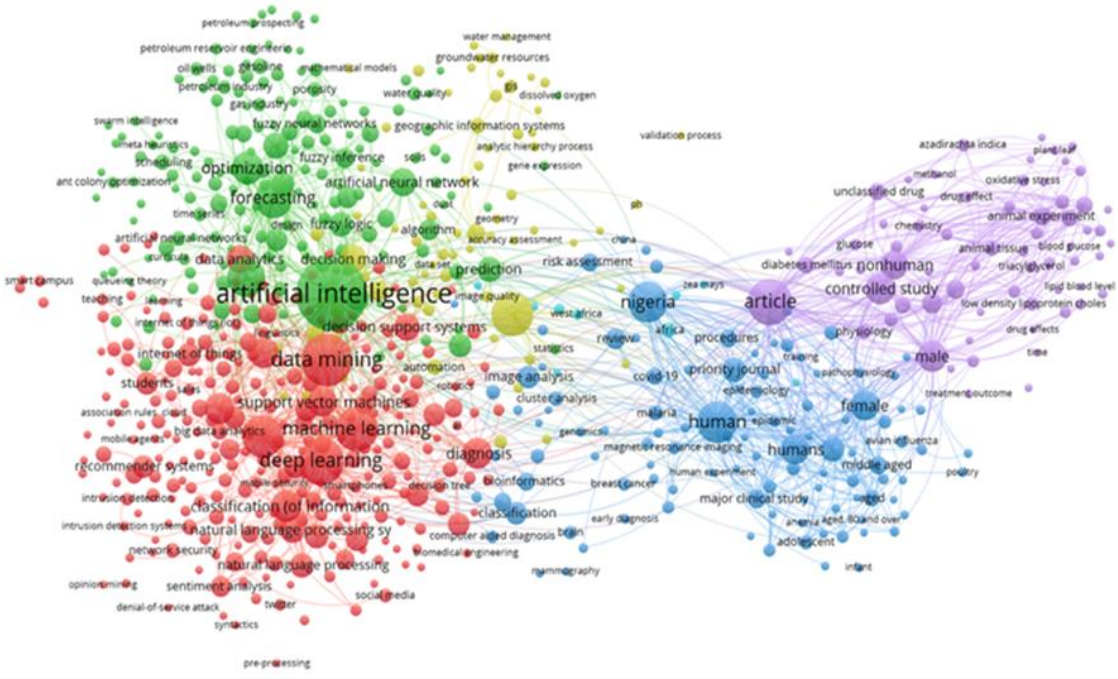


Figure 11. Keyword co-occurrence

## 5. CONCLUSION

In this study, various techniques were employed to ensure the objectivity of the results obtained. One such technique was descriptive analytics, which allowed for a quantitative analysis of the data, thereby eliminating any potential subjective biases that may have influenced manual literature and expert surveys. The use of topic modelling further enhanced the objectivity of the study by clustering related documents together, allowing for a more in-depth analysis of the data. Moreover, scientometric analyses were conducted to reveal

key concepts, keyword co-occurrences, authorship networks, and other relevant metrics. This technique allowed for a better understanding of the structure and progression of AI research in Nigeria. The study's reliance on the Scopus database and selected keywords ensured that the results obtained were a fair representation of AI research in Nigeria. Scopus is the largest academic research database globally and is widely used by the Times Higher Education Ranking body. The study's findings shed light on various areas for improvement in the national economy if AI research is focused on them. To further improve the study, natural language processing techniques can be employed to achieve more precise topic clustering, and other databases can be included to capture all Nigerian AI researchers. The study's results highlighted the major research focus of Nigerian AI researchers, including topics such as applying machine learning to text, data mining on databases, experiments, prediction and classification, education, natural resources, network traffic analysis, image analysis, internet, mobile, and medical analytics. The LDA topic modelling generated the ten best topics, which represent unique areas addressed by the researchers. Furthermore, the study's reliance on scientometric analyses revealed the leading institutions in AI research in Nigeria. According to the Scopus database, Covenant University had the highest number of publications at 375, followed by the Federal University of Technology with 135 publications, and the University of Ibadan in third place with 121 publications. In conclusion, this study provides objective insights into the structure and progression of AI research in Nigeria. The use of natural language processing, machine learning, and statistical algorithms eliminated any potential subjective biases that may have influenced manual literature and expert surveys. The study's reliance on the Scopus database and selected keywords ensured that the results obtained were a fair representation of AI research in Nigeria. Further improvements can be made by employing additional data sources and natural language processing techniques to enhance the study's objectivity.

## APPENDIX

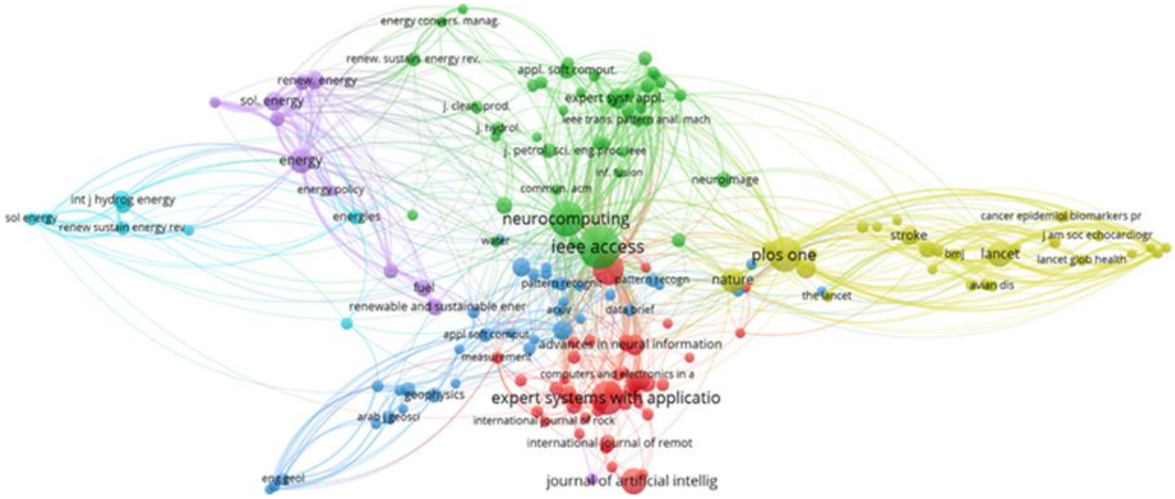


Figure 12. Co-citation sources

## ACKNOWLEDGEMENTS

We express our appreciation to Covenant University for their support and sponsorship through the Centre for Research, Innovation, and Discovery (CUCRID) towards the publication of this research.

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