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MAPPING THE GROWTH OF BLOCKCHAIN TECHNOLOGY PUBLICATION: A BIBLIOMETRIC STUDY (2009–2023) USING OPENALEX DATA

Sayed Mohamed Jelani, Abdul Hameed
Semi-Professional Assistant,
Central University of Tamil Nadu, Tamil Nadu, India.
sjelani91@gmail.com

Ashkar, Kamaludheen
Assistant Librarian,
Indian Institute of Science Education and Research,
Thiruvananthapuram, Kerala.
ash.kairali@gmail.com, ashkar@iisertvm.ac.in

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ABSTRACT

This study examines the transformative role of blockchain technology in library operations, focusing on its potential to enhance data security, privacy, and operational efficiency. Blockchain, initially designed for secure financial transactions, is increasingly applied in library science to address challenges in user data management, acquisition processes, and collaboration. The analysis spans 2019 to 2023, leveraging bibliometric data from OpenAlex and applying frameworks like Bradford's and Lotka's Laws to uncover trends in publication growth, academic impact, and research collaboration. The findings reveal a substantial annual growth rate of 31.94% in blockchain-related research, with articles accounting for over 71% of the outputs. On average, publications received 16.38 citations, indicating strong academic influence. Keywords such as blockchain, IoT, cybersecurity, and decentralised systems dominate the thematic landscape, reflecting the growing importance of privacy-preserving technologies and decentralised frameworks in libraries.However, the study identifies significant challenges, including limited international collaborations, security concerns, and adoption barriers. The absence of global partnerships represents a missed opportunity to advance blockchain research on a broader scale. While blockchain offers innovative solutions for decentralised library management and secure data storage, its successful implementation demands strategic planning and cross-border cooperation.

Keywords: Blockchain technology, Bibliometric analysis, OpenAlex

Introduction

The Fourth Industrial Revolution (Industry 4.0) has ushered in an era of unprecedented technological transformation, marked by the proliferation of digital technologies across various industries (Kuzior & Sira, 2022). Among these advancements, blockchain technology stands out as a revolutionary innovation, fundamentally altering how information is recorded, shared, and secured (Yli-Huumo *et. al.*, 2016).Since its inception as the foundational technology behind Bitcoin, the first crypto currency, blockchain has transcendedits initial purpose to become a critical enabler of applications in finance, supply chain

management, healthcare, and beyond (Habil *et al.*, 2024). This evolution underscores the immense significance of blockchain technology in reshaping global industries, and fostering transparency, efficiency, and trust. Blockchain's meteoric rise in popularity has sparked intense research activity, leading to the rapid development and diversification of its applications.

The intellectual environment surrounding blockchain research is marked by innovation, collaboration, and interdisciplinary engagement, reflecting the technology's expanding scope and complexity. Central to blockchain's functionality are its consensus mechanisms, which ensure the security, decentralisation, and integrity of distributed networks (Ahn *et al.*, 2024). Over the past decade, significant advancements in these mechanisms have further solidified blockchain's position as a cornerstone of digital transformation.

Given the accelerating adoption and evolution of blockchain, a comprehensive bibliometric study becomes imperative to map its scholarly trajectory. Bibliometric analyses provide valuable insights into the intellectual landscape, prolific contributors, emerging trends, and geographic distribution of research activity. Such studies not only highlight the role of academic journals in disseminating knowledge but also serve as a resource for fostering global collaboration and facilitating resource allocation (Habil *et al.*, 2024). By identifying influential authors, institutions, and regions driving blockchain innovation, bibliometric research equips stakeholders with actionable insights, promoting further scholarly inquiry and innovation.

This paper aims to elucidate the multifaceted research landscape of blockchain technology over a 15-year period. Leveraging OpenAlex, a comprehensive scholarly data platform, this study examines the evolution of blockchain research, focusing on publication trends, prominent contributors, and key areas of application. The findings aim to cater to the informational needs of diverse stakeholders, including researchers, policymakers, and industry practitioners, while contributing to a deeper understanding of the global trajectory of blockchain technology. Through this endeavour, the study seeks to provide a critical resource for navigating the transformative impact of blockchain in the digital age.

Review of Related Literature

Blockchain technology is rapidly growing and evolving, presenting numerous opportunities for libraries to enhance their operations. Its capabilities, such as secure data storage, privacy preservation, and improved collaboration, make it a promising tool for libraries to store, preserve, and share information effectively (Abid, 2021). Byleveraging blockchain, libraries can secure user and patron records, advance user privacy, and improve the management of research data.Additionally, blockchain facilitates streamlined acquisition processes, including
ordering books, paying vendors, and subscribing to journals (Suman & Patel, 2021).

The potential for decentralised libraries, where user records are stored on blockchain rather than centralised databases, offers a revolutionary approach to user data management, granting users greater control over their circulation and borrowing histories. Although blockchain technology was not initially a prominent research topic, interest has surged, with academic publications exploring its applications and adoption trends growing rapidly (Anascavage & Davis, 2018). However, challenges remain, such as identifying practical use cases, addressing security issues, and overcoming adoption barriers (Meth, 2019).

The application of blockchain in constructing smart libraries shows promise, offering solutions for protecting user privacy through features like immutability, traceability, and secure data analysis (Xu & Shang, 2024). Despite uncertainties about whether blockchain will become a mainstream solution for libraries, the technology holds significant potential to transform library operations if implemented thoughtfully. Librarians are urged to explore the possibilities to stay ahead of technological advancements and contribute to shaping its role in the library ecosystem (Meth, 2019). The evolving research on blockchain highlights the need for continued exploration of its applications, adoption rates, and potential roadblocks, ensuring libraries can harness its transformative power for the future (Anascavage & Davis, 2018).

Objectives of the Study

The aim of this paper is to perform a bibliometric analysis of scholarly literature available on "Blockchain technology". The specific objectives were to:

1. explore the publication pattern and trend of Blockchain Technology over a period of time;
2. identify the level of contribution of authors, journals on Blockchain Technology;
3. application of Bradford Law on Blockchain Technology Publications; and
4. find the significant keywords and trending topics in Blockchain Technology.

Methodology

The methodology for this study involved a systematic collection and analysis of bibliometric data to explore research trends on the application of blockchain technology in libraries. The literature was sourced from *OpenAlex*, a comprehensive scholarly database, using the keyword *"Blockchain and Libraries"* to ensure a targeted focus. The dataset included various types of documents, such as articles, books, and reviews, published between 2019 and 2023, representing the most recent advancements in this area.The collected data was analysed using *Biblioshiny*, a graphical interface for *Bibliometrix* in R, which is widely used for bibliometric and scientometric studies. The analysis followed a structured approach,

starting with data cleaning to filter out irrelevant and duplicate records. Key bibliometric indicators, such as annual scientific production, citation impact, and document typology, were calculated to understand the dataset comprehensively. Visualisations, including line charts and bar graphs, werecreated to illustrate trends in publication growth, citation metrics, and collaboration patterns.

Detailed Description of the Dataset and Insights

Table 1: Quantitative Detail from the Data

Timespan	2019:2023
Sources (Journals, Books, etc)	5082
Documents	10868
Annual Growth Rate %	31.94
Document Average Age	2.43
Average citations per doc	16.38
References	299449
DOCUMENT CONTENTS	
Keywords Plus (ID)	6211
Author's Keywords (DE)	6211
AUTHORS	
Authors	31465
Authors of single-authored docs	1681
AUTHORS COLLABORATION	
Single-authored docs	1832
Co-Authors per Doc	3.67
International co-authorships %	0
DOCUMENT TYPES	
Article	7774
Book	270
book-chapter	734
Dataset	6
Dissertation	206
Editorial	26
Erratum	4

Letter	4
Other	104
Paratext	247
peer-review	41
Preprint	734
Report	90
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The dataset provided in Table 1 provides a comprehensive overview of scientific publications from 2019 to 2023, showcasing significant growth and diversification in academic output. The total number of documents grew annually at an impressive rate of 31.94%, with the sharpest increase observed between 2022 and 2023, culminating in 3,809 publications in 2023. Articles dominate the dataset with 7,774 entries, accounting for over 71% of all outputs, while preprints (734) and reviews (628) also contribute significantly. Long-form contributions, such as book chapters (734) and books (270),emphasize the diversity in academic dissemination. Despite this growth, the dataset reveals no instances of international co-authorship, suggesting that collaborations were predominantly national or local. On average, each document involved 3.67 co-authors, highlighting the collaborative nature of modern research.

Citation metrics further underscore the dataset's academic impact, with an average of 16.38 citations per document and nearly 300,000 references evidencing extensive engagement with prior literature. The presence of 6,211 unique keywords reflects a wide range of research themes, while the

dataset's focus on documents with an average age of 2.43 years emphasizes its relevance to recent scientific efforts. This analysis paints a vivid

picture of a vibrant academic ecosystem characterized by growth, collaboration, and thematic variety. However, the absence of global partnerships suggests an opportunity to foster greater international collaboration in the future.

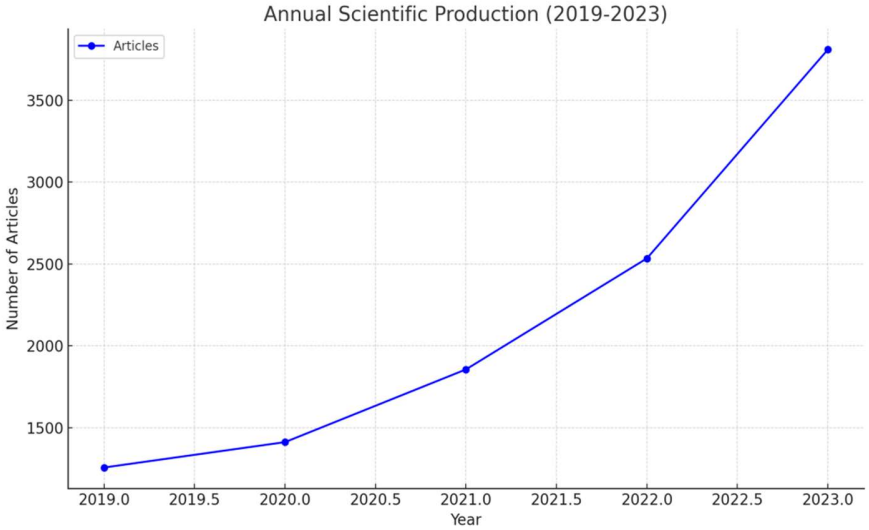


Fig. 1: Annual Scientific Production

The annual scientific production data reveals a steady and significant growth in the number of articles published from 2019 to 2023. In 2019, the dataset recorded 1,257 articles, which increased modestly to 1,412 articles in 2020. The pace of growth accelerated in subsequent years, with 1,856 articles published in 2021 and 2,534 articles in 2022. By 2023, the number of articles surged to 3,809, representing the highest annual output during this period (Fig. 1). This consistent upward trajectory reflects a growing focus on research, possibly driven by advancements in technology, an increase in funding, and global demand for innovative solutions. The sharp rise in 2023 underscores a particularly productive year, signaling an intensified emphasis on scientific output across various disciplines.

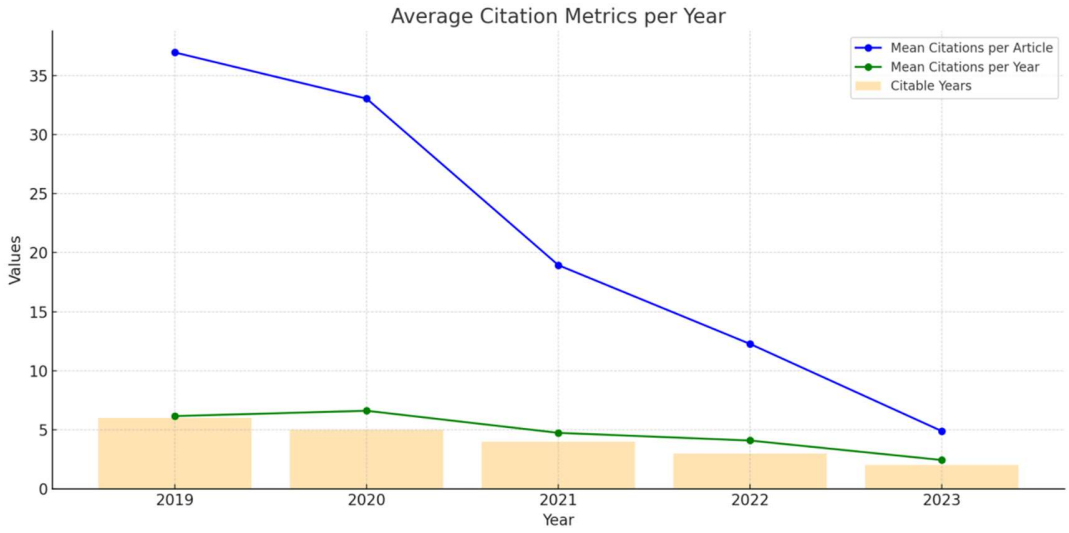


Fig. 2: Average Citation per Year

The average citation per year provides insights into the impact and visibility of articles over time. In 2019, articles had the highest average total citations per article (36.95), translating to an average of 6.16 citations per year over their 6 citable years. This indicates that these earlier publications have had ample time to gain recognition and citations. In 2020, the average total citations per article dropped slightly to 33.04, but the average annual citations rose to 6.61, suggesting these articles maintained a strong yearly impact despite having fewer citable years (5 years).

The average citations per year continued to decline for more recent publications. Articles from 2021 received an average of 18.94 total citations, or 4.74 citations per year over their 4 citable years. In 2022, the figure further dropped to 12.27 total citations and 4.09 citations per year, reflecting the reduced exposure time for these publications. Finally, in 2023, the most recent articles had an average of 4.89 total citations and 2.44 citations per year, due to their limited window of just 2 citable years (Fig. 2). This pattern highlights the natural lag in citation accumulation for newer publications and underscores the importance of considering both the total and annual citation metrics when evaluating the impact of research over time.

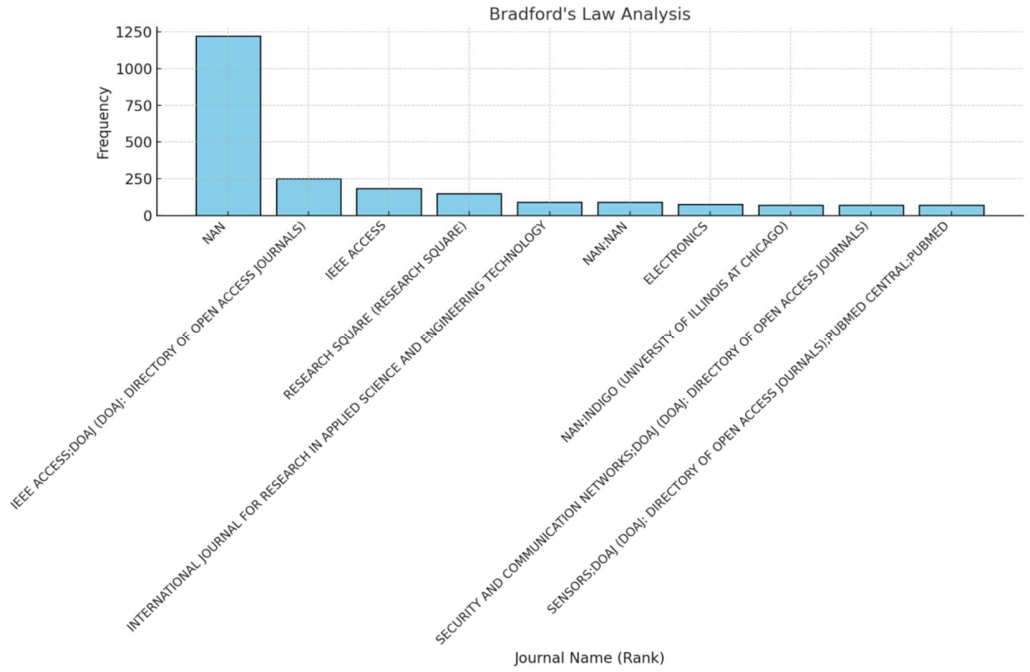


Fig. 3: Bradford's Law Analysis

Bradford's Law of Scattering, which describes how articles on a specific topic are distributed across various sources or journals. The data is structured to rank sources based on the frequency of articles they publish, highlighting their contribution to the field. It categorizes the sources into zones, with Zone 1 representing the core journals that publish the majority of articles, followed by Zone 2 and Zone 3, which contain progressively more journals contributing fewer articles overall.

The top-ranked source, NAN, leads with the highest frequency of 1223 articles, representing a substantial proportion of the dataset and underscoring its pivotal role in the subject area (see Figure 3). The second-ranked source, IEEE ACCESS; DOAJ (DOAJ: Directory of Open Access Journals), contributes 251 articles, significantly adding to the cumulative total of 1474 articles. Following this, IEEE ACCESS ranks 3rd with 183 articles, further increasing the cumulative frequency to 1657, and highlighting its productivity within Zone 1. *Research Square* ranked 4th with 147 articles, continues this trend, raising the cumulative total to 1804. Similarly, the *International Journal for Research in Applied Science and Engineering Technology* contributes 90 articles, reaching a cumulative total of 1894.

At 6th place, DOAJ publishes 87 articles, expanding the total to 1981 and rounding off the high-impact sources of Zone 1. Ranked 7th, MDPI SENSORS adds 83 articles, increasing the cumulative frequency to 2064. PUBMED, ranked 8th, contributes 81 articles, emphasizing its role in the dataset and Zone 1. *IEEETransactions on Power Delivery*, at 9th place, adds 80 articles, raising the cumulative total to 2225. Finally, *MDPI Electronics*, ranked 10th, publishes 77 articles, bringing the cumulative total for these high-productivity sources to 2302. These top 10 sources exemplify the core groupof journals that dominate the article distribution in alignment with Bradford's Law. The analysis provides a clear representation of Bradford's Law, helping to analyze and prioritise journal contributions effectively.

Top Contributors Analysis

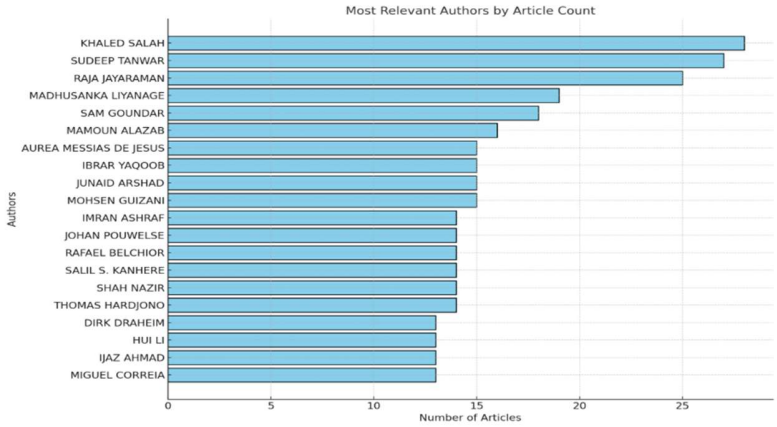


Fig. 4: Most Relevant Authors by Article Count

Figure 4 shows the top contributors in terms of authored articles and their fractionalized contributions, which account for shared authorship. Leading the list is Khaled Salah, who has authored 28 articles with a fractionalised contribution of 5.06, indicating his significant presence across multiple publications. Following closely is SudeepTanwar, with 27 articles and a fractionalised value of 4.20, reflecting his active research involvement, albeit with slightly less individual contribution per article than Khaled Salah. Raja Jayaraman, with 25 articles and a fractionalised value of 4.39, shows a strong individual input in his publications. Similarly, MadhusankaLiyanage contributed 19 articles with a fractionalised value of 4.48, underscoring his impactful role as a co-author. Notably, Sam Goundar, with 18 articles, stands out for his high fractionalised contribution of 6.93, suggesting a leading role in the majority of his publications.

The next five authors, Aboul Ella Hassanien, MdZakirulAlamBhuiyan, Anirban Sarkar, Chung-Ming Huang, and Sheng-Lung Peng, have contributed between 14 and 18 articles
each. Their fractionalised contributions vary, highlighting differences in their roles as either primary authors or collaborators. Collectively, these top authors demonstrate a substantial impact in their respective fields, with variations in both volume of output and individual contribution to their works. This data underscores the prominence and influence of these researchers in the overall dataset.

Top Authors and Impact

Leading the dataset is Khaled Salah, with an h-index of 15, a g-index of 28, and an m-index of 2.5, indicating a strong influence across his 28 publications since 2019, which have garnered 1,095 total citations. Similarly, SudeepTanwar also has an h-index of 15 and a g-index of 27, but with a higher m-index of 3.0, reflecting a remarkable annual impact (Fig. 5). His 27 publications since 2020 have accumulated 1,419 citations, the highest among the top contributors. MadhusankaLiyanage, with an h-index of 13, g-index of 19, and an m-index of 2.17, has contributed 19 publications since 2019, earning 992 citations. Another prominent author, Raja Jayaraman, demonstrates strong productivity with an h-index of 13, g-index of 25, and 753 total citations from 25 publications since 2020. MamounAlazab follows closely, with an h-index of 12, g-index of 16, and an m-index of 2.4, reflecting 16 impactful publications and 1,374 citations since 2020.

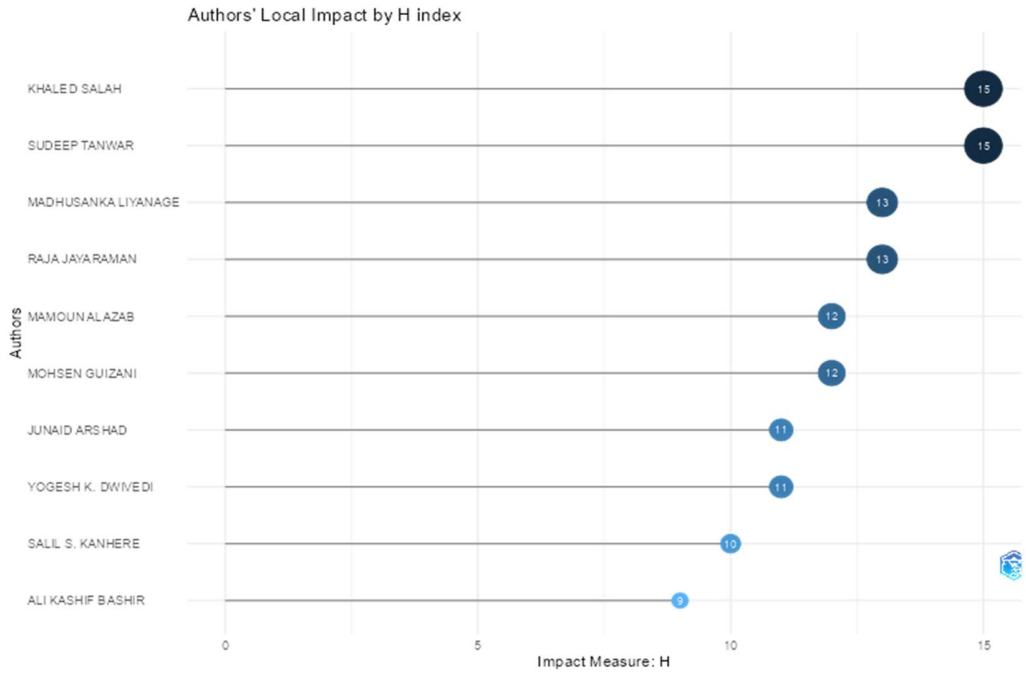


Fig. 5: Authors' Local Impact by H index

Other notable authors in the top 10 include Sam Goundar, MdZakirulAlamBhuiyan, Aboul Ella Hassanien, Anirban Sarkar, and Sheng-Lung Peng, whose h-indices range between 9 and 12. Their significant numbers of publications and citations highlight their strong presence in their respective fields. Collectively, these authors demonstrate consistent annual productivity and influence, as reflected by their m-index values. Beyond the top 10, numerous other authors with h-indices below 9 contribute meaningfully to the dataset, showcasing smaller yet significant numbers of publications and citations. These contributions, while less pronounced than the top authors, represent the essential diversity and breadth of research within the dataset, emphasizing the collaborative nature of scientific

Evolving Keyword Trends

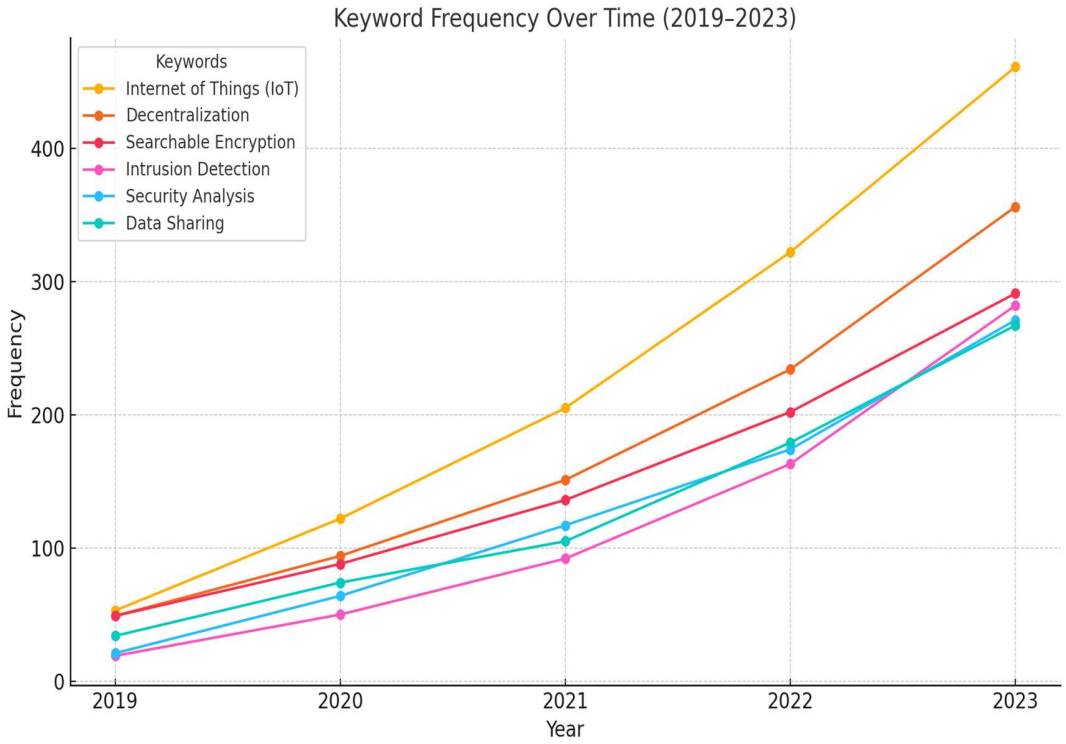


Fig. 6: Keyword frequency

Figure 6 illustrates the frequency of selected keywords related to IoT, decentralization, and security over five years (2019–2023), showcasing evolving research trends. Mentions of Internet of Things (IoT) have steadily risen from 53 in 2019 to 461 in 2023, reflecting its growing significance in modern technological ecosystems, particularly in smart devices andindustrial applications.Similarly, decentralization has increased from 49 mentions in 2019 to 356 in 2023, highlighting the shift toward distributed systems and reducing centralised control, particularly in blockchain and digital infrastructure. The term searchable encryption also shows remarkable growth, rising from 49 mentions in 2019 to 291 in 2023, underscoring the demand for privacy-preserving technologies that allow encrypted data to be queried securely.

Other key terms such as intrusion detection, security analysis, and data sharing exhibit consistent growth, reflecting their critical roles in addressing modern cybersecurity challenges. Mentions of intrusion detection have grown from 19 in 2019 to 282 in 2023, while security analysis increased from 21 to 271 during the same period, indicating a focus on assessing and enhancing system security in interconnected environments. Data sharing, which rose from 34 mentions in 2019 to 267 in 2023, highlights the importance of secure and efficient data exchange mechanisms in distributed systems. Collectively, these trends emphasize the increasing focus onsecurity, privacy, and decentralization in advancing technological research and development.

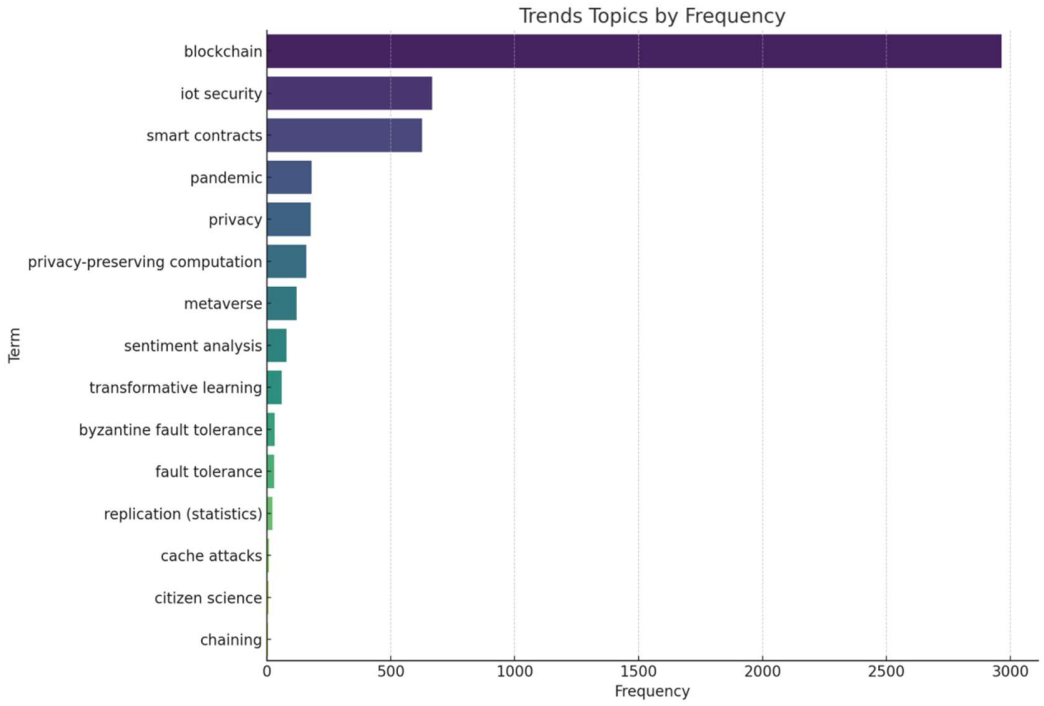


Fig. 7: Trend Topics

Figure 7 highlights the evolution of key research terms, focusing on their frequency and temporal relevance. For instance, cache attacks, with a frequency of 9, were predominantly discussed between 2019 (Q1) and 2020 (Q3), reflecting early concerns about vulnerabilities in caching mechanisms within cybersecurity.Similarly, citizen science, mentioned 7 times, emerged in 2019 (Q1) and remained relevant until 2022 (Q3), showcasing the increasing role of public participation in scientific research. Another term, chaining, with 5 occurrences, was primarily discussed between 2019 (Q1) and 2021 (Q3), likely referring to chaining mechanisms in blockchain or data systems.

On the other hand, terms such as Byzantine fault tolerance and fault tolerance demonstrate sustained relevance, with frequencies of 32 and 30, respectively. These concepts first appeared in 2020 (Q1) and remained prominent through 2023 (Q3), emphasizing their ongoing importance in the development of robust systems capable of withstanding faults and malicious behaviors, particularly in blockchain and distributed computing. Broader trends reveal that terms like cache attacks and chaining peaked earlier, indicating focused explorations of specific technical challenges, whereas concepts like fault tolerance and Byzantine fault tolerance continue to play foundational roles in current research. Additionally, the rise of terms like citizen science highlights emerging interest in participatory approaches to technology and research, indicating a shift toward more inclusive scientific practices. Collectively, these trends provideinsights into the changing priorities and sustained focus areas within the research community.

Results and Key Findings

The study systematically analysed bibliometric data from 2019 to 2023 to explore the application of blockchain technology in libraries. Using OpenAlex, a scholarly database, and the keyword "Blockchain and Libraries," relevant documents, including articles, books, and reviews, were collected and examined. Biblioshiny, a Bibliometrix interface in R, was used for data cleaning, visualizations, and bibliometric analysis, highlighting trends in annual scientific production, citations, and collaboration patterns.

Key findings reveal significant growth in publications, with a 31.94% annual increase, peaking at

3,809 outputs in 2023. Articles dominate the dataset, comprising over 71% of publications. Citation metrics show an average of 16.38 citations per document, reflecting academic impact. However, the absence of international co-authorship underscores the need for global collaborations. Bradford's Law analysis identified core journals, such as IEEE ACCESS and DOAJ, as major contributors, while Lotka's Law revealed a small group of highly prolific authors driving most of the research output.

Keyword analysis underscores blockchain's central role, with frequent associations to

IoT, security, and smart contracts. Trends highlight increasing interest in decentralized systems, security analysis, and data sharing. Despite a natural decline in citations for recent publications due to limited exposure, consistent annual growth and thematic diversification indicate a vibrant and expanding research field. This study underscores the growing importance of blockchain technology in libraries while identifying opportunities for broader international collaboration and thematic exploration.

Conclusion

This study highlights the transformative potential of blockchain technology in reshaping library operations. Blockchain's capabilities-secure data storage, privacy enhancement, and decentralized management—offer innovative solutions for modern library challenges. From safeguarding user data to streamlining acquisition processes, blockchain can significantly improve operational efficiency and user experience. The bibliometric analysis reveals rapid growth in blockchain-related research within library science, with notable academic impact. However, challenges persist, including limited global collaboration, security concerns, and barriers to practical adoption. The absence of international partnerships underscores the need for greater global engagement to advance blockchain research and its applications in libraries.

While blockchain holds immense promise, its successful integration into library systems requires thoughtful planning, addressing technical and operational barriers, and fostering partnerships across institutions and borders. Libraries must actively explore this technology to ensure they remain at the forefront of innovation and meet the evolving demands of their users. Finally, blockchain represents a powerful tool for the future of libraries, capable of transforming how they manage information, securedata, and engage with users. By addressing existing gaps and investing in strategic implementation, libraries can harness blockchain's full potential, paving the way for more secure, efficient, and decentralized systems that redefine their role in the digital age. This study provides a foundation for further exploration, emphasizing the importance of collaboration and innovation in unlocking the transformative capabilities of blockchain in library science.

Recommendations

From the findings, the study recommends the following:

1.This study recommends fostering international collaboration to address the current lack of cross-border research partnerships in blockchain applications for libraries, enabling the exchange of expertise and resources to develop globally relevant solutions.

2.Encouraging interdisciplinary research that integrates blockchain with fields such as cybersecurity, IoT, artificial intelligence, and data science can expand its scope and

practical relevance.

3.Libraries and related institutions should invest in capacity building through targeted training and professional development programmes to prepare staff for blockchain adoption, while ensuring robust security and privacy frameworks aligned with legal and ethical standards.

4.Policymakers and funding agencies are encouraged to provide financial and infrastructural support to accelerate experimentation and implementation, while prioritising open access to blockchain-related research outputs to enhance visibility and scholarly impact. Collectively, these strategies will help overcome adoption barriers, drive innovation, and position blockchain as a transformative tool for modern library services.

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AUTHORS' PROFILES



Sayed Mohamed Jelani A. is currently serving as a Semi-professional assistant at the Central University of Tamil Nadu. She has over a decade of professional experience in academic and school library services. Her professional interests include bibliometric studies, emerging library technologies, blockchain applications in library science, and digital resource management. She qualified for the UGC-NET in Library and Information Science in 2025. She has authored and co-authored over 25 research publications in reputed journals, conference proceedings, and edited book chapters. Her notable works include studies on the National Digital Library of India, AI tools in libraries, audio app usage in academia, remote access platforms, open access publishing, digital scholarship initiatives, and library marketing through social media.



Ashkar Kamaludheen (known as Ashkar Kairali) is currently working as an Assistant Librarian at the Indian Institute of Science Education and Research (IISER) Thiruvananthapuram. He hasserved in several nationally important institutions, including the Central University of Tamil Nadu, Indian Institute of Information Technology, Design and Manufacturing (IIITDM) Kurnool, andDigital University Kerala. He qualified for the reputed UGC-NET in Library and Information Science in 2017. He was served as a resource person for library automation software Koha and digital library software DSpace as well. His professional expertise spans library software, opensource solutions, cloud computing, digital libraries, and library automation. He has authored andco-authored numerous publications in reputed journals, conference proceedings, and edited volumes.