Vol. 19(1), pp. 47-57, January-March, 2024
DOI: 10.5897/IJPS2023.5040
Article Number: D965FF071959
ISSN: 1992-1950

http://www.academicjournals.org/IJPS

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International Journal of Physical Sciences

Full Length Research Paper

Modelling and optimization of rice production in Nigeria: bibliometric analysis and future research.

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Received 30 August, 2023; Accepted 15 February, 2024

Rice production plays a vital role in enhancing employment opportunities, GDP, and food security, thereby contributing to the prosperity of the country. This study aimed to evaluate the current state of research in the field and identify potential areas for future modeling and optimization of rice production. Data were sourced from the reputable academic citation database and research tool, Web of Science, spanning the period from 2012 to May 2023. Bibliometric software, such as Bibliometrix or Biblioshiny, was employed for data analysis. The analysis revealed insights such as 4058 authors contributing to 1965 articles published across 188 journal sources. The most prolific year was 2013, witnessing the publication of 240 articles. China emerged as the most productive nation, contributing 8774 articles, while the journal source "Applied Mathematical Modeling" stood out with 1004 articles. Among individual journals, the University of Tehran's "Journal Source" led with 77 papers. Notably, author Jaber M.Y. demonstrated significant productivity with 23 articles. Additionally, the study proposed several areas for further investigation, focusing on modeling and optimization, with the potential to bolster rice production development in Nigeria and globally.

Key words: Modelling, optimization, bibliometric, bibliometrix, rice production.

INTRODUCTION

After cassava and maize, rice stands as the third most popular staple food in Nigeria and has gained significance as a crucial crop for food security (KPMG, 2019). Nigeria's annual rice consumption surpasses 7 million metric tons, yet only around half of this demand is met domestically. Moreover, millions of individuals in Nigeria, spanning from farmers to input suppliers, processors, marketers, and merchants, find employment within the country's rice value chain. According to the Federal Ministry of Agriculture and Rural Development of Nigeria (https://fmard.gov.ng), approximately 5 million people are employed along the rice value chain in Nigeria.

Optimal rice harvest relies on the availability of qualitative and sufficient farm inputs. Farmers require finances to acquire essential inputs and cover labor costs, fertilizers, and pesticides for nurturing healthy seedlings. Land preparation, including ploughing, harrowing, and ridging, is essential before transplanting

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seedlings. The cost inputs involved in rice cultivation encompass fertilizers, pesticides, herbicides, irrigation, hired labor, land preparation, and transportation (Sary et al., 2018). Similarly, Daniel and Afofum (2019) assert that vital inputs for rice cultivation include seed quantity, fertilizer, irrigation services, and insecticides. However, not all rice farmers have adequate access to these inputs due to resource scarcity and insecurity issues, particularly prevalent in the northeastern region of Nigeria affected by insurgency (Brechenmacher, 2019). These challenges contribute to diminished crop yields and food insecurity in various parts of the country.

Despite the considerable efforts of various researchers, rice production in Nigeria continues to fall short of demand. Ajiboye et al. (2021) utilized the Johansen Error Correction model to assess rice yield response in Nigeria. Akintayo et al. (2011) employed descriptive statistics and regression models to analyze the disparity between potential and actual rice yields in the North Central region, albeit with a limited dataset and without considering resource constraints in their model development. Similarly, Putri et al. (2018) developed a rice prediction model using multiple regression but only incorporated crop health and soil fertility variables, overlooking the impacts of farm inputs. Additionally, Abiola et al. (2016) modified the Cobb Douglas production function to determine rice yield in Mada Malaysia, yet their model did not account for any constraints. Yuliawan and Handoko (2016) applied the Shiery Rice model with a Geographical Information System (GIS) to assess the effects of temperature rise on yield in Indonesia, neglecting input variables in their model formulation, similar to other authors. Shaikh et al. (2016) estimated parameters of the Neo-classical and Cobb-Douglas production functions using the ordinary least square (OLS) method. Chikezie et al. (2020) utilized the Cobb-Douglas production function model to predict farm-level technical efficiency.

Nevertheless, despite the significant contributions from these studies, rice production in Nigeria remains insufficient to meet demand. Therefore, the development of a comprehensive rice yield model that incorporates rice input variables and production constraints could significantly enhance rice productivity in the country.

The purpose of this research is to add to the current knowledge about mathematical modelling for the best rice production. It aims to respond to the following research queries for this purpose:

i) What is the current state of research in mathematical modelling for optimal rice production around the world?
ii) Who are the most productive and influential authors in the field of optimal rice production modelling?
iii) What are the most dynamic publication sources in this field?
iv) What are the potential research avenues for optimal rice production modelling?

This study is grounded in a bibliometric analysis of drought-predicting data sourced from the Web of Science (WoS) database, aimed at addressing the research topics outlined. The structure of the essay is as follows: Part 2 presents the methodology utilized in the study. Part 3 outlines the results obtained, followed by a discussion. Part 4, 5, and 6 cover the contributions, limitations, conclusions, and directions for future research, respectively.

METHODOLOGY

The bibliometric approach was selected for this study because the primary objective was to evaluate the state of knowledge development in optimal rice production modeling. This research methodology is recommended for assessing the extent or advancement of a discipline by examining various indicators, such as the most influential and frequently referenced publications, journals, authors, institutions, and countries (Hejase and Hejase, 2013). It also enables the evaluation of network collaboration among authors, institutions, and nations. Furthermore, this research strategy is advantageous as it facilitates the analysis of a substantial volume of publication data.

Data retrieval and analysis

To achieve the objective of this research, data were extracted from the reputable world-class database known as Web of Science. Operated by Clarivate Analytics, Web of Science is a widely used online academic citation database and research tool that provides access to a vast collection of scientific literature across various disciplines (Clarivate, 2023).

The database primarily focuses on scholarly journals, conference proceedings, patents, and other research materials. Renowned for its comprehensive coverage and indexing of high-quality scientific literature, Web of Science includes articles from thousands of journals worldwide, spanning diverse subject areas such as natural sciences, social sciences, engineering, and the humanities. Moreover, the database incorporates conference proceedings, enabling researchers to access the latest findings presented at academic conferences (Liu, 2018).

A filtered search was conducted using the following keywords: "Mathematical Modelling" OR "Optimization", AND "Rice Yield" AND "Nigeria" Production from Web of Science within the timeframe of 2012 to May 2023. A total of 1946 related articles were downloaded and analyzed using bibliometric software called Bibliometrix, also known as biblioshiny. Bibliometrix is an open-source R tool dedicated to quantitative research in scientometrics and bibliometrics, consolidating all the main methods of bibliometric analysis.

RESULTS AND DISCUSSION

Main information on the collected documents

Table 1 presents the key details of a dataset comprising papers on the modeling and optimization of rice production sourced from the Web of Science. From this table, it is evident that our search yielded a total of 1965 items, including articles, reviews, procedural documents, editorial materials, and data papers. These materials

Table 1. Main information about the articles.

Description	Results	Description	Results
Main information about data		Authors collaboration	
Timespan	2012:2023	Single-authored docs	181
Sources (Journals, Books, etc)	188	Co-Authors per Doc	2.91
Documents	1965	International co-authorships %	33.44
Annual growth rate %	-12.11	Document types	
Document average age	6.05	article	1875
Average citations per doc	17.02	article; early access	4
References	1	article; proceedings paper	53
Document contents		correction	8
Keywords Plus (ID)	3463	editorial material	3
Author's Keywords (DE)	6568	review	22
Authors		Authors collaboration	
Authors	4058	Single-authored docs	181
Authors of single-authored docs	158	Co-Authors per Doc	2.91
		International co-authorships %	33.44

Source: R web based software: Biblioshiny.

Table 2. Mean total citation (TC) per article and per year.

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Mean TC per Art	24.99	26.85	24.04	18.4	23.34	16.52	17.16	14.5	11.19	6.19	1.98	0.95
No of articles	153	240	157	159	202	207	166	166	135	206	133	37
Mean TC per Year	2.08	2.44	2.4	2.04	2.92	2.36	2.86	2.9	2.8	2.06	0.99	0.95

Source: R web-based software: Biblioshiny.

were published between the years 2012 and May 2023. The sources in which these documents were published amount to 188, indicating the extensive coverage of the topic of modeling and optimization by various journals and publishing companies.

Mean citation per article, mean citation per and mean TC (total citations) per year

Table 2 displays the Mean Total Citation per Article per Year, a metric commonly used to gauge the average number of citations received by articles published within a specific journal, field of study, or by researchers affiliated with a particular institution or country. This metric offers insights into the impact and influence of scholarly publications, calculated by dividing the total number of citations received by a set of articles by the number of articles within that set. A higher mean citation per article indicates a greater impact and influence of the articles within the academic community (Eydesdorff and Bornmann, 2016).

Additionally, Table 2 presents the Mean Total Citations per year, which refers to the average number of citations received by publications within a specific year. This metric provides insights into the citation impact and influence of research output within a particular time frame, calculated by summing up the total number of citations received by all publications in a given year and dividing it by the number of publications published in that year (Bornmann and Marx, 2014).

The results in Table 2 outline the mean Total Citations per article, the number of articles per year, and the mean Total Citations per year for the period spanning 2012 to May 2023. Notably, the data indicate that 2013 witnessed the highest number of articles, with a mean Total Citations per article of 240 and 26.85, respectively. Conversely, the year 2016 recorded the highest Total Citations per year, amounting to 2.92.

Annual scientific production

Scientific production encompasses the generation of knowledge and advancements across various fields through research and scholarly activities, including the creation of scientific papers, articles, books, patents, conference presentations, and other forms of intellectual

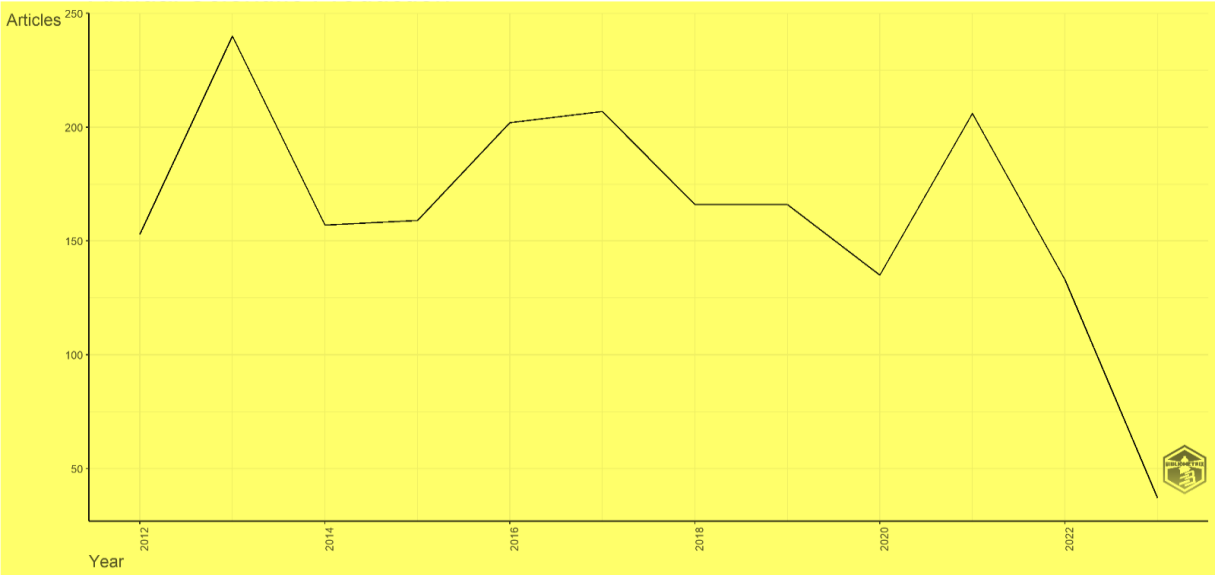

Figure 1. Annual scientific production.
Source: R web-based software: Biblioshiny.

Table 3. Source growth dynamics.

Sources	Articles
Applied Mathematical Modelling	1004
Esaim-Mathematical Modelling and Numerical Analysis-Modelisation Mathematique Et Analyse Numerique	389
Russian Journal of Numerical Analysis and Mathematical Modelling	71
Mathematical Modelling and Analysis	56
International Journal of Production Research	27
Mathematics and Computers in Simulation	19
Mathematical Modelling of Natural Phenomena	13
Energies	8
Journal of Cleaner Production	6
Journal of the Operational Research Society	6

Source: R web based software: Biblioshiny.

output that contribute to our collective understanding of the world and its phenomena.

This production is fundamental to societal progress, driving innovation, informing policy decisions, and enhancing overall well-being (Beard, 2015). The accumulation of scientific knowledge builds upon existing theories and findings, leading to breakthroughs and new discoveries that shape our understanding of the universe and drive technological advancements (Šimelytė et al., 2021).

Figure 1 depicts the graph of annual scientific production for the period under consideration. The graph illustrates the pattern of the increase in scientific material production between 2012 to 2014 and 2020 to 2023.

Furthermore, Table 3 presents the productivity source ranking, with the Applied Mathematical Modelling journal topping the list with 1004 articles, followed by Esaim-mathematical modelling and numerical analysis with 389 articles. Other sources are ranked accordingly as presented in Table 3.

Ranking of the most relevant authors and affiliations

The most relevant author typically refers to an individual who has made substantial contributions to a specific research paper or article. These contributions can include designing the study, conducting experiments or analyses,

Table 4. Most relevant authors.

Authors	Rank	Articles	Articles fractionalized
JABER MY	1	23	8.17
WANG Y	2	19	4.88
ZHANG Y	3	19	6.27
LIU Y	4	16	5.83
WANG X	5	14	3.69
ERN A	6	13	5.17
TAVAKKOLI-MOGHADDAM R	7	12	3.75
JOLAI F	8	11	3.37
QUARTERONI A	9	11	3.50

Source: R web based software: Biblioshiny.

interpreting results, writing the manuscript, and providing intellectual insights that significantly enhance the quality and credibility of the work. The relevant author is often the primary author (first author) or the corresponding author (last author) of the paper, but this can vary depending on the field and publication norms. Conversely, the most relevant affiliation refers to the affiliations that have made a significant impact through the number of articles they have published. Table 4 and Table 5 present the top most relevant authors and affiliations, respectively. Jerry, with 23 articles, emerged as the most productive author among the top ten. Similarly, the University of Tehran, with 77 articles, was identified as the most productive affiliation among the ten affiliations, which is consistent with the findings of Hossein et al. (2018).

Top 10 most cited documents

Table 6 presents the results of the top 10 most cited documents, which refers to academic or scientific papers, research articles, books, or other scholarly works that have received the highest number of citations from other researchers or authors. Citations are references made by one scholarly work to another, typically to acknowledge the source of information, credit the original author's work, or provide evidence and support for claims made in the citing paper (Bornmann and Daniel, 2008).

KLEMES JJ's paper titled "CURR OPIN CHEM ENG," published in 2013, garnered a total of 290 citations and a Total Citations (TC) per year of 26.36, making it the most cited document. Following closely is ARGYROPOULOS CD's paper titled "APPL MATH MODEL," published in 2015, with a total citation of 285 and a TC per year of 31.67, securing the second position. The rankings for the remaining documents are presented accordingly.

The most cited countries

The term "most cited country" refers to the country whose scientific research output receives the highest number of citations in academic papers and publications. Citations serve as references to previous works made by researchers in their own research papers when discussing related findings, theories, or methodologies. The more a country's research is cited by other scientists globally, the higher its citation impact, which is often considered a measure of the country's influence and contribution to the scientific community. Being the most cited country indicates that a significant proportion of the world's research community finds the scientific output from that country to be valuable and influential. It can be an indicator of the country's strong research institutions, highly skilled researchers, and impactful contributions to various fields of knowledge (Raan Van, 2004; Wagner and Leydesdorff, 2005).

The result of the top 10 most cited countries is presented in Table 7. China, with a total citation of 8774, emerged as the most cited country, a finding affirmed by Zhou and Leydesdorff (2006). Following China is Iran, with 4914 documents, and then the USA with 2167 documents, with other countries ranked accordingly.

Source production over time and ranking

Journal source ranking refers to the process of evaluating and categorizing academic journals based on their quality, impact, and reputation within the scholarly community. Various methods and metrics are employed to rank journals, aiming to assist researchers and institutions in identifying the most reputable and influential publications in their respective fields. These rankings serve as valuable tools for academics in deciding where to publish their research and for institutions in evaluating the research output of their faculty members (SJR).

Figure 2 illustrates the graph of the top five productive journal sources, while Table 8 presents the ranking of sources based on their production frequencies. According to Table 8, Applied Mathematical Modelling, with a frequency of 1004 articles, secured the top rank. This is

Table 5. Most relevant affiliation.

Affiliation	Univ Tehran	Univ Concepcion	Islamic Azad Univ	Univ Oxford	Ryerson Univ	Amirkabir Univ Technol	Iran Univ Sci and Technol	Shenyang Aerosp Univ	France	Indian Inst Technol
Articles	77	57	56	53	50	46	43	40	38	37

Source: R web-based software: Biblioshiny.

Table 6. Most cited documents.

Paper	Rank	Total citations	TC per Year	Normalized TC
KLEMES JJ, 2013, CURR OPIN CHEM ENG	1	290	26.36	10.80
ARGYROPOULOS CD, 2015, APPL MATH MODEL	2	285	31.67	15.49
AMIN SH, 2013, APPL MATH MODEL	3	274	24.91	10.20
PISHVAEE MS, 2012, APPL MATH MODEL	4	263	21.92	10.52
RAMEZANI M, 2013, APPL MATH MODEL	5	223	20.27	8.31
GHARAEI A, 2019, APPL MATH MODEL	6	200	40.00	13.79
WANG GG, 2014, APPL MATH MODEL	7	199	19.90	8.28
LI JQ, 2014, APPL MATH MODEL	8	195	19.50	8.11
LUO J, 2018, APPL MATH MODEL	9	187	31.17	10.90
CHENG HY, 2020, APPL MATH MODEL	10	184	46.00	16.44

Source: (R web based software: Biblioshiny).

Table 7. The most cited countries.

Country	China	Iran	USA	India	Canada	Italy	France	Germany	Turkey	United kingdom
TC	8774	4914	2167	1829	1641	1479	1408	1322	1102	1099
Average article citations	20.20	29.10	15.60	22.00	37.30	25.10	8.70	11.70	22.00	11.40

Source: (R web based software: Biblioshiny).

followed by Esaim-mathematical modelling and numerical analysis -modification mathematique et analyse numerique, with a frequency of 389 articles.

The rankings for other sources are presented accordingly in Table 8.

Collaboration mapping between countries

Collaboration between countries in the field of publication refers to the process whereby researchers, academics, and professionals from different nations collaborate to produce and disseminate knowledge through various forms of written work, such as research papers, articles, books, and reports. This collaboration is crucial for advancing science, technology, and humanities as it brings together diverse perspectives, expertise, and resources to address complex global

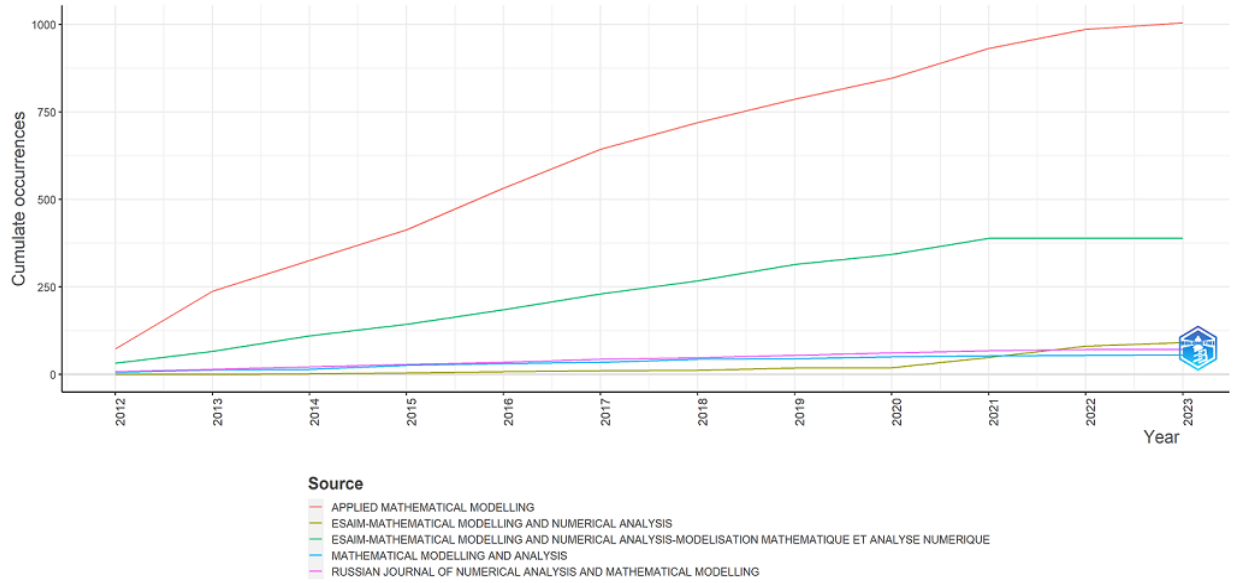

Figure 2. Sources production over time.
Source: R web based software: Biblioshiny.

Table 8. Sources ranking.

Element	Rank	h_index	g_index	m_index	TC	PY_start
Applied Mathematical Modelling	1	65	95	5.417	22729	2012
Esaim-Mathematical Modelling and Numerical Analysis-Modelisation Mathematiquee Et AnalyseNumerique	2	35	55	2.917	5264	2012
International Journal of Production Research	3	14	25	1.167	640	2012
Esaim-Mathematical Modelling and Numerical Analysis	4	9	19	0.9	432	2014
Mathematics and Computers in Simulation	5	9	13	0.75	201	2012
Mathematical Modelling and Analysis	6	8	10	0.667	209	2012
Russian Journal of Numerical Analysis and Mathematical Modelling	7	8	14	0.667	301	2012
Journal of Cleaner Production	8	5	6	0.5	72	2014
Journal of the Operational Research Society	9	5	6	0.5	75	2014

Source: (R web based software: Biblioshiny).

challenges (UNESCO, 2021).

Figure 3 illustrates the map of collaboration across the globe, while Table 9 provides the ranking of pairs of countries based on their collaboration frequencies. According to Table 9, the collaboration between China and the USA, with a frequency of 61, ranked first. Following closely is the collaboration between the USA and Germany, with a frequency of 21, ranking second. The collaboration between France and the USA, with a frequency of 3, ranked third, with other collaborations listed accordingly in the table.

The country's productivity

Country article productivity is a measure of the number of research articles produced by a country in a particular field or discipline, serving as a useful metric for assessing the research output of a country and comparing it to others. This metric is widely employed in bibliometric research to evaluate the research output of countries across different fields and disciplines. Moreover, the productivity of academic journals in a country can serve as a significant indicator of the country's research output, scientific advancement, and engagement in the global academic community (Horta and Yonezawa, 2018).

Analysis conducted by Bibliometrix revealed that China, with 1430 articles and 8774 citations, emerged as the most productive nation worldwide within the considered interval. Conversely, Nigeria, Azerbaijan, Luxembourg, Philippines, Thailand, and Venezuela are ranked number 70 out of 78, with each country having 2 documents from

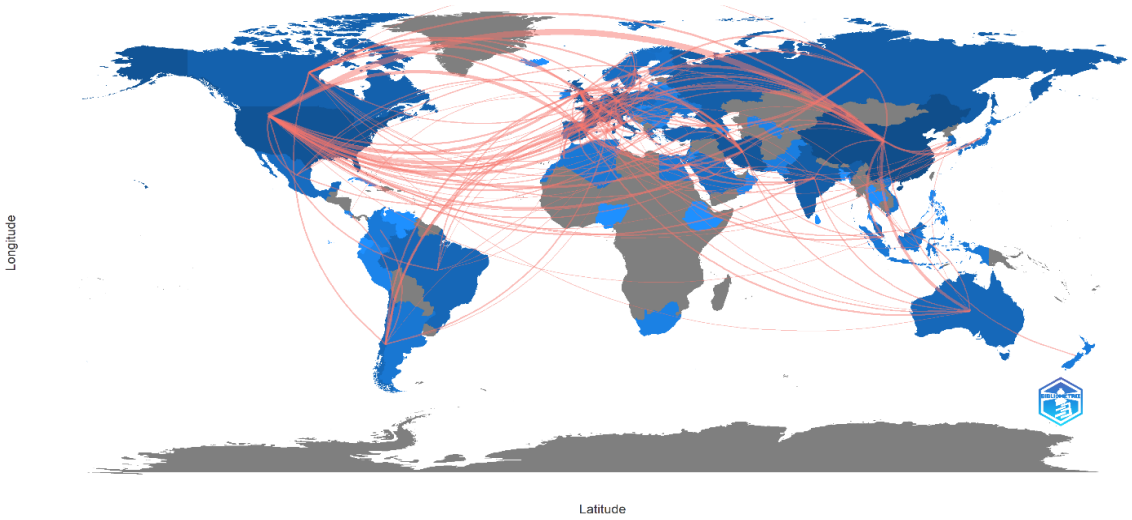

Figure 3. Country collaboration.
Source: R web-based software: Biblioshiny.

Table 9. Countries collaboration.

From	To	Rank	Frequency
China	USA	1	67
Usa	Germany	2	21
France	USA	3	19
France	Italy	4	18
France	United Kingdom	5	18
Germany	United Kingdom	6	17
Italy	Switzerland	7	16
China	Australia	8	15
USA	Italy	9	15
USA	United Kingdom	10	14
China	United Kingdom	11	13
CHINA	Singapore	12	11
ITALY	Canada	13	10
USA	Iran	14	10
USA	Russia	15	10
CHINA	Canada	16	9
CHINA	France	17	9
CHINA	Japan	18	9
FRANCE	Germany	19	9
USA	Spain	20	9

Source: R web based software: Biblioshiny.

the Web of Science within the research period. More detailed results on Country Productivity are presented in Figure 4 and Table 10a and 10b, respectively.

Thematic map

A thematic map is a type of map that displays spatial patterns or distributions of a specific theme or subject matter, rather than simply showing geographic features like rivers, mountains, or political boundaries. Thematic maps utilize visual elements such as colors, symbols, and patterns to represent the variations or concentrations of the chosen theme across a geographical area.

Figure 5 presents the thematic map of the area of study, which highlights "model," "optimization," and "design"

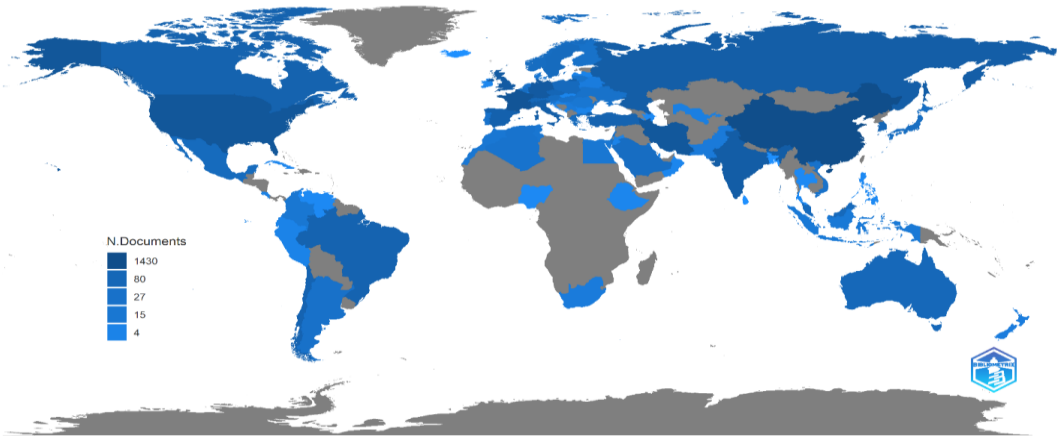

Figure 4. Country scientific production.
Source: R web based software: Biblioshiny.

Table 10a. Country`s total citation.

Country	China	Iran	USA	India	Canada	italy	France	Germany	Turkey	United kingdom
TC	8774	4914	2167	1829	1641	1479	1408	1322	1102	1099
Average article citations	20.20	29.10	15.60	22.00	37.30	25.10	8.70	11.70	22.00	11.40

Source: R web-based software: Biblioshiny.

Table 10b. Country`s articles production frequency.

Region	China	France	USA	Iran	Germany	UK	India	Russia	Italy	Spain
Frequency	1430	657	523	475	348	303	250	232	209	155

Source: R web-based software: Biblioshiny.

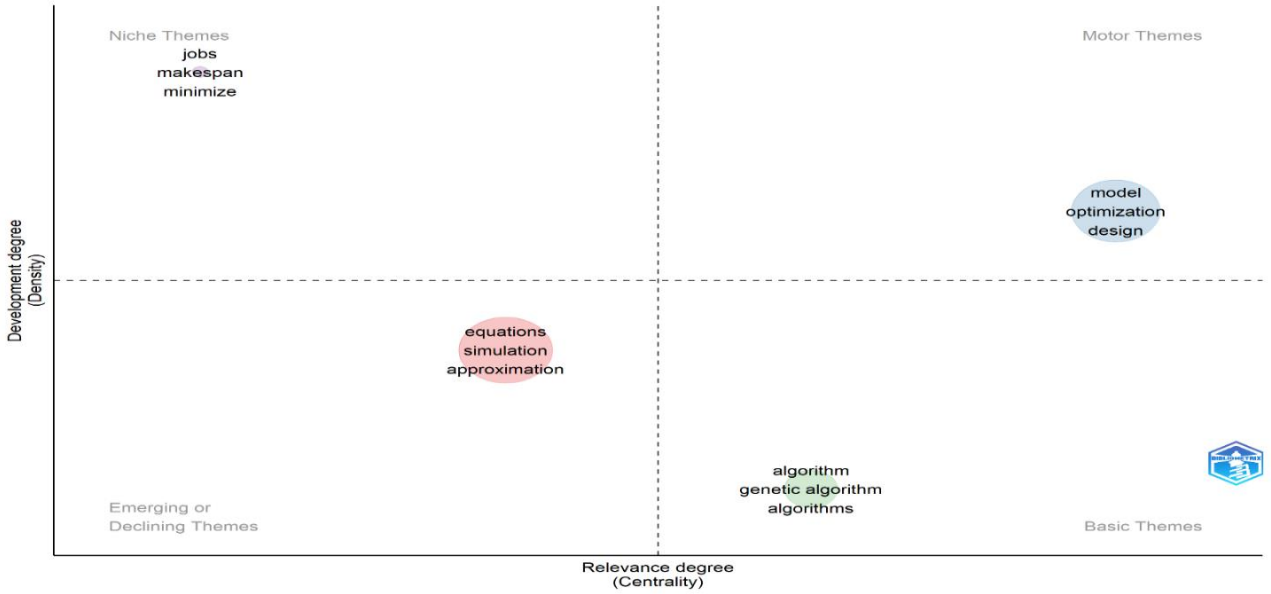

Figure 5. Thematic map.
Source: R web-based software: Biblioshiny.

Table 11. Cluster of titles.

Topic	Cluster	Title	Cluster
Single machine	10	Optimal control	3
Finite volume	7	Reduced basis	3
Finite element	6	Conservation laws	3
Element method	6	Error analysis	3
Element methods	6	Error estimation	3
Navier-stokes equations	6	Supply chain	2
Boundary conditions	6	Mathematical modelling	2
Mixed finite	6	Network design	2
Virtual element	6	Chain network	2
Element approximation	6	Closed-loop supply	2
Deteriorating items	5	Genetic algorithm	2
Inventory model	5	Vehicle routing	2
Trade credit	5	Facility location	2

Source: R web-based software: Biblioshiny.

as the developed themes, while "equation," "simulation," "approximation," "algorithm," and "genetic algorithm" are identified as emerging themes (Ahmad, 2014). These emerging themes and basic themes depicted in Figure 5 represent major research areas that can be explored by potential researchers. For instance, potential research topics under the emerging themes may include "Equation - Precision agriculture," "Approximation - Optimal resource allocation approximation," "Simulation - Modeling and simulation of crop production," and under the basic theme, "Genetic Algorithm - Crop breeding.

Title cluster

Title clusters, also referred to as thematic clusters or title families, are groups of research articles that share a common theme, topic, or subject matter. They serve as a method to organize related research within academic journals, conference proceedings, and other scholarly platforms.

Table 11 presents the clusters of some titles in the area of study. For instance, "Single machine" had the highest cluster count of 10, followed by "Finite volume" with a cluster count of 7, and other clusters are enumerated accordingly in table.

CONCLUSION AND FUTURE RESEARCH DIRECTIONS

This paper's primary objective was to provide a comprehensive overview of the development of the discipline of modeling and optimization in Africa. This goal was achieved through a bibliometric analysis of modeling and optimization data sourced from the Web of Science (WoS) database. The study aimed to highlight the most important authors, connections, and sources in the field of modeling and optimization.

The analysis revealed that China, with a total of 1430 articles and 8774 citations, emerged as the most productive nation in this field. Conversely, Nigeria, with only two documents, was among the least publishing countries in the research area during the period considered. The publication source "Applied Mathematical Modelling" was identified as the most relevant journal publication source, with 65-h index and 95-g index articles. The most cited document was "KLEMES JJ, 2013, CURR OPIN CHEM ENG," with a total of 290 citations. Additionally, the study identified several relevant future study areas, including:

i) Precision agriculture
ii) Optimal resource allocation approximation
iii) Modelling and simulation of crop production
iv) Genetic Algorithm-crop breeding.

Limitation of the study

This study exclusively utilized data extracted from the Web of Science and did not incorporate data from other databases. Additionally, the extracted data were rigorously analyzed using a web-based software called Biblioshiny.

Recommendations

The study recommends that:

1) Researchers in Nigeria should focus their research on rice production towards:

i. Precision agriculture

ii. Optimal resource allocation approximation
iii. Genetic algorithm crop breeding.
2) Further studies should be conducted by extracting data from more than one reputable database, and the data should be analyzed using multiple Bibliometrix software tools.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to the Regional Scholarship and Innovation Fund (RSIF) for their financial support. Additionally, they acknowledge Université de Abomey-Calavi, Benin Republic, and Federal University of Technology, Minna, Nigeria, for providing the platforms necessary to conduct this research.

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